

COMPLEMENTARY SAFETY ASSESSMENTS
OF THE FRENCH NUCLEAR INSTALLATIONS

**REPORT
BY THE FRENCH NUCLEAR
SAFETY AUTHORITY**

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SUMMARY

GENERAL INTRODUCTION	3
CHAPTER 1 SUMMARY OF THE TARGETED INSPECTIONS CARRIED OUT IN 2011 ON TOPICS RELATED TO THE FUKUSHIMA ACCIDENT	15
CHAPTER 2 COMPLEMENTARY SAFETY ASSESSMENTS OF THE NUCLEAR POWER PLANTS AND EUROPEAN STRESS TESTS	75
CHAPTER 3 COMPLEMENTARY SAFETY ASSESSMENTS OF THE NUCLEAR FACILITIES OTHER THAN NUCLEAR POWER REACTORS	211
REFERENCES	347
GLOSSARY	349

GENERAL INTRODUCTION

1. The organisation of nuclear safety and radiation protection regulation in France

The regulation of nuclear safety and radiation protection in France is based on two main Acts:

- Act 2006-686 of 13th June 2006 on transparency and security in the nuclear field (TSN Act);
- Planning Act 2006-739 of 28th June 2006 concerning the sustainable management of radioactive materials and waste.

ASN, which has been an independent administrative authority since the TSN Act of 2006, is tasked, on behalf of the State, with regulating nuclear safety and radiation protection in order to protect workers, patients, the public and the environment from the hazards involved in nuclear activities. It also contributes to informing the public in these fields. It assists the Government in the event of a radiological emergency.

Since the TSN Act was passed, ASN has enjoyed greater powers enabling it to punish offenses and take all necessary measures in the event of an emergency.

ASN is run by a commission of five commissioners who perform their duties in complete independence, on a full-time basis, and are appointed for a non-renewable mandate of 6 years.

ASN relies especially on the expertise of the Institute for Radiation Protection and Nuclear Safety (IRSN) and on its advisory committees of experts.

With regard to nuclear safety and radiation protection, after receiving the opinion of ASN, the Government issues the general regulatory texts concerning transparency, nuclear safety and radiation protection, as well as major political decisions regarding nuclear facilities (authorisation of a basic nuclear installation, final shutdown).

Parliament has an oversight role, in particular of the policy undertaken by ASN. The French Parliament's office for the evaluation of scientific and technological options (OPECST) regularly produces reports on particular aspects of nuclear safety and radiation protection. Every year, ASN sends Parliament its report on the state of nuclear safety and radiation protection.

The French High Committee for Transparency and Information on Nuclear Security (HCTISN), created by the TSN Act, is an information, consultation and debating body concerning the hazards linked to nuclear activities and their impact. It comprises elected officials, associations, trades union representatives, qualified personalities, licensees and representatives of the public authorities.

2. French nuclear safety regulations

The French regulations applicable to civil basic nuclear installations are in conformity with various conventions, international standards and European legislation: IAEA "Basic safety standards"; Convention on Nuclear Safety for civil nuclear power generating reactors; Joint convention on the safety of spent fuel management and the safety of radioactive waste management; Euratom treaty; Euratom directive of 25th June 2009 establishing a community framework for the nuclear safety of nuclear installations.; Euratom directive of 19th July 2011 establishing a community framework for the responsible and safe management of spent fuel and radioactive waste (which will be transposed in 2013).

French nuclear safety regulations include all the general legal texts setting down nuclear safety rules, whether binding (Act voted by Parliament, decrees and ministerial orders and ASN regulatory decisions) or non-binding (ASN basic safety rules and guides).

2.1 Acts

The TSN Act of 13th June 2006 on transparency and security in the nuclear field extensively overhauled the legal regime applicable to basic nuclear installations. It in particular made this regime "integrated" with the aim of preventing the hazards and detrimental effects of all types that nuclear facilities are liable to create: nuclear or non-nuclear accidents, radioactive or other pollution, radioactive pollutions and others, production of radioactive wastes or others, noise, and so on.

Act 2006-739 of 28th June 2006 on the sustainable management of radioactive materials and waste, known as the "Waste" Act, creates a coherent, exhaustive legislative framework for the management of all radioactive waste.

2.2 Main decrees and ministerial or inter-ministerial orders in force

Decree 2007-1557 of 2nd November 2007 on basic nuclear installations and the control, from a nuclear safety point of view, of the transport of radioactive materials, known as the "procedures" decree, implements article 36 of the TSN Act. It defines the framework for carrying out procedures in nuclear facilities and deals with the entire lifecycle of a nuclear facility, from its authorisation decree and commissioning up to final shutdown and decommissioning. Finally, it makes clear the relations between the Ministers responsible for nuclear safety and ASN, in the field of basic nuclear installation safety.

The order of 10th August 1984 on the quality of the design, construction and operation of basic nuclear installations, known as the "quality" order, specifies the steps that the licensee of a nuclear facility must take to define, obtain and maintain the quality of its facility and the conditions necessary for ensuring its safe operation.

The order of 31st December 1999 amended by the order of 31st January 2006 stipulates the general technical regulations, except for water intakes and effluent discharges, designed to prevent and mitigate off-site detrimental effects and hazards resulting from the operation of nuclear facilities.

The order of 26th November 1999 sets the general technical requirements concerning the limits and procedures for water intakes and effluent discharges subject to authorisation in nuclear facilities.

Pressure vessels specifically designed for nuclear facilities are subject to particular requirements that are regulated and monitored by ASN. They are defined in the decree of 13th December 1999 and in specific orders.

ASN has undertaken to incorporate most of these texts into a single order setting out the essential requirements applicable to all basic nuclear installations (BNI) for the protection of humans and the environment from the risks of accident, chronic pollution or other detrimental effects. This order, known as the "BNI regime order", underwent a number of consultation processes, including two public consultations. It will be submitted to the Ministers responsible for nuclear safety in early 2012, for their signature.

2.3 ASN decisions

Pursuant to article 4 of the TSN Act, ASN can take regulatory decisions to point out decrees and orders issued concerning nuclear safety or radiation protection, which are submitted to the Government for approval.

ASN also issues individual decisions concerning nuclear activities (for example, commissioning authorisation for a basic nuclear installation, authorisation to use radioactive material transport packaging, authorisation to use radioactive sources, definition of requirements concerning the design, construction, operation or decommissioning of a facility, etc.). Since its creation in 2006, ASN has issued about 90 binding decisions, half of which concern water intakes and environmental discharges.

2.4 ASN basic safety rules and guides

On a variety of technical subjects concerning nuclear facilities, ASN has in the past drawn up basic safety rules (RFS). These are recommendations which clarify the safety objectives and describe practices that ASN considers to be satisfactory. As part of the current overhaul of the general technical regulations, the RFS are being gradually replaced by "ASN guides".

There are at present about forty RFS and other technical rules from ASN, which can be consulted on its website.

3. The nuclear safety approach in France

The nuclear safety approach in France is based on:

- the prime responsibility of the licensee for the safety of its facilities, under the oversight of ASN ;
- continuous improvement of nuclear safety and radiation protection.

The safety principles and approaches presented below were implemented gradually. They included experience feedback from accidents. Safety can never be totally obtained and, despite the precautions taken in the design, construction and operation of nuclear facilities, an accident always remains possible. There must thus be a constant desire to move forwards and to implement a continuous improvement approach in order to reduce the risks.

To ensure the safety of nuclear facilities, the French regulations require that they be designed, built and operated to deal with a certain level of risk. These risks in particular comprise natural hazards, such as earthquake and flooding. The regulations also require the implementation of a "defence in depth" arrangement, which consists of a set of redundant, diversified measures (automation, systems or procedures) able to prevent accidents, manage them if they are not preventable or, failing which, mitigate the consequences. These arrangements are regularly checked and systematically reviewed on the occasion of the ten-yearly periodic safety reviews created by article 29 of the Act of 13th June 2006.

3.1 The "defence in depth" concept

The main means of preventing and mitigating the consequences of accidents is "defence in depth". This involves a series of consecutive, independent levels of protection. If one level of protection, or barrier, were to fail, the next level would take over.

An important aspect in the independence of the levels of defence is the use of technologies of different natures ("diversified" systems).

The design of a nuclear facility is based on a defence in depth approach. For example, for nuclear reactors, there are the following five levels:

First level: prevention of abnormal operation and system failures

This entails choosing a robust and prudent design for the facility, incorporating safety margins, able to withstand its own failures or off-site hazards. This implies conducting a study of the normal operating conditions that is as complete as possible, to determine the most severe constraints to which the systems will be subjected. An initial design of the facility incorporating safety margins can then be established.

Second level: Control of abnormal operation and detection of failures

This entails designing control and limitation systems which maintain the facility well within its safety limits. For example, if the temperature of a system rises, a cooling system is activated before the temperature exceeds the authorised limit. Monitoring the good condition of the equipment and the correct operation of the systems is part of this level of defence.

Third level: managing accidents without core melt

This entails the assumption that certain accidents, which are the most penalising and encompass all the accidents of a given family, can occur, and to design some safeguard systems to deal with them.

These accidents are generally based on conservative hypotheses, in other words it is assumed that the various parameters determining this accident are the most unfavourable possible. Furthermore, the single failure criterion is applied, in other words, in the accident situation, the failure of a component is also postulated. This means that the systems responding in the event of an accident (emergency shutdown, safety injection, etc.) must comprise at least two redundant channels.

Fourth level: managing accidents with core melt

These accidents were examined following that which occurred at Three Mile Island (1979) and are now incorporated into the design of new reactors such as the EPR. The aim is either to rule out these accidents, or to design systems able to deal with them. The study of these accidents will be reassessed in the light of the experience feedback from the Fukushima accident.

Fifth level: mitigation of the radiological consequences of significant releases

This involves implementing emergency plan provisions, including population protection measures: sheltering, administration of stable iodine tablets to saturate the thyroid and prevent it from absorbing the radioactive iodine carried by the radioactive plume, evacuation, restrictions on the consumption of water or foodstuffs, etc.

3.2 Safety management

Safety management consists in creating a safety culture within the risk management organisations. The safety culture is defined by INSAG¹, an international consultative group for nuclear safety reporting to the Director General of the IAEA², as being a range of characteristics and attitudes which, for both organisations and individuals, ensure that matters relating to the safety of nuclear facilities are given the priority attention warranted by their importance.

The safety culture thus reflects how the organisation and the individuals perform their roles and assume their responsibilities with regard to safety. It is one of the key factors in maintaining and improving safety. It requires that each organisation and each individual pay particular and appropriate attention to safety. It must be expressed at an individual level by a rigorous and prudent approach and a questioning attitude which ensure compliance with rules while leaving room for initiative. It is applied operationally in the decisions and actions relating to the various activities.

3.3 Operating experience feedback

Operating experience feedback contributes to defence in depth. It consists in implementing a reliable system for detecting any anomalies that may arise, such as equipment failures or errors in the application of a procedure. This system should be able to ensure early detection of any abnormal operation and draw the conclusions (particularly in organisational terms) such as to prevent these anomalies from happening again. Operating experience feedback includes events taking place in France and abroad with pertinence for improved nuclear safety or radiation protection.

4. ASN regulation of civil nuclear facilities

The French civil nuclear fleet is the world's second largest. It comprises a total of 150 nuclear facilities: 58 pressurised water reactors producing most of the electricity consumed in France, one EPR type reactor under construction, the various fuel cycle facilities, research facilities and facilities currently undergoing decommissioning.

¹ INSAG: International Nuclear Safety Group

² IAEA: International Atomic Energy Agency

ASN, with the technical support of IRSN and its advisory committees, devotes particular attention to rigorous regulation of safety. In accordance with the law, it ensures continuous improvement of safety in French civil nuclear facilities, through the process of periodic safety reviews and the incorporation of operating experience feedback.

Every year, ASN performs more than 700 inspections in the French civil nuclear facilities. These inspections are by means of spot-checks and by analysis of the proof of regulatory compliance provided by the licensee.

In addition to this continuous monitoring, the licensees are required – under ASN oversight – to periodically review (generally every ten years) the safety of their facilities, in accordance with part III of article 29 of the TSN Act. The ten-yearly periodic safety review is an opportunity for a detailed inspection of the conformity of the facility with its own nuclear safety requirements. Its aim is also to make changes to the facility in order to improve its level of safety and as far as possible comply with the requirements applicable to the most recent facilities. The safety review enables ASN to assess the possibility of continuing with operation of the facility up until the next ten-yearly periodic safety review.

ASN also examines anomalies occurring in the nuclear facilities. It ensures that the licensee has made a pertinent analysis of the event, has taken appropriate steps to correct the situation and prevent a reoccurrence, and has sent out operating experience feedback. ASN and IRSN also conduct an overall examination of experience feedback about events. This feedback can result in requests to improve the condition of the facilities and the organisation adopted by the licensee, but also in changes to the technical regulations.

Operating experience feedback includes those events occurring in France and abroad with pertinence for enhancing nuclear safety or radiation protection.

Finally, ASN is heavily committed to relations with its foreign counterparts, whether bilateral, European union or international level. ASN is developing active bilateral cooperation (more than 20 cooperation agreements with its counterparts); it is a member of several nuclear safety and radiation protection Regulatory Bodies. In compliance with the provisions of the TSN Act and at the request of the Government, ASN also takes part in the French representation to the international and European organisations in charge of nuclear safety and radiation protection.

5. ASN's sanctions powers

In certain situations where the licensee's actions are not in conformity with the regulations or the legislation, or when it is important for it to take appropriate action to deal immediately with the most important risks, ASN has a number of means of action at its disposal.

In the event of failure to comply with the regulations, its available tools are primarily:

- ASN official request to the licensee through an inspection follow-up letter;
- ASN formal notice to the licensee to regularise its administrative situation within a specified time, or meet certain stipulated conditions;
- administrative sanctions, pronounced after formal notice, which can go as far as temporary suspension of operation of the nuclear facility.

The administrative sanctions are defined in articles 41 to 44 of the TSN Act:

- placing in the hands of a public accountant of a sum corresponding to the amount of the work to be performed;
- performance of the work by another party at the expense of the licensee (any sums previously placed with the public accountant can then be used to pay for this work);
- suspension of working of the facility or of a particular operation, until the licensee restores conformity.

The law also makes provision for interim measures taken to safeguard public security, safety and health or to protect the environment. ASN may therefore:

- temporarily suspend the operation of a BNI, immediately informing the Ministries responsible for nuclear safety, in case of any serious and imminent risk;
- at any time, stipulate the evaluation and the implementation of the measures necessary in the event of a threat to the above-mentioned interests.

In parallel with ASN's administrative actions, reports can be drawn up by the ASN inspectors and forwarded to the public prosecutor's office.

6. The French approach to the complementary safety assessments (CSAs)

As with the Three Mile Island and Chernobyl accidents, detailed analysis of the experience feedback from the Fukushima accident could take about ten years³.

The Fukushima accident, triggered by an earthquake and a tsunami on an exceptional scale, confirmed that despite the precautions taken in the design, construction and operation of the nuclear facilities, an accident is always possible. In this context, and given its knowledge of the 150 French nuclear facilities, through its regulation and oversight, ASN considered in the days following the accident that a complementary assessment of the safety of the facilities, with regard to the type of events leading to the Fukushima disaster, should be initiated without delay, even if no immediate emergency measures were necessary.

These assessments were carried out in addition to the safety approach performed permanently and described previously.

These complementary safety assessments are part of a two-fold approach: on the one hand, performance of a nuclear safety audit on the French civil nuclear facilities in the light of the Fukushima event, which was requested from ASN on 23rd March 2011 by the Prime Minister, pursuant to article 8 of the TSN Act and, on the other, the organisation of "stress tests" requested by the European Council at its meeting of 24th and 25th March 2011.

6.1 Specifications consistent with the European specifications

In order to manage the complementary safety assessments, ASN issued twelve decisions on 5th May requiring the various licensees of the nuclear facilities to perform these complementary safety assessments in accordance with precise specifications. The complementary safety assessments concern the robustness of the facilities to extreme situations such as those which led to the Fukushima accident. They complement the permanent safety approach followed.

To ensure consistency between the European and French approaches, the French specifications for the complementary safety assessments were drafted on the basis of the European specifications produced by WENRA⁴ and approved by ENSREG⁵ on 25th May 2011. The provisions of the French specifications are consistent with those of the European specifications.

The complementary safety assessment thus consists of a targeted reassessment of the safety margins of the nuclear facilities in the light of the events which took place in Fukushima, that is extreme natural phenomena (earthquake, flooding and a combination of the two) placing considerable strain on the safety functions of the facilities and leading to a severe accident. The assessment first of all concerns the effects of these natural phenomena; it then looks at the loss of one or more systems important for safety involved in Fukushima (electrical power supplies and cooling systems), regardless of the probability or cause of the loss of these functions; finally, it deals with the organisation and the management of the severe accidents that could result from these events.

³ It should be remembered that after the Three Mile Island accident, it took six years to evaluate the proportion of the reactor core which had melted.

⁴ WENRA: Western European Nuclear Regulators' Association

⁵ ENSREG: European Nuclear Safety REgulators Group

Three main aspects are included in this assessment:

- The steps taken in the design of the facility and its conformity with the design requirements applicable to it;
- The robustness of the facility beyond the level for which it was designed; the licensee in particular identifies the situations leading to a sudden deterioration of the accident sequences ("cliff-edge effects"⁶) and presents the measures taken to avoid them;
- All possible modifications liable to improve the facility's level of safety.

6.2 Specifications broader than the European specifications

ASN decided to apply the complementary safety assessments to all French nuclear facilities and not simply to the power reactors. Thus, virtually all of the 150 French nuclear facilities will undergo a complementary safety assessment, including for example the EPR reactor currently under construction, or the spent fuel reprocessing plant at La Hague⁷. In this respect, the French specifications have been extended compared to those adopted at the European level by ENSREG.

As of the beginning of the process, the association of stakeholders, particularly HCTISN, asked ASN to place particular emphasis on social, organisational and human factors, especially subcontracting. The Fukushima accident showed that the ability of the licensee and, as necessary, its subcontractors to organise and work together in the event of a severe accident is a key factor in the management of such a situation. This ability to organise is also a key aspect of accident prevention, facilities maintenance and the quality of their operation. The conditions for the use of subcontracting are also tackled in the French complementary safety assessments.

On 3rd May 2011, the HCTISN issued a favourable opinion of the specifications for the complementary safety assessments.

6.3 Specifications which can also take account of some of the situations resulting from a malevolent act

Even if the Fukushima accident involves no malevolent acts and even if such acts are not considered in the European Council conclusions of March 2011, the complementary safety assessments approach can cover some of the situations arising from such an act.

Malevolent acts are in fact one of the possible causes (equipment failure, natural hazard, human activities) of a loss of electrical power or cooling which could lead to a nuclear accident. The loss of electrical power and cooling, regardless of the cause, are specifically covered by the complementary safety assessments and appear in this report.

Specifically combating malevolent acts is being examined by the European Member States in a group devoted to this subject.

The close link between these subjects (malevolent acts, safety) means that in most of the relevant countries (United States, Canada, Japan, Russia, Finland, Spain, Sweden, Switzerland, Ukraine, etc.) they are dealt with by the nuclear Regulatory Body. In this respect, France is an exception.

6.4 Categorization of the facilities concerned

The complementary safety assessments concern virtually all the 150 basic nuclear installations in France (58 nuclear power generating reactors, EPR reactor under construction, research facilities, fuel cycle plants).

⁶ For example, in the case of flooding, the water level would gradually rise and a cliff-edge effect would be reached when the water level reaches the top of the embankment and floods the entire site.

⁷ Fewer than about ten facilities are excluded, as their decommissioning is nearing completion.

These facilities have been divided into three categories, depending on their vulnerability to the phenomena which caused the Fukushima accident and on the importance and scale of the consequences of any accident affecting them.

For the 79 facilities felt to be a priority, including the 59 power reactors in operation or under construction, the licensees (AREVA, CEA, EDF, Laue-Langevin Institute) submitted their reports to ASN on 15th September 2011. Given the time available, ASN asked the licensees of the priority nuclear facilities to present their conclusions according to the data at their disposal and based on existing safety studies and the expert opinions of the engineers. The licensees were also to propose complementary studies, to be carried out in particular on the weak points and the "cliff-edge" effects identified, as well as an appropriate calendar for these studies.

For the facilities of lower priority, the licensees are required to submit their reports before 15th September 2012.

Finally, the other facilities will be dealt with through appropriate ASN requests, in particular on the occasion of their next ten-yearly periodic safety review, except for about ten facilities for which decommissioning is nearing completion.

6.5 Assistance of a diversified technical expertise

In accordance with the principle of the licensee's prime responsibility, which is the keystone of nuclear safety and a principle that is recognised in international legal texts, the complementary safety assessments led first of all, and for each facility concerned, to the production by the licensee of a report in response to the specifications defined by ASN.

In order to analyse the reports submitted by the licensees on 15th September 2011, ASN called on the expertise of its technical support organisation, IRSN, which forwarded its report in early November. On 8th, 9th and 10th November 2011, ASN also convened two of the seven advisory committees it consults on the most important subjects: the advisory committee for reactors and the advisory committee for laboratories and plants. These advisory committees, consisting of French and foreign experts, submitted their opinion to ASN on 10th November 2011.

At the same time the ANCCLI, the national association of CLIs (local information committees) mandated a number of experts to examine the reports submitted to ASN by the licensees. Several CLIs also initiated analyses: the Fessenheim CLIS sent ASN a study on the risk of flooding for the Fessenheim NPP; the CLIs at Civaux, Dampierre, Golfech, Gravelines, Saint-Laurent and the three CLIs of the Cotentin peninsula forwarded their opinions on the reports from the licensees. Finally, the experts mandated by the Grand Duchy of Luxembourg and the German States of Saarland and Rhineland-Palatinate, as well as the CGT trade union national mines-energy federation, sent ASN analyses of these reports.

The complementary safety assessments thus led to considerable mobilisation on the part of the licensees, experts, stakeholders and ASN.

ASN's initial conclusions on the complementary safety assessments of the priority nuclear facilities are based on a review of all this work and the results of its regulation and monitoring actions. They are the subject of this report.

6.6 An open and transparent approach

ASN attached the greatest importance to this approach being both open and transparent: the French High Committee for Transparency and Information on Nuclear Security (HCTISN), the local information committees (CLI) and several foreign Regulatory Bodies were invited to take part as observers in the targeted inspections carried out by ASN and to attend meetings of the advisory committees. These various stakeholders also received copies of the reports sent in by the licensees.

On its website (www.asn.fr) ASN also made available on-line the reports from the licensees, the IRSN report, the opinions of the advisory committees and the follow-up letters to its inspections.

Finally, ASN published several information notes and held three press conferences on 9th May, 14th September and 17th November 2011.

This ASN report will also be made public and presented to the press.

On 8th December 2011, the HCTISN issued an opinion on the complementary safety assessment process. This opinion underlines the fact that the information concerning the Fukushima accident was made known to the public in a satisfactory manner.

7. The targeted inspections

ASN initiated a campaign of targeted inspections on topics related to the Fukushima accident. The purpose of these inspections was to run field checks on the conformity of the licensee's equipment and organisation with the existing baseline safety requirements.

The topics dealt with during these inspections were as follows:

- protection against off-site hazards, in particular the ability to withstand earthquakes and protection against flooding;
- the loss of electrical power;
- the loss of heat sinks;
- operational management of radiological emergencies.

7.1 Organisation of the targeted inspections

Thirty-eight inspections were scheduled and performed by teams comprising several ASN inspectors accompanied by IRSN representatives. This campaign of inspections involved 110 days of inspection in the field.

These targeted inspections were scheduled between June and October 2011. For any given site, they took the form of in-depth inspections lasting several days, involving spot-checks on all the topics mentioned above. They were based on baseline requirements common to the NPPs on the one hand and to civil nuclear facilities on the other. They placed emphasis on field visits rather than documentary checks.

A summary of the targeted inspections is presented in chapter 1 of the report. This summary, based on the inspection follow-up letters, contains the most representative observations for each category of facilities. It is not therefore exhaustive and does not represent ASN's judgement of the safety of these nuclear facilities.

All the requests made by the ASN inspectors are available in the follow-up letters sent out to the licensees, posted on the ASN's website (www.asn.fr).

7.2 Transparency and public information

In the same way as all the other ASN inspection follow-up letters, those concerning the post-Fukushima targeted inspections were posted on the ASN website (www.asn.fr).

ASN also wished to involve the representatives of civil society in its inspections. ASN thus proposed that the local information committees (CLIs) of the nuclear facilities and the French High Committee for Transparency and Information on Nuclear Security (HCTISN) could take part in the targeted inspections as observers, subject to the approval of the licensee.

ASN also invited the inspectors of the German, Swiss, Belgian and Luxembourg Regulatory Bodies to attend a few targeted inspections in France.

More than 100 outside observers thus took part in the targeted inspections carried out by ASN, primarily in the NPPs.

8. A long-term approach

The experience feedback from the Fukushima accident could take about ten years. As a first step it was felt that an immediate evaluation of the robustness of the facilities to extreme situations should be carried out. This is the goal of the complementary safety assessments, which led to an exceptional mobilisation of the licensees, experts, stakeholders and ASN.

After the complementary safety assessments on the priority nuclear facilities, ASN considers that the facilities examined offer a sufficient level of safety requiring no immediate shutdown of facilities. At the same time, ASN considers that the continued operation of the facilities demands that their robustness to extreme situations be improved as rapidly as possible.

Therefore in the first quarter of 2012, ASN will be imposing a range of requirements on the licensees and will tighten up the safety requirements concerning the prevention of natural hazards (earthquake and flooding), the prevention of risks linked to other industrial activities, subcontractor monitoring and how nonconformities are dealt with. The corresponding ASN decisions will be posted on the www.asn.fr website. ASN will subsequently ensure that the licensees comply with the hundred or so requirements it will have issued and take account of the new safety requirements it will have approved.

ASN will also take into consideration the conclusions of the peer reviews conducted at the European level.

ASN also considers that additional studies will need to be undertaken to complete certain aspects, in particular the initial analyses carried out by the licensees. It will send the licensees the corresponding requests in letters which will also be posted on its website.

In the summer of 2012, ASN will present the progress of all of these measures.

ASN will also continue the process of complementary safety assessments of nuclear facilities with lower priority, for which the reports have to be submitted by the licensees before 15th September 2012.

ASN considers that these initial complementary safety assessments confirmed the benefits of such an innovative approach, complementing the existing safety approach. It envisages continuing this process of complementary assessment of safety margins by making it a mandatory component of the ten-yearly periodic safety reviews.

Finally, ASN will continue to participate actively in all the analyses to be conducted worldwide, in order to gain a clearer understanding of the Fukushima accident.

CHAPTER 1

SUMMARY OF THE TARGETED INSPECTIONS CARRIED OUT IN 2011 ON TOPICS RELATED TO THE FUKUSHIMA ACCIDENT 15

1.. INTRODUCTION	15
1.1 Organisation of the targeted inspections	15
1.2 Transparency and public information	15
2.. SUMMARY OF THE PRESSURISED WATER REACTOR (PWR) TARGETED INSPECTIONS CARRIED OUT IN 2011 ON TOPICS RELATED TO THE FUKUSHIMA ACCIDENT	16
➤ Summary of the inspections	16
2.1 Protection of facilities against off-site flooding	18
2.1.1 Introduction	18
2.1.2 Organisation	18
2.1.3 Special operating rule in the event of flooding	19
2.1.4 Monitoring of forecast criteria (meteorological, flood and tidal)	19
2.1.5 Decision-making in an alert situation	20
2.1.6 Implementation of procedures	20
2.1.7 Actions and modifications performed following the event at Le Blayais	20
2.1.8 Monitoring of volumetric protection (PV)	21
2.1.9 Maintenance of flood protection features	21
2.1.10 Mobile pumping resources (MMP)	22
2.1.11 Powering the pumps after loss of off-site power supplies	22
2.1.12 Site isolation in the event of flooding	23
2.1.13 Flooding of galleries between units and management	23
2.1.14 Diversity of telecommunication resources	23
2.1.15 Optimisation of discharges at the prediction of a flooding risk	23
2.1.16 Exercises: deployment of flood protection and prevention equipment (cofferdams, sandbags, mobile pumping resources)	23
2.1.17 Overall evaluation of the "protection of facilities in an off-site flooding situation"	24
2.2 Earthquake protection of the facilities	24
2.2.1 Introduction	24
2.2.2 Organisation	25
2.2.3 Instrumentation	28
2.2.4 Event earthquake approach	30
2.2.5 General evaluation on the topic "Protection of facilities in an earthquake situation"	31
2.3 Loss of heat sink	32
2.3.1 Introduction	32
2.3.2 Organisation / human factors	32
2.3.3 Conformity of pumping station systems with the EDF national frame of reference (deployment of particular directive DP 143)	33
2.3.4 Integration of experience feedback (REX) particularly interim requirement 303 concerning how to deal with clogging of the heat sink	33
2.3.5 Anticipation: monitoring, prevention and detection resources	34
2.3.6 Management of cooling in a degraded situation	34
2.3.7 Maintenance, servicing and availability of equipment, upkeep of premises	35
2.3.8 General evaluation of the "loss of heat sink" topic	36
2.4 Loss of electrical power supplies	36
2.4.1 Introduction	36
2.4.2 Organisation and operation	36
2.4.3 Backup electricity generating sets	37
2.4.4 Combustion turbines (TAC)	38
2.4.5 Backup turbine generator (LLS)	38
2.4.6 Electrical transformers	39
2.4.7 Fuel oil storage	39
2.4.8 Storage of oil and coolant fluid	39
2.4.9 Management of the loss of electrical power supplies	39
2.4.10 General evaluation of the "loss of electrical power supplies" topic	40

2.5 Operational management of accident situations.....	40
2.5.1 Introduction.....	40
2.5.2 Incident or accident operating rules.....	40
2.5.3 Organisation put into place for the on-site emergency plan (PUI).....	41
2.5.4 General evaluation on the topic "management of accident situations".....	46
3.. SUMMARY OF TARGETED INSPECTIONS CONDUCTED IN 2011 CONCERNING TOPICS RELATED TO THE FUKUSHIMA ACCIDENT ON LABORATORY, PLANT, WASTE AND DECOMMISSIONING FACILITIES (LUDD)	47
➤ Summary of inspections	47
3.1 General presentation of the sites and facilities.....	48
3.1.1 Experimental reactors.....	48
3.1.2 Nuclear fuel cycle facilities.....	48
3.1.3 Other facilities (ATPu, Masurca).....	50
3.2 Protection of the facilities against off-site flooding.....	50
3.2.1 Experimental reactors.....	50
3.2.2 Nuclear fuel cycle facilities.....	51
3.2.3 Other facilities.....	53
3.3 Protection of facilities against earthquakes.....	54
3.3.1 Experimental reactors.....	54
3.3.2 Nuclear fuel cycle facilities.....	55
3.3.3 Other facilities.....	58
3.4 Loss of heat sink.....	59
3.4.1 Experimental reactors.....	59
3.4.2 Nuclear fuel cycle facilities.....	59
3.4.3 Other facilities.....	60
3.5 Loss of electrical power supplies.....	61
3.5.1 Experimental reactors.....	61
3.5.2 Nuclear fuel cycle facilities.....	61
3.5.3 Other facility.....	64
3.6 Operational management of accident situations and crisis management.....	64
3.6.1 Introduction and frame of reference considered.....	64
3.6.2 Organisation put into place for management of incident/accident situations.....	65
3.6.3 Coordination with external players.....	67
3.6.4 Exercises and integration of experience feedback.....	67
3.6.5 Crisis management resources.....	67
3.6.6 Crisis premises and assembly points.....	68
3.6.7 Conclusion.....	69

SUMMARY OF THE TARGETED INSPECTIONS CARRIED OUT IN 2011 ON TOPICS RELATED TO THE FUKUSHIMA ACCIDENT

1. Introduction

In addition to the complementary safety assessments, ASN conducted a campaign of targeted inspections on topics related to the Fukushima accident. These inspections, carried out on all the nuclear facilities considered to be high-priority, were designed to check the actual conformity of the licensee's equipment and organisation in the field with the existing safety frame of reference.

The following topics were covered by these inspections:

- protection against external hazards, in particular against earthquakes and flooding,
- the loss of electrical power supplies,
- the loss of heat sinks,
- operational management of radiological emergency situations.

1.1 Organisation of the targeted inspections

38 inspections were scheduled and carried out by teams comprising several ASN inspectors accompanied by representatives from the IRSN. This campaign of inspections represented 100 days of inspection in the field.

These inspections, referred to as "targeted" inspections were scheduled between June and October 2011. For each of the given sites, the inspections lasted several days (not necessarily continuous) and involved spot-checks on all the topics mentioned above. The inspections were based on a frame of reference common to the nuclear power plants (NPP) on the one hand, as well as the other civil nuclear facilities on the other, with preference being given to field visits over documentary checks.

This summary contains the observations most representative of each facility category and is not therefore exhaustive. All the requests submitted by the ASN inspectors are nonetheless available in the follow-up letters sent out to the licensees. The references of these follow-up letters are provided in the appendix.

The conclusions of the targeted inspections enabled ASN to complete its analysis of the complementary safety assessment reports, so that it could issue additional requirements aimed at strengthening the nuclear safety of the facilities.

1.2 Transparency and public information

In the same way as all the other ASN inspection follow-up letters, those concerning the post-Fukushima targeted inspections were published on the ASN's website (www.asn.fr).

In addition, ASN wanted to involve the representatives of civil society in its inspections. ASN thus proposed that the local information committees (CLI) of the nuclear facilities and the French High Committee for Transparency and Information on Nuclear Security (HCTISN) participate in a number of the targeted inspections as observers, subject to the approval of the licensee.

ASN also invited inspectors from the German, Swiss, Belgian and Luxembourg nuclear safety regulators to attend a number of targeted inspections in France.

51 outside observers thus took part in the targeted inspections performed by ASN, primarily on the nuclear power plants.

2. Summary of the pressurised water reactor (PWR) targeted inspections carried out in 2011 on topics related to the Fukushima accident

➤ Summary of the inspections

The inspections showed that the five subjects targeted by the programme were not always correctly integrated into the current frame of reference. The main steps to be taken by EDF are summarised below.

1. With regard to the topic of flooding, the conclusions of the inspections are diverse and vary according to the sites. ASN considers that the organisation put into place to manage the flooding risk complies satisfactorily with the expectations. However, ASN does consider that the management of volumetric protection¹ needs to be improved on some of the sites inspected. EDF will therefore focus its efforts in particular on the monitoring and maintenance of volumetric protection. ASN also considers that EDF needs to define and implement exercises for testing the ability of the equipment and crews to deal with this type of situation and to incorporate experience feedback from these exercises. Finally, ASN considers that improvement is required on the following topics:

- *the strict application on the sites of special operating rules in the event of flooding;*
- *monitoring of meteorological, flood and tide parameters;*
- *the schedule for the performance of actions decided on in the light of the experience feedback from the partial flooding of the Le Blayais site in 1999;*
- *management of mobile pumping resources.*

2. With regard to the topic of earthquakes, ASN finds that the inspections revealed shortcomings on several sites and that progress is required on all the sites as a whole. It is important to conduct exercises simulating an earthquake leading to the implementation of planned procedures and to prepare the personnel for this type of situation. ASN moreover considers that greater consideration must be given to the event-earthquake problem in the procedures and day-to-day operations of the units. Finally, EDF must ensure compliance with RFS I.3.b² concerning seismic instrumentation, in particular with regard to operator familiarity with the equipment, its upkeep and its calibration. On the whole, ASN considers that this subject requires permanent vigilance on the part of EDF, so that the potential implications of a hazard of this nature during the day-to-day operation of the reactors are not lost.

EDF informed ASN that it has already taken steps in response to ASN's findings (seismic risk awareness campaigns launched on all the sites, appointment of a local seismic coordinator, currently ongoing checks of the positioning of the seismic measurement sensors, and updating of procedures). ASN considers that this subject should be the focus of priority action in 2012.

3. ASN finds that the heat sink, which plays a fundamental safety role, requires particular vigilance. Recent heat sink clogging or partial loss of heat sink events, at Cruas and Fessenheim in December 2009 in particular, revealed its vulnerability and led EDF to initiate a plan of action to enhance the robustness of all the heat sinks. ASN asked EDF to conduct a design review of all heat sinks. ASN will be asking EDF for the detailed conclusions of this design review, site by site, along with the associated plan of action with its milestones and deadlines.

The inspections carried out by ASN in 2011 showed that the general condition of the facilities was correct but that a certain number of problems still persisted on certain sites. Rigorous operation and maintenance, monitoring of the condition of the equipment and structures, and exhaustive application of the national directives are as a general rule areas of improvement for many sites. At numerous sites, maintenance of the SEC (Essential Service Water) system needs to be improved.

¹In a flooding situation, the equipment designed to ensure reactor safety must remain operational. Therefore, when necessary, systems are thus put into place to protect against the various hazards that could lead to flooding. This protection is based on several lines of defence (embankments, walls, water drainage networks, etc.), including volumetric protection. The perimeter of volumetric protection, which encompasses buildings containing equipment designed to guarantee reactor safety, was defined by EDF to guarantee that the arrival of water outside this perimeter does not lead to flooding of the premises situated inside the perimeter. In concrete terms, the volumetric protection consists of walls, ceilings and floors. Protection of existing openings in these walls (doors, other openings, etc.) can constitute potential points of water ingress in the event of flooding.

² RFS I.3.b of 8th June 1984 concerning seismic instrumentation.

EDF plans to reinforce the heat sink safety frame of reference by early 2013.

4. With regard to electrical power supplies, the ASN inspectors judged the EDF sites to be on the whole satisfactory but nonetheless there was room for improvement on the following points:

- rigour in utilisation of the operating and maintenance documents (filling out of operational documents, updating of maintenance programmes);*
- physical condition of certain fuel storage equipment (piping corrosion, water infiltration);*
- management of fluids needed by the electricity generating sets (periodic analyses);*
- periodic inspections associated with the TAC (combustion turbine) on certain sites.*

5. Operations in an accident situation could be improved. The PUI (on-site emergency plan) arrangements implemented by the sites are satisfactory. ASN finds that EDF needs to improve management of the fallback stations and certain agreements with outside organisations.

1.12.1 Protection of facilities against off-site flooding

2.1.1 Introduction

Context

Flooding is a risk that is designed into the facilities and reassessed on the occasion of the periodic safety reviews or in response to certain exceptional events, such as the partial flooding of the Le Blayais nuclear power plant during the storm on 27th December 1999. This reassessment in particular concerns the maximum water level considered in the design of the site protection structures, called the flood safety margin level (CMS). The method for calculating this CMS is given by fundamental safety rule RFS I.2.e. The revised CMS takes account of the additional causes of flooding, such as high intensity rainfall, failure of water retention facilities, rising ground water or, for coastal sites, tidal waves.

Following the partial flooding of the Le Blayais power plant in December 1999, EDF complied with ASN's request for an overall reassessment of the flooding risk for each of its nuclear sites.

Initially, the platform elevations were set according to the water level calculated upstream of or at the site, taking account of margins, in particular with respect to future settling. Embankments were built in certain cases (Le Blayais). On the occasion of the CMS reassessment following publication of RFS I.2.e, mobile protections (cofferdams) were put into place on sites with a CMS higher than the platform elevation (Belleville for example). Following the Le Blayais incident, protection improvement actions were decided on. They have been completed on some sites and are either in progress or planned for others.

Stakes

The risks caused by flooding and high water are primarily:

- the loss of the water supply by flooding of the pumping equipment or large-scale arrival of detritus;
- the loss of off-site power supplies by flooding of the switchyard;
- flood-related loss of equipment important for safety;
- prolonged isolation of the site, in particular making it impossible to relieve the shift crews, refuel the emergency generator sets or bring in mobile emergency resources.

Inspection frame of reference

EDF describes the results of its assessments and the protection against the resulting off-site flooding risks in each of its safety reports and also in the flood files produced (also called "stage 3 site files"), updated to take account of ASN's requests following the advisory committee meetings of 21st and 22nd March 2007 devoted to examining the protection of the pressurised water reactors in service and the other nuclear facilities against the risks of off-site flooding.

The sites also rely on operational documents, in particular to anticipate and manage a flood situation. This for instance concerns the flooding special operating rules (RPC) specific to each site and used to ensure early initiation of measures to limit the risks (example: reactor shutdown) or the effects of flooding.

The purpose of the inspections on this topic was to verify the conformity of the facilities with this frame of reference. Field visits were carried out to check the progress of the action plan implemented by EDF and check the availability and condition of the equipment contributing to protecting the site in the event of flooding, especially the equipment participating in volumetric protection (PV) and the mobile pumping resources. A number of exercises were held related to the deployment of protection equipment.

2.1.2 Organisation

The ASN inspectors investigated the organisation put into place for management of the flooding risk.

The EDF head office departments established a set of documents for each of their sites, presenting the off-site flood risk protection measures (systems and procedures) tailored to the specificities of the site. Most of the sites have a flood coordinator, which was found to be satisfactory by ASN, although their roles and duties are not always described (Bugey, Saint-Alban, and Cruas).

Depending on the site-specific flooding vulnerability, some sites are covered by an on-site emergency plan (PUI) specific to management of this type of crisis, referred to as a "flood safety PUI" (for example Belleville or Le Blayais) used in the event of an alert. Some sites hold flood safety PUI deployment

exercises (every 4 years at Le Blayais) supplemented by partial exercises (deployment of pumping resources or "mini" cofferdams³ every year at Le Blayais). Maintenance and monitoring of the equipment is usually the responsibility of joint teams (in charge of the daily rounds).

ASN finds that most of the sites offer a satisfactory response to this problem.

2.1.3 Special operating rule in the event of flooding

The EDF head office departments issue operating memos called special operating rules (RPC), to deal with the risk of flooding on vulnerable sites. These rules are mandatory and must be applied by the sites (in other words the requirements must be incorporated into the operating instructions applicable to the site) no later than 6 months after they are received. These reports are regularly updated to take account experience feedback on the one hand and the results of the vulnerability studies on the other.

National doctrine is implemented by most of the sites, albeit sometimes belatedly (Bugey, Blayais). However a number of discrepancies were detected by the inspectors: inconsistent alert criteria (Blayais), a waiver in place for several months with no means of mitigation implemented (Belleville), inconsistency with the requirements of the PUI (Bugey), absence of Météo France alert because no agreement in place (Cattenom), and RPC requirements not fully implemented (Saint-Alban).

Some sites have not adopted the latest version of the RPC and plan to do so in the coming months (Tricastin in progress, Dampierre in May 2012). On the Gravelines site, the RPC has not been applied since 2008, and has since then been replaced by a new RPC, issued in 2010, which has not been implemented either. Finally, certain new applicable RPCs radically modify the scenarios; for example, in Tricastin, the site is now considered potentially susceptible to isolation and exposure to a loss of off-site power supply in the event of flooding, which was not the case in the procedures in effect on the day of the inspection.

Certain analyses would benefit from being carried out systematically when the RPCs are implemented locally, but are not (no analysis of the discrepancies between the different versions carried out in Chooz, no analysis of the impact on socio-organisational and human factors in Gravelines).

ASN therefore considers that the special operating rules in the event of flooding could be better implemented on the sites.

The operating procedures when they do exist mention numerous actions to be taken depending on the alert levels. For example, at Belleville, there is provision for a variety of measures to isolate the site and guarantee its electrical power supply (connection of the step-down transformer to the Gauglin substation, blocking of the circuit-breakers, verification of the volumetric protection, closure of openings and valves, and positioning of cofferdams, etc.). The installation of the cofferdams, sandbags and mobile pumping resources and the closure of the watertight doors are totally dependent on human intervention. This type of organisation therefore fails to take account of a rapidly evolving event (for example such as a dam burst), a lack of accessibility to the platform as a whole or a lack of competent personnel at any given moment.

ASN finds that EDF must study the possible development of passive resources, in other words that require no human intervention.

2.1.4 Monitoring of forecast criteria (meteorological, flood and tidal)

The alert system (criteria and procedures to be followed in the various phases) is generally described in particular operating rules and instructions (CPC) associated with flooding. These alert systems generally consist of various phases (usually surveillance, vigilance, pre-alert and alert) during which specific actions are triggered. The criteria differ according to the sites (for example forecasting of wind speed and water levels at the Blayais intake, Rhone river discharge and discharge gradients at Bugey, Seine river discharge at Nogent).

A national agreement was signed by Météo France and EDF DTG (General Technical Department) on 29th May 2009, providing the sites with the information necessary, particularly wind and precipitation, for anticipating a flood risk situation. There are other agreements, for instance with the SHOM (French naval hydrographic and oceanographic service) for tides, with the dam operator (for example at Bugey with the Compagnie Nationale du Rhône "CNR"). Some Government departments are also called on: for example, it is the Office of the *Préfet* of the Ain *département* which informs the Bugey NPP (nuclear power plant) of a

³ Provisional embankment or dam put in place to protect a zone.

dam failure, the Office of the *Préfet* of the Ardennes *département* which informs the Chooz NPP concerning Meuse river high water alerts.

The inspections revealed a number of isolated anomalies which could compromise detection of these thresholds being reached and thus the appropriate action being taken in good time:

- absence of monitoring: Bugey (no monitoring of water levels for several days because the fax machine was out of paper), Nogent (range of instrumentation sensor values incompatible with the pre-alert phase threshold);
- absence of monitoring: Bugey (lack of stringency in filling out the Rhone river discharge monitoring procedures), Cruas (Rhone discharge values not updated frequently enough, certain values ignored);
- multiple criteria: Cruas, Blayais and Flamanville (different criteria depending on the documents);
- risk of erroneous values: Blayais (procedure fails to take account of the measurement uncertainties), Bugey (Rhone discharge value calculations essentially guesswork), Gravelines (no checks on meteorological forecast readings);
- no agreement with an organisation providing Rhone river discharge monitoring data: Saint-Alban.

ASN finds that the monitoring of meteorological, high-water and tidal criteria needs to be improved.

2.1.5 Decision-making in an alert situation

Responsibility for dissemination of information varies according to the organisation of the sites. On most sites, the site protection department receives the forecasts and transmits them to the control room. The information is sometimes sent directly to the control room (Nogent, Blayais). On most sites, the operations shift manager validates the phase changes triggering the specific measures of the planned procedures for dealing with a flooding risk.

Meteorological, high-water or tidal data are generally correctly transmitted and interpreted. However, the inspectors noted:

- a lack of ergonomics in the alert procedures on certain sites (particularly Belleville, Cruas, Paluel, Saint-Laurent) liable to lead to confusion and thus erroneous or belated decision-making;
- a lack of communication between departments: Penly (tides monitoring file not shared by the departments), Fessenheim (the parties concerned are insufficiently familiar with the organisation put into place for transmission of the meteorological data to the operations department), Cruas (shift operations manager not informed of changing discharge rates frequently enough, no reactor designated as pilot).

ASN finds that implementation of the flood alert system on the sites needs to be improved.

2.1.6 Implementation of procedures

Some sites were concerned by situations requiring the transition to the vigilance phase or activating of the site flood safety PUI (for example Fessenheim in 2007, Belleville in 2008, Blayais in 2009 and 2010, Bugey, Saint-Alban and Tricastin in 2010).

The experience feedback is on the whole positive. However, the sites of Tricastin and Saint-Alban were unable to present the inspectors with the completed operations procedure corresponding to the last transition to vigilance phase, in particular the part corresponding to volumetric protection control.

ASN therefore finds that during the course of actual crises, the instructions were on the whole followed, but that improvement is needed on certain sites.

2.1.7 Actions and modifications performed following the event at Le Blayais

For each site, a report defines the work to be performed as a result of the operating experience feedback from the partial flooding of the Le Blayais site in December 1999. This work can consist in installation of cofferdams, closures, seals between buildings, raising or building embankments, etc. The inspectors checked that the deadlines were met and that upkeep and monitoring were performed in compliance with the recommendations.

Some sites apply the modifications in full (Cattenom, Fessenheim, Belleville). Others are in the process of doing so, in accordance with the planned deadlines (Saint-Laurent, Tricastin, Dampierre).

The inspectors did however observe delays or deviations:

- the volumetric protection conformity work is well behind schedule on some sites (Chooz);
- the "bunkerisation" requested for the BES (site maintenance building) on Saint-Alban and for the Cruas main gatehouse has not been carried out. Moreover, the Saint-Alban site was unable to clearly demonstrate whether compensatory measures had been taken. Finally, the civil engineering work (protective screen and raising of the access road backfill) is behind schedule;
- the cofferdams procured for the Saint-Alban site do not conform to the procurement specifications;
- at Gravelines, the minimum margin in relation to the CMS is not in line with the EDF frame of reference requirements for a part of the site (Eastern access side wall).

ASN finds that the progress of the work decided on following the event at Le Blayais in 1999 must comply with the deadlines agreed with ASN. In particular, compensatory measures must be rapidly implemented for sites on which the work has been postponed.

2.1.8 Monitoring of volumetric protection (PV)

The EDF head office departments have drawn up a national doctrine that is to be applied by the sites.

The sites are required to carry out daily monitoring of the volumetric protection and take certain measures in the event of a loss of tightness (planned or unplanned). Volumetric protection must be managed in the "Sygma" equipment management software. The teams must also exercise the openings and closures in the volumetric protection and control the conformity through hold-points after elements of the volumetric protection are operated..

The implementation work has been under way at Le Blayais since 2008 and appears to be more advanced on this point than the other sites (e.g.: Dampierre, Cattenom). Other sites are asking Le Blayais for help with implementing the national report. This monitoring is sometimes performed at the same time as the fire sectoring (Saint-Alban, Dampierre for example). Other sites, Bugey, Flamanville, Penly, Paluel, Saint-Alban, Saint-Laurent and Cattenom have implemented this report, receiving no comments from ASN. Finally, on some sites, this report has not been implemented (in Chooz for instance, because volumetric protection is not yet in place).

The field visits did however reveal that improvement is required on several sites, which are not currently in compliance with the national doctrine:

- no exhaustive identification of the elements contributing to the PV (Fessenheim, Nogent, Bugey, Flamanville, Chooz, Gravelines, Blayais);
- no check on the elements contributing to the PV before divergence (Cruas, Fessenheim, Gravelines, Dampierre);
- no daily exhaustive check of the PV (Tricastin, Blayais);
- no use of Sygma (particularly Nogent, Gravelines, Chinon).

ASN finds that PV management on the whole needs to be improved.

2.1.9 Maintenance of flood protection features

The inspectors examined the periodic checks performed on the protection features (volumetric protection, cofferdams, embankments, pumps, etc.). These tests are generally formally included in the sites' specific maintenance programmes and the periodic tests.

There are monitoring instructions for most embankments (Blayais, Flamanville, Cruas) and cofferdams. Field visits have also demonstrated the overall good condition of the protective features on certain sites (Fessenheim, Gravelines, Cattenom, Chooz).

However, the inspectors did observe that certain elements of the facilities (openings, cofferdams, protective walls, seals between buildings) were in poor condition (leaks, damage, poor quality) and were consequently liable to jeopardize the volumetric protection on the sites concerned. The rise in the groundwater level combined with the presence of water in the location of the electricity generating set fuel tanks during an event at Cattenom on the 15th May 2010 demonstrates that the issue was not adequately controlled. Other anomalies were also observed on several sites; for example:

- Cattenom: presence of water in the backup generator set fuel tanks following infiltration through the seals between buildings forming the PV between the groundwater and the buildings;
- Dampierre: damaged concrete on a pumping station access hatch;
- Nogent: presence of rainwater in the pumping station owing to defective openings that are part of the PV;
- in Flamanville, the "civil engineering" basic maintenance programme for the site only makes provision for visual inspection of the embankment, with no underwater inspection. The embankment check-out showed that the tip of the intake channel embankment was sinking significantly.

Furthermore, correction of the anomalies affecting the PV is sometimes a lengthy process (6 months at Dampierre, 8 months at Cattenom) or not even traced (at Saint-Laurent, for example, there is no complete record of the installation of the flood panels, despite the presence of a problem with the lifting resources). The inspectors noted that on several sites, the seals between buildings had no expiration date. In this case, ASN considers that regular monitoring will be required.

ASN finds that the monitoring and upkeep of the protection systems need to be improved as a whole.

2.1.10 Mobile pumping resources (MMP)

The inspectors questioned the sites concerning the mobile pumping resources (MMP) available in the event of flooding. Following the meeting of the advisory committees (for reactors and for laboratories and plants) on 21st and 22nd March 2007, the capacity and number of MMP were validated for all the sites. The number of MMP and their capacity varies according to the site's vulnerability and the number of reactors (8 pumps at Dampierre and Cattenom, 6 at Bugey, Saint-Alban and Blayais, 3 at Belleville, 1 at Flamanville, 4 at Saint-Laurent, 11 pumps at Tricastin).

These mobile pumping resources are managed by specific flood reports or by reports related to the PUI safety requirements (for example Bugey) detailing their management and their location.

These mobile pumping resources are sometimes subject to annual preventive maintenance (Cattenom, Fessenheim, Tricastin) but this is often not the case (Dampierre, Gravelines), in particular concerning the hoses; nonetheless, some sites have decided to draft memos to initiate these checks (Nogent, Saint-Laurent). Finally, the inspectors point out that this maintenance must be staggered, so that a minimum number of MMP is guaranteed to be available on the site (unlike at Tricastin, for instance, which performs all its tests on the same day off the site and which, in the event of flooding, then has no other pumping resource). Finally, some pumps are not equipped with a meter giving warning of the saturation of the tanks.

ASN finds that MMP management on the sites needs to be improved.

For those sites with mobile pumping resources, the equipment is in good condition and sometimes stored in dedicated areas.

For all the sites questioned, the MMPs are specific to flood management and are not required for fire-fighting purposes, a fact that ASN considers to be satisfactory.

2.1.11 Powering the pumps after loss of off-site power supplies

Most sites have fuel tanks and electricity generating sets, but their number and their operating capacity vary from site to site, in particular between those sites impacted by a loss of off-site power in the event of flooding and those which are not. The operating time is linked to the fuel capacity and the possibility of fuel resupply.

The case of the Tricastin site must be highlighted as it only has a single electricity generating set for supplying pumps remote from power sources. It complies with the requirements of the flood frame of reference of 2004, but does not take account of the risk of losing off-site power supplies in the event of flooding. This must therefore be reviewed in the light of the 2011 flood RPC, which modifies this diagnostic and considers the site to be exposed to LOOP (loss of off-site power) in the event of flooding. The Le Blayais site must also test the procedures planned in the event of a loss of off-site power, that is installation of a bypass system by RTE (the Electricity Transmission System).

ASN finds that the power supply to the pumps in the event of LOOP needs to be improved.

2.1.12 Site isolation in the event of flooding

The characteristics of site isolation in the event of flooding are known and described in the safety report. They depend on numerous parameters (elevation of roads, vulnerability of the environment, etc.) and differ from site to site (7 days for Belleville, 3 days for Nogent, 12 hours for Gravelines, 2 days for Tricastin). For the sites impacted by the risk of isolation, procedures to deal with this situation are defined (Nogent, Saint-Alban), in particular in the PUI.

It should be pointed out that the new 2011 flood RPC for Tricastin states that this site is now exposed to isolation, requiring that the site review its entire strategy in this area. Similarly, at Cruas, the new procedures have extended the isolation period from 2 days to 12 days, yet no steps have been taken on the site to deal with this extension. Certain flood situations are foreseeable (Blayais, Belleville) or would develop slowly (Fessenheim) making it possible to anticipate organisation of the alert. Some sites have also signed agreements with the Government departments concerned, such as the SDIS (Belleville, Blayais).

ASN considers that overall, site isolation management is satisfactory, except for Tricastin and Cruas which will rapidly need to include the risk of isolation in their operating procedures and organisational arrangements.

Several sites have limited the risk of isolation by building heliports (Cattenom, Chooz, Nogent, Tricastin and 2 at Belleville) or plan to build them in the coming years (Fessenheim in 2015). Saint-Alban plans to modify the access roads to prevent them from becoming flooded and a helicopter landing exercise was held.

The provisions in terms of the resources (human, material, supplies, etc.) in the event of flooding in order to guarantee the living conditions of the staff blocked on the site are generally those of the PUI (Cattenom, Fessenheim) or the RPC (Blayais). Some sites have taken steps in case it is necessary for the personnel to stay on the site (Fessenheim). Certain sites, not subject to flooding (Nogent for example), nonetheless have 90 inflatable mattresses and inflators as part of the PUI arrangements, enabling a 60-strong duty crew to sleep on-site, along with survival rations for 24 hours permanently stored in the warehouse.

ASN finds that EDF has made adequate provision for isolation of the sites in its definition of the resources deployed in the event of site isolation.

2.1.13 Flooding of galleries between units and management

On certain sites (Chooz, Nogent, Paluel) the turbine hall galleries between units cannot be sealed, potentially leading to flooding of the turbine hall (as happened at Nogent in 2006), which could require multi-unit management. Nonetheless, this appears to be defined in most of the operating procedures (Blayais, Cattenom, Chooz, Fessenheim).

ASN finds that EDF has taken satisfactory account of the possibility of flooding of the galleries between units in its operating procedures.

2.1.14 Diversity of telecommunication resources

The telecommunication resources would appear to be diversified and the internal connection cables are designed to withstand flooding. The sites inspected have at least one satellite phone.

ASN finds this organisation and its implementation to be satisfactory.

2.1.15 Optimisation of discharges at the prediction of a flooding risk

When there is a predicted flooding risk, most of the operating procedures define what steps are to be taken (drainage of tanks for instance). The inspectors did however observe that the Chooz site failed to take this into account, considering that the know-how of the staff was sufficient.

ASN finds that the steps to be taken when a flood risk is announced must be clearly indicated.

2.1.16 Exercises: deployment of flood protection and prevention equipment (cofferdams, sandbags, mobile pumping resources)

The inspectors asked whether mobile pumping resource deployment exercises were held. This is the case on most sites, but the exercises are often incomplete and do not include a real operating test (Blayais, Belleville, Tricastin) or are held too infrequently (last exercise in 2008 at Saint-Alban and in 2004 at

Chooz). Other sites have never carried out this type of exercise, but some plan to do so (Nogent). Finally, experience feedback from these exercises is not always taken into account (Saint-Laurent). At Gravelines, the exercises (2010) showed that the mobile pumping resources are not utilised regularly enough to guarantee pumping within a reasonable time.

On several sites, the inspectors carried out exercises with the mobile pumping resources and were on the whole satisfied with the results at Cattenom, Penly, Saint-Alban and Fessenheim. However, at Tricastin, during the three exercises held, a number of anomalies were identified and the inspectors noted that the cofferdam deployment plan is not ergonomic, that the identification of the cofferdams is confusing, that the mobile protection system deployment report is not exhaustive and that the seals used are of poor quality.

The exercise carried out during the inspection of Saint-Alban showed that some of the steps required by the procedures are inadequate: action liable to lead to radioactive releases off the site (in a scenario in which the flood water is contaminated with radioactive particles), fire door not blocked and liable to damage the pump hose, action entailing a breach of containment and fire sectoring, incomplete fire procedure leading to absence of PV control in certain cases.

The conclusions of the exercise performed at Cruas also showed that improvements are needed with regard to the storage of pumping equipment, the deployment time (3 hours), the length of electrical cables, and so on.

Overall, the inspectors observed that few sites actually deploy the MMP during exercises designed in particular to improve the procedures in place and train the staff for these situations. ASN finds that MMP deployment exercises and actual operating tests should be performed on all the sites at least once a year and that the lessons learned must be incorporated into the procedures.

2.1.17 Overall evaluation of the "protection of facilities in an off-site flooding situation"

ASN considers that the organisation put into place to manage the risk of flooding provides a satisfactory response to its expectations. The same applies to multi-unit management, isolation management (except at Tricastin and Cruas) and the diversity of communication resources.

However, ASN finds that management of volumetric protection needs to be improved on several sites. EDF will therefore have to focus its efforts on volumetric protection monitoring and maintenance.

EDF will also be required to define and hold exercises for testing the equipment and crews in this type of situation and take account of the feedback from these exercises.

Finally, EDF will have to improve:

- rigorous application on the sites of the particular flood operating rules;
- monitoring of the meteorological, high water and tidal parameters;
- the schedule for the performance of the actions decided on as a result of experience feedback from the partial flooding of the Le Blayais site in 1999;
- management of the mobile pumping resources.

1.22.2 Earthquake protection of the facilities

2.2.1 Introduction

Context

Earthquakes are among the natural hazards that nuclear facilities must be able to deal with. Protection of the facilities against the risks linked to earthquakes is based on the one hand on the definition of the seismic loadings to be considered in the design and, on the other, on the parasismic measures to be adopted to prevent the effects associated with these loadings. These measures are designed into the facilities and periodically reassessed according to changing know-how and regulations, in particular on the occasion of the ten-year periodic safety reviews.

During these periodic safety reviews, a large number of checks are run by the licensee and evaluated by ASN and the IRSN.

Fundamental safety rule RFS 2001-01, which was published in 2001, defines the seismic loadings to be considered. This RFS is supplemented by ASN guide 02.01, dated 2006, which sets out the construction

rules to be applied to prevent the effects associated with earthquakes. EDF also applies RFS I.3.b relative to seismic instrumentation.

Stakes

An earthquake can have simultaneous effects on several parts of a nuclear facility and its environment. It can cause an event initiating an accident, while disabling the safeguard systems designed to deal with this initiating event. It can have more wide-ranging effects on the facility and its environment, such as an outbreak of fire or the loss of electrical power to the facility.

The design principle adopted is that the plant must be designed to be restored to and maintained in safe shutdown conditions after an earthquake corresponding to a hazard level at least equivalent to that of the safe shutdown earthquake (SSE). The equipment, systems and structures, to which behaviour and performance requirements are allocated (integrity, functional capability, operability). Consideration must also be given to the possible failure of elements having no safety role but which, in the event of an earthquake, could constitute a hazard for systems contributing to safety from the seismic risk viewpoint.

Inspection frame of reference

EDF describes the results of its evaluations and the resulting protection measures in each of its safety reports, which are periodically assessed by ASN through the periodic safety reviews conducted on the facilities.

The sites also rely on operational documents, to anticipate and manage an earthquake situation. This for example includes reports of periodic tests or maintenance performed on the instrumentation used by the sites in the event of an earthquake.

The purpose of the inspections on this topic was to check the conformity of the facilities with this frame of reference. These inspections in particular involved field visits and exercises to assess the effectiveness of the organisation put into place by EDF.

2.2.2 Organisation

During the course of the inspections, particular attention was given to analysing the effectiveness of the planned organisational arrangements in the aftermath of an earthquake.

For the purposes of this analysis, the inspectors used the organisation memos in effect, the breakdown of responsibilities and the training plans for the on-site and external respondents. An exercise simulating the occurrence of an earthquake was also performed on virtually all the sites inspected, to check that the measures stipulated in the memos are possible and are performed correctly in good time.

Seismic frame of reference

ASN considered it satisfactory that certain sites have a seismic coordinator. However, the inspectors observed that several sites had not appointed this person (with a list of duties, training qualifications, responsibilities) and provided no evidence of any training on this point.

Post-seismic operating documents

Inconsistencies were found in certain operational documents used in the event of an earthquake (for example, inconsistent flowchart and procedure text, inversion of the numbering of the 3-axis accelerometers on the EAU⁴ rack, in particular at Flamanville). A number of instructions also fail to indicate how to respond to unavailability of one of the measurements (for example, at Chooz in the event of a failure of the accelerometer on the floor of the reactor 1 building fuel pit floor).

Finally, certain operating documents do not meet quality standards (validation date, handwritten annotations, etc.).

Section 2.3 of RFS I.3.b ("Operation of seismic instrumentation") states that: "if the earthquake level corresponding to a spectrum with an amplitude half the design response spectrum for the site is exceeded by any of the measurements, the licensee shall immediately go to the shutdown state considered, for each unit, to be the safest". The procedure on certain sites concerning what to do in the case of an earthquake

⁴ EAU rack: Containment instrumentation system for seismic monitoring and measurement

states that if the half design response spectrum is exceeded, the reactors are taken to the safest state, jointly with the RTE (electricity transport grid) and the COPM (production contracts operations centre).

ASN finds that this step does not meet a safety requirement, does not conform to RFS I.3.b and that the procedures have to be corrected accordingly.

Post-seismic diagnostic

RFS I.3.b states that "operation may only resume once ASN has been provided with evidence of the harmlessness of the earthquake for the subsequent behaviour of the facility; an analysis of the behaviour of equipment important for safety will be [...] necessary to obtain authorisation to continue with operation of the units." The inspections revealed that there was no official list of the checks to be performed on the facilities (equipment and buildings) following an earthquake larger than half the operating basis earthquake. Some sites stated that the alarms present in the control room were able to indicate the unavailability of equipment important for safety. These alarms do not give the status of the buildings and equipment not important for safety (IPS) but which enable the reactor to be kept in a safe state over the long term. Other sites indicated that EDF head office departments would be called on in a situation such as this.

ASN considers that any crisis situation must be anticipated and that detailed official procedures must be in place so that when the time comes, decisions can be taken in stressful conditions. ASN considers that the diagnosis to be carried out following an earthquake cannot be based simply on the alarms situated in the control room. This diagnosis must be formalised and must take account of the condition of the reactor at the time of the earthquake.

Resources available in the event of an earthquake

During the inspections, the inspectors observed that the earthquake is managed by the crisis organisation and the material and organisational means defined by the PUI. Following an earthquake, this approach fails to take account of the potential condition of the internal communication routes for access by the emergency services, the vulnerability of fluid networks or the condition of certain buildings in which emergency resources are stored, or of other buildings housing persons designated in the procedures as decision-makers.

ASN finds that for all of its sites, EDF needs to identify the general means that would be essential in the event of an earthquake on the site. EDF will check that these means (both on and off the site) are robust to the safe shutdown earthquake as defined in the safety reports. As applicable, other means will be defined in a PUI (radiological or other) and implemented.

Training

Generally speaking, the inspectors observed that on most of the sites, the operating staff are not made aware of the seismic risk (characteristics and physical manifestations of an earthquake exceeding the alarm trigger threshold or the reactor shutdown threshold).

Inclusion of the seismic risk in the training programme

The training programme followed by the EDF staff ("Professional Academy") requires familiarity with the requirements of internal directive (DI) n°81 "continued qualification for accident conditions of the equipment installed in PWR units". This DI requires that the approach taken consider the earthquake event ⁵. New staff also receive tutoring. Finally, awareness-raising campaigns are also conducted (for example at Blayais in 2007, Flamanville since 2010).

However, a number of observations made during the field visits showed that the event earthquake approach was not correctly and completely taken into account (for example an overhead crane on the Le Blayais site was not in the parked position). The operational documents do not always mention this point (analysis of risks and inspection programmes for the Chooz construction site for example).

⁵ Certain functions and equipment require seismic qualification in order to guarantee that they are fully available following an earthquake. Furthermore, the operation of this equipment must not be affected by equipment that is not seismic classified, in particular temporary equipment put in place for maintenance worksites.

More broadly, on most of the sites, the inspectors noted that the only training requirement with regard to the subject of earthquakes is that covering the earthquake event approach.

ASN finds that EDF must define awareness-raising and training measures in addition to those that already exist, for the site personnel, whether on-site staff or external staff, in order to ensure that the seismic risk is continuously taken into account on the site on a long term basis.

Shutdown after earthquake

All of the sites apply fundamental safety rule (RFS) I.3.b concerning seismic instrumentation. Section 2.3 ("Operation of seismic instrumentation") states that: "if the earthquake level corresponding to a spectrum with an amplitude half the design response spectrum for the site is exceeded by any of the measurements, the licensee shall immediately go to the shutdown state considered, for each unit, to be the safest". The time to shutdown does not appear in the operating instructions presented. Furthermore, the sites told the inspectors that no earthquake simulation exercises had been held (see training section of this chapter). The estimated emergency shutdown time therefore has to be tested and confirmed in the field. Finally, during the exercises performed, some sites were unable to correctly respond to this requirement (longer than 1 hour at Le Blayais, 1h30 at Fessenheim), in particular as a result of insufficiently precise instructions and a lack of operator awareness.

ASN finds that, for all of its reactors, EDF must check that the organisation in place today enables all of its reactors to comply with the abovementioned requirement of the RFS I.3.b. As applicable, the sites shall deploy an appropriate organisation (procedure and training).

In the light of the shortcomings observed, ASN will require that EDF study the possibilities for installing an emergency shutdown device in the event of an earthquake.

Performance of earthquake exercises

Most of the sites informed the inspectors that they had not carried out any exercises on the subject of earthquakes. This type of exercise permits determining the effectiveness of the arrangements made to deal with an earthquake and the training given.

ASN finds that it is necessary that EDF's crisis exercise programme take account of the earthquake topic and the resulting consequences (fire, explosion, etc.).

Instrumentation training

During most of the inspections, an exercise was held in the control room to simulate the occurrence of an earthquake and overshoot of an accelerometer alarm threshold. This exercise required familiarity with the working of the acceleration electronic recording cabinet (containment instrumentation system for seismic monitoring and measurement – or EAU rack) and an accelerograph, used if the EAU rack is unavailable. It was also necessary to calculate the intensity of the earthquake using the values recorded by the EAU rack. The result of this calculation was then used to help guide the operating crews with management of the event.

On some of the sites, training is provided on use of the EAU rack. However, in some cases, the inspectors were able to observe:

- that this training had not been given or written up in the individual training logs;
- that this training had not led to an evaluation;
- that no exercises had been carried out concerning this rack;
- that the staff were unable to calculate the values enabling a decision to be reached on whether or not to shut down the reactor;
- that the operators were insufficiently familiar with all the instrumentation functionalities (in particular the EAU rack).

Finally, during the course of an exercise simulating a malfunction of the EAU rack (at Chooz and Cruas), the inspectors observed that the operators were unable to interpret the peak accelerograph sensor data. In the event of an earthquake and unavailability of the rack, the plates of the peak accelerograph located in the control room are sent by transporter to the Thermal and Nuclear Studies and Project Service

(SEPTEN) for interpretation. However, the Nogent NPP demonstrated its ability to interpret these data during the course of an unannounced exercise initiated by ASN.

ASN finds that the staff liable to have to collect and analyse the data indicating the characteristics of an earthquake, in particular those in charge of operating the reactor, need to be trained in the use of the instrumentation and in particular the reading of the values given by the control room peak accelerograph.

Resistance of equipment and buildings

EDF internal technical directive DT 320 concerning the inventory per reactor of the equipment nonconformities still not closed, requires that by 1st July 2011 the sites:

- create and then keep an up-to-date list of uncorrected equipment nonconformities comprising deviations that are:
 - generic and not yet closed on the reactor;
 - local, leading to a significant safety-related event (ESS) and to a significant event report and not yet closed on the unit.
- be able to provide this list at all times.

Several sites were unable to present this list and identify the nonconformities, which is liable to have an impact on seismic risk management.

The inspectors observed that in certain cases, when this list was available, there was no safety analysis of nonconformity combinations (Nogent, Penly for example).

ASN finds that EDF must keep this list up-to-date (defined according to DT 320) and analyse nonconformity combinations on each of its reactors.

2.2.3 Instrumentation

Operating basis earthquake (OBE) values

The EDF head office departments issued an internal memo setting out the OBE values to be considered in the reactor control system. The acceleration values to be considered for the OBE may differ between the documents used by the sites (operating instructions, safety report).

Earthquake: justification of site classification

The studies conducted by EDF showed that the geology of the Dampierre site is heterogeneous; the seismic instrumentation will therefore be completed in 2013 and 2014. The site is at present unsure of whether the values given by the sensors are underestimates or overestimates. An earthquake bigger than the operating basis earthquake might therefore not be detected and not lead to shutdown of the units.

RFS I.3.b (§ 2.2.3) states that classification of a site as "homogeneous" must be justified by the licensee. Failing which, the site is classified as "heterogeneous". This classification then determines the instrumentation with which the site is to be equipped. The Penly and Flamanville sites presented no evidence to justify the applicable category.

Equipment condition

The facility visits and examination of the maintenance reports revealed discrepancies in the manual of instructions for maintaining qualification (RPMQ) for accident conditions:

- the EDF national frame of reference requirements stipulate that for the seismic accelerometers, four screws must attach the sensor to the ground, with a tightening torque of 0.7 daN.m. The inspectors however found on various sensors that unit mounting screws were missing (Nogent, Cattenom, Blayais), mounting screws were rusted (Nogent, Paluel) and the tightening torques on the four ground mounting screws had not been checked;
- similarly, EDF national frame of reference requirements stipulate that for the peak accelerographs, the four mounting screws between the sensor and the ground must be torqued to 0.5 daN.m. The inspectors found that mounting screws were corroded on the Nogent and Golfech sites;
- some sites did not incorporate the RPMQ requirements into their local procedures (Blayais).

ASN finds that non-compliance with these requirements is liable to compromise the qualification of the accelerometers and accelerographs.

The free field⁶ sensor was also checked. Some inspections showed that the free field sensor was unable to perform its functions (traces of corrosion on the free field sensor accelerometer at Saint-Alban, faulty sensor owing to electromagnetic disturbance at Dampierre).

A number of potential anomalies were also recorded during the field visits or document analyses:

- certain check-points that are not explicit enough to guarantee the actual free field operation of the sensor (Blayais);
- at Civaux, during the exercise which involved applying the operating procedure to the shock perception criterion, the inspectors noted that the USB flash-drive installed in the EAU rack and designed to replace the flash-drive in place when its recording capacity is no longer sufficient, was defective;
- at Bugey, during the field visit, the inspectors found that the free field sensor was simply placed on the ground, making it vulnerable to shocks, etc.

Other anomalies were recorded on certain sites, with no traceability regarding their resolution (Paluel for example).

Identification and positioning of sensors

The inspectors queried the positioning of the sensors (especially the free field sensors). Some sites were unable to provide any justification (Tricastin, Penly, Flamanville).

The inspections also highlighted non-compliance with RFS I.3.b on several sites. RFS I.3.b (§ 2.2.3.1) stipulates that a 3-axis accelerometer be located *"on the basemat of another building housing systems important for safety and the foundations of which are different from those of the reactor building"*. Some sites failed to comply with this stipulation; this is the case at Cruas, Nogent, Penly and Bugey. For these last three sites, the accelerometer associated with this requirement is the sensor placed on the floor at level 0 of the nuclear auxiliaries building, about fifteen metres above the basemat.

The RFS states (§ 5.2.2) that free field devices must be *"sufficiently far from all sources of vibrations or significant shocks as could disrupt the seismic measurements"*. At Penly, the accelerometer is in fact situated on the site platform at the edge of a road where vehicle traffic can create vibrations. The Saint-Alban accelerometer is located in the basement of the safety building. No justification for this choice of location was presented.

ASN finds that the correct positioning must be checked for all the sensors required by RFS I.3.b; if necessary, they will be relocated.

Instrumentation maintenance and calibration

The inspectors noted that the seismic instrumentation accelerometers are regularly maintained and periodically checked (Paluel, Golfech, Penly, Nogent, Cattenom). However, the exact content of the maintenance operations is not always described in the official operating documents (at Chooz for example).

RFS I.3.b (§ 2.2.4) requires that the devices also be calibrated, in particular because the loading response may drift over time, given that the sensors comprise electrotechnical components. Some sites are unable to state whether or not the devices have been calibrated since they were installed (Paluel, Golfech, Penly, Nogent, Fessenheim) or whether their response to a real mechanical loading had been tested (Cattenom). Automatic calibration of the sensors is performed daily when ordered by the EAU seismic rack, however the technology of these sensors and the various parameters measured during these calibrations were not presented to the inspectors (Nogent, Chooz) and it was impossible to demonstrate that the mechanical characteristics can be checked by means of these calibrations.

⁶ Free field corresponds to locations where soil movements can be considered to be undisturbed by the proximity of heavy buildings; RFS I.3.b considers that a point is in free field if its distance from the heavy buildings (nuclear islands, turbine halls, cooling towers) is at least 100 metres.

ASN finds that EDF needs to review its calibration procedures and their implementation in order to comply with the requirements of RFS I.3.b.

Setting of free field sensor trigger thresholds

RFS I.3.b (§ 2.2.2.1) states that the equipment making up the seismic instrumentation must allow measurement of accelerations with a scale range of at least 0.01 g to 1 g. On several sites (Golfech, Civaux, Flamanville, Penly, Tricastin, Paluel), the free field accelerometer is set such that accelerations of less than 0.25 g may not trigger the alarm in the control room. The free field accelerometer is in fact the soil motion reference, independent of the influence of the construction on the site.

ASN finds that for all its sites, EDF must verify the alarm settings related to the free field sensor recordings and, as necessary, restore conformity with the requirements of RFS I.3.b.

2.2.4 Event earthquake approach

Some functions and equipment require seismic qualification to guarantee complete availability following an earthquake. Moreover, the operation of this equipment must not be affected by equipment that is not seismic classified. As of the second ten-year in-service inspections of the 900 MWe plant series, EDF thus initiated what is known as the "event earthquake" approach, the aim of which is to prevent any damage to an item of equipment important for safety (IPS) by a non-IPS item. This approach applies to all the EDF reactors. This rule guarantees that the IPS equipment remains available after an earthquake occurs.

Integration of the national frame of reference and risk analyses

The EDF head office departments established rules for integrating this approach (potential hazards and associated countermeasures) into a requirement (operational integration of the event earthquake) that the sites are required to incorporate into their local safety requirements (organisation memos, procedures, training programme, etc.) no later than 6 months after receiving them.

Certain sites (Bugey, Chooz for example) are late in integrating the national frame of reference with regard to consideration of the risk of damage to equipment important for safety. This delay concerns the integration of "event earthquake" requirements into the provisions applicable to worksite phases during which temporary equipment such as scaffolding or biological protection is deployed and could constitute potential hazards. The earthquake is therefore not incorporated into the processes used for analysis of the worksite risk (Bugey, Cattenom, Chooz).

ASN finds that the event earthquake approach needs to be incorporated into the site procedures as rapidly as possible, in particular for the worksite risks analyses.

Implementation of the approach through the field visits

The field visits showed that the earthquake event risk merits greater consideration; for example, the inspectors detected the following:

- Civaux electrical building: several mobile (wheeled) parts of unplugged electrical cabinets were not blocked and, in the event of an earthquake, could strike cabinets containing equipment important for safety;
- in an area close to the control room at Golfech: presence of several items liable to damage electrical cabinets containing equipment important for safety;
- Tricastin and Saint-Alban control rooms: presence of a wheeled console (needs to be mobile so that the operating procedures can be more easily moved around, in particular those concerning accident situations) whose wheels were not immobilised and not secured to the ground in front of the control room monitoring equipment and an extinguisher;
- Saint-Alban control room: computer monitors in the control room liable, in the event of an earthquake, to fall onto the facility control keyboards and pushbuttons.

The inspectors did however note the reactivity of the Flamanville site, which took steps regarding the items (repositioning or removal of the drum) liable to constitute a risk for the electricity generating set fuel tanks.

At Golfech, each crane is marked by a panel mentioning the crane reference and the rules to be followed for the parking positions as part of the " earthquake event " approach, which constitutes a good practice. However, during the inspection of the turbine hall and the diesel hall, anomalies were observed in the positioning of the cranes when they are not in use. Trolleys not in their parking position and hooks not kept in the raised position were observed.

The field visits showed that the earthquake event approach needs to be better taken into account on the sites.

Temporary operating facilities during reactor outage or reactor at power

Some temporary devices may, if they fall, constitute a hazard by damaging or disabling other equipment important for safety. This primarily concerns biological protection and scaffolding.

Before installing them, the sites must therefore analyse the risk of falling and take preventive measures. The time for which such items are in place must also be kept to the strict minimum.

The inspectors therefore asked for the risk analyses performed on the occasion of the last work carried out. Reading them showed that the risk analyses presented are not always complete; for example, no account is taken of the risk of falls for objects with a mass of less than 10 kg, items which are in place for less than a week, and a distance from equipment important for safety of more than 1 metre (concrete example in Cattenom).

Certain risk analyses were not carried out; for example, in the nuclear auxiliaries building at Nogent, the inspectors found that scaffolding had been in place for three months and could constitute a hazard for a pump important for safety, even though no work was in progress. At Chinon, the inspectors found the presence of items (scaffolding parts, stepladder, etc.) in the train A pumping station for reactors 1 and 2 and on the lower levels of the reactor 3 fuel building.

The inspectors did however note that on several sites, there was an " earthquake event " technical guide and that the sites implemented the approach via a complete local memo.

Similarly, a number of preventive measures are taken; for example at Le Blayais, the site clamps the scaffolding when the work exceeds 7 days: this modification takes half a day and helps reduce the scaffolding hazard for the IPS equipment situated nearby.

Duration of presence of hazardous items in the vicinity of equipment important for safety

The inspectors found that the rules varied according to the sites with respect to the time a potentially hazardous item could remain in the vicinity of an item of equipment important for safety (1 week at Tricastin, 72 hours according to head office departments).

The facility visits also showed that this time was significantly exceeded in certain cases (Tricastin, Golfech).

Even if some sites demonstrated good practice of the event earthquake approach, ASN finds that the inspections demonstrated that considerable progress still needs to be made on this subject, from both the documentary viewpoint (risk analyses) and the implementation and staff training aspects.

Evaluation of facility conformity

As part of the reactors conformity check prior to their third ten-year in-service inspection, EDF launched a survey of all the local modifications not concerning equipment important for safety which could be considered as potential hazards to equipment important for safety and classified seismic-resistant. Several sites were unable to present this list (Blayais, Nogent).

2.2.5 General evaluation on the topic "Protection of facilities in an earthquake situation"

The inspections showed that on the majority of sites, some of the RFS I.3.b instrumentation requirements are not met: insufficient number of sensors, requirements concerning the maintenance and qualification of sensors not met, incorrect positioning of sensors or no justification of this positioning, lack of calibration, incorrect settings, absent or incomplete procedure. These anomalies could delay the reactor shutdown stipulated by RFS I.3.b, or could even lead to this decision not being taken. ASN will thus require that EDF examine the possibility of installing an emergency shutdown system in the event of an earthquake.

Furthermore, even though some training had been given, the exercises initiated by ASN during the inspections demonstrated that on most sites, the operators liable to have to use the data from the seismic instrumentation had little if any ability to do so, which could also delay reactor shutdown or even lead to this decision not being taken.

ASN finds that EDF needs to overhaul its organisation (equipment and procedures) and its staff awareness and training, to ensure conformity with RFS I.3.b and its objectives. EDF informed ASN that it has already initiated measures to address ASN's findings (verification of positioning of seismic measurement sensors, operator information, updating of procedures).

ASN finds that verification of the effectiveness of the procedures entails the performance of realistic exercises. This type of exercise is not currently held. This programme of exercises should also take into account the experience feedback from the Fukushima accident, in other words should take into account the hazards resulting from an earthquake (fire, explosion, industrial risk, mobilisation of the public services, absence of communication routes) and the known vulnerabilities of the facility (for example, on some sites, emergency buildings not designed to withstand a SSE). ASN also considers that EDF must for all its sites identify the general resources that are essential in the event of an earthquake on the site and check that these resources (both on and off the site) are robust enough to withstand the safe shutdown earthquake as defined in the safety reports. As applicable, other resources shall be defined in a PUI (radiological or other) and deployed.

The inspections and in particular the field visits, clearly showed the need to improve awareness and good practices with respect to the approach for the earthquake event. ASN finds that EDF needs to develop and implement an appropriate training programme on this topic and update the site documents (in particular the risk analyses). The national reports will need to be applied as rapidly as possible. EDF informed ASN that it has already taken steps to address the ASN findings (nomination of a local seismic coordinator, seismic risk awareness-raising campaigns launched on all the sites).

Finally, ASN finds that certain sites must more rigorously monitor the discrepancies concerning the seismic resistance of certain equipment and perform an overall analysis of the impact of these discrepancies.

1.32.3 Loss of heat sink

2.3.1 Introduction

Reactor cooling is a function important for the safety of a nuclear facility. To prevent the dispersion of radioactivity, the cladding surrounding the nuclear fuel must be prevented from bursting and the fuel from melting. This in particular requires removal of the heat given off by the nuclear reaction and the residual heat remaining after the chain reaction is stopped.

This function is performed by a system which pumps in cold water from an outside source (sea or river). The water in the cooling system is then either sent directly back into the environment or, when the river discharge is too low or the heating too high given the sensitivity of the environment, it is cooled in a cooling tower.

The goal of the inspections was two-fold. The first goal was, following the national inspection campaign on this topic in 2007, to check the conformity of the facilities with the EDF "heat sink" frame of reference requirements currently applied to the French nuclear power plants. Various natural or climatic hazards – such as drought or large-scale arrival of clogging material – have also in recent years had consequences on the heat sinks of French NPPs. The second goal of the inspections was thus to assess the extent to which EDF has taken into account experience feedback and effectively deployed countermeasures and procedures for dealing with comparable hazards.

2.3.2 Organisation / human factors

The aim was to check that the sites are correctly organised so that they can integrate and locally apply the requirements of the national frame of reference. The relations between the site and the head office departments were examined. The distribution of responsibilities within the sites was investigated.

EDF has set up a national network of "heat sink" correspondents in each NPP. ASN observed disparities in the organisations put into place for monitoring the "heat sink" system equipment. Most of the sites have their own heat sink engineer specifically dedicated to monitoring this equipment, but this type of

organisation is not systematic: some NPPs only have a "heat sink correspondent" who also performs other duties at the same time.

The inspectors observed disparities in the monitoring of the heat sink equipment by the sites. In general, those sites where there was no clearly identified person in charge of monitoring the "heat sink" system were less reactive and exhaustive in applying the EDF national requirements. For example, on the Cattenom⁷ site, where no "heat sink" engineer is appointed, ASN observed a lack of site commitment to preventing heat sink loss risks and a lack of anticipation in the maintenance of certain structures. The recommendations contained in the EDF requirement documents concerning heat sink safety were incompletely adopted and monitoring of the progress of the actions taken was less rigorous than on the other sites.

There is also room for improvement in the relations between the NPPs and the EDF head office departments. On numerous occasions, the inspectors found sites waiting for answers or analysis by EDF head office departments, with no real indication of when this would be done. For example, on several sites (including Cattenom and Golfech) the inspectors found deviations from the EDF national frame of reference for the "heat sink" system awaiting processing by the EDF head office departments. Synergy between EDF head office departments and the sites must thus be improved in general.

2.3.3 Conformity of pumping station systems with the EDF national frame of reference (deployment of particular directive DP 143)

The 2003 EDF particular directive DP 143 asks the sites to diagnose the conformity of the pumping station systems with the applicable national frame of reference and to take all steps to deal with any anomalies. Exhaustive application by the sites would guarantee the conformity of the NPP pumping stations with the EDF national frame of reference.

ASN observed that the steps expected to achieve conformity have been or are in the process of being taken, although anomalies were nonetheless observed at Cattenom NPP. This latter NPP has a list of identified anomalies still in the process of being corrected, but the inspectors were unable to obtain any corresponding deadlines. For its part, the Le Blayais site had problems with integration of the requirements of DP 143. A few sites still need to finalise a number of actions.

Overall, ASN observes that EDF is making efforts to bring all the heat sinks into conformity with the national frame of reference and is asking EDF to clear the actions still ongoing.

2.3.4 Integration of experience feedback (REX) particularly interim requirement 303 concerning how to deal with clogging of the heat sink

Natural hazards such as the large scale arrival of clogging material (algae, plant debris, fry, silt, etc.) have in recent years had impacts on the heat sinks of several EDF nuclear power plants. EDF was thus asked to learn the lessons from these events and take corrective measures to reduce the vulnerability of its NPPs to the risk of total or partial loss of the heat sink. The inspectors in particular examined application of the internal requirement concerning how to react to clogging of the heat sink (DT 303), as happened to the fleet on two occasions at the end of 2009.

In most cases, the inspectors found that operating experience feedback had been satisfactorily integrated by the sites inspected. At least four sites (Bugey, Cattenom, Fessenheim and Golfech among others) have however not yet completed their assimilation of DT 303. For the others, not all the requirements of the directive are applied, which requires further corrective action on the part of EDF. Despite the fact that cooling tower fouling was the cause of a partial heat sink loss in the past, there is no systematic monitoring of this under quality assurance conditions (for example at Saint-Alban). Several sites have mentioned that the internal requirement concerning the collection of data on the heat sink clogging risk (DT 222) for the time being only concerns the coastal sites and that an update to be issued by the EDF head office departments should include the riverside sites by 2012.

Examination of local experience feedback showed that the equipment in place was adequate for dealing with heat sink problems, although sometimes not without difficulty. For example, the equipment which retains the plant debris at Golfech was unable to contain the large scale arrival of algae in June 2011. More

⁷ The Cattenom site is however less susceptible to the risk of loss of heat sink owing to the presence of Mirgenbach Lake which constitutes a cooling water reserve of several weeks in the event of loss of the Moselle river primary heat sink.

generally, complete integration of experience feedback concerning the loss of heat sinks following the large-scale arrival of clogging material is an ongoing process that needs to be continued by EDF.

2.3.5 Anticipation: monitoring, prevention and detection resources

In order to anticipate any problems related to the heat sink, EDF has set up technical and organisational arrangements for monitoring, prevention and detection of potential heat sink "hazards". Prevention of the clogging risk was looked at earlier ("integration of experience feedback"); this part looks at the steps aimed at preventing and detecting the other risks.

ASN observed that certain sites had implemented agreements with other organisations so that they could receive warning and anticipate any problems related to the heat sink: river or dam operator organisations, weather forecasts, information network between various sites, independent port authority for estuary sites, etc. The inspectors found considerable organisational differences between the sites: for example, the Rhone river sites have not all concluded an agreement with the Compagnie Nationale du Rhône (CNR), the Nogent site has an agreement with the Voies Navigables de France (VNF), but the Chooz site has no agreement with the operators on the Meuse river or the manager of the Revin STEP (energy transfer pumping station), with the only possible "off-site" alert coming from the office of the *préfet*.

Some sites analyse water quality, with trend monitoring to detect any changes, while others do not. This water quality monitoring, sometimes no more than just a visual inspection, is not systematically performed under quality assurance conditions (Saint-Alban, Chooz, Tricastin especially). The Le Blayais site has initiated research to improve its understanding of the river parameters to be monitored. The visual checks on the heat sink performed by the auxiliary operators are not always conducted under quality assurance conditions (for example at Golfech, Nogent among others).

With regard to the risk of clogging by ice crystals (frazil), the inspectors saw that this risk was dealt with diversely and the measures sometimes need to be completed, for example by means of an arrangement making provision for a supply of hot water (at Flamanville, Golfech, Gravelines especially).

The sites are required to take bathymetry (water depth) measurements of any silting or sanding at the water intake. Above a certain threshold, EDF begins dredging operations. The inspectors observed that this operation is correctly carried out on most of the sites. One of them, the Bugey NPP, which is potentially less exposed to the risk, has not taken any measurements for several years (2007 in fact).

With regard to the detection resources, ASN observed that all the sites have instrumentation (sensors, etc.) capable of at least detecting a drop in the water intake. The inspectors noted that this equipment, which is not all classified important for safety (IPS), is often inadequately monitored. On several sites (Saint-Alban, Bugey, Chooz among others) the licensee was unable to prove that the equipment was serviceable because there were no checks logged under quality assurance. At Chooz and Bugey especially, the inspectors found a discrepancy between the local measurement and the instrumented flow measurement, which could lead to an overestimation of the actual flow. On the other hand, some sites such as Golfech have extended the scope of the checks beyond what is required by the frame of reference requirements.

On this topic, the inspectors thus observe a disparity in the way the various risks are considered from one site to another, leading to differences in the measures taken. The precision with which the arrangements are implemented and monitored could on the whole be improved.

2.3.6 Management of cooling in a degraded situation

The inspectors observed that all the sites have operating and control instructions for the facilities in the event of a degraded situation or climatic hazard. The special operating rules for extreme heat, extreme cold, frazil ice are known, available and implemented. Certain coastal sites, in particular Paluel, have also opted to apply "oil slick" risk management owing to a special operating rule known as "i-polmar". The inspectors did however observe that this procedure was not included in the personnel training curriculum. On coastal sites with oil slick booms, their deployment could be slowed down in certain cases owing to the absence of *ad hoc* anchorage or means of access.

Moreover, the inspectors found that there were facility operating procedures to deal temporarily with an occasional loss of the heat sink. These are known to the sites. The inspectors found no major nonconformity on this point. Some sites are designed with a relative degree of independence: for example the Civaux NPP is self-sufficient for 10 days, while the Cattenom site could be independent for more than 15 days.

This essentially documentary topic appeared to be well managed by the NPPs. Its operational implementation is dealt with later on in the "Operational management of accident situations" section.

2.3.7 Maintenance, servicing and availability of equipment, upkeep of premises

Some of the heat sink equipment is classified as "important for safety" and in this respect should be subject to required periodic testing to ensure that it is available. Independently of this classification, this and other equipment must be covered by a maintenance programme to ensure that it is kept in good working order.

The inspectors discovered that on most of the sites, there were maintenance or periodic test anomalies. These discrepancies are not all serious and are not generalised, but do clearly show that efforts are needed in this area. At Le Blayais and Penly for instance, a delay in integrating certain maintenance requirements was remarked upon. Another example was when the inspectors identified 8-yearly maintenance operations to be carried out on the Saint-Alban trash rake which had not been carried out as at the date of the inspection (standard replacement of the motorised hydraulic pump, standard replacement of the hydraulic lifting motor and standard replacement of the two hydraulic translation motors), periodic tests that were unsatisfactory but not repeated on the drum screen sensors (CFI, circulating water filtration system), or health check-ups on "critical" equipment such as the circulating water system (CRF) or the essential service water system (SEC), and on "important" equipment such as the containment spray system (EAS) and the raw water system (SEB) which had not yet been carried out on sites using the new maintenance methodology referred to as AP 913 (Bugey, Paluel for instance). On the whole, generalised use of this preventive maintenance methodology should encourage the licensee to enhance its vigilance with regard to monitoring of heat sink equipment.

With regard to the condition of the structures and equipment, ASN's assessment is once again contrasted. On the whole, ASN observed a clear improvement in the condition of the equipment and the cleanliness of the premises when compared with the 2007 inspection campaign. It must be remembered that the atmosphere in the pumping rooms is particularly corrosive, especially on the coastal sites. The improvement is significant for those sites applying the O2EI (obtaining exemplary conditions in the facilities) approach in the pumping rooms. Even though the overall impression is good, the inspectors listed a number of equipment and structure anomalies resulting from the lack of corrective action. On half of the sites visited, the inspectors found signs of water infiltration in the pumping rooms, traces of advanced corrosion on the equipment (SEC and SEI lines especially, sometimes even on the pumps), or significant leaks from the SEC, CRF or CFI pumps, located at the packing glands, flanges and vents. The lighting in the premises visited appeared to be deficient on some sites, making the interventions more difficult. On several occasions the inspectors observed intervention requests that had not been processed as of the date of the inspection, thus exceeding the recommended times (Civaux, Flamanville among others). The premises are cleaner, but the condition of the equipment could still be improved.

The SEC piping attracted the attention of the inspectors in two particular cases. At Paluel, additional investigations carried out in 2011 revealed that certain segments require particularly close monitoring and that a localised defect required repair. This complementary investigative approach, which is considered to be a good practice, was not a part of any maintenance programme and consequently leads to no systematic corrective action. At the Gravelines NPP, corroded or nonconforming anchors compromised the seismic resistance of the SEC system filter supports, leading to conformity repair work in accordance with the ASN request. This system would therefore seem to require appropriate vigilance on the part of the licensee, especially for coastal sites.

Finally, at Civaux, Flamanville and Paluel among others, the inspectors found that there was no local maintenance programme for the SEC system and that periodic maintenance was carried out on the basis of the national maintenance programmes.

To conclude, significant progress has been achieved since 2007 and the general condition of the facilities is good, but could be better.

2.3.8 General evaluation of the "loss of heat sink" topic

ASN finds that the heat sink, which is an important system, demands particular vigilance. The recent heat sink clogging or partial loss events, at Cruas and Fessenheim in December 2009 especially, demonstrated its vulnerability and led EDF to initiate an action plan to reinforce the robustness of all the heat sinks. ASN specifically asked EDF to initiate a design review of all the heat sinks. ASN will be asking EDF for the detailed conclusions of the heat sink design review site by site, along with the corresponding action plan with completion dates.

The inspections carried out by ASN in 2011 showed that the general condition of the heat sinks was good but that a certain number of nonconformities persisted on certain sites. Stringent operation and maintenance, close monitoring of the condition of equipment and structures and exhaustive implementation of national directives are as a general rule the areas for improvement for many sites. On numerous sites, maintenance of the SEC system was deficient and thus requires particularly close attention. EDF intends to strengthen the safety frame of reference for the heat sink, estimated for early 2013.

1.42.4 Loss of electrical power supplies

2.4.1 Introduction

Each reactor is connected to the electricity grid by a line called the "main line". Before sending the grid the electrical energy it has produced via the generator, the reactor uses the step-down transformer (TS) to draw off the electrical energy needed to power the panels and switchboards providing the energy required by the equipment it needs in order to function, as well as the equipment needed for the safety of the facility. If there is an incident on the main line, it is capable of isolating itself from the electricity grid via its step-down transformer and can continue to supply its panels and switchboards itself.

When the reactor is not producing electricity, or if the main line is unavailable, the panels and switchboards are then supplied via a second line, called the auxiliary line. The reactor is then powered directly from the electricity grid, via the auxiliary transformer (TA).

Failure of the off-site sources is considered in the design of the reactors. To take account of this risk, each reactor has on-site energy sources capable of supplying the electrical panels and switchboards essential to the correct working of the safety equipment. The reactor's on-site sources thus consist of two diesel electricity generating sets. Each nuclear power plant has an additional on-site energy source, the technology of which differs according to the plant series to which it belongs: a station blackout diesel (SBO) for the 900 MWe NPPs or a combustion turbine (TAC) for the 1300 MWe and N4 series.

In the event of total loss of both off-site and on-site electrical sources, there is one final backup turbine generator (LLS) type electrical power source which runs on the steam produced by the reactor itself.

The goal of the inspections was to examine NPP practices with regard to the operation, maintenance and enhanced reliability of the equipment contributing to the electrical power supply for the equipment necessary for the safety of the facilities.

Application of the EDF technical frame of reference was verified by means of spot-checks, particularly with regard to the general operating rules and the maintenance programmes. Field visits were also carried out on the electrical buildings, the backup electricity generating sets and the TACs, in the control room and in the battery rooms. Finally, a real-situation exercise was held with the EDF operating crews, who were asked to align and start-up a backup electricity generating set, during the course of certain inspections.

2.4.2 Organisation and operation

ASN considers that the documentation associated with the operation and maintenance of the electrical power supplies could be improved.

Formal structure of documents

During the spot-checks of the operating documents, the inspectors found a lack of rigorous structuring of these documents on most sites, in particular:

- the particular requirements and the limiting conditions of chapter III of the general operating rules (RGE) are not always included in the maintenance operation files (especially at Bugey, Saint-Alban);

- there is no formal structure for the reports on certain checks (correct operation of the level measurement devices in the backup generator fuel storage tanks, visual check on areas containing backup batteries, etc.) (Golfech, Fessenheim);
- filling out of the operational documents and periodic test reports, the associated second level check, and the drafting of anomaly sheets if the results are unsatisfactory or satisfactory with reservations, is sometimes partial or insufficient (particularly at Civaux, Golfech).

Equipment preventive maintenance

During their examination of the basic preventive maintenance programmes (PBMP), the inspectors in particular observed that:

- certain PBMP updates, especially those under the responsibility of the head office departments, were produced belatedly (Golfech, Paluel, Penly, Saint-Alban);
- some new equipment, such as the OPzS batteries, is not at present covered by an appropriate maintenance programme (Fessenheim).

The inspectors also observed that certain maintenance monitoring programmes were ineffective (EDF monitoring of the quality-related activities performed by contractors, in accordance with article 4 of the order of 10th August 1984).

Cleanness of premises

During the visits, the inspectors observed a remarkable lack of upkeep of some areas on the majority of the sites:

- cigarette butts were found at the bottom of a manhole in a fuel oil transfer area (Civaux);
- bird droppings, which could disrupt the operation of the electricity generating set air coolers, are still present owing to the postponed installation of bird defence systems on the roofs (Gravelines);
- several areas contain puddles of oil, fuel or coolant caused by seepage or small leaks (Civaux, Nogent, Paluel);
- a fuel pump leak tank was three-quarters full of a liquid that could not be identified on the day of the inspection (Nogent).

2.4.3 Backup electricity generating sets

ASN finds that the periodic inspections and servicing of the backup electricity generating sets could be improved.

Analysis of fluids

To ensure that the backup electricity generating sets are in good working order, the quality of the fluids (oil, fuel and coolant) is periodically analysed by the licensee in accordance with the national preventive maintenance programmes.

During the course of the spot-checks, the inspectors found that the quality of these analyses could be improved, in particular:

- the licensee does not consider these analyses to be a "quality-related activity" as defined in article 2 of the order of 10th August 1984; in this respect, it does not apply the resulting quality requirements to these activities, in particular the provisions of article 4 of the order of 10th August 1984 which stipulates appropriate monitoring (Cattenom, Fessenheim);
- in certain local preventive maintenance programmes as of the date of the inspection, no provision was made for periodic fluid analyses (Chooz);
- some of the analyses required by the PBMP (zinc and phosphate levels in the coolant fluid, fuel checks at delivery) may not be performed (Golfech, Paluel, Penly);
- in the analysis reports concerning, for example, the water content levels, there is a lack of precision; different measurement units from those of the PBMP were also used (Chinon, Dampierre, Gravelines, Paluel, Saint-Laurent);

- the fluid analysis results are not systematically and formally reviewed by the licensee, in particular when the limits set are almost reached, when two analysis methods lead to different results or when the results are abnormal (Bugey, Civaux, Flamanville, Paluel, Penly).

Equipment obsolescence

While reviewing the end of maintenance reports concerning operations performed recently on the electricity generating sets, the inspectors found that the licensee is faced with problems of obsolescence on the supply of certain spare parts (Chooz). On the occasion of the last complete inspection therefore, the licensee had to keep certain items in service because no spares were available. These parts are currently being procured and to date no item has been replaced by another type of equipment owing to obsolescence.

Corrosion

During the visits, the inspectors found problems with corrosion, especially on the electricity generating set coolers or certain fire extinguishing system valves (Paluel, Tricastin).

Emptying of the day tank

The inspectors observed that on the date of the inspection, there was still a risk of emptying of the electricity generating set day tank through inadvertent operation of the remote valve (Civaux).

2.4.4 Combustion turbines (TAC)

ASN finds that the checks performed by the licensee on the TAC need to be improved.

TAC start-up

The inspectors examined the reports of the tests performed by the licensee and ran TAC start-up tests; on this occasion, the inspectors found that:

- the TAC start-up times were longer than those required by the RGE on several sites (Cattenom, Golfech, Belleville);
- the Belleville TAC did not start the first time;
- the Fessenheim TAC was unavailable on the day of the inspection;
- certain periodic test results, close to the limits set by the RGE (start-up time) or exceeding those of the test procedures (filter head loss, air barrier pressure), are not analysed by the licensee (Flamanville);
- certain emergency crew procedures were not updated and fail to take account of the specificities of new TACs (Paluel).

Other anomalies

During the inspections, the inspectors also observed various equipment anomalies affecting the TACs including:

- damaged electrical cabinet closure system (Civaux);
- no equipment markings (Civaux);
- numerous past requests for maintenance not as yet dealt with (Golfech);
- damaged foaming agent storage trailer (Golfech);
- damaged vibration pads (Nogent).

2.4.5 Backup turbine generator (LLS)

The backup turbine generator (LLS) runs on the steam recovered from the steam generators, driving a turbine coupled to a generator and converting mechanical energy into electrical energy.

ASN finds that the checks run by the licensee on the LLS are on the whole satisfactory. However, management of the anomaly sheets could be improved (Flamanville, Golfech, Saint-Alban).

2.4.6 Electrical transformers

An electrical transformer is a converter able to modify the voltage and intensity of a current; an oil circuit is incorporated to act as an electrical isolator and as a coolant for removal of the heat produced.

ASN finds that the checks run by the licensee on the electrical transformers are on the whole satisfactory. However, the inspectors did observe that certain oil analyses of these electrical transformers are unsatisfactory; some of the measured values in particular were imprecise and not even systematically measured and no justification was provided for the limit values being exceeded (Saint-Alban).

2.4.7 Fuel oil storage

Each site has fuel oil storage tanks specifically for supplying each electricity generating set or combustion turbine.

ASN finds that the fuel oil storage conditions could on the whole be improved.

Fuel oil deliveries

During the spot-checks, the inspectors found that on most sites, fuel oil delivery practices could entail risks of common-mode failure of all the electricity generating sets, in particular:

- the two electricity generating sets of the same reactor can be supplied by the fuel oil from the same delivery;
- the CPY series sites refuel the diesel generators from the SBO tank used as a buffer tank. This situation is liable to create a common-mode risk;
- as none of the sites ran checks on the conformity of the product at delivery, only the periodic analyses would be able to detect any nonconformity, thus delaying the implementation of any corrective measures.

Corrosion

During the visits to the fuel oil storage areas, the inspectors observed internal or external corrosion problems on the fuel oil piping and tanks on the majority of the sites (Civaux, Flamanville, Gravelines, Paluel, Fessenheim).

This corrosion is facilitated by:

- water infiltration or leakage, (Civaux, Golfech);
- a lack of inspection of the condition of the piping and tanks (Flamanville, Golfech, Paluel).

Over and above the problems of the cleanness of the premises (see section 2.4.2), the inspectors also observed a small leak from one fuel tank (Chooz).

For the 1300 MWe and N4 series reactors, the inspections also revealed vulnerability of the fuel oil tanks areas to flooding.

2.4.8 Storage of oil and coolant fluid

On the Paluel site, all the oil and coolant fluid needed for in-service make-up of the various electrical equipment items, is stored in a single place; this situation could lead to a common-mode failure risk for all this electrical equipment.

2.4.9 Management of the loss of electrical power supplies

In the event of loss of a reactor's two electricity generating sets, EDF has drafted an inter-plant unit backup procedure (I-LHT) allowing rapid connection of this reactor to a backup generating set belonging to another reactor on the site.

On the whole, this procedure is in place on all the reactors, with rare exceptions (Fessenheim for instance only has this system for one reactor).

The inspectors had a simulation of this I-LHT procedure run on certain sites; these exercises were felt to be on the whole satisfactory. However, documentary anomalies highlighted the lack of regular testing of this procedure (Civaux).

2.4.10 General evaluation of the "loss of electrical power supplies" topic

With regard to the electrical power supplies, the inspectors considered the EDF sites to be on the whole satisfactory, but that improvement was possible on the following points:

- rigorous operating and maintenance documentation (filling out of operational documents, updating of maintenance programmes);
- physical condition of certain fuel oil storage equipment (piping corrosion, water infiltration);
- management of the fluids needed by the electricity generating sets (periodic analyses);
- periodic inspection of the TACs on certain sites.

1.52.5 Operational management of accident situations

2.5.1 Introduction

Incident or accident operations are based on the condition-based approach (APE). The APE consists in defining operating strategies according to the identified physical state of the nuclear steam supply system, regardless of the events which led to this state. If the state degrades, a permanent diagnostic enables the ongoing procedure or sequence to be abandoned and a more appropriate one to be adopted.

The APE operating documents are based on the incident or accident operating rules given in chapter VI of the general operating rules (RGE). At the time core deterioration is detected (core melt), steps described in the Severe Accident Intervention Guide (GIAG) are designed to safeguard the containment in order to minimise the consequences of the accident. Responsibility is then transferred to the emergency teams who have the Emergency Team Intervention Guide (GAEC) at their disposal.

In order to deal with these accident situations, the NPPs have the backup equipment (fixed or mobile) necessary in the event of an emergency. Three types of equipment are identified according to their use: equipment specified in the complementary domain accidents safety studies and presented in the various safety cases (complementary domain equipment MDC), mobile equipment used for the accident operating procedures of chapter VI of the general operating rules (mobile safety equipment MMS) and the mobile equipment used during implementation of the on-site emergency plan (PUI) when requested by the emergency crews (PUI mobile equipment).

The main objectives of the inspections on this topic were to ensure the presence and applicability of the documentation necessary for accident operations (rules, guides and operating procedures), personnel training, availability, quality of testing and maintenance performed on the equipment needed to manage an accident.

2.5.2 Incident or accident operating rules

Management of the operating frame of reference covering accident operations

The documents needed for operation in an accident or severe accident (AG) situation are on the whole correctly managed. The nuclear power plants at Saint-Alban, Saint-Laurent, Nogent, Tricastin and Bugey nonetheless need to improve their management of chapter VI of the general operating rules: incorporation of the local and national temporary safety instructions⁸ into chapter VI of the RGE and into the accident operating procedures. For its part, the Paluel NPP will need to ensure the accessibility of the severe accident (AG) documentation (GIAG), by improving the ergonomics of the control room.

⁸ Temporary modification designed to remedy a deviation

Operating personnel training and qualification

The personnel training and qualification aspect is on the whole satisfactory. Nonetheless, qualification monitoring is not always carried out in the Cattenom and Cruas NPPs. Flamanville NPP has no provision for the refresher courses necessary for maintaining severe accident management skills. The Golfech and Fessenheim sites need to implement a tool for rigorous monitoring of training and the qualification summary forms. The Tricastin NPP needs to modify its organisation in order to clarify the options chosen for handling a non-validated evaluation.

Equipment necessary for accident management

On the whole, management of the equipment necessary for dealing with an accident situation could be improved in all the NPPs. The requirements of EDF internal directive n°115 concerning management of mobile safety equipment and mobile PUI equipment are in fact neither adopted by nor applied by a majority of the sites:

- management of the equipment maintenance tests needs to be improved on several sites: Blayais, Paluel, Cattenom, Gravelines, Bugey, Fessenheim, Saint-Laurent and Saint-Alban;
- the equipment is not stored in the place described in the documents or it is situated in a place liable to suffer from an on-site or off-site hazard, particularly on the following sites: Saint-Alban, Gravelines, Nogent or Flamanville;
- incorrect intervention order references in the Tricastin local technical procedure, owing to the transfer of management of certain equipment items between departments on the site;
- unplanned equipment handling at Flamanville or handling using an outside contractor at Tricastin, with concerns over the ability of the contractor's staff to modify the I&C of an elevator and thus enable handling of a pump in an accident situation;
- confusion in the local procedures between the time needed to prepare the equipment for use and the duration of use on the Dampierre, Gravelines, Tricastin and Blayais sites;
- implementation time longer than that required in the operating rules, for replacement of the diaphragm by a ring on the containment atmosphere monitoring system (ETY) in the Cruas NPP.

Integration of operating experience feedback (REX) by the site

Integration of operating experience feedback (REX) is on the whole satisfactory for most of the sites. However, the Cattenom, Cruas and Tricastin NPPs will have to improve how they organise the collection of "operating experience feedback on application of the condition-based approach (APE)" following implementation of incident/accident instructions.

The exercises and accident situation simulations took place on the whole satisfactorily.

2.5.3 Organisation put into place for the on-site emergency plan (PUI)

General organisation

The goal of this part is to check the organisation put into place on the sites to comply with the requirements of the PUI frame of reference. On the sites, a procedure must therefore specify the organisation put into place in accordance with the PUI and the roles and responsibilities of the PUI coordinator and the various managers involved in the PUI organisation must be formally stipulated. The EDF national frame of reference in particular states that the organisation be built around several individuals, that PUI modifications be approved by the hygiene, safety and working conditions Committee CHSCT and that a transverse organisation be put in place to guarantee the consistency of the measures to be taken by the various emergency management command posts. This latter point usually corresponds to regular site meetings of the PUI commissions (or committees).

The sites presented their procedures stipulating the PUI organisation put into place. This procedure is complete and up-to-date with the exception of a few sites.

Each site has a PUI coordinator, sometimes accompanied by a second person. However, the PUI coordinator does not always have a specific document defining his duties and responsibilities, this being in particular the case at Golfech. These are sometimes defined in the site's organisation memoranda. With the exception of a few sites, where the PUI organisation relies entirely on the PUI coordinator, there is a PUI network on each site, in which the PUI coordinator has activity field correspondents and a manager

per command post (PC). A PUI commission convenes the network 4 times a year to follow-up the corrective measures identified during analysis of operating experience feedback of exercises and actual situations. However, these PUI commissions did not meet in 2010 or 2011 on the Golfech site.

The general organisation put into place by the sites for the PUI is satisfactory. The sites will nonetheless need to ensure that the duties of the PUI coordinator are clearly defined in a specific document and that this organisation is robust and does not rely on a single person. In this respect, the PUI correspondent networks are a good initiative.

External relations

As part of their preparations for management of an emergency, the sites must conclude agreements with the off-site emergency organisations which could be involved in the management of a crisis. The sites must in particular have agreements with the emergency services, including the departmental fire and emergency service (SDIS) and hospitals. The sites must also have information agreements with the offices of the *préfets*, nearby industrial sites and Météo France. These information agreements are essential during the management of an emergency because they enable events to be anticipated. Moreover, in an emergency situation, the sites can receive assistance from external organisations with additional material and/or human resources. The sites can therefore conclude agreements with neighbouring industrial sites, neighbouring countries, the AMT-C⁹, the GIE-Intra and the EDF Regional Delegation.

If they are to be considered operational, the site agreements concluded with these external organisations must be regularly tested and updated.

The information agreements with the offices of the *préfet* are satisfactory. However, the requirements in terms of the time within which the site needs to inform the office of the *préfet* are not always clearly defined. Many of these agreements now include delegation of power from the office of the *préfet* to the site for triggering of the off-site emergency plan (PPI) in the reflex phase. These or other agreements with neighbouring industrial firms, enable the sites concerned to be informed of "hazards related to the industrial environment" in the vicinity of the site. Coastal sites have also drawn up agreements with the offices of the maritime *préfets* (information in the event of maritime pollution for example).

With regard to information concerning meteorological conditions, EDF has a national agreement with Météo France. Concerning extreme weather conditions, the sites conclude specific agreements with the inter-regional offices of Météo France or obtain information through the agreement with the office of the *préfet*. The Cruas site has taken out a subscription to the *météo flash* weather bulletin service.

Each site has an agreement with the SDIS emergency services which determines the organisation and the resources that can be mobilised in the event of an emergency. This agreement is tested during exercises at least once a year. Some sites will need to clarify the arrangements of this agreement.

The agreements concluded with the hospitals are frequently very old: some go back to 1994 or, in the case of the Golfech site's agreement with Agen hospital, even to 1989. The conditions for updating of these agreements are unclear and they are sometimes simply renewed tacitly. Agreements have also been concluded with the SAMU (emergency ambulance service) and the SMUR (emergency medical service) but they are also very old. For example, the Tricastin site's agreement with the SMUR dates back to 1981.

Assistance agreements are also signed between neighbouring nuclear sites in each region so that backup can be provided if necessary. Some of these agreements would benefit from being clarified. The assistance agreements with the GIE-Intra and the AMT-C are managed at a national level. The conditions for recourse to the GIE-Intra and the AMT-C are recalled in the PUI for some sites, but others do not seem to be aware of them. There are also agreements between each NPP and the EDF regional delegation. However, for the Cruas site, this agreement has never advanced beyond the draft stage and never been signed.

If personnel are evacuated to the fall-back centre, most of the sites have an agreement with a transporter for the provision of buses. However, the possible impact of a transport requisition order from the *préfet* on the availability of buses in the event of population evacuation following triggering of the PPI, is frequently not considered. On the Cruas site, no measures are currently taken for managing evacuation to the fall-back centre.

Finally, concerning possible agreements with neighbouring countries, these are primarily the responsibility of the offices of the *préfet* via the PPI.

⁹ AMT-C: Thermal Maintenance Agency - Centre

Generally speaking, the procedures for revision of all these agreements are not clearly defined.

The agreements defining the relations with external organisations in the event of an emergency could be on the whole improved. They are sometimes lacking in precision and the revision and testing procedures are often inadequate. The agreements concluded with the hospitals are particularly old.

Operational part

In an emergency situation, the alert is given by the site emergency director (PCD1). In order to adapt the alert to the events happening on the site, the PCD1 must have at his disposal the guideline flowchart enabling him to trigger the type of PUI appropriate to the situation being encountered. To manage the situation on the site, the emergency crews must then have access to action sheets. These sheets must be kept up to date in the various emergency command posts and must be regularly revised.

On the sites where an exercise has been held or where the PCD1 has been placed in a real situation, the use of the PCD1 guideline flowchart is satisfactory. Few comments were made on the flowcharts verified during the documentary inspections.

The availability of the action sheets was checked in the various emergency control centres and was felt to be satisfactory, with the exception of a few sites where greater checks on this availability are required. The content of some of the action sheets also needs to be optimised on some sites, to allow faster access to the telephone numbers to be called in an emergency situation.

The operational part of the PUI organisation put into place by the sites is satisfactory. The sites will have to ensure that the action sheets are both available and effective.

Human resources: on-call staff and training

To ensure that the staff are trained and qualified before they take on PUI on-call duties, a training plan must be established for each member of the PC. Nomination of an agent as an on-call officer, following the relevant training programme, must be formally stipulated. A process for monitoring the training and refresher courses must also be put into place on the sites to avoid any discrepancies and delays in refresher courses.

The training plans for the PC members are defined in procedures incorporated into the PUI. The qualification of the agents, in particular those of the local emergency team (ELC) and the severe accidents operating personnel, is satisfactory, with the exception of a few sites.

The on-call organisation procedures are formally structured in a sheet or weekly schedule which gives the names of the persons on-call. Nomination of the agents on-call is officialised by a document signed by the agent and then countersigned. The number of persons on-call is sufficient: it varies between 4 and 6 people depending on the site and on the on-call rota.

Management and monitoring of training (including refresher courses) are sometimes carried out manually via Excel files and could therefore be optimised. For the Cruas site, follow-up of the refresher courses needs to be improved. Other sites use more appropriate software and systems. If anomalies are detected, they are generally corrected quickly.

Although general monitoring and follow-up of training is usually good, the definition of the initial training, management of qualifications, setting up on-call teams and following-up the training needed by the personnel has to be improved with regard to a certain number of points. The sites will have to acquire robust software or systems enabling them to monitor and trace the personnel training and qualification.

Human resources: exercises and operating experience feedback

In addition to the training, the staff holding PUI on-call duties have to carry out regular PUI radiological safety (SR) exercises. The frequency of participation in the PUI exercises is defined in the EDF PUI frame of reference. In order to meet the requirements concerning staff participation in the PUI SR exercises, the sites are required to monitor these participations. In addition to the PUI exercises, the sites are required to hold annual personnel mobilisation exercises.

All of the exercises performed, but also any real emergency situations encountered, must be the subject of formally structured operating experience feedback. Any corrective measures decided on through operating experience feedback (REX) must also be monitored and followed up.

The sites annually schedule regular and varied exercises: radiological and conventional safety, evacuation, etc. The staff are required to take part in at least one PUI SR exercise every year. On the majority of the sites, the PUI engineer monitors this participation by means of an operational and easily usable table. When staff participation anomalies are detected, they are generally remedied on the occasion of the following exercises. For the Cruas and Golfech sites, these anomalies are not always in fact corrected by the first exercises of the following year and monitoring of the processing of these anomalies needs to be further optimised.

Each exercise is written up in a detailed report used for the operating experience feedback analysis by the PUI commissions. REX measures are then defined and formally stipulated in action plans. This monitoring and the traceability of the actions need to be improved on certain sites. However, for the Golfech site, only one exercise in 2010 was written up in a report and monitoring and follow-up of the corrective measures is not rigorous enough.

The performance of exercises and the formal structuring of the operating experience feedback by the sites are satisfactory. The sites must however focus on the traceability and systematic follow-up and monitoring of REX measures.

Material resources

The requirements concerning the telecommunication resources necessary for emergency management are given in the RMTC. The sites have implemented this frame of reference, which in particular sets out the requirements concerning redundancy and the tests to be performed on the telecommunication resources of use in an emergency. The tests relating to the PPI sirens were in particular reviewed.

During the inspections, the availability and operability of the material resources in the event of off-site hazards were checked.

Finally, the sites have PUI vehicles. These vehicles are used in an emergency situation to take measurements and samples around the site. Their contents must be regularly checked and tests on the equipment in these vehicles must be scheduled and performed.

The requirements of the telecommunication resources frame of reference (RMTC) in the event of an emergency are applied on all the sites, but not always in full. Therefore, the sites must focus on identifying any remaining discrepancies. The requirements concerning redundancy and the periodic testing of telecommunication resources are met, apart from a few isolated cases. Some sites need to verify the availability of telecommunication and PUI material resources in the event of flooding.

The PUI and PPI sirens are tested once a month. However, the PPI sirens audibility test was only carried out once, at commissioning of the power plants. The RMTC requires that preventive maintenance be conducted annually on the PPI sirens. During the spot-checks carried out, the inspectors found that this preventive maintenance was not carried out at Golfech and Cruas. The operating tests on the population address system in the reflex response phase (SAPPRE) are run during the national crisis exercises.

Exercises to deploy and implement off-site resources on the site are regularly held, in particular with the SDIS emergency services. However, exercises involving the resources of the GIE INTRA are not held on all the sites. In the case of an event affecting several facilities, the sites still have to demonstrate that they have sufficient equipment.

All the sites have two PUI vehicles, many of which were recently renewed. The inventory checks and periodic tests performed on the contents and working of the PUI vehicles is satisfactory, with the exception of a few isolated remarks.

Management of the material resources could be improved with regard to a certain number of points. The sites will in particular need to focus on exhaustive implementation of the requirements set out in the RMTC and on adequacy of the material resources in the case of an event affecting several facilities.

Crisis management premises: assembly points

Each site defines the personnel assembly points. These points are distributed around the sites and access to them is clearly marked. They are located outside the controlled areas and are easily accessible. These premises are designed to temporarily accommodate the persons present on the site at the moment an alert is triggered. Their goal is to protect the site personnel during the first few hours of the crisis and enable them to be counted and informed of the situation.

To achieve these goals, the assembly points must be at least equipped with a system for counting the personnel assembled in them, suitable means of communication for the dissemination of information, means of communication with the emergency bunker (BDS) and means for monitoring the radiological conditions.

These assembly points must be equipped with a mechanical ventilation system that can be stopped.

All the sites have a sufficient number of well-distributed assembly points. They are clearly marked on the site drawings and the access routes are signposted. On only one site do the staff directions to these points need to be improved.

In these assembly points, personnel counting by means of badges has become generalised on the sites. In general, all the necessary equipment is available: means for checking bodily contamination, radiation meters, means of communication with the other premises and megaphones for dissemination of information to the personnel present, iodine tablets (sometimes not available in-situ but brought from the emergency bunker), emergency directory, lamps, armbands. Some sites can cut off the ventilation in the assembly points, which is a good practice for premises outside nuclear islands which is identified in the EDF PUI frame of reference.

The distribution and upkeep of the assembly points on the sites is satisfactory. The sites will concentrate on the quality of signposting guaranteeing rapid access to these points by the personnel. Generalised adoption of badges for automatic personnel counting is expected for all the sites.

Emergency management premises: emergency bunker (BDS)

The BDS management procedures must be formally laid out in a memo on the sites.

The BDS, which is the on-site emergency management building, must be designed to enable the emergency teams to perform their duties and protect the personnel and equipment it contains against hazards, radiation and contamination. The BDS must thus be protected against off-site hazards and it must be able to operate independently. The BDS premises must be compatible with the number of persons present in an emergency situation and with the duration of the crisis. They must be able to meet the needs of the persons concerned (water, sanitation, food, iodine tablets).

The BDS must also be equipped with means of monitoring bodily contamination, means of measuring the radiological conditions and a decontamination line with all necessary equipment. The availability and operability of the BDS equipment, in particular the backup diesels, must be guaranteed and periodically checked. The effectiveness of the iodine traps must also be regularly verified.

BDS management is defined in the site PUI memoranda, in particular comprising the inventory of equipment in each PC. Each of the BDS visited contains fax machines specifically for transmission and for reception and clearly identified so as to avoid confusion. The useful documents are present, in particular the directories and procedures. There are sometimes a few discrepancies concerning updating of telephone numbers in the directories.

Each site has contamination monitoring systems in the BDS and installs a decontamination line for the staff entering it. Some sites still however need to improve this decontamination line (sufficient number of showers, sanitary facilities in the contaminated zone). Iodine tablets are also present in sufficient quantities.

The self-sufficiency of the BDS was checked: most of the premises have daily rations and water for at least 48 hours. However, some sites are short of bottled water in the event of the mains water being undrinkable, which is the case on the Golfech site. The minimum fuel oil level for the diesels offers the BDS at least four days of independent operation (delivery possible within 48 hours). Periodic tests are regularly performed and the level of fuel oil is checked every month.

For some sites, the non-floodable nature of the BDS has been checked, but this still has to be demonstrated for others. Similarly, the seismic resistance of the BDS is often uncertain. The mounting of the communication equipment (telephones, faxes, computers, printers, etc.) on the tables on which it is placed, or even the strength of the satellite antenna, also need to be confirmed. The iodine trap effectiveness tests were checked and are generally satisfactory. Habitability and access have not always been demonstrated in the event of a severe accident (Gravelines). Finally, over-pressurisation of the BDS has yet to be demonstrated for certain sites, in particular Golfech.

Management of the emergency bunker on each site is therefore still open to improvement. Resistance of the premises to off-site hazards (flooding and earthquake) is still to be verified or proven, as is over-

pressurisation to prevent the possible transfer of contamination. The sites will focus on the self-sufficiency of the BDS.

Emergency management premises: fall-back centre

The sites have a fall-back centre located off the site, generally at a distance of more than 5 km, and not under the prevailing winds. The purpose of this point is to accommodate the personnel in the event of site evacuation, so that they can be protected and informed. This point can also be used in a crisis as an assembly point for the personnel shifts present on the site. To achieve this, the organisation of the point must make it possible to impose the following route: check on contamination, decontamination of persons as necessary, clean zone for non-contaminated or decontaminated persons. It is important that this routing separate contaminated individuals from those who are not. The layout of the premises and the planned organisation must also be able to meet the needs of the personnel (sanitary facilities, water, food, iodine tablets). Periodic checks must be carried out to verify the contents of the fall-back centre. A procedure stipulating the organisation of the fall-back point and detailing its equipment must be present on the sites.

Each site has a fallback centre, located off the site, which can accommodate the personnel in the event of site evacuation. However, too many fall-back centres are less than 5 km from the sites, such as at Golfech. Management of these premises needs to be improved on certain sites. Management of the fall-back point on the Golfech site needs to be improved as a whole. The capacity is satisfactory but one of the fall-back points seen during the inspections is not only for the licensee's personnel but is also stipulated in the PPI as a place for grouping the population. Some are short of supplies (food rations, clothing), while others need to overhaul the decontamination line. The lists of equipment present in the fall-back points are not always up-to-date or monitored. For the Tricastin and Cruas sites, the fall-back points were combined but ASN had not been informed beforehand. This was discovered on the occasion of the post-Fukushima inspections, which cannot be considered satisfactory.

Management of the fall-back points located outside the sites can be improved as a whole. The inventories of the equipment present need to be produced and periodically checked, the decontamination lines need to be tested, in particular with checks on the satisfactory ergonomics of the premises (no crossover of the different circuits). Finally, some fall-back centres are not far enough from the sites in the event of a severe accident.

Emergency management premises: emergency technical centre

The emergency technical centre houses the ELC in an emergency situation. It is important for this centre to be equipped with tools and the technical documentation needed by these teams. The documentation must be up-to-date and the communication equipment needs to be regularly checked.

The emergency technical centres inspected and the useful technical documentation they contain are satisfactory.

Communication routes

During the seismic inspections, the inspectors found that the documentation concerning the analysis of the impact of an earthquake on both the on-site facilities and the off-site facilities, in particular the communication routes for access to the site, were generally insufficient or non-existent.

ASN considers that for each of its sites, EDF needs to analyse the impact of an earthquake, both off-site, in particular on the communication routes allowing access to the site, and on-site. Means of mitigation must be defined and implemented if the occurrence of an earthquake were to compromise the planned arrangements using the on-site and off-site communication routes which fail to withstand an earthquake. This subject must be handled by the complementary safety assessments.

2.5.4 General evaluation on the topic "management of accident situations"

Accident situation management can be improved. The organisation implemented by the sites under the PUI is satisfactory, although certain points still need to be improved further:

- management of the fall-back points;
- certain agreements concluded with outside organisations.

3. Summary of targeted inspections conducted in 2011 concerning topics related to the Fukushima accident on Laboratory, Plant, Waste and Decommissioning facilities (LUDD)

➤ *Summary of the inspections*

In 2011, inspections were carried out on the high-priority facilities other than the power reactors:

- *all the facilities operated on the AREVA NC site at La Hague;*
- *all the facilities operated by AREVA and its subsidiaries on the Tricastin site;*
- *the Mélox plant operated by Mélox SA (Marcoule);*
- *the FBFC plant operated at Romans-sur-Isère;*
- *five facilities operated by CEA: the Osiris reactor (Saclay), Masurca reactor (Cadarache, currently shut down), Phénix reactor (Marcoule, shut down), the ATPu (Cadarache, undergoing decommissioning) and the RJH reactor (Cadarache); this last reactor, which is under construction, underwent only a very partial inspection given the current state of its construction;*
- *the high- flux reactor (RHF), operated by the Laue-Langevin Institute in Grenoble.*

These facilities are characterised by a wide variety of activities, operated in accordance with frames of reference requirements comprising a common part (for example, the fundamental safety rule relative to earthquakes and ministerial orders, especially the orders of 10th January 1984 and 31st December 1999) plus their own specific requirements (general safety rules, safety reports and specific requirements set by ASN decisions).

The 19 inspections carried out showed few deviations from the safety frames of reference of the facilities. However, as some of these frames of reference were not up-to-date, this point will need to be confirmed for the facilities concerned.

Certain periodic checks and tests are not performed either systematically or exhaustively. Several inspections thus led to improvements being required from the licensees with regard to this aspect.

On the whole, the site personnel are trained in emergency management. The licensees must however take the necessary steps to ensure that this training is actually given to all the personnel liable to be concerned, including those from outside the site. In addition, this training should be supplemented by the organisation of crisis exercises on specific targeted topics (loss of electrical power supplies, loss of cooling functions).

For crisis management on multi-licensee sites, agreements have been concluded between some licensees. The ASN inspectors asked that this practice be made general and that greater thought be given overall to a ranking of the interventions in the eventuality of a large number of facilities being simultaneously concerned.

The ASN inspectors observed that the alert procedure trigger tests were performed satisfactorily. Nonetheless, the means required to trigger this alert could be rendered unserviceable in the event of a severe accident such as an earthquake or flood. The licensees must identify additional means to be implemented to prevent this risk.

In a post-accident situation, the ASN inspectors observed that access to certain facilities would be difficult, for example in the case of very high water. In addition, the maintained operability of certain emergency resources was not always demonstrated, for example when they are housed in structures not designed to withstand the safe shutdown earthquake (SSE). Management of these situations would be also be made difficult owing to the loss of the release monitoring resources following the loss of electrical power supplies, and the loss of telecommunications, the autonomy of which is limited. Several inspections revealed that auxiliary premises, emergency premises or premises housing response equipment and crews were not designed to withstand an SSE. The maintained accessibility of the backup electrical power supply resources must be examined. Finally, most of the sites have not established any procedures for long-duration crisis management.

1.63.1 General presentation of the sites and facilities

3.1.1 Experimental reactors

Osiris

The pool type Osiris reactor, with an authorised power of 70 MWth, operated by CEA, is primarily designed for technological irradiation of structural materials and fuels for various power reactor technologies. It is also used for a number of industrial applications, in particular for the production of medical radionuclides.

The Jules Horowitz reactor (RJH)

The Jules Horowitz reactor, currently under construction on the Cadarache site, and which is to be operated by CEA, will be able to perform activities similar to those today carried out with the Osiris reactor. It will however comprise a number of significant changes, with regard both to the experiments performed in it and to safety. The targeted inspection on the topics related to the Fukushima accident was only partial given the current state of construction of the facility.

Phénix

The Phénix reactor, built and operated by CEA in collaboration with EDF, is a sodium-cooled fast neutron reactor demonstrator. It was authorised by decree of 31st December 1969, and initial reactor divergence took place in 1973. Its initial rated power of 563 MWth was reduced to 350 MWth in 2002. The plant finally ceased operating at power coupled to the grid in early 2009. Tests corresponding to the end of operations, called the end-of-life tests, were then carried out until early 2010.

The high-flux reactor (RHF)

The high-flux reactor at the Laue-Langevin Institute in Grenoble, is a neutron source primarily used for experiments in the field of solid physics, nuclear physics and molecular biology. The maximum power of the reactor, initially authorised by the decree of 19th June 1969, then amended by decree 94-1042 of 5th December 1994, is of 58.3 MWth. The core of the reactor, located in a containment, is cooled by heavy water contained in a reflective tank, itself immersed in a light water pool. Three vertical and four angled channels direct the neutrons to the experiments halls located outside the reactor building. Vertical tubes are also used to irradiate samples.

3.1.2 Nuclear fuel cycle facilities

La Hague site

The La Hague site is located on the coast at the north-western tip of the Cotentin peninsula, 6 km from Cap de La Hague and 20 km west of the city of Cherbourg. The site covers the communes of Digulleville, Jobourg, Omonville-la-Petite and Herqueville in the Manche *département*.

The site covers a single area of 220 ha on a plateau culminating at 180 m above sea level. To this can be added 70 ha in the Moulinets valley to the south on the seashore: this valley was blocked by a dam creating a freshwater reservoir of 400,000 m³ used to supply the site.

Seven BNIs, devoted to reprocessing of spent fuel from power and research reactors, are installed on the site. They are operated by AREVA NC. Four of them are currently undergoing final shutdown in preparation for their forthcoming decommissioning.

The facilities which were the subject of the targeted inspections on the La Hague site are the following:

Facilities in service:

- the **UP3-A** plant (BNI 116) and the **UP2-800** plant (BNI 117) reprocessing light water reactor spent fuels;
 - UP 3 (BNI 116), reprocessing spent fuel assemblies and plutonium bearing materials, with a nominal capacity of 800 t per year of fuel;

- UP2-800 (BNI 117), facility reprocessing spent fuel, like UP3, and also with a nominal capacity of 800 t per year of fuel, but also designed to reprocess MOx fuel;
- **STE 3 (BNI 118)**, industrial complex reprocessing liquid effluents and purifying radioactive effluents before they are discharged at sea.

Facilities shut down

- **the UP2-400 plant (BNI 33)** created for reprocessing of GCR spent fuels, that is peeling and dissolution of fuels, separation of fission products, uranium and plutonium, then purification and packaging of the U and the Pu. This facility is today shut down and the final shutdown and decommissioning authorisation application is currently under review;
- **STE 2 (BNI 38)**, facility which, prior to discharge at sea, reprocessed low and intermediate level radioactive liquid effluents from the UP2-400 plant. It also stores low or intermediate level wastes mainly from UP2-400 for which the disposal solutions had not been defined at the time they were produced. This facility is today shut down and the final shutdown and decommissioning authorisation application is currently under review;
- **ELAN2B (BNI 47)**, facility designed for the fabrication of sealed sources of caesium 137 and strontium 90. This facility is today finally shut down and the shutdown and decommissioning authorisation application is currently under review;
- **HAO (oxide high activity) facility (BNI 80)**, built for unloading, shearing, cutting and dissolving fuel from ordinary water reactors, today at the decommissioning phase.

Tricastin site

The Tricastin site is located within an area bounded by the Rhone river to the west and the Donzère canal at Mondragon to the east. The canal is about 100 m away, while the left bank of the Rhone is 5 km away. It is surrounded to the north by former CEA facilities and to the east by the EDF power plant, from which it is separated by a road; to the south by the CD 204 road and to the west by agricultural land.

The facilities inspected were:

- **the Georges Besse I plant (GB I) (BNI 93)** operated by Eurodif, located on the communes of Pierrelatte (Drôme), St Paul-Trois-Châteaux (Drôme) and Bollène (Vaucluse) which uses gaseous diffusion to enrich uranium in the chemical form of uranium hexafluoride (UF_6) up to 5% isotope 235. Its creation authorisation decree dates from 8th September 1977 and its commissioning license was received on 25th August 1983. It is currently operating at reduced power and production is scheduled to come to an end in late 2012;
- **the Georges Besse II plant (GB II) (BNI 168)** under construction on the Tricastin site, to be operated by the Société d'enrichissement du Tricastin (SET). It uses ultra centrifuging to enrich the 235 isotope of uranium in the chemical form of uranium hexafluoride (UF_6). This process has two main advantages over the gaseous diffusion process used by Eurodif: significantly less energy consumption and greater control of the risk of dissemination of radioactive and chemical materials (small stocks of UF_6 in the enrichment modules and the process operating conditions);
- **the Areva NC site (formerly COGEMA)** at Pierrelatte in the Drôme (26) whose activities are primarily the front-end of the fuel cycle with the W plant (which transforms the depleted uranium from the Eurodif establishment into stable uranium oxide for long-term storage) and the cycle back-end with the TU5 facility (BNI 155, which reprocess the uranyl nitrate from the La Hague site and converts it into uranium tetrafluoride (UF_4) or uranium oxide);
- **the Comurhex I plant** comprises facilities classified on environmental protection grounds for the chemical transformation of natural uranium tetrafluoride (UF_4) into uranium hexafluoride (UF_6) in order to supply the enrichment plants and a basic nuclear installation, shut down since 31st December 2008, which transformed uranyl nitrate ($UO_2(NO_3)_2$) from reprocessing of spent fuels into uranium sesquioxide (U_3O_8) and uranium hexafluoride (UF_6). A new plant is under construction, and will be a facility classified on environmental protection grounds (Comurhex II);
- **the Socatri plant**, an auxiliary company of Tricastin (BNI 138), on the commune of Bollène (Vaucluse), working with equipment and effluents from Eurodif (clean-up and maintenance of components). Socatri also provides services on behalf of Andra (storage of low-level, long-lived waste).

Nuclear fuel fabrication facilities (Mélox, FBFC)

Mélox

The Mélox plant is today the only nuclear facility producing MOX fuel, which consists of a mixture of uranium and plutonium oxides. It is located on the Marcoule site. The decree of 20th March 2007 authorised the plant to increase its output to 195 tonnes of heavy metal.

The FBFC plant at Romans

The FBFC plant at Romans produces uranium oxide powder or fuel assemblies, exclusively destined for light water reactors (PWR or BWR). The operation of this plant is regulated by a creation authorisation decree dating from 1978 and amended in 2006 to allow an increase in production capacity.

3.1.3 Other facilities (ATPu, Masurca)

ATPu

The plutonium technology facility (ATPu) produced plutonium based fuel elements, first of all for fast or experimental reactors and then, as of the 1990s, for PWRs using MOX fuel. The activities of the Chemical Purification Laboratory (LPC) were associated with those of the ATPu: physical-chemical checks and metallurgical examinations of plutonium-based products, reprocessing of effluents and waste contaminated with alpha emitters. Since 1994, AREVA NC has been the industrial licensee operating the ATPu and the LPC. From a regulatory standpoint, CEA nonetheless remains the nuclear licensee of these facilities.

Given that it was impossible to demonstrate the ability of these facilities to withstand the seismic risk, AREVA NC terminated the commercial activities of the ATPu in August 2003. Since then, CEA has been engaged in the final shutdown and decommissioning process.

Masurca

The Masurca reactor, operated by CEA, for which the creation authorisation decree dates back to 14th December 1966, is designed for neutronic studies, primarily on fast neutron reactor cores, and the development of neutronic measurement techniques. In the facility's current configuration, the core is unloaded (since the last periodic safety review in 2007) and the fissile material is being stored in the storage and handling building (BSM). This configuration should continue for another few years.

1.73.2 Protection of the facilities against off-site flooding

3.2.1 Experimental reactors

Generally speaking, the frames of reference of these facilities do not directly cover off-site flooding.

Monitoring of this risk, especially by the shift crews, is however carried out. It should be noted that agreements or MoUs are in place with the offices of the *préfet*, with Météo France or with the dam operators (either directly with the BNI, or via the centre). In the event of heavy rainfall, flooding or a dam burst, the alert would be given by the off-site parties. It should be noted that there is generally no rule for ranking the deployment of the emergency resources common to several facilities, as the safety frames of reference make no provision for multi-facility accidents.

Osiris

In the light of the frequency and the moderate intensity of the feared events and the results of the complementary safety assessments, the inspectors felt the situation to be satisfactory. However, particular attention needs to be paid to the risk of flooding through the technical galleries.

RHF

The inspectors found that the current frame of reference in force was adhered to. They did however note that a reassessment of the flood hazard was underway, as the current design of the facility was insufficient to deal with the consequences of the submersion wave that would result from the various Monteynard dam burst scenarios. Without in any way pre-judging the discharge and level adopted following this reassessment, which is to appear in the updated safety report planned for 2012, the inspectors observed that the fall-back centre, the backup electricity generators, the batteries and the doors of the reactor building were currently designed for a water level of 210.5m NGF. Above this level, they are vulnerable to the risk of flooding.

With regard to the emergency response resources, these are defined in the PUI and in a special operating instruction on "what to do in the event of flooding". However, the list given in these documents will need to be checked and updated, especially with regard to the pumping resources available on the BNI. It should also be pointed out that a motor-driven pump could also be made available to the RHF by CEA in Grenoble. The procedures for using and transporting this motor-driven pump need to be defined, particularly for a scenario in which CEA is also flooded and might also need it. The normal and emergency pumping resources appeared to be in good condition. However, certain flood door seals were found to be in poor condition and the closures on openings also need to be refurbished.

Phénix

The inspectors found that the ventilation system was not seismic qualified and that the availability of the resources for measuring and sampling the radioactive gas discharges could not be guaranteed in case of Maximum Historically Probable Earthquake (MHPE) type earthquake. They thus asked that the necessary steps be taken and justifications provided.

3.2.2 Nuclear fuel cycle facilities

La Hague site

The flood risk at La Hague would stem from heavy rainfall and the presence of groundwater under the facilities. The main observations made during the inspections and the additional requests are presented below.

Examination of the frame of reference showed the following discrepancies: inconsistency in the management of a degraded situation in certain operating instructions, depending on the heavy rainfall typology and the absence of any measures to compensate for unavailability of the sump level sensor.

Furthermore, it would seem that the personnel's specific flood risk training is today insufficient. The inspectors asked for a general earthquake or flooding exercise to be held on the site. An exercise such as this has not yet ever been organised.

The inspectors also identified additional measures to take account of experience feedback from a 2006 event in order to check the availability of the groundwater raising systems for the semi-buried facilities (44 pits). They thus requested a study on the risk of malfunction of the groundwater raising pumps if the water to be pumped comprises large quantities of suspended particles, as a result of earthquake or flooding.

The inspection found two occasions of damaged waterproof covering on the building roofs. The inspectors also looked at the question of the durability of the watertightness (PVC) of the buried facility basemats. This problem is in principle not included in the monitoring programme.

Certain electrical cables needed for the backup functions are also buried in trenches. The watertightness of these cables in immersion conditions needs to be demonstrated.

To conclude, the inspectors noted relative susceptibility of the buried facilities to the risk of flooding, with corrective measures required on the means of pumping the groundwater (availability monitoring to be improved, modifications to be made). They asked that a study be conducted on the continued functioning of the pumping resources if the water were to contain particles in suspension.

The observations also showed that monitoring of the maintained integrity of the civil engineering watertightness systems needs to be improved. The qualification of certain electrical equipment

must be demonstrated in flood accident conditions. Finally, the licensee shall ensure that its drainage networks are kept in good condition.

Tricastin site

Concerning the Tricastin site, protective structures have been built along the Gaffière river upstream, at the site and downstream, to prevent the risk of flooding by a high water level potentially capable of occurring every 500 years. These works were performed following the "flooding" advisory committee meeting of 2007. Their purpose is to protect all the facilities, except for the Socatri establishment and the Tricastin operational hot unit (BCOT). The inspections highlighted that there was no inspection, testing and maintenance programme for these new structures.

In the event of off-site flooding, some premises of the Socatri and Eurodif establishments would need to be protected by the installation of cofferdams, but there is also no programme of periodic checks and maintenance for this equipment or of its seating surfaces.

Moreover, to the south of the site, in the event of large-scale flooding, the water could enter the Socatri facilities, in particular the fissile materials storage building. In the inspection follow-up letter ASN asked the licensee to check whether tie-down would be affected if the building were flooded. This tie-down would help prevent the criticality risk.

For the entire site, the inspectors revealed that particular attention would be needed on the upkeep and monitoring of the rainwater networks, which must guarantee the water drainage capacity in the event of heavy rainfall. An up-to-date drawing showing the locations of the rainwater drains and a servicing plan for these drains were requested.

To conclude, for the facilities examined, protection against the risk of off-site flooding would seem to be provided through compliance with the safety frame of reference in force. Periodic inspection, maintenance and testing programmes will need to be drawn up, with appropriate intervals, and will have to be followed.

Nuclear fuel fabrication facilities (Mélox, FBFC)

Concerning Mélox, for reasons related to prevention of the criticality risk, Pu oxide in the form of powder or solid can only be used in areas without water. This constraint includes fire-fighting measures.

As of 1985, COGEMA aligned the design principles of the Melox plant with the provisions adopted for the NPPs (RFS I.2.e): safety maximum thousand year flood CMM (increased by 15%) and the proposed location of "sensitive" buildings on the high ground of the site chosen.

The safety study (safety report index B – August 2005) thus selected 4 scenarios: rising groundwater, torrential rain (Cévennes mountains storm phenomenon), flooding of the Rhone river, Rhone embankment burst in the event of an earthquake.

With regard to the first two points, flood risk prevention is based on construction measures and the quality of construction. The Mélox facility, on the higher part of the site (+40 NGF), places the plant out of reach of the Rhone flood safety margin level CMS (+37.5 NGF), the effects of this high water on the outflow channel and the consequences of an embankment burst.

The site analysis enclosed with the preliminary safety analysis report (February 1988), the design options and the resulting choices, are a robust package which has never been called into question since the plant was commissioned (February 1995).

The points at which information arrives from the outside are the general surveillance post (PSG) and the nuclear materials protection post (PMN). This information is transmitted to the shift supervisors. Finally, Mélox can receive the support of the AREVA flooding referral agent. There are also agreements between Mélox and various points of contact: Météo France, CNR, CEA, in particular the FLS and the civil security services, the dam operators and the office of the *préfet* of the Gard. Mélox also maintains close ties with the departmental fire and emergency service (SDIS).

For the Marcoule sector, CEA at Marcoule is responsible for keeping a watch and has thus installed and operates the necessary monitoring resources. Mélox however has its own weather station but does not have its own system for monitoring the level of the Rhone river or the groundwater.

As it is out of range of a CMS, Mélox is not equipped with passive protection systems. With regard to the active systems, the inspectors noted that it could be possible to receive a backup mobile lifting pump from CEA.

Accessibility in the event of extreme flooding of the Rhone is guaranteed by boat or by helicopter (helipad at CEA). However, accessibility by boat in the event of very high water needs to be confirmed owing to the presence of strong currents. Mélox has the necessary resources (sleeping arrangements, canteen) to maintain personnel on the site for a period of a week (corresponding to the fuel reserves for the backup electricity generating sets). With respect to telecommunications, the licensee has redundant lines using diversified technologies.

The inspectors noted that Mélox had no technical gallery "between facilities" (leading to the facilities on the Marcoule site). Furthermore, in the event of flooding, only the discharges from the stack (sole point of discharge) would be monitored. Finally, Mélox learned significant lessons from the Cevennes mountains storm episode of 2002 and the flooding of 2003, especially its accommodation of the inhabitants of the village of Codolet which suffered catastrophic flooding in 2002.

To conclude, the facility is in conformity with its frame of reference and the design measures taken rule out all risk of off-site flooding. The inspectors noted however that on the occasion of the Cevennes mountains storm events of 2002, part of the population of the nearby town of Codolet was accommodated at Mélox, to a certain extent justifying the options taken for the siting of the plant.

Relations with the CEA site at Marcoule are the subject of agreements that the inspectors nonetheless felt to be insufficiently precise with regard to the resources that would be deployed on behalf of Mélox. In this respect, it would seem probable that the available intervention or emergency resources shared in the event of an extreme climatic situation, would be deployed to the entire industrial site, according to circumstances.

Finally, the inspectors found that accessibility by boat in the event of very high water still needed to be confirmed because of the strong currents.

With regard to FBFC at Romans-sur-Isère, the site is not concerned by river flooding or a rise in groundwater, given the elevation separating it from the height of the Isère river or the water table. The risk of flooding would only come from heavy rainfall. A study is underway to characterise the drainage capacity and the condition of the rainwater network and to identify the potential points of water ingress into the buildings.

3.2.3 Other facilities

ATPu

The licensee has implemented instructions for how to respond to an incident situation, valid for all the personnel and covering the flooding risk. The probe alarms are managed by the FLS, which has a reflex response sheet for normal working hours (HN) and outside normal working hours (HHN). A second note defines who to mobilise through the list of on-call personnel.

There is a remote-monitoring network and flood alarms in the facility, along with detection probes plus pumps managed by the BNI. The remote monitoring and alarm network is directly and permanently linked to the centre's security command post. The sumps are checked during the rounds by the management/security patrols or the RSE. The groundwater level is periodically checked via piezometers located near to the facility. The equipment is periodically checked and maintained. A loss of electrical power resulting from hypothetical flooding of the basement could in theory lead to loss of facility monitoring (unless the GEF (static generator set) or GEM (mobile generator set) electrical backup is activated).

The BNI's rainwater drainage networks, consisting of open or buried manifolds, take part in preventing the risk of flooding. Following the inspection, the licensee was asked to justify the frequency of checks and cleaning of the rainwater drainage networks within the perimeter of BNI 32.

To conclude, no nonconformity with the frame of reference was observed. The current frame of reference rules out any vulnerability of BNI 32 to flooding. However, it must be ensured that the hazard considered is indeed conservative enough (consideration of rainfall with a minimum return frequency of a hundred years, inclusion of rising groundwater, etc.).

Masurca

The siting of Masurca at Cadarache makes it relatively immune to off-site flooding, not considered by the licensee to be a potential risk. In any case, a significant anomaly was found during the inspection in that the site's general documents, given the prolonged shutdown of the facility (about 10 years) are no longer representative of the current level of risk to the facility. These documents state that the Masurca facility is one of the priority Cadarache facilities in terms of electrical power supply, which is no longer necessarily the case given that the core has been unloaded.

A corrective action request was therefore submitted, consisting in updating:

- the PGSE (general presentation of the facility safety) regarding the list of priority facilities for backup electrical power, given the current situation of the Masurca facility (core unloaded);
- the various corresponding operational memos and procedures.

1.8

1.93.3 Protection of facilities against earthquakes

3.3.1 Experimental reactors

In general, these facilities do not have a "seismic" referral agent, but tend to rely on centres of expertise (case of the CEA BNIs) or external parties if further expertise is needed on this subject. Reciprocal information agreements are defined (with the FLS and the office of the *préfet* in particular). These facilities also have several seismic detectors which are periodically inspected. Emergency shutdown measures are generally triggered by these detectors. Instructions in the event of an earthquake are also defined.

Osiris

The situation was felt to be satisfactory. However, the inspectors asked for checks on the strength of the UST (technical support unit) and FLS (local safety organisation) buildings on the centre, as they contain the emergency resources necessary for intervention on Osiris in the event of an earthquake and for the mitigation measures that could be necessary to allow access to the reactor. The inspectors also asked the licensee to define specific steps for reactor restart after an extreme natural phenomenon, particularly an earthquake.

RHF

Following the inspection, ASN asked that the licensee complete the final modifications that had been started further to the seismic reassessment performed between 2002 and 2007, concerning the increased seismic resistance of some of the equipment liable to constitute a hazard if it fell onto equipment important for safety. These modifications should have been completed by the summer of 2011. Concerning the modifications already made, the inspectors found that the documents summarising the quality of the work already done to strengthen the polar crane against a SSE were not finalised, even though the work had been completed. These documents will also be used to confirm the conformity of the work done with the proposed improvements. It would also appear necessary to raise the seismic risk awareness of the parties involved: the inspectors in this respect found that some carriages were not immobilised, that certain lifting cranes or booms were not in the safe position and that gas cylinders were not suitably stowed.

The question of access to the site in the event of a major earthquake could also arise (peninsula configuration). Finally, it was mentioned that the means of communication were liable to be affected by an earthquake. However, the inspectors noted that the licensee intends to purchase a satellite telephone. The inspectors underline that the performance of an "earthquake" exercise in May 2011 and the real progress made are highly positive signs.

Phénix

The system monitoring radioactive gas effluents prior to release is not designed to seismic standards (as is the case with the Osiris and RHF reactors). The inspectors asked the licensee to detail the remedial measures necessary to keep the gaseous effluent monitoring system serviceable after an earthquake.

3.3.2 Nuclear fuel cycle facilities

La Hague site

In accordance with RFS 2001-01, the seismic risk for the La Hague site is characterised by an intensity of VI-VII MSK, for the maximum historically probable earthquake. This intensity is increased by one degree to characterise the safe shutdown earthquake at VII-VIII MSK (SSE). The licensee must identify the equipment participating in the facility's safety demonstration and define requirements with respect to its seismic resistance.

With regard to the seismic detection instrumentation and resources, the inspectors asked for justification of the setting of the seismometer controlling the shutdown of operations above the NPH pool. The inspectors also found that the establishment's seismograph had been out of service for eight months and was not considered a priority by the licensee. They also made observations concerning justification of the seismic design of the pool make-up water equipment, especially the buffer tanks.

Other requests concerned the management of inspections and periodic tests (CEP):

- as currently performed, a CEP is unable to test a safety system automatically making the facility safe (stoppage of material transfer) in the event of seismometer unavailability;
- certain automated safety systems triggered by seismometers are not covered by any CEP.

The justification of the continued seismic qualification (calculation or testing) of the equipment performing functions important for safety must be demonstrated (ageing), in particular on the basis of its servicing and upkeep. The inspectors also asked for an overall earthquake or flooding exercise to be held on the site, as an overall exercise of this type has never been organised.

For the facilities undergoing seismic strengthening or on which studies are currently in progress, the inspectors observed a lack of any documents indicating the progress of the overall worksite schedule, or tracing any anomalies or delays.

The inspectors noted the existence of a seismic vulnerability study on the site's non-nuclear buildings, the conclusions of which had not yet been examined by experts from outside AREVA. Another remark was made during the inspection on the fact that the conformity studies during the safety reviews only covered 10% of the rooms in the nuclear buildings.

With regard to potential hazards within the facility, the inspectors requested additional information on the accessibility and protection of the temperature probes on the R4 unit tanks in the event of an earthquake.

Conclusion

The inspectors noted that the seismic design of certain equipment items, whether this qualification was part of the original design or maintained after modification, needs to be demonstrated, in particular with regard to the instrumentation part. Moreover, the ageing topic needs to be integrated in order to justify the continued seismic qualification of equipment taking part in functions important for safety.

In the light of the studies performed, the electrical backup resources for the facilities would probably be damaged by other equipment not designed to seismic standards. This finding needs to be addressed by the licensee so that these resources are kept serviceable and accessible in the event of an incident, even if there is a third safeguard level of electrical backup.

In addition, the continued long-term effectiveness (unavailability, CEP) of the seismograph and the correct tripping of the automated safety systems must be reinforced. Finally, a study of the vulnerability of the site's non-nuclear buildings has not yet been analysed and will need to be examined in order to identify the consequences of such an earthquake and in particular its effects on the accessibility of the various site facilities.

Tricastin site

The recent facilities on the site (Georges Besse II) or those under construction (Comurhex II) are designed to safe shutdown earthquake standards (SSE).

The older facilities were not designed in compliance with these frame of reference. At Eurodif for instance, the ability of the U annex to withstand the SSE is not demonstrated and measures are in place to limit the quantities of uranium present in this annex. The inspections revealed no breach of these restrictions.

For Socatri, the strength of the URS building still needs to be demonstrated on the occasion of the ongoing periodic safety review. For W, operated by AREVA NC, the hydrofluoric acid store would not withstand a SSE and there are uncertainties regarding the SSE resistance of the "ovens" zones. With regard to Comurhex I, neither the BNI nor the SEVESO class chemical facilities are built to SSE design standards.

From an organisational viewpoint, there is no overall approach to seismic resistance on the site, with the facilities being organised independently, each under the responsibility of a different licensee. However, there are links between the GBII and Eurodif emergency organisations and Eurodif staff can take part in the emergency crews of the Société d'enrichissement du Tricastin (SET) or Socatri. The licensees have local initial response teams (ELPI) but the site FLS also responds to all events.

The inspections revealed no major discrepancy with regard to the intended earthquake management resources stipulated in the safety report and in the general operating rules.

In the facilities, the equipment identified as EIS (element important for safety) in a seismic situation is designed for this risk: maintained function, integrity, stability, absence of potential hazard, as applicable. However, the list of EIS in the case of an earthquake is limited: for example, in the GB II plant, the list of EIS depends on the situation of the facility and there are for example "backup" diesel generators, but which are not EIS, with no "safety" function and not designed to seismic standards (the diesels and their fuel reserves).

In the GBII facility, the devices that are "active" in the event of an earthquake (emergency drainage for example) are designed to protect the "investment" rather than being required on safety grounds.

However, in the event of an emergency further to an earthquake (UF₆ leak, criticality accident, etc.), the licensees of the Tricastin platform can find themselves in a delicate situation:

- some facilities have no specific instructions concerning how to react in the event of an earthquake (Comurhex for example);
- most of the facilities have no seismic qualified backup electrical power supplies, because this is not required by the safety frame of reference. Some equipment has a battery or UPS (uninterruptible power supply) backup electrical power supply, but this can be limited to only 30 minutes;
- the means of communication and monitoring in the facilities are backed up by batteries, for a time ranging from only 30 mn to a few hours (also not designed to seismic standards);
- on most of the facilities, the crisis centres, the electrical power supply to the control room, the backup electrical generators and the communication networks are not designed to seismic standards;
- the availability of the fire detection and firefighting resources cannot be guaranteed (power supply to detectors, networks, water);
- the availability of the resources of the FLS and its ability to intervene on several licensees at Tricastin simultaneously following an earthquake remains to be proven. No water, food, nor stable iodine is stored in the individual facilities, as this has all been grouped for the site as a whole. The food stocks present in the canteens are not protected from any contamination.

Finally, the inspectors observed that the availability of the facility or release monitoring resources could not be guaranteed in the event of an earthquake, because this is not generally required in the applicable safety frames of reference.

At Eurodif, the licensee found anomalies with tightening of the diffuser anchors in the slab supporting them. The licensee also found an anomaly on the U annex store area: on a 48Y type container of UF₆ undergoing cooling, the cover protecting the drain valve against shocks was not locked. This device is not however designed to withstand an earthquake. This anomaly was also observed on other covers and was analysed as a significant safety-related event, with corrective measures.

Finally, the inspectors noted that all the facilities do not have a procedure for managing the stowed position of the cranes and other large lifting devices, considered to be potential sources of hazards in the event of an earthquake.

To conclude, the inspections conducted on the Tricastin site as a whole show that the licensees in general comply with the seismic strength requirements stipulated in their safety frame of reference but that they would have difficulties with managing an accident situation further to a major earthquake, owing to the loss of electrical power supplies, means of communication, supervision of the facility or to the non-seismic design of the auxiliary premises, crisis or fall-back centres, and premises housing the resources and personnel of the FLS.

The licensees also failed to consider the potential hazard that certain items can constitute in the event of an earthquake: appropriate protections and procedures are not systematically identified and implemented.

Nuclear fuel fabrication facilities (Mélox, FBFC)

For Mélox, the creation authorisation decree of 21st May 1990 stipulates the design and construction objectives to be met: maintain and guarantee the functions important for safety, that is confinement of materials and prevention of the criticality risk. The earthquake to be considered is level VIII-IX (MSK), the response spectrum being established on the basis of resonators appropriate to the site. Mélox was built on backfill of high-grade materials resting on the alluvial layer. Exposure to site effects is currently being assessed.

As of the design stage, the potential effects of an earthquake on the confinement of material (not guaranteed, responsibility transferred to the first civil engineering barrier), the risk of criticality (the option being to keep the material localised and guarantee sub-criticality regardless of the secondary control mode), the handling risk, the risk from the release of heat and the risks of fire and explosion, were taken into account.

Furthermore, the licensee considered ensuring the safe state of the facility in the event of an earthquake, by studying the conditions determining management of the associated risks and linked to the loss of electrical power and the loss of the facility's control system.

In the event of an earthquake, production is stopped and the facility is shut down to a "safeguard" safe state. The equipment that is required to remain functional after an earthquake (backup controls, batteries, cableways associated with safeguard I&C), along with the routes giving access to the safeguard command post, are designed in accordance with seismic standards.

The facility is in conformity with its frame of reference. The civil engineering works and equipment for which integrity must be guaranteed in the event of an earthquake, have been identified according to precise safety objectives. Seismic detection is threshold-based, internal and without recording. In the event of an alarm or pre-alarm, the facility switches to safeguard operations.

With regard to the SSE, sub-criticality is guaranteed by keeping the materials localised, with the dispersible fraction being contained by the civil engineering structures at the interface between the cells and the glove boxes or shielded chains (barrier transfer). No off-site emergency services response time is stipulated. If the site were to be isolated, the measures and resources to be used would be those associated with the flood risk.

All of these provisions, in conjunction with the one-week self-sufficiency in the event of isolation, are a strong point in favour of the Mélox plant.

For the off-site intervention resources, the inspectors noted that in the event of an earthquake which could affect all the facilities on the Marcoule site, there is no guarantee that the emergency response manpower levels allocated to intervention on the Mélox facility would be sufficient.

Finally, the inspectors found that the instrumentation is the original equipment and does not meet current standards. The licensee conducted an obsolescence study as part of the complementary safety assessment.

In the FBFC facilities, only the buildings necessary for production (buildings C1 and AP2, and HF station) are built to SSE standards, either owing to their original design, or as a result of the renovation work carried out since 2006. The other buildings (especially those intended to house the crisis command post

(PC) or containing the intervention resources) and the utilities (in particular the gas and electricity supplies) are not designed to SSE standards. In particular, the R1 process building (materials recycling) would not withstand an earthquake and neither would the equipment it contains.

The licensee intends to ensure that the facilities are made safe in the event of an earthquake. It has also deployed a seismic detection and cut-out system (DCS) which will be operational in January 2012 and which will automatically cut-off the utility supplies (especially explosive gases) in the event of an earthquake.

The inspectors found that certain release monitoring systems had batteries (2h for the site's radiological monitoring devices for example), but that the seismic resistance of the environmental monitoring systems was not guaranteed.

To conclude, the inspection of the FBFC on the earthquake topic brought to light the need to strengthen the R1 process building and rapidly finalise the service entry of the seismic cut-off system (DCS).

3.3.3 Other facilities

ATPu

The plutonium technology facility is equipped with a seismic detection system which would automatically cut off the water and electricity supplies to the facilities and trigger the BNI's on-site emergency plan (PUI). There are 6 accelerometers for the BNI, along with accelerometers in the centre which trigger FLS alerts.

Inspection of these accelerometers is the responsibility of AREVA NC. The actuators controlled are positioned in the ATPu, the LPC and the LEFCA.

The inspectors examined the seismic accelerometer checks carried out in 2010. They found that one device was faulty. The licensee nonetheless indicated that the failure of a single device would not compromise the safety function, owing to the redundancy of the accelerometers. In the inspection follow-up letter, ASN asked the licensee to submit its experience feedback on the reliability of the accelerometers and the time taken to replace this equipment if defective (availability of spares, qualification of persons involved, etc.).

A number of the centre's water tanks are not designed to withstand the SSE and neither are the pumping systems. The licensee mentioned plans to build tanks for that purpose. The inspectors found that the walkie-talkies and the protective suits intended to protect the reconnaissance team personnel against the possible dissemination of radioactive substances are stored in the premises of BNI 32, which is not designed to withstand a strong earthquake defined as being of intensity greater than 5 on the MSK scale. Neither would the area designated as the advance command post (PCA) withstand such an earthquake.

The inspectors found that the BNI 32 procedure detailing the steps to be taken following an earthquake needed to be updated to take account of the progress made with the decommissioning of the facility.

To conclude, the inspectors found:

- **satisfactory points: the seismic detection system is operational, steps are being taken to raise personnel awareness but need to be extended to all parties, including the contractors;**
- **points to be improved: the means of communication and the protective suits to be used in the event of an earthquake are stored in a room which would not withstand the earthquake; the post-seismic intervention procedures need to be updated to take account of the progress made with the facility decommissioning work.**

Masurca

The inspectors found that in the event of an SSE, the facility would be unable to guarantee the availability (integrity and/or operability) of its emergency resources housed in structures not designed to withstand the SSE. The licensee however considers that the inventory of its active resources and their seismic design are no longer pertinent given that, in the current configuration, no active means are required to maintain the BNI in a safe state. Furthermore, the ability of the BNI's specific monitors to withstand an SSE is not guaranteed. In this respect, the BNI is no longer independent and would need to call in mobile resources

from the centre. Finally, the availability of the BNI's internal communication networks (not designed to SSE standards) cannot be guaranteed.

1.103.4 Loss of heat sink

3.4.1 Experimental reactors

Osiris

The inspectors found that the filtration systems verified appeared to be satisfactory. The availability of the emergency resources appears to be satisfactory on Osiris and there are degraded mode instructions. The persons concerned would seem to be adequately familiar with the emergency resources.

Finally, an inconsistency on the anomaly threshold concerning the optimum filling level of the Osiris pool was identified between the safety report and the instructions on how to respond to an accidental drop in the level of the pool.

RHF

The reactor can be cooled for several days by natural convection in closed-circuit, by means of the water reserves consisting of the pools in the reactor building. These systems do not require any electrical power supply either, as the water is circulated by natural convection. In normal operation, the inspectors noted that the log of cooling parameters was correctly kept for the RHF.

A request in the follow-up letter concerned the availability of the RHF ultimate backup, which needs to be specified, that is the FLS motor-driven pump. The inspections showed that even if maintenance was carried out on the RHF pumps and cooling systems, it was nonetheless inadequately traced, in particular with regard to justifying that the required level of performance is maintained. Although the checks and periodic tests are rigorously managed, especially for tests prior to a new cycle, preventive maintenance of the passive equipment and indeed the equipment as a whole that contributes to seismic resistance needs to be better structured (civil engineering maintenance programme, already requested elsewhere).

Phénix

It should be noted that because reactor power operations ceased in February 2010, thermal leakage alone is sufficient to remove the residual heat. Forced convection cooling is thus no longer necessary.

3.4.2 Nuclear fuel cycle facilities

La Hague site

The cooling function is important for safety on the La Hague site. It is necessary in order to control the temperature of the spent fuel stored in the pits, or certain exothermal processes. The licensee is thus required to manage this function and ensure that it is maintained durably and in a post-accident situation.

The inspection demonstrated that the procedure for making the transition to safeguard mode by natural ventilation of the ECC (stores of packages of compacted hulls and end-pieces) would be difficult to apply in a real situation. Moreover, the heat insulation of the ventilation ducts in this store is in poor condition and two ventilation dampers were in an inappropriate position.

Remarks were made and questions raised concerning the operability of pool water manual makeup resources following an exercise which in particular covered the deployment of the piping, which proved to be difficult and the time needed to install the only cofferdam not pre-positioned to contain the waters below the pools.

Similarly, uncertainty existed with regard to the operability of the pool level measurement in post-accident conditions, given the design of the remote bubbler tube. There is also no guarantee of post-accident conditions monitoring of the tank temperatures, in particular in the R1 unit, owing to the potential hazards.

The fan coil units for the pool water operate in manual mode (no automation), even though there is provision for an automatic mode. The inspectors asked that the safety of this operating mode be demonstrated.

The field visits highlighted discrepancies in the equipment contributing to the cooling function in safeguard mode: lack of clamping of a pipe restraint device, absence of a valve tightness plug, lack of an oil reserve on the cooling pumps; deteriorated external condition of certain exchangers; deteriorated (rusted) condition of pumps. A risk of potential damage from stored equipment was identified as being possible on the safeguard cooling lines.

To conclude, anomalies were identified on the equipment taking part in cooling (exchangers, fan coil units, piping), with the conclusion being that their maintenance needs to be improved and the continued adequacy of their design over time needs to be checked.

Moreover, the continued use of natural ventilation in one of the stores, here the ECC, would seem to be compromised by the anomalies observed during the inspection.

Tricastin site

None of the facilities inspected during the campaign covered by this report shows any increased safety risk in the event of loss of the heat sink or cooling systems.

Only the total loss of the cooling at Eurodif for several tens of hours (the estimate varies depending on the outside temperature) would lead to the UF₆ solidifying in the diffusers, entailing probably irreversible clogging of the plant, although with no releases into the environment.

Consequently, the licensees have made no provision for any organisation or specific means to prevent this risk.

Nuclear fuel fabrication facilities (Mélox, FBFC)

For Mélox, the inspectors found that there was tutor-based training in the use of the reflex response sheets. The alarms are transmitted to the control room (security post in the PSG) and to the two safeguard consoles. The inspectors noted that the structures, equipment and functions that need to remain operational were listed.

The cooling units are equipped with several control stations. If the chilled water is lost, connection to the industrial water network is possible. The stock of spares is monitored. For the filters, there is a minimum safety stock designed to deal with an earthquake, supplemented by an off-site depot (Pont-Saint-Esprit).

No general loss of cooling has been recorded since the creation of Mélox. The annual exercises led the licensee to renovate the safeguard stations.

To conclude, the facility is in conformity with its frame of reference. Cooling of the STE stores is safeguarded and, in the event of a loss of the cooling coils - even though they are designed to seismic standards – it would be possible to connect industrial water from a fire hydrant or from the Rhone river. The inspectors also noted that Mélox, owing to changes in the materials used and the growth in its production capacity, has had to acquire additional storage capacity (pellets, rods, assemblies) which are equipped with their own cooling system. The inspectors considered that the impact of this new equipment on the safety of the plant should be the subject of an overall assessment.

For FBFC, only a few areas of the facilities require cooling, and for no more than a few hours once they are shut down. This mainly concerns the BTU sintering furnaces, owing to their hydrogen risk during operation. These furnaces comprise closed-circuit cooling towers. The inspectors found no anomalies concerning this equipment.

3.4.3 Other facilities

ATPu

The loss of heat sink was not considered to be pertinent for the ATPu. Only one thermal equipment item is used during operation (the oven in cell C12) but in principle it represents no particular cooling-related safety issues.

Masurca

For Masurca, the inspectors noted that the licensee considers that in the current configuration, the facility does not require "active" cooling (see part 3.3.1). The licensee thus considers that natural ventilation and

the design of the cladding in the cells are sufficient for evacuation of the residual heat from the fissile material and confinement of the material.

1.113.5 Loss of electrical power supplies

3.5.1 Experimental reactors

When this point was examined, the inspections showed that the distribution of responsibilities for the upkeep of the facilities (BNI / RTE) was clearly defined. There are agreements between the licensee and RTE and they make provision for priority resupply of the facilities in the event of a power break.

The inventory of normal electrical power supplies and emergency backup resources is generally defined in the safety report. However, for the RHF, the safety report is not up-to-date on this point, but its update is scheduled for 2012. Updated plans were however presented on the occasion of the inspection. Only one electricity generator was designated as a safety requirement, given that the RHF is designed to be cooled for several days using natural convection with no circulating pump.

With regard to the means for monitoring the operation of the electrical power supplies, a flowchart of the electrical lines was observed in the Phénix control room. This is kept up-to-date by a specific person. Operating memos and operating instructions are defined for each electricity supply source (diesel, normal supply, etc.). The electrical switchboards are also retransmitted to the RHF control room. A backup electrical switchboard is present in the emergency command post, in case the control room systems were to be destroyed by an earthquake (the building which houses it being the only one designed to withstand the earthquake).

Generally speaking, the inspectors considered that the normal and backup electricity supply systems were in good condition and regularly monitored, in particular those of the RHF (parameters recorded during the rounds, periodic testing and testing at the beginning of each cycle). However, a number of inspections did show that further information or improvements were required on the performance of maintenance and certain periodic tests on the emergency resources, as well as how these resources are used, particularly with regard to:

- identification of the battery life safety criteria (RHF);
- the need to perform endurance tests on the backup generator set GES (RHF);
- the practicalities of resupplying the RHF's backup electricity generator in the PCS (management of the fuel reserve in particular) and the requirements concerning fuel quality, along with the associated verification methods;
- traceability of monitoring of first-level maintenance of the electricity generating sets, performed by a contractor (Osiris);
- qualification retesting of the air tanks, pressure vessels, electricity generating sets (Phénix);
- the strategy concerning the use of CEA Grenoble's mobile electricity generator for the RHF;
- the lack of any formal procedure for ranking of priorities concerning deployment of the emergency resources, in particular with regard to the electricity power supplies, especially for Osiris on the CEA Saclay site.

During the visits to the facilities, the inspectors observed that for Phénix, the documents available to the personnel on entering the room in the event of intervention on the electricity generating set were in poor condition. One of these documents mentioning the electrical emergency stop position of the electricity generating set was not fully representative of the layout of the existing safety devices.

The availability of the access routes necessary for bringing in the emergency resources, especially in the event of earthquake or flooding, needs to be guaranteed.

3.5.2 Nuclear fuel cycle facilities

La Hague site

The loss of electrical power supplies to the site is an accident that could result from an earthquake, or from flooding, or from loss of the ERDF grid. Electrical power is needed to maintain certain safety functions in the facilities, such as cooling of the pits or fission products, ventilation of the storage areas or

the instrumentation system used to monitor the main parameters in the facilities (temperature, pressure, water level, radiological environment, etc.).

Some equipment therefore has to be identified as important for safety and be the subject of particular monitoring in order to maintain its functions in both normal and accident conditions. It should be pointed out that electricity distribution comprises 3 modes: normal, backup, safeguard.

The inspectors found that modifications to the electrical power supplies had been made with no checks on the quality of the work done or the requalification of the hardware (addition of electrical cabinets leading to the room heating up, with the cabinet doors then kept open for ventilation; transformation of a cloakroom into an equipment room, electrical modifications made with no checks subsequent to the works (in particular a change to the power balance).

A known problem with the reliability of the measurement system (displacement type) for the fuel tank levels of the backup generator set (GES) meant that there was drift in their operating modes. Hardware changes were not made under quality assurance conditions in the manual mode restart procedure for the site's electrical power supplies in the event of loss of the ERDF grid (dating back to 1993, handwritten modifications). Furthermore, the resupply of the GES in a post-accident situation, given that the fuel tank is located outside the buildings, could be problematical if these areas are inaccessible, for instance following an earthquake.

Identified operating experience feedback concerning circuit-breaker settings following unplanned ventilation losses (magnetic protection) has not in recent years always been integrated. Other feedback is being processed with regard to the premature wear of the connecting rod bearings of certain backup generating sets.

The site visit in particular revealed advanced corrosion of the lines connecting the GES underground tanks to their motor unit and particularly high levels of corrosion on the backup generator sets' cooling water lines. The inspectors also found that several bargraph type indicators intended for operation of the safeguard systems were faulty in certain fall-back centres. Finally, the visits carried out were also an opportunity to question the licensee about the risk of loss of the fall-back centres for units R1 and R7, and thus of the electrical safeguard, in the event of on-site flooding, given the presence in adjacent premises of water pipes not qualified as seismic-resistant.

To conclude, the accessibility of the safeguard electrical power supply resources would not always appear to be guaranteed in post-accident conditions, particularly with regard to fuel resupply. The advanced state of corrosion of some backup generator sets equipment requires action to remedy these anomalies rapidly. The inspections brought to light the need for improved requalification of the facilities and updating of the documentation, if the function is not to be degraded.

Generally speaking:

- **the organisation and the means for backup electricity supply on the site, and maintained operation of the equipment important for safety taking part in functions important for safety, sometimes with reliance on off-site resources, must be more formally structured, made more reliable and be more regularly tested (site accessibility, mobilisation of emergency teams in a large-scale incident situation, etc.);**
- **the actual self-sufficiency of the site with regard to its electrical power supply must also be reviewed in the light of the above.**

Tricastin site

The subject of electrical power supplies is dealt with by the licensees in accordance with the safety report and the general operating rules in force. The inspections revealed no divergence from this frame of reference. The safety issues related to the loss of electrical power supplies, for the facilities themselves, are minor. However, if electrical power is lost, the facilities would lose their dynamic containment, environmental monitoring and means of communication.

As the consequences of a loss of electrical power are highly limited in terms of the safety of the facilities, the licensees have made no provision for any specific organisation. Only the electrical power supplies of Eurodif are designed to minimise the risk of total loss of off-site sources (12 electrical sources are provided to supply the plants). However, according to the safety report, the "total loss of electrical power"

scenario does not lead to environmental releases. After a few tens of hours, it would lead to the UF₆ solidifying in the diffusers, a process that would probably be irreversible.

For the GB II plant, as the loss of electrical power supplies would not represent a safety issue for the facility, they are not designed to comply with seismic standards. There are backup resources but not all the operating procedures have yet been drafted. The inspectors' comments primarily concerned the inspections, periodic tests, maintenance, and operating procedures for these resources.

In several facilities at Tricastin, an interruption of the ventilation after an earthquake, owing to an intentional or otherwise break in the electrical power supplies, can halt measurement of release activity or lead to loss of the environmental monitoring systems.

For Eurodif, monitoring to ensure that there are no leaks of chlorine trifluoride (ClF₃) is carried out by a patrol every two hours: this point is not included in an operating document. A check-list of the operations to be performed is currently being drafted.

To conclude, the subject of electrical power supplies is dealt with on the whole satisfactorily, in accordance with the safety frame of reference in force. The safety issues related to the loss of electrical power supplies alone are minor for the facilities on the Tricastin platform. Consequently, the design of the normal or backup electrical power supplies, their monitoring, their periodic testing and their maintenance are thus appropriate for equipment not classified as "elements important for safety" (EIS).

However, in a number of facilities, the loss of electrical power leads in the medium term to the loss of the means of monitoring the facility from the control room and a loss of the means of communication. Managing an accident situation at the same time as this loss of electrical power would thus be relatively problematical.

Therefore, the checks, in particular the second-level checks on the backup power supply resources, for instance the UPS systems and batteries, need to be strengthened, to ensure that they are available and that they would function for long enough if the electrical power supplies were to be lost.

Nuclear fuel fabrication facilities (Mélox, FBFC)

Mélox

The immediate or eventual consequences of the loss of electrical power are shutdown of the production equipment or the equipment driven by a drive fluid, plus the loss of cooling, reheating and inerting functions. The nature of the corresponding risks thus varies with the nature and function of the workstations, with issues in terms of confinement, radiation protection, criticality, release of heat, fire, on-site or off-site flooding, handling and explosion.

Electrical energy can be supplied by a cascade of different sources, thus enhancing the operating reliability of the equipment contributing to the safety of the facility.

A general agreement signed with CEA in March 2010 specifies the property limits and the operating perimeter.

The inspectors noted that EDF/normal backed-up "switchover" at equivalent power and redundancy, gives the Mélox plant a degree of independence. The Mélox plant is relatively self-sufficient. A permanent EDF supply is not therefore essential, as the two GEF which take part in the "normal/backed-up" layer can for 48 hours provide power equivalent to that of the EDF lines, with the same degree of redundancy. The alarms are transmitted to the PSG and to the safeguard command posts.

The inspectors found that:

- an inventory of the elements to be safeguarded was drawn up (loss of normal and backup EDF supplies and loss of backup generator sets);
- the safeguard generators have self-sufficiency of one week (limited to 48h for the GEF handling normal backed-up) determined solely on the basis of the capacity (60 m³) of the fuel reserve (with no outside resupply). The tanks are designed to withstand the site's reference earthquake;
- radiation protection monitoring and the criticality detection and alarm systems (EDAC) are not safeguarded;

- in the event of loss of safeguard, the batteries provide one hour of operation for the stack discharge sampling and measurement devices.

To conclude, the facility conforms to its frame of reference. The "normal" power supply is being strengthened by the installation of two functionally redundant GEF in place of the present single generating set.

Finally, still in accordance with the safety analysis conducted at the design stage, the detection of criticality accidents (EDAC) and the monitoring of contamination are not safeguarded in a post-seismic situation. In the event of a loss of safeguard, discharges would continue to be monitored for about one hour.

The FBFC plant

The plant is relatively immune to the risk of loss of electrical power supplies, a situation which it has already experienced for several hours. It has backup systems (electricity generating sets, batteries, etc.) which are in good condition and satisfactorily monitored. The plant's electricity generators have already undergone full-load endurance testing, which can only be considered a positive point. The premises containing the electricity generators and the batteries are not designed in accordance with seismic standards and their susceptibility to flooding is not known. However, as the licensee has made provisions for making the facilities safe as of the occurrence of a seismic, flooding or other type of alert, their availability is not required in order to prevent the occurrence of an accident.

3.5.3 Other facility

ATPu

The licensee's strategy is to cut the electrical power supplies in the event of an earthquake. There is thus no provision for raising personnel awareness of the loss of electrical power issue.

There are two HV/LV PU1 (normal mode) and PU2 (secondary mode) substations. These two items are redundant. However, there is no automated system for switching from one to the other. Furthermore, they are not designed to withstand either an earthquake or flooding. Maintenance and the inspections and periodic tests on this equipment are performed by the centre (CEGELEC and COFELY companies managed by the STL). The facility has electricity generating sets running on fuel oil (GEF) and UPS devices (security and process system). As necessary, the licensee may call on the mobile electricity generators (GEM) of the FLS.

In the event of loss of the normal electrical power supply, power to the stack discharge monitoring systems would be maintained for only 10 minutes, by means of the UPS devices. There is no procedure for total loss of electrical power. The licensee states that the BNI would be brought to a safe state (evacuation and automatic closure of doors).

Renovation work is planned for the BNI 32 electrical network: replacement of all the cells by plans to build the new 63/15kV substation, with complete switchboard replacement for certain equipment items. The follow-up letters requested information on the current level of progress achieved in implementation of this plan of action.

To conclude, the inspectors noted that the upkeep of the electrical network and the apparently good condition of the GEFs were points for satisfaction.

1.123.6 Operational management of accident situations and crisis management

3.6.1 Introduction and frame of reference considered

This review is a summary of the inspections carried out in the aftermath of the Fukushima accident, on the topic "operational management of accident situations" in the LUDD. The latest version of the inspection requirements comprises a list of 37 questions, drawn up from the LUDD PUI guideline plan of 1999, experience feedback from PUI inspections and the Fukushima event.

As things currently stand, and pending the overhaul of the BNI regime, the frame of reference concerning crisis management in the LUDD is the PUI guideline plan communicated to the licensees in a letter of 28th March 1999. The only requirements concern the content of the PUI (PUI guideline plan of 1999).

Therefore, the requests made following the targeted inspections are more observations of problems with the implementation of the PUI than conformity deviations.

3.6.2 Organisation put into place for management of incident/accident situations

General organisation

The documents requested were always presented to the inspectors, whether organisation memos, PUI supervisor assignment letters, or reflex response sheets. The La Hague site in particular demonstrated a good level of general organisation.

The organisation and the procedures for taking account of experience feedback from exercises and from actual events that have occurred could on the whole be improved, especially with regard to operational communication during management of the crisis.

The facilities on the Tricastin site (Socatri, GBII, Eurodif, Comurhex and AREVA NC) presented reflex response sheets that were unknown to ASN, even though these documents are an integral part of the PUI, itself subject to ASN approval in the event of modification. **The reflex response sheets are updated outside the scope of the PUI, which constitutes a deviation from the PUI guideline plan.**

The inspections concerning CEA Saclay and CEA Cadarache reveal insufficient coordination of the crisis organisation between the site PC and the local PCs, in particular:

- the composition of the local PCs in terms of PUI functions;
- personnel training in these functions (use of reflex response sheets and standard messages, directories, means of communication, etc.);
- procedures for alerting the centre's management (reaching trigger criteria).

The inspectors organised emergency exercises during the inspections. The support services such as the FLS (Local Safety Organisation) and the SPR (Radiological Protection Service) demonstrated their full effectiveness during these exercises. However, **the reconnaissance by the local initial response teams (ELPI) on the site of the accident and communication with the FLS were deficient during the course of exercises on the Tricastin site**, in particular concerning AREVA NC and Eurodif. This coordination could be improved through a precise definition of the role of the ELPI and by holding exercises with effective deployment of the mitigation resources and coordination between ELPI and FLS.

Long-term crisis management

Most of the sites have no procedures for long-term crisis management. Full-scale deployment of the emergency teams, as is for example the case on the RHF, means that all the personnel of the reactor division are called onto the site, even though their presence is not necessarily required as of the beginning of the crisis.

However, the AREVA site at La Hague and CEA Saclay reinforced their long-term organisation following the snow episodes of 2009-2010 and as part of the preparations for a flu pandemic (H1N1 swine flu).

National alert

ASN's national alert procedure was tested satisfactorily. However, in the event of an earthquake or flood type severe accident, which would lead to the loss of all means of external communication, the sites would be unable to trigger the alert with the means currently at their disposal. The need for the sites to acquire additional telecommunication resources, such as satellite phones, was pointed out (see crisis management resources).

Procedures, instructions, reflex response sheets

The licensees' staff are on the whole well familiar with intervention procedures and instructions in the event of a crisis situation. Nonetheless, effective implementation of these procedures and instructions was not systematic during the exercises held. Only the Mélox inspection highlighted the need to improve the content of the FLS intervention plans.

During the course of exercises, reflex response sheets are not always used, particularly on the Tricastin site or the RHF.

PUI training

Crisis management training generally comprises two parts: severe accidents specific to the site (developed in part A4 of the PUI) and the PUI functions occupied. Although personnel familiarity with the first part can be considered adequate, it would seem that **training in performing the PUI functions could benefit from a more formal framework, particularly with regard to the use of reflex response sheets and competence monitoring and follow-up** (CEA Saclay, ILL, AREVA NC Tricastin, GBII, Eurodif, Comurhex, Socatri, ATPu).

On the sites of the AREVA group, some on-call staff have followed no specific or refresher training for their PUI duties, including the on-call managers (AREVA NC Tricastin, GBII, Eurodif, Socatri, Comurhex, FBFC). On the GB II site, the pool of available on-call staff was supplemented by Eurodif personnel who are not trained in the GB II PUI and whose skills and level of competence have not been verified.

PUI and PPI trigger procedures in reflex phase

The staff concerned are on the whole well familiar with the emergency plan trigger criteria. The powers of the *préfet* to trigger the PPI in the reflex phase have been delegated to most of the sites, except for CEA Saclay (currently at the signing stage): this responsibility lies with the head of the establishment. The question of sub-delegation of these powers within the licensee's organisation has been evoked (ILL, GB II) in order to identify whether this responsibility should lie with the on-call executive, the shift supervisor or the on-call manager. The inspectors asked for the decision-maker to be clearly identified, as this person may not actually be the executing party.

Moreover, the participants in the crisis do not necessarily have decision-making guideline sheets or memorisation tools for effective, rapid, unambiguous detection (ILL, La Hague, Eurodif, GBII). On the CEA site at Saclay, the local PCs are unaware of any operational criteria to justify alerting of the site management. This point is also related to the definition of trigger criteria in the PUI.

The definition of PUI and PPI reflex trigger criteria is all the more important outside normal working hours, during which the head of the establishment, who generally has sole responsibility for triggering the reflex PPI, is not necessarily available. **A definition of the decision-maker within the site organisation, along with formal identification of this sub-delegation, is essential.**

The decision-maker must also permanently have at his disposal tools summarising the trigger criteria.

In many facilities, the decision-maker also has to reach the site, with varying journey times. In the event of access problems (earthquake, flooding, chemical releases, etc.), the decision-makers should carry a case that they can use from their home (at least for triggering the first PUI/PPI alerts) and/or enabling them to delegate this decision.

Others

Management of the injured and counting of the personnel on the site are dealt with satisfactorily. Most of the sites rely on the FLS, which is capable of providing a real-time list of the persons present.

For situations in which the majority of the personnel would be incapable of acting (e.g.: large-scale leak of highly toxic products following a major earthquake), the procedures and means of managing the crisis generally enable an alert to be sent very quickly to an outside entity, which could then take steps to call in material and human response resources, possibly from another site. However, this type of procedure is not relevant to a site such as La Hague, for which it would be hard to bring in emergency assistance from the outside. **If off-site resources are to be called in, this would need to be covered by agreements. Implementation of these agreements must then be checked by means of drills.**

On the La Hague site, the security locking of access turnstiles and FLS lockdown of the site for "materials policing" reasons, would be such as to severely impede personnel transfers or even intervention by the FLS vehicles in the event of an earthquake.

3.6.3 Coordination with external players

The information agreements with the offices of the *préfets* are satisfactory. As mentioned earlier, they now include delegation of authority to trigger the PPI in the reflex phase, except for CEA Saclay (currently at the signing stage).

Agreements have in general been concluded with all crisis stakeholders, SDIS, gendarmerie, hospitals, etc. The La Hague site is also covered by an aerial surveillance agreement. The implementation of these agreements, in particular with the SDIS, is generally tested during the drills.

With regard to multi-licensee sites, coordination agreements are essential. These are not always complete, such as for example the incomplete nature of the mobile emergency resources stipulated by the ILL. Assistance agreements are also signed with other licensees outside the sites (GIE INTRA).

The national crisis organisation requires real-time provision of site meteorological data for assessment of the zone affected and the possible radiological consequences of any releases. **This point must of course be covered by an up-to-date agreement with Météo France.**

3.6.4 Exercises and integration of experience feedback

The sites schedule exercises on an annual basis, generally one per year. Personnel participation in the exercises is monitored by the HR department or the PUI supervisor. The training courses generally include participation in a PUI exercise, at specified intervals. A few isolated nonconformities were observed, for example at Socatri or Comurhex.

On the sites with several BNIs operated by the same licensee (CEA Saclay, CEA Cadarache), **this scheduling does not necessarily include participation by all the BNIs on the site, either simultaneously or alternately. The facilities are not covered exhaustively.** In this respect, the inspection of the La Hague site was an opportunity to run an exercise in 4 units simultaneously (local PCs) without saturating the general PC. It should also be noted that a large-scale exercise is planned for the Cadarache site in 2012.

In terms of good practices, Mélox runs an annual exercise on the transition to safeguard of the electrical power supplies.

Each exercise is written up in a report contributing to experience feedback. However, a number of follow-up letters mention a lack of structure in the monitoring of the participants and the corrective measures, or even a complete absence of this report, several months after the exercise (CEA Saclay).

3.6.5 Crisis management resources

Inventory and monitoring of PUI equipment

The equipment necessary for or dedicated to crisis management is generally listed and subject to appropriate periodic inspections. However, some facilities such as RJH or Masurca do not carry out their own monitoring of this equipment, without necessarily checking that the CEA site actually does. On some sites, the inspections revealed that these lists were incomplete by comparison with the equipment actually used and that there were no periodic checks (ILL, ATPu, Osiris, Phénix).

For Masurca, the inspection found a significant discrepancy in that the site's general documents, given the prolonged shutdown of the facility (about 10 years now), are no longer representative of the current level of risk on the facility. In the current configuration, they erroneously give Masurca priority as regards the other facilities in the event of an emergency.

Backup electrical power supply resources (also see 3.5)

The technical checks on the correct operation of the backup electrical power supplies, such as electricity generating sets, batteries and UPS devices are not performed exhaustively with respect to the defined programmes (Osiris, ILL, Phénix, Eurodif, Comurhex, Socatri).

The radiological monitoring equipment and criticality alarms have to be backed up by these safeguard power supplies, which is not for example the case in Mélox. It should be noted that on the La Hague site, the backup electricity supply to the FLS security turnstiles and gates is not seismic qualified. They could prove to be major obstacles to evacuation or emergency intervention, including in the case of a very slight

earthquake, because the gates and access points would then be blocked (triggering of the "plutonium strong-box" response).

The backup electricity supplies would generally be unavailable in an earthquake. Periodic inspections are not exhaustively carried out or followed-up.

Means of communication

The means of telecommunication used in a crisis are diversified but not redundant. They are backed up for a limited duration, about a few hours. Most of the sites inspected are equipped with wireless connections constituting the only operational means of alert and communication in the event of an earthquake or flood type severe accident, with the exception of ILL Grenoble (landline telephone network only, but a satellite phone has been ordered). These resources must necessarily be operational in the event of an earthquake.

The means of communication are generally known and periodically checked. However, on the Tricastin and Saclay sites, the minimum means required (fax, telephones, etc.) are neither identified nor checked in the control rooms, which means that information to the site PC cannot be effectively guaranteed (no written confirmation via a standard message for example). With regard to the Tricastin site, another area for improvement is the provision of a dedicated means of communication for the FLS, in order to improve coordination with the ELPI and the various crisis PCs.

In the event of a severe accident such as an earthquake or flooding, the licensees generally have means of communication that are robust enough to trigger the national alert. However, there is insufficient back-up duration to provide more than a few hours of information transmission.

Alert systems

Automatic population alert systems are deployed on most sites, except for ILL Grenoble and FBFC, where this is being planned. However, they would cease to be operational in an earthquake, flood or loss of electrical power situation. Unlisted telephone subscribers are sometimes excluded from this alert system (detected at La Hague).

Like the national alert siren, which is a regulatory requirements, the automatic population alert system is a good practice that should be adopted as standard by all the facilities.

3.6.6 Crisis premises and assembly points

Habitability

The crisis premises are robust enough to remain accessible in the event of flooding. However they are not generally seismic qualified (ATPu, Phénix, Mélox, FLS and support services at Saclay, GB II, FBFC).

All the crisis premises at Tricastin would not withstand a SSE. This point was also identified during the CSAs.

Protection equipment

With the exception of Phénix, most of the control rooms are not equipped with HEPA filters that would enable a healthy atmosphere to be maintained in the event of releases on the site (ATPu, Masurca, Osiris, La Hague, Mélox). The proposed means of mitigation would then be:

- wearing masks (La Hague): this could lead to difficulties in the performance of tasks and communication between individuals;
- deactivating the ventilation (Mélox): the risk of anoxia in the room should be examined, given the number of staff present and the prevailing crisis situation.

The inspections sometimes revealed insufficient monitoring of the equipment made available to the staff in the event of a crisis (ILL, Phénix, local PCs at CEA Saclay).

Self-sufficiency

Most of the crisis premises are supplied with water and food to ensure independent operation, but sometimes far from adequately (ILL). Some sites stipulate transport from the site canteen, which raises the question of the feasibility of this measure in the event of earthquake, flooding or a toxic leak.

The question of the provision of stable iodine tablets arises on the Tricastin site, because the fuel cycle facilities are located within the PPI reflex perimeter of the Tricastin NPP. The various licensees who are subsidiaries of AREVA have their own stocks in their own facilities, except for GB II and Socatri. All the workers on the Tricastin platform must have access to iodine tables pre-positioned in their facilities, in order to maintain an iodine administration time compatible with the accident **scenarios envisaged in the reflex phase on the Tricastin EDF NPP**.

Remote PC

No remote PC has been created for the LUDD. Only OSIRIS envisages fallback to the Saclay CCC (Saclay national crisis coordination centre) but the procedures have yet to be specified. The RHF has an emergency command post, but it is too small to accommodate all the crisis teams. Fallback to the CEA FLS was mentioned, but the procedures also need to be clarified. It is however worth remarking on the exercise conducted at FBFC, which rapidly adapted to total unavailability of the crisis premises by choosing to transfer the crisis cells to the gatehouse and doing so efficiently, even though several premises on the site were considered to be destroyed by earthquake or exposed to fire.

3.6.7 Conclusion

For the CEA sites, the inspectors found that coordination between the sites and the various local PCs required better organisation in the PUI. For the local PCs, the inspections showed that a more robust organisation was necessary in order for them to handle their information transmission role, particularly:

- their composition in terms of PUI functions;
- personnel training in these functions (use of reflex response sheets and standard messages, directories, means of communication, etc.);
- operational criteria to justify alerting of the site management.

These observations will need to be incorporated into the complementary safety assessments to be performed on the Cadarache and Marcoule sites in 2012.

For the AREVA sites, specific training of the staff in their PUI functions, including for the management, must be given before they take on their on-call duties. Repeated nonconformities were observed.

On the Tricastin site, the discrepancy with respect to the guideline plan concerning updating of the reflex response sheets within the PUIs must be dealt with. Moreover, accommodation of the FLS by the ELPs and their coordination during the intervention is a major area for improvement. Finally, the pre-positioning of iodine tablet stocks, at least in the crisis PCs, is required at GBII and Socatri.

For all the LUDD, the anomalies observed during the targeted inspections revealed five main areas of progress concerning the licensees and liable to constitute possible changes to the frame of reference:

1. **appropriate training for the PUI position occupied, with the use of reflex response sheets;**
2. **improve the formal structure and responsibility for triggering the PPI in the reflex phase within the establishment's organisation, equipping the persons concerned with decision-making aids, taking the form of portable briefcases;**
3. **regularly carry out large-scale exercises involving several PCs and implementing off-site emergency response resources;**
4. **improve the availability of the crisis premises and assembly points, in the event of an earthquake or toxic release;**
5. **deploy the automatic population alert system to all the LUDDs.**

CHAPTER 2

COMPLEMENTARY SAFETY ASSESSMENTS OF THE NUCLEAR POWER PLANTS AND EUROPEAN STRESS TESTS75

1 OVERVIEW OF THE FRENCH NUCLEAR POWER PLANT FLEET	75
1.1 Description of the nuclear power plants.....	75
1.1.1 Main characteristics.....	76
1.1.2 Description of the main safety systems	78
1.2 The main differences between nuclear power plant installations.....	83
1.3 The periodic safety reviews.....	84
1.4 Use of probabilistic studies in the reactor safety assessment	85
2 EARTHQUAKES.....	87
2.1 Design of the facilities.....	87
2.1.1 Seismic level for which the facilities are designed.....	88
2.1.2 Steps designed to protect the facilities from the earthquake for which they are designed.....	96
2.1.3 Conformity of facilities with existing safety requirements.....	101
2.2 Evaluation of safety margins	103
2.2.1 Seismic level leading to significant damage of the fuel assemblies	107
2.2.2 Seismic level leading to a loss of containment	107
2.2.3 Seismic level leading to non-design-basis flooding.....	107
2.2.4 Measures envisaged to reinforce the robustness of the facilities to the seismic risk	108
3 FLOODING	109
3.1 Design of the facilities.....	110
3.1.1 Floods for which the facilities are designed	110
3.1.2 Measures to protect facilities from the flooding risk, including in the design process.....	113
3.1.3 Conformity of facilities with the current baseline safety requirements	116
3.2 Evaluation of safety margins	118
3.2.1 Estimation of margins in the event of flooding	118
3.2.2 Measures envisaged to reinforce the robustness of the facilities to the flooding risk.....	124
4 OTHER EXTREME NATURAL PHENOMENA RELATED TO FLOODING	128
4.1 Equipment design for these extreme climatic phenomena	128
4.2 Evaluation of safety margins	130
4.2.1 Estimation of margins in extreme meteorological conditions	130
4.2.2 Measures envisaged to reinforce the robustness of the facilities to extreme meteorological conditions	132
5 LOSS OF ELECTRICAL POWER SUPPLIES AND COOLING SYSTEMS	133
5.1 Loss of electrical power supplies	133
5.1.1 Loss of the off-site electrical power supplies	135
5.1.2 Loss of off-site electrical power supplies and conventional backup supplies.....	137
5.1.3 Loss of the off-site electrical power supplies and of the conventional backup supplies and any other on-site backup electrical power source	142
5.1.4 Conclusion on the planned measures to protect the facilities against the risk of electrical power supply loss	144
5.1.5 Measures envisaged to enhance facility robustness with respect to electrical power supply losses ...	145

5.2	Loss of the cooling systems / heat sink	146
5.2.1	Loss of the primary heat sink	151
5.2.2	Loss of the primary heat sink and the alternate heat sink	156
5.2.3	Conclusion on the planned measures to protect the installations against the risk of losing the ultimate cooling system or the heat sink.....	157
5.2.4	Measures envisaged to increase the robustness of the facilities with respect to loss of the ultimate cooling system / heat sink.....	158
5.3	Loss of the main cooling system combined with loss of the off-site electrical power supplies and the on-site backup supplies.....	162
5.3.1	Site autonomy before loss of the normal conditions of core and fuel pool cooling.....	163
5.3.2	External actions planned to prevent damage to the fuel	163
5.3.3	Measures envisaged to reinforce the robustness of the facilities with respect to loss of the main cooling system combined with total loss of the off-site and backup electrical power supplies.....	164
6	SEVERE ACCIDENT MANAGEMENT	165
6.1	Licensee's accident management organisation and measures.....	165
6.1.1	Licensee's accident management organisation	165
6.1.2	Possibility of using existing equipment.....	167
6.1.3	Identification of factors that can hinder accident management and the resulting constraints.....	170
6.1.4	Conclusion on the organisational provisions for accident management.....	175
6.1.5	Measures envisaged to reinforce accident management capabilities.....	175
6.2	Existing accident management measures further to loss of core cooling.....	176
6.2.1	Before the fuel in the reactor vessel becomes damaged	176
6.2.2	After the fuel in the reactor vessel has been damaged.....	177
6.2.3	After reactor vessel melt-through	178
6.3	Maintaining containment integrity after damage to the fuel in the reactor core	178
6.3.1	Elimination of the risk of high-pressure fuel damage or core meltdown.....	179
6.3.2	Management of the hydrogen risk in the reactor containment.....	179
6.3.3	Prevention of reactor containment overpressure	180
6.3.4	Prevention of re-criticality	181
6.3.5	Prevention of basemat melt-through.....	182
6.3.6	Supply of electricity and compressed air for operation of the equipment used to preserve the containment integrity	184
6.3.7	Instrumentation required to protect the integrity of the containment	184
6.3.8	Ability to manage several accidents in the event of simultaneous core melt / fuel damage in different units on the same site	185
6.3.9	Conclusions concerning the planned steps to maintain the integrity of the containment in the event of a severe accident.....	186
6.3.10	Steps envisaged for strengthening maintained containment integrity after fuel damage.....	187
6.4	Measures to limit radioactive releases in the event of a severe accident.....	187
6.4.1	Radioactive releases after loss of containment integrity.....	187
6.4.2	Accident management after uncovering of the top of the fuel in the pool.....	188
6.4.3	Conclusions concerning the steps taken to limit radioactive releases in the event of a severe accident	191
7	CONDITIONS CONCERNING THE USE OF OUTSIDE CONTRACTORS (EXCLUDED FROM THE SCOPE OF THE EUROPEAN "STRESS TESTS").....	193
7.1	Scope of activities concerned by subcontracting.....	193
7.2	Management of subcontracted activities	195
7.2.1	Contractor selection procedures	195
7.2.2	Steps taken to ensure satisfactory working conditions for the contractor companies.....	196
7.2.3	Monitoring of subcontracted activities	197
7.3	Conclusions on the conditions for the use of contractor companies	199
7.4	Measures envisaged by ASN to strengthen the requirements concerning the conditions for the use of contractor companies.....	201

8 CONCLUSION..... 203
8.1 Steps to increase the robustness of the facilities (already implemented)203
8.2 Identified safety problems204
8.3 Strengthening of nuclear safety and forthcoming work204

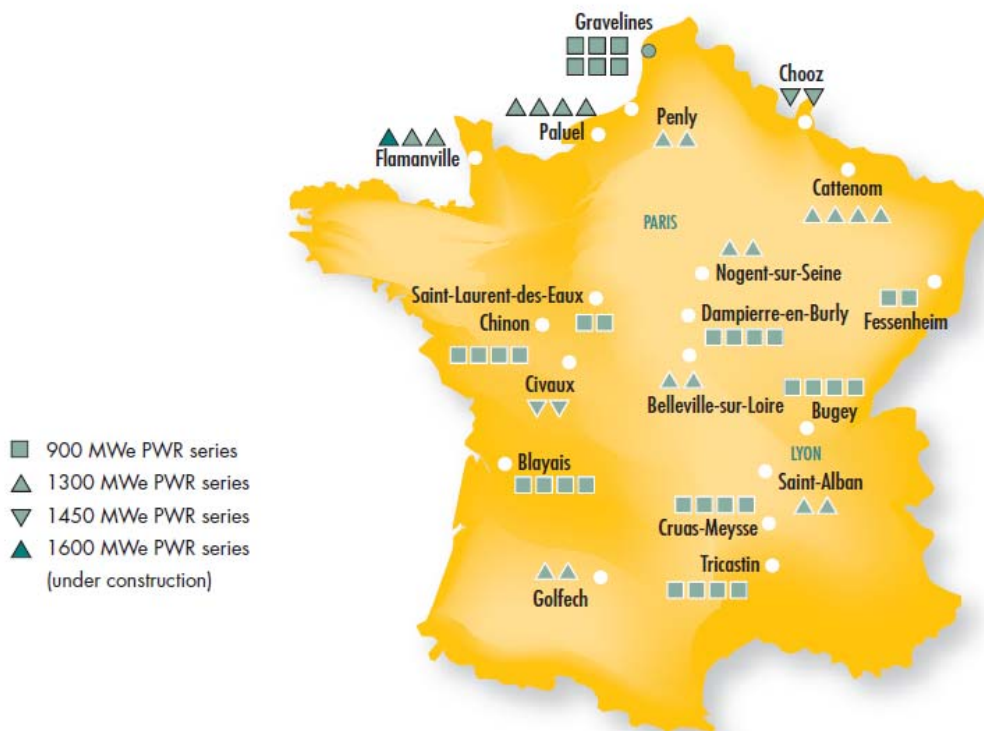
COMPLEMENTARY SAFETY ASSESSMENTS OF THE NUCLEAR POWER PLANTS AND EUROPEAN STRESS TESTS

1 Overview of the French nuclear power plant fleet

1.1 Description of the nuclear power plants

The nineteen French nuclear power stations (NPPs) currently in operation are relatively similar. Each station comprises from two to six pressurized water reactors (PWRs), giving a total of fifty-eight reactors in service. In addition to this, an EPR-type PWR is currently under construction at the Flamanville site, and an authorisation application has been made for another reactor of this type at the Penly site. For all the reactors in service, the nuclear island was designed and built by Framatome, with Electricité de France (EDF) acting as architect engineer. Today these reactors are all operated by EDF.

The illustration below shows the geographical location of the NPPs in France. There are no French reactors situated in French territories outside main-land France.



Four NPPs are situated by the sea, and represent:

- 14 reactors in service,
- 1 reactor under construction,
- 1 projected reactor, for which EDF has submitted an authorization application.

One NPP with 4 reactors (Blayais) is situated on an estuary, which means it is subject to the influences of both sea and river.

The other sites are situated beside waterways (mainly large rivers).

The table below gives a synthesis of the reactors and their geographical situation:

NPP site	Number of reactors	Geographical situation
Belleville	2	River site
Blayais	4	Estuary site
Bugey	4	River site
Cattenom	4	River site
Chinon	4	River site
Chooz	2	River site
Civaux	2	River site
Cruas	4	River site
Dampierre	4	River site
Fessenheim	2	River site
Flamanville	2 + EPR(under construction)	Coastal site
Golfech	2	River site
Gravelines	6	Coastal site
Nogent	2	River site
Paluel	4	Coastal site
Penly	2 + EPR (project)	Coastal site
Saint Alban	2	River site
Saint Laurent	2	River site
Tricastin	4	River site

1.1.1 Main characteristics

Certain technological innovations have been introduced on the reactors over time as the NPP fleet has grown. The installations can thus be divided into six groups called "series", which differ from one another in certain respects.

The thirty-four 900 MWe reactors consisting of:

- the CP0 series, comprising the four reactors at Bugey (reactors 2 to 5) and the two reactors at Fessenheim ;
- the CPY reactors, comprising the twenty-eight remaining 900 MWe reactors, which can be subdivided into CP1 (eighteen reactors at Le Blayais, Dampierre-en-Burly, Gravelines and Tricastin) and CP2 (ten reactors at Chinon, Cruas-Meysse and Saint-Laurent-des-Eaux).

The twenty 1300 MWe reactors consisting of:

- the P4 reactors, comprising the eight reactors at Flamanville, Paluel and Saint-Alban;
- the P'4 reactors, comprising the twelve reactors at Belleville-sur-Loire, Cattenom, Golfech, Nogent-sur-Seine and Penly.

Lastly, the N4 series comprising four 1450 MWe reactors, two at Chooz and two at Civaux.

The table below lists the reactors and their characteristics:

Site	Number of reactors	Net power ¹ (MWe)	Thermal power ² (MWth)	Type of reactor	Date of first divergence
Belleville	2	1310	3817 (4117)	P4	Reactor 1 : 1987-9 Reactor 2 : 1988-5
Blayais	4	910	2785 (2905)	CPY (CP1)	Reactor 1 : 1981-5 Reactor 2 : 1982-6 Reactor 3 : 1983-7 Reactor 4 : 1983-5
Bugey	4	Reactor 2 : 910 Reactor 3 : 910 Reactor 4 : 880 Reactor 5 : 880	2785 (2905)	CP0	Reactor 2 : 1978-4 Reactor 3 : 1978-8 Reactor 4 : 1979-2 Reactor 5 : 1979-7
Cattenom	4	1300	3817 (4117)	P'4	Reactor 1 : 1986-10 Reactor 2 : 1987-8 Reactor 3 : 1990-2 Reactor 4 : 1991-5
Chinon	4	905	2785 (2905)	CPY (CP2)	Reactor 1 : 1982-10 Reactor 2 : 1983-7 Reactor 3 : 1986-9 Reactor 4 : 1987-10
Chooz	2	1500	4720	N4	Reactor 1 : 1996-7 Reactor 2 : 1997-3
Civaux	2	1495	4720	N4	Reactor 3 : 1997-11 Reactor 4 : 1999-11
Cruas	4	915	2785 (2905)	CPY (CP2)	Reactor 1 : 1983-4 Reactor 2 : 1984-8 Reactor 3 : 1984-4 Reactor 4 : 1984-10
Dampierre	4	890	2785 (2905)	CPY (CP1)	Reactor 1 : 1980-3 Reactor 2 : 1980-12 Reactor 3 : 1981-1 Reactor 4 : 1981-8
Fessenheim	2	880	2785 (2905)	CP0	Reactor 1 : 1977-3 Reactor 2 : 1977-6
Flamanville	2	1330	3817 (4117)	P4	Reactor 1 : 1985-9 Reactor 2 : 1986-6
Golfech	2	1310	3817 (4117)	P'4	Reactor 1 : 1990-4 Reactor 2 : 1993-5
Gravelines	6	910	2785 (2905)	CPY (CP1)	Reactor 1 : 1980-2 Reactor 2 : 1980-8 Reactor 3 : 1980-11 Reactor 4 : 1981-5 Reactor 5 : 1984-8 Reactor 6 : 1985-7
Nogent	2	1310	3817 (4117)	P'4	Reactor 1 : 1987-9 Reactor 2 : 1988-10
Paluel	4	1330	3817 (4117)	P4	Reactor 1 : 1984-5 Reactor 2 : 1984-8 Reactor 3 : 1985-8 Reactor 4 : 1986-3

Penly	2	1330	3817 (4117)	P'4	Reactor 1 : 1990-4 Reactor 2 : 1992-1
Saint Alban	2	1335	3817 (4117)	P4	Reactor 1 : 1985-8 Reactor 2 : 1986-6
Saint Laurent	2	915	2785 (2905)	CPY (CP2)	Reactor 1 : 1981-1 Reactor 2 : 1981-5
Tricastin	4	915	2785 (2905)	CPY (CP1)	Reactor 1 : 1980-2 Reactor 2 : 1980-7 Reactor 3 : 1980-11 Reactor 4 : 1981-5

(1) Source : *Elecnucl*, 2011 edition, CEA.

(2) the value between parentheses indicates the design value whereas the other value is that stated in the creation authorization decree.

1.1.2 Description of the main safety systems

The heat produced by the fission of uranium or plutonium atoms is used to produce steam. The steam is then expanded in a turbine which drives an alternator that generates a 3-phase electric current of 400,000 Volts. After expansion, the steam passes through a condenser where it is cooled on contact with tubes circulating cold water taken from the sea, from a waterway (river) or from an atmospheric cooling system.

Each reactor comprises a nuclear island, a conventional island, water intake and discharge infrastructures, and possibly a cooling tower.

The nuclear island essentially consists of the nuclear steam supply system comprising the primary system and the systems designed for reactor operation and safety: the chemical and volumetric control (RCV or CVCS), the residual heat removal (RRA or RHRS), safety injection system (RIS or SIS), containment spray system (EAS or CSS), steam generator main feedwater system (ARE or MFMS), electrical, I&C and reactor protection systems. Various support functions are also associated with the nuclear steam supply system: primary waste treatment (TEP or CSTS), boron recovery, feedwater, ventilation and air-conditioning, backup electrical power (diesel generating sets).

The fuel storage pool

The nuclear island also comprises the main steam system (VVP) that removes the steam to the conventional island, and the building (BK) housing the fuel storage pool. Built adjacent to the reactor building, the BK building is used to store the fuel assemblies before and during the plant unit shutdowns and to cool the spent fuel (a third or a quarter of the fuel is replaced every 12 to 18 months depending on the fuel management strategy). The fuel is kept immersed in a pool filled with the water that acts as a radiological shield. The water in the pool contains about 2500 ppm of boric acid to continue to absorb the neutrons emitted by the nuclei of the fissile elements, but which are too few in number to maintain nuclear fission. Furthermore, each fuel element is placed in a metal compartment whose design and separation distance from the other compartments prevent a critical mass being reached. The fuel pool is cooled by the reactor cavity and spent fuel pool cooling and treatment system (PTR or FPC(P)S).

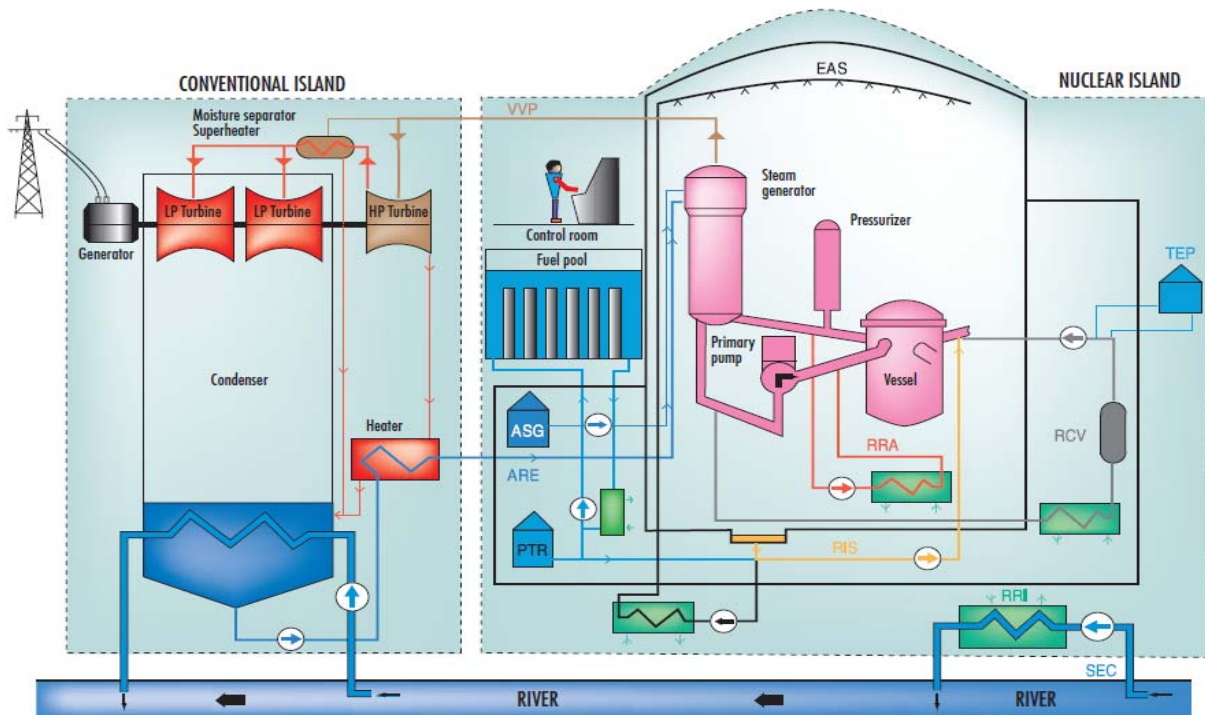
The conventional island equipment includes the turbine, the AC generator and the condenser. Some components of this equipment contribute to reactor safety.

The secondary systems belong partly to the nuclear island and partly to the conventional island.

The safety of pressurised water reactors is guaranteed by a series of strong, independent, leaktight barriers, for which the safety analysis must demonstrate their effectiveness in normal and accident operating situations. There are three barriers:

- the fuel cladding (first barrier)
- the main primary and secondary systems (second barrier)
- the reactor building containment (third barrier).

Below is a schematic diagram of a pressurised water reactor:



Core and fuel management

The reactor core consists of rods containing uranium oxide pellets or mixed uranium and plutonium oxides (fuel referred to as MOX) contained in metal tubes, referred to as the “cladding”, grouped in fuel “assemblies”. As a result of fission, the uranium or plutonium nuclei emit neutrons, which in turn produce further fissions: this is known as the chain reaction. These nuclear fissions release a large amount of energy as heat. The primary system water enters the core from the bottom of the reactor vessel at a temperature of about 285°C, flows up along the fuel rods and exits through the top at a temperature of about 320°C.

At the beginning of the operating cycle, the core has a very large reserve of energy. This gradually falls during the cycle, as the fissile nuclei disappear. The rate of the chain reaction, and hence the reactor power, is controlled by:

- inserting control rod assemblies containing elements that absorb neutrons, to varying depths in the core. These enable the reactor to be started and stopped and its power level to be adjusted to the electrical power to be produced. Dropping of the control rod assemblies under the effects of gravity triggers automatic reactor trip;
- the concentration of boron (absorbing neutrons) in the primary system water is adjusted during operation as the fissile material in the fuel becomes depleted.

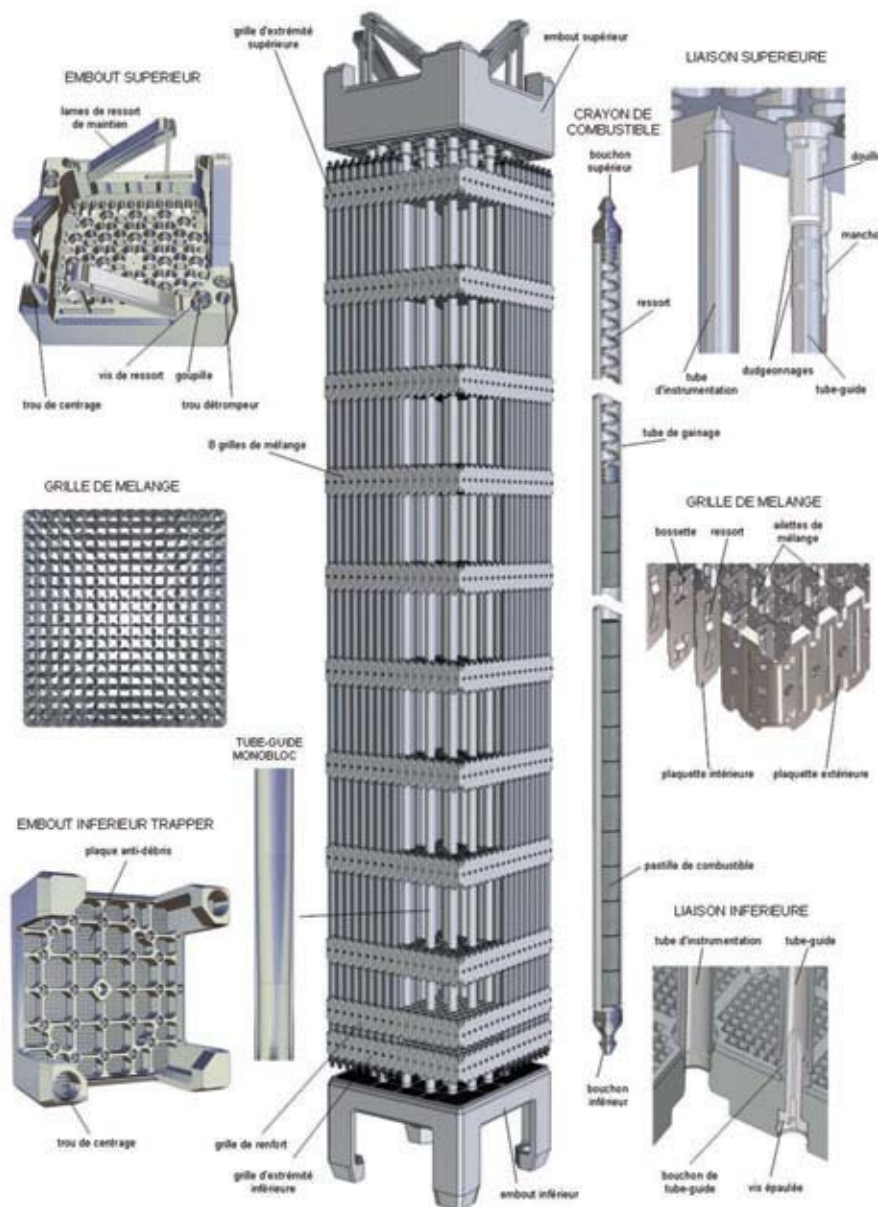
At the end of the cycle, the reactor core is unloaded for replacement of part of the fuel. EDF uses two types of fuels in its pressurised water reactors:

- uranium oxide based fuels (UO₂) with uranium 235 enrichment to a maximum of 4.5%. These fuels are fabricated in several plants in France and abroad, which belong to the fuel suppliers AREVA and WESTINGHOUSE;
- fuels consisting of a mixture of depleted uranium oxides and plutonium (MOX). The MOX fuel is produced by the AREVA MELOX plant. The initial plutonium content is limited to 8.65% (average per fuel assembly) and provides an energy equivalence with UO₂ fuel initially enriched to 3.7% Uranium 235. This fuel can be used in the 900 MWe reactors for which the decree authorising their creation (the DAC) provides for the use of MOX. There are twenty-two reactors authorized to use MOX.

Fuel management is specific to each reactor series. It is characterised in particular by:

- the nature of the fuel used and its initial fissile content;
- the maximum degree of fuel depletion at removal from the reactor, characterising the quantity of energy extracted per ton of material (expressed in GWd/t);
- the duration of an operating cycle;
- the number of new fuel assemblies loaded at each reactor refuelling shutdown (generally 1/3 or 1/4 of the total number of assemblies);
- the reactor operating mode, to characterise the stresses to which the fuel is subjected

The diagram below illustrates a fuel assembly for a pressurised water reactor:



The primary system and secondary systems

The primary system and the secondary systems are used to transport the energy given off by the core in the form of heat to the turbine generator set which produces electricity, without the water in contact with the core ever leaving the containment.

The primary system comprises cooling loops (three loops for a 900 MWe reactor, four loops for a 1,300 MWe, 1,450 MWe, or EPR reactor), the role of which is to extract the heat released in the core by circulating pressurised water, known as the primary water. Each loop, connected to the reactor vessel containing the core, comprises a circulating, or primary pump, and a steam generator (SG). The primary water, heated to more than 300 °C, is kept at a pressure of 155 bar by the pressuriser, to prevent it boiling. The entire primary system is located inside the containment.

The primary system water transfers the heat to the water in the secondary systems, via the steam generators. The steam generators are heat exchangers containing thousands of tubes through which the primary water circulates. These tubes are immersed in the water of the secondary system and heat it to boiling point without ever coming into contact with the primary water.

Each secondary system consists essentially of a closed loop through which water runs in liquid form in one part and as steam in the other part. The steam produced in the steam generators is partly expanded in a high-pressure turbine and then passes through moisture separator-reheaters before final expansion in the low-pressure turbines, from which it is then routed to the condenser. The condensed water is then heated and sent back to the steam generators by the extraction pumps relayed by feed pumps through reheaters.

The cooling systems

The purpose of the cooling systems is to condense the steam coming from the secondary system turbine. To do this the condenser is comprised a heat exchanger containing thousands of tubes in which cold water pumped from an outside source (river, sea) circulates. When the steam comes into contact with the tubes it condenses and can be returned in liquid form to the steam generators.

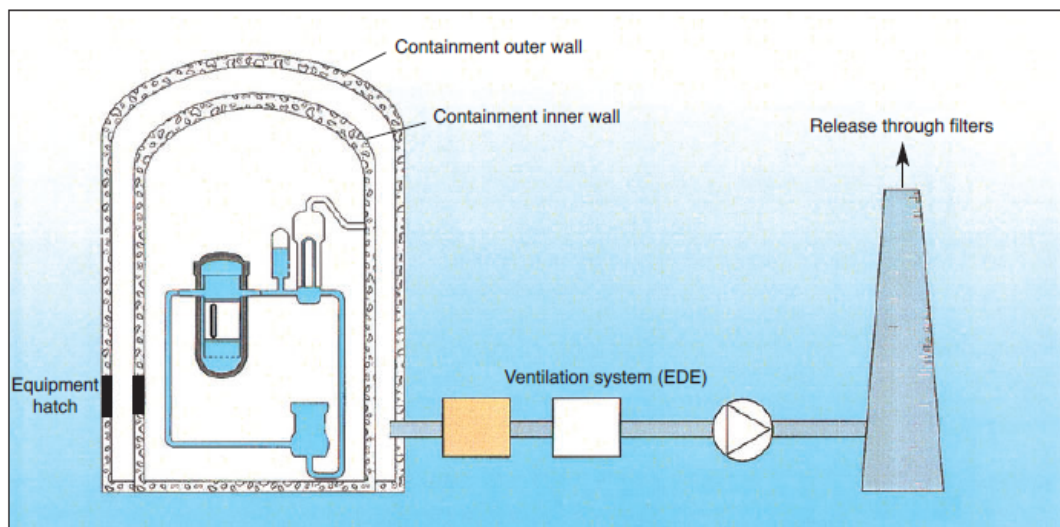
The cooling system water heated in the condenser is then discharged to the natural environment (open circuit) or, when the river flow is too low or the heating too great in relation to the sensitivity of the environment, cooled in a cooling tower (closed or semi-closed circuit).

The reactor containment building

The PWR reactor containment building fulfils two functions:

- protection of the reactor against external hazards;
- containment, thereby protecting the public and the environment against radioactive products likely to be dispersed outside the primary system in the event of an accident. The containments are therefore designed to withstand the pressures and temperatures that could be reached in an accident situation, and offer sufficient leaktightness in such conditions.

The schematic diagram below shows the containment building of a 1300 MWe reactor:



The containments are of two types:

- the 900 MWe reactor containments, consisting of a single wall of pre-stressed concrete (concrete containing steel cables tensioned to ensure compression of the structure). This wall provides mechanical resistance to the most severe design accident pressure and structural integrity against external hazards. Leaktightness is assured by a metal liner on the inside of the concrete wall;
- the 1,300 MWe and 1,450 MWe reactor containments, comprising two walls, an inner wall made of pre-stressed concrete and an outer wall made of reinforced concrete. Leaktightness is provided by the inner wall and the ventilation system (EDE or AVS) which, in the annular space between the walls, channels any radioactive fluids and fission products that could come from inside the containment as a result of an accident. Resistance to external hazards is mainly provided by the outer wall.

The photo below shows a view of the exterior concrete of a 900 MWe reactor building:



The main auxiliary and safeguard systems

In normal operation or during normal shutdown of the reactor, the role of the auxiliary systems is to provide basic safety functions: control of neutron reactivity, removal of heat from the primary system and fuel residual heat, containment of radioactive materials. This chiefly involves the chemical and volume control system (RCV or CVCS) and the residual heat removal system (RRA or RHRS).

The purpose of the safeguard systems is to control incidents and accidents and mitigate their consequences. This primarily concerns the safety injection system (RIS or SIS), the reactor building containment spray system (EAS or CSS) and the steam generator auxiliary feedwater system (ASG or EFWS).

The other systems important for safety

The other systems necessary for reactor operation and important for safety include:

- the component cooling system (RRI or CCWS), which cools equipment; this system operates in a closed loop between the auxiliary and safeguard systems, and the essential service water system (SEC or ESWS), which uses the heat sink to cool the RRI system;
- the reactor cavity and spent fuel pool cooling and treatment system (PTR or FPC(P)S), used notably to remove residual heat from irradiated fuel elements stored in the spent fuel pool;
- the ventilation systems, which play a vital role in containing radioactive materials by depressurising the environment and filtering all discharges;

- the fire-fighting water systems;
- the instrumentation & control system and the electrical systems.

1.2 The main differences between nuclear power plant installations

In spite of the standardizing of the French nuclear reactor fleet, a number of technological innovations have been introduced as the design and construction of nuclear reactors have progressed.

Compared with the CP0 series reactors of the Bugey and Fessenhiem NPPs, the CPY series has a different building design, an intermediate cooling system between the system that sprays the containment in the event of an accident and that containing the water from the heat sink, and provides for greater management flexibility.

Significant changes with respect to the CPY series have been made in the design of the circuits and systems protecting the core of the 1300 MWe reactors (plant series P4 and P'4) and the design of the buildings accommodating the installation. The increased power has resulted in a primary system with four steam generators (SG) offering a greater cooling capacity than on the 900 MWe reactors, which have three SGs. Furthermore, the reactor containment has a double concrete wall instead of a single concrete wall with a steel sealing liner as is the case with the 900 MWe reactors.

The P'4 series reactors display a few differences with respect to the P4, notably the fuel building and the design of certain systems.

The N4 series reactors differ from the preceding reactors more particularly in the design of the SGs which are more compact, the design of the primary pumps, and the control room computerisation.

A 1650 MWe EPR-type pressurised water reactor is under construction at the Flamanville NPP, which already has two 1300 MWe reactors. Furthermore, ASN is currently examining an application from EDF to create another EPR PWR on the Penly site.

The EPR reactors under construction at Flamanville (Flamanville 3, BNI 167), and planned at Penly (Penly 3), are four-loop reactors with a unit electrical output of about 1 650 MWe. Compared with the existing power reactors operating in France, they are characterized by the fact that severe accident scenarios are integrated from the design stage. Based on the principle of a quadrupling (4 trains) of the safeguard systems (with a few exceptions) and, in addition to the presence of an aircraft crash-resistant shell (protecting the reactor building, the fuel building and two buildings housing two engineered safeguard trains) to counter external hazards, the EPR incorporates, for example:

- prevention measures, in particular:
 - to prevent high-pressure core meltdown accidents ;
 - to enhance the reliability of the on-site electric power supplies by adding two diversified diesel generator sets (ultimate backup);
 - to protect the water supply of the safeguard systems cooling the reactor core and containment;
 - by installing the IRWST (in-containment refuelling water storage tank) directly in the reactor building;
 - by having an alternate heat sink based on the "reversed" use of the sea discharge channel, to take in water from the sea;
- mitigation measures such as a corium collector under the reactor vessel in the reactor building, or having a double-walled containment with a metallic internal sealing liner in the reactor building.

For the spent fuel pools of the 900 MWe CP0 and CPY series reactors, the fuel assemblies will be placed in storage rack compartments. These storage racks are made from a corrosion-resistant material not specifically designed to absorb neutrons, sub-criticality being guaranteed by the geometric arrangement of the assemblies. The fuel pools of the CP0 series reactors have 313 compartments, while the CPY series have 382.

To load the spent fuel assemblies into the transportation container, the container must be placed in the loading pool, a dedicated location that communicates with the fuel storage pool.

As from the 1300 MWe series reactors, the fuel pool storage racks have been manufactured in a neutron-absorbing material in order to guarantee sub-criticality in spite of a denser storage arrangement than for the preceding reactors.

The fuel pools of the 1300MWe P4 series reactors have 459 storage compartments.

As from the P4 series, the transportation containers are loaded beneath the loading pool. This means that the heavy handling crane used in the CP0, CPY and P4 series reactors is not necessary, allowing the height of the fuel building to be lowered.

The fuel storage pools have capacities of 630 compartments for the P4 series reactors, 612 for the N4 series reactors, and 1167 for the EPR reactor.

For the EPR reactor, the reactor cavity and spent fuel pool cooling and treatment system (PTR) has an additional train with a diversified heat sink and can be resupplied with electricity by the ultimate backup generator sets.

1.3 The periodic safety reviews

The French safety standard requires French nuclear installations to be designed and built to withstand - without jeopardising their safety - the most severe natural phenomena (earthquakes, floods, etc.) that have already occurred in the surrounding area, with an additional safety margin. Moreover, it requires the implementation of a system of "defence in depth" that consists of a series of redundant and diversified measures (automatic mechanisms, systems or procedures) to prevent the occurrence of an accident or to mitigate its consequences. These measures are checked at each stage in the life of the nuclear installations (examination of the safety options, creation authorisation, commissioning authorisation, etc.) and re-examined systematically during the 10-year safety reviews instituted by article 29 of the act of 13 June 2006. This periodic safety review provides the opportunity for an in-depth examination of the condition of the NPPs, to check that they comply with all the safety requirements. An additional aim of the review is to improve the safety of the installations, particularly by comparing the applicable requirements with those applied by the licensee to more recent NPPs.

The periodic safety reviews therefore constitute one of the cornerstones of safety in France, by obliging the licensee not only to maintain the level of safety of its NPP but also to improve it.

The review process

The periodic safety review comprises a number of successive steps.

1. **The conformity review:** this consists in comparing the condition of the installation to the applicable safety requirements and regulations including, notably, the creation authorisation decree and ASN's requirements. This step ensures that changes to the installation and its operation, as a result of modifications or ageing, comply with applicable regulations and do not compromise the installation's safety requirements. This ten-year conformity check does not relieve the licensee of its permanent obligation to guarantee the conformity of its installations.
2. **The safety review:** this aims to appraise the safety of the installation and to improve it with respect to:
 - French regulations and the most recent safety objectives and practices in France and abroad;
 - operating experience feedback from the installation;
 - operating experience feedback from other nuclear installations in France and abroad;
 - lessons learned from other installations or equipment prone to risk.

ASN may rule - possibly after consulting the GPR (advisory committee for safety of nuclear reactors) - on the study topics envisaged by the licensee before the launch of the safety reassessment studies, during the phase known as the periodic safety review orientation phase.

3. ***Deployment of the improvements resulting from the periodic safety review:*** the 10-year in-service inspections provide an excellent opportunity to apply the modifications resulting from the periodic safety review. To determine the schedule for the 10-year inspections, EDF has to take into account the deadlines for the performance of hydrostatic tests set by the regulations for nuclear pressure equipment and the frequency of the periodic safety reviews provided for by the TSN Act.
4. ***Submission of the licensee's report on the conclusions of the safety review:*** on completion of the 10-year in-service inspection, the licensee sends ASN a report on the conclusions of the safety review. In this report the licensee adopts its position regarding the conformity of its installation with the regulations and on the modifications made to remedy the observed anomalies or to improve the safety of the installation. The review report contains the elements provided for in article 24 of decree 2007-1557 of 2 November 2007, amended.

1.4 Use of probabilistic studies in the reactor safety assessment

The demonstration of the safety of these installations is based firstly on a deterministic approach, by which the operator guarantees the resistance of the installation to reference accidents. This approach is supplemented by probabilistic safety assessments (PSA) based on a systematic examination of the accident scenarios to assess the probability of arriving at unacceptable consequences. They provide a global view of safety, integrating the resistance of the equipment and the behaviour of the operators.

The PSAs help to determine whether the measures adopted by the licensee are satisfactory or not. They enable the safety problems relating to the design or operation of the reactors to be prioritized, and constitute a means of dialogue between the licensees and the administration.

For the existing reactors, the PSAs are carried out and updated during the 10-year reviews.

For the future reactors (case of the EPR), the PSAs are developed at the same time as the design becomes clearer so as to highlight situations involving multiple failures for which measures must be taken to reduce their frequency or limit the consequences.

Two types of PSA are used in France:

- level-1 PSAs for identifying the sequences of events leading to fuel meltdown and to determine their probabilities;
- level-2 PSAs for assessing the probability of releases outside the containment (into the environment), according to their nature and scale.

The level-1 and 2 PSAs are used in the periodic safety reviews to evaluate the frequency of core meltdown or release and, for PSA1, how it has evolved with respect to the evaluation made at the end of the preceding review, by integrating an analysis of the modifications of the system characteristics (equipment reliability for example) and operating practices. The identification of the main factors contributing to the total probability of core meltdown or the probabilities of releases reveals any weak points for which changes to the installation or its operation are considered advisable or indeed necessary. Classifying them in order of importance enables the priority improvements to be determined. If it is decided that modifications are necessary, the PSAs enable the advantages and drawbacks of the envisaged solutions to be measured or evaluated. The appropriateness of these modifications must be demonstrated by analysing their impact on the contributions to the probability of fuel meltdown. These studies take into account both the reactor operating and shutdown states. The table below defines the PSAs currently available and the main categories of initiating events considered per reactor series in France.

Series	Events considered for the level 1 and 2 PSA
900 MWe reactors (CP0-CPY)	Failures internal to the reactor (PSA 1 and 2) Fire (PSA 1)
1300 MWe reactors (P4-P'4)	Failures internal to the reactor (PSA 1 and 2) For the review associated with the 3rd 10-year inspection, the following will also be considered: - events associated with the spent fuel pool building (BK) (EPS 1 and 2); - internal fire and flooding (PSA 1).
1400 MWe reactor (N4)	Failures internal to the reactor (PSA 1). A level-2 PSA will be performed for the next safety review.
1650 MWe reactor (EPR) under construction	The level 1 and 2 PSAs will be revised in view of the commissioning authorisation application. They will take into account: - the events internal to the reactor; - the events associated with the spent fuel pool building (BK); - earthquake; - internal fire and explosion; - internal flooding.

Moreover, in the framework of the 3rd general review of the 1300 MWe reactors, a study was conducted to verify the possibility of extending the level-1 PSAs to earthquakes.

2 Earthquakes

An earthquake is an event liable to lead to failures which could affect all the facilities on a site, in particular the systems important for safety. The possibility of an earthquake is factored into the design of the facilities and is periodically reassessed on the occasion of the periodic safety reviews (see § 1.3).

The CSAs demonstrated that the current seismic margins on EDF's NPPs are sufficient to avoid cliff edge effects in case of limited exceeding of the current safety requirements. These CSAs confirmed the interest of the periodic reassessment of the seismic risk on the occasion of each ten-year periodic safety review. This process of seismic risk review at each periodic safety review should be continued. Furthermore, following the analysis of EDF's CSAs reports and the targeted inspections to which this led in the summer of 2011, ASN has identified several areas in which safety could be improved, related to the seismic robustness of the facilities.

With regard to the seismic risk, ASN will therefore require that EDF:

- Ensures that the equipment used to control the basic safety functions is protected against fire in the event of an earthquake. The main measures to protect the facilities against fire are not at present all designed to withstand the facility's baseline safety requirements earthquake;
- Increases how this risk is taken into account in the day-to-day operation of its reactors: improved operator training, improvement in how the "event-earthquake" issue is considered, compliance with the fundamental safety rule concerning seismic instrumentation (maintenance, operator familiarity with the equipment, calibration). In a number of NPPs, ASN observed deficiencies in the application of the seismic risk safety requirements in force;
- For the Tricastin, Fessenheim and Bugey sites, provides a study analysing the seismic robustness of the dykes and other structures designed to protect the facilities against flooding and to present the consequences of a failure of these structures.

Furthermore, following the Complementary Safety Assessments (CSAs) performed on the nuclear facilities in the wake of the Fukushima accident, ASN considers that the safety of the nuclear facilities needs to be made more robust to very unlikely risks that are not currently considered in the design of the facilities or following their periodic safety review, and to include this requirement in the regulatory framework.

These facilities must be given the resources enabling them to deal with, such as:

- combination of natural phenomena of an exceptional scale, greater than the phenomena considered in the design or the periodic safety review of the facilities
- very long-term loss of electrical power supply or cooling function situations which could affect all the facilities on a particular site.

ASN will thus be requiring that the licensees set up a "hard core" of material and organisational measures to guarantee the operational nature of the structures and equipment, such as to be able to manage the basic safety functions in these exceptional situations. This subject is developed further in part 16 of this report.

2.1 Design of the facilities

In addition to the facility's initial seismic design, and during the course of the reactor second and third ten-yearly outage inspections (VD2 and VD3), ASN specifically requested that the changes to the safety requirements and new scientific knowledge in the field of this hazard and the parasismic justification to be taken into account.

It is important to note that the updating of the "Safe Shutdown Earthquake" SSE on the site is simply one aspect of the periodic safety reviews regarding the seismic field. The development of methods and computing resources used for parasismic engineering has fine-tuned the evaluation of the seismic strength of buildings and equipment. Reinforcements may therefore be decided, not simply on the basis of a reassessment of the hazard,

which constitutes input data for the calculation of structures and equipment, but also on the basis of developments in parasismic engineering.

In addition, seismic operating experience feedback (both nuclear and non-nuclear) and the construction robustness studies are also sources for evaluating seismic conformity.

2.1.1 Seismic level for which the facilities are designed

The approach used to define the seismic loads to be considered in the design of the facilities is a deterministic one:

- it is postulated that any earthquake known in the region of the site (taking account of historical observations over a period of about 1,000 years) is liable to reoccur with the same characteristics in the position most unfavourable to the facility, while remaining compatible with the geological and seismic data;
- from this, the intensity of the "Maximum Historically Probable Earthquake" (MHPE) is deduced;
- as part of the safety approach and to take account of uncertainty surrounding the data and the available knowledge, a degree of intensity is arbitrarily added to the MHPE to define the SSE;
- the installation is then designed to withstand a hazard level at least equivalent to that of the SSE; reactor safe shutdown, fuel cooling and containment of radioactive products must be guaranteed for this type of earthquake;
- this approach also takes account of soil effects and paleo-earthquakes¹.

Given the standardisation of the nuclear reactors operated in France, EDF has introduced the notion of the Design-Basis Earthquake (DBE): this is the envelope spectrum of the various SSE spectra associated with the different sites of the same plant series.

Moreover, a basic safety rule (RFS - see § 2.1.2) defines acceptable methods for determining all the movements to which the "seismic-classified" civil engineering structures are subjected, based on the seismic motion considered and the corresponding load levels, in order to allow design and verification:

- of the civil engineering strength of these structures subjected to the loads resulting from earthquakes and other actions combined with earthquakes;
- of the correct behaviour and performance of the equipment in the facility.

Characteristics of the Design-Basis Earthquake (DBE)

ASN requires that basic nuclear installations be designed to withstand an earthquake higher than the maximum earthquake that has occurred during the last thousand years in the area in which they are sited.

The licensees are therefore required to define an earthquake for design purposes. The rule for determining this earthquake is defined in a RFS. The RFS defined by ASN are in particular designed to explain the regulatory objectives and, as applicable, describe the practices considered by ASN to be satisfactory. They are periodically reviewed to take account of changing knowledge and new information. The first RFS on the subject, RFS 1.2.c², dates from 1981. It was revised in 2001, which this revision being known as RFS 2001-01³. These RFS are also used to check the design of the installations in operation on the occasion of the periodic safety reviews, with reinforcements defined as and when necessary.

These rules define two seismic levels, the MHPE and the SSE, which is that used to check that the earthquake finally adopted by the licensee in the design of its facility (DBE) is in conformity with the requirement.

¹ Paleo-earthquake: earthquake which left traces of deformation in the surface geological layers

² RFS 1.2.c of 1st October 1981 concerning the determination of the seismic motion to be taken into account for the safety of the facilities

³ RFS 2001-01 of 31st May 2001 concerning the determination of the seismic risk for the safety of surface basic nuclear installations.

EDF has adopted a programme of standardised plant series for the nuclear reactors on its nuclear islands, which enabled it to pool the design studies. The other structures, known as the "site structures" were specifically designed for each site.

The nuclear island comprises:

- The reactor building (BR), containing the reactor and all the pressurised reactor coolant systems, and the containment,
- A fuel building (BK), housing the new and spent fuel storage and handling facilities,
- A safeguard auxiliaries and electrical building (BAS/BL),
- A building for the other nuclear auxiliaries (BAN),
- An operations building (BW).

The site structures include the other buildings and facilities necessary for the operation of the plant, including the heat sink and the intake channel.

In general, the design spectra adopted were determined as follows:

- CP0 and CPY: For the design of the CP0 and CPY plant series, the spectral shape used was that known as the "EDF spectrum", defined as the smoothed mean of eight accelerograms recorded during five earthquakes of Californian origin. The accelerations are normalized according to the local seismicity.
- P4 and P'4: The DBE for Paluel, the first P4 site, was changed during the course of its construction. At the beginning of construction, the spectral shape used hitherto for the units was that of the "EDF spectrum". During construction, a new spectral shape was taken from that established by the *Nuclear Regulatory Commission* (NRC - nuclear safety regulator in the U.S.A.) in its *Regulatory Guide* 1.60, which was also adopted in France as the reference for the design of the 1,300 MWe plant series. For the buildings, this led EDF to use the following in turn:
 - the EDF spectrum normalized to 0.2 g.
 - for a transitional period, the NRC spectrum normalized to 0.2 g.
 - the NRC spectrum normalized to 0.15 g.

For the following reactors, P4 and P'4, EDF adopted the NRC spectrum normalized to 0.15 g with zero period for the standard DBE applicable to nuclear island design, compatible with the sites chosen for the reactors in this plant series.

- N4: The standard DBE spectrum, applicable for the design of structures and facilities for the N4 plant series, is the NRC spectrum normalized to 0.15 g with zero period. It is normalized to a zero period acceleration of 0.15 g in the horizontal directions and 0.133 g in the vertical direction (which differs from the usual rule which has 2/3 of the horizontal spectrum correspond to the vertical spectrum, and corresponds to 2/3 of an acceleration normalized to 0.2 g. This is a design convention for this plant series).
- EPR: the DBE is the European EUR spectrum normalized to 0.25 g at zero period.

The following table summarises the different design spectra for the nuclear island and site structures:

Site	Plant series	Nuclear island DBE	Site structure DBE
Bugey	CP0	EDF normalized to 0.1 g zero period	EDF normalized to 0.1 g zero period
Fessenheim	CP0	EDF normalized to 0.2 g zero period	EDF normalized to 0.2 g zero period, hors BL
Blayais	CPY	EDF normalized to 0.2 g zero period	EDF normalized to 0.2 g zero period
Chinon	CPY	EDF normalized to 0.2 g zero period	EDF normalized to 0.2 g zero period

Cruas	CPY	EDF normalized to 0.2 g zero period, supplemented by a "high-frequency" spectrum normalized to a zero period acceleration of 0.3 g	EDF normalized to 0.2 g zero period, supplemented by a "high-frequency" spectrum normalized to a zero period acceleration of 0.3 g
Dampierre	CPY	EDF normalized to 0.2 g zero period	EDF normalized to 0.1 g zero period
Gravelines	CPY	EDF normalized to 0.2 g zero period	EDF normalized to 0.2 g zero period
Saint Laurent	CPY	EDF normalized to 0.2 g zero period	EDF normalized to 0.2 g zero period
Tricastin	CPY	EDF normalized to 0.2 g zero period	EDF normalized to 0.2 g zero period, verified at a higher frequency site spectrum, normalized to 0.3 g
Flamanville 1-2	P4	NRC normalized to 0.15 g zero period	NRC normalized to 0.15 g zero period
Paluel	P4	EDF normalized to 0.2 g, then NRC normalized to 0.2 g, then NRC normalized to 0.15 g	EDF normalized to 0.2 g, then NRC normalized to 0.2 g, then NRC normalized to 0.15 g
Saint Alban	P4	NRC normalized to 0.15 g zero period	NRC normalized to 0.1 g, then verified at NRC normalized to 0.132 g
Belleville	P ⁴	For the design of the nuclear island: NRC spectrum normalized to 0.15 g zero period and, for the nuclear island foundations and reinforcements, owing to the low seismicity of the site: NRC normalized to 0.1 g zero period.	NRC normalized to 0.1 g zero period
Cattenom	P ⁴	NRC normalized to 0.15 g zero period	NRC normalized to 0.15 g zero period
Golfech	P ⁴	NRC normalized to 0.15 g zero period	NRC normalized to 0.15 g zero period
Nogent	P ⁴	For the design of the nuclear island: NRC spectrum normalized to 0.15 g zero period and, for the nuclear island foundations and reinforcements, owing to the low seismicity of the site: NRC normalized to 0.1 g zero period.	NRC normalized to 0.15 g zero period
Penly	P ⁴	NRC normalized to 0.15 g zero period	NRC normalized to 0.15 g zero period
Chooz	N4	NRC normalized to 0.15 g zero period, (normalized to 0.15 g in the horizontal direction and 0.133 g in the vertical direction) and spectrum offset by reducing the frequencies by a ratio of 2/3 and normalized to 0.12 g zero period.	NRC, offset and normalized to 0.12 g zero period
Civaux	N4	NRC normalized to 0.15 g zero period, (normalized to 0.15 g in the horizontal direction and 0.133 g in the vertical direction) and spectrum offset by reducing the frequencies by a ratio of 2/3 and normalized to 0.12 g zero period.	NRC normalized to 0.15 g zero period
Flamanville 3	EPR	EUR normalized to 0.25 g zero period	EUR normalized to 0.2 g zero period

Methodology used to evaluate the Design Basis Earthquake (DBE)

The conformity of the basic nuclear installations with the regulations is periodically checked every ten years, on the occasion of the periodic safety reviews. These reviews are the opportunity to perform an in-depth, detailed conformity examination, to reassess the SSE levels in the light of the most recent data and new knowledge, to re-examine equipment for which seismic resistance is required, to take account of changes in the field of parasismic engineering and to make the corresponding necessary improvements to the facilities.

The seismic motions corresponding to the SSE are established on the basis of a RFS, which has itself evolved to take account of new data and knowledge.

The regulatory requirements: RFS 1.2.c and 2001-01:

A deterministic approach is used to define the seismic hazard to be considered in the design of the facilities.

The general approach to characterising the seismic hazard follows 3 steps:

- geological and seismic characterisation of the region, to identify zones with homogeneous characteristics,
- definition of one or more reference earthquakes,
- calculation of the seismic motion at each site.

The approach is, for each site, to look for an earthquake encompassing the known historical earthquakes in the most penalising epicentre positions (in terms of MSK intensity, representative of surface effects) while remaining compatible with geological and seismic data.

The whole of France is covered by seismotectonic zoning.

Information on past earthquakes was obtained from the interpretation of historical archives describing the damage caused, characterising 1,000 years of seismicity (the SisFrance database contains about 10,000 documents describing more than 6,000 events, and 100,000 observation points), plus a catalogue of instrumental measurements taken since the 1960s (CEA/LDG database).

Definition of the MHPE

The “Maximum Historically Probable Earthquakes” (MHPE) are the earthquake or earthquakes which, for the site concerned, produce the highest intensities, bearing in mind that:

- the historical earthquakes of the tectonic domain to which the site belongs are considered as being capable of reoccurring under the site,
- the historical earthquakes belonging to a neighbouring tectonic domain are considered as being capable of occurring at the point in this domain closest to the site.

The intensity of an earthquake cannot be directly used in the design of a facility.

Earthquakes are described by their response spectrum (given by the zero period acceleration value, expressed in "g"). For this, it is necessary to determine the magnitude and the focal depth of the historical events.

For each MHPE, a “Safe Shutdown Earthquake” (SSE) is deduced by means of a simple relationship in terms of MSK⁴ intensity on the site:

Definition of the SSE

The intensity of the SSE on the MSK scale is conventionally defined by:

$$I_{SSE} = I_{MHPE} + 1$$

The MSK scale was determined such that a one-degree increase corresponds overall to a doubling in the motion parameter.

⁴ The Medvedev-Sponheuer-Karnik scale (also called MSK scale) is a scale measuring the intensity of an earthquake.

The SSE response spectrum is obtained by conventionally adopting a magnitude which is that of the MHPE plus 0.5 on the Richter scale.

Transition from RFS 1.2.c (1981) to RFS 2001-01 (2001)

The first RFS for determining seismic motion to be considered for the safety of facilities dates from 1981, this is RFS 1.2.c⁵. It was revised in 2001, becoming known as RFS 2001-01⁶. The RFS revision retained the general approach and added to the previous text by taking account of changes to scientific knowledge and the seismic operating experience feedback from the previous 20 years.

The main changes to the RFS concern:

- the rule for the definition of seismo-tectonic zones in complex fault configurations (fault families).
- the use of the available correlations (linking magnitude to intensity and to focal distance) best suited to the French context and established on the basis of a range of homogeneous macroseismic data.
- the notion of fixed spectrum: the fixed spectrum characterising nearby earthquakes has been abandoned in favour of a site spectrum set at 0.1 g with infinite frequency. The RFS revision requires a check that the SSE is higher than a minimum level. This minimum level encompasses a moderate earthquake close to the facility (M=4 at 10 km) and a major event (M=6.6 at 40 km). This minimum level is defined for the two site conditions, both rock and sediment. This approach is in conformity with IAEA's recommendation (*Seismic Hazard Evaluation for Nuclear Power Plants, Safety Standards series n° NS-G3-3*). Considering this minimum level offers a safety margin and compensates for the lack of data available in low-seismicity regions.
- The incorporation of seismic operating experience feedback and changing calculation methods: the operating experience feedback from earthquakes in the 1980s showed the significant influence of the surface geological layers, in particular in alluvial zones. These effects, referred to as "site effects" act on the amplitude of the seismic motion, its duration and its frequency. The response spectrum definition was supplemented in the RFS by additional indicators such as strong phase duration, the Arias intensity, the maximum soil speed, etc., which are of use for the designers of structures. Site effects are included by using spectral acceleration attenuation laws, including the complex geometry of sedimentary zones and the geological characteristics of the top thirty metres on the sites (determined by using local instrumental data), which were updated in relation to the previous RFS.
- Taking account of new and changing knowledge in the field of geology: in the early 1990s, signs of paleo-earthquakes of a magnitude higher than certain events in the SisFrance base were discovered. These earthquakes left geological traces by disrupting geological layers or modifying the landscape.

Site design response spectrum (design-basis earthquake - DBE):

For the design of each plant series, EDF used a design spectrum encompassing the overall SSE spectrum for each site, using the data and knowledge available at the time.

Special steps were taken for sites with seismic characteristics outside the envelope of the standardised plant series (owing to specific local, in particular geological characteristics).

Conclusions concerning the adequacy of the Design-Basis Earthquake (DBE)

Following a periodic safety review, the changes decided for a plant series are implemented on each reactor, generally on the occasion of the reactor ten-yearly outage inspection. The modifications are thus deployed to the entire plant series over a time-frame that is consistent with the initial time of construction of the corresponding reactors.

⁵ RFS 1.2.c of 1st October 1981 concerning the determination of the seismic motion to be taken into account for the safety of the facilities

⁶ RFS 2001-01 of 31st May 2001 concerning the determination of the seismic risk for the safety of surface basic nuclear installations.

As at 30th June 2011, the seismic conformity baseline applicable to the various reactors was as follows:

Reactor	Plant series	Version of modifications implemented on the reactor (ten-yearly outage-VD)	Applicable seismic baseline	Conformity of the DBE with the earthquake chosen by EDF in accordance with the RFS for the version of the modifications applicable as at 30 th June 2011
Bugey 2-4	CP0	VD3	RFS 2001-01	The new SSE was reassessed at 0.145 g, which requires the installation of reinforcements to restore the seismic margins. The work has been completed on these two units.
Bugey 3-5	CP0	VD2	RFS I-2-C	The earthquake adopted is covered by the DBE. However, the VD3 baseline showed the need for seismic reinforcements. The work is complete on Bugey 5 and will be completed on Bugey 3 in 2013.
Fessenheim 1	CP0	VD3	RFS 2001-01	The earthquake to be taken into account remains covered by the design-basis earthquake.*
Fessenheim 2	CP0	VD2	RFS I-2-C	Far-field earthquakes remain covered by the "EDF 0.2 g" DBE. The near-field earthquakes involved a high-frequency overshoot of the design level, considered to have no impact on the safety of the facility. No modifications were implemented during VD2 (the high frequencies do not intercept the natural frequencies of the buildings). For the VD3 preparations, the earthquake to be considered remains covered by the design-basis earthquake (for RFS 2001-01).*
Blayais	CPY	VD2	RFS I-2-C	RFS 2001-01 was used in the preparations for VD3 and shows that the minimum fixed earthquake and the site SSE are both covered by the DBE.
Chinon	CPY	VD2	RFS I-2-C	The earthquake defined in RFS I-2-C encompassed the DBE. In the preparations for the VD3, the earthquakes resulting from RFS 2001-01 entailed an overshoot above 7 Hz. A study was carried out to demonstrate that there was no impact on the site structures, the buildings and the equipment of the nuclear island. A study is in progress concerning the reactor building internal structures.
Cruas **	CPY	VD2	RFS I-2-C	The earthquake resulting from application of the RFS I-2-C is covered by the DBE. The earthquake resulting from application of the RFS 2001-01 shows an overshoot above 8 Hz. The analyses performed during the preparations for VD3 show that there is no impact on all the buildings and equipment.

Dampierre	CPY	VD2	RFS I-2-C	The DBE encompasses the earthquake selected by RFS I-2-C. In the preparations for VD3, the DBE was compared with the earthquakes resulting from RFS 2001-01. For the nuclear island, the overshoots above 10 Hz are considered to have no impact. For the site structures, the overshoots above 2 Hz were the subject of verifications. They have no impact on the site buildings and structures. These overshoots are linked to the adoption in the new rule of the minimum fixed earthquake, given the low level of local seismicity.
Gravelines	CPY	VD2	RFS I-2-C	The earthquake resulting from RFS I.2.C was justified at the time of VD2. During the preparations for VD3, the earthquake resulting from RFS 2001-01 was verified. The new reference earthquake entailed an overshoot for the nuclear island beyond 5 Hz, considered to have no impact. The implementation of reinforcements and minor changes to the site structures and equipment has been completed at Gravelines 1 and will be carried out during the ten-yearly outages on the other reactors (end of works in 2017).
Saint Laurent	CPY	VD2	RFS I-2-C	The nuclear island DBE encompasses the earthquake resulting from RFS I.2.c and 2001-01. The earthquake for the site structures is covered by the earthquake resulting from RFS I-2-c and entails slight overshoots beyond 7 Hz, for the earthquake resulting from RFS 2001-01. The absence of impact on the site structures and equipment was confirmed.
Tricastin 1-2	CPY	VD3	RFS 2001-01	For the design of Tricastin, two reference earthquakes were used: EDF 0.2 g and DSN 0.3 g, both of which encompass the earthquakes resulting from the application of RFS I-2-C and 2001-01.
Tricastin 3-4	CPY	VD2	RFS I-2-C	For the design of Tricastin, two reference earthquakes were used: an EDF spectrum normalized to 0.2 g and a spectrum with more high frequencies normalized to 0.3 g to take account of the specific characteristics of the site. These earthquakes encompass those resulting from application of RFS I-2-C and 2001-01.
Chooz	N4	VD1	RFS 2001-01	The earthquake resulting from RFS 2001-01 is covered by the DBE.
Flamanville 1-2	P4	VD2	RFS 2001-01	The DBE encompasses the earthquakes resulting from RFS I-2-C and 2001-01.
Paluel	P4	VD2	RFS 2001-01	The DBE encompasses the earthquake resulting from the application of RFS 2001-01 up to 25 Hz. The slight overshoot above 25 Hz has no impact.
Saint Alban	P4	VD2	RFS 2001-01	The DBE encompasses the earthquakes resulting from RFS I-2-C and 2001-01.

Belleville	P'4	VD2	RFS 2001-01	For the standard design, the DBE encompasses the earthquake resulting from RFS 2001-01. For the civil engineering reinforcements bars on the nuclear island and the site structures, the NRC 0.1 g spectrum entails slight overshoots beyond 4.5 Hz. Studies have confirmed that these overshoots are covered by the structural design margins.
Cattenom 1-2-3	P'4	VD2	RFS 2001-01	The DBE encompasses the earthquakes resulting from RFS I-2-C and 2001-01.
Cattenom 4	P'4	VD1	RFS I-2-C	The DBE encompasses the earthquakes resulting from RFS I-2-C and 2001-01.
Golfech	P'4	VD1	RFS I-2-C	The DBE encompasses the earthquakes resulting from RFS I-2-C and 2001-01.
Nogent	P'4	VD2	RFS 2001-01	The DBE encompasses the earthquakes resulting from RFS I-2-C and 2001-01.
Penly	P'4	VD1	RFS I-2-C	The DBE encompasses the earthquakes resulting from RFS I-2-C and 2001-01.
Civaux	N4	Before VD1	RFS I-2-C	Civaux was initially designed on the basis of RFS I-2-C. During the preparations for VD1, the facility underwent a seismic check resulting from RFS 2001-01. DBE overshoots beyond 5.5 Hz were brought to light. The licensee conducted studies to show that there was no significant impact on the buildings and equipment of the nuclear island and site structures, other than the BAS/BL equipment. Additional studies are in progress, as part of the preparations for the ten-yearly outage, to check the seismic qualification of the BAS/BL equipment.

* For Fessenheim, the need for seismic reinforcement is not linked to a reassessment of the hazard, but to the implementation of new parasismic calculation methods performed during the periodic safety reviews (see § 2.1.2).

** The Cruas site has the particularity of being built on a basemat resting on parasismic supports, which considerably reduces the seismic loadings applied to the structures and equipment of the nuclear island, lowering the frequency of the island between 1 and 1.5 Hz.

It can be seen that the main DBE overshoots are, pursuant to RFS 2001-01, due to:

- the use of a fixed minimum earthquake defined conventionally for zones with very low seismicity (Dampierre, Belleville, Saint Laurent),
- a reassessment in the high frequencies of the regulation earthquakes, frequencies which generally have little impact on the design of buildings and structures, as they are beyond their frequency of interest.

ASN considers that these are overshoots for which the implementation of changes and reinforcements enables the margins to be restored (the goal of a reassessment being in particular to define the changes to be implemented for conformity with reassessed requirements). In addition, when the applicable baseline safety requirement is not yet the RFS 2001-01, EDF has already carried out studies in preparation for the forthcoming ten-yearly outage inspections using this baseline, in order to define and implement the necessary reinforcements or changes.

The DBE margins for the nuclear island and the site structures are not identical, in that the site structures were designed on the basis of earthquakes normalized on local seismic characteristics.

The robustness of the civil engineering structures participating in prevention of the loss of the heat sink (in particular the pumping station and networks) or electrical power supplies (in particular the

electrical and diesel buildings) shall be analysed by EDF in the study that ASN will ask it to conduct on the incorporation of long-term H1 or H3 site situations (see § 5).

It is important to note that updating of the site SSE is simply one part of the periodic safety reviews concerning seismic aspects. The development of computing methods and resources utilized by paraseismic engineering has helped fine-tune the evaluation of the seismic strength of buildings and equipment. Reinforcements can thus be decided, not solely on the basis of a reassessment of the hazard, which constitutes input data for the design of structures and equipment, but also on the basis of changes to paraseismic engineering. Thus, the seismic modifications implemented during the VD3 at Fessenheim, are not due to a reassessment of the seismic hazard, but to the use of new computing methods.

Seismic operating experience feedback (nuclear and non-nuclear) and construction robustness design studies are also sources for the evaluation of seismic conformity.

In addition to the initial seismic design of the facility, ASN made specific requests on the occasion of the second and third ten-yearly outage reactor inspections, to take account of changes to the baselines and to available scientific data in the field of the hazard and the paraseismic justification.

ASN considers that the seismic reassessments conducted since the design of the units, based on reassessed hazards and changes to paraseismic justification methods, were performed satisfactorily.

ASN noted the conformity of the reactors with this baseline, subject to the implementation of identified reinforcements and changes, scheduled for the ten-yearly outages.

2.1.2 Steps designed to protect the facilities from the earthquake for which they are designed

Identification of systems, structures and components (SSCs) for which availability is required subsequent to an earthquake

The plant shall be designed so that it can be restored to and kept in safe shutdown conditions after an earthquake corresponding to the SSE.

The licensee shall demonstrate that it meets the three safety objectives:

- controlled reactivity (including the safe shutdown function),
- residual heat removal,
- containment of radioactive materials.

These objectives are the responsibility of equipment, systems and structures to which behaviour requirements are attributed (integrity, functional capability, operability).

- integrity: applies to pressure vessels playing a safety role; it aims to maintain the containment capacity.
- functional capability: aims to maintain the function of a system for a mission duration defined in the safety analysis report.
- operability: aims to ensure correct working of the mobile parts and mechanisms, for performance of the safety functions of this equipment and the nominal working of actuators and control systems.

During the design process, the equipment, systems or structures necessary for the safety demonstration are classified on a list of elements important for safety. Depending on its safety role, this equipment is placed in a safety class which comprises seismic classification requirements defined by the regulations or by the RFS (RFS IV.1.a of 21st December 1984 concerning the classification of certain mechanical equipment, RFS IV.1.b concerning the design and classification of safety-class electrical equipment, etc.).

These elements are designed to perform their functions in all plant operating situations (normal, transient, incident and accident). The behaviour requirements are determined by the role to be played by the equipment, systems or structures in the various operating situations.

The seismic classification requires justification either by calculation, or by testing on a vibrating table, or through analysis on a case by case basis.

The resulting design requirements are proportional to their safety class. For the main primary system, they are defined by the order of 26th February 1974⁷ and for the main secondary system by RFS II.3.8⁸, for all the reactors in service. For level 2 and 3 mechanical equipment, the design requirements and criteria are defined by RFS IV.2.a of 21st December 1984 concerning the requirements to be taken into account in the design of safety-classified mechanical equipment, carrying or containing a pressurized fluid and classified level 2 or 3.

For electrical equipment, the requirements are defined in RFS IV.1.b of 31st July 1985 concerning the design and classification of safety-classified electrical equipment.

RFS V.2.g⁹ defines the acceptable methods for determining all the movements to which the "seismic classified" civil engineering and structures are subjected, on the basis of the seismic motion considered, as well as the corresponding load levels, to allow the design and verification:

- of the civil engineering strength of these structures subjected to the loads resulting from earthquakes and other actions combined with the earthquakes,
- of the correct behaviour and performance of the equipment in the facility.

Following the adoption of the new RFS 2001-01 concerning the determination of the seismic motion for surface basic nuclear installations, in place of RFS I.2.c dating from 1981, RFS V.2.g was revised to take account of changes to parasismic engineering know-how (for example, the development of dynamic analyses on detailed 3-dimensional models, the improved knowledge of soil behaviour and soil/structure interactions, the development of time-based calculations on advanced models, the incorporation of non-linear phenomena, whether of geometrical or rheological origin) and to ensure consistency with RFS 2001-01. These requirements are included in ASN guide 2-0110.

For example, the seismic changes implemented on the occasion of the Fessenheim VD 3, are not due to a reassessment of the seismic hazard, but to the use of new computation methods.

In its CSAs reports, EDF recalls that it sets seismic classification requirements for:

- IPS (important for safety) equipment (defined in the design) and certain non-IPS equipment, on a case by case basis,
- the PAM (post-accident monitoring) measures,
- certain equipment required for safety sectorisation,
- equipment adjacent to a seismic classified system and needed to ensure the isolation between a seismic-classified part and a non-seismic-classified part,
- equipment containing radioactive materials which, in the event of a leak, could lead to significant releases.

Equipment which, if it fell, could lead to the loss of seismic-classified IPS equipment, is the subject of seismic verification (see § "Protection against the indirect effects of an earthquake").

In the CP0 plant series, about 5,600 equipment items are seismic-classified. In the CPY plant series, about 5,200 equipment items are seismic-classified. In the 1,300 MW plant series, about 8,500 equipment items are seismic-classified. In the N4 plant series, about 9,200 equipment items are seismic-classified.

ASN considers that the implementation of this baseline safety requirement by EDF is satisfactory.

⁷ Order of 26th February 1974 concerning the reactor coolant system (RCS) for pressurised water reactors (PWR)

⁸ RFS II.3.8 of 8th June 1990 concerning the construction and operation of the main secondary system, for all 900 and 1,300 MWe plant series

⁹ RFS V.2.g of 31st December 1985 concerning seismic calculations for civil engineering structures

¹⁰ ASN Guide 2-01 of 26th May 2006 on taking account of the seismic risk in the design of civil engineering structures for basic nuclear installations

Main operating provisions

Operating principle in the event of an earthquake:

In order to be able to rapidly take adequate steps to bring the plant units to the shutdown state felt to be safest for each one, and maintain it in this state, or to continue with operations, RFS I.3.b recommends the installation of seismic instrumentation for pressurised water reactors.

The procedure to be followed then depends on the level of the earthquake in relation to the Half Design Response Spectrum ($\frac{1}{2}$ DRS: spectrum corresponding to an earthquake which should not modify the behaviour of the facility with regard to an SSE occurring subsequently and the spectrum of which is half the DBE).

- if the $\frac{1}{2}$ DRS threshold is not exceeded, each unit can continue to operate provided that a visual inspection is carried out on structures and equipment.
- if the $\frac{1}{2}$ DRS threshold is exceeded, the units must go to the shutdown state considered for each unit to be the safest. The resumption of operation may only be initiated with the approval of ASN.

The operation of this seismic instrumentation was the subject of a series of targeted inspections by ASN in 2011 (see § 1 of this chapter).

During these targeted inspections, ASN on certain sites identified nonconformity of the seismic instrumentation with RFS I.3.b, problems with operator interpretation of the measurements taken by this instrumentation, and a lack of clarity in the reactor shutdown procedures. These deviations can delay reactor shutdown as specified in RFS I.3.b, or could even lead to this decision not being taken. Moreover, the required inspection following the occurrence of the $\frac{1}{2}$ DRS, defined by RFS I.3.b and constituting a prerequisite for restart of the reactors on the site, is not clearly defined. **ASN will require that EDF perform a conformity check on its facilities with respect to RFS 1.3.b.**

Furthermore, even though a degree of training has been dispensed, the exercises triggered by ASN during the inspections showed that on most sites, the operators had problems in analysing the data produced by the seismic instrumentation, which could delay shutdown of the reactors or even lead to this decision not being taken. **ASN will require that EDF define and monitor an operations personnel training programme to enhance their preparation for a possible earthquake.**

ASN will also require that EDF study the advantages and drawbacks of implementing automatic shutdown of its reactors in the event of seismic loading, enabling the reactor to be shutdown to a safe state appropriate to each site, if the seismic level corresponding to a spectrum with half the amplitude of the design response spectrum is exceeded.

Protection against the indirect effects of the earthquake

SSC failure, "event earthquake" approach

In addition to the design-basis earthquake resistance of the IPS equipment necessary in the event of an earthquake, the safety approach was supplemented by an approach called the "event earthquake", the aim of which is to prevent damage to an equipment item necessary in the event of an earthquake by an item or structure not seismic-classified. This approach is being implemented on the occasion of the ten-yearly outage inspections. This only considers direct mechanical damage or direct spraying of mechanical or electromechanical equipment.

The hypotheses adopted by EDF in the approach are as follows:

- equipment that is not designed to withstand an earthquake can fail and thus constitute a potential hazard.
- seismic-classified equipment must not have its function or integrity compromised by failure of an item that is not seismic-classified.

- no simultaneous occurrence of earthquake and the following is postulated:
 - an independent incident or accident condition,
 - an independent internal hazard (for example fire),
 - another independent external hazard.

An examination must be conducted on the possible hazards that non-seismic-classified equipment represents for seismic-classified equipment by:

- considering the potential hazards representing an effective risk for the target;
- checking that none of the equipment items performing safeguard, reactor protection and their support functions is jeopardized.

The list of potential hazards identified in particular includes the structures and items (weighing more than 10 kg) not designed to withstand an earthquake (unfixed loads, handling machinery not tied down, cabinets, fans, civil engineering structures, tanks, large equipment on small piping, equipment running through the premises, false ceilings, piping with a diameter larger than 50 mm, etc.).

The event earthquake approach was extended to the potential damage to the nuclear island buildings by the turbine hall.

When the analysis leads to the need for protection, the measures taken can involve:

- relocating the target or the hazard source,
- installing reinforcements to ensure the hazard's ability to withstand the earthquake,
- installation of protection on the target,
- justification of the target's ability to withstand the hazard by analysis or by testing,
- modification of the operating conditions of these equipment items.

Implementation of this approach is being requested by ASN on the occasion of the ten-yearly outage inspections (as of the 900 MWe VD2). The approach comprises two parts, one national, which can lead to modifications to a plant series, and one local.

During the course of its inspections, ASN observed the difficulty experienced by the licensee with ensuring optimum integration of this requirement on certain sites on a day-to-day basis, in particular during maintenance operations, construction site operations, the use of scaffolding and the utilisation and conservation of handling resources. **This is why ASN will be requiring that on each site, EDF ensure the effective implementation of the "event earthquake" approach.**

Loss of off-site power supplies:

The PWR safety demonstration studies the simultaneous occurrence of a major earthquake and the loss of off-site power supplies, insofar as they are not designed to withstand a major earthquake.

At the same time, EDF introduced the "LOOP combination" which simulates the consequences of an earthquake during an accident transient. The safety case thus gives the combination of incidents and accidents with a LOOP: these transients are only managed by means of seismic-classified equipment.

The total loss of electrical power supplies (situation H3) to a single unit on the site is included in the baseline safety requirements. It is the result of the loss of off-site power supplies associated with the impossibility of restoring the switchboards backed up by the back-up generators in each unit. These backup sources comprise autonomous and functionally independent diesel generators. In the event of the failure of these unit diesel generators to start or connect, it is possible to connect a site emergency generator or a diesel generator belonging to a neighbouring unit.

There is only one emergency generator per site, which is not designed to withstand an earthquake. In the event of a common mode affecting all site backup diesels, only one of the site units could be backed up. In the event of an earthquake, the availability of this emergency generator cannot be guaranteed. ASN sees this as a weak point in the ability of the facilities to deal with an on-site H3 situation, in particular if resulting from an earthquake. ASN duly notes the measures envisaged by EDF to improve the robustness of its facilities vis-à-vis these situations, which in particular consist in ensuring the earthquake robustness of the additional measures defined for the on-site H3 situation. These aspects are also described further in § 5.

ASN considers that the reinforcement objectives proposed by EDF are satisfactory. ASN will thus require that EDF increase the life of its batteries and supplement the electrical backup by emergency diesels, allocated to each reactor, which will have to be a part of the hard-core (see § 8) and will therefore have to withstand significantly higher seismic levels than the DBE.

Conditions for access to the site following an earthquake:

In the event of major disruption to roads and structures, the emergency response organisation calls on the public authorities who, in addition to triggering the off-site emergency plan (PPI) if necessary, take special measures. These measures allow on-call personnel to be brought in.

The plant safeguard systems requiring external supplies (fuel, oil, etc.) have an autonomy of several days, varying according to the systems and described in the safety analysis report.

ASN observes that EDF has not demonstrated site autonomy for a period of fifteen days (time considered by EDF for restoration of the off-site power supply) in all circumstances, in particular following an earthquake or flooding leading to the site being isolated (these aspects are detailed in § 5 of this chapter).

ASN will require that EDF secure its on-site stocks of fuel and oil and ensure that they can be replenished in all circumstances, to guarantee an autonomy of at least 15 days.

Earthquake-induced fire risk:

The buildings consist of sectors to prevent the propagation of a fire. These sectors comprise a seismic strength requirement.

The buildings and premises housing IPS equipment are subject to general equipment installation requirements to prevent the loss of the safety function in the event of a fire (in particular, redundant systems must not be installed in the same sectors, cables must be geographically separated whenever possible, and so on).

Fire-fighting systems are subject to seismic strength requirements and they are separated from non-seismic-classified parts by seismic-classified isolating devices.

However:

- the sectoring, fire detection and fixed extinguishing systems are designed to withstand to half of the DBE for the 900 MW and 1,300 MW plant series;
- operating experience feedback mentions outbreaks of fire in normal operating situations on IPS equipment;
- fire detection and fixed extinguishing systems are not electrically backed-up by seismic qualified equipment;
- seismic qualification of fire detection only applies to equipment installed within the context of the study of the reference accidents in the safety analysis report.

ASN will require EDF to reinforce the fire sectoring, fire detection and fixed extinguishing systems so that they can withstand a SSE, and electrically back up the detection and control systems of fire protection system with seismic-qualified equipment.

Earthquake-induced explosion risk:

Application of the SSE design requirement to the hydrogen systems and inclusion of the "event earthquake" approach for lines carrying hydrogen in the nuclear island, is in progress on the N4 plant series, and is scheduled:

- between 2009 and 2019 for the 900 MWe reactors,
- between 2015 and 2023 for the reactors of the 1,300 MWe plant series.

ASN will ask EDF to speed up application of the SSE design requirement to hydrogen systems and the implementation of the "event earthquake" approach for lines carrying hydrogen.

The hydrogen presence detectors and the shut-off valves situated outside the reactor building are not covered by seismic strength requirements. **ASN will be asking EDF to guarantee the ability of this equipment to withstand a SSE and to supplement the forthcoming safety requirements.**

ASN considers that management of the explosion risk, for these lines, also entails correct application of a maintenance programme and ensuring that there are no nonconformities.

2.1.3 Conformity of facilities with existing safety requirements

The conformity of nuclear facilities with the safety requirements that are applicable to them is a key component of their safety and their robustness to accident initiators or hazards. For ASN, this conformity must be continuously managed and be based on a systematic search for possible nonconformities, which must be dealt with in a way commensurate with the safety stakes. The detection, notification and processing of nonconformities are now the subject of ASN requirements defined in the order of 10th August 1984¹¹ and in the general operating rules for nuclear power plants which, for example, specify the time within which the reactors must be shut down according to the importance of the nonconformity. These nonconformities may be the result of errors in the initial design, the construction, modifications made during the course of operation or during maintenance operations, but also following reassessments of the safety requirements stipulated by ASN during the periodic safety reviews. They may for example concern equipment whose ability to resist an earthquake to be withstood by the facilities is not guaranteed.

EDF's general organisation for guaranteeing conformity

The review of the seismic conformity of the equipment, conducted by the licensee and checked by ASN, comprises a number of complementary parts:

- the detection of nonconformities, particularly concerning maintenance and scheduled periodic tests,
- examination of unit conformity (ECOT) and the complementary investigation programme (PIC), performed as part of the periodic safety reviews,
- incorporation of international operating experience feedback,
- performance of specific studies or inspections dedicated to evaluating the seismic robustness of the facilities (robustness diagnosis, implementation of the Seismic Margin Evaluation-SMA method, etc.).

The basis of this examination is the updated safety requirements, both for the hazard and for justification of the seismic strength of equipment and structures.

The conformity evaluation of the equipment and structures is an opportunity for a regular review, based on specific checks and studies, of the adequacy of their initial design. ASN considers this organisation to be pertinent.

Processing of seismic nonconformities:

Seismic-classified equipment undergoes maintenance in accordance with the maintenance programmes, as do the anchors and supports.

¹¹ Order of 10th August 1984 concerning the quality of design, construction and operation of basic nuclear installations.

The main nonconformities detected during processing concern:

- locking the threaded fasteners of certain valves,
- cracking of electrical relays or their sockets,
- default fixings of certain Printed Circuit Board (PCB),
- sensor qualification faults,
- excess lubricant on the contacts of certain relays,
- strength defects of lines, exchangers, catwalks or access towers.

All these nonconformities are not simultaneously present on all the reactors.

Similarly, two design anomalies are being processed:

- Sufficiency of steam generator auxiliary feedwater system reserves to deal with a loss of off-site power.
- modelling of the physics of hydraulic flows under the reactor vessel dome (which has an impact on the definition of the safe shutdown times of the reactor when facing loss of power supply).

These nonconformities are the subject of significant event notifications and are being processed accordingly with ASN oversight.

Conformity examinations on the occasion of the ten-yearly periodic safety reviews:

The periodic safety review conducted by EDF is an opportunity on the one hand to carry out a detailed examination of the situation of the facility, in order to check that it in fact complies with all the rules applicable to it (conformity review) and, on the other, to improve its safety level (safety reassessment) in particular by comparing the applicable requirements with those in force for facilities with more recent safety objectives and practices and by taking account of changes to available knowledge and national and international operating experience feedback.

The conformity review consists more precisely in comparing the state of the facility with the safety requirements and the applicable regulations, in particular its authorisation decree and all ASN prescriptions. This conformity review aims to ensure that any evolution of the facility and its operations, due to modifications or to ageing, complies with all the rules applicable to it. This ten-yearly review does not however relieve the licensee of its permanent obligation to guarantee the conformity of its facility.

In addition, the licensee implements a complementary investigation programme to consolidate the hypotheses adopted concerning the absence of damage in certain zones considered not to be susceptible and thus not covered by a preventive maintenance programme. The checks carried out under the complementary investigation programme are spot-checks and differ from one reactor to another, in order to cover all the areas concerned by maintenance.

For the safety reassessment, the conformity of the equipment, structures and components is checked in terms of the compliance of their seismic strength with the reassessed baseline level.

Detection of a seismic strength nonconformity during the ten-yearly outage inspections may lead to a significant event notification, processed accordingly with ASN oversight.

Incorporation of international operating experience feedback:

In its approach, EDF incorporated some of the operating experience feedback from the July 2007 earthquake in the Japanese power plant at Kashiwasaki-Kariwa, especially by defining the scope of seismic inspections it performed and studying the consequences of a transformer fire.

Following the Fukushima accident, EDF conducted an initial series of field reviews on all its sites, which included earthquakes (specific reliability review: WANO SOER 2011-2). A number of observations were made, but none called into question the reliability of the systems.

ASN considers that the process to search for nonconformities during normal operation, maintenance, conformity reviews and safety reassessments, during the complementary investigations (event-earthquake approach, specific seismic inspections, etc.), and on the occasion of the inspections performed following the Fukushima accident, is satisfactory.

The nonconformities identified during the CSAs do not directly compromise the safety of the facilities concerned but they can, in particular if combined, constitute factors such as to weaken the facilities. **ASN will therefore require that EDF reinforce the detection and processing of nonconformities. ASN will in particular propose that the regulatory requirements on this topic be strengthened by means of a draft order setting out general rules for basic nuclear installations, especially with regard to an assessment of the cumulative impact of the various nonconformities present in a facility. These requirements will be reinforced by means of ASN prescriptions.**

Deployment of mobile resources after a DBE

The post-earthquake deployment procedures do not require the use of mobile resources up to the design-basis earthquake. The issue of replenishment of consumables (fuel, oil, etc.) is dealt with in the paragraph on site accessibility after an earthquake.

2.2 Evaluation of safety margins

On the occasion of the complementary safety assessments, ASN asked EDF:

- based on the available information, to give an evaluation of the level of earthquake beyond which the loss of fundamental safety functions or fuel damage (in vessel or pool) was inevitable,
- to identify the weak points and cliff-edge effects, according to the scale of the earthquake
- to propose measures to prevent these cliff-edge effects and reinforce the robustness of the facility.

On the basis of an analysis conducted in a very short period of time, EDF reviewed the seismic strength margins of the structures and equipment important for safety, in order to determine the level of acceleration for which, with a high level of confidence, the facility has a very low probability of failure.

EDF supplemented its general study with studies of equipment for which there could be performance discontinuities, based on an analysis performed in a very short period of time, and proposed modifications or reinforcements as applicable.

Finally, EDF carried out the seismic inspection of a sample of the equipment needed to operate the unit in the event of total loss of off-site and on-site power supplies, whether or not seismic-classified, for all the nuclear power plants in service.

In its overall margin study, EDF identifies three margin sources:

- Margins between the MHPE and the SSE and between the SSE and the DBE.
- The response of the structure
- The design criteria for the structures and equipment.

Seismic loading margin:

EDF states that using a plant series spectrum for all the reactors of the same series as the design response spectrum, is a conservative approach in that this spectrum is broad-band and designed to cover the characteristics of all the sites. In the frequency ranges of the structures, it therefore considers acceleration levels higher than those which would be transferred to the structures in the case of the spectrum of a site SSE.

For each site, EDF proposes a table of margin factors between the reassessed site SSE and the DBE, between 1 and 6 or 10 Hz (because this is the frequency of interest for the structures). It considers it an unnecessary penalty to take account of the rest of the unfiltered seismic signal.

EDF adopts margin values between 1 and 1.7 depending on the sites and the buildings considered.

Margin on the structure response:

EDF mentions an attenuation on the structures of the free-field signal measured, owing to their significant foundation depth, the interaction between the soil and the structures and inertial effects conservatively incorporated into the models.

Margin on the design criteria of structures and equipment:

EDF states that the design of the facilities and their construction are based on codified or standardized methods and that these codes or standards comprise considerable safety margins in that the design rules remain within the linear elastic domains, for a fraction of the elastic domain.

In addition, EDF regularly conducts multipartite design and R&D actions to characterise the behaviour of structures in the post-elastic domains. As part of its ageing projects and the "operating lifetime" project, EDF carries out R&D work on the conformity criteria and the implicit margins usable. EDF has also carried out or taken part in destructive tests on components and structures comprising defects, in order to study the margins and phenomenology of collapse mechanisms.

According to EDF, seismic operating experience feedback (for flexible lines and light cableways) or tests on a vibrating table (equipment or structure mock-ups) or on anchor pull-out, show considerable margins.

EDF focused in particular on the behaviour of:

- large components,
- flat-bottomed tanks,
- pipes,
- supports,
- ventilation ducts,
- relay cabinets and I&C switchboards,
- cableways.

The margin factors identified by EDF are higher than 2, except for the tanks and relay and I&C cabinets (where there is enough strength but not the functionality in the event of an earthquake greater than the design-basis earthquake).

In any case, there is margin in relation to the design-basis earthquake.

Performance of specific studies or inspections dedicated to evaluating the seismic robustness of the facilities:

For the Tricastin site, as a means of assimilating the method, the licensee carried out an SMA (Seismic Margin Assessment).

This method was developed by the American electricity utilities and their safety regulator and aims to study the robustness of the facility to an earthquake larger than the design-basis earthquake.

This evaluation concerning the deterministic study of the strength of equipment, systems and structures necessary for shutdown of the unit to a safe state, considering as standard a small RCS break and a loss of off-site power.

It is performed using hypotheses different from those of the safety case (earthquake larger than design-basis, conformity criteria based on "average" behaviour of the equipment).

This method complements the studies and includes a field cross-check of the actual condition of the equipment, systems and structures necessary for reactor safe shutdown (design, qualification, anchors, foundations, etc.).

This type of inspection also allows identification of the points which, if improved, would reinforce the robustness (construction measures, protection, relocation of equipment and so on).

It is a different but complementary review of the approach for checking the design-basis earthquake conformity of the equipment.

With regard to the Tricastin site, the study showed the robustness of the facility and the conservative nature of the engineering practices used in the construction, which are consistent across all the power plants in service.

Over and above the search for a higher hazard margin, one benefit of this type of study lies in the cross-checking of the real condition of the equipment and the implementation of good practices in addition to the conformity baseline.

Another advantage is that, on the basis of hypotheses, methods and criteria that are different but which are consistent with those adopted at the design, this type of method makes it possible to check that all or part of the safety objective has been met.

When processing a nonconformity on the PTR¹² tanks at Bugey, EDF carried out a CP0 robustness study which was in some ways similar to the SMA approach. Following these studies, anomalies were detected in the design of the anchors, leading to appropriate corrective actions. This confirms the potential benefits of these methods.

ASN considers that using SMA type assessments for verification of the French nuclear power plant reactors, is of very real interest and considers that the development of review methods for equipment, systems and structures, in order to implement the best practices resulting from these assessments or from operating experience feedback should be generalised. ASN will be asking EDF to include this topic in the forthcoming periodic reactor safety reviews.

In addition to the SMA approach, on the occasion of the 1300 MW periodic safety review, EDF proposed an experimental seismic probabilistic safety assessment (EPS) for the Saint Alban site.

This subject is today being investigated and cannot therefore be implemented in the complementary safety assessments.

EDF seismic inspections on equipment necessary for reactor operation in the event of total loss of off-site and on-site power supplies beyond the design-basis earthquake.

EDF carried out a study of the seismic behaviour (guaranteed functionality, satisfactory anchors, absence of interactions with nearby equipment and structures) of the main equipment items not seismic-classified and necessary in this situation.

EDF identified a deficiency on the SER¹³ and PTR tanks, the CRF¹⁴ valves on certain sites, some electrical cabinets and a number of interactions to be considered. In its reports, EDF stated that it will be initiating studies into reinforcing the robustness of these items. Furthermore, some equipment requires special studies and, as applicable, modifications (valves on certain SAR¹⁵ tanks, etc.).

As a result of these inspections, EDF identified the following areas for vigilance and complementary improvement measures for a hazard beyond the design-basis earthquake:

- Electrical equipment: Some equipment is not seismic-qualified or, if so qualified, its functional behaviour beyond the DBE is not guaranteed. EDF will thus be identifying the equipment required to manage loss of heat sink, loss of electrical power, severe accident situations and topping up the spent fuel pools. It will be proposing a programme of action to render them robust.

¹² PTR: reactor cavity and spent fuel pool cooling and treatment system. The PTR acts as a tank for the safety injection system (RIS)

¹³ SER: Conventional island demineralised water distribution system

¹⁴ CRF: Circulating water system

¹⁵ SAR: Instrument compressed air distribution system.

- Seals between buildings: some seals between buildings are filled with materials such as expanded polystyrene, which no longer corresponds to current practice in parasismic engineering. A large part of these materials is removed during the ten-yearly outages. If it is to be retained, an assessment of the impact of interaction between buildings at 1.5 SSE will be performed.
- Venting-filtration system for the containment in the event of a severe accident: this equipment is currently not covered by any seismic resistance requirement. EDF is initiating a complementary analysis to assess the seismic resistance of this equipment.
- EDF will be studying additional measures necessary for unit safe shutdown in the event of a loss of off-site power caused by an earthquake larger than the design-basis (which requires a study of the adequacy of the steam generator backup system water inventory and the speed of connection to the residual heat removal system).
- EDF envisages speeding up the conformity work on the RRI (CCWS) section that is not seismic-qualified.

EDF conclusions concerning the seismic margins

Based on all the margins studied (seismic loading, structural response, design criteria for structures and equipment) and the seismic inspections it carried out, EDF concludes that the seismic capacity of the containment and of the structures and equipment which, in the event of failure, would compromise the safety functions, is 1.5 times greater than the spectrum corresponding to the SSE. EDF considers that this level easily exceeds the seismic context of the sites, up to hazard values that are implausible for these sites.

ASN position statement:

The licensee's assessment did not identify the level of earthquake leading to the gradual loss of the various basic safety functions on the basis of a hazard increasing progressively beyond the DBE.

EDF studied the consequences of an earthquake with a value of 1.5 times the SSE, which it does not consider to be plausible and which enabled it, within the allotted time, to use seismic verification methods according to the industrial state of the art and not requiring any lengthy studies or research.

ASN considers that, within the allotted time, the principle of studying the consequences of an earthquake significantly larger than the design-basis earthquake allows robustness studies to be conducted to identify the weakest points beyond the design-basis earthquake.

ASN considers that EDF's performance of targeted inspections on the seismic behaviour of equipment for a hazard level higher than that used in the design, and EDF's commitment to performing a seismic behaviour review of the equipment necessary in loss of heat sink or loss of electrical power supply situations are sufficient.

ASN considers that the margin review supplemented by inspections, enabled equipment modifications or reinforcements to be defined for an earthquake larger than the facility's design-basis earthquake and beyond the initial design hypotheses.

ASN considers that the modifications and reinforcements identified (strengthening of tanks and anchors, limiting interactions, additional seismic qualification studies, etc.) can be performed rapidly.

ASN considers that these studies complement the periodic review approach for the seismic part, which hitherto did not exceed the design-basis and only concerned the conformity of the equipment and structures as described in the safety case.

However, although ASN does not question the general approach adopted in identifying the various conservative values, ASN does believe that the margin values presented and evaluated on the basis of an analysis performed within a very short period of time, are inadequately justified.

ASN considers that some of the margins proposed by the licensee correspond to provisions used in the design to offer protection against the uncertainty and variability of the seismic hazard, in the same way as the variability of the behaviour of materials or uncertainties linked to modelling or construction. Consequently, ASN considers

that these design provisions cannot be simply compared to margins in the absence of a detailed justification concerning the uncertainties mentioned above. Furthermore, the margin values proposed by the licensee were established according to expert opinions in the light of the deadline for the complementary safety assessments.

While duly noting the conservative nature of the approach beyond the initial or reassessed regulation design-basis earthquake, ASN thus considers that the overall margin evaluation needs to be taken further and in greater detail.

ASN also considers that the identification of the equipment liable to experience behaviour discontinuities, given the time available for the exercise, cannot be exhaustive, particularly for those points that are hard to check or modify (for example: the fuel transfer tube between the reactor building and the fuel building).

ASN will be asking EDF to complete its review of the items liable to experience behaviour discontinuities and initiate the necessary corrective measures as applicable.

2.2.1 Seismic level leading to significant damage of the fuel assemblies

The robustness study performed by EDF for a hazard equivalent to 1.5 SSE identifies no failure of the systems performing fundamental safety functions.

On this point, ASN has no remarks in addition to those made concerning the application of the robustness analysis approach by EDF beyond the design-basis earthquake.

2.2.2 Seismic level leading to a loss of containment

The robustness study performed by EDF for a hazard equivalent to 1.5 SSE identifies no failure of the containment.

On this point, ASN has no additional remarks to those made concerning the application of the robustness analysis approach by EDF beyond the design-basis earthquake.

2.2.3 Seismic level leading to non-design-basis flooding

Combination of a seismic risk and an off-site flooding risk:

In the initial design and following the partial flooding of the Le Blayais plant, EDF's calculations took account of the flood safety margin level which, if exceeded, entails the highest water level on the site.

In its CSAs reports, EDF took account of the topography of each of the sites and identified the water reserves above the site (and thus liable to create flooding in the event of a break) which are not considered robust to a SSE. EDF evaluated the volumes of water that could flood the platform.

The examination performed in principle identifies no risk not already covered by the existing or planned protection measures. Nonetheless, in order to consolidate this assessment, EDF propose complementary studies for certain sites:

- on an earthquake initiating a dam failure, to confirm that the protections for the sites concerned against the flooding created by this dam failure cannot be damaged by the earthquake;
- on an earthquake liable to lead to several dam failures, to confirm that the flood protections for the sites concerned are sufficient.

In the light of the geographical situation of the structures concerned, the feared effect is the arrival of water on the nuclear island platform, exceeding the building access thresholds. The potential consequences of this scenario are presented in the flooding part (§ 3) of this chapter.

For each of its sites, EDF also studied the plausibility of the scenarios leading to cliff-edge effects. EDF examined the consequences of the collapse of all the tanks and pipes leading to spillage of the entirety of their contents. Conservatively, EDF considered the tanks to be filled to their maximum capacity and evaluated the total volume poured onto the nuclear island platform on each site and compared the water level reached with the building access and platform access thresholds. EDF concludes that the off-site flooding risk created by an earthquake exceeding the level for which the facility is designed cannot be ruled out for several sites.

For those sites on which the off-site flooding risk created by an earthquake and exceeding the level for which the facility is designed, cannot be ruled out, EDF proposes a study to determine how real is the water risk on the nuclear island platform. In the light of the results, EDF will determine whether or not additional protection is necessary.

In addition, for the Gravelines site, the retaining walls along the sides of the intake channel need to remain stable in order to guarantee the heat sink flow. This point was evaluated on the occasion of the VD3. ASN however considers that additional studies going beyond the SSE need to be carried out by EDF.

2.2.4 Measures envisaged to reinforce the robustness of the facilities to the seismic risk

With regard to earthquakes, the complementary safety assessments concerned an evaluation of the conformity of the facilities with their safety requirements and a study of their robustness beyond the design-basis earthquake, up to 1.5 SSE.

Beyond the current safety requirements, EDF proposed additional measures to prevent the serious consequences of extreme situations, on a deterministic basis, regardless of their plausibility.

EDF proposed defining a hard core of reinforced equipment such as to prevent severe accidents and avoid significant radioactive releases into the environment, over and above the current safety requirements, for the deterministic situations studied in the complementary safety assessments.

EDF intends to draw up a list of the main hard core items and the robustness requirements to be applied to them, according to the following calendar:

- For the power plants in operation: June 2012
- For the EPR, according to a calendar included in the Flamanville 3 commissioning file review schedule.

ASN considers that the approach proposed by EDF is appropriate and will require that EDF rapidly submit for approval the requirements associated with this hard core (see § 8) which shall include significant fixed margins in relation to the design-basis earthquake.

3 Flooding

Floods are events liable to lead to failures that can impact all the facilities on a site and in particular lead to either a loss of cooling water supply, or a loss of off-site electrical power, or prolonged isolation of the site.

Flooding is a risk that is taken into account in the design of the facilities and reassessed on the occasion of the periodic safety reviews or further to certain exceptional events, such as the partial flooding of the Le Blayais nuclear power plant during the storm on 27th December 1999. This reassessment in particular concerns the maximum water level considered in the design of the site protection structures, called the flood safety margin level (CMS), but also all the phenomena and combinations of phenomena that can be the cause of a flood (high river level, storm, rainfall, rising groundwater level, failures of systems and water retention systems and structures, etc.).

Analysis of EDF's complementary safety assessments (CSA) shows that the complete review of the way this risk is taken into account in the nuclear power plants, completed in 2007, enables the facilities to be given a high level of protection against the risk of flooding. In order to ensure that this high level of protection is actually reached, ASN will require that EDF:

- within the time stipulated following the 2007 "flooding" reassessment, and no later than 2014, complete the protective works and measures for the nuclear power plants;
- improve the volumetric protection¹⁶ of the facilities. The ASN inspections revealed that management of volumetric protection needs to be improved on several of the sites inspected;
- complete the heat sink design review, in particular with regard to prevention of the clogging risks, initiated further to the Cruas incident in 2009;
- reinforce the protection of the facilities against the flood risk over and above the current baseline safety requirements, for example by increasing the volumetric protection. The CSA in fact revealed the existence of cliff-edge effects (total loss of electrical power supplies) for levels close to those adopted in the safety requirements.

Furthermore, following the complementary safety assessments (CSA) of the nuclear facilities, carried out in the wake of the Fukushima accident, ASN considers that nuclear facilities need to be made more robust to highly improbable risks which are not as yet considered in the design of the facilities or following their periodic safety review.

This involves providing these facilities with the means to enable them to deal with:

- a combination of natural phenomena of an exceptional scale and greater than those adopted in the design or during the periodic safety review of the facilities,
- very long duration loss of electricity sources or heat sinks, capable of affecting all the facilities on a given site.

ASN will thus be requiring that the licensees create a "hard core" of reinforced material and organisational measures to guarantee the operational nature of the structures and equipment allowing control of the basic safety functions in these exceptional situations. This subject is covered further in § 8 of this chapter.

¹⁶ In a flood situation, the equipment able to guarantee the safety of the reactors must remain operational. Protective devices are thus implemented, whenever necessary, to offer protection against the various unforeseen circumstances that could lead to flooding. This protection is based on several lines of defence (embankments, walls, water drainage networks, etc.), including volumetric protection. Volumetric protection, which encompasses the buildings containing equipment able to guarantee reactor safety, was defined by EDF in such a way as to guarantee that an arrival of water from outside this perimeter does not lead to flooding of the premises inside it. In concrete terms, volumetric protection comprises walls, ceilings and floors. Protection of the existing openings in these walls (doors and others) can constitute possible routes for water entrance in the event of a flood.

3.1 Design of the facilities

3.1.1 Floods for which the facilities are designed

In its specifications, ASN asked EDF to give:

- the characteristics of the flood for which the facility is designed (in particular the water level considered), their justification, as well as the values of these parameters taken into account for the facility's initial authorisation decree;
- the methodology selected for evaluating the characteristics of the flood for which the facility is designed (return period, past events considered, their location and the reasons for this choice, the margins added, etc.); flooding sources considered (tsunami, tide, storm, dam burst, etc.); validity of historical data.

ASN also asked the licensee to state its position regarding whether the facility flood level design is adequate.

For the design of the flood protections, the sites use basic safety rule RFS I.2.e of 12th April 1984 ("Consideration of the off-site flood risk"). This text in particular defines a method for determining the water levels to be considered when designing the facilities. This method is based on the definition of the flood safety margin level (CMS) and differentiates between three cases:

1. For coastal sites, the CMS corresponds to the combination of the maximum calculated tide (coefficient 120) and the thousand year storm surge.
2. For river sites, the CMS (or CBMS) is the highest of the following two levels:
 - a. Level reached by a river whose discharge is obtained by increasing the thousand year flood level by 15%;
 - b. Level reached by a combination of the highest known flood waves, or the hundred-year flood level if higher, and collapse of the most prejudicial retaining structure.
3. For estuary sites, the CMS is the highest of the following three levels:
 - a. Level reached by a combination of the thousand year river flood level and the tide of coefficient 120;
 - b. Level reached by the combination defined in 2.b and a tide of coefficient 70;
 - c. Level reached by the combination of the thousand-year marine surge and the tide of coefficient 120.

Following the partial flooding of the Le Blayais nuclear power plant in December 1999, EDF updated its CMS evaluation of all the sites and systematically took account of other hazards liable to cause flooding:

1. For all the sites:
 - The deterioration of a water storage structure (pipeline, air cooling tower ponds, water storage ponds, etc.) close to the site, for which the waterline is higher than the platform of this site;
 - The intumescence¹⁷;
 - High intensity rainfall (hundred-year return period) and regular and continuous rainfall (maximum hundred-year averages over 24 hours);
 - A rise in the ground water level;
 - Failure of a system or equipment item.
2. For river sites:
 - Influence of the wind on the river or the chop (determined for a hundred-year wind).
3. For coastal sites
 - Wave swell

¹⁷ Free surface deformation wave caused by a sudden variation in the speed of (discharge) flow. Phenomenon comparable to fluid "hammers" in a pipe. Known as "positive" intumescence when there is a sudden reduction in speed, and conversely "negative" intumescence when there is a sudden increase in speed. It can be observed at sudden stoppage/startup of the units on a run of river hydroelectric plant, or CRF pumps on a once-through PWR nuclear power plant intake channel.

EDF also took account of certain hazard combinations taking account of the degree of interaction between these phenomena, the order of magnitude of the frequency of occurrence and the potential risks associated with the various hazards or combinations thereof. The following were thus taken into consideration:

1. For river sites:
 - Thousand-year flood and chop;
 - High-intensity rainfall and medium discharge river;
 - Regular and continuous rainfall and hundred-year flood level;
 - Intumescence and various flood situations.

2. For coastal sites
 - The CMS (as defined by RFS I.2.e for coastal sites and recalled previously in this report) and a hundred-year wave swell;
 - High-intensity rainfall and mean tide high water level (coefficient 70);
 - Regular and continuous rainfall and overall hundred-year sea level (including storm surge and tide);
 - Intumescence and various flood situations.

EDF has also taken into account the possible damage to structures (located above the sites or on the platform, such as channel embankments, reservoirs, dams, tanks, etc.) as well as damage to systems or equipment (mainly those associated with the pumping station, the circulating water intake and discharge channel and the CRF¹⁸ system) which could lead to the presence of large volumes of water on the site platforms. For the channel embankments and reservoirs, EDF is studying their behaviour in response to the following hazards: earthquake, airplane crash and off-site hydrocarbon explosion.

This method complementing RFS I.2.e was evaluated by IRSN. After obtaining the opinions of the advisory committees¹⁹ in December 2001 and March 2007, ASN considered this methodology to be on the whole satisfactory.

However, ASN did ask EDF to revise its studies concerning a system or equipment break and to supplement the methodology for characterising the high-intensity rainfall hazard, to ensure that the protection measures for these two hazards are sufficient.

Additionally ASN has submitted specific requests concerning the sites of Belleville and Tricastin:

- The Belleville CMS considered by EDF does not cover the significant influence of the Strickler coefficient²⁰. If the calculation does take account of this influence, then it leads to a higher water level, estimated at 47 cm by EDF. However, EDF did not update the CMM value accordingly. ASN asked EDF to update the Belleville CMM value to take account of the uncertainty surrounding the Strickler coefficient.
- The Tricastin CMS needs to be revised to take account of failure of the Vouglans dam. EDF presented new studies in 2008 giving the water level at the Tricastin site in the event of failure of the Vouglans dam. In its hypotheses, EDF postulated a median water level (in other words reached 50% of the time) in the Vouglans dam at the time of its failure. ASN considers this hypothesis to be insufficiently conservative and asked EDF to take account of a higher water level in the Vouglans dam at the time of its failure in its CMS calculation for the Tricastin site.

¹⁸ CRF: circulating water system

¹⁹ See Introduction of this report

²⁰ Coefficient representative of the roughness of the river bed.

The following table presents the current CMS level with regard to the altimetry of the nuclear island platform:

Current design								
Ref. Level	Current CMS level	Location	Current design hazard	Elevation of the nuclear island platform		Elevation of lowest access threshold for buildings classified important for safety (IPS)		
Blayais	NGFN	5.11		Thousand year storm surge + tide 120	4.50	on 30/06/2011	4.41	With infinite settling
Belleville	NGFO	142.06	At the NI	CMM	141.55	on 30/06/2011 (settling stabilised)	141.73	on 30/06/2011 (settling stabilised)
Bugey	NGFO	197.37		REB	197.00	on 30/06/2011 (<i>no settling of the PF</i>)	196.92	on 30/06/2011, settling stabilised
Cattenom	NGFN	155.61	At the NI	CMM	171.00	on 30/06/2011	170.90	on 30/06/2011
Chinon	NGFO	37.40	At the NI	CMM + failure of val d'Authion dyke	37.20	on 30/06/2011	37.22	With infinite settling
Chooz	NGFN	109.54	At the NI	CMM	114.7	on 30/06/2011	114.65	on 30/06/2011 (settling stabilised)
Civaux	NGFN	75.80	At the NI and the water intake	REB	76.7	on 30/06/2011 (settling stabilised)	76.77	on 30/06/2011 (settling stabilised)
Cruas	NGFO	80.60	Cruas Plain	REB	80.50	on 30/06/2011 (settling stabilised)	80.50	on 30/06/2011 (settling stabilised)
Dampierre	NGFO	125.69		CMM	125.50	on 30/06/2011	125.46	With infinite settling
Fessenheim	NN	206.26 215.89	Alsace Plain GCA	CMM	205.50	on 30/06/2011	205.47	on 30/06/2011, settling stabilised
Flamanville	NGFN	7.79		Thousand year storm surge + tide 120	12.40	on 30/06/2011	-	N/A
Gravelines	NGFN	6.12		Thousand year storm surge + tide 120	5.52	on 30/06/2011 (settling stabilised)	5.51	With infinite settling
Golfech	NGFN	61.38	At the NI	CMM	62.22	on 30/06/2011	62.17	au 30/06/2011
Nogent	NGFN	66.07	At the NI	REB	68.15	on 30/06/2011	68.05	With infinite settling

Paluel	NGFN	7.40		Thousand year storm surge + tide 120	25.30	on 30/06/2011	-	N/A
Penly	NGFN	7.74		Thousand year storm surge + tide 120	12.00	on 30/06/2011	-	N/A
Saint Alban	NGFO	147.46		REB	147.00	on 30/06/2011	147.05	With infinite settling
Saint -Laurent	NGFO	83.47		CMM	83.65	on 30/06/2011	83.58	With infinite settling
Tricastin	NGFO	50.90	Rhone low-water channel ²¹	CMM	52.00	on 30/06/2011	51.85	With infinite settling
		59.56	Donzère Canal					

NGFN: French normal general datum system normal

NGFO: Orthometric datum system

CMS: flood safety margin level

CMM: maximum thousand year flood

REB: dam burst or collapse

GCA: Grand Canal d'Alsace

NI: nuclear island

N/A: not applicable

In parallel, ASN and IRSN launched a revision of RFS I.2.e concerning the inclusion of the flooding risk, taking account of all the work done since the flood at the Le Blayais nuclear power plant. The new guide for BNI protection against the flooding risk will concern the choice of hazards liable to lead to flooding of the site and the methods for characterising them all. This draft guide was the subject of a consultation in June 2010, broadened to include the general public (www.asn.fr). After consideration of the remarks collected, the guide will be submitted to the advisory committees for their opinion. They will be meeting in May 2012. ASN aims to distribute this new guide in 2012.

3.1.2 Measures to protect facilities from the flooding risk, including in the design process

In its CSA specifications, ASN asked EDF to describe the steps taken to protect the facility in the event of a CMS.

ASN in particular asked EDF to identify the structures, systems and components (SSC) which must remain available after a flood to ensure a safe state, including the steps taken to ensure the operation of the pumping station and the measures to guarantee the backup electricity supply.

ASN also asked EDF to identify the main design measures to protect the site against flooding (level of the platform, of the embankment, etc.). In addition, ASN asked EDF to clarify the main operating provisions (including emergency procedures, mobile equipment, etc.) for issuing an alert of an imminent flood and then for mitigating the consequences of the flooding.

²¹ The low-water channel, or ordinary bed designates the space occupied permanently or temporarily by a water course. The flood plain is differentiated from the low-water channel, which is the zone limited by the banks. The flood plain is the space occupied by the water course when in flood.

Material provisions

In its CSA reports, EDF indicates that the elevation of the site platforms was set according to the water height initially calculated. It should be noted that RFS I.2.e was published in 1984 and certain elevations were thus calculated using different methodologies. Since the design of the sites, these heights have thus been re-evaluated to take account of:

- Evolution of the calculation rules (publication of RFS I.2.e for example);
- a broader range of data;
- evolution of available knowledge (modelling techniques for example);
- operating experience feedback from the incident at Le Blayais in 1999.

The following table shows some of the steps taken by EDF to protect the plants against the risk of flooding (flood, dam burst, rainfall, etc.):

	Existing protection
Blayais	Embankments
Belleville	Peripheral embankments
Bugey	Protective embankments and walls
Cattenom	Platform elevation
Chinon	Flood gates (cofferdams)
Chooz	Platform elevation
Civaux	Platform elevation
Cruas	Banks of the Rhone + Northern periphery wall
Dampierre	East and South protection embankments
Fessenheim	GCA Protection bank and embankment
Flamanville	Platform elevation
Gravelines	Intake channel walls and embankments
Golfech	Platform elevation
Nogent	Platform elevation
Paluel	Platform elevation
Penly	Platform elevation
Saint Alban	North and East wall
Saint Laurent	Platform elevation
Tricastin	"Gaffière" stream protections and Donzère canal embankments

In its CSA reports, EDF presents the steps taken to protect the sites against flooding. These steps are based on the approach adopted by all the sites following the partial flooding at Le Blayais ("Le Blayais operating experience feedback" approach). EDF conducted a safety analysis for each site, drawing up a list of systems and equipment necessary to reach and maintain a safe state.

For all of the sites, EDF also took account of all the support systems contributing to their operation (electricity sources, I&C, fluids) and certain air-conditioning or ventilation systems. The CSA reports give the list of these systems and equipment for each of the sites.

EDF has differentiated between two equipment categories: those of the nuclear island and those of the pumping station. In order to reach a conclusion on the absence of water in the premises housing the equipment to be protected in the event of flooding, EDF has adopted a two-step approach:

1. EDF compares the water height liable to be reached at the various possible water inlet points (or by-pass);
2. EDF mentions the material and operating measures aimed at protecting the facility against the flood level for which it is designed.

The material provisions concern the following fields:

- civil engineering: construction of protective walls, raising or reinforcement of embankments, installation and repair of seals between buildings, installation of pumping systems, raising of equipment, installation of thresholds, etc.
- mechanical: installation of specific equipment (sluice gates, watertight doors, closures), modification of existing equipment (for example increase in pump capacity or installation of nonreturn valves), and so on.
- electrical and I&C equipment: raising or relocation of the electrical equipment (in particular I&C), installation of automatic systems or shutoffs (for example for the closures), installation of electrical backups for certain equipment, transmission of alarms to the control room, etc.

Subsequent to the evaluation of this "Le Blayais operating experience feedback" approach, and the opinion of the advisory committees in March 2007, ASN considered that the steps planned or already in place on the sites represented significant progress in terms of safety and should provide the power plants with a sufficient level of protection against off-site flooding.

However, certain modifications and tasks defined by the "Le Blayais operating experience feedback" approach have yet to be carried out. These modifications primarily concern work to guarantee the peripheral protection of the Cruas and Tricastin sites in the event of the maximum thousand year flood and dam burst, finalisation of the peripheral protection work on the Saint-Alban site, raising and strengthening of the wave protection at Gravelines, installation of an automatic shutdown controller for the circulating water system (CRF) on certain sites, electrical back-up for the plant sewer system (SEO) pumps on the Gravelines and Le Blayais sites and installation of door threshold sills at the entrance to certain buildings on some of the sites. **To ensure that this work is completed as rapidly as possible, this issue will be the subject of an ASN requirement.**

Furthermore, in order to prevent any entrance of water into a perimeter encompassing the buildings containing equipment required to guarantee reactor safety (equipment necessary for emergency shutdown and maintaining a safe shutdown state in the event of off-site flooding), EDF has set up volumetric protection (VP) on all sites. This perimeter encompasses at least the infrastructures of the premises to be protected (in this case, the perimeter of the VP excludes level +0.00 m); on certain sites, it is extended above level +0.00 m. The choice of the contour takes account of the specificities of each site or the construction constraints. The perimeter of the VP consists of the outer walls of this assembly: walls, floors and ceilings. These walls may comprise openings which could compromise the role of the VP if not watertight (doors, openings, hatches); measures are thus taken accordingly to ensure their watertightness;

Operating measures

In addition to the material provisions, EDF presents its operational measures for each site, aimed at protecting the facility against the flood level for which it was designed. The operating measures comprise:

- alert systems in the event of a foreseeable hazard (failure of a retaining structure upstream of the site, riverside or coastal flooding, possibly combined with extreme winds, rainfall) liable to lead to flooding of the site. These alert systems comprise several surveillance levels: maximum of four phases (watch, vigilance, pre-alert and alert). Depending on the risk to the site, there are not always 4 phases;
- Agreements with organisations within or outside EDF (Météo France, prefecture, etc.) in order to obtain forecasts concerning the above hazards.
- special operating rules in the event of a flood (flood RPCs) which are based on alert systems in order to anticipate the steps to be taken to protect the sites in the event of a flood (during the flood rise and fall phases) as well as to prepare for the possible transition to emergency shutdown state. These RPCs in particular make it possible to anticipate and manage the possible isolation of the site;
- local procedures (in particular clarifying the flood RPCs).

These operating measures are determined according to both the vulnerabilities of the sites and the critical events in the case of flooding, that is isolation of the site, loss of off-site electrical sources, loss of the pumping station and flooding of the site platform.

Given the lack of vulnerability of some sites, EDF concluded that it was not necessary to install an alert system on them.

For those sites concerned by flood RPCs, ASN checked their implementation during targeted inspections between June and October 2011 (see chapter 1); on this occasion, ASN observed that the flood RPCs had not been applied on certain sites (Chooz, Cruas, Nogent, Tricastin, Dampierre, Gravelines)²², even though they radically alter the flooding hypotheses (for example, in Tricastin, the site is now considered potentially subject to isolation and exposed to a LOOP), which is not the case in the current procedures. **ASN will require that EDF adapt the organisation on the Cruas and Tricastin sites to deal with isolation in the event of flooding.**

Finally, in its specifications, ASN asked EDF to clarify whether other effects, either linked to the flood itself or to the phenomena which triggered the flood (such as very poor meteorological conditions) were considered, in particular the loss of off-site electrical power, the loss of the water intake (effect of debris, of hydrocarbon slicks, etc.) and the situation outside the facility, including complete blockage or delay in access to the site by personnel and equipment.

In the CSA reports, EDF states that loss of off-site electrical power (in particular as a result of a storm) and of the water intake (which could result from the massive arrival of clogging material or hydrocarbon slicks) were taken into account. The analysis led EDF to propose additional studies and material and operating measures for certain sites (for example: raising the level of the interconnection center on certain sites).

3.1.3 Conformity of facilities with the current baseline safety requirements

In its specifications, ASN asked EDF to describe the general organisation set up to guarantee conformity (periodic maintenance, inspections, tests, etc.); ASN in particular asked EDF to describe the organisation enabling EDF to ensure that the mobile equipment outside the site, provided for in the emergency procedures, is available and remains in good working conditions. Any anomalies observed, and the consequences of these anomalies in terms of safety, as well as the programming of remedial work or compensatory measures, were to be specified. Finally, ASN asked EDF to submit the conclusions of the specific conformity examinations initiated following the accident in the Fukushima nuclear power plant.

In its CSA reports, EDF states that the flood protection conformity of its facilities is based on:

- periodic surveillance through periodic tests or inspections as part of the preventive maintenance programmes on equipment contributing to protection, identified in the design studies;
- monitoring and management of the VP.

With regard to the periodic inspections carried out on the equipment contributing to flood risk protection, EDF has stated that the monitoring or maintenance programme for certain equipment items was in the process of being deployed on certain sites. The equipment concerned constitutes the lines of defence against off-site flooding.

ASN thus considers that these monitoring and maintenance programmes must be implemented as early as possible, in order to guarantee the availability, integrity and correct operation of the measures adopted in case of flood.

EDF states that the monitoring and protection of the VP, designed to provide a long-term guarantee of its watertightness at all times, is based on the following two checks:

- verification that there is no deterioration of the watertightness of the VP over time: the various components of the VP are subjected to maintenance, as identified in the basic preventive maintenance programmes (PBMP).

²² For Chooz, the notification of modification pursuant to article 26 of decree 2007-1557 of 02/11/2007 was filed by EDF and is currently being examined by ASN. For Nogent and Tricastin, the process is ongoing.

- a VP management rule, which must be applied to all the sites, in order to ensure real-time monitoring of VP tightness breaks, both planned and unforeseen.

During the targeted inspections conducted in June and October 2011, ASN observed numerous anomalies regarding the monitoring, maintenance and perimeter of the volumetric protection. For example:

- the conformity work decided on subsequent to the Le Blayais operating experience feedback, which was to have been completed in 2007, is not finished on all the sites;
- some sites notified discrepancies observed between the VP perimeter identified in the EDF national level report and the actual situation on the site;
- some sites notified the fact that it was impossible to test the "waterstop"²³ seals, which are a key part of the VP . For example, the Cattenom site declared a significant safety-related event (ESS) regarding flooding of the fuel oil tank room, partly owing to a loss of tightness of the "waterstop" seals;
- the identification of equipment and structures at the VP limits is absent on some sites;
- the day-to-day management and monitoring of the VP are not always carried out correctly, sometimes even not at all.

Following the submission of the CSA reports, EDF has made the following commitment: *"The VP conformity remediation work will be completed on all the NPPs before the end of 2011.*

With regard to the operational monitoring of the volumetric protection components, EDF confirms that the national VP management requirements will be effectively applied on all sites by the end of March 2012.

The problem of the WATERSTOP seals observed at Cattenom has already been dealt with by a conformity remediation action. The maintenance programme for these seals will be reviewed on the basis of this experience feedback.

EDF has also conducted an initial analysis of the feedback from the inspections on the Flooding topic. Based on this initial analysis, EDF considers that the nature of the findings is not such as to compromise the safety of the units concerned.

By the end of March 2012, EDF will carry out an overall analysis of the findings of the "Post-Fukushima" inspections or the points raised by the NPPs regarding volumetric protection. EDF will then present:

- *the reactive measures already taken by the NPPs,*
- *the strategy for dealing with findings of a generic nature,*
- *the solutions provided to the requests for extension of the current volumetric protection perimeter."*

ASN considers that the measures proposed by EDF are satisfactory.

Given that VP plays a key role in protecting the plants against the off-site flooding risk and that the anomalies observed are such as to compromise certain conclusions of the CSAs, ASN will be requiring that EDF implement rapid conformity remediation work.

In particular, with regard to the waterstop seals, EDF considers that these cannot be subjected to watertightness testing. EDF therefore presented a strategy consisting in examining the stresses and displacement generated by differential settling of the buildings, for all the seals. Where the design of the seals does not enable them to deal with the corresponding displacements and stresses, EDF installed additional tightness strips on the inner wall side. ASN considers that EDF did not take account of seal ageing in its approach. **Monitoring of the "waterstop" seals is a key factor in ensuring the effectiveness of the volumetric protection, so ASN will be asking EDF to demonstrate the effectiveness of its strategy and draw up a list of the sites for which an additional system needs to be deployed.**

EDF has also initiated a specific reliability review in accordance with the conclusions of the 2001-2 SOER report (*Significant Operating Experience Report*) issued by WANO (*World Association of Nuclear Operators*). ASN noted that when the licensee identified particular findings, it presented corrective measures. ASN considers that these corrective measures are satisfactory; however, EDF needs to set a deadline for each one.

²³ Tightness of the expansion joints in the concrete walls (water stop strip)

3.2 Evaluation of safety margins

3.2.1 Estimation of margins in the event of flooding

In its specifications, ASN asked EDF to state the flood level the facility could withstand without damage to the fuel (in the reactor vessel or in the pool) and the levels leading to the initiation of accident situation measures. EDF was able to call on the available information (and take account of the studies to confirm the engineer's assessment).

In its CSA reports, for the various hazards considered for each site, EDF presented the margins - when available - between the flood level reached and the level of the protections, for the purposes of the current design and reached a conclusion regarding any additional measures to be taken. These tables offer a satisfactory response to the ASN request.

EDF also studied a number of situations which it feels are representative when evaluating cliff-edge effects. These cases are summarised below and assume hypotheses going beyond the design-basis, contrary to what was presented hitherto in this part of the report devoted to flooding.

In its CSA reports, EDF analysed three types of cliff-edge effects that could be triggered by a flood:

1. Flood causing the loss of site heat-sink (situation H1), initiated by a rise in the water levels leading in turn to loss of the circulating water filtration system (CFI) then submersion of the essential service water system (SEC) pumps. For certain sites, the loss of the SEC pumps occurs before the loss of the filtration system. In its CSA reports, EDF states that:
 - the loss of the filtration system on the sites equipped with rotating drum screens would imply long-term unavailability of certain devices on the filtration system, although without leading to a certain loss of the function,
 - the loss of the chain screen drive motors could lead to long-term unavailability of filtration. In this case, the risk of an H1 situation through clogging cannot be ruled out. For the Fessenheim plant, the pumping station is situated at a higher altitude than the site platform, so the essential service water system can function by gravity in the event of flooding.
2. Flood causing a LOOP (loss of off-site power) situation resulting from a loss of equipment through submersion initiated by at least one of the following events:
 - Loss of all the off-site power substations (HV line outgoing feeders) through equipment submersion. This scenario can directly affect an entire site (except if special corrective measures are taken).
 - Loss of transformers supplying the safety auxiliaries from the off-site grid, these transformers being located inside the site:
 - directly at the output from the generation unit (TP main transformers and TS step-down transformers),
 - TA auxiliary transformers (supply circuit separate from that of the TP and the TS).
3. Flood causing total loss of the electricity sources (H3 situation) associated with the possible loss of the reactor backup systems, this type of effect being initiated by the presence of a layer of water on the nuclear island platform.

With regard to flooding caused by an earthquake bigger than design-basis, EDF identified critical cliff-edge effects owing to the positioning of the structure concerned, which are liable to constitute potential sources of flooding following an earthquake of intensity higher than the SSE. Depending on the sites, these cliff-edge effects are the arrival of a layer of water on the nuclear island platform exceeding the building access thresholds, which would lead to an H3 situation, or the arrival of a layer of water causing submersion of the auxiliary transformers, which would lead to a LOOP type situation.

In its CSA reports, in order to evaluate the robustness of the facility to cliff-edge effects, EDF:

- identified the cliff-edge effects caused by off-site flooding and calculated the corresponding water levels;
- conducted "beyond design-basis" vulnerability analyses, by increasing certain current design scenarios by a fixed amount;
- compared the water levels reached for each of the increased scenarios with the water levels leading to cliff-edge effects;
- proposed studies to confirm the existence of the cliff-edge effect or the steps to be taken to reinforce the robustness to such a cliff-edge effect.

Scenarios adopted

EDF considered the following scenarios, according to the geographical situation of the site:

1. For all the sites:

<p>Maximum high-intensity rainfall (PFI): PFI rainfall intensity used in the design, doubled</p>	<p>ASN considers that a factor of 2 corresponds to a correct order of magnitude for reaching a hazard that is significantly more penalising than that of the current safety requirement baseline. However, ASN considers that the duration adopted is in principle not sufficiently penalising, given the saturation of the rainwater networks.</p> <p>ASN considers that EDF's commitment to a vulnerability study for rainfall times longer than the network concentration time is satisfactory.</p>
<p>Combination of a PFI lasting 60 minutes with complete blockage of the site's SEO rainwater drainage network outlets</p>	<p>ASN considers than in the CSAs, this combination can go significantly beyond the rainfall levels currently adopted for the sites. This combination is a means of identifying the flooding levels as of which cliff-edge effects appear and thus meets the requirements of the specifications.</p>
<p>Flooding caused by an earthquake bigger than design-basis: identification of the structures present on or directly above the platform and liable to constitute potential sources of flooding following an earthquake of an intensity greater than the SSE, if the structure or equipment is not considered robust to an earthquake beyond design-basis.</p> <p>During the investigation, EDF made the following commitment:</p> <p><i>"In order to complete the analysis of the flood risk caused by an earthquake "beyond baseline safety standards ", presented in the RECS (complementary safety assessment report), EDF will by the end of 2012 evaluate the risk of damage to the walls surrounding the cooling towers on the four sites concerned, on the basis of:</i></p> <ul style="list-style-type: none"> • <i>the effective distance between wall and cooling tower,</i> • <i>the possibility of justifying the absence of significant damage to the cooling tower shell for earthquakes bigger than the SSE</i> <p><i>If damage of the wall following collapse of the cooling tower under the effect of an earthquake "beyond baseline safety standards" cannot be avoided, the effects in terms of induced flooding will be analysed. As applicable, additional measures will be proposed in order to guarantee protection of the equipment in the "CSA hard core".</i></p>	<p>ASN considers that the study approach proposed by EDF would appear to be satisfactory.</p> <p>ASN considers that the approach adopted by EDF and the undertaking made, provide a satisfactory response to the specifications.</p>

2. For coastal sites, EDF chose a CMS scenario (combination of the maximum level of the astronomical tide and the thousand year storm surge) plus a additional increase of 1 metre (which, according to EDF, corresponds to a storm surge with a return period between one hundred thousand and one million years).

ASN considers that the additional 1 metre adopted by EDF to characterise the marine hazard for coastal sites in the CSAs goes significantly beyond the marine levels currently utilised for these sites and thus meets the requirements of the specifications.

3. For river sites:

<p>Augmented river flood: 30% increase of the CMM rate of flow.</p> <p>Moreover, following submission of the CSA reports and on the occasion of the examination of these reports by IRSN, EDF made the following undertaking:</p> <p><i>"For sites on which the platform is currently considered to be above water level in the case of a maximum river flood scenario, particularly Tricastin and St Alban, EDF will examine (by end 2012) whether any phenomena induced by this type of flood on the behaviour of hydraulic structures are liable to lead to a revision of the levels adopted in the initial evaluations.</i></p> <p><i>The conclusions of this complementary analysis will be taken into account for the protection of the equipment in the "CSA hard core".</i></p> <p><i>For the particular case of the Tricastin NPP mentioned in the IRSN recommendation, EDF underlines the fact that the planned modifications to the Donzère-Mondragon hydraulic facility, to guarantee site protection against the CMM, provides for the creation of a emergency safety device (lateral weir on the right bank) designed to limit the level in the canal, including in the event of a malfunction of the facility's hydraulic systems."</i></p>	<p>ASN considers that the 30% increase on the river flood adopted by EDF in its CSA reports goes significantly beyond the river flood levels currently used for its sites and thus meets the requirements of the specifications.</p> <p>The results given in the CSA reports are however to be considered in the light of significant uncertainties surrounding these initial evaluations. The behaviour of hydraulic structures in the case of the maximum river flood scenarios would need to be examined in greater detail, in particular for the Tricastin and Saint-Alban sites.</p>
<p>Earthquakes initiating dam bursts (including Le Blayais): EDF proposes performing additional studies on an earthquake initiating a dam burst (to confirm that the site protections against the flooding caused by this dam burst cannot be destroyed by the earthquake) and on an earthquake liable to cause several dam bursts (to confirm that the site flood protections are sufficient).</p> <p>During the course of the examination, EDF made the following undertaking:</p> <p><i>"For the purpose of the studies concerning the effects of dam bursts caused by an earthquake "beyond baseline safety standards", mentioned in the RECS, EDF will consider the induced risks to the equipment in the "CSA hard core" by multiple dam bursts situated in the same valley."</i></p>	<p>ASN considers that the approach adopted by EDF and its undertaking provide a satisfactory response to the specifications.</p> <p>ASN will nonetheless be asking EDF to supplement its rainfall scenarios beyond design-basis, extending them to all sites.</p>

4. EDF also studied other augmented scenarios when considering the flooding induced by an earthquake beyond design-basis or specific site characteristics, in particular flooding caused by the loss of integrity of the SEA (demineralisation plant water supply system) circulating water ponds (Flamanville, Penly and Paluel). Concerning the collapse of the SEA ponds on the three sites, EDF considers that the stability of the ponds is guaranteed for an earthquake bigger than the SSE.

ASN considers that this approach is satisfactory, provided that the tightness of these ponds is guaranteed, in particular as EDF considers the SEA pond to be the emergency make-up source.

Water heights resulting from the augmented rainfall scenarios and earthquakes beyond design-basis

EDF calculated the water level resulting from the augmented scenarios, considering the protections implemented on the site for protection against the design-basis hazards, including those for which implementation is planned subsequently (for example 2014 for Cruas and Tricastin).

ASN considers that this approach does not conform to the specifications and that EDF needs to take account of the real status of the facilities as at 30th June 2011.

The consequences of the reference flood augmentation scenarios vary widely. The nuclear island platforms of some sites would remain above water level. For the others, the flooding could reach up to about two metres on the nuclear island platforms. For a certain number of riverside sites, EDF considers that the water height estimates, based on extrapolations from existing studies or models, would need to be consolidated.

The consequences of each of the two rainfall scenarios are on the centimetre scale. Depending on the site, EDF considers that the volumes of water associated with each of the two maximum rainfall scenarios are either contained by the roadways or liable to cause a layer of water a few centimetres high on the nuclear island platforms.

With regard to the flood scenarios induced by an earthquake beyond design-basis, the water levels obtained are of the centimetre or decimetre scale, in certain cases. However, depending on the sites, EDF estimates that:

- either the risk of flooding can be ruled out because the platform on which the failed structure is situated is well below the nuclear island platform,
- or the associated water volumes are contained by the roadways,
- or the associated water volumes are liable to create a layer of water a few centimetres high on the nuclear island platform.

EDF was unable to issue a final statement for all the sites concerning the consequences of this type of hazard in the situations considered. Further studies are still required.

Evaluation of the water heights induced by these three scenarios is based on the principle of calculating the spreading of the volume of rainwater not evacuated by the network. ASN considers that certain hypotheses need to be checked (hydraulic, topographical hypotheses) and that the studies are not sufficiently conservative to cover the dynamic flow effects. Additional data would seem to be necessary to justify the spreading hypotheses as well as the hydraulic hypotheses utilised in the studies, in particular those concerning blockage of the drains²⁴.

For certain sites, EDF considers that the volumes of water induced by these three scenarios will be contained by the roadways of the site platforms. For the others, the water elevation is compared with the building access thresholds. In the event of an H1, LOOP or H3 risk, EDF proposes studying the plausibility of a water layer risk on the nuclear island platforms and, as applicable, the TA/Ts transformers. During the investigation, EDF specified that these studies will retain the water layer spreading hypothesis, but will be able to enable the conservative nature of the current evaluations to be reduced.

However, ASN considers that the uncertainties surrounding the hydraulic and spreading hypotheses adopted by EDF can lead to flood heights in excess of those presented, therefore the margins should not be calculated down to the nearest centimetre.

At the meeting of the advisory committees in November 2011, EDF made the following undertaking, which offers a satisfactory response to the specifications:

"The influential parameters listed (duration of precipitation, absorption and drainage capacity) are considered beyond the baseline safety standards with a view to verifying protection of the "Hard Core" equipment".

In order to initiate the studies announced in the RECS, aimed at providing a more detailed characterisation of the layers of water induced by the "PFIx2", "PFI+SEO blockage", and "flooding induced by an earthquake bigger than design safety standards" scenarios, EDF intends to define and justify the various hypotheses utilised (land absorption capacity, evacuation flows to off-site land, spreading hypotheses, consideration of dynamic effects, consideration of topographical data).

Furthermore, concerning the maximum scenario "PFIx2", a vulnerability study concerning the duration of precipitation greater than the network concentration time will be performed".

²⁴ System primarily designed to collect run-off water and channel it to the sewer network.

With regard to the envelope nature of the scenarios utilised, ASN considers that the approach adopted by EDF clearly aims to define maximum augmented hazards covering all the phenomena which could lead to or contribute to flooding, by examining supplementary scenarios for certain sites.

The analysis presenting cliff-edge effects induced by the flooding risk, supplied by EDF in the CSA reports, complies with the ASN request.

Special case of embankments

Following the meeting of the advisory committees in July 2011, the purpose of which was to examine the methodology proposed by the licensees for performance of the CSAs, ASN asked EDF to examine the consequences of a failure of the embankments along the Grand Canal d'Alsace close to the Fessenheim site, as well as those of the Donzère canal close to the Tricastin site.

Concerning the consequences of a failure of the Donzère-Mondragon canal embankment for Tricastin and the failure of the Grand Canal d'Alsace embankments for Fessenheim, EDF provided an answer which should be considered preliminary owing to the lead-times associated with the CSAs.

With regard to Tricastin, whether the failure is on the left bank or the right bank of the embankments of the Donzère-Mondragon canal, EDF considers that the existing peripheral protections (sluice-gates, watertight screen) would prevent flooding of the NPP platform.

With regard to Fessenheim, the consequences of a failure of the Grand Canal d'Alsace embankments would be the presence of a layer of water on the site, liable to lead to a scenario involving total loss of the off-site and on-site power supplies, as well as the potential loss of other nuclear island equipment.

Whether for Fessenheim or Tricastin, EDF underlines the absence of any precise study data today available for the height of this layer of water. In the RECS, EDF proposes:

- Conducting a detailed examination of the ability of the embankments to withstand a level higher than the SSE and to determine a flood flow to be considered beyond the design-basis,
- In the light of the results, initiating calculation of the corresponding flood fields,
- If necessary, defining and implementing the appropriate material and organisational countermeasures to prevent the critical situations considered in this kind of analysis, namely significant releases into the environment (for the reactor building case), and fuel uncover (for the fuel storage building case).

ASN considers that EDF's undertaking responds in part to its request and that EDF will need to conduct studies giving a precise indication of the water level on the Tricastin site in the event of failure of the Donzère-Mondragon embankments and on the Fessenheim site in the event of failure of the Grand Canal d'Alsace embankments and to evaluate the resulting consequences. ASN will issue a requirement on this subject.

Strength of the Tricastin embankments

The Tricastin Nuclear Power Plant (NPP) is situated alongside the Donzère canal in Mondragon (right bank), to the east of the Rhone river, within the Tricastin nuclear site, which in particular comprises various facilities devoted to the fabrication of nuclear fuel. Cooling of the Tricastin NPP relies on a once-through circuit supplied by the water of the Donzère - Mondragon canal diverted from the Rhone river.

EDF has identified two hazards liable to lead to flooding of the site, following failure of the embankments of this canal: earthquake and CMM.

In the event of an earthquake, the studies performed by EDF prior to the meeting of the advisory committee in March 2007 concluded that the embankments were stable, subject to effective monitoring and maintenance by their owner, the Compagnie Nationale du Rhône (CNR). Following examination of the dossier, IRSN on the whole confirmed the EDF diagnosis and considered that the two phenomena which could compromise the stability of the embankments are liquefaction and internal erosion at the singularity level of the embankment body. Concerning the liquefaction risk, piezometry (water height in the embankments) is an essential parameter;

ASN considers that the current level of embankment monitoring is inadequate and incapable of accurately characterising the piezometry of the canal embankments.

Consequently, ASN considers:

- with regard to the internal erosion risk, EDF will need to identify the local singularities (pipes or buried structures, transition sector between two different types of embankments, etc.) and, as necessary, work will need to be carried out to eliminate the risk of internal erosion in these sectors;
- pending a study on the vulnerability of the section of the right bank of the embankment, EDF will have to conduct a geotechnical²⁵ survey of its component materials and monitor its piezometry;
- given the safety issues associated with the resistance of the embankments of the Donzère-Mondragon structure, EDF must check with the CNR that the monitoring and upkeep of these embankments guarantees the long-term effectiveness of their drainage, along with the absence of any disorders. EDF shall in particular ensure that this monitoring is able to confirm the effectiveness of the piezometric device.

These actions also aim (in addition to covering the behaviour of the embankment in the event of an earthquake) to ensure the ability of the embankment to withstand a maximum thousand year flood (CMM).

In the event of an SSE and the CMM, ASN considers that the Tricastin NPP is not immune to flooding due to failure of the canal embankments

In the event of a CMM, the main issue for protection of the Tricastin NPP against the flooding risk concerns the integrity of the Donzère-Mondragon canal structures and maintaining an acceptable water level in the canal, to avoid stressing the embankments beyond their design loadings. The hydraulic facility was designed on the basis of a project flood (9,900 m³/s) corresponding to a flow rate far lower than the flow rate at present used for protection of the Tricastin NPP (flow rate of 13,700 m³/s).

Thus, in 2006, EDF and the CNR defined a strategy to protect the Tricastin site, consisting of a combination of several material and operational countermeasures within the Donzère-Mondragon facility. They consist in:

- Raising the low points and locally consolidating the embankment on the left bank upstream of the guard dams and bund walls in the Donzère reservoir, opposite the town of Donzère;
- Raising and reinforcing the new navigable channel through the guard dams at the entrance to the canal;
- Installation of a cofferdam rapid removal system on a reservoir dam sluice-gate;
- Extension of the operating setpoint beyond the "project flood";
- Installation of a canal emergency safety device (DSU). This would consist in creating a lateral weir on the right bank of the canal.

ASN considered this strategy to be satisfactory in principle, provided that the work to implement the countermeasures was performed rapidly. However, ASN asked EDF to provide a certain number of complements and justifications in particular regarding the stability of the structures and the embankments.

These data have not yet been provided and the countermeasures implementation work has not yet started; however, an agreement between CNR and EDF was signed and the work is scheduled for completion by late 2014. Pending the performance of this work, ASN considers that protection of the Tricastin NPP cannot be guaranteed in the event of a CMM.

On 27th May 2011, in its opinion on the continued operation of Tricastin reactor n°1 after thirty years of operation, ASN issued a requirement for performance of this work before 31st December 2014.

²⁵ Soil survey: in-situ survey and laboratory study to define all the physical, chemical and mechanical characteristics of the soils in place.

The Fessenheim NPP is located below the right-bank embankment of the Grand Canal d'Alsace (GCA). In the Fessenheim CSA report, EDF recalled that a number of studies had been performed. EDF analyzed four embankment failure modes in these studies, and carried out the following reinforcement work:

- loss of tightness at the seals: protective embankments built around the site (to divert leaks), reinforcement of the site drainage network (to recover any water that percolated through these protective embankments and discharge it downstream) and monitoring of the body of the embankment (to check that there is no saturation, prevent and detect leaks in a normal situation and after an earthquake) with predetermined alert levels allowing appropriate intervention;
- failure by internal erosion: injections into the embankment;
- failure by overtopping²⁶ due to settling caused by an earthquake.

ASN considers that the approach adopted by EDF for studying embankment failure is satisfactory. With regard to the state of the embankment and its general understanding, ASN considers that the permanent monitoring and seismic alert measures are appropriate. Similarly, ASN considers that the preventive work completed improves the stability and watertightness of the potentially fragile areas.

3.2.2 Measures envisaged to reinforce the robustness of the facilities to the flooding risk

Based on the results presented above, ASN asked EDF:

- to state whether additional protection measures can be envisaged or implemented (depending on the time between the alert and the flood);
- to indicate the weak points;
- to specify any cliff-edge effect²⁷;
- to identify the buildings and equipment that would be flooded first;
- to state whether steps could be envisaged to prevent these cliff-edge effects or reinforce the robustness of the facility (design modification, procedural modifications, organisational measures, etc.).

In its CSA reports, EDF envisages various solutions according to the cliff-edge effect identified and the maximum scenario which led to this cliff-edge effect. The following table identifies the various EDF proposals:

	Maximum flood scenario	Maximum rainfall scenarios and structural failure scenarios for an earthquake bigger than design-basis
When a cliff-edge effect linked to an H3 situation is identified	EDF proposes studying a solution to reinforce the protection of the equipment necessary for operation in an H3 situation.	EDF proposes studying the plausibility of a risk of the presence of water on the nuclear island platform. Based on the results, EDF will determine whether additional protections are necessary.
When a cliff-edge effect linked to an H1 situation is identified	For some sites, EDF proposes studying the need for reinforced protection of the pumping station.	EDF identified no measures allowing reinforcement of the robustness of the facilities.
When a LOOP cliff-edge effect is identified	EDF did not propose any measure to reinforce the robustness of the facilities.	EDF proposes studying the plausibility of a risk of the presence of water on the transformer platform. Based on the results, EDF will determine whether additional protections are necessary.

²⁶ Overtopping is the river flowing over the top of the embankment. This generally leads to external erosion and rapidly entails breaching of back-filled structures.

²⁷ Cliff-edge effect: major discontinuity in the scenario, leading to a significant and irreversible worsening of the accident

In its CSA reports, EDF also proposes other measures to reinforce the robustness of the facility:

- a study of the consequences:
 - of a rise in the groundwater level on the structural resistance of the buildings of units 1 and 2 on the Penly site;
 - of a karst²⁸ flood on the lack of buoyancy of the buildings on the Paluel site;
- studies to confirm the ability of the protective embankments to withstand a CBMS+1m under the effect of wave swell;
- studies on the seismic behaviour of the protections in the event of an earthquake initiating dam bursts and studies concerning multiple dam bursts;
- study on the seismic resistance and electrical backup of the SEO lifting²⁹ pumps.

For the Tricastin site, EDF proposes carrying out studies on seismic strength and electrical backup of the SEO rainwater lifting device. ASN considers that the approach proposed is satisfactory.

For three sites (Tricastin, Fessenheim and Bugey), on which the heat sink is at a higher elevation than the site platform, there is a risk of a major leak in the event of rupture of the cooling systems (CRF) for the facilities connected to them. Although in the examination EDF stated that the valves can isolate the system from the heat sink in all circumstances, a study programme was initiated to improve the robustness of these isolation valves up to a level beyond design-basis, yet to be defined. EDF also states that: "*appropriate reinforcement of the door counterweight arms will then be implemented*". EDF concludes that as things currently stand, this point does not compromise the safety of the facilities. However, given the risk of the channel emptying, ASN considers that all the elements (sensors, automation, valves, part upstream of the valves, etc.) preventing the channel draining to the site in the event of a rupture of the cooling system, must be included in the above-mentioned study.

With regard to the consequences of the various scenarios, IRSN indicated that the orders of magnitude of the water levels obtained on the nuclear island platform are of a few centimetres for the maximum rainfall and flooding scenarios induced by an earthquake beyond design-basis, and up to about two metres on the site platforms for the maximum river flood scenarios.

ASN considers that neither the CSA reports, nor the complementary data presented by EDF during the examination clearly describe EDF's strategy with regard to the cliff-edge effects identified and that the solutions envisaged by EDF to reinforce the robustness of the facility are primarily solutions that would be such as to mitigate the accident (strengthening of the equipment necessary for operation in an H1 or H3 situation).

ASN estimates that this approach does not offer a satisfactory response to the requirements and that the prevention of cliff-edge effects needs to be strengthened. For example, ASN considers that sufficient raising of the VP would, in most cases, be able to prevent H1/H3 cliff-edge effects for the maximum rainfall and flooding induced by an earthquake beyond design-basis scenarios. **ASN will require that EDF present the modifications it envisages in order to reinforce the protection of the facilities against the risk of flooding beyond the current baseline safety standards, for example, by raising the volumetric protection, to prevent the occurrence of total loss of heat sink or electrical power supply situations for the maximum rainfall and flooding induced by an earthquake beyond design-basis scenarios.**

In particular on the occasion of the targeted inspections, ASN noted the vulnerability to flooding of the diesel halls on certain sites. For example, on some sites, EDF claims that there are kerbs of about ten centimetres in front of the diesel hall access points. However, on the site, ASN observed that these kerbs are not always present. ASN will be formulating a request on this subject.

Case of embankments on the Tricastin site

EDF states that the seismic resistance of the embankments on the Donzère Mondragon canal are significantly robust beyond the SSE. Given the time available, EDF presented the results of an existing study concerning failure of the embankments along the Donzère-Mondragon canal. According to EDF, the potential

²⁸ Flood from the karst (limestone formation in which water has excavated numerous cavities)

²⁹ Pump transferring fluid from one elevation to a higher one.

consequences are the presence of a layer of water on the site, liable to create an H3 type situation. Among the measures that could be envisaged to reinforce the robustness of the facility, EDF proposes initiating studies defining the steps to be taken as necessary for an earthquake bigger than the SSE.

EDF states that in the event of a CMM scenario plus 30%, the water in the canal would reach a level very close to the top of the embankment. EDF checked that there would be no overtopping of the embankments in this situation. As regards the CMM plus 30% scenario, ASN considers it acceptable for EDF to assume that the embankments would be stable, provided that:

- the material and organisational measures planned to guarantee the protection of the Tricastin site against a CMM are carried out;
- the embankments are well-maintained and the reservations applicable to them have been lifted (including their guaranteed ability to withstand to a CMM), as requested by ASN in 2007 and 2008;
- there is no low point at the top of the embankment below the level reached by the water in this scenario;
- there is no internal or external erosion.

EDF justifies its guarantee of the ability of its embankments to withstand 1.5 times the SSE by the presence in the embankment SSE behaviour studies of choices that EDF qualifies as "conservative margins". However, an analysis of these choices shows that these hypotheses are in fact more realistic than pessimistic. To conclude, ASN considers that all the elements associated with the embankment studies involving the SSE cannot rule out failure of the embankment for earthquakes with a 50% higher spectrum. To obtain a pertinent opinion on the embankments for an earthquake bigger than the SSE, ASN considers that specific studies are needed.

ASN will be requiring that EDF conduct studies on the resistance of the embankment beyond the SSE, taking account of conservative hypotheses.

Concerning the proposal for the Tricastin embankment behaviour studies beyond the SSE, ASN considers that this approach is satisfactory, because it is such as to ensure that there is no cliff-edge effect beyond the SSE. It should be noted on this point that the SSE is not a design-basis case for the embankments. These were not designed and built on a parasismic basis, but their resistance was verified subsequently. There is thus in principle no particular reason for the SSE associated with the Tricastin NPP to constitute any threshold whatsoever for the seismic behaviour of the embankments.

EDF proposed action meeting the ASN requests and which also concerns the resistance of the embankments to the earthquake included in the baseline safety standards. These elements will be examined.

"Concerning the detailed examination of the Tricastin embankments for earthquake levels higher than the SSE, EDF will indeed take account of the elements mentioned by IRSN, that is:

- *the impact of uncertainties concerning the actual composition of the embankments,*
- *the impact of any local singularities in the embankment deterioration mechanisms,*
- *the stability of the guard dams in the event of a significant drop in the canal waterline following a left-bank breach.*

The complementary investigations felt to be necessary (geotechnical survey, improvement of the monitoring system including piezometry of the zones considered to be sensitive) will be initiated subject to prior agreement by the Donzère hydraulic facility concession-holder.

The study sector will also be adapted according to the embankment failure scenarios liable to generate an actual risk of flooding of the platform."

Case of Fessenheim embankments

On the basis of the information in the CSA reports for the Fessenheim NPP, ASN considers that the behaviour of the embankment following an earthquake of a level equal to 1.5 times the SSE, should be acceptable in terms of stability and any leak rates, insofar as the studies have already established satisfactory justification for earthquakes set at 0.2g (far-field quakes) and 0.25g (near-field quakes) and in that preventive work to improve stability and leaktightness has already been carried out in the potentially fragile areas.

With regard to the state of the embankment and its general understanding by EDF, ASN considers that the permanent monitoring and seismic alert systems are satisfactory and appropriate. For seismic levels ranging from 0.2g to 0.5g, ASN considers that the countermeasures in place are sufficient so that the consequences of any damage to the embankment, in terms of leaks, remain acceptable for the facility.

ASN also points out that because of the particular behaviour of this type of facility (a localised breach leads to complete failure of the embankment) and over and above any demonstration by calculation, the robustness of the canal embankments is based both on their guaranteed state (good understanding of these embankments, management of any problems) and on their constant monitoring.

Given the time available, EDF presented the results of an existing study on the failure of the embankments of the Grand Canal d'Alsace. According to this study, the potential consequences are the high water level on the site.

Concerning the embankment failure scenario, regardless of the origin, EDF proposes:

"Initiating a detailed examination of the ability of the embankments to withstand a level higher than the SSE, and determining a flood flow to be considered above the design level (ignoring completely implausible earthquake levels, in order to define the most appropriate countermeasures).

- In the light of these results, initiating calculation of the corresponding flood fields.*
- In the light of these results, defining and implementing appropriate material and organisational countermeasures to prevent the critical situations which are, for this type of analysis [...], significant release into the environment by the reactor and dewatering of the fuel assemblies in the fuel building."*

With regard to the risk of total collapse of the embankment, regardless of the origin, ASN considers the proposal in the CSA report to be satisfactory and notes the clarification made during the examination:

"The material measures to be taken in this context would concern reinforcement of the robustness of the embankments (prevention) and/or reinforcement of the protection of the equipment necessary for management of an H1/H3 situation H1/H3 (mitigation), EDF being unable, as the studies currently stand, to issue a definitive position on the technical solutions to be preferred".

ASN considers that EDF needs to confirm these elements.

4 Other extreme natural phenomena related to flooding

Flooding can be accompanied by other climatic phenomena. This is why, in its resolution of 5th May 2011, ASN asked EDF to conduct an analysis similar to that performed for flooding and earthquakes.

As an example, one could mention the storm which swept across France in December 1999, characterised by both high tide and strong winds, which led to partial flooding of the Le Blayais NPP platform and electrical disruption of the Nogent and Le Blayais sites.

4.1 Design of the facilities

With regard to the extreme meteorological conditions related to flooding (storm, torrential rain, etc.), ASN asked EDF to clarify:

- The events or combinations of events taken into account and the reasons they were (or were not) selected for the design of the facilities;
- The weak points, specifying any cliff-edge effects, as well as an identification of the buildings and equipment that would be affected;
- Whether steps could be envisaged to prevent these cliff-edge effects or reinforce the robustness of the facility (modification of the design, modification of procedures, organisational measures, and so on).

EDF devoted a chapter of the CSA reports on each of its sites to the extreme meteorological conditions related to flooding. In its CSA reports, EDF considered four phenomena:

- the direct effects of wind on the facilities;
- the effects of projectiles generated by extreme winds;
- the effects of hail;
- the effects of lightning.

Equipment design for these extreme climatic phenomena

Wind

The structures were designed in accordance with the latest revision of the Snow and Wind 65 rules available for the construction of each plant series. On the occasion of each periodic safety review, EDF checks that the buildings important for safety (IPS) and the buildings housing IPS systems or equipment were able to withstand winds with characteristics conforming to the updated Snow and Wind rules (1999 and 1984 editions, amended in 2000).

EDF also checked the design of the buildings, in particular in the light of operating experience feedback concerning the storms which swept across France in December 1999 and more recently (Klaus in 2009 and Xynthia in 2010). EDF considers that these storms led to no damage to the nuclear island buildings and the civil engineering structures of the pumping station. The systems and equipment performing the reactor safety functions are chiefly located in these buildings and structures and the effects of wind had no impact on safety.

On the occasion of the latest periodic safety reviews of the 900 MWe and 1300 MWe series, EDF checked the wind-resistance of the equipment classified IPS-NC³⁰ located outside these civil engineering structures. The CSA reports, however, fail to mention this equipment.

Projectiles were also generated by the extreme winds (gravel, antennas, parts of roofs, etc.) during the three storms mentioned above; EDF evaluated their energy at a speed of about 200 km/h. EDF considers that this is

³⁰ Equipment important for safety but not safety-classified, that is: equipment for which a failure is liable to prejudice compliance with the safety objectives (integrity of the pressure envelope of the main primary system, shutting down the reactor and keeping it in a safe state, preventing and mitigating the radiological consequences of accidents), equipment for which correct operation is only necessary in the long-term to achieve these objectives, certain equipment required in the event of a hazard (fire, flooding, etc.). Since the design stage, the IPS-NC class has been extended to include other equipment necessary for the safety demonstration.

insufficient to damage the structures or civil engineering works performing a safety function or housing systems or equipment participating in such a function. Only the IPS equipment situated outside buildings is liable to be damaged by such projectiles. The majority of the equipment important for safety is situated inside the buildings and thus protected from any risk of damage. Moreover, as a general rule, light objects (weighing less than about 2 kilos) or low rigidity items (heat insulation, branches, etc.) are not likely to damage outdoor IPS equipment.

Nonetheless, on the occasion of the latest periodic safety reviews, EDF defined a baseline for safety requirements concerning protection against projectiles generated by extreme winds. This baseline defines heavy and lightweight projectiles considered at all altitudes and in all directions, according to a speed taking account of past events and the regulations. This baseline also defines "targets" to be protected and stipulates a combination of loss of site electrical power supplies with loss of the heat sink. However, EDF did not include the IPS-NC equipment situated outside the civil engineering structures in this baseline, something that ASN has asked EDF to remedy in the next periodic safety reviews.

Hail

In its CSA reports, EDF states that hail was not considered in the design of the units.

Lightning

In its CSA reports, EDF states that the protection of the facilities against lightning is in conformity with the ministerial order of 15th January 2008 (concerning lightning protection of certain classified facilities) abrogated and replaced by the order of 19th July 2011³¹. According to the approach to lightning protection adopted by EDF, the preventive measures and protection systems must ensure that the consequences of a lightning strike on the safety of the facilities are encompassed by those defined in the initial design of the reactors with regard to category 2 incidents (frequency of less than 10^{-2} per reactor and per year).

In accordance with the above-mentioned order, an analysis of the lightning risk was carried out to demonstrate the environmental acceptability of the consequences of a lightning strike, using an approach based on standard NF EN 62305-2 of 2006 ("Lightning protection: risk evaluation"). EDF states that further to this study, preventive measures and protection systems will be defined, with a view to implementation on 1st January 2012. Before this date, the equipment installed in compliance with the prior regulations³² is monitored in accordance with standard NF C 17-100.

Lightning can have direct effects (when the impact is directly on the building's structure) as well as indirect effects (lightning strike in the vicinity of the structure or the building). With regard to direct effects, the buildings and structures of the NPPs comprise at least level II protection as defined in standard IEC 61024 or NFC 17-100. Protection is provided by a mesh cage. Pipes and tanks are by their very nature protected against lightning. With regard to the indirect effects, various measures are implemented by EDF (antennas and piping grounded, measurement cables shielded and connected at one end, etc.).

With regard to the lightning hazard, the EPR is designed in accordance with the "lightning safety baseline applicable to the EPR". Adequate steps are thus taken to ensure that the safety functions of the systems and equipment necessary to bring the unit to a safe state and to prevent and mitigate radioactive releases are not unacceptably affected. The chosen hazard characteristics are those concerning protection level I, as defined by standard NF EN 62 305-1, or NF C 17-100.

Given the lightning protection measures taken, EDF considers that the consequences of a lightning strike on the safety of the facilities are effectively covered by those defined at the initial design of the units with regard to a category 2 incident.

³¹ Order of 19th July 2011 amending the order of 22nd October 2010 concerning the classification and parasismic construction rules applicable to "normal risk" class buildings

³² Article 35 of the order of 31st December 1999 as amended, stipulating the general technical regulations for preventing and mitigating nuisances and external risks arising from the operation of basic nuclear installations
Order of 28th January 1993 concerning lightning protection of certain classified facilities

Snow

With regard to snow, EDF did not feel that there was any need to consider it in the CSA. On this point, other licensees concerned by the ASN decision of 5th May 2011 included snow in the extreme natural phenomena and there are thus disparities between licensees of nearby sites. ASN will be asking EDF to present studies taking snow into account.

Combinations of extreme climatic phenomena

EDF considers that the event combinations considered can generate a risk capable of creating a common mode failure, in other words a risk of the unavailability of functionally redundant equipment or systems. A situation such as this is liable to lead to total loss of the heat sink (situation referred to as H1), or a loss of off-site power supplies (LOOP) on all the units of an NPP. These situations are presented in § 5 of this chapter.

4.2 Evaluation of safety margins

4.2.1 Estimation of margins in extreme meteorological conditions

Wind

EDF considers that the design of the buildings for the off-site explosion risk guarantees their robustness to extreme winds. EDF evaluated the existing margin by comparison with this event. EDF concludes that for all its sites, all the buildings designed for the "off-site explosion" risk are thus robust to extreme winds, with significant margins.

For buildings not covered by the "off-site explosion" design, EDF considers that the loads associated with extreme winds are not liable to have consequences for reactor safety. Concerning the direct effects of wind on the equipment necessary in an H3, H1 or severe accident situation and situated outside the buildings (ASG steam generator auxiliary feedwater system piping and demineralised water distribution tanks for the conventional SER parts), EDF concludes that the loads associated with extreme winds do not compromise their strength.

ASN considers that the profiles of the two situations ("off-site explosion" and "extreme wind") are not the same: there is a single load on the structures from an explosion, whereas gusting wind leads to several loadings. ASN also considers that the wind speed to be included in these studies should be consolidated. EDF simply analyses the behaviour of its facilities and the possible cliff-edge effects for a wind speed value of about 200 km/h. This value is close to that of the amended 1999 Snow and Wind 65 rules (which give speeds varying on the whole between 150 km/h and 200 km/h for the NPPs). ASN then considers that the value used by EDF to study the cliff-edge effects does not go far enough beyond the scenarios used for the design of the facilities. Moreover,

ASN considers that a speed of 200 km/h is one that is rarely observed in metropolitan France but is not the maximum speed recorded within the past thirty years (storm of 16th October 1987: observed wind speeds of 216 km/h).

On the occasion of the examination in preparation for the meeting of the advisory committees in November 2011, EDF made an undertaking to "*transmit a statistical study within 6 months, allowing verification of the limited behaviour of exceptional wind speeds and confirmation of the maximum wind speed to be considered when evaluating any cliff-edge effects. The values adopted for each site will be compared with the maximum speed recorded by Météo France's metropolitan weather stations representative of each site.*"

This undertaking is also a partial response to ASN's request. **ASN considers that EDF needs to conduct studies which also take account of the specific nature of gusting winds and will send EDF a request accordingly.**

ASN considers that the conclusions on the direct effects of wind are also valid for the indirect effects of wind: ASN considers that the wind speed value to be used in these studies needs to be consolidated.

ASN also considers that, for wind speeds of about 200 km/h, EDF should check that the only projectiles to be taken into account are indeed cladding sheets which are not liable to damage the outdoor IPS equipment, owing to their lack of rigidity.

Hail

Most IPS equipment is situated indoors, which offers it protection from hail damage. With regard to the robustness of the buildings themselves to the effects of hail, EDF considers that the maximum impact could be pitting of the cladding, but without penetration. No incident related to a hailstorm has been observed on the reactors in service.

The targets identified with respect to hail are primarily those already considered in the analyses covering wind-generated projectiles. Piping and tanks are considered to be able to withstand the impact of hail.

The consequences of blockage of the rainwater drainage networks, which could be caused by hail, are dealt with in § 3 of this chapter.

ASN considers that the elements presented by EDF concerning hail are succinct: in particular, no hail loading value (intensity, diameter of hailstones, etc.) was mentioned. ASN will ask EDF to propose a more precise definition of extreme hail loading and to conduct a more detailed analysis of the resistance of the equipment.

Lightning

EDF considers that there is no plausible cliff-edge effect liable to be created by lightning, given:

- the high robustness of the facilities required for management of an accident situation with regard to the lightning risk and its effects;
- the confirmation from operating experience feedback of the effectiveness of this robustness, up to high levels;
- the functional redundancy and the diversity of certain systems, especially those linked to the electrical power supplies.

To reinforce the robustness of the facilities, EDF nonetheless states that a preventive maintenance programme for the "Hot non-IPS structures" and a maintenance programme for the "turbine hall" are currently being drafted. They will cover the metal cladding. EDF considers that maintenance of the cladding will limit the risk of it being damaged by a storm, for the buildings within the scope of these maintenance programmes, thus increasing the protection of the facilities against the lightning-related risks.

With regard to lightning-induced cliff-edge effects on PWRs in operation, ASN observes that EDF bases its position solely on arguments related to the design or to positive operating experience feedback at high intensity levels, but without mentioning any values which clearly indicate the absence of a cliff-edge effect.

During the examination in preparation for the meeting of the advisory committees in November 2011, ASN noted that on the EPR (Flamanville 3, Penly 3), EDF mentioned analysis of operating experience feedback which revealed the occurrence of lightning strikes of an intensity of up to 454 kA (Chooz in April 2011). EDF specified that a study will be conducted on the EPR to assess the consequences of a lightning strike in excess of 200 kA for the equipment installed outside the "mesh cage". This feedback from Chooz and this study are not mentioned in the CSAs for the PWRs in operation.

ASN considers that an "extreme lightning" loading, defined on the basis of the available operating experience feedback, should be defined and taken into account for the PWRs in operation, concerning the equipment needed to manage H1, H3 and severe accident situations. ASN will ask EDF to conduct such studies.

Combination of extreme climatic phenomena and loss of heat sink (H1) and loss of electrical power supply (H3) situations

Contrary to what ASN requested in its decision of 4th May 2001, EDF does not include these extreme natural phenomena in the H1 and H3 analyses presented in the CSA reports (see § 5 of this chapter). However, during the examination preceding the meeting of the advisory committees in November 2011, EDF indicated that it would be including them in the analyses of the action to be taken for H1, H3 and severe accident situations.

ASN considers that EDF must take account of the extreme meteorological conditions linked to flooding in the definition of the "hard core" (see § 8).

With regard to the EPR, EDF states that to prevent any cliff-edge effect beyond the baseline safety standards, the additional equipment that could be deployed following the CSAs will be designed for or protected against extreme climatic conditions. ASN considers this approach to be satisfactory.

4.2.2 Measures envisaged to reinforce the robustness of the facilities to extreme meteorological conditions

In its specifications, ASN asked EDF, on the basis of the conclusions of the previous analysis, to state whether measures could be envisaged for preventing these cliff-edge effects or to enhance the robustness of the facility (modification of the design, modification of procedures, organisational measures, etc.).

Concerning the reactors in operation, during the examination in preparation for the meeting of the advisory committees in November 2011, EDF made an undertaking to study the ability of the venting-filtration system required in the event of a severe accident (filter U5) to withstand the direct and indirect effects of wind, as well as the ability of the equipment needed to operate the emergency management centres and situated outside the building to withstand the indirect effects of wind. Moreover, to reinforce the robustness of the facilities, EDF states that a preventive maintenance programme for the "Hot, non-IPS structures" and a maintenance programme for the "turbine hall" are currently being drafted. They will cover the metal cladding. EDF considers that maintenance of the cladding will limit the risk of it being damaged by a storm, for the buildings within the scope of these maintenance programmes and will thus increase the protection of the facilities against the lightning-related risks. In addition, ASN will ensure that the definition of the "hard core" takes account of the extreme meteorological conditions linked to flooding.

Concerning the EPR, EDF states that in order to prevent any cliff-edge effects beyond the baseline safety standards, the additional equipment that could be deployed following the CSAs will be designed for or protected against extreme climatic conditions. ASN considers this approach to be satisfactory.

5 Loss of electrical power supplies and cooling systems

Even after the nuclear chain reaction has stopped, the nuclear fuel in the reactor and the spent fuel pool must be cooled in order to remove the residual power. For this it is necessary to ensure continuity of the electrical power supply to certain key components (for example the cooling system pumps), and the supply of cooling water (from a river or the sea, for example).

ASN has therefore asked EDF analyse the induced losses of the following safety systems, in relation to the experience feedback from the Fukushima accident:

- loss of the electrical power supplies (including the case of total loss of the off-site and on-site electrical supplies);
- loss of the cooling sources (heat sink);
- the above two losses combined.

ASN considers that EDF's responses on the whole comply with the requested specifications.

The analysis of EDF's Complementary Safety Assessment (CSA) reports has shown that some heat sink and electrical power loss scenarios can lead to core meltdown within a few hours in the most unfavourable cases.

ASN thus considers it necessary to increase the robustness of the facilities in a number of ways to enable them to cope with long-duration losses of electrical power supplies or cooling means, which could affect all the facilities on a site. ASN will instruct EDF to implement reinforced measures integrated in the "hard core" mentioned in § 8 of this chapter, comprising in particular a diesel generator and a ultimate backup water supply, capable of withstanding large-scale on-site and external hazards exceeding the baseline safety requirements and coping with total loss of electrical power supplies or cooling means, in order to prevent core meltdown in these situations. Pending progressive deployment of these measures, which will take several years, ASN will prescribe the implementation of these provisional measures, such as mobile electricity generating sets, as of 2012.

5.1 Loss of electrical power supplies

Each reactor is linked to the electricity transmission system by a line called the "main line". Before delivering the electrical energy produced at the main generator to the electrical power grid, the reactor - via the step-down transformer (TS) - draws the energy it needs to supply the electrical panels that energize the equipment vital for its operation, and the equipment necessary for the safety of the facility. If the main line fails, the reactor can isolate itself from the electricity transmission system and, via the step-down transformer, continue supplying the electrical panels; this procedure is called "house load operation".

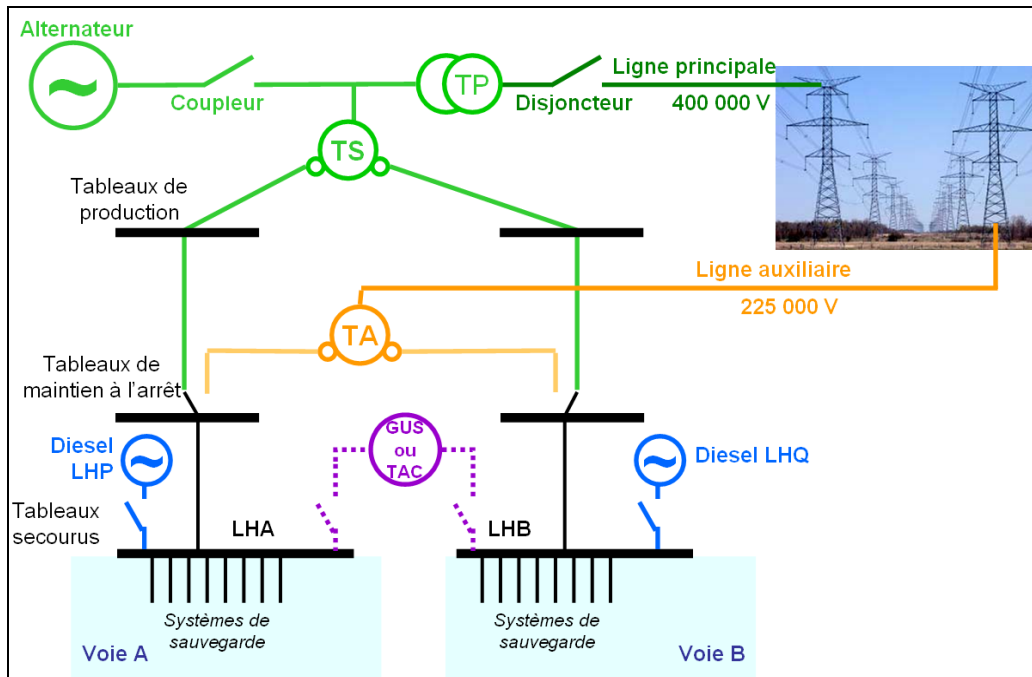
When the reactor is not producing electricity, or if the main line is out of service, the electrical panels are supplied via a second line called the auxiliary line. In this case the reactor is supplied directly by the electricity transmission system via the auxiliary transformer (TA).

To have sufficient on-site electrical power sources, each reactor has redundant conventional backup sources capable of supplying the electrical panels vital for correct operation of the safety equipment. The conventional backup sources for each reactor in service consist of two emergency diesel generator sets, while the EPR reactor has four main generator sets.

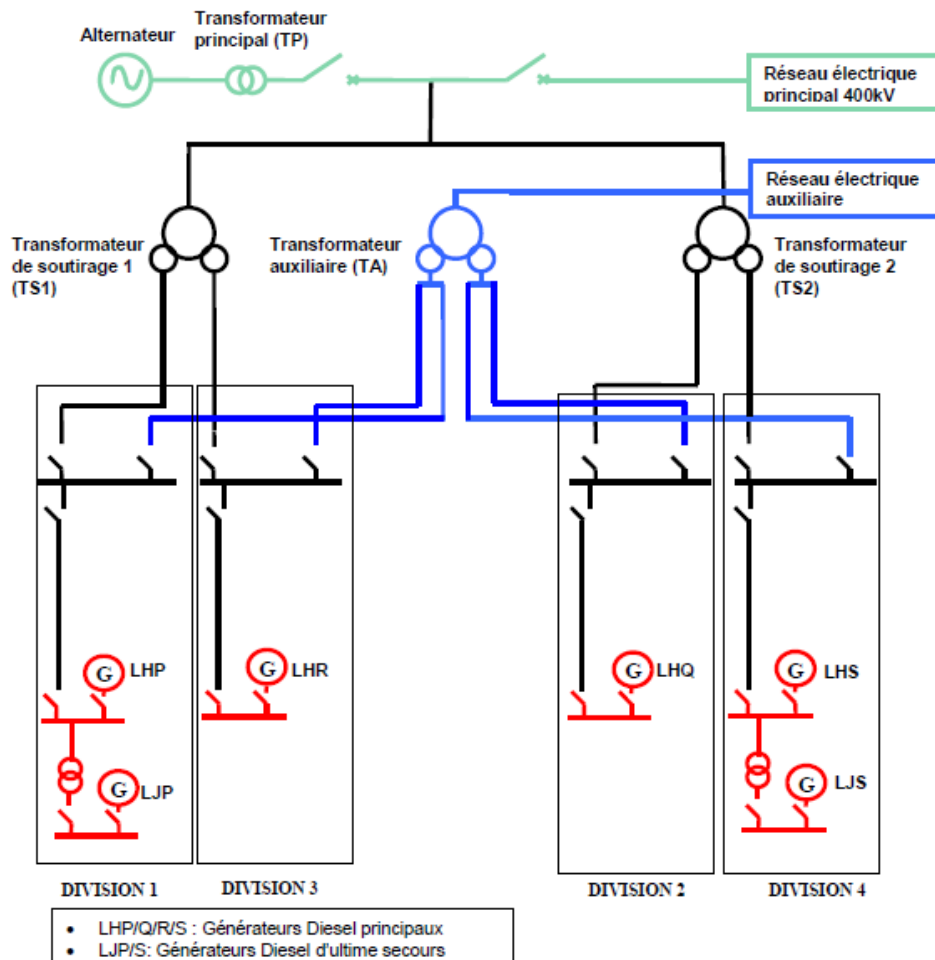
Each NPP also has an additional on-site emergency power source, whose technology differs according to the plant series involved:

- for the 900 MWe series, one ultimate backup diesel-generator set (GUS) per site;
- for the 1300 MWe and N4 series, one combustion turbine (TAC) per site;
- for the EPR reactor, two ultimate backup diesel-generator sets (SBO – Station blackout) per reactor.

Electric batteries with a power autonomy of one hour on the reactors in service and two hours on the EPR reactor ensure and guarantee continuity of the electrical supply to certain key equipment items when the generator sets are not operating.



Schematic diagram of the electrical power supplies of a reactor in service



Schematic diagram of the electrical power supplies for an EPR reactor

If the off-site electrical sources and the abovementioned on-site backup sources should fail, specific equipment is provided to supply certain items that are critical for managing this situation:

- on each in-service reactor, one ultimate electrical power source provided by a turbine generator (LLS) driven by steam from the steam generators (SG);
- on the EPR reactor, two batteries dedicated to this situation (called "12-hour" batteries).

ASN has asked EDF to study the successive loss of all these electrical power sources in the complementary safety assessments, considering initially that only one reactor is concerned, and in a second phase that all the facilities of a given site are affected simultaneously.

The targeted inspections carried out by ASN in 2011 found that the state of the electrical power supplies was generally satisfactory, though a number of shortcomings exist on certain sites. Generally speaking, the consistency of the operating and maintenance documents, the condition of certain items relating to fuel storage, the management of generator set fluids and the periodic inspections of the combustion turbines (TAC) are areas in which many sites could make improvements.

5.1.1 Loss of the off-site electrical power supplies

For each reactor, ASN has asked EDF to:

- describe the facility's design measures that take into account this power loss situation, the backup means provided, and their conditions of use;
- indicate the length of time the on-site electrical power supplies can function without external backup;
- specify the measures taken to extend the utilization time of the on-site electrical power supplies (refuelling of the diesel generator sets, etc.);
- indicate any measure envisaged to increase the robustness of the facility (design change, change in procedures, organisational arrangements, etc.).

Loss of the off-site electrical power supplies of a reactor is a situation analysed for the baseline safety standard; it corresponds to loss of the main and auxiliary lines and failure of house load operation.

In a situation of off-site electrical power supply loss:

- the reactor loads are energized by the on-site source, i.e. the backup diesel generator sets; these generator sets start automatically in the event of simultaneous loss of the main and auxiliary systems or a significant voltage drop on the backed-up electrical panels;
- the control rods drop under gravity, which terminates the nuclear fission reaction and controls the reactivity;
- the reactor core continues to emit heat (called residual power), which must be removed from the core to prevent its temperature from rising and ultimately damage it;
- the reactor coolant pumps (RCP) are no longer supplied with electricity, as their power demand is too great for them to be supplied by the generator sets; the flow in the primary system decreases rapidly; after complete stoppage of the RCPs, natural circulation in the primary loops removes the residual power which decreases as a result of the power decay further to the automatic reactor shutdown;
- on the secondary side, the reactor shutdown trips the turbine and closes the turbine inlet valves; as the steam generator main feedwater pumps (feedwater flow control system - ARE) have stopped due to the initiating event, the feedwater supply terminates until the auxiliary feedwater system (EFWS) starts up; the residual power is removed by the steam generator with opening of the main steam safety relief valves to the atmosphere (GTC-a for the reactors in service, or VDA for the EPR reactor);
- the spent fuel pool cooling systems are backed up by the reactor emergency generator sets.

In the complementary safety assessment (CSA) reports, EDF pointed out that starting the emergency generator sets gives the management team the electrical power sources necessary to bring the reactor to a safe condition if the off-site electrical power supplies are lost.

In the scheduled and systematic actions to identify any deviations on its facilities (periodic tests, maintenance, regulatory inspections, installation conformity reviews carried out as part of the periodic safety review), EDF identified a number of nonconformities directly or indirectly affecting the generator sets of the reactors in service.

ASN considers that although these nonconformities do not represent an immediate safety hazard, they do affect the robustness of the backup generator sets. EDF notified ASN of these nonconformities and they are being monitored specifically.

Regarding the autonomy of the on-site electrical power supplies, EDF pointed out in the CSA reports that the reference case studied to determine the robustness of the facility considers a situation where the off-site electrical power supplies for the entire site are lost for two weeks. The following procurement measures have been planned on the basis of this situation:

- fuel autonomy is guaranteed for 3.5 days; procurement is covered by a national contract, that requires delivery within 24 hours in emergencies and 3 days in normal situations; EDF also points out that strategic fuel reserves are reserved for its needs;
- oil autonomy is 3 days for the reactors in service and 10 days for the EPR reactor; beyond this, procurement is possible in accordance with provisions specific to each site. Whatever the case, EDF considers that the availability of resources is ensured for two weeks;
- the initial cooling water reserves for the generator sets of the reactors in service provide two weeks of autonomy. For the EPR reactor, the initial cooling water reserves ensure at least 10 days of autonomy for the "high temperature" water and 22 days for the "low temperature" water;
- the compressed air reserves required to start each generator set allows five start-ups and can be replenished by compressors; the diesel engines have a stand-alone air-water cooling system.

EDF indicates in its CSA reports that the ultimate backup generator sets (SBO) of the EPR reactor provide an additional electrical power supply of at least twenty-four hours.

ASN considers that the supply management methods are capable of guaranteeing 3 days autonomy for the generator sets of the reactors in service and 4 days for the EPR reactors.

ASN notes that EDF has not demonstrated that the site can be autonomous for two weeks under all circumstances, and notably after an earthquake or a flood leading to isolation of the site. ASN will ask EDF to ensure the reliability of the on-site fuel and oil stocks and their replenishment under all circumstances so that at least two weeks' autonomy is ensured.

Regarding the measures taken to extend the utilisation time of the on-site electrical power supplies, EDF has specified in the CSA reports that:

- on the reactors in service, the use of independent thermostatic valves (i.e. controlled only by the fluid passing through them) instead of electropneumatic valves to regulate backup generator set cooling guarantees the operation of these generator sets if the compressed air distribution system (SAR) goes down;
- on the EPR reactor, ensuring the long-term operating reliability of the backup generator sets depends on the activation of additional protection mechanisms if problems arise that risk causing rapid destruction of the generator set if they are not solved quickly, and they can be repaired in a relatively short time. The aim is to limit the consequences of a possible failure that could damage the generator set by preventively shutting it down: long-duration failures can thus be avoided by making short-duration shutdowns for repair work;
- as a single generator set suffices for the safety systems, the others could be shut down, to save fuel for example.

ASN considers that EDF's proposal to draft an operational procedure for "economising" a generator set when necessary should be put into application.

Regarding the measures that can be envisaged to enhance the robustness of the facility, EDF proposed in the CSA reports that the protection logic of the 1300 MWe series generator sets be modified by manually restoring the "non-priority" protection mechanisms that are disabled automatically in the "short-term" operating phases (this has already been done on the 900 MWe and N4 series generator sets). The aim is to limit the consequences of a possible failure that could damage the generator set by preventively shutting it down: long-duration failures can thus be avoided by making short-duration shutdowns for repair work.

ASN considers that the proposed improvements, which meet the CSA specifications, should be implemented.

Regarding the extension of the off-site electrical power supply loss to the entire site, which is not analysed for the baseline safety standard, EDF specifies in its CSA reports that this does not change its analysis; this is because in this situation reactor management does not require any particular equipment or equipment common to several reactors.

ASN considers that EDF must take into account this off-site electrical power loss scenario when ensuring the reliability of on-site fuel and oil stocks and their resupply.

5.1.2 Loss of off-site electrical power supplies and conventional backup supplies

For each reactor, ASN has asked EDF to:

- provide information on the capacity and autonomy of the batteries;
- indicate for how long the site can cope with loss of the off-site electrical power supplies and the backup energy sources without external intervention before serious damage to the fuel becomes inevitable;
- indicate what external action external is planned to prevent fuel damage:
 - equipment already on the site, for example equipment from another reactor;
 - equipment available off the site, assuming that all the reactors on a given site have suffered damage;
 - generators that are geographically very close (e.g. hydroelectric generators, gas turbines, etc.) which can be used to power the facility via dedicated connections;
 - the time necessary for each of these systems to be operational;
 - the availability of competent human resources, in particular to make these exceptional connections and render them operational;
- identify the moments when the main cliff-edge effects occur;
- indicate whether measures can be taken to prevent these cliff-edge effects or to reinforce the robustness of the facility (design change, change in procedures, organizational arrangements, etc.).

Loss of the off-site electrical power supplies and the conventional backup supplies of a reactor is a situation analysed for the baseline safety standard; it results from loss of the off-site electrical power supplies combined with failure to resupply the electrical panels that are backed up by the reactor's backup generator sets.

In this situation of loss of the off-site electrical power supplies and the conventional backup supplies of a reactor in service:

- the residual power of the core is removed by natural circulation if the primary system is closed, or by evaporation if the primary system is open;
- if the reactor is initially under power or in hot shutdown condition, the rod cluster control assemblies (RCCAs) drop down into the core and cooling of the thermal barrier of the reactor coolant pumps (RCP) is ensured by the charging pump of the chemical and volume control system (CVCS) common to a pair of reactors and supplied with electricity by the backup turbine generator (LLS);
- if the primary system is open or sufficiently open, the ultimate backup diesel-generator set (GUS) for the 900 MWe series or the combustion turbine (TAC) for the 1300 MWe and N4 series can supply the charging pumps of the CVCS, thereby providing make-up water to the primary system;

- for the secondary system, the steam generators are supplied if necessary via the auxiliary feedwater system (EFWS) by two turbine-driven pumps; the residual power is removed to the atmosphere by the main steam safety relief valves GCT-a (turbine bypass system-atmosphere);
- the spent fuel pool cooling systems are no longer supplied with electricity, which can result in evaporation of the pool water and possibly exposure of the fuel (within a time specified further on), and can ultimately lead to meltdown of the stored fuel.

For the EPR reactor, in the event of loss of the off-site electrical power supplies and the conventional backup power supplies:

- an ultimate backup diesel-generator set (SBO), which is started manually from the control room, supplies the pumps of the EFWS system; the "2-hour" and "12-hour" batteries are charged automatically by the SBO generator when it is in operation;
- if the reactor is initially under power or in hot shutdown state, the rod cluster control assemblies drop into the core; the residual power is removed by natural circulation; the thermal barrier of the RCPs is cooled automatically by the shutdown sealing system (DEA) supplied by the "2-hour" batteries;
- for the secondary system, the steam generators are supplied if necessary via motor-driven pumps of the EFWS system which are supplied with electricity by the SBO generators; the residual power is removed by the atmospheric steam dump valves (VDA);
- if the reactor is shut down and the primary system is just open or fully open, the residual power is removed by evaporation; a low-pressure injection channel of the safety injection system (IRWST - in-containment refuelling water storage tank) supplied by the SBO generator enables primary system make-up to be accomplished and a channel of the ultimate heat removal system in the containment (EVU/SRU) removes the residual power from the containment;
- a cooling system of the spent fuel pool can be supplied with electricity by an SBO generator.

Regarding the capacity and autonomy of the batteries of the reactors in service, EDF has specified in the CSA reports that the storage batteries:

- ensure automatic power sources switchover;
- supply power for at least one hour to the instrumentation & control necessary to diagnose the problem and orient the operating team during an electrical power failure.

EDF also specified in the CSA reports that operating procedures for lost external and on-site electrical power supply situations provide for operation in "battery saving mode", enabling high-priority functions to be powered for longer by load-shedding lower-priority functions.

For the EPR reactor, EDF state in the CSA reports that:

- four "2-hour" batteries can supply the instrumentation & control, the man-machine interfaces and the containment internal isolation valves for at least two hours;
- two "12-hour" batteries can supply the instrumentation and control (I&C) dedicated to severe accidents (CCAG), the severe accidents console (CAG), the iodine filtration of the inter-containment space, the containment external isolation valves and the emergency lighting of the control room, of the crisis technical room and of the fallback station, for at least twelve hours.

On the EPR reactor, as the "2-hour" batteries are necessary to couple the main generators and ultimate backup generator sets (SBO) to the electrical system, the following cliff-edge effects were identified during the examination prior to the meeting of the advisory committees in November 2011:

- a common cause failure affecting the four "2-hour" batteries in a situation of off-site electrical power supply loss would lead to the total outage of all the generator sets and a severe accident;
- the measures necessary for reactor vessel containment and switching over to the severe accidents console must be carried out before these "2-hour" batteries become discharged.

For the EPR reactor, ASN therefore considers that EDF must propose measures to give the "2-hour" batteries the diversification that meets the same requirements as for the generator sets. This point is currently being examined as part of the detailed design analysis of the Flamanville 3 EPR reactor generator sets.

Given the cliff-edge effects that battery discharge creates for all the reactors, ASN will instruct EDF to significantly increase the autonomy of the batteries used in the event of loss of the off-site and on-site electrical power supplies.

Regarding the time lapse before serious fuel damage becomes inevitable, in the event of loss of the off-site electrical power supplies and conventional backup supplies for a reactor without external intervention, EDF has specified in the CSA reports that for the reactors in service:

- when the primary system is closed, the autonomy depends on the volume of water reserves of the secondary system supplying the steam generators; failure to resupply the SGs followed by loss of their function leads to heating of the primary system and a rise in pressure until the pressuriser discharge valve opens, gradually emptying the primary system; if no complementary measures are taken, the fuel will become exposed a few days after the start of the accident;
- when the primary system is just open, as the residual power is lower, it takes longer for the fuel to become exposed than when the primary system is closed;
- when the primary system is sufficiently open, a gravity make-up of a limited fraction of the spent fuel pool water is applied to compensate for the vaporisation caused by the loss of the primary cooling system at shutdown; this is followed by a make-up from the PTR (reactor cavity and spent fuel pool cooling) system tank:
 - on the 900 MWe series, by the charging pumps of the CVCS system of the neighbouring reactor; if no additional measures are taken, the fuel will become exposed more than a day after the start of the accident;
 - on the 1300 MWe and N4 series, by the mobile motor-driven cooling pump; if no additional measures are taken, the fuel will become exposed several days after the start of the accident;
- for the spent fuel pool, permanent make-up by the fire-fighting water distribution or production system (JPD or JPP) pumps of the neighbouring reactor prevents the fuel from becoming exposed.

For the EPR reactor, EDF has specified in the CSA reports that:

- the reactor presents no risk of core meltdown or radioactive release for at least the twenty-four hours of operation of the SBO generator sets; when cooling is ensured by the SGs, the auxiliary feedwater system (EFWS) tanks run dry after about two days, but they can be replenished from the tanks of the classified fire-fighting water production system (JAC) by the EFWS system resupply pumps (which can be backed up electrically by the SBO generator sets), giving a total water autonomy of seven days, perhaps a bit more: the fuel would start suffering damage about nine days after the initiating event;
- if the reactor is not in cold shutdown state with the reactor cavity full, the spent fuel pool cannot be cooled because the SBO generator set is dedicated to reactor management; one of the JAC system pumps can make -up water to compensate for the evaporation and avoid exposing the fuel during the twenty-four hours of autonomy of the SBO generator set; the fuel will become exposed about 5 days after the initiating event;
- if the reactor is in cold shutdown state with the reactor cavity full, cooling of the spent fuel pool is ensured for twenty-four hours; the fuel will become exposed more than 2 days after the initiating event.

Regarding loss of the off-site electrical power supplies and the conventional backup supplies for the entire site, which is a situation that is not analysed for the baseline safety standard, EDF specifies in its CSA reports that, for the reactors in service:

- as the GUS and the TAC are common to the site, they will only be able to supply one reactor on the site;

- when the primary system is closed, the core will become exposed more than 24 hours after the start of the accident;
- when the primary system is just open, if the primary system vents fail to close, the fuel will become exposed after about ten hours; this situation is similar to loss of the off-site electrical power supplies and all the backup supplies of a reactor;
- when the primary system is sufficiently open:
 - for the 900 MWe series, the chemical and volume control system (CVCS) charging pumps are no longer available; if no complementary measures are taken, the fuel will become exposed a few hours after the start of the accident;
 - for the 1300 MWe and N4 series, the technical specifications (TS) limits this situation to just one reactor on a site, always leaving the possibility of using the mobile motor-driven cooling pump; the fuel will become exposed several days after the start of the accident;
- for the spent fuel pools, as all the pumps of the fire-fighting water production or distribution system (JPP or JPD) are out of service, the fuel will become uncovered within a day and a half.

For the EPR reactor, EDF specifies in its CSA reports that the extension of the loss of off-site electrical power supply to the entire site does not change its analysis of the reactor section, but it does not give any details on the spent fuel pool section; in this situation, reactor management does not require any equipment that is specific or common to the site. ASN considers that EDF must adopt a position regarding the missing assessment.

Regarding the external measures planned to prevent the fuel being damaged, EDF has specified in its CSA reports that the means for managing loss of the off-site electrical power supplies and the conventional backup supplies would be implemented by competent and qualified personnel, assisted and advised by the crisis management teams.

The planned external actions for managing loss of the off-site electrical power supplies and the conventional backup supplies over the entire site, examined by EDF in its complementary safety assessments, correspond to the requirements of ASN decision No. 2011-DC-0213.

Regarding the measures that can be envisaged to prevent the cliff-edge effects or to reinforce the robustness of the facility, EDF has proposed in its CSA reports, for the reactors in service;

- to study and verify the resistance of the EFWS system turbine-driven pumps and the backup turbine generator (LLS) to the temperature rise in the buildings beyond twenty-four hours;
- to install on each reactor an "ultimate backup diesel generator set":
 - its role will be to energise one motor-driven pump of the EFWS system, and to take over the functions of the LLS if this is not available;
 - it will be able to ensure in total autonomy for 48 hours, the partial electrical supply of one backed-up electrical panel within about one hour after losing the external and internal electrical power supplies;
 - it will be powerful enough supply electricity for one primary system injection means and one motor-driven pump of the EFWS system;
 - it will also be capable of supplying electricity for the auxiliaries that isolate the reactor containment, for the ventilation systems of the control room, the nuclear auxiliary building and the fuel building, and the backup of the system for placing the inter-containment space under vacuum;
 - it shall be designed for hazard robustness;
- pending installation of this "ultimate backup diesel generator set", to provide one or more small emergency generator sets that will guarantee the electrical supply for the minimum necessary instrumentation & control and control room emergency lighting;
- to install on the 900 MWe series reactors a motor-driven cooling pump for injecting water into the core from the PTR system tank;
- to put in place lasting ultimate backup means (wells, ponds, etc.) for replenishing the EFWS and PTR systems and the spent fuel pool with water, along with the associated material and human resources;

some of these material resources could be provided by the "FARN" (Nuclear Rapid Intervention Force)³³;

- to equip the sites in the short term with high-power mobile stand-alone lighting equipment to facilitate interventions on the premises;
- to draft an operating document for the situation of loss of off-site electrical power supplies and the backup energy sources;
- to update the current operating procedure as part of a modification of the chapter VI procedures of the general operating rules (GOR):
 - anticipation of rapid cooling,
 - limiting of steam generator depressurisation;
- for the 900 MWe series and for states where the primary system is just open, to change the primary system pressure build-up procedure to remove the residual power by the steam generators, thereby having sufficient secondary pressure to supply the required turbine-driven auxiliary feedwater pump and maintain the required SG water inventory when the primary system can be repressurised;
- to modify the operating documents so that the necessary measures are taken as soon as loss of the heat sink or total loss of the electrical power supplies is confirmed, without waiting for deployment of the on-site emergency plan (PUI);
- to study the complementary operating measures, notably by providing charts to evaluate the TAC or the GUS for management of the spent fuel pools in these situations;
- to study the appropriateness of having a generator set to back up the information strictly necessary for managing loss of the spent fuel pool cooling;
- ultimately, to study the feasibility of transferring control of the existing spent fuel pool make-up system to premises totally protected against the effects of steam and improve the functioning of the steam vent.

For the EPR reactor, to prevent cliff-edge effects or to increase the robustness of the facility, EDF has proposed in its CSA reports:

- to implement a mobile means of pumping fuel from the main generator set tanks to resupply the SBO generators, should it be impossible to obtain fuel from the exterior;
- to envisage resupplying the ASG system tanks from the freshwater ponds of the demineralized water production system (SEA);
- to study and implement means of controlling the explosion risk resulting from radiolysis of the spent fuel pool water if there is no ventilation;
- to implement a passive or automatic system for opening the fuel pit area vent to improve the prevention of a pressure build-up situation in the fuel pit area;
- to implement gravity make-up of the spent fuel pool with water from the SEA ponds via an external connection with the fuel building, that will compensate for water losses by evaporation and at least maintain the water level;
- to study the measures to take to increase the robustness of the fuel pool instrumentation (water temperature, water level, dose rate in the fuel pit area) for managing the situation, and water top-up in particular.

ASN considers that EDF's electricity supply backup proposals, which comply with the CSA specifications, must be implemented.

EDF has identified the need to keep information vital for operations management available in the control room and to maintain control room lighting. However, it has not assessed the risk of a cliff-edge effect associated with certain information losses in the control room, with exhaustion of the batteries and the absence of lighting in situations with the primary system open or LLS unavailable. ASN notes that EDF's proposal to deploy one or

³³ See § 6 of this chapter

more small emergency generator sets that guarantee an electrical supply for the minimum necessary I&C and control room emergency lighting would solve this problem.

ASN considers that EDF's proposal to provide an additional robust electrical power supply means called "ultimate backup diesel generator set (DUS)" for use in the event of loss of the other off-site and on-site electrical power supplies, and which complies with the CSA specifications, must be implemented. Pending deployment of this additional electrical power supply means, ASN also considers that EDF's proposal to provide one or more small emergency generator sets must be implemented. ASN will issue a requirement on this subject.

For the EPR reactor, the SBO generator sets already have robustness features. To have a level of robustness at least equal to that of the reactors in service with the deployment of an additional hazard-resistant means of supplying electrical power, ASN will ask EDF to study the integration of the SBO generator sets in the "hard core" of the material and organisational measures, which are subject to more stringent requirements, particularly with respect to the earthquake and flooding risks (refer to § 8 of this chapter).

For the 900 MWe series, EDF proposes - for primary system just-open situations - to modify pressure build-up management so as to remove the residual power via the steam generators. ASN considers that EDF must prove that the proposed change in management of the primary system just-open situation will effectively result in a sufficient delay before the fuel becomes exposed to implement external means for the medium- and long-term management of a situation of loss of the off-site and on-site electrical power supplies on a site.

5.1.3 Loss of the off-site electrical power supplies and of the conventional backup supplies and any other on-site backup electrical power source

For the situation of loss of the off-site electrical power supplies and the conventional backup supplies and any other on-site backup electrical power source, ASN has asked EDF, for each reactor, to:

- provide information on the capacity and autonomy of the batteries;
- indicate for how long the site can cope with loss of the off-site electrical power supplies and backup energy sources without external intervention before serious damage to the fuel becomes inevitable;
- indicate what external action is planned to prevent fuel damage to the fuel:
 - equipment already on the site, for example equipment from another reactor;
 - equipment available off the site, assuming that all the reactors on a given site have suffered damage;
 - generators that are geographically very close (e.g. hydroelectric generators, gas turbines, etc.) which can be used to power the facility via dedicated connections;
 - the time necessary for each of these systems to be operational;
 - the availability of competent human resources, in particular to make these exceptional connections and render them operational;
- identify the moments when the main cliff-edge effects occur;
- indicate whether measures can be taken to prevent these cliff-edge effects or to reinforce the robustness of the facility (design change, change in procedures, organizational arrangements, etc.).

Loss of the off-site electrical power supplies and all the backup supplies of a reactor results from the loss of the off-site electrical power supplies combined with failure to resupply the electrical panels that are backed up by:

- the emergency generator sets of the reactors in service or the main generator sets of the EPR reactor ;
- the ultimate backup diesel-generator set (GUS) for the 900 MWe series;
- the combustion turbine (TAC) for the 1300 MWe and N4 series;
- the ultimate backup generator sets (SBO) for the EPR reactor;
- the backup turbine generator (LLS) for the reactors in service.

In the CSA reports for the reactors in service, EDF also considered the loss of the auxiliary feedwater system (EFWS) turbine-driven pumps, even though they function independently of the electrical power sources.

For the reactors in service, this is not a situation analysed for the baseline safety standard. For the EPR reactor, as this situation is included in the baseline safety standard, the "2-hour" and "12-hour" batteries are provided.

In the situation of loss of the off-site electrical power supplies and all the backup supplies of a reactor:

- if the reactor is initially under power or in hot shutdown state, the rod cluster control assemblies (RCCAs) drop down into the core; the residual power is removed by natural circulation if the primary system is closed, and by evaporation if the primary system is open;
- the primary system is no longer provided with water make-up;
- the thermal barrier of the reactor coolant pumps (RCP) is no longer cooled;
- on the secondary system, the steam generators are no longer supplied;
- the spent fuel pool cooling systems are no longer supplied with electricity.

EDF has carried out a conservative analysis of this situation for all the reactors in service, considering all the reactors of a given site together, not each reactor individually. In its CSA reports, EDF considered the EPR reactor to be isolated from the other reactors on the site.

For the case of loss of the off-site electrical power supplies and all the on-site emergency power supplies, EDF specified in its CSA reports that the capacity and autonomy of the batteries were the same as in the preceding case of loss of the off-site electrical power supplies and the conventional backup supplies.

Regarding the time without external intervention before serious damage to the fuel becomes inevitable in the event of loss of the off-site electrical power supplies and all the on-site emergency power supplies, EDF specified in the CSA reports that, for the reactors in service

- when the primary system is closed, considering deterioration of the RCP seals leading to a significant breach in the primary system, the core would become exposed after about one day;
- when the primary system is just open, the accident operating procedures currently demand maximum cooling of the primary system, resulting in complete emptying of the SG; if no water make-up is provided, the fuel would become exposed in about ten hours;
- when the primary system is sufficiently open, a gravity make-up of a limited fraction of the spent fuel pool water is applied to compensate for the vaporisation caused by the loss of the primary cooling system at shutdown; this is followed by a make-up from the PTR system:
 - on the 900 MWe series, the CVCS system charging pumps are no longer available; if no additional measures are taken, the fuel will become exposed a few hours after the start of the accident;
 - on the 1300 MWe and N4 series, the technical specifications (TS) limits this situation to one and only one reactor on site, always leaving the possibility of using the mobile motor-driven cooling pump; the fuel will become exposed several days after the start of the accident;
- for the spent fuel pools, as all the pumps of the fire-fighting water production or distribution system (JPP or JPD) are unavailable, the fuel will become exposed within a day and a half.

For the EPR reactor, EDF has specified in the CSA reports that in the event of loss of all the external and on-site electrical power supplies:

- if the reactor is at full power, the fuel in the core will suffer damage after a few hours;
- if the core is unloaded, the fuel in the pit will become exposed more than one day after the initiating event (more than four days after the event if the core is in the vessel).

In this situation of loss of the off-site electrical power supplies and the conventional backup supplies and of all other on-site emergency electrical power sources, ASN observes that the CSAs reveal short-term cliff-edge

effects characterised by a shorter time before core exposure than that specified for deployment of the FARN means.

Regarding the external measures planned to prevent the fuel being damaged, EDF has specified in its CSA reports for the reactors in service that the measures are identical to the preceding case of loss of the off-site electrical power supplies and the conventional backup supplies.

For the EPR, EDF has specified that the design measures (redundant, diversified and robust electrical power sources) and the associated external measures help prevent damage to the fuel.

The external measures for managing situations of loss of the off-site electrical power supplies and the conventional backup supplies, and any other on-site emergency source examined by EDF in its complementary safety assessments correspond to the requirements of ASN decision 2011-DC-0213.

Regarding the measures that can be envisaged to prevent cliff-edge effects or to increase the robustness of the facility, apart from the measures proposed in the event of loss of the off-site electrical power supplies and the conventional backup supplies and described earlier, EDF has proposed in the CSA reports:

- for the 900 MWe series, to study resetting of the EFWS system turbine-driven pumps from the control room (for the states in which this is possible);
- for the 1300 MWe and N4 series, and for states where the primary system is just open, to change the primary system pressure build-up procedure to remove the residual power by the steam generators, thereby having sufficient secondary pressure to supply the required turbine-driven auxiliary feedwater pump and maintain the required water inventory of the SG when the primary system can be pressurised again;
- for the EPR:
 - to extend the electrical supply for the functions supplied by the "12-hour" batteries by implementing supplementary fixed or mobile electrical power sources;
 - to put in place a means of restarting the severe accidents I&C in the event of it has been cut-off;
 - to put in place devices and mobile electrical power supply means necessary to:
 - ensure the habitability of the control room,
 - for the spent fuel pool, supply one cooling channel of the PTR system or a water make-up from the tank of the JAC system;
 - to integrate the essential information concerning the development of the situation in the fuel building (fuel pool temperature, water level measurement, etc.) on the severe accidents I&C and the severe accidents console (PAG) which are supplied by the "12-hour" batteries.

ASN has observed that EDF proposes measures to increase the times before the core becomes exposed, including:

- deploying additional pumping means to make-up the primary and secondary systems;
- operating procedure studies and changes to limit the risk of a breach at the RCP seals if their cooling is lost;
- increasing the autonomy of the feedwater supply for the steam generators and the primary cooling system.

ASN considers that it is necessary for EDF to effectively increase the time lapses before the core becomes exposed. It considers that the supplementary measures proposed by EDF, which will increase robustness in the event of loss of the electrical power supply and the cooling water, must be implemented.

5.1.4 Conclusion on the planned measures to protect the facilities against the risk of electrical power supply loss

In its conclusions to the CSA reports, EDF considers that the backup means provided to cope with total and summed loss of the electrical power sources ensure good robustness of the facilities, particularly given the number of lines of defence included in the design and assumed to be lost in a deterministic manner in the required scenarios.

ASN observes in the CSA reports that EDF has performed the assessment relative to electrical power supply losses without considering that they could be caused by an external hazard (earthquake, flooding, etc). Yet such an external hazard can lead to failure of the equipment planned to be used to counter the loss of the electrical power supplies.

ASN therefore considers that the times before the fuel suffers damage in the event of electrical power supply loss could be shorter than those indicated by EDF in the CSA reports, particularly if the power loss was induced by an earthquake or a flood.

ASN considers that EDF must improve the hazard robustness of some of the proposed supplementary measures for managing electrical power loss situations. ASN will instruct EDF to propose during 2012 a "hard core" of material and organisational measures that will be subject to more stringent requirements, particularly with respect to the earthquake and flooding risks (see § 8).

5.1.5 Measures envisaged to enhance facility robustness with respect to electrical power supply losses

EDF has summarily proposed in the CSA reports the following measures to counter the risk of a loss of the electrical power supplies for the reactors in service

- a hazard-resistant generator set called the "ultimate backup diesel generator" will be installed on each reactor; it will be able to deliver electrical power for :
 - the minimum necessary I&C and control room lighting,
 - the information required in case of loss of spent fuel pool cooling,
 - the ultimate water make-up pump for replenishing the EFWS system tank, the PTR system tank and the spent fuel pool,
 - the information necessary in core meltdown situations,
 - the containment isolation valves, the ventilation filtration of the control room and the ventilation filtration of the inter-containment space,
 - one motor-driven pump of the EFWS system and a make-up for the primary system;
- in an initial phase pending installation of the "ultimate backup diesel generator", two small fixed generator sets will be provided:
 - one to supply the minimum reactor I&C and control room lighting,
 - the other to supply the ultimate water top-up pump for replenishing the EFWS system tank, the PTR system tank and the spent fuel pool;
- the possibility of resupplying power in the short term to the functions necessary for managing losses of spent fuel pit cooling shall be studied;
- enhancing the operating reliability of the LLS in the event of a temperature rise in the buildings beyond 24 hours without ventilation will be studied, and modifications will be proposed if revealed necessary by the studies.

For the EPR reactor, EDF has proposed the following measures in the CSA reports:

- extending the autonomy: mobile means of pumping fuel from the main generator set tanks to replenish the SBO generator sets;
- extension of the duration of electrical supply for essential functions by deploying supplementary fixed or mobile electrical power sources;
- means of restarting the severe accidents I&C.

During the examination of the CSA reports by the IRSN, ASN's technical support organisation, EDF took the following commitments:

- in order to ensure simultaneous injection at the seals on the 900 MWe series reactors, where there is only one RCV system charging pump for two reactors, EDF will carry out a study to determine the appropriateness of the flow that supplies the primary pump seals of each of the two reactors, in the event of loss of the off-site electrical power supplies and the site backup energy sources; the results of this study should be available at the end of the first quarter of 2012;

- to avoid a breach at the RCP seals in a situation of total loss of the external and on-site electrical supplies for the reactors in service, EDF has started examining the implementation of robustness tests on the new high-temperature seals installed on the reactors in service in place of the O-rings; a programme will be defined in April 2012;
- EDF will examine the devices existing or under development across the world to ensure sealing of the RCP shaft seals at shutdown; on the basis of the results, EDF will adopt a position at the end of the first half of 2012 on a design modification allowing simultaneous injection at the seals on the two neighbouring reactors of the 900 MWe series;
- EDF will carry out a study of operation with accelerated cooling to reach a state where injection at the RCP seals is no longer necessary;
- as with the 1300 MWe and N4 series, EDF will shortly install on the 900 MWe series a motor-driven pump that ensures adequate make-up of the primary system when the latter is sufficiently open; in the short phase of direct opening of the reactor vessel with the closure head loosened, EDF will check - for March 2012 on the reactors in service - that this motor-driven pump can be used for make-up operations, pending installation of the "ultimate backup diesel generator" which will supply power to a means of make-up the primary system;
- for the EPR reactor, EDF will present an analysis of the situations of generalised electrical power failure by the end of 2012, and decide whether additional provisions are necessary;
- To define the requirements of the hard core equipment, EDF will consider diversification and independence, and will verify the risks of common mode failure in particular.

ASN considers that the electrical power supply reinforcement objectives proposed by EDF must be implemented.

In order to set the objectives for these reinforcements and the corresponding deadlines, ASN will issue an instruction governing the implementation of an additional hazard-resistant electrical power supply means and, pending this, the implementation of a temporary generator sets on each reactor.

EDF has undertaken to determine whether the output of the CVCS system charging pump is sufficient for the injection at the RCP seals on the two neighbouring reactors simultaneously. If the pump output cannot be demonstrated as being sufficient, ASN considers that EDF should in the short term define a modification that makes simultaneous injection at the seals of the two neighbouring 900 MWe series reactors possible. Moreover, if a breach at the RCP seals cannot be avoided in a situation of loss of a site's off-site and on-site electrical power supplies, ASN considers that means for managing the breach must be deployed to prevent this situation degrading into a severe accident.

ASN considers that the principle of EDF's commitment to take diversification and independence into account as means of achieving the hard core requirements, and to verify the minimising of common mode failure risks, is satisfactory.

5.2 Loss of the cooling systems / heat sink

The heat sink provides the water to remove the thermal power from the nuclear fuel, to cool the systems of the nuclear or conventional facilities, and it supplies certain specific systems such as the fire-fighting system or water for industrial use. A reactor needs to be permanently connected to a heat sink, even after shutdown.

The water is taken directly from the natural environment, that is to say the sea for coastal NPP sites, or a waterway for NPP's situated on the banks of a river.

The water intake structures and the pumping station pump and filter the raw water which, once collected and filtered, is used to cool the systems via heat exchangers. The pumping station is connected directly to the intake-outfall structure. Each site usually has one pumping station for two plant units. Each pumping station has two redundant and geographically separated channels.

The water intake structure varies from one site to another. For riverside NPPs, it usually consists of:

- a deflector panel;
- a floating skimmer boom to limit the entry of floating debris;
- waterways that can supply several under-river tunnels. Each waterway is equipped with removable trash racks.

The water intake supplies the under-river tunnels which open out in a settling pit at the entrance to the plant unit intake channel. This intake channel divides to serve the pumping stations of each pair of plant units.

Starting upstream and working downstream, the equipment used for the transit and filtration of the raw water, comprises the advance grids (widely spaced bars, no trash rack), the preliminary filtration grids (more closely spaced bars, equipped with trash rack), a filtering system (chain filters or rotating drum screens), and lastly the suction pumps. The water transits chiefly through specially built channels, streams or concrete water pipes.

Raw water suction, delivery and filtration are ensured between minimum and a maximum levels called the lowest and highest safe water level respectively. The calculation of these levels takes into account the specific environment of the site. Taking the various design criteria into account ultimately determines:

- the shape and height of the dykes,
- the depth of the pipes,
- the setting and dimensions of the filtration system,
- the setting of the filtration system cleaning and disposal systems,
- the setting of the safety pumps.

The last 3 points determine the form and depth of the pumping station.

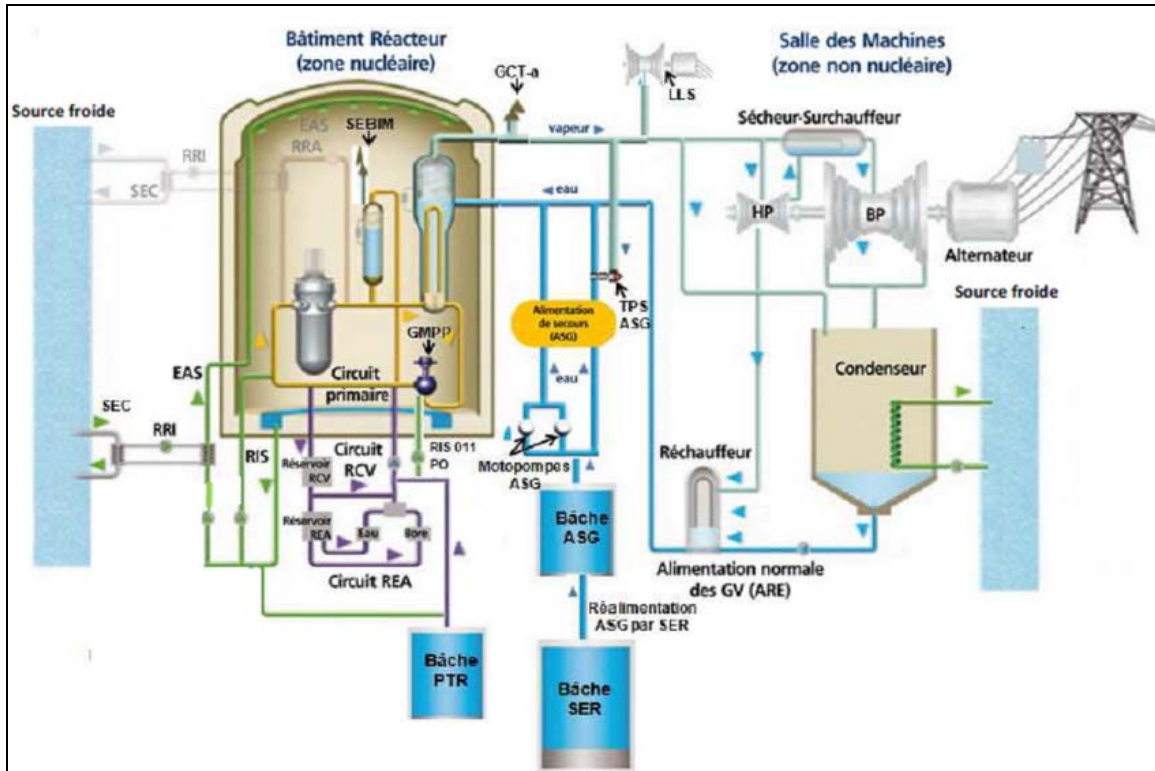
The reactors in service are designed to have an autonomy of at least 100 hours after a heat sink loss.

If the heat sink loss affects all a site's reactors simultaneously, the targeted autonomy announced by EDF is 24 hours for seashore NPPs and 60 hours for riverside NPPs in the case of an unpredictable hazard (e.g. sudden influx of clogging material), and 72 hours in case of a predictable hazard (e.g. a climatic event such as extreme cold + frazil ice) in which case the tanks can be filled to maximum level as a preventive measure.

The heat sink is usually the natural environment to which the nuclear facilities are connected, but other heat sinks do exist in the NPP, which are used according to the status of the plant units and also serve to cool down the core or the spent fuel pool:

Equipment or system used as "Heat Sinks":

	Equipment or systems used	Heat Sink
Normal operation	Steam generators (SG)	<ul style="list-style-type: none"> o Normal feedwater o Auxiliary feedwater to steam generators (EFWS) and turbine bypass system (GCT-a).
Accident operation	Steam generators	EFWS water, demineralised water, raw water, turbine bypass system (GCT-a)
	Residual heat removal system (RHRS)	CCWS (component cooldown system) water cooled by the ESWS (essential service water system)
	Safety injection system (SIS)	PTR (Reactor cavity and spent fuel pool cooling and treatment system) tank water
	Containment spray system (CSS)	<ul style="list-style-type: none"> o CCWS water cooled by the ESWS o PTR tank water



The ASN specifications required EDF to describe the design measures for preventing loss of the heat sink (for example, several water intakes in different places, use of an alternate heat sink, etc.).

The pumping station equipment is subject to safety requirements defined in the heat sink baseline safety standard.

EDF indicates in its complementary safety assessments the water intake, the pumping station and the intake channel are monitored firstly through the periodic patrol inspections and secondly through application of the basic preventive maintenance programs (PBMP), which includes taking bathymetric measurements and cleaning channels.

The heat sink water levels are monitored permanently, and vigilance, pre-alert and alert thresholds are specified. These thresholds are set such that preventive measures can be taken, particularly regarding the need to increase feedwater supplies, and optimised management of plant unit shutdown with the aim of reducing the residual energy to be removed from the core.

In France, no nuclear power reactor apart from the EPR of Flamanville 3 currently under construction has an alternate heat sink (lake, water table or atmosphere). This being said, some NPPs have a larger water reserve through their design. At the Civaux and Cattenom NPPs there are seismic-classified ponds that constitute the heat sink of the ESWS safety system³⁴: dedicated ponds at Civaux giving 10 days' autonomy, Mirgenbach lake with 30 days' autonomy. Another particularity of the Civaux site is that the safety cooling circuit functions in a closed loop with a forced draft cooling tower associated with the reserve pond (whereas on most NPP sites the safety cooling system is an open loop configuration, the water being taken from and discharged into its natural environment).

Lastly, EDF revises the design data periodically during the periodic safety reviews with the aim of reinforcing or improving the robustness of the facility.

³⁴ "SEC" system: Essential Service Water System (which comes directly from the heat sink)

EDF has provided solutions for the various risks of heat sink loss:

1. Extreme cold: to prevent the water intake from freezing up

As soon as winter temperatures prevail, pumping station monitoring is tightened under the "Extreme Cold" procedures, and the systems involved in the heat sink are placed in "winter" configuration: infrastructures identified as sensitive are subject to tightened monitoring.

2. Extreme heat: to avoid loss of the heat sink due to low water levels

During springtime, river-based NPPs step up monitoring in order to detect abnormal heat sink temperatures or levels. In case of alert, "extreme heat " or "low water" procedures enable monitoring to be adjusted and measures to be taken to protect the heat sink by adapting production if necessary. The coastal NPP sites are naturally protected against this risk. In practice, the NPPs concerned by heat sink low water situations are generally shut down well before the lowest safe water level is reached, to limit their environmental impact.

3. Oil spill: to avoid the water intake getting clogged up by an influx of hydrocarbons.

Some NPP sites are protected from this risk by their geographical location. In such cases, a daily inspection patrol of the heat-sink related facilities suffices to check the quality of the cooling water. The other NPP sites (on the coastline, on an estuary , beside a navigable canal, etc.) however, are exposed to the risk. In 2003 EDF carried out a probabilistic assessment of the drift of an oil slick offshore of the sites situated on the English Channel and the North Sea. This study assessed the probability of arrival of an oil slick resulting from an accident as 2.10-3/year for the NPPs on the Normandy coast.

Protection of the heat sink is based on design features and an operating doctrine that allows alerting of the NPP, surveillance of the oil slick in collaboration with the public authorities, and preventive shutdown of the plant units if there is a confirmed risk of an oil slick entering the intake channel. In the event of large-scale oil pollution offshore of the NPP, the alert is raised by the public authorities, and the situation generally leads to triggering of the "POLMAR" (maritime pollution) plan. Agreements between EDF, the French maritime authorities and Météo France (the French met office) enable the movement of an oil slick to be monitored and its position with respect to the water intakes of the nuclear sites to be communicated to EDF. Entry of an oil slick into the NPP surveillance zone results in the application of graded prevention actions to ensure the availability of the protection means, prepare plant until shutdown and, if necessary, implement the provisions of the on-site emergency plan:

- raw water consumption is limited as a precautionary measure to preserve the backup heat sink. The site plant units are gradually shut down to reduce the flow drawn in at the pumping station to the level required for reactor cooling;
- a floating pontoon equipped with vertically descending sheets situated in front of the intake waterway limits the ingress of a surface oil slick into the pumping station, subject to the preventive shutdown of the circulating water system (CRF) pumps, which reduces the inflow of water to just the essential service water (ESWS) flow required to cool the safety-related auxiliaries;
- the filters and their washing systems also help limit the hydrocarbon influx.

These instructions can also be triggered by an observation made as a result of pumping station monitoring, by the appearance of a rotating drum filter clogging or circulation pump tripping alarm. EDF estimates that the ESWS system instrumentation, and the flow measurements in particular, remain operational up to a hydrocarbon level of 10%.

4. Clogging agents: to avoid obstruction of the water intake

All the pumping stations have designed-in protection against massive influxes of clogging agents through lines of defence which vary from one site to another according to the particularities of the environment, but which typically are:

- At the water intake entry point, the first element met is a set of movable grids with widely spaced bars;
- At the pumping station entry point, the first element met is the "upstream" grid which has more closely spaced bars. A few metres downstream, one or two coarse filtration grids prevent the ingress of large floating objects. These coarse filtration grids are usually equipped with trash racks (one per grid) which raise any debris and direct it via a discharge channel to a waste collection bin.

The arrival of clogging agents in the pumping station is detected by the alarms specific to this system: monitoring of suction head loss, SEF alarms³⁵, loss of head of the SFI³⁶ filtration resources. The associated protection systems will automatically trip the pumps that are not safety-classified, thereby significantly reducing the head loss at the bounds of the filtering elements to guarantee their integrity and reduce the influx of debris. This system protects the ESWS system safety pumps against a low level at suction and ensures their lasting supply.

Preventive measures that can be initiated manually from the control room and followed by local verifications, including the stopping of one or more non-safety-classified pumps and starting of high-pressure washing and high-speed operation of the rotating drum filters. An operator will be sent to assess the situation; the operating teams have a specific procedures to guide the management of this situation .

In response to a partial heat sink loss incident at the Cruas NPP in 2009 caused by a massive influx of vegetation debris, ASN asked EDF to undertake a design review of all the heat sinks to assess and reinforce their robustness to natural hazards. The results of this technical design review are expected in 2012.

5. To avoid heat sink loss due to natural phenomena (storms, spring tides, etc.)

Some NPP sites manage these situations by a specific operating procedure that integrates the phenomena of storms with simultaneous presence of clogging agents that can affect the availability of the water intake. The aim of this procedure is to avoid total loss of the heat sink by maintaining the flow necessary for operation of the pumps that are important for safety, and facilitate the cleaning of clogged equipment. This procedure prescribes the monitoring of numerous parameters such as the pumping station alarms, the weather conditions - especially wind speed and direction, historical wind records, tidal conditions and sea state, the change in operation of the neighbouring plant unit CRF pumps, the nature of the clogging agent and the actions to implement. It also prescribes tightened monitoring of the pumping station and envisages several cases of plant unit shutdown. Each NPP site also establishes specific instructions, such as for lashing down objects in the event of high winds.

ASN considers that the heat sink, which is an important system, requires particular vigilance. Its vulnerability was highlighted by the recent events of clogging and partial loss of the heat sink at Cruas and at Fessenheim in December 2009, which led EDF to initiate a plan of action to reinforce the robustness of all its heat sinks. **ASN has more particularly asked EDF to conduct a design review of all its heat sinks. ASN will instruct EDF to provide detailed conclusions of the heat sink design review, site by site, along with a plan of action with completion dates.**

The inspections ASN carried out in 2011 found the general condition of the heat sink facilities to be satisfactory, and that almost all of them are in conformity with the EDF's national baseline safety standard, though there are still some deviations on a number of sites. As a general rule, operating and maintenance rigour, equipment and structure condition monitoring, and exhaustive application of national directives, are areas for improvement on most sites. Despite noteworthy progress attributable to the EDF's OEEI initiative (French acronym meaning "to achieve an exemplary condition in installations"), a number of sites still have pumping station equipment displaying leaks or relatively advanced corrosion. Several sites displayed shortcomings in the maintenance of the SEC system, which is classified for safety and therefore merits greater attention.

The risk of heat sink loss (by clogging, freezing, etc.) is not addressed equally from one site to another, and generally requires greater attention. The recent events have shown that the means currently in place have been sufficient to cope with the hazards, though sometimes with difficulty. EDF has therefore started to reinforce the robustness of its heat sinks against the risk of "massive influx of clogging material."

Personnel training has occasionally displayed deficiencies, making it a area for progress included in the plan of action implemented by EDF in 2010 in response to the heat sink clogging events at Cruas and Fessenheim.

Lastly, EDF has planned to tighten the baseline safety standard for the heat sink, with early 2013 announced as the plan of action completion date.

³⁵ SEF : raw water coarse filtration system (the first filtration of the water drawn from the natural environment

³⁶ SFI : raw water filtering system (in the pumping station)

5.2.1 Loss of the primary heat sink

In its specifications, ASN asked EDF to study the induced losses of safety systems, and loss of the alternate heat sink in particular. Initially, EDF will analyse each facility or installation individually; in a second phase it will be assumed that all the installations or facilities (reactors, pools, etc.) on a given site are affected simultaneously. For the reactors having several heat sinks (namely the Flamanville 3 EPR reactor), the successive loss of the heat sinks must be considered. For each of these situations, indicate the time for which the site can remain in this situation without external aid, before damage to the fuel becomes inevitable.

The situation of total heat sink loss is called "H1". This situation can affect either a single reactor or all the reactors on a site, and in the latter case it is referred to as a "whole-site H1".

Total loss of the natural heat sink leads to loss of the cooling functions of the core and spent fuel pool in the fuel building (BK³⁷). It is detected in the ESWS system by appearance of the low flow alarms which will lead to first one, then two SEC channels being declared unavailable in succession. Total loss of the heat sink renders the feedwater function and the essential service water system (ESWS) unusable. This is followed by gradual heating of the component cooling system (CCWS). The following systems gradually become unavailable : the component cooling system (CCWS), the residual heat removal system (RHRS), the reactor cavity and spent fuel pool cooling and treatment system (PTR), the primary pumps (loss of cooling of the bearings, motor and thermal barrier), the safety injection system (SIS) and the containment spray system (CSS).

The measures taken with equipment immediately present on the site enable the following functions to be ensured for the time necessary to restore the heat sink:

- maintaining of one charging pump necessary for injection at the primary pump seals. It allows make-up of borated water and reactor depressurising by auxiliary spraying;
- the thermal inertia of the primary system borated water reserve (PTR tank) is then used as a backup heat sink under an operating procedure devised for this purpose. In the long term the component cooling system (CCWS) no longer cools the auxiliaries correctly. It is stopped manually and declared unusable when the fluid temperature exceeds its maximum operating temperature (temperature at heat exchanger output exceeding 50 or 55°C depending on the sites);
- replenishing of the auxiliary feedwater system reserve (EFWS tank) to allow removal of residual power by the steam generators in the longer term, if the residual heat removal system (RHRS) becomes unavailable.

Evaluation of the impact of an H1 situation on the reactors (affecting first one, then all the reactors of a site)

EDF has identified 4 possible configurations:

- Primary system closed and residual heat removal system (RHRS) not connected
- Primary system closed and residual heat removal system (RHRS) connected
- Primary system just open
- Primary system sufficiently open

Case 1: H1 situation affecting a single reactor

The thermal inertia of the primary system borated water reserve (PTR tank) is used in the event of loss of the essential service water system (ESWS). It allows the following to be kept in service: one of the primary system pumps, normal spraying and letdown (CVCS). The reactor is thus taken through to shutdown status following a procedure similar to a normal reactor shutdown.

In the primary system closed states, a cliff-edge effect in a situation of total heat sink loss ("H1" situation) is associated with the exhaustion of the feedwater reserves (EFWS + SER). On the basis of the SER water volumes required by the technical specifications (TS), the site has an autonomy of several days (100 hours). The SER tanks are

³⁷ BK: Nuclear fuel storage building

usually filled well above the required thresholds, which means that the autonomy is greater. EDF considers this period is sufficiently long to restore the heat sink before the core starts to become exposed.

In the primary system open and just-open states, the primary system make-up by the CVCS system is available. Water is supplied from the PTR tank which can be replenished according to the procedures implemented on the initiative of the national crisis team. The primary system closed situation mentioned above therefore encompasses the primary system just-open situation.

Case 2: Loss of the heat sink for all the plant units of a site

EDF estimates that the plausible time required to restore the heat sink is about three days for riverside sites and one day for seaside sites.

Primary system closed states: on the basis of the EFWS and SER water volumes commonly encountered, the feedwater autonomy is greater than the plausible time required to restore the heat sink. Consequently there is no cliff-edge effect and EDF considers that the heat sink will have been restored before the core starts becoming exposed.

Primary system just-open state: as the residual power is lower, the primary system closed situation encompasses the primary system just-open situation.

Primary system open states: the thermal inertia of the primary system borated water reserve (PTR tank) is used and the vaporisation is compensated by topping up the primary system from the PTR tank. The residual power to remove is also lower than in the primary system closed situation.

EDF therefore estimates that in all cases the heat sink will have been restored before the core becomes exposed. To reinforce facility robustness in a whole-site H1 situation, EDF is in the process to re-assess the minimum thresholds of the Technical Specifications (TS) for the SER tanks in order to guarantee the targeted autonomy.

Particular case of the EPR:

Loss of primary heat sink on a plant unit in state A, B or C³⁸ with primary system closed or just open

In an initial condition with a reactor operating at full power, the EFWS tanks will be empty after about 2 days . Replenishing these tanks with water from the JAC³⁹ tanks gives a total water autonomy of 7 more days counting from the loss of the heat sink (i.e. 9 days in all). Damage to the fuel starts about 9 days after the initiating event. The other initial situations are encompassed by the one described above because the residual power to remove is lower.

Loss of the primary heat sink on a plant unit in state C, primary system not pressurisable or in state D

The study of this accident scenario shows that the core remains covered for several days and long-term removal of the residual power is ensured.

For all the plant units of the EPR site:

Extending loss of the heat sinks to the entire site changes nothing in the scenario for loss of the heat sink for a single plant unit, as the Flamanville 3 EPR has no equipment in common with the site's plant units 1-2. Given national and international operating experience feedback for coastal sites, the plausible time for restoring the heat sink has been estimated at one day.

³⁸ State A: under power and hot shutdown or intermediate state with all the reactor's automatic protection functions available; some functions may be disabled at low pressure;

State B: intermediate shutdown above 120°C, shut down cooling system not connected ; some automatic protection functions may be disabled;

State C: intermediate shutdown and cold shutdown with cooling system in operation and primary system closed or able to be closed rapidly;

State D : cold shutdown with primary system open

³⁹ JAC : safety-classified fire-fighting water production system.

Loss of the primary heat sink, reactor in state A, B or C with primary system closed or just open

Extension of the incident to the entire site does not change the scenario described previously, given that operation of the Flamanville 3 EPR does not require equipment common to plant units 1 and 2. Damage to the fuel of the Flamanville 3 EPR will start about 9 days after loss of the heat sink.

Loss of the primary heat sink, reactor in state C, primary system not pressurisable or in state D

Extension of the incident to the entire site does not change the scenario described previously, given that operation of the Flamanville 3 EPR ensures the long-term removal of the residual power and does not require equipment common to plant units 1 and 2.

EDF has not studied the situation of combined loss of the primary and alternate heat sinks.

For the EPR, EDF therefore considers that in all cases the heat sink will have been restored before the core becomes exposed. When the JAC tanks are empty (about 7 days after loss of the heat sink), replenishing of the EFWS tanks of the Flamanville 3 EPR from the freshwater ponds of the SEA (demineralisation plant water supply system) is envisaged. This resource, which is shared between the three plant units and the replenishing of the EFWS and BK building tanks, could be called up at the request of the national crisis team to provide several days of additional autonomy.

To conclude, when the primary system is closed, the residual power is removed from the reactor core by the secondary system. In this case EDF identifies a cliff-edge effect related to the exhaustion of the feedwater reserves. This time this would take is evaluated at "several days". EDF considers that the heat sink (which can be restored in one or three days depending on the site) will in all cases have been restored before the core becomes exposed. In situations where the primary system is not pressurisable, the residual power is removed by vaporisation of the reactor cavity water in the containment. In such cases, the primary system is provided make-up via the CVCS system. The cliff-edge effect is not detailed by EDF. In the particular case of the EPR, a cliff-edge effect is associated with the feedwater autonomy, evaluated at about 2 days. This corresponds to the specified autonomy of the EFWS tanks, which can subsequently be replenished by the tanks of the JAC system which is dedicated to this, increasing the autonomy to 9 days.

ASN considers that the heat sink loss accident situations analysed by EDF in its complementary safety assessments correspond to the requirements of ASN decision 2011-DC-0213 for the existing reactors and just for the Flamanville 3 EPR. As required by the specifications, they are established considering gradual losses of the water resources, with the exception of the following cases which EDF should have studied:

- total loss of the primary heat sinks combined with loss of the alternate heat sink on the Flamanville 3 EPR (situation only studied for the spent fuel pool in building BK)
- situation H1 (total loss of the heat sink) on the Civaux NPP site. This situation was only studied for one plant unit on the Civaux site and not for the entire site.

Apart from the H1 situation on the Civaux site, the postulated situations are examined considering first one plant unit, then all the plant units of a site as being affected, as required by the specifications.

Pursuant to ASN decision 2011-DC-0213, the site H1 situation should be explicitly studied for all the plant units on the Civaux site.

ASN is going to ask EDF to evaluate the robustness of the Flamanville 3 EPR reactor with respect to complete loss of the primary and alternate heat sinks, and the combination of this with a general electrical power loss situation .

If only one plant unit was affected, ASN considers the EDF's estimate of the time before the heat sink is restored (several days) to be plausible, as the baseline safety standard currently in effect already requires an autonomy of 100 hours for total loss of the heat sink on one reactor.

If all the reactors on a site were to be affected simultaneously, the feedwater volumes (EFWS + SER) would be reduced, as the SER tank is divided between several plant units. The last periodic safety reviews evaluated the autonomy at 24 hours (can reach 2 to 3 days on certain sites).

ASN considers that the times before the core becomes exposed should have been clearly indicated.

ASN will ask EDF to give a qualitative evaluation of the times.

In states where the primary system is not pressurisable, ASN observes that EDF has not calculated a cliff-edge effect for the H1 situation. ASN agrees that the time before the core becomes exposed would be longer in an H1 situation than in a situation of total loss of the electrical power supplies (see § 5.1. of this chapter), due to additional possibilities of making-up the primary system from the PTR tank. More precisely, the times calculated in the "H3" situation are from 70 to 80 hours when the reactor cavity is full; more than one day when the reactor cavity is not full, subject nevertheless to the robustness of the equipment used for H1 management (CVCS pumps, electrical panels, etc.). Reservations on this point are made in the following paragraph.

In states where the primary system is pressurisable, a cliff-edge effect associated with feedwater exhaustion is observed. ASN estimates the time before core exposure, evaluated at several days, to be acceptable given the water quantities regularly observed and prescribed in the operating technical specifications: 100 hours of autonomy if a single plant unit is affected, and at least 24 hours (possibly more) if a whole site is affected. ASN considers that EDF's proposal to re-assess the minimum required water reserves and study additional means of resupplying water is satisfactory.

EDF has not examined in the H1 situation the case where the primary system vents remain open, whereas failure of the vents to close was examined for the H3 situations. Given the additional available sources of make-up for the primary system, such a situation appears to be covered by the "primary system not pressurisable" states.

Assessment of the impact of an H1 situation on the spent fuel pools:

EDF has chosen the operating ranges of APR⁴⁰ or RCD⁴¹ at end of unloading as states that are penalising to consider for an accident situation affecting only one plant unit. This is because it is in these plant unit states that the residual power of the fuel stored in the spent fuel pool is at maximum level.

For the analysis of an accident scenario affecting the entire site, EDF has taken a situation where one of the site plant units is in APR or RCD (states penalising for the spent fuel pools) while the others are under power. EDF also studied the case where a fuel assembly is being handled in the spent fuel pool.

With a single plant unit affected:

Loss of the heat sink induces a total loss of spent fuel pool cooling. The procedure applied in this situation provides for:

- stopping of the fuel handling operations and placing those fuel assemblies actually being handled in safe condition;
- alignment of spent fuel pool make up in priority by SED⁴², then by JPI⁴³.

The other measures aiming at guaranteeing the accessibility of the premises adjacent to the BK hall, and that the pressure in the hall does not rise, are equivalent to those for situation H3 - total loss of electrical power supplies.

Loss of spent fuel pool cooling results in gradual heating of the water. The JPP⁴⁴ system guarantees permanent make up of the spent fuel pool. Throughout this period where topping up is guaranteed, the level of water in the

⁴⁰ APR: Refuelling shutdown

⁴¹ RCD: Reactor completely unloaded

⁴² SED: Reactor demineralised water distribution system

⁴³ JPI: Nuclear island fire protection system

spent fuel pool remains well above the top of the fuel assemblies. There is no risk of reaching the feared situation (exposure of the fuel assemblies). Depending on the residual power in the pool, the autonomy is estimated to be at least one month, a duration that is amply compatible with an external intervention.

With a whole site affected:

The site's autonomy with respect to situations of heat sink loss associated with natural external hazards was verified during the third 10-year inspection of the 900 MW plant units. The target is to have several days' autonomy. The equipment and water reserves available are:

- the SED system and all the SED tanks;
- the JPI and JPP systems.

Operator management of the situation for each plant unit is identical to the preceding case, as the JPI and SED systems remain available.

Kinetics of the phenomenon

The JPP system guarantees permanent topping up of the spent fuel pool. There is no risk of reaching the feared situation (exposure of the fuel assemblies). Throughout this period where make up is guaranteed, the level of water in the spent fuel pool remains well above the top of the fuel assemblies.

Conclusion for one site

As the SED and JPI systems remain available and make-up continues if the heat sink is lost, the fuel assemblies will not become exposed in an H1 situation affecting the entire site. If the JPP is affected (for example in case of heat sink clogging), only the SED system will be able to make up the spent fuel pool in the BK building. In this case the time before the fuel becomes exposed is estimated at a few days in the states where the residual power in the spent fuel pool (APR and RCD states) is at maximum level, and about one week in the other less penalising cases.

For the EPR:

Loss of the primary heat sink leads to the loss of the CCWS/ESWS trains, and therefore loss of cooling of the two main PTR trains.

In states C with the primary system not pressurisable, D, and potentially part of state E45, two EVU trains are required to manage the situation of the boiler. In this case the spent fuel pool is no longer cooled. Topping up with water by a JAC pump aligned on one of the two JAC tanks (1000 m³ and 2600 m³) prevents the exposure of the fuel assemblies. Making up by the JAC enables the water level in the spent fuel pool to be maintained for:

- about four days with the JAC tank of 1000 m³;
- more than 10 days with the JAC tank of 2600 m³.

The time before the fuel assemblies in the storage rack become exposed is about 18 days, which is compatible with an external intervention.

In the other states, the third PTR train, cooled by EVU/SRU, can be started with alignment on the diversified heat sink (outfall structure) in the event of loss of the primary heat sink, to ensure the cooling of the spent fuel pool.

⁴⁴ JPP: Fire-fighting water production system

⁴⁵ State "E" of the EPR: Cold shutdown with reactor cavity full for reloading.

5.2.2 Loss of the primary heat sink and the alternate heat sink

No reactor in operation has an alternate heat sink.

Only the EPR has an alternate heat sink. It comprises two independent systems (EVU and SRU) which themselves are made up of two redundant channels in the pumping station. The SRU system can draw in raw water from the main pumping station ("normal" mode) or from the outfall structure in the sea ("diversification" mode).

EDF has not studied the consequences of loss of the alternate heat sink on the safety of the EPR reactor.

Consequences of loss of the heat sink on the spent fuel pools:

In this scenario, the 3 PTR cooling trains are lost due to the loss of the CCWS/ESWS and EVU/SRU trains.

In states A, B, C with the primary system pressurisable, the 2600 m³ JAC tank is dedicated to replenishing the ASG tank. Making up by JAC gives a time lapse of about four days before the fuel assemblies stored in the rack become exposed, which is compatible with an external intervention.

In states C with the primary system not pressurisable, D, and potentially part of state E, the topping up by JAC enables the level in the spent fuel pool to be maintained for:

- about four days with the JAC tank of 1000 m³;
- more than ten days with the JAC tank of 2600 m³.

The time lapse before the fuel assemblies stored in the rack become exposed is about 18 days, compatible with an external intervention.

In states E and F⁴⁶, making up by JAC enables the level in the reactor cavity to be maintained for:

- more than one day with the JAC tanks of 1000 m³;
- more than three days with the JAC tank of 2600 m³.

The time lapse before the fuel assemblies stored in the rack become exposed is about 5 days, compatible with an external intervention.

ASN observes that for the Flamanville EPR, EDF has not studied the consequences of the successive loss of first the primary heat sink, then the alternate heat sink on the safety of the reactor. This configuration was only studied for the spent fuel pools. This scenario should also have been combined with a total loss of the electrical power supplies.

ASN will ask EDF to conduct complementary studies to assess the consequences of a complete loss of the primary heat sink (ESWS) and alternate heat sink (SRU) of the Flamanville 3 EPR on the damage to the reactor core.

Regarding the assessment of the consequences of heat sink loss on the spent fuel pools, ASN observes that the time lapses before the core becomes exposed are purported to be longer than the time specified in the baseline safety standard: a few days with maximum residual power in the BK building spent fuel pool, and about one week in the states other than APR - RCD. These times seem compatible with an external intervention and with the means that EDF envisages implementing to make an additional water make-up.

If the make-up means are lost, the times and consequences are identical to those for an electrical power loss situation.

⁴⁶ State "F" of the EPR: Cold shutdown with the reactor core completely unloaded. This state is used to carry out work on the primary system components. This state is not to be analysed with respect to reactor core protection.

5.2.3 Conclusion on the planned measures to protect the installations against the risk of losing the ultimate cooling system or the heat sink

In all the configurations studied by EDF, for both the reactors and the spent fuel pools, the estimated time before the feared situation (nuclear fuel exposure) occurs is greater than the required time estimated by EDF to restore correct operation of the heat sink. The identified cliff-edge effects depend on the quantity of feedwater available. Moreover, EDF adds that the time lapse before the core becomes exposed will be much longer in the states where the primary system is open than that calculated for situations of electrical power supply loss (evaluated at several days).

ASN agrees that the time lapses before exposure occurs could be longer in states where the primary system is not pressurisable than in H3⁴⁷ situations, due to additional primary cooling system make-up possibilities. Nevertheless, ASN observes that the EDF's calculations and reasoning imply hazard robustness of the equipment used to manage a whole-site H1 situation. Yet the cliff-edge effects associated with the temperature resistance of the equipment required in H1 situations have not been investigated. Consequently, ASN considers the demonstration of EDF's capacity to manage a lasting whole-site H1 situation insufficient, since the complementary measures implemented rely partly on existing equipment items used in H1 situation management (CVCS pumps, electrical panels, I&C, etc.) which could have been damaged or lost, notably because in this configuration they are no longer cooled and can ultimately become unavailable.

Likewise, in the current baseline safety standard EDF has not defined systematic requirements relative to earthquake resistance and flood protection of the equipment used in H1 situations. Yet ASN observes certain weaknesses in the capacity of the facilities to withstand a whole-site H1 situation induced by an earthquake, including at the level of the current baseline safety standards earthquake, or by flooding beyond the baseline safety standard. In the event of such hazards, ASN considers that the core could become exposed in just a few hours in an H1 situation (for all plant unit states). Likewise, for the EPR reactor, ASN notes that the operability of the SRU system (which is the EPR's alternate heat sink) is not guaranteed in the event of a design-basis earthquake.

In its studies EDF envisages examining the possibility of giving the means for guaranteeing water make up a higher hazard robustness margin than the current baseline safety standard. ASN considers that the proposed improvements - which meet the CSA specifications - must be implemented. ASN will issue a requirement this subject. In case of confirmed insufficiency, ASN will ask EDF to reinforce the robustness of the equipment contributing to the management of a whole-site H1 situation.

Likewise, the the temperature resistance of the equipment situated in areas that are no longer cooled has not been exhaustively verified. ASN considers that certain key equipment items could ultimately be lost through the heating up of such areas. These include:

- the RCV pumps, whose rooms are cooled by a ventilation system that is no longer cooled in an H1 situation;
- electrical or I&C equipment supporting other equipment used in H1 situations;
- the low pressure safety injection (LPSI) pumps used in an H1 situation, while their motors (1300 MWe, 1450 MWe) and the pumps themselves (1300 MWe) are cooled by the CCWS system, which will ultimately be lost in an H1 situation.

⁴⁷ Short-term cliff-edge effects characterised by a shorter time before core exposure than that planned by EDF for the implementation of the FARN have been identified in the H3 situation. This time is a few hours for the 900 MWe series in states with the primary system open - reactor cavity not full (due to the current absence of independent means of injection to the primary system), and about 10 hours with the primary system just open (all plant units). In the primary system open state on the 900 MWe series with the current operating procedure, the time to core exposure in a whole-site H3 situation is about 8 hours (because the pump injecting at the primary pump seals is common to two plant units). Moreover, in the case of an H3 situation combined with loss of the ILS, TPS ASG and TAC/GUS, the time is just a few hours with the primary system closed. In the primary system open states on the 1300 MWe and 1450 MWe series, and in the primary system open and reactor cavity full (all series), the time in an H3 situation (excluding summed effects) is longer (several days).

ASN will ask EDF to supplement its demonstration with a temperature sensitivity study of the equipment items required to manage a whole-site H1 situation and which are situated in areas that are no longer cooled. This study must be carried out considering a representative duration of utilisation of these equipment items in the event of a lasting H1 situation and considering that the entire site may be affected.

More specifically for the spent fuel pools:

ASN observes that the availability of water from the fire-fighting network to make up the spent fuel pools is not guaranteed in the event of an earthquake. In a situation of total loss of the electrical power supplies, this system will not function.

EDF proposes an ultimate backup make-up means specific to each plant unit, which will draw water from the water table or large-capacity ponds using a stand-alone motor-driven pump or an electric pump backed by the ultimate backup diesel generator (DUS). EDF specifies that the study of this ultimate make-up means is planned for the end of 2012.

ASN considers that the proposed improvements, which meet the CSA specifications, must be implemented. It will issue a requirement on this subject.

More specifically for the EPR:

The cooling system of the EPR reactor spent fuel pool has a third cooling train. The heat sink of this third train is independent and should therefore remain functional if the heat sink common to the main two cooling trains is lost. In all the reactor operating ranges, the spent fuel pool can be made up by the fire-fighting system. This fire-fighting system is also used when necessary to replenish the tanks of the auxiliary feedwater supply to the steam generators. It must therefore be available in all the reactor operating ranges.

In the framework of Flamanville 3 EPR commissioning examination, ASN will ask EDF to present its maintenance and management strategy for the systems shared between the spent fuel pool and the reactor (such as the fire-fighting water system) in order to minimise their temporary unavailability.

Capacity of the site to manage an accident involving heat sink loss:

Managing an H1 situation involves many actions, some in the control room but above all locally. EDF provides little information on how they are performed, given the ambient conditions in the premises, their accessibility, and the human resources available to implement them on all the plant units.

Furthermore, means evaluated in an H1 situation are planned to be used by EDF as part of the complementary measures to prevent severe accidents. **ASN considers that EDF must back up its conclusions regarding the capability of the NPPs to manage a degraded situation (H1 or H3) on several plant units simultaneously, including when a plant unit suffers a severe accident. If necessary, EDF will define additional provisions for the management of this situation. ASN will issue a requirement on this subject.**

These requests are applicable to the reactors in service and to the EPR.

5.2.4 Measures envisaged to increase the robustness of the facilities with respect to loss of the ultimate cooling system / heat sink

ASN asked EDF to "indicate what measures could be envisaged to prevent or delay the onset of these cliff-edge effects, to improve the site's autonomy and increase the robustness of the facility (design change, change in procedures, organisational arrangements, etc.)."

For the reactors in service, EDF proposes measures to increase the time lapses before the core becomes exposed. EDF proposes increasing the on-site water reserves (to supply the feedwater system, the primary cooling system and the spent fuel pool) as a complement to the FARN, which will then take over.

Ultimate make-up means for all the reactors:

EDF proposes implementing an ultimate make-up means by pumping water from the water table or large-capacity ponds using a stand-alone motor-driven pump or an electric pump backed by the ultimate backup diesel generator (DUS). This system will be a fixed installation on all the sites and will allow the make up of the EFWS and PTR tanks and the spent fuel pools (before 2015). EDF has confirmed that the make-up means and its supporting systems will be dimensioned for the needs of the entire site. The output will be sufficient to supply the spent fuel pool building (BK) and either the EFWS tank or the PTR tank simultaneously.

Ultimate make-up means from the demineralisation plant water supply system (SEA) ponds (Paluel, Penly and Flamanville sites)

The demineralisation plant water supply system (SEA) ponds at the Paluel, Penly and Flamanville sites are situated on the cliff (total capacity of 150,000 m³ at Flamanville, 36,500 m³ at Penly and 36,000 m³ at Paluel). The CSA reports for Flamanville 1-2 and 3 and Penly 3 indicate that the ultimate make-up will be made from these ponds. For Penly 1-2 and Paluel, an ultimate make-up means by pumping water from the water table or tanks is mentioned but not detailed. During the examination, EDF pointed out that for these three sites (all plant units), the ultimate make-up would be provided by the existing SEA ponds.

These ponds are not included in the safety demonstration at present, therefore they are not safety-classified and have no seismic requirement. EDF nevertheless indicates that they are stable under the stresses of the SSE (safe shutdown earthquake), and even beyond. The ponds are connected to the demineralisation plants by two pipes (SEI - industrial water system) which are not designed to withstand an earthquake at Flamanville and Paluel but are at Penly (level not specified). The risk of rupture of the SEI pipes is studied for Flamanville and Paluel, as EDF considers that the consequences of complete emptying of the ponds are acceptable with respect to the flood risk (water retained in the galleries and turbine halls). As regards the ultimate make-up function of the ponds, EDF indicates that it will make the valve chamber and the SEI pipes earthquake resistant at Flamanville (not specified for Paluel).

ASN considers that if the SEA ponds and the SEI pipes and valves are to be part of the ultimate defence against H1 situations, or even a severe accident, including situations induced by an earthquake exceeding the baseline safety standard, they must be included in the "hard core" of tightened material and organisational provisions.

Ultimate make-up means at Civaux and Cattenom

These sites have large water reservoirs which constitute the backup heat sink (ponds at Civaux giving an autonomy of 10 days, Mirgenbach lake at Cattenom giving an autonomy of 30 days). ASN emphasizes that the earthquake-resistance stability of the Mirgenbach lake dam at Cattenom "presents moderate margins beyond the SSE" according to chapter 4 of the CSA reports. For these sites like the others, the CSA reports mention the implementation of long-lasting ultimate water make-up means (pumping from the water table, ponds, etc.) for the EFWS and PTR tanks and the spent fuel pools.

ASN considers that the characteristics of the ultimate means envisaged by EDF must satisfy the requirements assigned to the systems, structures and components of the "hard core" of tightened material and organisational provisions.

Particular case of the Flamanville 3 EPR

The complementary measures envisaged by EDF concern, among other things, the ultimate make-up of the EFWS tanks and the spent fuel pool with water from the ponds of the demineralisation plant water supply system (SEA), and reinforcement of the ultimate backup diesel generators. The ultimate water make-up solution for the spent fuel pool envisaged by EDF by gravity feed from the SEA ponds could compensate for the evaporation losses and enable a minimum water level to be maintained once the JAC water reserves are exhausted. The autonomy provided by the ponds considerably increases the time lapse before the fuel assemblies stored in the rack become exposed. For the whole-site situation, pooling of water reserve utilisation is envisaged, which will reduce the gain in autonomy compared with the single plant unit situation.

ASN considers that these water supply reinforcement measures, in their principles are likely to enhance the robustness of the facilities. They have the advantage of reinforcing and increasing the autonomy of the means of making up the primary and secondary cooling systems with the aim of coping with lasting site H1 situations, not taken into account in the current baseline safety standard. **ASN considers that this ultimate make-up means must have substantial autonomy and function in a situation of total electrical power supply loss. ASN considers that the other safety objectives of this ultimate make-up means are:**

- to be functional at the natural hazard levels considered in the CSAs,
- to be able to be implemented under the particular conditions that may be present on the site, especially skyshine irradiation from the fuel stored in the BK building spent fuel pit (low water inventory),
- to be able to be implemented within a time scale compatible with the envelope scenario considered,
- to allow boration of the water injected into the primary system.

ASN will issue a requirement on this subject.

ASN draws attention to the fact that the quality of the make-up water must be compatible with its used by the safety equipment (EFWS pumps, EVU spray nozzles on the Flamanville 3 EPR, etc.) and that the necessity to constitute a stock of boron for the replenishing of the PTR tank will have to be studied.

The risks that wells descending into the water table could represent in the event of a severe accident will also have to be taken into account.

EDF is taking other complementary measures:

- EDF has indicated that it was defining a "hard core" of equipment items comprising a limited number of structures, systems and components strictly necessary for the management of a whole-site H1+H3 situation, and therefore the safety objective is to prevent large radioactive releases into the environment. EDF has specified : "this hard core will include key existing and complementary equipment items (fixed or mobile), some of which serve to prevent entry into a severe accident (SA) condition (severe accident prevention)".
- EDF will verify the adequacy of the current water reserves of the auxiliary feedwater system (EFWS) for the steam generators (in 2012);
- EDF undertakes to reassess the minimum thresholds of the TS for the SER tanks in order to guarantee the targeted autonomy;
- EDF undertakes to implement additional pumping means for making up the primary and secondary cooling systems
 - motor-driven cooling pump in the primary system open states on the 900 MWe series,
 - ultimate backup diesel generator (DUS) to supply one CVCS pump and one EFWS motor-driven pump on all the reactor series.
- EDF envisages installing a motor-driven cooling pump for injecting water into the core from the PTR tank in situations of total loss of the electrical power supplies (before 2015);
- EDF envisages installing an ultimate backup pumping unit specific to each plant unit and having an ultimate make-up means that will draw water from the water table or from large-capacity ponds to enhance the reliability of the spent fuel pit top-up function;
- EDF will conduct studies and make operating procedure changes to limit the risk of a breach at the primary pump seals if their cooling is lost.

Specifically for the EPR reactor, EDF plans:

- to reinforce the facilities' robustness against flooding
- limit water ingresses via the slabs in the pumping station and outfall structures. This provision concerns the EFWS, JAC, SEC and SRU systems used in H1 situations.

ASN considers that these planned improvements will enhance the robustness of the facilities, even though it may express some reserves or require additional information regarding their appropriateness or application in certain cases.

One ASN reserve concerns EDF's proposal to use existing equipment (CVCS or SIS pumps, electrical panels, EFWS equipment, PTR tank, etc.) as part of the complementary measures, knowing that some of these equipment items may have been damaged or lost. In effect, robustness to hazards beyond the baseline safety standard is not guaranteed. As an example, the ultimate make-up means (pumping from the water table or reservoirs) powered by the new ultimate backup diesel generator will be used to supply the secondary system via the ASG tank, the lines and an existing motor-driven ASG pump, and to supply the primary system via the PTR tanks and the existing lines. It is important for EDF to guarantee their robustness, taking into account:

- the reliability, hazard robustness and ease of use of the additional equipment;
- the risks of common mode failure (associated for example with an induced internal hazard) or common cause failure (associated with the design, production or maintenance...) between the key existing equipment items and those added as part of the additional measures;
- the risks of failure - whether intrinsic or associated with a hazard - of the existing equipment that EDF proposes to reuse as part of these ultimate defence measures (electrical panels, RCV pumps, ASG equipment, etc.).

ASN considers that the complementary measures proposed by EDF for the whole-site H3 situation provide robustness with respect to the H1 situation (less degraded) and cover failure of the means used specifically in this situation. However, with a defence-in-depth approach, it is important to prevent an H1 situation from evolving irreversibly towards more a severely degraded situation (whole-site H3) in which the consequences can no longer be mitigated by a small set of equipment.

With this aim in view, ASN considers that EDF must start reflecting on the development of its baseline safety standards, in the light of the Fukushima experience feedback, to integrate the lasting whole-site H1 situation.

ASN considers it necessary for EDF to examine the temperature resistance of the "key" equipment situated in premises where the ventilation system is no longer cooled in the event of lasting loss of the heat sink for the entire site.

To enable the complementary measures to provide a robust ultimate line of defence against the cliff-edge effects identified in the CSA reports for whole-site H1 situations, and notably those induced by an earthquake or flooding beyond baseline safety standards, EDF must, when it defines the hard core equipment items, look for new measures that are independent and diversified with respect to the existing means, including in their supporting systems in order to minimise the risks of common mode failure between the existing means and the complementary means.

In particular, EDF must look for easy-to-use and robust injection means situated as close as possible to the steam generators and the primary cooling system (rather than have the ultimate make-up means depend on the reliability of the RCV pumps, whose temperature resistance displays uncertainties).

ASN considers it necessary for EDF to install hazard-resistant backup systems that can continuously remove the residual power in the event of total loss of the heat sink.

ASN also considers it necessary for EDF to propose reliable and hazard-resistant means of injecting borated water into the reactor core.

For the EPR, ASN will ask EDF for complementary studies of SRU system reinforcement in "diversification" mode (that is to say with intake from the sea outfall structure rather than the main pumping station, as is the case in normal mode), given the high probability of having to switch to this mode in an accident situation.

ASN considers it necessary to implement EDF's proposal to constitute a hard core of material and organisational measures, associated with tightened requirements, to prevent a degraded situation (type H1) from evolving into a severe accident. Complying with this requirement will lead EDF to:

- define the list of necessary structures, systems and components (SSC) to prevent core meltdown in lasting whole-site H1 or H3 situations;
- demonstrate the earthquake and flood robustness of its SCCs and implement any necessary additional measures to ensure this robustness;
- make an additional verification of the robustness and accessibility of these SCCs, considering the hazards and effects induced by an earthquake or flood beyond the current baseline safety standard.

ASN considers it necessary for EDF's proposals relative to the equipment items included in this hard core to meet the requirements set forth above, and must notably be dimensioned to withstand hazards of a higher intensity than those considered in the existing baseline safety standards.

Once EDF has defined the "hard core" elements targeted for greater robustness against risks exceeding the baseline safety standard, (see section 16), ASN will ask it to revise its baseline safety standard in the light of the Fukushima experience feedback and start examining the robustness - against the baseline safety standard risks - of those equipment items that are not included in the "hard core" but nevertheless used in whole-site H1 situations.

These demands are applicable to the reactors of the fleet in operation and to the EPR.

Medium- or long-term accident management:

The complementary measures proposed by EDF with respect to H1/H3 situations aim essentially at allowing water make-ups to be made (to the secondary system, primary system and spent fuel pools) to extend the autonomy of the reactors and spent fuel pools. Making these make-ups, when it is not possible to restore a cooling system, enables core meltdown to be delayed but not necessarily prevented. In the case of the primary system, once a certain volume of water has been injected into the reactor building, the ability to restore lasting means of cooling may be compromised. ASN insists on the necessity to ultimately restore a cooling system in order to reach a safe condition, on the existing plant units and the Flamanville 3 EPR alike (the "EVU spraying of SEA water" modification brings only a limited additional time margin), and to integrate this necessity in the strategy of the FARN48.

EDF must study the means for ultimately restoring lasting cooling of the reactors and spent fuel pools, using elements from the Fukushima accident experience feedback, including in cases where the heat sink has been seriously damaged.

Lastly, the FARN activation criteria in the event of a hazard or accident, and the dimensioning of the associated means, will have to be adapted to enable the FARN to effectively take over management of all the postulated accident situations (all reactor states considered) and thus avoid core exposure. It would moreover be pertinent for the FARN's reflections to focus more generally on the means of ensuring or restoring the safety functions in the medium/long term, independently of specific accident scenarios.

5.3 Loss of the main cooling system combined with loss of the off-site electrical power supplies and the on-site backup supplies

For each reactor, ASN has asked EDF to:

- indicate for how long the site can withstand loss of the "main" heat sink combined with loss of the off-site electrical power supplies and the backup energy sources, without external aid, before serious damage to the fuel becomes inevitable;

⁴⁸ See § 6 of this chapter.

- indicate what external action is planned to prevent fuel damage to the fuel, and the resources available:
 - equipment already on the site, for example equipment from another reactor;
 - equipment available off the site, assuming that all the reactors on a given site have suffered damage;
 - the availability of human resources;
- indicate the times within which the above resources can be available;
- identify the time within which the main cliff-edge effects occur;
- indicate what measures can be envisaged to prevent these cliff-edge effects or to increase the robustness of the facility (design change, change in procedures, organizational arrangements, etc.).

ASN has asked EDF to take two situations into consideration for the loss of the off-site electrical power supplies and the on-site backup supplies:

- loss of the off-site electrical power supplies and loss of the conventional backup supplies (safeguard means in particular);
- loss of the off-site electrical power supplies and loss of the conventional backup supplies , and any other emergency source (including the ultimate backup means).

ASN has asked EDF to take into consideration the loss of the main cooling system combined with total loss of the off-site and backup electrical power supplies, considering initially that only one reactor is affected, and in a second phase that all the facilities of a given site are affected simultaneously.

Loss of the main cooling system combined with total loss of the off-site and backup electrical power supplies is not analysed for the baseline safety standard.

EDF specifies in the CSA reports that the situation of total loss of the heat sink combined with total loss of the electrical power supplies has no additional impact compared with the total electrical power loss alone: as the pumps of the intermediate cooling system (CCWS) are supplied by the backed-up electrical panels, the loss of the electrical power supplies intrinsically causes total loss of the heat sink.

EDF has also pointed out that the impact of an earthquake or a flood on these combined situations has been examined in the CSA reports.

ASN observes that EDF has analysed loss of the main cooling system combined with loss of the off-site electrical power supplies and loss of the conventional backup power supplies. Nevertheless, in its CSA reports EDF has not analysed the loss of the main cooling system combined with loss of the off-site electrical power supplies and loss of the conventional backup power supplies and any other emergency source. ASN considers it necessary for EDF to adopt a position regarding the missing assessment.

5.3.1 Site autonomy before loss of the normal conditions of core and fuel pool cooling

EDF specifies in the CSA reports that from a thermohydraulic viewpoint, this situation is identical to that described in the paragraph relative to loss of the off-site electrical power supplies and the conventional backup power supplies (see § 5.1.2).

ASN does not question EDF's conclusions, but nevertheless notes that this combined situation is more penalising with regard to the recovery of the support functions, since it is not enough to simply recover an electrical power supply - it is also important to restore a heat sink.

5.3.2 External actions planned to prevent damage to the fuel

Regarding the external actions planned to prevent damage to the fuel, EDF has specified in the CSA reports that in terms of facility management, the situation evoked is identical to that described in the paragraph relative to loss of the off-site electrical power supplies and the conventional backup power supplies (see § 5.1.2).

The planned external actions for managing loss of the main cooling system combined with loss of the off-site electrical power supplies and the on-site backup supplies examined by EDF in its complementary safety assessments correspond to the requirements of ASN decision 2011-DC-0213.

5.3.3 Measures envisaged to reinforce the robustness of the facilities with respect to loss of the main cooling system combined with total loss of the off-site and backup electrical power supplies

Regarding the measure that could be envisaged to prevent cliff-edge effects or reinforce the robustness of the facility, apart from the measures proposed in case of loss of the off-site electrical power supplies and the conventional backup supplies described earlier, and apart from the measures presented in the preceding paragraphs, EDF has proposed in the CSA reports:

- to study the means of guaranteeing protection of the equipment necessary for the management of this situation with a flood level (to be defined) that goes beyond the baseline safety standard;
- to undertake studies to ensure the earthquake resistance of the motor-driven cooling pump, which will allow the same autonomies as considered in the paragraph relative to the loss of the off-site electrical power supplies and the conventional backup supplies to be obtained;
- to ensure the earthquakes robustness of the measures envisaged in the paragraph relative to the loss of the off-site electrical power supplies and the conventional backup supplies (see § 5.1.2) to cover the present situation.

During the technical examination carried out by the IRSN, ASN's technical support organization, EDF also gave a commitment to define a hard core that will include "key" existing and complementary equipment items (fixed or mobile), some of which serve to avoid severe accidents. The resistance of this hard core equipment with respect to certain hazards, the level of which remains to be defined, will be verified. Measures to reinforce the protection of the hard core equipment will also be envisaged if necessary.

ASN considers that the improvements proposed by EDF to reinforce the electrical power supply and cooling resources, which comply with the CSA specifications, must be implemented.

ASN will require EDF to identify this hard core of reinforced material and organisational provisions, and the requirements it must satisfy.

6 Severe accident management

This chapter presents the organisational and material measures implemented by EDF to managing severe accidents (SA). Severe accidents are characterised by significant damage to the fuel in the reactor building or the fuel building.

In order to fulfil the duties incumbent upon it in an emergency situation, the licensee must have a robust organisation, particularly for the extreme situations studied in the context of the Complementary Safety Assessments (CSAs). ASN will therefore instruct EDF to integrate in the hard core provisions (see § 8), the elements vital for emergency management, that is to say the emergency management rooms, the necessary material resources, the communication means and the technical and environmental instrumentation. ASN will also ask EDF to include in the hard core the operational dosimetry, measuring instruments for radiation protection, and the personal and collective protection equipment.

The emergency management premises shall be designed to deal with hazards beyond the current baseline safety requirements. They shall be accessible and habitable during long-duration emergencies and be designed to accommodate the crews necessary for the long-term management of the site. The control rooms are also vital for emergency management, therefore it is important that their accessibility and habitability should permit the management and monitoring of all the site reactors if hazardous or radioactive substances are released.

ASN will also prescribe the implementation of an emergency response system comprising specialised teams and equipment, capable of taking over from the personnel on a site affected by an accident and of deploying additional emergency response resources within 24 hours, with operations starting on the site within 12 hours from the time of call-out.

The Fukushima accident proved that an external hazard could affect several facilities on a given site simultaneously. In the light of the CSAs, ASN considers that the EDF's current emergency organisation does not take sufficient account of this possibility. ASN will therefore ask EDF to supplement its emergency organisation so that it can manage a "multi-facility" event. On sites with several licensees, it is also important that they coordinate emergency management and limit the impact on the neighbouring facilities. An instruction will be issued in this respect, demanding the reinforcement of coordination between the licensees and operators of nuclear and non-nuclear facilities alike.

Moreover, ASN considers that at present the means of limiting releases in the event of core meltdown are not sufficiently robust for the levels of risk considered in the CSA. In the same way as for the prevention measures, ASN will require EDF to define a series of measures to limit releases in the event of a severe accident resulting from risks of a higher level than those considered in the current baseline safety standard. EDF shall in particular propose improvements to the venting and filtration system in order to improve its robustness and its effectiveness. EDF shall continue with its studies into the prevention of the pollution of groundwater and surface waters in the event of a severe accident with core melt.

Regarding the spent fuel pool, given the difficulty or even the impossibility of deploying effective means of mitigating the consequences of prolonged exposure of the fuel assemblies, ASN will require EDF to define and implement tightened measures to prevent the fuel assembly exposure.

6.1 Licensee's accident management organisation and measures

6.1.1 Licensee's accident management organisation

In the CSA specifications ASN asked EDF to present its emergency organisation for managing accident situations, including the availability of competent personnel capable of intervening, shift management, measures taken to optimise personnel intervention (consideration of stress, psychological pressure, etc.), recourse in accident situations to outside technical support (and alternative solutions should this support become unavailable), as well as the procedures, training, and exercises.

In its CSA reports, EDF describes the site emergency organisation planned to respond to incident, accident or severe accident (SA) situations. This organisation is described in the site On-Site Emergency Plan (PUI), which is required by the regulations and devised to cover situations presenting a significant risk for the safety of the facilities, and which can lead to the release of radioactive, chemical or toxic substances into the environment. The PUI covers the management of SAs. It also describes the measures designed to aid and protect the persons present on the site, preserve or restore the safety of the facilities and limit the consequences of accidents for the public and the environment. The PUI defines the functions necessary for managing the emergency and the conditions of shift relief.

EDF also describes the diverse provisions of the PUI to ensure optimised personnel intervention:

- Personnel safety: the staff shall be grouped at assembly stations in order to count and inform them. EDF indicates that the means implemented in normal operation to monitor radiological conditions on the site and to monitor the personnel remain operational and adapted to the conditions that can exist in SA situations, except in the event of total loss of electrical power. Lastly, if the site is contaminated, control room ventilation is switched to iodine traps to prevent it being contaminated by radioactive iodine;
- Emergency team preparation and speed of response: immediate action shall be taken following occurrence of the SA, in direct application of the operating procedure documents;
- Intervention: the mobile devices implemented under the PUI are stored and routed so as to limit personnel exposure during assembly and utilisation of the devices in an accident situation.

The outside technical support resources the sites can call upon is also described in the CSA reports. They can for example be provided by Intersite Assistance, AMT-C (EDF's Thermal Maintenance Agency - Centre), Groupe INTRA, etc. The conditions of mobilisation and intervention of these resources form the subject of agreements between the sites and the entities on which they depend.

The procedures implemented in the management of SAs, the training and exercise drills are also detailed in the CSA reports. These three points form part of the GIAG (Severe Accident Intervention Guide) and the sites' PUI baseline. In practice the initial operator training syllabus presented by EDF already includes a part devoted to "Severe Accidents", and exercises simulating SA situations are held regularly. Certain national PUI exercises can therefore be based on scenarios simulating entry into the SA domain. The internal PUI exercises held by EDF cover all the domains, design accidents, fuel building (BK) incidents and severe accidents.

EDF moreover indicates that it has analysed the sizing of the operating teams for application of the current severe accident management procedures, particularly for events affecting several reactors. EDF indicates that in this context it has postulated the situation where it is impossible for the on-call teams to reach the site for the first 24 hours following an unpredictable large-scale hazard affecting the entire site. EDF concludes from these analyses that the sizing of the operating teams, in conformity with the current baseline, does not always allow application of the SPE (permanent surveillance document), and notably the surveillance of the criterion for opening the pressuriser relief lines (LDP) in the event of a severe accident affecting two reactors. This finding led EDF to study the appropriateness of the human and material resources for the deployment of the hard core equipment items (including the immediate measures specified in the GIAG) and the additional equipment proposed further to the CSAs. The main steps involved in this study, the conclusions of which are scheduled for the end of 2012, are:

- listing of the duties to accomplish (emergency management, control of the facilities, etc.) on all the reactors of a site;
- listing of the activities to carry out with their main characteristics, such as duration, conditions of interventions, etc.;
- identification of the additional material resources to be implemented, taking their utilisation constraints into account from the design stage;
- final verification of the suitability of the human resources (numbers and skills) for all the activities to be carried out;
- identification of any additional training needs.

ASN considers that the emergency organisation implemented on the sites is satisfactory for the design-basis scenarios affecting a single installation. Nevertheless, EDF's current organisation and studies do not sufficiently address the management of a "multi-facility" emergency, possibly resulting from an external hazard, affecting all or part of the installations of a given site simultaneously and at different levels. **In such a situation, ASN considers that the operating and emergency teams must be of adequate size to ensure all their duties on all the site's installations. ASN will therefore require EDF to supplement its organisation to take into account accident situations affecting all or part of the facilities of a given site simultaneously.**

ASN also considers it necessary, assuming an extreme situation of one of the types studied in the CSAs, for EDF to guarantee for each reactor the feasibility of all measures planned for in the operating documents (accident operating procedures, GIAG) with the operating and emergency teams present on the site, taking into account the necessary shift reliefs. ASN will issue a requirement on this subject.

6.1.2 Possibility of using existing equipment

In the CSA specifications ASN asked EDF to address the following aspects of severe accident management: the possibility of using existing equipment, the provisions for using mobile devices (availability of such devices, time required to bring them to the site and put them into operation), the management of supplies (fuel for diesel generators, water, etc.), the management of radioactive releases and provisions to limit them, and the communication and information systems (internal and external).

– Possibility of using existing equipment:

For the use of existing equipment, EDF indicates in the CSA reports that the equipment used is generally the SA-specific equipment and, if conditions permit and its use is compatible with the containment control objective, non-SA-specific equipment. There is a limited number of equipment items specific to the SA domain on the EDF sites. The measures required by the GIAG are predetermined and limited. They are based on the use of existing equipment items which are also predetermined and limited. Any other equipment utilisation or measure that might be requested by the National Emergency Organisation shall be jointly appraised by the various emergency teams to check that it is not of a prejudicial nature (particularly with regard to containment).

ASN observes that as a general rule, the current baseline safety standard contains no hazard-resistance requirements for the SA-specific equipment (equipment and instrumentation). **Consequently, EDF cannot guarantee the availability of existing equipment in the extreme situations studied in the CSAs. ASN will require EDF to integrate the equipment necessary for emergency management, including the SA equipment, into the "hard core" (see § 8).**

Furthermore, experience feedback from the Fukushima accident leads to questioning of the permanent availability and operability of the dosimetry and radiological protection equipment. **ASN considers that the active dosimetry means, the measuring instruments for radiation protection and the personal and collective protection equipment must be permanently available on the sites and in sufficient quantity. ASN will issue a requirement on this subject.**

– Provisions for using mobile devices:

EDF indicates in the CSA reports that at present there is no specific national mobile device for severe accident management. There is however a local mobile device planned specifically for such situations: a processing unit for the plant unit radiation monitoring system (KRT) U5 for measuring the activity released during containment decompression by the venting-filtration system U5. Other mobile devices not specific to severe accident management can also be used if they have been set up before entry into the SA condition and if their operation is not contrary to the severe accident management objectives. As a general rule, the mobile devices called upon to manage all types of accident situation must be made available in predetermined times and conditions. Each site defines the organisation for putting into service and operating the mobile devices and guaranteeing their availability. To guarantee the availability of these devices, each one has a specific sheet describing its identification, its purpose, where it is stored, the service responsible for it, the duty function to contact for its

deployment, the time necessary for its deployment, the required assembly processes and the associated list of periodic tests. To verify the permanence of availability of these devices and the resistance of the premises in which they are stored, EDF undertakes for each site to appraise the emergency equipment storage conditions and their resistance to the various types of hazard considered in the CSAs. This study will identify the required reinforcements.

ASN considers that the study proposed by EDF will provide useful information for assessing the resistance of the emergency equipment storage premises. Moreover, during its inspections ASN observed that the equipment necessary for emergency management, and in particular the MMS (mobile safety equipment), the PUI equipment and the MDC (complementary domain equipment), was not managed satisfactorily by the sites and that the storage conditions did not guarantee permanent availability, particularly in the event of external hazards. **For ASN, the equipment necessary for emergency management must be included in the "hard core" of tightened material and organisational provisions (see section 16). The devices, their storage places and deployment procedures must be identified in the site PUIs. They must be tested regularly, and training in their deployment must be provided during exercises. ASN will issue a requirement on this subject.**

– Management of supplies for the diesel generators:

In the CSA reports, EDF presents information on the autonomy of the diesel generators and the provisions for extending their utilisation in the event of loss of off-site power (LOOP). This point is detailed in paragraph 5 of this chapter.

The minimum guaranteed autonomy for fuel is 3.5 days per generator set in the least favourable load conditions. The conditions of supply are covered by a national contract, which provides for delivery within 24 hours in emergency situations. Strategic reserves of fuel are held specifically by EDF.

The sites have sufficient oil reserves to guarantee an autonomy of more than 3 days. Beyond this, supply is guaranteed by measures specific to each site.

For all the plant series, the initial water reserves for cooling the diesel generators are sufficient to ensure two weeks' autonomy. Diesel generators have an independent air-water cooling system. Each diesel generator has a compressed air reserve that allows 5 start-ups.

ASN considers that the supply management methods are capable of guaranteeing 3 days autonomy for the generator sets. ASN considers that EDF must ensure the reliability of the on-site fuel and oil stocks and their replenishment under all circumstances to ensure at least two weeks' autonomy (see § 5).

– Management of radioactive releases and measures to limit them:

In the CSA reports EDF describes the measures implemented on the sites to manage and limit radioactive releases. The requirements relative to containment monitoring are thus set out in a procedure applied by the safety engineer in an accident situation before entry into a severe accident condition, and in a containment monitoring guide used by the emergency teams. In a severe accident situation, this containment monitoring guide remains applicable and takes priority over all the other measures demanded in the severe accidents management guide. Detection of containment deficiencies is signalled by high activity measurements on the plant radiation monitoring systems (KRT).

EDF states that it has put in place extensive prevention means that reduce the probability of SA situations occurring, and means to mitigate their impact on man and the environment. When the residual power can be removed from the reactor containment, releases into the environment are limited. In this case the releases come from potential leaks from the reactor containment.

The reactor containment is described in § 1.1.2. This containment is designed to withstand 5 bars absolute pressure for all the plant series, and its resistance is verified every 10 years.

Furthermore, concerning the reactors in operation, the venting-filtration system U5 (described in § 6.2.2), reserved for the ultimate safeguarding of the reactor containment, once the gas plume induced by its opening has gone, enables the off-site radiological consequences to be limited. This system, which filters the aerosols that form in the reactor containment in the event of loss of reactor vessel or primary cooling system leaktightness, retains a large proportion of the radionuclides. If U5 is opened, the population protection measures would be implemented around the nuclear site during the radiological emergency phase. To limit iodine releases and reduce the radiological impact on the site and the populations in a severe accident situation, EDF indicates in the CSA reports that it plans studying a passive device for increasing the pH in the reactor building sumps, including in a situation of total loss of the electrical power supplies (SBO - site blackout).

As the earthquake was not considered a plausible severe accident initiating event at either the design stage or during the periodic safety reviews (see § 6.1), given all the design measures taken on the structures, systems and components classified for safety, the U5 system components - apart from the containment penetration and the isolation valves - are not seismic classified. The U5 system sand filter was therefore not subject to specific requirements with respect to the seismic risk when it was installed. Consequently, this system could, in the event of an SA further to an earthquake, cease to be operational or even become prejudicial for other safety-classified equipment items. **EDF has undertaken to conduct a study on the earthquake resistance of the U5 system. It has also announced the launching in a second phase of a broader reflection on the U5 system filtration that could, if necessary, lead to changes in this system in the longer term. ASN will issue a requirement on this subject.**

Insofar as they were not subject to specific design requirement with respect to external hazards, ASN considers that at present, the means for limiting releases in the event of core meltdown are not resistant to the hazard levels adopted for the CSAs, particularly for earthquake levels exceeding the design-basis earthquake. The changes resulting from the studies announced by EDF will have to guarantee the resistance of these means. **ASN will thus require EDF to carry out a detailed study of the possibility of improving the U5 venting-filtration system, taking into account hazard robustness, filtration efficiency if used on two reactors simultaneously, the improvement in the filtration of the fission products, especially iodine isotopes, and the radiological consequences of opening, notably on accessibility of the site, of the emergency management rooms and of the control room.**

– The communication and information systems (internal and external):

In the CSA reports, EDF gives the communication objectives and principles applied to ensure on-site communication between the emergency teams and the grouping areas, and communication with the off-site players. The objectives of these systems are to alert the on-site and off-site players as quickly as possible (EDF staff and public authorities alike), to alert the populations if a reflex response phase PPI (off-site emergency plan) criterion is attained, to exchange information with the various emergency management centres both on site and off site, and to inform the public and the medias.

EDF indicates that the means of communication used when deploying the organisation can be deficient (either following immediate degradation as a result of an initiating event, or by exhaustion of the batteries ensuring their operation). To enhance the reliability of these various means of communication, EDF undertakes to study the reinforcement of the strategic connections by communication means that have greater autonomy and are resistant to earthquakes and flooding (i.e. totally independent of hard-wired communication links). The aim is to equip the emergency management rooms with satellite-link telephones with greater autonomy enabling the shift operations supervisor to give the alert, the local and national players to establish or continue their communications, and the FARN (nuclear rapid intervention force) - if it should be required to intervene - to establish contact with the on-site participants. The FARN is a national EDF entity currently being set up, which will be capable of rapidly providing material and human aid to a site in serious difficulty. This entity is described in greater detail in the paragraph "*Extensive destruction of infrastructures around the facilities*" below.

ASN considers that communication is a primary element in emergency management and that it is essential for EDF to be able to alert the public authorities and, if delegated power by the prefect, to alert the populations in order to protect them, inform on-site personnel of the situation, particularly if the site has to be evacuated, and

to communicate with the on-site and off-site emergency teams, whether local or national. **ASN will thus require EDF to integrate the communication means vital for emergency management in the "hard core" of reinforced material and organisational provisions. These means will include the means for alerting the public authorities and the population alert systems if the off-site emergency plan is triggered in the reflex response phase. They will also have to be made resistant to the extreme situations studied for the CSAs.**

6.1.3 Identification of factors that can hinder accident management and the resulting constraints

In the CSA specifications, ASN asked EDF to evaluate the envisaged accident management measures considering the situation such as it could occur on the site:

- extensive destruction of infrastructures around the facility, including the means of communication (making technical support and personnel reinforcement from outside the site more difficult);
- the disruption of work efficiency (including the impact on the accessibility and habitability of the main and secondary control rooms, the premises used by the emergency teams and any area required to be accessible for accident management) caused by high dose rates in the rooms, by radioactive contamination and the destruction of certain facilities on the site;
- the feasibility and efficiency of the accident management measures in case of external hazards (earthquakes, flooding);
- electrical power supply outage;
- potential failure of the instrumentation;
- the impact of the other neighbouring facilities on the site.

– Extensive destruction of infrastructures around the facility:

With regard to the envisaged accident management measures in the event of extensive destruction of the infrastructures around the facility, EDF indicates in the CSA reports that its emergency organisation does not include a specific response structure for this situation, nor to clear the site. In the event of major damage to roads and civil engineering structures, EDF calls upon the public authorities who, in addition to the PPIs specific to the emergency situation, implement the provisions of the "ORSEC" national emergency response plan. The aim of these provisions is to facilitate site access for the duty teams.

To cope with the extreme case of total defaulting of the duty personnel or failure of the communication means (particularly with the exterior) used during deployment of the emergency organisation, EDF indicates that it is currently conducting complementary studies on:

- reinforcing the skills of the operating team so that it can take the necessary minimum measures to prevent or delay core meltdown;
- reinforcing the communication links by having communication means with greater autonomy and which are earthquake- and flood-resistant;
- the creation of a Nuclear Rapid Intervention Force (FARN);
- taking into consideration the working conditions of the operating personnel, the on-call personnel and the FARN. They must be able to guarantee the health and safety of the workers. The psychological aspect is taken into account.

In the CSA reports, EDF presents the broad lines of the requirements applicable to the FARN. EDF thus plans for the FARN to be able to:

- intervene within 24 hours, in continuity and replacement of the operating teams that will have fulfilled the emergency measures for the site concerned and whose access infrastructures may be partially destroyed;

- work autonomously for several days on a partially destroyed site (non-seismic tertiary buildings, for example), whose environment could be radioactive, and - on some sites - possibly affected by chemical pollution;
- deploy heavy-duty protection or intervention means within a few days;
- ensure a permanent link with company management, site management and teams, and the local authorities in order to manage and coordinate the interventions;
- prepare for continuation of the intervention beyond the first days of autonomy in the event of a long-lasting emergency.

ASN considers that EDF has not finished analysing the weak spots in the organisation according to the scale of the external hazard that led to the emergency situation. Consequently, ASN will issue several requirements concerning:

- **the defining of the human actions required for the management of the extreme situations analysed in the CSAs, including situations affecting several reactors and those that could have consequences on the accessibility and habitability of the emergency management rooms. EDF will verify that these actions can effectively be carried out, including for the FARN, given the intervention conditions likely to be encountered in such scenarios;**
 - **the integration in the hard core of reinforced material and organisational provisions of the communication means that are vital for emergency management;**
 - **the FARN. This will be capable of responding within 24 hours, with operations beginning on the site within 12 hours from the time of call-out. It will comprise specialised crews and equipment capable of taking over from the personnel on a site affected by an accident and of deploying additional emergency response resources, including in situations involving large-scale releases. EDF will specify the organisation and size of these crews, in particular the activation criteria, their duties, the material and human resources at their disposal, the organisational arrangements made to guarantee the maintenance and the permanent operability and availability of these material resources, and finally their training and skills currency processes.**
- Disruption of work efficiency caused by high local dose rates, radioactive contamination and destruction of certain facilities on the site:

EDF presents the impact of this type of situation on the accessibility and habitability of the control rooms. In a severe accident situation, if the pressure in the reactor building rises, it may be necessary to depressurise the containment to maintain its integrity by using the U5 system filter. EDF states that in the light of the current preliminary studies on the habitability of the control room after opening the U5 system filter, the permanent presence of personnel in the control room is to be avoided in the period (24 hours) following opening of U5 system filter.

In the CSA reports, EDF also presents the impact of these situations on the various rooms used by the emergency teams to manage the accident. The accessibility, habitability and operability of the Emergency Technical Rooms (LTC) are identical to those of the control rooms after opening the U5 system filter.

EDF specifies in the CSA reports that the emergency rooms (security block (BDS), emergency equipment stores, etc.) were designed without a specific regulatory requirement relative to flooding and earthquake, yet pragmatically these places are required to remain operational in the event of external hazards. EDF's analysis of the earthquake resistance of the BDS shows that these building generally have structural resistance up to SSE (safe shutdown earthquake) level. The habitability of the BDS, however, is temporarily not ensured after opening the U5 system filter. On this latter point, EDF undertakes, further to the CSAs, to carry out a more comprehensive study on the scale of a site to assess the habitability of the control rooms and the BDS, and site accessibility after opening the U5 system filter on a reactor in a severe accident situation.

EDF also includes among the future actions mentioned in the CSA reports, the performance of preliminary studies to improve the robustness of the BDS's to ensure they remain operational, particularly in the event of an

earthquake and high winds. EDF also indicates that it will undertake a general reflection on the BDS's to identify the needs in order to improve the organisation and habitability of the emergency rooms. Lastly, EDF undertakes to carry out a study comprising firstly a per-site appraisal of the emergency equipment storage conditions and the resistance of the storage premises to the different types of hazard considered (earthquake, climatic event, flooding, etc.) and secondly the identification of improvements to cope with it.

Furthermore, managing an H1 or H3 situation involves many tasks, not only in the control room but above all in the facilities. EDF's reports on the CSAs provide little information on the conditions of performance of these tasks: the atmosphere in the rooms (particularly the temperature which can be very high if there is no ventilation), accessibility in case of hazard damage, available human resources to carry out these tasks on all the facilities.

The information presented by EDF in the CSA reports does not guarantee the resistance, habitability and accessibility of the emergency management rooms and control rooms in the extreme situations analysed for the CSAs and in case of opening of the U5 system filter. ASN points out that the emergency organisation on the sites relies on having premises which must be available to manage the emergency for the required duration. **ASN will therefore require EDF to ensure that these emergency management rooms, situated on or near the site and providing personnel protection (among other things), can withstand the extreme situations analysed in the CSAs and form part of the "hard core". They shall be accessible and habitable during long-duration emergencies and designed to accommodate the crews necessary for long-term site management.**

ASN also considers that the control and monitoring of all the reactors on the impacted site must be ensured in the event of hazardous substance releases or opening of the venting-filtration system (U5). ASN thus considers that everything must be done so that opening of the U5 system on a reactor does not prevent the management of all the reactors on the site, considering that their condition at that moment may be more or less degraded. **In this respect, ASN will attentively analyse the encompassing but nevertheless realistic nature of EDF's study to assess the consequences of opening the U5 system filter on the habitability of the control room, the emergency shutdown panel, and the management of the site as a whole. ASN will require EDF to ensure the control and monitoring of all the reactors of a site in the event of hazardous substance releases or opening of the U5 venting-filtration system from the control rooms, the emergency shutdown panels or the emergency management rooms.**

Furthermore, ASN will ask EDF to define the human actions required for the management of the extreme situations studied in the CSAs, including situations affecting several reactors and those that could have an impact on the accessibility and habitability of the emergency management rooms. EDF will verify that these actions can effectively be performed under the working conditions that could be encountered in such scenarios. EDF will take account of the relief of the emergency teams, the logistics necessary for the interventions, and will indicate any material or organisational adaptations envisaged. This request will be taken up in an ASN requirement.

Lastly, ASN will require EDF to submit a list of the necessary emergency management skills, specifying whether these skills could be held by outside contractors. EDF will provide proof that its organisation ensures the availability of the necessary skills in a emergency situation, and notably when it is possible that outside contractors will be used.

- Feasibility and effectiveness of measures to manage accidents in case of external hazards (earthquake, flooding):

EDF indicates in the CSA reports that application of the procedures by the operators in the control room is not affected by an external hazard (earthquake, flooding), as the control room is robust to the design-basis hazards. In the event of a severe accident combined with flooding or an earthquake, EDF specifies that the equipment used in the reactor containment will not be damaged. The operating team has procedures for dealing with this situation and managing its consequences (loss of heat sink in particular). The actions to carry out in the facilities must be secured, particularly if building lighting is lost. The communication means used in normal operation could be rendered inoperative by the external hazard.

As indicated earlier, ASN considers that failure of the means of communication in an emergency situation is unacceptable, therefore it is vital to reinforce them. **ASN will therefore require EDF to integrate in the "hard core" of reinforced material and organisational provisions, the communication means that are vital for emergency management.**

In the CSA reports, EDF presents the conclusions of its analysis concerning the H1 and H3 situations. These analyses however do not consider that an external hazard can be the cause of such situations. Consequently, the times given in these reports for the H1 and H3 situations alone are not representative of cases where these situations are induced by an earthquake or flooding, even with the hazard levels of the current baseline safety standard. This is because the current baseline includes no systematic requirement regarding the earthquake resistance and flooding protection of the equipment used in H1 and H3 systems.

ASN observes certain weaknesses regarding the ability of the facilities to withstand a whole-site H1 or H3 situation induced by an earthquake, including the earthquake level of the current baseline safety standard or flooding beyond the baseline safety standard. **ASN takes note of the measures envisaged by EDF to improve the robustness of the facilities with respect to these situations and which consist in making the complementary provisions defined for the whole-site H3 situation robust to earthquakes, and studying means for guaranteeing protection of the H1/H3 equipment against a flood exceeding the baseline safety standard. ASN will ask EDF for additional proof of the improvement of facility robustness against these situations.**

– Loss of electrical power supply:

Total loss of electrical power supplies (loss of the off-site sources and the on-site diesel generators) is a situation taken into account in the severe accident management guide (GIAG). This situation could moreover lead to loss of the telecommunication means used in normal operation. The dynamic containment achieved by the ventilation systems would be lost, and particularly the main control room ventilation function and the filtration of that ventilation via the iodine trap. Permanent habitability of the control room is guaranteed, unless the U5 system filter is opened, in view of the modifications presented in the CSA report. If the U5 system is used, the habitability can be temporarily compromised. In this respect, EDF has planned to reinforce the electrical backup of control room ventilation and filtration through the Ultimate Backup Diesel Generator (DUS). Pending implementation of this modification, the FARN will deploy means to ensure the electrical backup of these equipment items for the damaged reactor.

As indicated earlier, ASN considers that control room habitability must be ensured if events presenting risks for operator safety should arise, such as the release of hazardous substances into the environment or opening of the U5 system filter. ASN will issue a requirement on this subject.

As indicated earlier, ASN considers that loss of the telecommunication means in the event of electrical power supply loss is unacceptable. The telecommunication means must therefore be reinforced in this respect. ASN will require EDF to integrate the telecommunication means necessary for emergency management into the "hard core" of reinforced material and organisational provisions.

– Potential failure of the instrumentation:

The instrumentation helps optimise management so as to delay or prevent entry into a severe accident situation if possible. In its CSA reports, EDF indicates that the situation diagnosis and prognosis are established by the emergency teams on the basis of the measurement of certain identified parameters. In case of loss of the electrical power supplies, the instrumentation that detects entry into the SA situation is no longer available in the control room. EDF has undertaken to ensure the electrical backup of this instrumentation by adding an Ultimate Backup Diesel Generator (DUS). However, in the event of an earthquake, the availability of the instrumentation useful in SA situations is not guaranteed because it is not earthquake classified.

In addition, as the containment pressure sensor is not backed up by the backup turbine generator (LLS), it will be unavailable in the event of electrical power supply loss. EDF plans for the electrical backup of this sensor by the FARN in order to counter the overall loss of the electrical power supplies.

ASN considers it unsatisfactory that the technical instrumentation necessary for managing an accident situation, and particularly a severe accident situation, should be lost due to an external hazard.

ASN will require EDF to include the technical instrumentation necessary for emergency management in the "hard core" provisions. This requirement will also extend to the environmental instrumentation necessary for emergency management, for which the external hazard resistance is not guaranteed either.

- Impact of other neighbouring facilities on the site:

Among the industrial facilities situated near the NPP sites, EDF identifies in the CSA reports the Installations Classified on Environmental Protection grounds (ICPE) which can be subject to Authorisation (A) or subject to Authorisation with public protection restrictions (AS). For the ICPE A facilities, EDF concludes that they present no hazard risk for the NPP sites. For the ICPE AS facilities, EDF uses the perimeter of the Technological Risk Prevention Plan (PPRT) of the ICPE to evaluate its impact on the NPP site, and distinguishes two cases:

- the maximum distance between the site and the ICPE AS is greater than the PPRT perimeter: in this case EDF concludes that this ICPE does not present a hazard risk for the site;
- the maximum distance between the site and the ICPE AS is less than the PPRT perimeter: in this case EDF specifies that types of effect (thermal, toxic, overpressure) that could affect the site.

EDF also mentions the existence of ICPEs subject to Declaration (D) in the environment of all the NPP sites and indicates that they present no known risk for the NPPs.

With regard to the risks caused by the industrial facilities internal to the site, EDF identifies, depending on the site, the presence of monochloramine treatment plants, of hydrazine hydrate storage facilities and of plant unit diesel generators. EDF identifies the hazard potential and the nature of the hazardous phenomena associated with these facilities. It also indicates the measures that would be taken in the event of an accident.

Regarding the identification of hazard sources relating to the on-site and off-site industrial environment, EDF does not always present the nature of the hazardous substances, the maximum quantities involved and the distances separating these hazard sources from the facility's safety targets in the CSA reports. For example, EDF concludes - without giving any justification - that the ICPE A and D facilities do not present a hazard risk for the sites. The CSA reports do not give an assessment of the consequences that the hazardous phenomena associated with these hazard sources - potentially aggravated in the event of an earthquake or flood - could have on the facilities which could have been made more vulnerable by the said earthquake or flood.

EDF has undertaken to propose by mid-2012 a plan of action to study and deal with, in the event of extreme situations, the risks associated with the industrial environment on and off the site, and to verify the robustness of the complementary safety measures and emergency management means with respect to hazards associated with the industrial environment. In the particular case of the Tricastin site, EDF has undertaken to assess the impact of the AREVA facilities on the Tricastin NPP in the accident situations analysed in the CSAs. For the Gravelines NPP, EDF has undertaken to assess the impact of the oil pipeline that crosses the NPP intake channel and its bridge on the site.

The hazardous phenomena associated with the hazard sources of the industrial facilities presented in the hazard studies have been taken into account in the design of the NPPs and are reassessed periodically, in accordance with the requirements of the order of 31 December 1999⁴⁹ and the recommendations of the RFS1.2.d⁵⁰ defined by ASN. **ASN nevertheless considers that EDF must examine these hazardous phenomena in the extreme situations analysed in the CSAs and draw its conclusions as to the complementary measures required. ASN also considers that EDF must assess the consequences of the induced hazardous phenomena (explosive, thermal, toxic, etc.) on its facilities, considering their condition after an**

⁴⁹ Order of 31 December 1999, amended, setting the general technical regulations intended to prevent and limit the harmful effects and risks resulting from the operation of basic nuclear installations

⁵⁰ RFS 1.2.d of 7 May 1982 relative to consideration of the risks associated with the industrial environment and transport routes

earthquake or flood of a "CSA level". Lastly, ASN will require EDF to strengthen its ties with the neighbouring operators, by means of conventions or detection and alert systems, to be rapidly informed of any event that could constitute an external hazard for its facilities, and to ensure coordinated emergency management with the neighbouring nuclear facilities and ICPEs' operators.

ASN also considers that EDF must examine the effects of the hazardous phenomena that could occur on industrial facilities containing hazards situated near its NPPs, taking into consideration the extreme situations studied in the CSAs. ASN will issue a requirement on this subject.

Regarding the transport routes and pipelines situated in the site environment, EDF identifies them in the CSA reports and specifies the natures of the products carried in the pipelines. EDF concludes for all the sites that the transport of hazardous substances can present hazard risks, but that these risks are limited and that they meet the objectives of the fundamental safety rule (RFS) I.2.d relative to risks associated with the industrial environment and the transport routes. The CSA reports do not give an assessment of the consequences of these hazardous phenomena - potentially aggravated in the event of an earthquake or flood - on the facilities which could have been made more vulnerable by the said earthquake or flood. EDF indicates that such assessments have already been carried out during the periodic safety reviews of the various sites in application of RFS I.2.d and that they demonstrate compliance with the RFS criteria. EDF thus considers that in view of the existing assessments and the fact that these hazardous substances are not constantly present near the site, complementary studies of the hazardous phenomena associated with the transport routes beyond the baseline safety standards are not necessary.

ASN nevertheless considers that EDF must assess the consequences of the hazardous phenomena associated with the transport routes and pipelines in the extreme situations studied in the CSAs, and draw its conclusions as to the complementary measures required. ASN shall issue a request in this respect.

6.1.4 Conclusion on the organisational provisions for accident management

ASN considers that EDF's emergency organisation and resources must remain operational for hazard levels very much higher than those considered for the design of the facilities, and for radiological or toxic environmental conditions resulting from a severe accident affecting several facilities on a given site. Furthermore, ASN considers that these resources must be highly flexible so as to be capable of managing unforeseen situations. In addition, ASN considers that EDF's organisational and material emergency management provisions must be supplemented to manage a situation affecting several facilities on a given site, including in the event of extensive destruction of the neighbouring facilities. **ASN also considers that EDF must analyse the applicability of the human actions required to manage the extreme situations studied in the CSAs, including the situations affecting all the facilities on the site and those that can affect the accessibility and habitability of the emergency management rooms. ASN will issue a requirement on this subject.**

6.1.5 Measures envisaged to reinforce accident management capabilities

In the CSA reports, EDF proposes several improvements or studies to reinforce the management of accident or severe accident situations on its sites. These improvements target more particularly:

- the appropriateness of the human and material resources for the activities associated with deployment of the "hard core" equipment and the additional equipment proposed further to the CSAs. This study will take the intervention conditions into account;
- the reinforcement of the material resources and communication means;
- the conducting of a study to improve the resistance and habitability of the BDS;
- the design of a Local Emergency Centre, integrating stringent habitability requirements and allowing more effective management of the emergency. The design requirements taken into account shall be consistent with those of the hard core;
- the reinforcement of the means of measurement and of technical and environmental information transmission, including meteorological information, necessary for emergency management;

- the creation of a Nuclear Rapid Intervention Force (FARN) and defining of its material and human resources;
- the functional earthquake resistance of the U5 system.

ASN considers that all these lines for improvement contribute to the reinforcement and robustness of accident and severe accident management on the sites. **ASN nevertheless considers that some of the points identified by EDF need to be clarified. It will therefore issue requirements instructing EDF to integrate in the hard core:**

- **the emergency management rooms. They must display high resistance to hazards and allow the management of a long-duration emergency;**
- **the mobile devices vital for emergency management;**
- **the active dosimetry equipment, the measuring instruments for radiation protection and the personal and collective protection equipment are also included in the hard core. They must be permanently available in sufficient quantity on the sites;**
- **the technical and environmental instrumentation for diagnosing the state of the facility and assessing and predicting the radiological impact on the workers and populations;**
- **the communication means vital for emergency management are included in the hard core provisions. They more particularly comprise the means of informing the public authorities and alerting the populations if the off-site emergency plan (PPI) is triggered in the reflex response phase.**

The requirements concerning the FARN must be supplemented, particularly in that it must be capable of intervening on the accident site in less than 24 hours to relieve the shift teams and deploy the emergency means of resupplying power, with operations on a site starting within 12 hours after the start of mobilisation. The FARN teams must be dimensioned to intervene on a 6 reactors-site, including a site where a massive release has taken place, and have appropriate instrumentation that can be deployed on the sites on arrival.

6.2 Existing accident management measures further to loss of core cooling

In the CSA specifications, ASN asked EDF to describe the accident management measures currently in operation at the different stages of a severe accident, particularly further to loss of the core cooling function:

- before the fuel in the reactor vessel becomes damaged;
 - possible actions to prevent fuel damage;
 - elimination of the possibility of fuel damage at high pressure.
- after the fuel in the reactor vessel has been damaged;
- after failure of the reactor vessel (core meltdown in the reactor pit).

6.2.1 Before the fuel in the reactor vessel becomes damaged

In the CSA reports, EDF indicates that the safety procedures for the reactor fleet in service and the EPR rely on a strategy of defence in depth, which can be summarized as follows:

- measures are taken to avoid incidents;
- if an incident occurs, the protection systems bring the reactor to a safe condition;
- safeguard systems prevent a more severe accident from leading to core meltdown.

The existing measures to prevent entry into a severe accident situation (therefore before the fuel in the reactor vessel becomes damaged), particularly further to situations of flooding, earthquake, loss of electrical power or of the heat sink, come under the incident/accident operation (CIA) procedure.

The measures that can be taken on the reactor fleet to prevent fuel damage aim at restoring a means of injecting water into the reactor vessel in order to - by reflooding the core - cool the fuel and stabilise the situation. The possible measures consist in:

- if necessary, restoring an electrical panel that can energise the backup systems;
- deploying an ultimate alignment for injecting water into the vessel of the impacted reactor.

On the Flamanville EPR, the various lines of defence (main diesel generators, ultimate backup diesel generator sets (SBO), replenishment of the ASG tank) limit the risk of entry into a severe accident situation.

6.2.2 After the fuel in the reactor vessel has been damaged

Beyond this point, a severe accidents management procedure aims at limiting the consequences in the event of core meltdown. If it has been impossible to avoid a severe accident, the operating priorities are turned towards controlling containment and reducing releases.

In the CSA report, EDF indicates the existing measures in response to the identified risk in a severe accident situation. They are indicated below and reviewed in detail with the planned or envisaged improvements further to the CSA, in the section relative to "Maintaining containment integrity after fuel damage in the reactor core".

– Risk due to the production of hydrogen:

Since the end of 2007, all the reactors in service are equipped with passive autocatalytic recombiners (PAR). The Flamanville EPR has PARs and devices for monitoring the concentration and distribution of hydrogen in the containment by interconnecting the two parts of the containment and favouring mixing by convection.

– Risk of slow pressurisation of the containment:

On the reactor fleet in service, this risk is dealt with by the existence of the venting-filtration system called "U5" and an associated operating procedure allowing decompression and filtration of the reactor containment in order to maintain its long-term integrity. Filtration is divided between a container internal coarse metallic filter and a sand bed filter (common to two reactors for the 900 MWe series). The opening of this system, which is an ultimate reactor containment protection measure, takes place after 24 hours as from a minimum pressure equal to the containment design pressure (about 5 bars absolute for all the plant series).

On the EPR, the EVU system removes heat from the containment and controls its pressure. This safeguard system consists of 2 redundant trains and has a dedicated cooling system which itself has a diversified backup water intake. In the event of loss of the electrical power supplies, while satisfying conditions compatible with operation of the reactor building ultimate heat removal system (EVU), this EVU system can be put into service for 2 days in order to preclude the risk of containment failure. Lastly, the integrity of the containment is maintained for 3 days after the initiating event if the EVU is not put into service.

– Risk of reactor containment leaktightness fault:

On the reactors in service, confirmation of the isolation of the containment penetrations is required as part of the immediate actions on entry into a severe accident situation. The activity is monitored so that restoration measures can be implemented if necessary. The U2 operating procedure (continuous monitoring of containment integrity) which is part of incident/accident operating procedure (CIA) is applicable in a SA situation. Its aim is to monitor the containment integrity under accident conditions and if necessary restore the reactor containment (by isolating the areas concerned, reinjection of highly radioactive effluents, etc.).

On the EPR, the containment and the peripheral buildings are designed such that there is no direct leakage path from the reactor containment to the environment. The building ventilation systems are backed up by the main diesel generators and the ultimate backup diesel generator sets (SBO).

– Risk of direct heating of the containment:

To avoid direct heating of the containment, which would result in rupture of the vessel under pressure, the SA operating procedure on the reactors in service requires depressurisation of the primary system by opening the pressuriser discharge lines immediately from entry into the severe accident (SA) situation.

On the EPR, two redundant primary system discharge lines enable the primary system to be depressurised, preventing the risk of reactor vessel rupture at high pressure, which could lead to loss of containment integrity by direct heating of the containment. The operator has one hour after entry into the SA situation to open these lines, which are supplied by the 12 hours batteries.

6.2.3 After reactor vessel melt-through

Added to the above-mentioned risks is the risk of basemat melt-through further to rupture of the reactor vessel containing the corium.

On the reactor fleet in service, EDF indicates in the CSA reports that restoring water makeup in the reactor vessel and depressurising the primary system - as required by the operating procedure on entry into the SA situation - enable the low-pressure makeups to flow into the primary system and help reflood the core, and - if achieved in required time - stop core meltdown and prevent reactor vessel melt-through. Reflooding the corium in the vessel or injecting water into the reactor pit via the perforated vessel to keep the corium flooded, limit the risk of basemat melt-through, or failing this, delay its occurrence. The severe accident management guide (GIAG) defines the water injection conditions, particularly with respect to the risks of early loss of containment. As the safeguard systems of the damaged plant unit were probably lost on entry into the SA, so-called "ultimate" alignments can be implemented by the emergency teams to flood the corium.

For the reactor fleet in service, there is also a risk of ex-vessel vapour explosion. EDF specifies in the CSA reports concerning them that an international research programme is in progress to characterise the conditions of occurrence and the intensity of such phenomena. EDF also indicates that the available studies show the containment to be well able to withstand the loads resulting from a vapour explosion. Its integrity would therefore probably not be compromised in this situation.

For the Flamanville EPR, the CSA report indicates that the corium catcher situated in a special compartment on the edge of the reactor pit, is designed to collect, cool and stabilise the corium. Prevention of basemat melt-through is thus based on a reactor pit and catcher that are both dry when the corium arrives, on the collection and spreading of the corium and on its passive cooling after spreading. In the longer term, the EVU system used in spraying mode enables the residual power to be removed from the corium.

6.3 Maintaining containment integrity after damage to the fuel in the reactor core

The ASN specifications required EDF to study the means of preventing and managing:

- loss of the core cooling function;
- loss of containment integrity, particularly the reactor containment.

The ASN specifications stated that the licensee had to describe the severe accident management measures and facility design elements to protect containment integrity after the occurrence of fuel damage.

The ASN specifications also stated that it was necessary to:

- identify any cliff-edge effects and evaluate the time before they occur;
- assess the appropriateness of the existing management measures, including the GIAGs, and the possible complementary measures.

The risks induced by these situations and the severe accident management means for controlling them and mitigating their consequences are presented below, through a description of the existing means and the complementary means envisaged further to the CSAs.

6.3.1 Elimination of the risk of high-pressure fuel damage or core meltdown

The ASN specifications required EDF to describe the severe accident management measures to eliminate any possibility of high-pressure damage to the fuel. This is because in a core meltdown accident situation affecting a PWR reactor, and when the primary system is not depressurised (no breach in the primary system and no cooling by the secondary system), meltdown can take place at high pressure; this is called pressure meltdown.

In the CSA reports, EDF indicates for the reactors in operation that the prevention of pressure meltdown sequences is based on voluntary opening of the pressuriser SEBIM valve tandems. The opening of the three valve tandems causes rapid depressurisation of the primary system which eliminates the risk of having a highly pressurised reactor vessel when melt-through occurs and the risk of loss of containment through its direct heating. Opening of the valve tandems is required in the majority of situations well before entry into a severe accident on a primary system overheat criterion. In a situation of total loss of the electrical power supplies, valve tandem opening is required in the event of loss of the steam generator supply from the turbine driven auxiliary feedwater pump (TPS ASG). Confirmation of valve opening is required by the severe accident operating documents.

EDF indicates that opening the SEBIM valves and keeping them open enables core meltdown to be avoided with the primary system at high pressure, which could lead to substantial pressurisation of the reactor containment atmosphere by fine spraying of the fuel when vessel rupture occurs (phenomenon of direct containment heating (DCH)). EDF specifies in the CSA reports that to fulfil this "primary system depressurisation" function, the current design of the remote control of the pressuriser SEBIM valves requires permanent energising of their solenoids, and therefore the availability of the electrical power source and power cables. A modification to improve SEBIM valve opening reliability, decided before the Fukushima accident and already been applied on certain reactors, is planned for the next 10-yearly inspection of each reactor. The solution chosen by EDF to improve its robustness is to replace the monostable remote control (solenoid) by a bistable control (magnetic latching on control by solenoid).

The modification proposed by EDF at the end of the CSAs also aims - in a situation of total loss of electric power sources and exhaustion of the batteries - to control the valve solenoids directly from the relaying rooms from a new stand-alone Mobile Backup Means (MMS). Operation is thus simplified and bypasses all problems of battery autonomy and radiation resistance of the electrical power supply for the valve solenoids. ASN considers that the proposed improvements, which meet the CSA specifications, must be implemented.

In the CSA report for the Flamanville 3 EPR, EDF indicates that the EPR is designed with two redundant primary system discharge lines enabling the primary system to be depressurised and avoid the risk of reactor vessel rupture at high pressure, which could lead to loss of containment integrity by DCH. The licensee has one hour after entry into the severe accident situation to open these lines which are supplied by batteries with 12 hours autonomy. ASN considers the principle of this proposal satisfactory; it will be examined in the framework of the Flamanville 3 EPR reactor commissioning.

6.3.2 Management of the hydrogen risk in the reactor containment

The ASN specifications asked EDF to describe the severe accident management measures to prevent any hydrogen deflagration or detonation (container inerting, recombiners or igniters). For the severe accident studies of the PWRs, the hydrogen risk is defined as being the possible loss of reactor containment integrity or of its safety systems further to a hydrogen deflagration.

In the CSA reports, EDF indicates that hydrogen can be produced during different phases of an accident:

- in-vessel, during the phase of core degradation due to the oxidation of the fuel element cladding and other materials present in the reactor vessel;
- ex-vessel, during the corium/concrete interaction.

The hydrogen so produced is released in the containment (through the primary system breach, the pressuriser relief tank, or the corium pool) where it is then mixed by the convection movements. In the CSA reports, EDF indicates that Passive Autocatalytic Recombiners (PAR) have been installed on all the reactors in operation in order to reduce the hydrogen concentration in the reactor building (BR) in the event of a severe accident. This installation has been effective since the end of 2007. Associated operating provisions are applicable on the sites. On completion of the CSAs, EDF undertook to study the hydrogen risk in the other peripheral buildings of the reactor containment. The study of the hydrogen risk in the inter-containment space on the 1300 MWe reactors is in progress as part of the periodic safety review associated with their third 10-yearly inspection.

In the CSA reports, EDF indicates that the potential cliff-edge effect caused by hydrogen in the containment would be a loss of reactor building (BR) containment in case of ignition of a plume with a high hydrogen concentration in the BR. The recombiners exclude loss of containment through slow deflagration by limiting the quantity of hydrogen in the BR in the event of a severe accident. EDF underlines that the probability of such phenomena occurring is extremely low, especially given the geometrical characteristics of the containment. The containment has a relatively "open" geometry which favours hydrogen mixing and therefore limits the risk of formation of a plume with a high concentration of hydrogen. Installation of the PARs, by reducing the quantity of hydrogen in the containment at a given moment in time, reduces the probability and the consequences of such phenomena. ASN considers that the ongoing R&D studies must be continued to further knowledge of these phenomena.

In the CSA report for the Flamanville EPR, EDF describes the planned design measures: hydrogen concentration monitoring is based on two types of device: PARs installed in the reactor building, and rupture and convection flaps and disks, whose opening ensures natural convection within the BR, thereby mixing and homogenising the containment atmosphere. ASN considers these measures satisfactory at this stage of the examination, which is continuing with a view to the commissioning of the Flamanville EPR reactor.

6.3.3 Prevention of reactor containment overpressure

The ASN specifications asked EDF to describe the severe accident management measures to prevent reactor containment overpressure.

The slow rise in the reactor containment pressure (linked to sump water vaporisation and possibly the formation of non-condensable gases from the decomposition of the basemat concrete by the corium, in the event of corium-concrete interaction (CCI), can lead to exceeding of its design pressure and ultimately loss of its integrity.

EDF indicates in the CSA reports that for the reactors in operation, the time before containment is lost due to exceeding of the mechanical characteristics of the reactor, varies from one to several days depending on the assumptions adopted for the studies. EDF considers that this leaves the operator the time to engage action to avoid containment destruction while controlling radioactive release as best possible. The U5 system operating rules were developed in order to avoid containment rupture by overpressure, whatever the circumstances. These rules provide a means of limiting the pressure to a value slightly below the design pressure of the reactor containments by means of the U5 venting and filtration system. Management of such a situation favours a filtered release through a device that can be reclosed if necessary. The reactor building is depressurised by opening two manual valves.

In the CSA report, EDF specifies that to exclude any risk of hydrogen combustion in the U5 system that could be induced by condensation of the vapour in the piping, there is a preheating system (venting line conditioning). This conditioning is lost in the event of total loss of the electrical power supplies. Although measures are taken to limit the risk of hydrogen combustion in the U5 venting line (pressure reduction upstream of the line limiting the risk of condensation, recombiners substantially limiting the hydrogen concentration), EDF has undertaken to re-examine the hydrogen risk and its possible impacts on the U5 system. **ASN considers that this examination must focus in particular on the impact of the oxygen already present in the U5 pipe and on the risk of hydrogen deflagration and its possible consequences at the U5 system outlet. ASN also considers that for the 900 MWe series, EDF must study the simultaneous use of the U5 system, which is common to two reactors. ASN will require EDF to study the possibilities of improving the U5 venting-filtration**

system taking into account robustness to hazards, filtration effectiveness when used simultaneously on two 900 MWe reactors and the improvement of the filtration of the fission products.

Regarding the implementation of a venting-filtration system, EDF specifies in the CSA reports for the reactors in operation that the risk of overpressure in the reactor containment is taken into account in the GIAG. The U5 system filter must not be opened until 24 hours after entering the SA situation to allow deposition of the aerosols in the reactor containment. This operating procedure is implemented by joint decision (EDF emergency teams, ASN, IRSN and public authorities).

In the CSA reports for the Flamanville EPR, EDF describes the EVU system that removes the heat from the containment and monitors its pressure. The residual power is transferred to the dedicated ultimate heat sink (SRU). The pressure is limited by the EVU spray function, the water being drawn into the IRWST (In-containment Refuelling Water Storage Tank) via the nozzles in the reactor building dome. The EVU comprises two independent trains in separate safeguard buildings. The ultimate heat sink (SRU), which also comprises two independent trains, is diversified: it can draw in seawater from either the pumping station or the discharge pond if the pumping station is unavailable. Containment integrity is maintained for 3 days if the EVU is not put into service.

In the CSA for the EPR, to avoid the cliff-edge effect resulting from prolonged loss of the electrical power supplies, EDF has proposed adding a mobile and independent water makeup system in the reactor building via the EVU spray nozzles. This system consists in adding remote valve controls, the deployment of a motor driven pump and the use of the water from the ponds of the demineralisation plant water supply system SEA. This system would be deployed within 48 hours, a time lapse that is consistent with the implementation of extensive mobile resources. It enables the containment integrity grace period to be extended to 5 days to recover an electrical power supply and a heat sink in order to restore the functions of the EVU system. ASN considers that the proposed improvements, which meet the CSA specifications, must be implemented.

In view of the foregoing information on the EVU system, the installation of a venting-filtration system on the Flamanville EPR is not planned by EDF, either in the design or in the CSA report. ASN nevertheless considers that over and beyond the modification proposed by EDF, the Fukushima accident makes it necessary to re-analyse this design choice in the event of long-term impossibility to restore a heat sink. This point is taken up in the paragraph *"Measures envisaged to reinforce the maintaining of containment integrity after fuel damage"*.

6.3.4 Prevention of re-criticality

The ASN specifications asked EDF to describe the severe accident measures to prevent the risk of re-criticality.

The fuel assembly geometry, the presence and arrangement of the control rods and neutron absorbers, the boron content of the water in the primary system and the PTR tank (IRWST for the EPR reactor) were studied at the design stage to exclude the risk of re-criticality in the case of design-basis accidents.

However, in the event of a severe accident, following the loss of the primary coolant as a result of the unavailability of all the safeguard systems, the core heats up and can start to melt. If the primary coolant is not recovered rapidly, the fuel and the core structure suffer damage, the core loses its shape, gradually forming a bed of debris and/or a corium pool which subsequently becomes relocated in the reactor vessel coolant inlet plenum or perforates the bottom of the vessel to reach the reactor pit. In this case the initial margins against re-criticality could be significantly reduced.

In the CSA reports, EDF indicates that it has carried out reactivity studies to analyse the risk of return to criticality for different corium configurations - compact or fragmented - in the reactor vessel or the reactor pit, on the basis of realistic assumptions (conservative in some cases). These studies conclude:

- that the criticality risk is nil when the corium is not fragmented in the water;
- that the criticality risk is excluded when the borated water is injected at the minimum boron concentration of the PTR tank.

Corium in reactor vessel:

EDF indicates in the CSA report that as the severe accident management guide (GIAG) prohibits the injection of non-borated water as long as the corium is in the reactor, the re-criticality risk is excluded for the corium-in-vessel configurations. This point does not prompt any remarks from ASN.

Corium in the reactor vessel pit:

In the CSA reports, EDF indicates that after reactor vessel melt-through, injection of clarified water could be envisaged after analysis and if recommended by the emergency team. The re-criticality risk is excluded in the short term, as the intense vaporisation of the water on contact with the corium tends to reduce the reactivity (increase in the vacuum level).

In the longer term, when the bed of debris can be cooled and there is little or no vaporisation (low vacuum level), the strong presence of neutron absorbing fission products and the incorporation of concrete are factors favouring a substantial reduction in reactivity.

Nevertheless EDF and the IRSN do not share the same opinion on the harmlessness of a clarified water injection; borated water makeup points must therefore be provided in the long term.

On the Flamanville EPR, as specified in the CSA report for this reactor, measures are taken to guarantee a dry reactor pit and a dry corium spreading area. ASN will examine whether these provisions are sufficient in the framework of EPR commissioning.

6.3.5 Prevention of basemat melt-through

The ASN specifications asked EDF to describe the steps taken to manage severe accidents in order to prevent the risk of basemat melt-through in the reactor buildings.

Flooding of the corium in the vessel

In the CSA reports, EDF states that maintaining the corium in the vessel avoids the ex-vessel corium-concrete interaction phase and thus contributes to the goal of maintaining the integrity of the containment. Stabilisation of the situation in the vessel entails restoring a means of injecting borated water into the reactor coolant system within a sufficiently short period of time to avoid vessel rupture, in other words before core damage is too far advanced to enable it to be cooled in the vessel.

The strategies for maintaining the corium in the vessel are based on:

- borated water makeup in the reactor coolant system;
- eventual use of the recirculation function to keep the core continuously flooded.

EDF states that possibilities for retaining the corium in the vessel are envisaged for the reactor fleet in a severe accident situation, based on existing systems not specifically designed to manage accidents with core melt and depending on their availability. The considerations are as follows:

- to enable the situation to be stabilised in the vessel, in-vessel injection must be restored before the formation of a significant corium pool in the core and, in any case, before the corium transits to the bottom of the vessel;
- if water is present in the reactor pit, allowing external cooling of the vessel, water injection into the vessel can allow stabilisation of the situation if it is restored before significant ablation of the vessel walls. It should be recalled that as things currently stand, flooding of the reactor pit is the result of operation of the containment spray system (EAS), when available, by run-off of spray water to the reactor pit.

In practice, the injection of borated water to the vessel by makeup drawing directly from the PTR tank, this latter if possible being resupplied, is preferred in order to keep the core flooded, while delaying the moment of transition to recirculation.

After the CSAs, EDF aims to have the reactor coolant system injection means backed-up by an Ultimate Backup Diesel Generator (DUS). An ASN requirement will concern the composition of the hard-core, of which these systems should be a part.

Flooding the corium in the reactor pit

Assuming failure of the vessel, the corium pours into the reactor pit. In the CSA reports, EDF states the strategy currently in place on the reactors in operation, which is to inject water:

- by an input of water subsequent to vessel failure, using reactor cooling system makeup through the breach at the bottom of the vessel, in accordance with severe accident operations. Furthermore, when the reactor pit is initially dry or containing a low water level, the risk of a steam explosion is considered to be low. According to EDF, the conclusions of the MCCI (Molten core concrete interaction) programme run under the aegis of the OECD confirm this ex-vessel reflooding strategy. This international scientific programme dedicated to the ability to cool the corium-concrete mixture, demonstrated on an experimental scale that a corium pool can be stabilised by the injection of water;
- by flooding of the reactor pit prior to vessel failure, linked to operation of the reactor building containment spray system (EAS) if available before entering the severe accident phase. If the reactor pit is flooded up to the level of the vessel bottom head, this significantly reduces the risk of basemat melt-through, as the retention of a part of the cooled corium in the vessel and corium contact with the water in the reactor pit reduces the quantity of corium that will contribute to the corium-concrete interaction (CCI).

In the CSA reports, EDF states that the current mitigation strategy, which aims to inject water before or after vessel melt-through, should be able to slow down or even prevent basemat melt-through. Complementary corium-concrete interaction tests (tests CCI-7) are planned for 2012 to confirm the possible stabilisation of a corium pool by means of flooding from above. However, ASN considers that transposition to the scale of a reactor is not direct and requires the use of computer codes. It is therefore problematical as things stand to draw complete conclusions on the situation of a reactor. R&D and testing need to be continued in this field.

In the CSA report for the Flamanville EPR reactor, EDF states that this reactor will have a corium catcher enabling spreading and cooling of the corium. Passive flooding of the spread corium in the catcher and removal of the residual heat by the EVU system thus ensure long-term protection of the basemat. The detailed design of the EVU system will be studied by ASN as part of the EPR commissioning process.

Risk of cliff-edge effects and means of mitigation

In the CSA reports, EDF states that the cliff-edge effects liable to compromise corium retention in the vessel are, for the reactor fleet:

- long-term loss of electrical power supplies; the countermeasure is to restore vessel makeup by a diversified means (generator-driven pump for example);
- non-restoration of the recirculation function after complete use of the borated water reserves. This takes several days. Limiting the injection flow to that strictly needed for residual heat removal and resupply of the PTR tank with borated water would enable this period to be extended.

In a long-duration total loss of electrical power supply situation (situation H3) combined with the loss of water supply to the steam generators (emptying of ASG tank), none of the present injection means would allow flooding of the corium in the vessel and in the reactor pit. As a result of the CSAs, EDF envisages using a generator-driven pump for the reactor fleet, allowing injection of water from the PTR tank to the reactor coolant system. EDF specifies that this will be incorporated into the means available to the FARN.

For the reactor fleet, in addition to these preventive measures, examination of countermeasures to the dissemination of radioactive products by the "water route", in other words the potential contamination of the

groundwater by liquid radioactive releases, is in progress. This examination, which began before Fukushima as part of the reactor operating life extension beyond 40 years, takes account of the opinion of the Advisory Committee which met in June 2009 on this subject and which was followed by ASN requests.

As part of the complementary safety assessments subsequent to the Fukushima accident, EDF decided to speed up the studies in response to the ASN requests, in relation to the schedule initially stipulated by ASN following the 2009 Advisory Committee meeting. These studies, which are specific to each site, comprise hydrogeological surveys based on in-situ measurements and feasibility studies concerning the technical measures, such as geotechnical or equivalent containments, designed to delay the transfer of contamination to the groundwater. EDF undertook to provide these studies in 2012 or 2013 depending on the sites. Given their unfavourable conditions in the event of pollution, ASN considers that the sites of Fessenheim, Bugey and Civaux are priorities. **ASN will require that EDF speed up the submission of the hydrogeological surveys. Furthermore, the possibility of implementing countermeasures to basemat melt-through and soil pollution are among the topics being examined as part of the more general ten-yearly safety reviews framework. In this context, ASN will be asking EDF to send it a feasibility study on the implementation of technical arrangements to prevent the transfer of radioactive contamination to the groundwater in the event of a severe accident leading to melt-through of the basemat by the corium.**

For the particular case of the Fessenheim reactors, the 1.50 m thickness of the basemat is the lowest in the fleet (3 to 4 metres for most reactors in the fleet). In the current situation, EDF considers that the time to melt through the basemat following a severe accident with fuel melt and vessel melt-through could be about one day in the worst case (malfunction of all safeguard systems). In July 2011, for the continued operation of Fessenheim reactor n°1 beyond 30 years, and without prejudice to the conclusions of the CSAs, ASN asked EDF to reinforce the Fessenheim basemat before 30th June 2013 in order to significantly increase its corium resistance in the event of a severe accident. The dossier, which has been submitted by EDF on 9th December 2011, will be examined by ASN in 2012.

6.3.6 Supply of electricity and compressed air for operation of the equipment used to preserve the containment integrity

The ASN specifications required that EDF also adopt a stance on the electrical systems used by the equipment designed to preserve the integrity of the reactor buildings containment.

In the CSA reports, EDF mentions that a limited number of items are needed for directly managing preservation of the integrity of the containment in the event of a reactor "severe accident". These are the containment isolation valves and the wide-range containment pressure measurement system which outputs information determining when to open the U5 filter if necessary.

Following the CSAs, EDF decided to back-up the electrical power supply to all this equipment with an Ultimate Backup Diesel Generator (DUS) to be added to each reactor. Pending the implementation of this modification, an electrical back-up (mobile diesel generator) will be installed by the FARN, except for the containment isolation valves. An ITS (temporary safety instruction) to request manual closure of these valves before entering the GIAG phase will be proposed by EDF. This is considered by ASN to be satisfactory.

6.3.7 Instrumentation required to protect the integrity of the containment

The pressure in the containment is managed by monitoring the wide-range containment pressure measurement. This monitoring system helps determine the moment at which to open the U5 device when the pressure in the reactor building exceeds a threshold.

In the CSA reports on the reactors in the fleet, EDF states that the primary pressure measurement on all plant series, as well as the wide-range containment pressure measurements at Fessenheim, the CPY and N4 plant series, are backed-up electrically via the LLS turbine generator set. In addition, following the CSAs, EDF undertook to conduct a feasibility study on short-term electrical back-up (less than 24 hours) of the containment pressure for the reactors of the Bugey NPP and the 1300 MWe plant series by the end of 2012.

In the CSA reports on the reactors in the fleet, EDF states that in situations involving a total loss of electrical power sources, the pressure measurement in the containment is lost. It is then possible to use the containment pressurisation kinetics charts available for the various plant series. In situations involving a total loss of electrical power sources, the unit having lost all its means of injecting water into the core, pressurisation of the containment is slow and opening of the U5 venting device therefore takes place after a few days. This time can be used to restore the unit's electrical power sources or deploy the mobile resources provided by the FARN.

EDF states that the Ultimate Backup Diesel Generator (DUS) will be able to provide electrical back-up for the instrumentation enabling operation to continue in a severe accident situation. This is satisfactory in principle. ASN will examine whether the information backed-up by the SBO diesel generator is complete, based on the proposals submitted by EDF for the hard-core.

In the meantime, ASN also considers that the operations shift crews must be able to access the containment pressure and vessel pressure measurements as of the first hours, in all circumstances, without waiting for the FARN. In addition, EDF undertook to guarantee that as of the first hours of an accident, the primary system pressure and containment pressure measurements would be available, including in the event of failure of the LLS turbine generator set, by deploying a small generator pending the installation of the Ultimate Backup Diesel Generator (DUS).

With regard to the robustness of this instrumentation, EDF states in the CSA reports for the reactors in the fleet that this entails no risk of unavailability in a flooding situation, but that it is not classified for the seismic risk. EDF will study its seismic resistance on the basis of the conclusions regarding the content of the hard-core.

Moreover, the installation of instrumentation dedicated to severe accident management, able to detect reactor vessel melt-through and the presence of hydrogen in the containment is currently planned for the third ten-yearly inspections for the 900 MWe and 1300 MWe reactors and the first ten-yearly inspections for the 1450 MWe reactors. **ASN considers that these elements would facilitate management of the situation by the licensee and the public authorities. ASN will require that the implementation of this instrumentation be accelerated and that it shall also be redundant.**

6.3.8 Ability to manage several accidents in the event of simultaneous core melt / fuel damage in different units on the same site

Feasibility of immediate GIAG actions

Assuming an event leading to simultaneous loss of all electrical power supplies and cooling for the reactor coolant system on all the reactors of a site, ASN considers that, for each reactor, the feasibility of all the immediate actions provided for in the GIAG must be guaranteed, in particular depressurisation of the reactor coolant system, with the operations and emergency crews present on the site.

In this respect, following the CSAs, EDF undertook to study the adequacy of the resources, both human and material, for the activities involved in implementing the equipment of the hard-core (including the immediate actions of the GIAG) and the additional equipment proposed following the CSAs.

The main steps in this study are as follows:

- identification of the missions to be performed (emergency management, operation of facilities, etc.) on all the units;
- identification of the activities to be performed, with their main characteristics in terms of duration, intervention conditions, etc.;
- consideration of the additional equipment to be implemented, with its implementation constraints being incorporated into its design;
- final check on the adequacy of the human resources (numbers and skills) for all the activities to be carried out;
- identification of any additional training requirements.

In late 2012, EDF shall inform ASN of the progress of the work, particularly with regard to the adequacy of the workforce present on the site.

Habitability of the control room

The situation considered for evaluating the habitability of the control room of the reactor fleet in the event of a severe accident is a core melt situation initiated by total loss of electrical power supplies, with opening of the containment venting and filtration system (U5) 24 hours after entering the GIAG phase.

In the CSA reports for the reactor fleet, EDF states that the existing preliminary studies, based on penalising hypotheses (injection of soda to maintain the alkaline nature of the Reactor Building sumps is not taken into account and the DVC ventilation-filtration of the control room is assumed to be unserviceable), mean that permanent operator presence must be avoided in the control rooms in the period following opening of the U5 system (for 24 hours).

Consequently, following the accident that occurred on the Fukushima site in Japan, among the possible measures for mitigating the radiological consequences, EDF envisages installing a system able to guarantee the alkaline nature of the water in the Reactor Building sumps and thus reduce the maximum quantity of organic iodine liable to be released in the event of an accident.

EDF also plans to reinforce the electrical back-up of the control room ventilation-filtration system (DVC system) by the Ultimate Backup Diesel Generator (DUS). Pending this modification, the FARN will deploy resources to provide electrical back-up for this equipment.

To conclude, ASN considers that everything must be done to ensure that opening of the U5 system on one reactor does not prevent management of all the reactors on the site, considering that these reactors may be damaged to varying degrees at this time and must thus be managed. In this respect, evacuation of the site, if prolonged, means that this requirement cannot be met. EDF undertook to evaluate the dose rates in the control room, in the BDS and on the site by mid-2012, taking account of the impact of the modifications decided on. ASN will issue a requirement on this subject.

On the Flamanville EPR, DCL (control room and electrical building conditioning) ventilation guarantees that the control room is habitable. In the case of a LOOP situation, a period of 3 days is available, during which the atmosphere in the control room remains breathable. EDF is studying the provision by the FARN of a mobile electrical power supply source within 3 days. The technical investigation will continue as part of the Flamanville EPR commissioning process.

6.3.9 Conclusions concerning the planned steps to maintain the integrity of the containment in the event of a severe accident

The planned steps to maintain the integrity of the reactor fleet containment rely on the U5 venting-filtration system as a last resort. As an earthquake is not considered in the design and during the periodic safety reviews as a plausible initiator of a severe accident, given all the design measures taken on the safety-classified structures, systems and components, the elements of the U5 system, except the containment penetration and the isolation valves, are not therefore seismic-classified. However, EDF states that the metal pre-filter and the piping inside the containment are able to withstand an earthquake.

EDF has undertaken to conduct an overall review of U5 system filtration taking account of the following points:

- the robustness of the current system to hazards;
- the filter common to a pair of units on the 900 MWe plant series;
- the impact on the habitability of the control room, the BDS, on site accessibility and the radiological consequences of opening of the U5 system;
- the feasibility of filtration of iodines and noble gases;
- the role of the U5 system, taking account of the other foreseeable measures to limit its utilisation or its role.

ASN considers that the proposed improvements, which meet the CSA specifications, should be implemented. It will issue a requirement on this subject.

With regard to the Flamanville EPR reactor, the design of which already offers improved protection against severe accidents, EDF will identify which among the planned equipment is to be included in the hard-core for the prevention and mitigation of the consequences of a severe accident, including systems or equipment allowing depressurisation of the reactor coolant system, isolation of the containment and control of the pressure in the containment. ASN will issue a requirement on this subject.

By virtue of its design, the Flamanville EPR reactor has no containment venting and filtration system. The EVU system has the role of removing heat from the containment and controlling its pressure, with the residual power being evacuated to the diversified ultimate heat sink SRU. To prevent a cliff-edge effect in the event of total and prolonged loss of electrical power, EDF envisages adding a mobile and independent water makeup system in the reactor building, via the EVU spray nozzles, which would be deployed within 48 hours of the beginning of the accident. This arrangement extends the 5-day period, beyond which the FARN would be responsible for providing a high-power mobile electrical device for resupplying the EVU/SRU chain. ASN has no objection to this additional system, but considers that EDF could go further (see following paragraph).

6.3.10 Steps envisaged for strengthening maintained containment integrity after fuel damage

In general for the reactor fleet, concerning the equipment designed to limit the consequences of a severe accident and radioactive releases, the current baseline safety requirements make no provision for off-site hazards. EDF shall, in response to a requirement to be issued by ASN concerning the hard-core, specify the hard-core equipment (existing equipment and additional countermeasures) preventing and mitigating the consequences of a severe accident. This equipment shall be robust to hazards beyond the current hazard level considered for the facilities. This in particular applies to the hydrogen recombiners and the U5 systems in use on the reactor fleet.

Moreover, in the light of the cliff-edge effect on the consequences of a reactor core melt, when a containment is already open, EDF undertook, after the CSAs, to study the feasibility of measures to guarantee the time needed to close the equipment hatch (TAM) in the event of total loss of electrical power.

With regard to the EPR, in addition to the steps planned to maintain the integrity of the containment, assuming the possibility that a heat sink might not be restored with certainty in the scenarios envisaged by the CSAs, ASN will be asking EDF to identify the existing or additional systems to be included in the hard-core to ensure management of pressure in the containment in the event of a severe accident and to perform a study of the advantages and drawbacks of the various possible systems.

With regard to the ability of the EPR's severe accident equipment to withstand hazards, the systems participating directly in heat removal and thus in maintaining the integrity of the containment have a seismic safety classification SC1⁵¹. In the Flamanville EPR's CSA report, EDF states that this equipment is robust to seismic levels beyond their design basis. As part of the Flamanville EPR commissioning review, EDF will send ASN a demonstration of the robustness of the hard-core equipment.

6.4 Measures to limit radioactive releases in the event of a severe accident

6.4.1 Radioactive releases after loss of containment integrity

In the CSA specifications, ASN asked EDF to tackle the steps planned to limit radioactive releases from the facilities in the event of a severe accident.

In the CSA reports on the reactor fleet, EDF states that the U5 venting-filtration device, even though reserved for ultimate safeguard of the containment and concerning which all the countermeasures are designed to prevent it from opening, can – once the gas plume resulting from its opening has passed – help limit the radiological

⁵¹ The requirements for seismic class 1 are, whenever required, operability during or after an earthquake, functional capacity, integrity and stability.

consequences off the site. Thanks to the effective filtration of long-lived products in the aerosols, such as caesium 137 with a radioactive half-life of about 30 years, the long-term radiological consequences of U5 opening are limited. If the U5 system were to be opened, population protection measures during the radiological emergency phase would be deployed around the nuclear site.

For the Flamanville EPR, EDF states in the CSA report that the core melt accident is part of the EPR design-basis and complies with strong stringent requirements. The radiological objectives associated with a severe accident are that in these situations, only protection measures that are extremely limited in terms of space and time should be necessary: limited sheltering of the population, no need for emergency evacuation beyond the immediate vicinity of the facility, no permanent rehousing, no long-term restrictions on the consumption of foodstuffs (in accordance with the technical directives applicable to the EPR). Equipment and devices specific to the management of a severe accident (for example passive flooding of the corium following its spreading in the specific area provided and the EVU system to control the containment pressure) were thus defined in the EPR design. In the CSA reports, EDF conducted a deterministic study of a combined failures situation leading to total loss of the SBO diesels. Assuming the unavailability of the soda injection and the shutdown of the ventilation and filtration systems for 24 hours, the rise in effective dose for the population would remain limited, but this situation would lead to an iodine release level that would require the deployment of population protection measures during the radiological emergency phase, such as the distribution of stable iodine tablets. EDF stated that it was examining the possibility of making the IRWST water alkaline, including in situations involving a total loss of electrical power supply.

6.4.2 Accident management after uncovering of the top of the fuel in the pool

For the purposes of the CAS, ASN asked EDF to "describe the measures taken to manage the consequences of the loss of the cooling function for the spent fuel pool or for any other fuel store (the following concern the storage of fuel):

- *before and after the loss of appropriate protection against radiation;*
- *before and after uncovering of the top of the fuel in the pool;*
- *before and after severe damage to the fuel in the store."*

The approach adopted by EDF in its complementary safety assessments concerning the spent fuel pools is to examine the consequences of a major natural hazard on the systems capable of removing the residual heat from the fuel stored in the pool, by examining the consequences of the loss of heat sink or electrical power supplies (see § 5).

In its CSA reports, EDF did not however study the possible consequences of a loss of the integrity of the pools or cavities in the fuel building or reactor building, as well as the systems connected to them. ASN considers that the natural hazards to be considered as part of the CSAs can induce risks other than the loss of electrical power sources or heat sinks, such as:

- the risk of deformation of the storage racks;
- the risk of falling loads;
- shaking of the civil engineering structures supporting the spent fuel pool;
- a breach of a pipe or leaktight barrier connected to the pool;
- the loss of integrity of a door or sluice.

These risks were analysed by IRSN during the review prior to the meeting of the advisory committees in November 2011. The analysis focused on evaluating the existing or foreseeable lines of defence to prevent uncovering of the fuel assemblies and melting of the fuel in the fuel building.

With this in mind and in order to limit the risk of accidental drainage of the spent fuel pool, several improvements to the material and organisational arrangements were mentioned for the NPP reactors in service:

- Doubling of the diameter of the siphon-breaker devices on the PTR system discharge line;
- Automation of isolation of the cooling system intake line.

ASN considers that the improvements proposed, which comply with the CSA specifications, must be implemented. ASN will be issuing technical requirements concerning the implementation of these equipment modifications on all the NPPs in service, as the EPR design already comprises effective measures to deal with these risks.

The Bugey and Fessenheim plants entail a particular risk of spent fuel pool damage in the event of a falling fuel transport container: in these plants, unlike the others, between the handling zones and the fuel building spent fuel pool, there is no seal separating the part of the BK supporting the pool from the heavy loads handling zone, which would prevent any transmission of loads in the event of a falling container.

ASN considers that EDF should present a study of the possible additional measures to prevent or limit the consequences of a falling container accident in the fuel building, incorporating the extreme situations studied in the CSAs. ASN will issue a requirement on this subject.

ASN also considers that the current provisions concerning the transfer tube and safe positioning of an assembly during the course of handling should be the subject of detailed studies by EDF.

With regard to the transfer tube on the NPPs in operation, analysis of the CSA reports showed that for the CP0, CPY and 1300 MWe plant series, the transfer tube rupture margins for seismic stresses going beyond the design-basis earthquake, could be limited. Moreover, the transfer tube is hard to inspect. It is therefore difficult to demonstrate that the risk of tube break is virtually to be ruled out.

ASN therefore considers that EDF must study changes to hardware or to operating conditions to prevent uncovering of an assembly during handling in the event of a transfer tube break. EDF must also study the possibility of modifications such as to limit a fall in the water inventory of the pools in the reactor and fuel buildings. ASN will issue a requirement on this subject.

In the case of the EPR, the design of the reactor and fuel buildings, which rest on a common basemat, thus limiting differential displacements, would make it possible to envisage a second containment barrier around the transfer tube such as to prevent the risk of uncovering of an assembly during handling.

As part of the analysis of the CSA reports, EDF stated that for technical reasons which it considered to be prohibitive, it did not envisage installing a system for automatic safe positioning of a fuel assembly when the ambient conditions ruled out access to the premises.

EDF prefers having the fuel assembly secured by operators present in the reactor building or the fuel building, making provision for the material or organisational measures enabling them to do so, while the ambient conditions are still acceptable. The goal is to ensure that the fuel assembly can be made secure within a period of less than two hours.

ASN considers that EDF must continue to carry out studies and look for solutions to counter the difficulties mentioned earlier, look for technical measures to prevent the risk of uncovering of a fuel assembly and ensure that an assembly being handled is safely positioned as rapidly as possible when the ambient conditions still allow access to the premises. ASN will issue a requirement on this subject.

Hydrogen management

Following the Fukushima accident, ASN asked EDF to examine the risks linked to the build-up of hydrogen in the buildings other than the containment, especially the fuel building. ASN in particular asked EDF to identify:

- The phenomena capable of generating hydrogen (radiolysis, zirconium/steam reactions);
- The possible build-up of hydrogen;
- The means implemented to prevent hydrogen explosion or detonation.

As part of the CSAs, EDF states that the presence of fuel assemblies in the BK pool can lead to the production of hydrogen in normal operation by radiolysis of the water and that an additional analysis is being initiated to assess the possible risk in the absence of ventilation.

EDF also states that oxidisation of the cladding by steam, would lead to the production of hydrogen in sufficiently large quantities to exceed the flammability threshold, but that bearing in mind the means used to prevent uncovering of the fuel assemblies, the risk of hydrogen production by oxidisation of the zirconium cladding is ruled out.

EDF therefore proposes completing its thermohydraulic studies of the fuel storage pool before the end of 2012, taking account of the different behaviour of the various areas of the spent fuel pool. In accordance with the hydrogen risk studies, particular steps may need to be taken depending on the result of these studies, such as the installation of passive autocatalytic recombiners in the fuel building. These studies cover both the NPP fleet in service and the EPR.

ASN considers these studies to be necessary in order to determine the material and organisational measures that could be taken on the NPPs in operation and on the EPR, such as the installation of passive autocatalytic recombiners in the fuel building.

ASN will issue a requirement on this subject.

Protection against radiation

ASN asked EDF to examine the current situation and the existing and complementary management measures, concerning protection against the level of radiation that could be reached.

In the CSA reports, EDF feels that a water height more than 1.5 m above the fuel assemblies is enough to ensure radiation protection compatible with human intervention, but that given the steam generated by the heating of the pool water, this intervention would take place in degraded ambient conditions.

EDF however considers that if the water height were to be less than this value, the thickness of the concrete walls would be sufficient to maintain equivalent dose rates at values compatible with human intervention in the adjacent premises, even if the ambient conditions were no longer to allow access to the BK pool area.

Nonetheless, the preparatory work for water makeup of the spent fuel pool would be carried out in advance, while the ambient conditions are not yet degraded. The makeup start/stop actions would not subsequently require entry into the spent fuel pool area or adjacent room.

For the NPP fleet in operation, outside the fuel building, the radiation from the fuel assemblies induced by skyshine generates dose rates that rise as the water level drops. In the CSA reports, EDF specifies that it is studying this phenomenon (which corresponds to the scattering of gamma radiation by the atmosphere) and gives initial dose rate estimates at 20 metres from the fuel building of about 1 mSv/h.

For the EPR, the airplane crash shell covering the fuel building offers a sufficient thickness of concrete (180 cm) to guarantee no dose rates induced by "skyshine" outside the building.

ASN considers that the Fukushima accident highlighted the accident management difficulties that could arise when the water inventory in a spent fuel pool is reduced. It thus appears necessary that EDF be able for as long as possible to manage a situation deteriorating in a spent fuel pool.

Based on this finding, EDF proposes supplementing the radiological environment studies already performed by developing its analysis of the dose levels liable to be received by the intervention personnel, induced by a reduced water inventory above the fuel assemblies and a two-phase state in the fuel storage pool.

ASN considers this approach to be satisfactory and will be drafting a technical requirement on this subject.

Mitigation of releases after fuel melt

In the CSAs, EDF does not describe the means for mitigation of releases after fuel melt in the spent fuel pool.

The fuel building containment was designed to take account of a fuel assembly falling and breaking during handling under water in the spent fuel pool. The elements not retained by the water of the spent fuel pool would be captured by the DVK fuel building ventilation system and filtered by filters and iodine traps.

In the case of an accident involving loss of pool cooling, this would lead to boiling of the water in the pool. Dynamic containment would then no longer be effective, as DVK system filtration is ineffective in the presence of the steam given off by spent fuel pool boiling. Furthermore, the fuel building consists of a metal cladding roof and a thin concrete wall (about 30 cm), for the entire fleet in operation and the EPR. The fuel building is not therefore designed to ensure static containment in the event of a pressure rise following a release of steam owing to boiling of the spent fuel pool.

Given the difficulty, if not the impossibility, of implementing effective means to limit the consequences of prolonged uncovering of fuel assemblies, ASN will issue requirements demanding that EDF reinforce the prevention measures and robustness of the facility to limit the possibility of such an accident, thus ensuring that this risk remains residual (see above).

Instrumentation necessary for accident management

As part of the CSAs, ASN asked EDF to analyse the adequacy and availability of the required instrumentation for monitoring the parameters of the spent fuel pool in the event of a severe accident.

For the NPPs in operation and the EPR, EDF proposes studying the steps to be taken to reinforce the robustness of the instrumentation in the spent fuel pool (water temperature, water level, dose rate in the hall) to ensure management of the situation and in particular management of makeup.

ASN considers that such modifications are essential in order to guarantee a clear picture of the status of the facility during a severe accident. Furthermore, the implementation of such modifications will not entail any major difficulties and should thus take place rapidly. ASN will issue a technical requirement on this subject.

Accessibility and habitability of the control room

In the event of an accident in the spent fuel pool, ASN asked EDF to evaluate the adequacy of the existing management measures, including the severe accident management guides and the possible additional measures. The accessibility and habitability of the control room were among the particular points to be examined by EDF.

In the CSA reports, the EDF analysis concludes that releases into the environment in the event of boiling of the BK spent fuel pool, without deterioration of the fuel assemblies, remain below those involved in a loss of coolant accident (LOCA) of category 4 in the baseline safety requirements. Consequently, the habitability of the control room remains guaranteed for the loss of cooling accident or the loss of water inventory in the BK spent fuel pool.

As mentioned above, an accident leading to deterioration of the fuel assemblies, subsequent to their uncovering in the BK spent fuel pool could lead to significant releases in the fuel building, against which it is hard or even impossible to implement effective means of mitigation.

Following the CSAs, EDF will examine the feasibility for the NPPs in operation and the EPR, of remote transmission of the makeup system controls to areas completely protected from the propagation of steam and of improving the operation of the steam outlet. ASN considers this approach to be pertinent.

6.4.3 Conclusions concerning the steps taken to limit radioactive releases in the event of a severe accident

In the CSA specifications, ASN asked EDF to look at the possible areas for improvement to limit radioactive releases.

Following the CSAs, EDF will examine the modifications necessary to systematically ensure an alkaline pH in the sumps of the reactors in service in the event of a core melt, in order to limit iodine releases and further reduce the short-term impact on the site and on the surrounding populations in a severe accident situation.

ASN will also be asking EDF to perform a detailed study on the possibilities for improving the U5 venting-filtration device, taking account of the robustness to hazards, the efficiency of filtration in the case of simultaneous use on two reactors, the improvement of filtration of fission products, in particular iodine and the radiological consequences of opening, especially in terms of accessibility of the site, the emergency management rooms and the control room.

Following the CSA on the EPR reactor, ASN considers that the design of this EPR reactor already ensures improved protection with regard to severe accidents. Of the planned equipment, EDF shall identify that which is to be a part of the hard-core for the prevention and limitation of the consequences of a severe accident, including systems or equipment to depressurise the reactor coolant system, isolate the containment and control the pressure in the containment. ASN will issue a requirement on this subject.

ASN also notes EDF's commitment to study the feasibility of implementing a system able, in a total loss of electrical power situation, to ensure the alkaline nature of the water in the IRWST tank. EDF has undertaken to perform a feasibility study for mid-2012.

7 Conditions concerning the use of outside contractors (excluded from the scope of the European "stress tests")

The Fukushima accident showed that the ability of the licensee and, as necessary, its contractors, to work together in a severe accident situation is a key factor in managing such situations. This ability to work together is also crucial for the maintenance of the facilities, the quality of their operation and the prevention of accidents. The conditions concerning the use of subcontractors are thus of particular importance and must enable the licensee to retain full control over and responsibility for the safety of its facility. This importance was also underlined by the stakeholders, particularly the HCTISN, right from the beginning of the ASN process to draft the specifications for the CSAs. The ASN specifications thus asked the licensees to analyse the conditions for the use of contractor companies.

In addition, and more generally speaking, ASN considers that integrating socio-organisational and human factors into the safety approach is vital and this aspect is considered both in the checks carried out by ASN and on the occasion of the periodic safety reviews of the facilities. Experience feedback from the Fukushima accident will also be taken into account in this respect. With its experience in the field of labour law oversight as well as in nuclear safety, ASN has already initiated a campaign of targeted inspections on the topic of subcontracting of activities within the EDF nuclear power plants. These inspections, carried out by teams comprising labour and nuclear safety inspectors, will be continued in 2012 and expanded to take in the nuclear facilities of other licensees, jointly with the ministry for labour.

ASN had already made plans to conduct more detailed examinations of the conditions concerning the use of subcontracting in EDF's nuclear power plants on the occasion of the two scheduled meetings of the advisory committee for nuclear reactors: one concerning safety management and radiation protection during reactor outages, the other specific to examining the oversight of the subcontracted activities. The additional requests submitted by ASN following the CSAs on those points which, given the time allotted for these evaluations, would not have been sufficiently detailed in the EDF reports, will in particular be investigated during this in-depth examination, for which ASN is calling on the expertise of IRSN and the opinion of the advisory committee for nuclear reactors.

7.1 Scope of activities concerned by subcontracting

The ASN specifications for the CSAs require a description and justification of the scope of the activities concerned by subcontracting, demonstrating that this scope is consistent with the licensee's full responsibility for nuclear safety and radiation protection.

In the CSA reports, EDF defines the contractor company as the company holding a contract and a subcontractor as an individual or corporate body who has received from the contractor company a part of the contract concluded with the client (in this case, EDF). For EDF, *contractor personnel* refers to the employees of a company, regardless of the level of subcontracting (contractor company or subcontractor).

EDF announces that the activities subcontracted annually involve 20,000 external employees, including 18,000 working in the controlled area⁵², 5,000 at a local level and 15,000 at a regional or national level. Temporary and fixed-term contract (CDD) workers account for 15% of the outside contractor personnel working in the controlled area. 6 to 7% of the total number of contractor personnel are foreigners, or some 1,200 workers.

These 20,000 employees of outside contractor companies are reinforcements for the 10,000 internal employees of EDF, who handle daily maintenance, preparation, oversight and verification of the correct performance of maintenance work during reactor outages.

EDF explains that the activities are subcontracted when there is a need to call on rare skills and specialised manpower, as well as to deal with activity peaks and the particularly seasonal nature of reactor outages. With respect to the nuclear power plants in operation, these requirements regarding activities subcontracted to contractor companies concern maintenance work, but also, for example, "security radiation protection" and

⁵² As defined in article R.4451-18 of the labour code

"engineering consultancy" activities. The breakdown of contractor employees according to the disciplines subcontracted by EDF in 2010 was:

- Nuclear logistics: 18%,
- Mechanics Turning Machines: 18%,
- Automation Electricity: 16%,
- Non-destructive controls and testing: 7%,
- Boilermaking Piping: 7%,
- Heat insulation-Scaffolding: 7%,
- Civil Engineering: 7%,
- Welding: 5%,
- Valves: 5%
- Security Radiation Protection: 4%,
- Engineering Consultancy: 4%,
- Ventilation-Air conditioning: 1%,
- Audit Consultancy: 1%.

In 2010, the contractor company expertise came for the most part within the field of maintenance operations.

ASN considers that the information presented by EDF is incomplete. EDF does not specify whether the above-mentioned figures concern only the NPPs in service, or also the head office departments (for example, does the 4% "Engineering Consultancy" cover the needs of the head office departments?) and does not define the categories of the professions presented (for example, what is covered by the "Nuclear Logistics" category?). These data should also be supplemented by an evaluation of the proportion of outside workers for each trade identified. This information would for example make it possible to find out whether, for example, the "Valves" activities are primarily carried out by contractor companies or not.

ASN also considers that EDF's justification for the use of subcontracting for maintenance and other activities, in particular during reactor outage periods, fails to demonstrate that the various reactor outage periods which take place during the course of the year on each of the NPPs generate seasonal peaks justifying the use of subcontracting.

Finally, resorting to subcontracting raises the question of maintaining skills and expertise within the licensee's organisation, in particular in the light of the possible extension of the operating lifetime of the existing nuclear facilities and the significant turnover of manpower. EDF's decision to outsource part of the activity carried out by the above-mentioned trades should not lead to a situation in which the licensee no longer has full control over the scheduling or quality of the maintenance work performed, which would be incompatible with its responsibility for the safety of its facility. EDF also mentions a "risk of loss of project ownership", identified in certain areas important for safety, such as "Valves" or "Piping-welding" operations, which explains its decision as announced in the CSA reports, to bring 200 valve specialists back in-house. EDF does not however specify the general measures taken to limit the risk of losing the skills necessary for the monitoring and oversight of the subcontracted activities.

To conclude, ASN considers that EDF has not adequately demonstrated that the scope of the activities subcontracted, both in terms of the types of activities concerned and the internal skills preserved, is compatible with the licensee's prime responsibility for safety and radiation protection. ASN will thus be asking EDF to add to the information provided in the CSA reports, in order to clarify the link between subcontracting and the licensee's exercise of its responsibility. These elements will constitute inputs to the evaluations performed by IRSN and the Advisory Committee for nuclear reactors (GPR), at the request of ASN, on the topic of the subcontracting control.

7.2 Management of subcontracted activities

7.2.1 Contractor selection procedures

The ASN specifications for the CSAs require a description of the contractor selection procedures: requirements concerning the qualification of the contractor companies (in particular the nuclear safety and radiation protection training of the operatives), formalisation of specifications and types of contracts, procedures for placing of contracts, steps taken to give the subcontracting companies and their employees medium-term visibility concerning their activities.

In the CSA reports, EDF lays out a number of the conditions involved in the selection of contractor companies for awarding of contracts:

- Qualification of the contractor companies (only the first tier subcontractor), issued following an evaluation of the technical know-how (analysis of an "aptitude assessment file") and the organisation (company audit). The order of 10th August 1984⁵³ stipulates that the licensee must set up a qualification system for the staff and the technical resources taking part in the performance of an activity concerned by quality. Qualification of the contractor companies by EDF does not extend to the subcontractors of the contracting company, but does cover the evaluation of the contractor's arrangements for monitoring the subcontractors. Qualification is issued for a period of 3 years, but can be called into question at any time, in particular based on the analysis of the contractor evaluation forms (FEP, see § 7.2.3). The possible sanctions are a stricter monitoring, the suspension of qualification and withdrawal of qualification. In 2010, 80 site audits were carried out by the qualification organisation, 86% of the contractor companies were the subject of at least one FEP and 5,803 FEPs concerning on-site maintenance were issued for 499 qualified service contractor companies.
- The socio-economic capacity of the company selected, in particular its compliance with the socially responsible subcontracting agreement and the sustainable development progress Charter.
- The actual training for nuclear safety and radiation protection of the employees of the contractor companies (all tiers). EDF states that three to four training courses must be followed by any outside person who is to work in a nuclear zone, regardless of his or her trade ("Advanced radiation protection" (1 to 5 days), "risk prevention" (5 days), "Nuclear Qualification" (1 to 3 days), "Contractor Safety Quality" (5 days)). EDF states that the actual teaching of the programme is checked during the site access formalities and that the knowledge acquired is checked by training organisations from outside EDF, audited by EDF (and the CEFRI⁵⁴ in the case of training related to radiation protection).
- The notion of "best bidder". The bids submitted by the candidates for the maintenance contracts are evaluated according to the notion of the "most economically advantageous bid", in other words certain criteria not related simply to price are considered by EDF. EDF in particular stipulates that "the part of the criteria not related to price in the bid evaluation can today reach 20%, half of which is linked to working conditions and the social environment of the work performed."

Finally, EDF mentions the creation of a system of bonuses to provide a greater margin for companies which contributed to the attainment of its objectives, which can be up to 5% of the value of the contract. The bonus system is based half on collective criteria related to the results of the site (duration of the outage, dosimetry, triggering of C3 portals) and half on individual criteria (obtaining a satisfactory A grade evaluation form). EDF also clearly wishes to increase the average duration of the on-site maintenance contracts, which went from 3 years in 2000, to 5 years in 2010.

ASN considers that the CSA reports are short of information on the frequency of application and the procedures for following-up the sanctions imposed on the contractor companies checked and penalised. ASN will be asking EDF to complete the CSA reports.

ASN considers that it would be opportune to see whether the employees of outside companies actually receive the same level of training as the EDF staff, in particular concerning the potential health risks following exposure

⁵³ Order of 10th August 1984 concerning the quality of the design, construction and operation of basic nuclear installations

⁵⁴ CEFRI: French Committee for the Certification of Companies for the Training and Supervision of Personnel Working with Ionizing Radiation

to ionising radiation, and the possible impact of the situation in terms of security, safety and the quality of maintenance.

Finally, ASN considers that the consequences of EDF's buying policy on working conditions, safety, quality and the application of social and labour laws must be assessed more objectively. There is in particular the question of the actual weight given to the "best bidder" criteria in the contracting process which, even though explicitly presented in the CSA reports, are backed up by no actual figures.

ASN will be asking EDF to add to the information transmitted about the contractor selection procedures and their implications for safety.

7.2.2 Steps taken to ensure satisfactory working conditions for the contractor companies

In its specifications, ASN asks for a description of the steps taken to ensure satisfactory working conditions for the contractor companies and a description of the organisation put in place for radiation protection of the workers.

In the CSA reports, EDF states that the working conditions of the contractor companies are officially laid out, first of all through the "Implementing an Attractive Industrial Policy" (MOPIA) project, aimed at enhancing EDF's attractiveness to contractor personnel. The MOPIA project was launched in 2008, and includes all aspects from industrial policy (decision to subcontract, definition of requirements, management of panels, etc.), to buying (selection strategy, types of contract, etc.), to relations with the contractors (social aspects, living standards on the sites, etc.). More precisely, according to EDF, the MOPIA project "*mainly concerns the following topics: placing innovative contracts giving most weight to the "best bidder", incorporating a significant bonus system; helping companies renew and develop the skills of their staff; improve the quality of the work; continue to improve safety results, further improve the living standards of the workers on nuclear sites.*" The MOPIA project is a follow-on from the "Progress and Sustainable Development Charter" signed in January 2004 by 13 professional organisations, which formalizes the conditions for the work done by contractor companies. This charter "*is binding upon the signatories in the following areas: developing the professionalism of the participating workers; equal health monitoring; the same nuclear safety training; the same risk prevention and recycling training for contractor and EDF personnel; transparency in the tendering process; improved workload visibility; reduction in both individual and collective dosimetry; improved risk prevention; improved working conditions and conditions around the sites; cleanness and environmental protection*". Subsequently, EDF Corporate Management and three trade union organisations signed an agreement on "*socially responsible subcontracting*" in October 2006.

In the CSA reports, EDF details a range of actions taken since 2006, to facilitate the life of the contractor staff on the sites, such as free provision of caretaker services, the provision of cloakrooms and sanitary facilities and transport services using EDF staff buses, internet wifi access, etc. Since 2000, contractor satisfaction has been measured by a barometer which, over the past 5 years, has revealed a high degree of satisfaction with regard to criteria such as "being made to feel welcome", "quality of accommodation", "rigorous safety" and "quality of radiological cleanness". EDF also mentions points on which there is dissatisfaction, in particular "wasted time" and "information about scheduling changes".

With regard to the medical monitoring of the employees of the contractor companies, EDF states that this is carried out by their employers, through the locally competent Joint Contractor Medical Services (SMIE). In the CSA reports, EDF states that it is bearing the financial cost of enhanced medical monitoring of the contractors, through agreements signed with the joint contractor health services of which the contractors are members.

EDF is aiming for a dose limit target of 18 mSv/year for all workers, a more ambitious threshold than that set out in the French regulations. EDF states that "*this threshold could be lowered in the coming months*". Moreover, according to EDF: "*The efforts made by EDF, and shared by the contractor companies, are leading to a significant and regular fall in individual and collective dosimetry. Since 2001, nobody has exceeded 20 mSv/year and, since September 2005, nobody has exceeded 18 mSv/year*". For temporary or fixed-term contract workers from outside contractors, EDF recalls the regulations, stipulating that radiation protection "*is controlled by rules that are stricter than for permanent contracts*". These workers do not intervene in areas where the dose rate is higher than 2 mSv/h and their dose limit is proportional to the duration of the employment contract. EDF points out that "*As a result of this obligation, the dose already received*

by the temporary worker has no influence on the dose that he or she can still receive on the occasion of a new contract." In 2010, according to figures provided by EDF, the trades identified as being the most exposed to ionising radiation are the heat insulators (2.88 mSv/an), welders (1.68 mSv/year), technical checkers and inspectors (1.79 mSv/year), mechanics and boilermakers (1.61 mSv/year) and the nuclear logistics personnel (1.55 mSv/year). On average, the contractor staff received a dose of 1.67 mSv/year, as opposed to 0.52 mSv/year for the employees of the EDF nuclear power generation division.

With regard to the occupational safety of the personnel of the contractor companies, EDF points out that most accidents recorded involved people falling over and injuries related to handling operations and were very rarely related to industrial risks (burns caused by steam, electrocution and so on.). EDF also details a programme of actions, including the creation on each NPP of a Joint Contractors Safety and Working Conditions Commission (CIESCT) and a occupational safety motivation programme for contractor staff, so far organised on 15 sites.

EDF announces that it is taking long-term measures to improve the skills of the employees of the contractor companies, in particular to help them boost the professional levels of their management, improve recruitment and enhance staff loyalty. For example, EDF has set up a contractor management academy, has created a complete nuclear environment training curriculum in partnership with the Ministry of National Education and is promoting the nuclear professions and trades.

Article R. 4451-117 of the Labour Code states that the *"occupational physician participates in informing the workers about the potential health risks of exposure to ionising radiation as well as about the other risk factors liable to aggravate them"*.

The EDF staff are monitored by the NPP occupational physician and the staff of the contractor companies by the occupational physician of these companies. ASN considers that the EDF staff and the employees of outside contractors may not receive the same level of information, in particular regarding the potential health risks of exposure to ionising radiation. ASN considers that, in accordance with the provisions of article L.4522-1 of the Labour code⁵⁵, EDF must ensure that the outside contractors working on the site take the defined preventive measures, in particular that appropriate information about the risks of ionising radiation is indeed provided by the occupational physicians of the contractor companies.

The conditions for intervention by contractors in a Radiological Emergency (SUR) are discussed in § 6 *Severe accident management*.

To conclude, ASN considers, on the basis of the CSA reports, that the steps taken by EDF to ensure good working conditions for the contractor companies are on the whole satisfactory. However, the analysis made by the licensees of events involving contractors needs to be taken further, in particular looking more closely at the corresponding working conditions. ASN will be asking EDF for additional information to assist with the evaluations carried out at its request by IRSN and the GPR, on the subject of safety and radiation protection management during reactor outages and the oversight of subcontracting.

7.2.3 Monitoring of subcontracted activities

The ASN specifications require a description of how subcontracted activities are monitored, in particular how the licensee continues to exercise its responsibility for nuclear safety and radiation protection.

The order of 10th August 1984 states that the licensee shall monitor its contractors and check the correct working of the organisation adopted, to guarantee quality. In the CSA reports, EDF explains that the purpose of monitoring is to identify situations that are potentially prejudicial to quality, to reduce the probability of nonconformity and, as applicable, to restore conformity in the best quality and lead-time conditions. This monitoring, which involves spot checks, is covered by an organisation specific to each EDF nuclear site, using

⁵⁵ Article L4522-1 of the Labour Code: "In the establishments mentioned in article L. 4521-1, when a worker or the head of an outside company or an independent worker is required to carry out work with potential particular risks owing to its nature or to the proximity of this facility, the head of the establishment of the user company and the head of the outside company jointly define the preventive measures as required by articles L. 4121-1 to L. 4121-4. The head of the establishment of the user company ensures that the outside company abides by the measures that it is the latter's responsibility to apply, in the light of the specific nature of the establishment, prior to performance of the work, during the course of the work and following its completion".

appropriate measures for monitoring of the activities performed. The monitoring of a task is entrusted to a monitoring supervisor, generally an EDF employee, except, for example, the monitoring of non-destructive testing (NDT) considered by EDF to be a specialised activity requiring specific skills. Monitoring of the contractors carrying out NDT is thus itself subcontracted. EDF states that the monitoring supervisors receive specific professional training for the activities involved, as defined in a monitoring programme.

During the performance of the work, the duties of the monitoring supervisor are primarily to ensure the traceability of the monitoring actions performed, to adjust monitoring when the activity performance conditions change (context, volume, etc.) and to take steps in the event of nonconformity with the contractual requirements. After the work is completed, the monitoring supervisor checks the records (filled out monitoring files, available documents, deviations processed with EDF approval, etc.), or has them checked, creates an evaluation of the work from the data collected and the shared findings and completes the drafting of the monitoring report. The result of this monitoring process is officially written up in the work evaluation forms (FEP).

The monitoring of subcontractors of the contractor companies is specifically dealt with by EDF. EDF states that it is the responsibility of the contractor company holding the contract to ensure that its subcontractors (tier 2 or higher) comply with the notified requirements. EDF explains that it monitors this follow-up. Since mid-2011, EDF has also been directly monitoring the activities of a subcontractor considered to be deficient, through the production of a work evaluation form (FEP).

ASN considers that EDF's response to the specifications on the subject of monitoring of subcontracted activities is detailed but incomplete, because no figures are given. There is in particular the question of the total number of FEPs issued by the monitoring supervisor, in other words does this correspond to the 5,803 FEPs presented in the part on qualification monitoring (§ 7.2.1) in the CSA reports. If so, considerable discrepancies are observed between the sites in 2011 with regard to the number of FEPs issued.

Furthermore, no mention is made by EDF of the total number of the interventions by contractor staff to which these 5,803 FEPs would refer. The question then arises of the adequacy of the technical monitoring for the volume of work subcontracted. In addition, EDF proposes no weighting of the monitoring performed according to the type of activity and its importance for safety.

EDF subcontracts some monitoring activities, but does not sufficiently explain the type of activity concerned, or the volume and the importance for safety. Neither does EDF mention the temporary contractor groups (GME), in particular how they are qualified and monitored.

Finally, ASN notes that EDF provides no information specifying the type of evaluation it performs on the organisation adopted by the contractor companies (tier 1), to enable them in turn to evaluate their contractors of tier 2 or higher. ASN remarks that EDF does not clarify the criteria enabling it to qualify a subcontractor as deficient, thus triggering monitoring of its work, through the production of a work evaluation form (FEP) (system in place since mid -2011).

To conclude, ASN considers that in its CSA reports, EDF does not give enough information about the adequacy of monitoring of the different types of subcontracted activities important for safety, whether in terms of volume of monitoring or weighting of monitoring, according to the importance for safety of the activity in question. Moreover, the presentation of the procedures for monitoring the activities subcontracted by EDF raises the question of the dilution of responsibility for monitoring contractors of tier 2 or higher. ASN will thus be asking EDF for additional information to improve supervision of subcontractor management, which will contribute to the assessments carried out at its request by IRSN and the GPR, on the topic of subcontractor oversight.

7.3 Conclusions on the conditions for the use of contractor companies

In the CSA reports, EDF says that it can guarantee the compatibility of its industrial subcontracting policy with its full responsibility as licensee for nuclear safety and radiation protection. EDF believes that it has put into place:

- a clear "do or buy" industrial policy and an industrial fabric strategy based on the availability of the facilities and nuclear safety,
- a qualification system guaranteeing the human resources, means and competence of the contractor companies,
- a transparent system for placing contracts, leaving considerable room for the "best bidder",
- technical, quality, nuclear safety and radiation protection requirements that are clearly laid out in the specifications prepared by EDF. Only bids meeting these requirements are selected for the commercial negotiation phase and bids with an "abnormally" low price are eliminated from the process,
- mandatory justification by the contractor companies of the actual training to their employees before they intervene on the site,
- monitoring of the activities of contractor companies on EDF NPPs, before and during the reactor outage, included in the operating experience feedback process,
- the goal of dosimetry reduction, through the design of the interventions,
- monitoring of the activities carried out by the contractors able to ensure the required level of quality. This monitoring by the monitoring supervisors enables the qualification of the contractor companies to be verified and renewed.

In the CSA reports, EDF announces the following two areas for improvement:

- limiting subcontracting to 3 tiers as of the call for bids stage. These measures would not modify the provisions in force for monitoring of the subcontractors.
- tightening up the provisions of the Progress and Sustainable Development Charter and the advances made as a result of the MOPIA project, in particular concerning the working conditions for the employees of contractor companies. This would take the form of the inclusion of "social specifications" in the calls for bids and contracts.

ASN considers that these two points presented by EDF are a step in the right direction towards improving the conditions for the use of contractor companies. However, EDF must provide information to prove that these two measures, in particular limiting subcontracting to 3 tiers, will enable it to effectively retain its full responsibility for nuclear safety and radiation protection.

On the basis of the IRSN report and the opinion issued by the Advisory Committees for "Reactors" and "Plants", subsequent to their meetings of 8th, 9th and 10th November 2011 devoted to reviewing the post-Fukushima complementary safety assessments conducted in 2011 by the licensee EDF, ASN considers that the aspects relating to subcontracting are a key element which can determine the operational robustness of the facilities. ASN will be asking EDF for additional information as the data given in the CSA reports are insufficient on the following points:

- Incomplete or missing figures concerning:
 - the proportion, nationwide, of outside staff for each trade identified,
 - the annual number of monitoring activities performed by the monitoring supervisors, compared with the number of tasks performed by the contractor employees, according to the various trades identified and their importance for safety; as well as the number of monitoring activities subcontracted;
 - the number of hours of mandatory training received by the EDF staff, so that for an equivalent trade or function, it can be compared with the number of hours of the same training received by each contractor employee,

- the actual weight given to "best-bidder" criteria in the contracting process, in order to assess the consequences of the EDF buying policy on working conditions, safety, quality and application of social and labour laws.
- A lack of information concerning how EDF:
 - ensures that the outside companies working on the site take the defined preventive measures, in particular that appropriate information about the risks of ionising radiation is actually provided by the occupational physicians of the contractor companies,
 - deals with the qualification and monitoring of temporary contractor groups (GME),
 - evaluates the organisation put into place by the contractor companies (tier 1) to monitor the subcontractors of tier 2 or higher, and to qualify a subcontractor as deficient, thus triggering monitoring of its activities, through the production of a work evaluation form (FEP).
- The evaluation of the contractor companies by the qualification organisation is neither systematic nor performed on a multi-year basis. With regard to the contractor companies inspected and sanctioned, EDF does not give the frequency at which these penalties are applied, nor how such penalties are monitored.

ASN also considers that the presentation of the monitoring procedures for activities subcontracted by EDF raises the question of the dilution of responsibility for monitoring contractors of tier 2 or higher (phenomenon of "cascaded" subcontracting).

To conclude, ASN considers that in the CSA reports, EDF did not sufficiently demonstrate that the scope of the subcontracted activities, both in terms of the types of activities concerned and the internal skills preserved, is compatible with the licensee's prime responsibility for safety and radiation protection. The additional information to be requested from EDF on the basis of the elements presented in this chapter, will contribute to the IRSN analysis as part of the investigation carried out at the request of ASN on the topic of subcontracting oversight by EDF. The Advisory Committee for nuclear reactors will be asked for its opinion on the oversight of subcontracting by EDF in late 2013.

Finally, ASN considers that the question of subcontracting must be considered in the same way as all aspects relating to humans and how they interact with systems (technical, organisational, etc.). This area of concern is referred to as "Organisational and Human Factors" (OHF). The lessons that could be learned from the Fukushima accident must thus be seen in the light of a detailed OHF analysis, on the one hand to understand the accident scenario (before the accident, during management of the dynamics of the accident and during the emergency management phase), and on the other, to validate the practical application of the measures resulting from the CSAs. **ASN thus considers that the questions of subcontracting and OHF must be the subject of attentive, continuous review, implementing methodologies that are scientifically sound and going further than a simple documentary analysis. This review should in particular cover the following points:**

- the link between subcontracting and the exercise of licensee responsibility,
- the effects on safety of particular contracting methods (cascaded subcontracting, internal or external subcontracting, best-bidder, etc.),
- the effects of contractor working and living conditions on safety,
- the risks relating to the potential loss of skills.

ASN also recommends that research programmes be initiated, at both national and European levels.

7.4 Measures envisaged by ASN to strengthen the requirements concerning the conditions for the use of contractor companies

ASN shall be taking several measures to reinforce the supervision of and requirements concerning the conditions for the use of contractor companies.

First of all, one observation is that the various elements presented by EDF in the CSA reports are sometimes contradicted by feedback from the "field", meaning that **ASN's inspections of the use and management of contractors by EDF will continue in the coming year, through a programme of specific inspections.** ASN monitoring of the "contractors" topic is being coordinated and performed jointly with regard to safety and labour inspection, as ASN is responsible for monitoring nuclear safety and labour inspection in the NPPs: occupational health and safety, working conditions and quality of employment of EDF staff, its contractors or its subcontractors, in the same way as the safety of the facilities, are the subject of coordinated monitoring and inspection. In 2011, all the NPPs were inspected on the "contractors" topic, except for Golfech, which had been inspected in 2010. For the coming year, ASN monitoring will in particular look at the regularity of the labour relations. In addition, ASN will systematically review the follow-up of sub contractor-related inspections. As and when necessary, ASN will carry out inspections on the subcontractors. ASN will eventually extend the inspections to intellectual services and to the conditions of work by approved organisations carrying out the statutory checks and inspections.

In the regulatory field, ASN submitted proposals to the ministers for nuclear safety, for the introduction of strengthened provisions concerning subcontractor monitoring into the order laying down the general rules for basic nuclear installations.

ASN in particular proposed that this order stipulate that the monitoring of activities important for safety performed by an outside contractor must not be delegated. Furthermore, in the general operating rules (GOR) the licensee will have to specify the principles and the organisation underpinning this monitoring, as well as the resources devoted to it, and shall justify that these are sufficient in the light of the scale of the activities important for safety entrusted to the outside workers. Finally, this order explicitly states that the licensee shall take all steps to ensure that the outside workers can detect any deviations concerning them and bring them to the licensee's attention as rapidly as possible.

In 2011, ASN and the General Directorate for Labour (DGT) worked together on a draft order defining the conditions for certification of companies performing maintenance or other work on nuclear facilities or using equipment emitting ionising radiation.

Article R. 4451-122 of the Labour Code stipulates that "The contractors performing maintenance or other work or using equipment emitting ionising radiation may only perform the activities specified on a list determined in the order, once they have obtained a qualification certificate proving their ability to perform work involving ionising radiation". Pursuant to article R. 4451-124 of the Labour Code, this order aims to enshrine in the French regulations the arrangements made by some licensees, while reviewing the list of activities or activity categories for which this certification is required, as well as the accreditation and certification procedures and conditions.

With regard to radiation protection, ASN intends to make a contribution to harmonising international regulations concerning dosimetric monitoring of roaming foreign workers. Thus, the specific question of subcontractors from abroad has been examined since 2007 by the HERCA association of European radiation protection regulatory bodies. **Consideration is being given to creating a European dosimetric passport, which would mean that the dose received by persons having worked in a nuclear power plant abroad would be known in France.**

Finally, all the additional information to be requested from EDF on the basis of the elements presented in this chapter, will contribute to IRSN's analysis as part of the investigations conducted at the request of ASN on the topic of management of safety and radiation protection during unit outages and the oversight of subcontracting by EDF.

ASN finally considers that the lessons learned from the Fukushima accident must be based on an in-depth analysis of the issue of the use of subcontracting, in the same way as all organisational and human aspects regarding the management of accident situations. With regard to the use of subcontracting, further thought must be given to the link between subcontracting and the licensees' exercise of their responsibility, the effects on safety of particular contracting procedures (use of cascaded subcontracting, the choice of contractor companies based on criteria unrelated to price, and so on), the effects on safety of contractor working and living conditions as well as the risks regarding the potential loss of skills at the licensee or within the local industrial fabric.

Concerning OHF aspects, an in-depth analysis will need to be carried out to identify the specificities of the intervention conditions in accident situations (difficulties with decision-making, adequacy of human resources, required skills, accessibility and habitability of the premises, stress and fatigue of workers, noise, heat and radiological environment, etc.) and to propose appropriate steps to be taken with respect to the specific nature of the intervention conditions identified. ASN will issue a requirement binding on the licensees. ASN also recommends that research programmes be initiated on the issues of subcontracting and OHF. Finally, ASN proposes setting up a working group on these subjects, comprising the licensees, the trade union organisations, the HCTISN⁵⁶, the Ministry for Labour and the Ministers responsible for nuclear safety.

⁵⁶ French High Committee for Transparency and Information on Nuclear Security

8 Conclusion

The approach defined by ASN for the complementary safety assessments (CSA) is to study the behaviour of nuclear facilities in severe accident situations caused by an off-site natural hazard or, independently of any hazard, according to accident scenarios with characteristics (duration, number of facilities concerned, seriousness of the situation, etc.) exceeding the current baseline safety requirements. The CSAs thus also consist of a verification of the preventive measures and the steps taken to mitigate the consequences using the defence in depth principle: initiating events (earthquake, flooding), resulting loss of safety systems (loss of heat sinks, loss of electricity sources) and severe accident management. This approach, carried out with the aim of avoiding serious consequences for the environment and the populations as the result of a hazard or accident situation exceeding the baseline safety requirements, can be broken down into two main phases:

- conformity with the current design, which is necessary for the robustness of the facilities;
- an approach to the beyond design-basis scenarios built around the principle of defence in depth.

ASN considers that EDF has carried out considerable work in the time available, in submitting its CSA reports, which comply with the spirit of the ASN specifications and which allow an analysis of the robustness of the facilities. EDF also presented proposals for improvements; ASN considers that these proposals provide a satisfactory answer to the objectives set for the CSAs.

Owing to the short time ASN allocated to EDF in which to carry out these studies, the evaluation produced in 2011 is simply the first step in the process aimed at integrating the experience feedback and lessons learnt from the Fukushima accident. This approach will be continued in the coming years.

8.1 Steps to increase the robustness of the facilities (already implemented)

In the light of the safety approach and the design methods used so far in France, along with the ten-yearly periodic safety reviews, the nuclear power plants look robust to the hazards considered in the baseline safety requirements. As a matter of fact, the periodic safety reviews of the NPPs require that EDF not only conducts a detailed conformity check of its facility, in order to maintain its level of safety over time, but also makes modifications to its facility in order to improve the level of safety of the installation. The level of the design-basis hazards are thus periodically reassessed on the occasion of the periodic safety reviews, to take account of operating experience feedback from France and abroad, plus the best international practices.

Conformity of installations

The conformity of nuclear installations with the safety requirements applicable to them is a key component of their safety and their robustness to the accident initiating events or hazards. For ASN, this conformity must be managed over the long-term and be based on a systematic search for any deviations which must then be processed in a way commensurate with the safety implications. The detection, notification and processing of non-conformities are now therefore the subject of ASN requirements as defined in the order of 10th August 1984⁵⁷ and in the general operating rules for nuclear power plants, which for example specify how quickly the reactors must be temporarily shut down according to the safety significance of the nonconformities.

The CSAs confirmed that the processes put into place at EDF to detect non-conformities, in particular via the periodic tests, maintenance and periodic safety reviews, were satisfactory. The CSAs were also an opportunity for EDF to carry out specific investigations into the condition of its facilities. EDF has undertaken to complete these by the end of 2012.

⁵⁷ Order of 10th August 1984 concerning the quality of the design, construction and operation of basic nuclear installations.

Earthquake

The complementary safety assessments demonstrated that the current seismic margins on the EDF nuclear reactors are satisfactory, in particular thanks to the periodic revision of the seismic risk on the occasion of each ten-yearly periodic safety review. These margins are the result both of the conservative values adopted for the seismic level considered and the application of paraseismic standards used for the design, the periodic safety reviews and the qualification of SSC.

Flooding

With regard to flooding, the complementary safety assessments show that the complete reassessment carried out following the flooding of the Le Blayais nuclear power plant in 1999 offers the installations a high level of protection against the risk of flooding.

Management of severe accidents

Improvements have been made to the reactors in operation and are designed into the EPR reactor, owing to the work achieved since the *Three Mile Island* accident. ASN is also making efforts to ensure that limiting radioactive releases into the environment in the event of any accident (with or without core melt) is a major objective of the continuous process to improve the safety of the installations. This process in France is in particular organised around the ten-yearly periodic safety reviews, which aim to enhance the baseline safety requirements applicable to the installations.

EPR reactor

For the Flamanville 3 EPR reactor, ASN considers that the safety objectives and the strengthened design of this type of reactor already offer improved protection against severe accidents. Its design in particular takes account of and incorporates measures to deal with the possibility of accidents with a core melt and combinations of hazards. Furthermore, all the systems necessary for the management of accident situations, even severe, are designed to remain operational for an earthquake or a flood as defined in the baseline safety requirements.

8.2 Identified safety problems

Loss of electrical power supplies and loss of cooling systems

EDF analysed loss of heat sink and loss of electrical power supply situations for the reactors, which go beyond the situations studied in the current baseline safety requirements, in particular considering that the postulated situations are assumed, on the one hand, to affect all the reactors on a site, on a long-term basis and, on the other, to be possibly the result of an off-site earthquake or flooding, including of a level higher than that considered in the current baseline safety requirements. Analysis of EDF's CSA reports showed that certain heat sink and electrical power supply loss scenarios can, if nothing is done, lead to core melt in just a few hours in the most unfavourable circumstances.

8.3 Strengthening of nuclear safety and forthcoming work

Conformity of installations

The deviations identified by the CSAs do not directly compromise the safety of the facilities concerned but, especially if they combine, they can constitute factors such as to weaken them. ASN will thus be requiring that the licensees tighten up the detection and processing of nonconformities. ASN will in particular be proposing that the regulations on this topic be strengthened via the draft order setting out general rules for basic nuclear installations, in particular with regard to assessing the cumulative impact of any deviations present in a facility. These stipulations will be backed up by ASN requirements.

Definition of a hard core

Following the complementary safety assessments (CSA) carried out on the nuclear installations after the Fukushima accident, ASN considers that the safety of nuclear facilities must be made more robust to improbable risks which are not currently included in the initial design of the facilities or following their periodic safety review.

These facilities must be given the means to enable them to deal with:

- a combination of natural phenomena of an exceptional scale and which exceed the phenomena used in the design or during the periodic safety review of the installations ;
- very long duration loss of electrical source or heat sink situations capable of affecting all the installations on a given site.

ASN will therefore require that by 30th June 2012, EDF define and then deploy a "hard core" of material and organisational measures able to manage the basic safety functions in these exceptional situations and stipulate what steps have been taken.

These steps would thus guarantee ultimate protection of the installations, with the following three objectives:

- Prevent a severe accident or limit its progression,
- Limit large-scale releases in an accident scenario which could not be controlled,
- Enable the licensee to perform its emergency management duties.

To define the requirements applicable to this hard core, EDF shall adopt significant fixed margins compared to the current baseline safety requirements. The systems, structures and components (SSCs) which are included in these measures shall be maintained in a functional state in the extreme situations studied by the CSAs. In particular, these SSCs shall be protected against the on-site and off-site hazards induced by these extreme situations, for example: falling loads, impacts from other components and structures, fires, explosions. The proposals to be transmitted by the licensees will be reviewed by ASN and its technical support organisation.

Regarding the EPR reactor of Flamanville 3, EDF proposed several measures to increase its robustness. ASN estimates that these propositions are relevant, and considers that they should be implemented. Similarly to other reactors, ASN will require EDF to identify the equipments to be included in the hard core, including the existing or complementary systems to ensure control of the pressure in the containment building in case of severe accident.

Earthquake

The complementary safety assessments demonstrated that the current seismic margins on the EDF nuclear reactors are sufficient to avoid cliff edge effects in case of limited exceeding of the current safety requirements. These CSAs confirmed the interest of the periodic review of the seismic risk on the occasion of each ten-yearly periodic safety review. Following the analysis of the CSAs and the targeted inspections it carried out in the summer of 2011, ASN identified a number of areas for improving safety, linked to the seismic robustness of the facilities.

With regard to the earthquake risk, ASN will thus be requiring that EDF:

- ensures that the equipment capable of managing the basic safety functions is protected against fire in the event of an earthquake. The main measures to protect the facilities against fire are not today designed to withstand the earthquake in the facility's baseline safety requirements;
- increases the way this risk is taken into account in the day-to-day operation of its reactors: enhanced operator training, improved consideration of the "event-earthquake" issue, compliance with the basic safety rule regarding seismic instrumentation (maintenance, familiarity of the operators with the equipment, calibration). In a number of NPPs, ASN observed deficiencies in application of the safety requirements in force for the seismic risk.

- for the Tricastin, Fessenheim and Bugey sites, provides a study analysing the level of seismic robustness of the embankments and other structures designed to protect the installations against flooding and to present the consequences of a failure of these structures.

Flooding

Analysis of the CSAs demonstrated that the requirements resulting from the complete reassessment of the consideration of this risk on the nuclear power plants, completed in 2007, give the installations a high level of protection against the risk of flooding. However, ASN observes that the steps such as to meet these requirements have not yet all been taken. In order to ensure that this high level of protection is actually reached, ASN will require that EDF:

- completes the NPP protective measures within the time allotted following the "flood" reassessment of 2007, and no later than 2014;
- improves its management of volumetric protection of the installations. The ASN inspections brought to light the fact that the management of volumetric protection needs to be improved on several of the inspected sites;
- completes the heat sink design review, in particular with regard to prevention of the risk of clogging, initiated subsequent to the Cruas incident in 2009;
- strengthens the protection of the facilities against the risk of flooding in excess of the current baseline safety requirements, for example by raising the level of the volumetric protection. The CSAs highlighted the existence of cliff-edge effects (loss of electrical power supplies) for levels close to those used in the baseline safety requirements.

Hazards resulting from the industrial environment

The risk of a threat to an NPP as a result of accidents induced by off-site hazards on nearby industrial facilities or communication axes, was examined in the frame of CSAs. The EDF analyses are based on the data in its possession, because it has no information on the robustness of the off-site industrial facilities to an earthquake or to flooding.

ASN will require that EDF completes this analysis, specifying the effects on its facilities of hazardous phenomena liable to occur on the facilities at risk situated in the vicinity of the site, including the extreme situations studied on the occasion of the CSAs.

ASN will examine this analysis together with the services of the ministry responsible for the prevention of industrial risks.

Loss of electrical power supplies and loss of cooling systems

Analysis of EDF's CSAs reports showed that certain loss of heat sink and loss of electrical power scenarios could lead to core melt within a few hours, in the most unfavourable situations.

ASN therefore considers that the robustness of the facilities needs to be increased by a certain number of means enabling them to deal with long-duration loss of electrical power sources or heat sink situations, capable of affecting all the facilities on a site. ASN will require that EDF implements strengthened measures, integrated into the hard core mentioned earlier, comprising a diesel generator and an emergency water supply able to withstand large-scale on-site and off-site hazards beyond the current basic safety requirements, able of dealing with a total loss of electrical power supply or cooling systems, such as to prevent core melt in these situations. Pending the progressive deployment of these measures, which will take several years, ASN will require the implementation of interim measures as of 2012, such as mobile electricity generating sets.

Management of severe accidents

To ensure that its duties in an emergency situation can be carried out, the licensee shall have a robust organisation, in particular in the extreme situations studied on the occasion of the CSAs. ASN shall therefore require that EDF include in the hard core the elements essential for emergency management, in other words the

emergency management centres, the material resources needed for emergency management, the means of communication and the essential technical and environmental instrumentation. ASN shall also ask EDF to include in this hard core the operational dosimetry resources, the measuring instruments required for radiation protection and individual and collective protection systems.

The emergency management premises shall be designed for hazards beyond the current baseline safety requirements. They shall be accessible and habitable during long-duration emergencies and designed to accommodate the crews necessary for long-term site management. The control rooms are also areas that are essential in emergency management and it is therefore important that their accessibility and habitability allow operation and monitoring of all the reactors on a given site in the event of a release of dangerous or radioactive substances.

ASN shall also require the implementation, before the end of 2013, of intervention measures comprising specialist crews and equipment, able to take over from the operating personnel on a damaged site in less than 24 hours, and to deploy additional emergency intervention resources in less than 24 hours, with operations beginning on the site within 12 hours from the time of call-out.

The Fukushima accident proved that an off-site hazard could affect several facilities on the same site at the same time. Following the CSAs, ASN therefore considers that the current emergency organisation at EDF does not take sufficient account of this possibility. ASN will thus be asking EDF to complete its emergency response organisation so that it is able to manage a "multi-facility" event. For multi-licensee sites, it is also important that the licensees coordinate the management of an emergency and limit the impact on the neighbouring facilities. This point will be the subject of a requirement stipulating the reinforcement of coordination between the licensees of nuclear, but also non-nuclear facilities.

ASN also considers that to date, the means of limiting releases in the event of a core melt are insufficiently robust to the hazard levels adopted in the CSAs. In the same way as for the preventive measures, ASN will be requiring that EDF define a range of measures able to limit the releases in the event of a severe accident involving hazards in excess of those adopted in the current baseline safety requirements. EDF will in particular propose improvements to the venting and filtration system to improve its robustness and its effectiveness. EDF will also complete its feasibility studies with a view to implementing technical measures such as a geotechnical containment or system with equivalent effect, designed to protect groundwater and surface waters in the event of a severe accident with core melt.

More particularly with respect to the spent fuel storage pools, EDF examined the consequences of a natural hazard, assuming that the integrity of the pools equipment remains undamaged. In these situations, EDF concludes that with regard to the residual heat removal from the fuel, long-term topping-up of the water in the pool must be guaranteed, in order to compensate for the boiling induced by the loss of cooling. This will be the subject of an ASN requirement. In the review of the CSA reports by IRSN, the risk of leakage from the equipment, such as to compromise the water inventory in the pools in the reactor building and the pools for spent fuel storage, was also considered. These situations can lead to a cliff-edge effect, particularly owing to the significant drop in the water inventory present, the resulting reduction in the time before dewatering of the fuel and the particular constraints of operational management of these accidents. In this respect, given the difficulty, or even the impossibility of implementing effective measures to limit the consequences of prolonged dewatering of the fuel assemblies, ASN will require that EDF define and implement reinforced measures to prevent dewatering of these assemblies.

Organisational and human factors and subcontracting

ASN considers that additional measures must be taken regarding emergency management and the training of the personnel involved. It will require that the licensees define the human interventions required for management of the extreme situations studied in the complementary safety assessments and take account of emergency crew shift changes and the required intervention logistics.

ASN will also require the licensees to send it a list of the skills required for emergency management, specifying whether these skills could be provided by outside contractors. The licensees shall demonstrate that their organisation can ensure the availability of the skills required in the event of an emergency, in particular in the event of the possible use of outside contractors.

Finally, ASN will require that the licensees provide their personnel liable to intervene in extreme situations with training and preparation to guarantee their readiness for mobilisation in such situations and that they ensure that the outside contractors liable to intervene in emergency management adopt similar requirements in terms of the preparation and training of their own personnel.

The Fukushima accident demonstrated that the ability of the licensee and, as applicable, of its contractors to coordinate their organisation to work together in a severe accident situation is a key aspect of managing such situations. This ability to organise is also an essential factor in the prevention of these accidents, the maintenance of the installations and the quality of their operation. Therefore the conditions concerning the use of subcontracting are of particular importance and must enable the licensee to retain full oversight and complete responsibility for the safety of its facility. Based on the complementary safety assessment reports, ASN considers that the monitoring of subcontractors performing activities important for safety needs to be enhanced, and in particular that this monitoring must not be delegated. The ASN draft order setting out the general rules applicable to basic nuclear installations, makes provision for this accordingly. ASN also considers that EDF's proposal to limit subcontracting to 3 tiers is an interesting one that merits further examination. Moreover, ASN will be continuing its ongoing examination of the management of subcontracting, based on the evaluations made at its request by IRSN and the advisory committee of experts, as well as on the conclusions of its targeted inspections. ASN recommends that research on these subjects be initiated at either a national or a European level. Finally, ASN will propose setting up a working group on these subjects, involving the licensees, the trade union organisations, the HCTISN, the ministry for labour and the ministries responsible for nuclear safety.

In addition, ASN considers that the renewal of the licensees' personnel and skills, at a time when one generation is replacing another and when considerable work is required as a consequence of the CSAs, is a fundamental point. ASN will be attentive to this issue.

CHAPTER 3

COMPLEMENTARY SAFETY ASSESSMENTS OF THE NUCLEAR FACILITIES OTHER THAN NUCLEAR POWER REACTORS 211

1. OVERVIEW OF THE SITES AND FACILITIES.....	211
1.1. Definition of the notion of priority facilities.....	211
1.2. Overview of the sites and facilities.....	214
1.2.1 Experimental reactors	214
1.2.2 Fuel cycle facilities	218
1.2.3 Other facilities	225
1.3. An approach adapted to the diversity of the facilities.....	225
1.3.1 Particularities of the approach for nuclear facilities other than power reactors	225
1.3.2. Identification of the feared situations.....	227
1.4. ASN's overall assessment of the identification of the feared situations.....	236
2. EARTHQUAKE.....	237
2.1. Design of the facilities	237
2.2. Experimental reactors	237
2.2.1 reactors operated by the CEA (Osiris, JHR, Phénix).....	237
2.2.2. Reactor operated by the ILL	242
2.3. Nuclear fuel cycle facilities (La Hague, Tricastin, Mélox, FBFC).....	245
2.3.1. Tricastin site.....	245
2.3.2. The La Hague site	249
2.3.3 Other facilities in the fuel cycle (Mélox, FBFC)	253
2.4. Other facilities (ATPu, Masurca).....	258
2.4.1. ATPu.....	258
2.4.2. Masurca.....	259
2.5. General provisions relative to the seismic risk	260
3. FLOODING.....	261
3.1. Design of the facilities	261
3.2. Experimental reactors	261
3.2.1 Reactors operated by the CEA (Osiris, JHR, Phénix).....	261
3.2.2. Reactor operated by the ILL	267
3.3. Nuclear fuel cycle facilities (La Hague, Tricastin, Mélox, FBFC).....	269
3.3.1 Tricastin site.....	269
3.3.2. La Hague site	271
3.3.3. Other facilities in the fuel cycle (Mélox, FBFC)	273
3.4. Other facilities (ATPu, Masurca).....	276
3.4.1 ATPu.....	276
3.4.2 Masurca	277
4. OTHER EXTREME NATURAL PHENOMENA.....	280
4.1. Design of the facilities	280
4.2. Experimental reactors	280
4.2.1. Reactors operated by the CEA (Osiris, JHR, Phénix).....	280
4.2.2. Reactor operated by the ILL	282

4.3. Facilities in the nuclear fuel cycle (La Hague, Tricastin, Mélox, FBFC)	282
4.3.1 Tricastin site.....	282
4.3.2. La Hague site	283
4.3.3. Other facilities in the fuel cycle (Mélox, FBFC)	283
4.4. Other facilities (ATPu and Masurca)	283
4.4.1. ATPu.....	283
4.4.2. Masurca.....	283
5. LOSS OF THE ELECTRICAL POWER SUPPLIES AND COOLING SYSTEMS	284
5.1. Experimental reactors	284
5.1.1. CEA reactors (Osiris, JHR, Phénix).....	284
5.1.2. Reactor operated by the ILL	292
5.2. Facilities in the nuclear fuel cycle (La Hague, Tricastin, Mélox, FBFC).....	294
5.2.1. Tricastin site.....	294
5.2.2. La Hague site	295
5.3. Other facilities (ATPu, Masurca).....	304
5.3.1. ATPu.....	304
5.3.2. Masurca.....	305
6. SEVERE ACCIDENT MANAGEMENT	307
6.1. Emergency management organisation and general provisions	307
6.1.1. CEA facilities (experimental reactors, Masurca et ATPu).....	307
6.1.2. The reactor operated by the ILL	309
6.1.3. Facilities of the nuclear fuel cycle	310
6.1.4. Conclusion	316
6.2. Severe accident management per facility.....	316
6.2.1. Experimental reactors	316
6.2.2. Reactor operated by the ILL	322
6.2.3. Facilities of the nuclear fuel cycle	326
6.2.4. <i>Other facilities</i>	330
7. CONDITIONS FOR USE OF OUTSIDE CONTRACTORS	333
7.1. AREVA.....	333
7.2. CEA	338
7.3. ILL	340
8. CONCLUSION	342
8.1. General evaluation	342
8.2. Safety implications	342
8.3. Improving the robustness of facilities and forthcoming works.....	343
REFERENCES	347

COMPLEMENTARY SAFETY ASSESSMENTS OF THE NUCLEAR FACILITIES OTHER THAN NUCLEAR POWER REACTORS

1. Overview of the sites and facilities

1.1 Definition of the notion of priority facilities

The French basic nuclear installations (BNI) other than the nuclear power reactors (NPP) represent 90 facilities around the country. They are of different types operated by different licensees, and comprise:

- the fuel cycle facilities, essentially operated by the AREVA group and its subsidiaries; these include the facilities at both the upstream end of the cycle (chemistry of uranium and production of fuel) and the downstream end (spent fuel reprocessing);
- the research facilities, particularly the experimental reactors but also the research laboratories. This chiefly concerns the facilities operated by the CEA and a few research organisations;
- a facility for manufacturing pharmaceutical radionuclides for medical purposes;
- the facilities involved in waste management (interim storage, treatment of waste and effluents, repositories);
- the facilities of all types in the decommissioning phase, particularly the EDF nuclear reactors that have been definitively shut down.



Two facilities are at the project stage, namely the experimental Jules Horowitz Reactor, under construction on the Cadarache site, and the ITER (International Thermonuclear Experimental Reactor) facility, for which the first civil engineering work began in 2010 and the creation authorisation application is currently being examined by ASN.

The great diversity in the facilities results in different implications, particularly with respect to the experience feedback from the Fukushima accident. A specific approach was therefore adopted to identify which of these facilities should be treated in priority in the complementary safety assessments.

This prioritisation approach consisted in identifying - among the facilities other than the nuclear reactors and considering their situation on 30 June 2011 - those representing the greatest challenges given their radiological and chemical inventory and their sensitivity to the seismic hazard, the risk of flooding or loss of the heat sink and electrical power supplies. Facilities at the end of the delicensing process - the last administrative phase after dismantling, decommissioning and post-operational cleanout - were excluded given the very low risks they represent, the hazardous substances having been completely removed from them.

This approach resulted in three groups of facilities:

- A group of 20 priority facilities that would undergo a complementary safety assessment as of 2011;
- A group of 22 facilities with relatively less important implications, that would be examined in 2012;
- The remaining facilities, about 35, for which the experience feedback from Fukushima would be taken into account in the periodic safety assessments, which might possibly be brought forward in time.

In decisions resolutions dated 5 May 2011, ASN thus finalized the list of facilities that would be examined in 2011 and 2012.

The 20 facilities examined in 2011 essentially comprise the fuel cycle facilities, and all those on the La Hague and Tricastin sites. The experimental reactors presenting the greatest challenges have also been considered as priority facilities.

Complementary safety assessments carried out in 2011

Licensee	Site	Facility	Type
CEA	Cadarache	Jules Horowitz Reactor	Experimental and irradiation reactor
		Masurca	Critical mockup
		ATPu	Laboratory for decommissioning
	Saclay	Osiris	Experimental and irradiation reactor
	Marcoule	Phénix	Fast-neutron reactor
AREVA Group	La Hague	UP3 plant	Reprocessing of irradiated fuel assemblies and materials containing plutonium
		UP2-800 plant	Reprocessing of irradiated fuel assemblies materials containing plutonium
		UP2-400 plant	Shut down: Reprocessing of UNGG spent fuel In service: interim storage of rinsing solutions; nuclear equipment clean-out; acid recycling
		STE2 A silos	Shut down: site liquid effluent treatment plant In service: interim storage of radioactive waste; effluent treatment
		HAO	In service: reception of spent fuel from reactors other than the French PWRs; interim storage of assembly structure waste
		Elan 2B	Shut down: fuel shearing and dissolution Shut down: production of sources of strontium 90 and caesium 137
		STE3	Treatment of liquid effluent from the La Hague site
	Marcoule	MÉLOX SA : Mélox plant	Production of MOX fuel
	Tricastin	Eurodif Production: Georges Besse plant and its annex	Gaseous diffusion uranium enrichment
		SET : Georges Besse II plant and its annex RECII	Gas centrifuge uranium enrichment
		TU5 W Plant	Conversion
		COMURHEX - Pierrelatte	Transformation of uranium
		Socatri	Maintenance of large components, effluent and waste treatment
Romans	FBFC Plant	Production of fuel for PWRs	
Laue-Langevin Institute (ILL)	Grenoble	High-flux reactor	Experimental reactor

Complementary safety assessments carried out in 2012

Licensee	Site	Facility	Type
CEA	Cadarache	Rapsodie	Experimental reactor
		MCMF	Storage of material
		LECA	Research laboratory
		CHICADE	Research facility
		CABRI	Experimental reactor
		PEGASE	Storage facility for nuclear fuel and radioactive waste (Pu drums)
		Storage yard	Waste storage
	Site support function		
	Saclay	Orphée	Experimental reactor
	Marcoule	Atalante	Research laboratory
		Site support functions	
AREVA	Romans	FBFC – CERCA plant	Fuel production
CIS BIO International	Saclay	CIS BIO plant (BNI 29)	Radionuclide production plant
EDF Facilities under decommissioning	Creys Malville	Superphénix, including TNA APEC	Fast-neutron reactor (shut down)
	Bugey	Bugey 1	Reactor under decommissioning
	Chinon	Chinon A1	Reactor under decommissioning
		Chinon A2	Reactor under decommissioning
		Chinon A3	Reactor under decommissioning
	Saint-Laurent	Saint-Laurent A1	Reactor under decommissioning
		Saint-Laurent A2	Reactor under decommissioning
	Chooz	Chooz A	Reactor under decommissioning
Brennilis	Monts d'Arrée-ELAD (BNI 162)	Reactor under decommissioning	
ITER ORGANIZATION	Cadarache	ITER	Research facility

Specific case of waste repositories and waste disposal facility projects

In view of the approach adopted to prioritise the facilities, the disposal facilities [the Manche waste repository (CSM) currently in long-term monitoring phase, and the Aube waste repository (CSA) in operation, dedicated to the disposal of low- and medium activity short-lived waste] were placed in category 3, given the criteria defined for the CSAs (potential source term, seismic risk, flood risk, loss of electrical power supplies, loss of heat sink, emergency situation management).

Furthermore, concerning the design of the structures of these same facilities, complementary studies are either being examined (as is the case with the earthquake resistance of equipment in the CSA waste conditioning unit) or will be provided in the framework of the review follow-up (as is the case with changes to be made in the CSM's surface cap). ASN will examine the files when it receives them.

Lastly, facilities projected for the future must be designed taking account of the experience feedback from the Fukushima accident. ASN has made the request to Andra which will adopt it in the functional requirements for the future drafts of the CIGEO file (disposal facility project for high- and medium-activity long-lived waste). This point will receive particular attention when examining risk control. As regards the disposal facility project for low-level long-lived waste (LLW-LL), the request has been made and this question will be examined when the project is at a more advanced stage of development.

The remainder of this chapter only addresses the priority facilities other than the nuclear power reactors that underwent a complementary safety assessment in 2011.

It presents the first conclusions from the reviews conducted by ASN, with the support of the IRSN, on the basis of the complementary safety assessment (CSA) reports submitted by the licensees in 2011. It constitutes the first step in a long experience feedback integration process. As regards the first conclusions, deadline dates for the measures requested by ASN are generally not specified, as more detailed discussions must be held with the licensees in order to confirm them.

1.2 Overview of the sites and facilities

1.2.1 Experimental reactors

Reactors operated by the CEA

Osiris

The Osiris reactor is situated in the north-east section of the CEA Saclay centre. This centre is situated on the Saclay plateau, about 20 km south-west of Paris. The site accommodates other BNIs operated by the CEA, including the ORPHEE (BNI 101) and ULYSSE (BNI 18 under decommissioning) reactors, the POSEIDON (BNI 77) irradiators, the LHA (BNI 49 under decommissioning) and LECI (BNI 50) laboratories, and another BNI operated by CIS bio International (BNI 29).

In addition, the site comprises several activity zones within a 5-km radius (technological domains of Saclay and Saint-Aubin, the "Les Algorithmes" technological park, the SOLEIL facility, etc), university and research organisations (SUPELEC, CETIAT, CNRS, University of Orsay, INRA, etc.) and a large population around the plateau (south-west Paris suburbs, Chevreuse Valley, etc.). The area around the site also features several major communication routes.

The Osiris pool-type reactor with a licensed power of 70 MWth, is intended primarily for the technological irradiation of structural materials and fuel for different power reactor processes. It is also used for a few industrial applications, especially the production of medical radionuclides. It is operated by cycles. Its critical mock-up, the 700 kWth ISIS reactor, is today essentially used for training purposes. This reactor is not concerned by the CSA exercise in 2011. These two reactors were licensed by decree of 8 June 1965. ASN Decision No.2008-DC-0113 of 16 September 2008 set the definitive operating shutdown of the Osiris reactor as 2015 at the latest.

The facility comprises:

- the reactor building which constitutes the containment vessel and houses the reactor pool containing the reactor block (70 MWth), a storage and transfer channel and the mechanisms;
- the peripheral annex buildings containing the hot shops, a truck airlock, the crown gallery with the ventilation/air-conditioning equipment among other things, experimental facilities, storage areas and the SPR (Radiological Protection Service) laboratory;
- the building containing the ISIS reactor (700 kWth).



The facility's last periodic safety review was carried out in 2009. In view of the renovation work finalized at the end of 2010 (Aménophis project), such as the installation of a backup ventilation system, ASN considered at the end of this review that the Osiris reactor could remain in operation until 2015.

The Jules Horowitz Reactor

The Jules Horowitz Reactor (JHR) was licensed by the creation authorisation decree of 12 October 2009. It is under construction on the Cadarache site. The first divergence is planned for 2016 – 2017.

The CEA Cadarache centre is located on the territory of Saint-Paul-lez-Durance village, on the left bank of the River Durance, on the Ravin de la Bête water table, a few kilometres downstream of the confluence of the rivers Verdon and the Durance. The nearest towns are Manosque (22,000 inhabitants) about fifteen kilometres to the north, and Aix-en-Provence (150,000 inhabitants) some thirty km to the south-west. The main communication routes and infrastructures follow the natural line of the Durance valley

The JHR will be able to be used for activities similar to those carried out at present with the Osiris reactor. It will nevertheless integrate significant developments regarding both the experiments (experiments in the reactor core and the periphery) and safety. The maximum reactor power provided for in the authorisation decree is 100 MW.

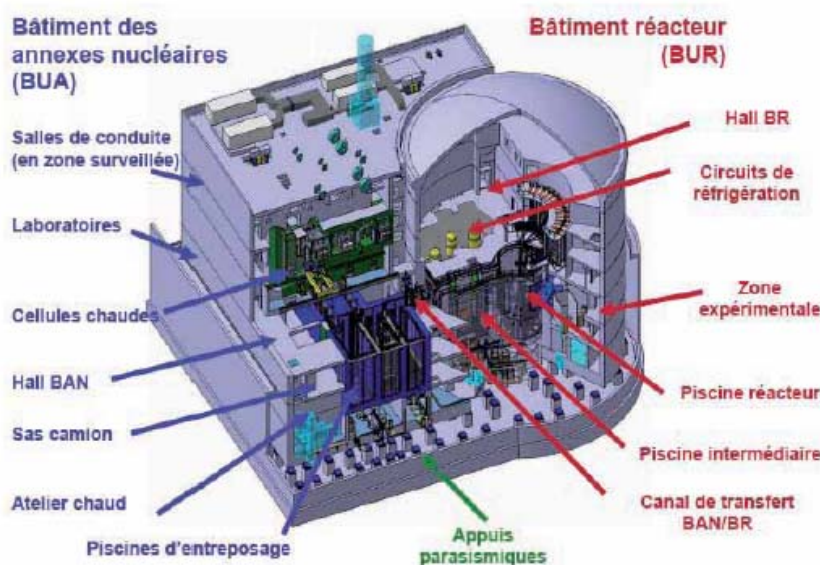
The JHR is intended to perform high neutron-flux irradiation experiments with a view to improving or qualifying the materials and fuel of existing and future reactors, and to produce a significant quantity of radioisotopes for medical uses.

Further to the creation authorisation decree, ASN issued its decision No. 2011-DC-0226 of 27 May 2011 setting the technical design and construction requirements for the BNI. This decision both freezes certain analysis parameters used in preparation of the authorisation decree and institutes stopping points for performing certain operations with strong implications. Targeted measures aim at ensuring the regular transmission of information to ASN.

Following the initial excavation, preparation and concrete-pouring work in 2009, embedding of the earthquake-resistant supports, reinforcement and concreting of the nuclear unit (UN) upper basemat in 2010, the civil engineering work continued in 2011 with the reinforcement and pouring of the first concrete walls of the nuclear auxiliaries building and of the containment vessel (reactor building) and the reinforcement before the pouring of the first concrete of the reactor pool. Pouring of the concrete for these latter two structures was subject to prior agreement of ASN in application of the abovementioned decision of 27 May 2011, and was authorised by ASN decision 2011-DC-0232 of 5 July 2011 for the containment vessel, and decision 2011-DC-0251 of 1 December 2011 for the reactor pool.

The JHR facility comprises:

- a nuclear unit (UN) consisting of the reactor building (BUR) which forms the containment vessel, and the nuclear auxiliary building (BUA), which contains the spent fuel storage pools in particular,
- associated nuclear buildings containing the backup facilities among other things,
- buildings containing support means, notably for cooling.



(Source CEA)

Phénix

The Phénix reactor is situated on the Marcoule site in the south of France, on the right bank of the river Rhone, north of Avignon, mid-way between the towns of Orange to the east and Bagnols-sur-Cèze to the west. This site accommodates other BNIs, such as Atalante operated by the CEA, the secret basic nuclear installations (BNIS) of the CEA, the CENTRACO waste incineration and melting plant operated by SOCODEL, and a facility classified on environmental protection grounds (ICPE), operated by CIS bio international.

The nearest towns - Orange and Bagnols-sur-Cèze - are 8 km away and are not situated downwind of the prevailing winds, which are essentially the Mistral blowing from the north, and to the lesser extent the Noroît blowing from the north-west.

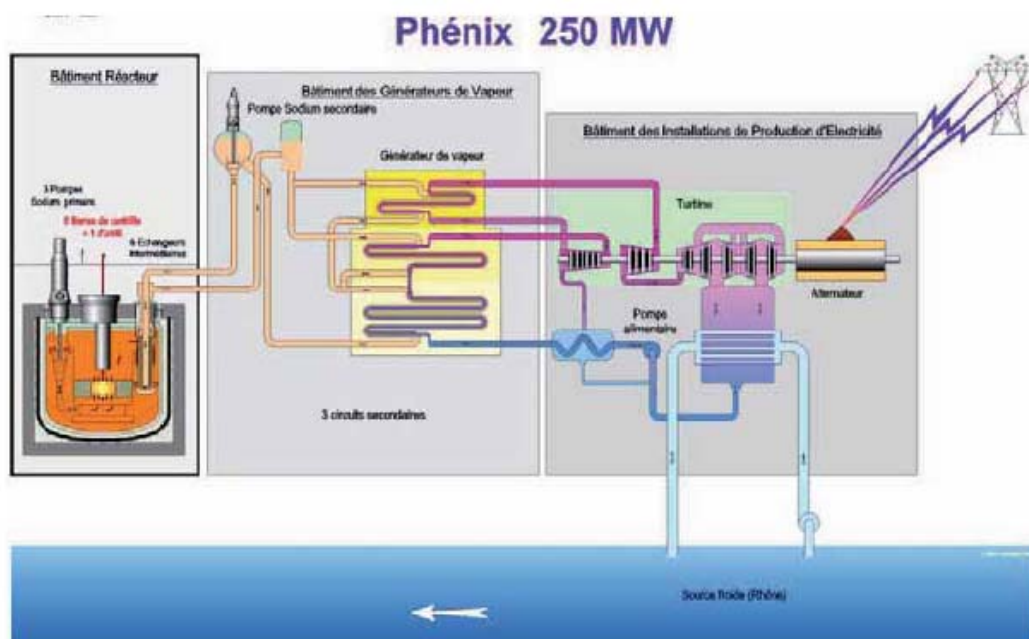
The communication routes and infrastructures follow the natural line of the Rhodanian corridor.

Built and operated by CEA in collaboration with EDF, Phénix is a demonstration sodium-cooled fast-neutron reactor. It was authorised by a decree of 31 December 1969 and made its first divergence in 1973. Its initial nominal power of 563 MWth was reduced to 350 MWth in 2002. The Phénix reactor definitively stopped delivering electrical power to the grid in early 2009. Tests corresponding to end of operation (end-of-life tests) were then conducted until the beginning of 2010. These tests were intended to supplement knowledge of sodium-cooled fast-neutron reactor systems in view of the possible development of a "Generation IV" electricity generating process, and also came within the framework of the studies of the prototype facility mentioned in article 3 of Act 2006-739 of 28 June 2006 relative to radioactive material and waste management.

The decommissioning authorisation application file was awaited at the end of 2011. The facility is currently in the phase of preparation for final shutdown for decommissioning. The decommissioning programme will include the installation of sodium treatment facilities.

The facility comprises:

- the reactor building housing the reactor and the primary cooling system, and constituting the containment vessel;
- the handling operations building, containing the fuel assembly storage drum, the washing pits, and cells, notably the irradiated fuel elements cell and the auxiliary cell;
- the steam generators building containing the secondary sodium storage tanks;
- the turbine hall;
- the other buildings (the nuclear auxiliary building, the supervision-office building (BCB), accommodating the control room, the pumping station, etc.).



Operating schematic (source CEA)

The high-flux reactor (HFR) operated by the Laue-Langevin Institute (ILL)

This reactor is installed in the north-west of the town of Grenoble, in the confluence of the rivers Isère and Drac, within the "scientific polygon" which accommodates numerous other facilities, including the nuclear studies centre along with other nuclear activities [CEA Grenoble, in the phase of delicensing, Laboratory of subatomic physics and cosmology (LPSC), the European Molecular Biology Laboratory (EMBL), Société Industrielle des Combustibles Nucléaires (SICN – AREVA Group)]. The main communication routes and infrastructures for the natural line of the Isère and Drac river valleys.

The high-flux reactor (HFR) operated by the ILL is a highly-enriched uranium reactor, moderated and cooled by heavy water. Its core consists of a single highly compact fuel element in uranium-aluminium alloy. The thermal power of the reactor is 57 MW. This facility was initially authorised by the decree of 19 June 1969 modified by decree 94-1042 of 5 December 1994.



(Source ILL)

The reactor vessel or "pile block" containing the core and the moderator/coolant is situated in a pit filled with demineralised water. Three systems in the immediate vicinity of the core allow the production of hot neutrons and cold and ultra-cold neutrons: the hot neutron source consists of a graphite sphere, while the most important of the two cold neutron sources is a sphere containing deuterium. These neutrons are sampled from within the vessel by thirteen horizontal thimbles and four angled thimbles. These thimbles are extended by neutron guides supplying experimental areas.

The reactor pool is linked to a transfer channel made up of three compartments, channels 1, 2 and 3, which can be isolated by gates. These channels serve more particularly for fuel handling, by means of loading-unloading casks. Channel 2 can be used for the interim storage of irradiated fuel elements.

The reactor has a double containment vessel, one concrete and one metal. A positive pressure of 135 mbar is maintained in the inter-containment space.

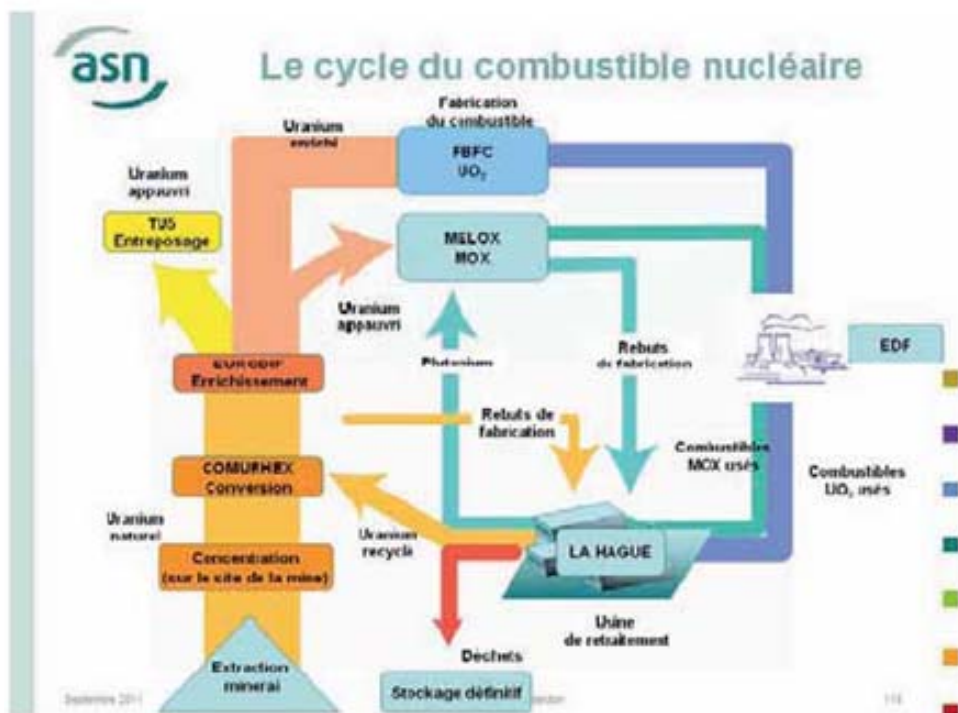
This reactor provides the most intense source of neutrons possible for experiments in fundamental civil research .

The cycle duration is just 46 days. The resulting fission product inventory is about one hundred times smaller for short-life fission products and about one thousand times smaller for long-life fission products than for an electricity generating reactor.

Total core meltdown in the reactor building area was taken as the design-basis accident.

Further to the periodic safety review conducted in 2002 by the advisory committee of experts for reactors, ASN had demanded that extensive work be carried out to reinforce the facility's earthquake resistance. Most of this work was completed in 2007, but a number of improvements remained to be made. A first part of the handling gantry reinforcement with respect to the seismic risk was carried out in 2010. As this is presented in the "earthquake" section of the CSA report, other works must still be carried out.

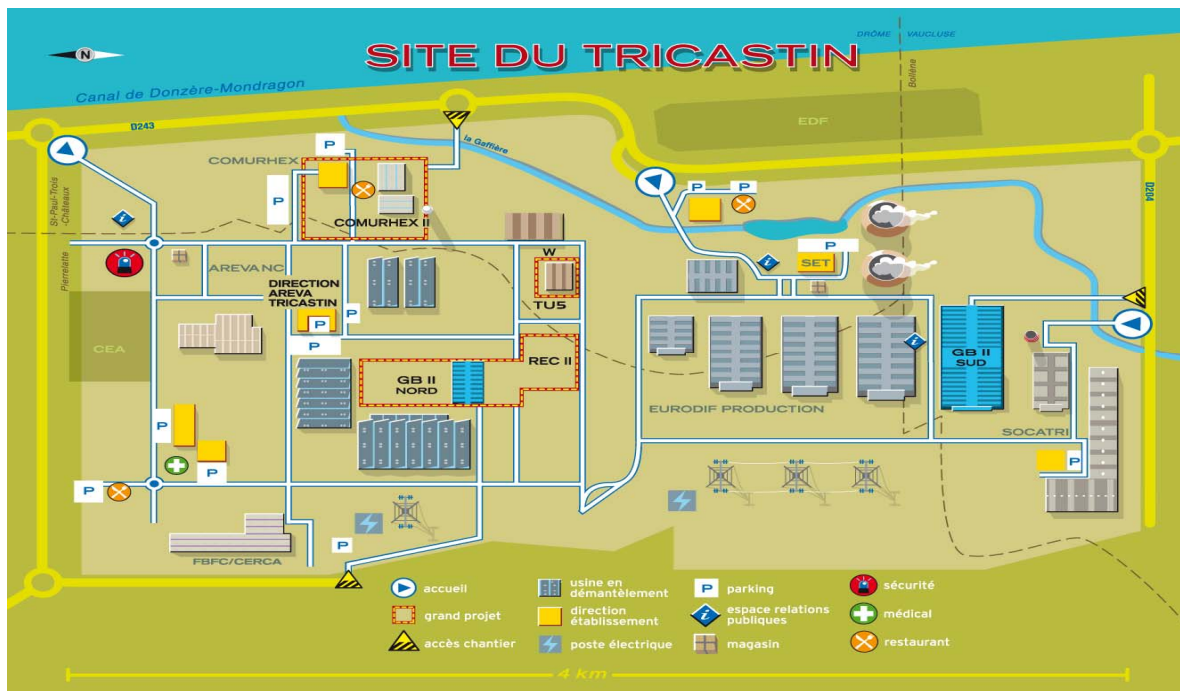
1.2.2 Fuel cycle facilities



The Tricastin site

The Tricastin site is located on the Pierrelatte plain between the River Rhone and the Donzère-Mondragon Canal. Apart from the nuclear facilities of the AREVA Group considered as high-priority, it accommodates the BNIs of other licensees: The Tricastin NPP, a BNIS of the CEA, other facilities of the AREVA Group: FBFC (production of reference standard radioactive sources), installations classified on environmental protection grounds (ICPEs) - SODEREC in particular - which treats the hydrofluoric acid produced by the facilities of AREVA NC and TRIADE (service activities for the BNIs).

The nearest urban areas are Saint-Paul-Trois-Châteaux (8,800 inhabitants) situated 3 km to the east, Pierrelatte (13,000 inhabitants) 4 km to the north north-west, and Lapalud (3,500 inhabitants) 4km to the south-west. They are not situated downwind of the prevailing winds, the main one being the Mistral blowing from the north. The main communication routes and infrastructures follow the natural line of the Rhodanian corridor.



The Georges Besse I plant

Enrichment by isotopic separation implemented in Eurodif's Georges Besse I plant (GB I) is based on the gaseous diffusion process. The plant comprises 1400 cascaded enrichment modules, divided into 70 sets of 20 modules grouped in leak-tight areas. The plant was authorised by a decree dated 8 September 1977.

The gaseous enrichment principle consists in diffusing gaseous uranium hexafluoride (UF_6) through porous walls called "barriers". These barriers give preferential passage to the uranium 235 isotope contained in the gas, thereby increasing the proportion of this fissile isotope in the UF_6 at each passage. The UF_6 is introduced in the middle of the cascade, with the enriched product drawn off at one end and the depleted residue at the other.

In 2010 the licensee announced the shut down of plant operation at the end of 2012. This will be followed by rinsing with ClF_3 for 3 years. The final shutdown and decommissioning operations that will follow should span ten years or so. The uranium enrichment activity will be taken over by the Georges Besse II plant (GB II), in which the enrichment process is based on gas ultra centrifugation.

The Georges Besse I plant (Eurodif) comprises:

- a gaseous diffusion cascade for isotopic separation of UF_6 in several stages:
 - small-sized stages: Low Enrichment Plant;
 - medium-sized stages: Very Large Plant;
 - large-sized stages: Extremely Large Plant;
- the UF_6 container storage areas;
- diverse auxiliary facilities: control room, reception/shipping/inspection facilities, transformation station, cooling towers, workshops and fluid production units, effluent treatment units, storerooms and storage yards.

The main risks intrinsic to the operation of this facility result from the quantities of UF_6 present on the premises:

- 800 tonnes of gaseous UF_6 in the diffusion cascade (90 tonnes in rinsing phase);
- 114 tonnes of liquid UF_6 in annex U for the infeed, drawing off, etc.(74 tonnes in rinsing phase);
- 40 tonnes of liquid UF_6 in the DRP (Programme Resource Department) shop (called REC1: UF_6 container reception and reconditioning shop);
- 30,000 tonnes of solid UF_6 in the storage yards (50,000 tonnes maximum);
- storage of chlorine trifluoride (ClF_3): 15 tonnes in 500 kg containers.

In accordance with the specifications, the complementary safety assessment was carried out considering the status of the facility on 30 June 2011.

The Comurhex plant

The plant comprises:

- ICPEs for chemical transformation of natural uranium tetrafluoride (UF_4) into uranium hexafluoride (UF_6) to supply the enrichment plants:
 - one anhydrous hydrofluoric acid (HF) electrolysis unit for producing the gaseous fluorine necessary for fluoridation of the UF_4 (structure 200);
 - flame reactors for fluorination of the UF_4 to obtain the gaseous UF_6 that is subsequently crystallised (structure 400) ;
 - an auxiliary chlorine trifluoride (ClF_3) production activity (structure 600);
 - effluent processing and maintenance units (structures 900, 100E, 1000, 800) ;
 - storage areas;
- BNI 105, shut down since 31 December 2008, which transformed the uranyl nitrate ($UO_2(NO_3)_2$) resulting from spent fuel reprocessing into uranium sesquioxide (U_3O_8) and uranium hexafluoride (UF_6) (structures 2000 and 2450).

The main risks intrinsic to this facility are the toxic and radiological risks associated with the use of uraniferous, fluorinated, chlorinated and nitrated products. Between 2013 and 2015 these units will be progressively replaced by those of the Comurhex II project currently under construction, a facility that will be subject to the legislation governing ICPEs (installations classified on environmental protection grounds).

The Socatri plant

The Socatri plant repairs, decontaminates and decommissions industrial and nuclear equipment, and treats the effluents resulting from these activities and the uraniferous effluents produced on the Tricastin site. It was licensed by a decree of 22 June 1984. It comprises:

- an effluent preparation shop for the dissolution of deposits;
- stations for treating effluents containing uranium;
- washing facilities for decontaminating material;
- related storage activities, including for third parties: Andra (low-level and long-life radioactive waste) and EDF (contaminated material).

The main risks in this facility are exposure to ionising radiation and contamination from effluents containing uranium and radioactive waste, as well as the chemical and inflammability risks inherent to certain substances.

The AREVA NC plant in Pierrelatte (TU5 W)

The TU5 facility transforms by defluoridation the depleted uranium resulting from the enrichment operations and by denitration the uranium recovered from the spent fuel reprocessing on the La Hague site, into uranium sesquioxide (U_3O_8).

This BNI, licensed by a decree of 7 July 1992, comprises:

- the TU5 unit which transforms the uranyl nitrate produced during spent fuel reprocessing into U_3O_8 by denitration;
- the storage yard (P18) of 213 litre drums containing the U_3O_8 powder produced.

The plant also includes an ICPE, the W plant, which converts the depleted UF_6 into U_3O_8 and a BNIS corresponding to the CEA's former military gaseous diffusion plants, currently in the decommissioning phase.

The main risks inherent to this facility are the risks of explosion associated with the inflammable substances (hydrogen), operation of the conversion furnace of the W plant, chemical risks associated with hydrofluoric acid in particular, and radiological risks.

The Georges Besse II plant

The Georges Besse II (GB II) uranium enrichment plant operated by the Société d'Enrichissement du Tricastin (SET), uses the gas ultra centrifuge process. It will ultimately replace the Eurodif plant that uses the gaseous diffusion process. Creation of the Georges Besse II (GB II) plant was authorised by a decree of 27 April 2007.

It comprises:

- two enrichment units (North and South) containing batteries of centrifuges in a cascade arrangement;
- facilities for the maintenance of the centrifuges and the supply of the inputs necessary for the enrichment units, the electrical power supply, etc.;
- the REC II unit for the transfer, sampling and inspection of the UF_6 containers;
- interim storage yards.

The main intrinsic risks result from the handling and storage of UF_6 , particularly within the REC II unit, where the UF_6 will also be used in liquid form.

At present only two modules (i.e. two times eight cascades) in the South unit have been put into service.

The La Hague site

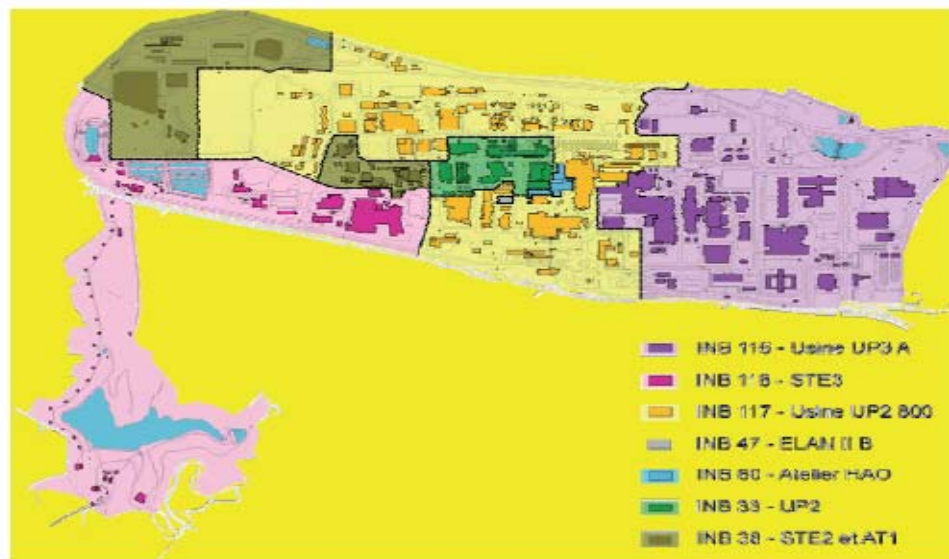
The AREVA NC plant in La Hague

The La Hague site is located on a plateau situated about 100 metres above sea level in the north-western tip of the Cotentin peninsula, 6 km from the La Hague cape:

- four facilities in which final shutdown and decommissioning of the majority of the units are either in progress or are due shortly:
 - the UP2-400 and AT1 units for reprocessing the spent fuel from the UNGG process and fast-neutron process (BNI 33) respectively;
 - the STE-2 station for treating liquid effluents from the above units (BNI 38);
 - the ELAN II B unit for the production of caesium 137 and strontium 90 sources (BNI 47);
 - the HAO unit for reprocessing the first spent fuel from the enriched uranium oxide process called the "light water" process (BNI 80);
- three facilities in operation:
 - the UP3-A (BNI 116) and the UP2-800 (BNI 117) facilities for reprocessing spent fuel from the light water process;
 - the STE-3 station for treating liquid effluents from the above units (BNI 118);
- some fifty auxiliary ICPEs, mainly for storing the chemical or inflammable products used on the site.

The nearest town is the Cherbourg-Octeville conglomeration situated some twenty kilometres to the east-south-east. It is not situated under the prevailing winds which blow essentially from the south-west or north-east. The winds can be very strong and often bring rain.

The main communication routes and infrastructures follow the axis of the peninsula; the port of Cherbourg is the main maritime traffic hub.



The UP2-400 plant (BNI 33) which was intended for reprocessing of the spent fuel from the UNGG process is currently basically awaiting for Final Shutdown and Decommissioning ("MAD/DEM"). Facility rinsing and cleaning operations were carried out when operational functioning stopped, to reduce the residual source term.

The part of the facility that is currently waiting for final shutdown and decommissioning comprises the MAU, MAPu, HA/DE, DEGAINAGE (decladding) and HA/PF units. Among these, only the HA/PF unit is still in operation to centralise and store the rinsing solutions. This unit still contains contaminated waste and spent ion-exchange resins awaiting transfer to a treatment process channel.

The other units of the facility are required for the general operation of the La Hague site, so they will be kept in operation:

- the central building including the central monitoring laboratory;
- the AD1/BDH unit for equipment decontamination;
- the STU unit for nitric acid storage.

Station STE2-A (BNI 38) used to treat the low- and medium-level liquid radioactive effluents before discharging to the sea. At the end of the operational functioning, the facilities underwent rinsing and clean-out operations.

Part of the facility is currently awaiting final shutdown and decommissioning, namely station STE2-A, building 128, building 119, silo 115, silo 130, and the pits and trenches in the North-West zone.

The other units of the facility are required for the general operation of the La Hague site, so they will be kept in operation:

- The storage area of conditioned waste and very-low level (VLL) activity soils in the North-West;
- The ordinary industrial waste (DIB) sorting area;
- STE-V for treating "V" effluents and interim storage of filtration sludge;
- Building 116 for cementing the CBF-K packages.

The ELAN II unit (BNI 47) was definitively shut down in 1977. Clean-out operations were carried out between 1980 and 1986. It is currently waiting for final shutdown and decommissioning.

The HAO unit (BNI 80) carried out the first reprocessing operations on spent nuclear fuels based on UO₂. The solutions resulting from this treatment were then transferred to the UP2-400 plant. The operating facilities have undergone dust removal or rinsing to reduce the residual source term. At present they still contain experimental reactor fuels (so-called "RTR" fuels) stored in pools, hull and endpiece waste stored in silos, and ion-exchange resins stored in silos pending processing. The unit is currently under decommissioning, with the exception of the North HAO section which is still in operation.

The UP3-A plant (BNI 116) reprocesses the irradiated fuel assemblies coming from the light-water nuclear reactors and research reactors, and processes substances containing plutonium. The main operations carried out in this unit are:

- unloading of the transport containers and storage of the irradiated assemblies in pools;
- shearing of assemblies;
- dissolution of the sheared sections in nitric acid;
- clarification of the dissolution solutions;
- separation of the fission products into sub-critical annular pulse columns;
- separation of the uranium and plutonium in mixer-settlers followed by purification of the uranyl nitrate and plutonium nitrate, the latter being subsequently converted to plutonium oxide;
- storage of the uranyl nitrate and plutonium oxide pending their shipping;
- concentration of the fission products and the medium- and high-activity effluents;
- vitrification of fission products and actinides and conditioning them in packages;
- storage of the packages for cooling;
- compacting, conditioning and storage of waste from structures (hulls and endpieces).

The UP2-800 plant (BNI 117) also reprocesses the spent fuel assemblies from light-water nuclear reactors and research reactors, and the treatment of material containing plutonium.

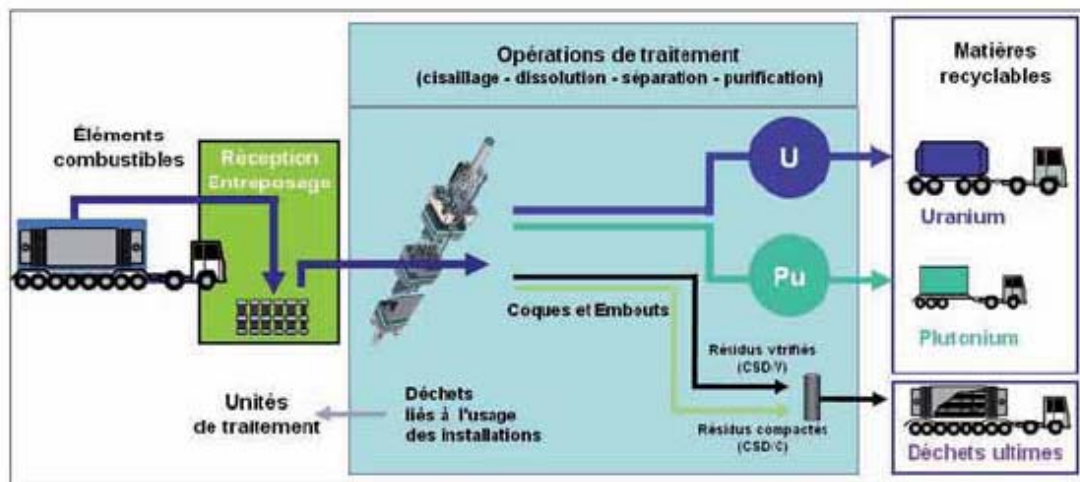
This unit performs operations similar to those of BNI 116, with in addition:

- destocking of the vitrified or compacted packages for their return to the customers, particularly foreign customers;
- maintenance and servicing shops for the shipping casks, tanks and containers;
- a processing unit for plutonium-rich waste;
- a waste decontamination unit to allow its storage in above-ground facilities.

The STE-3 station (BNI 118) purifies radioactive waste before discharging it in the sea. The main operations performed on this unit are:

- reception and storage of active effluents;
- treatment of these effluents;
- interim storage of wastewater for checking before discharge into the sea;
- bitumen coating of sludge from active effluent treatment;
- interim storage of coated drums before disposal to a repository;
- mineralisation of the organic solvent effluents and their incorporation in a cemented matrix in drums for shipping to the Aube waste repository.

The risks inherent to these facilities result from the manipulation of radioactive powders (irradiation, contamination, criticality), the use of chemical or inflammable reagents and the production of hydrogen by radiolysis.



Other facilities in the cycle

The Mélox plant

The Mélox plant is situated on the Marcoule site in the south of France, on the right bank of the river Rhone, north of Avignon, mid-way between the towns of Orange to the east and Bagnols-sur-Cèze to the west. This site accommodates other BNIs, the BNIS and BNI of the CEA, the Centraco BNI, and a facility classified on environmental protection grounds, operated by CIS Bio International. The nearest towns - Orange and Bagnols-sur-Cèze - are 8 km away and are not situated downwind of the prevailing winds, which are essentially the Mistral blowing from the north, and to the lesser extent the Noroît blowing from the north-west.

The main communication routes and infrastructures follow the natural line of the Rhodanian corridor.

The facility was authorised by a decree of 21 May 1990. It produces MOX (mixed oxide) fuel. The manufacturing process of the Mélox plant comprises a number of functions grouped by unit in building 500:

- the reception and storage of UO₂ and PuO₂ powders;
- the making up of the MOX mixture from these powders;
- the production of the fuel pellets by pressing and sintering the mixture;
- the manufacture of fuel rods;
- assembly of the fuel rods on metal structures constituting the individual modules to be introduced into the reactors;
- the inspection, interim storage and shipping of the manufactured products.

Auxiliary buildings (501 to 508) accommodate the functions of administration, surveillance, maintenance, fluid and equipment supplies, treatment of scraps, effluents and waste.

The main risks are associated with the handling of UO₂ and PuO₂ powders (irradiation, contamination, criticality).

The FBFC plant of Romans-sur-Isère

The FBFC plant of Romans-sur-Isère is located on the East boundary of an industrial zone situated about 1 km to the east of the town (34,000 inhabitants), between the road D 1092 to the north and the right bank of the river Isère to the south. The town is not downwind of the prevailing winds, especially the Mistral which blows from the North.

Apart from the FBFC facilities, the industrial site comprises two polymer production plants, an agri-food business company, a large retailer and the site of the Romans international fair.

The main communication routes and infrastructures follow the natural line of the Isère valley.

The facilities present on the FBFC site comprise:

- BNI 63 which manufactures fuel elements for research reactors and was authorised by decree on 9 May 1967 ;
- BNI 98 which manufactures fuel assemblies for the French nuclear power reactors of the pressurized water reactor (PWR) type, authorized by decree dated 2 March 1978;
- auxiliary facilities, including one ICPE, storage buildings or areas.

The PWR fuel assembly manufacturing process involves several phases:

- chemical conversion of the UF₆ into UO₂ powder which is then sent to the fuel assembly manufacturing process;
- the manufacture of UO₂ pellets from the UO₂ powder which is compressed into cylindrical pellets;
- the manufacture of fuel rods consisting of long zirconium alloy tubes in which the UO₂ pellets are stacked;
- the manufacture of fuel assemblies by placing fuel rods in skeleton assemblies;
- recycling of the solid uranium discards resulting from the fuel assembly manufacturing process.

The main intrinsic risks are associated firstly with the presence of UF₆ and HF (chiefly chemical risks), but also substances containing uranium (irradiation, contamination, criticality).

1.2.3 Other facilities

The ATPu (plutonium technology unit)

The ATPu entered service in 1964 for the manufacture of experimental reactor fuels, and notably the Phénix and Superphénix fast-neutron reactors. It entered the phase of definitive ceasing of operation in 2003, with the stoppage of fuel rod production. Its shutdown and decommissioning were authorised by a decree of 6 March 2009.

The current decommissioning phase concerns the equipment in which the radioactive material was placed (glove boxes and their internal equipment, effluent tanks and associated conduits, overhead transfer tunnels between glove boxes). It should be finished in mid-2013.

Depending on their function when in operation, the equipment items can contain residues of uranium or plutonium oxide powder, green or sintered fuel pellets, and ground manufacturing discards (mixed oxides or mixtures of oxides). Chemical products and inflammable liquids are used to decontaminate the equipment or to fix the contamination.

The main risks presented by this facility are the risk of disseminating radioactive material, external exposure to radiation, the criticality risk and the chemical or explosion risks associated with the use of decontamination or contamination-fixing products.

The Masurca reactor

The Masurca reactor, whose creation was authorised by a decree of 14 December 1966, is dedicated to determining the neutron characteristics used for the sodium-cooled fast-neutron reactors.

In its current configuration, the reactor core has been unloaded since 2007 further to the last periodic safety review, to allow work to bring it into conformity with a view to its continuing use for the experimental programmes associated with the future generation IV reactors.

This is a low-power reactor (5 kW). The facility comprises:

- the reactor building (BR) consisting of a metal containment chamber kept at negative pressure. The core is made up with fuel assemblies when the experimental programmes are run;
- the storage and handling building (BSM) housing all the neutron simulation elements, whether fissile, fertile or inert (sodium and others) that enter into the composition of the core;
- the instrumentation and control building (BCC) which contains all the reactor control, monitoring and measurement components;
- the auxiliary building (BA) which contains the auxiliary systems for the reactor (ventilation, cooling, utilities).

Given the current configuration of the facility, the reactor building only contains nine sealed sources. The BSM houses the fissile materials, the sodium, the fertile and inert materials stored in separate storerooms, and the materials of the active laboratory and the radioactive sources stored in the source room safe. The BCC and the BA contain no nuclear or hazardous substances.

The reactor is not due to resume operation until 2017. The complementary safety assessment was carried out taking account of the state of the facility on 30 June 2011, in accordance with the specifications. The main risk inherent to the facility results from the storage of substances in the BSM. Consequently, for the purpose of the CSA, this facility is examined as a material storage facility and not as an experimental reactor.

These two facilities are installed on the Cadarache site described earlier (§ 1.2.1 / JHR).

1.3 An approach adapted to the diversity of the facilities

1.3.1 Particularities of the approach for nuclear facilities other than power reactors

The complementary safety assessment approach undertaken by ASN is common to all the facilities. This complementary assessment consists in a targeted re-assessment of the safety margins of the nuclear facilities in the light of the events that occurred at Fukushima, namely extreme natural phenomena taxing the safety functions of facilities that could lead to a severe accident.

The technical specifications for the European stress tests were defined for power reactors with regard to the severe accidents that could affect them and lead to cliff-edge effects. The specifications that ASN prescribed to the licensees in its decisions of 5 May 2011 apply to all the nuclear facilities. Two types of facility have thus been considered: the nuclear power reactors and experimental reactors on the one hand, and the other facilities on the other hand.

The CSA reports include a descriptive section for each facility, specifying:

For the nuclear power reactors and experimental reactors:

- the type of reactor (including the radiological inventory, the nature of the fuel and its enrichment, the nature of the moderator and the coolant, the characteristics and state of the containment vessel) ;
- the thermal power;
- the date of the first divergence;
- the existence and number of new or spent fuel storage areas (or shared storage areas);
- the specific features of the various installations that are important for safety.

For the other nuclear facilities:

- the type of facility;
- the activities (nuclear, chemical, biological), including waste or fuel storage, with the maximum authorised inventory;
- the authorised inventories for radioactive material and chemicals, with their characteristics, particularly type and form;
- the specific risks (nuclear and chemical risks in particular): criticality, irradiation, risk of explosion, fire, etc.

For the other facilities, the licensees have defined the nature of the severe accidents they consider could lead to cliff-edge effects. **These severe accidents or feared situations** are specified for each facility in the CSAs. Some are not related solely to the nuclear risk, particularly in the case of fuel cycle facilities, for which the severe accidents are closely related to the chemical risk.

The following elements have thus been examined in particular:

For the nuclear power reactors and experimental reactors:

- loss of the core cooling function;
- loss of the cooling function of fuel stored dry or under water;
- loss of containment integrity, and reactor containment in particular.

For the other nuclear facilities:

- loss of the cooling function;
- loss of radioactive or hazardous product containment;
- loss of the means of controlling explosion risks, particularly hydrogen explosion;
- loss of the means of preventing criticality risks;
- loss of fire-fighting means.

The procedure adopted for the CSAs thus consisted in examining two main points:

- conformity of the facility with respect to its safety frame of reference, defined according to its design and any past periodic safety assessments;
- the robustness of the facilities beyond its design-basis hazard levels and evaluation of the corresponding margins; key systems, structures and components (SSC) have thus been identified in order to make a targeted evaluation of robustness to the feared situations.

In the case of facilities other than the reactors operated by EDF, the safety frame of reference to consider for the compliance review is made up of the common provisions (fundamental safety rule, ministerial orders in particular) and measures specific to the facilities (general operating rules, safety report). The following paragraphs thus specify for each facility the safety frame of reference considered for the compliance evaluation.

To assess the robustness of the facilities, the licensees have identified for each facility their margins with regard to the design dimensioning, taking hazard levels that go beyond the scenarios considered up until now.

Moreover, ASN has asked for the identification of a hard core of reinforced material and organisational provisions whose availability must be guaranteed under extreme conditions in order to prevent or manage a severe accident. As this notion was only introduced during the examination of the CSA reports, ASN will ask the licensees to provide it with additional information.

ASN will thus ask all the licensees to define a **hard core of reinforced material and organisational provisions** for the extreme situations analysed in the CSAs, with the aim of:

- preventing or mitigating a severe accident;
- limiting massive releases in an uncontrollable accident scenario;
- enabling the licensee to fulfil the emergency management duties incumbent upon it.

The licensee must submit the requirements applicable to this hard core to ASN for approval. To define these requirements the licensees are asked to adopt significant fixed margins with respect to the current safety frame of reference (for earthquakes for example, fundamental safety rule No.2001-01, the state-of-the-art parasismic rules, and the constructive measures of ASN guide 2-01). The systems, structures and components (SSC) that form part of these provisions must be kept functional in the extreme situations studied in the CSAs. More particularly, these SSCs shall be protected against internal and external hazards induced by these extreme situations, such as falling loads, impacts from other components and structures, fire and explosions.

For the implementation of these provisions, the licensees are asked to favour the addition of independent and diversified SSCs whenever possible, in order to limit common mode risks.

1.3.2. Identification of the feared situations

Experimental reactors

Reactors operated by the CEA

The JHR and Osiris facilities

- The feared situations or "degraded states" in CEA terminology considered consist in the meltdown under water or in air of irradiated fuel elements with associated loss of containment.

In the case of the JHR, the CEA also considers the situation corresponding to a criticality accident in case of loss of storage geometry.

The CEA identifies the following key core cooling equipment items to prevent these feared situations:

- in the short and medium term:
 - for the Osiris facility, the reactor emergency shutdown system and the natural convection valves;
 - for the JHR facility, the reactor emergency shutdown system, the mixing pump installed on train 3 of the primary cooling system and its set of electrical power supply batteries SUS B, the natural convection valves and their set of electrical power supply batteries SUS A ;
- in the long term:
 - the pools connected to the reactor and their sealing system.

As regards the spent fuel pools, the CEA highlights the pools and their sealing system.

For the Osiris facility the CEA also identifies water make-up means appropriate for the kinetics of the studied scenario.

For the criticality accident situation retained on the JHR, the CEA identifies the racks and cabinets in the pools or storage rooms as key equipment items.

For the JHR and Osiris facilities, ASN considers that the CEA has satisfactorily identified the feared situations. It nevertheless considers that the key equipment items and the potential threats to them have been only partially identified, and that beyond the pools, the pile block as a whole and the primary cooling system must be considered as key equipment items. The CEA has made a commitment in this respect.

Phénix

The feared situations or "degraded states" considered to identify the key equipment items for this facility are:

- losses of sodium containment that could lead to a sodium fire or a sodium-water reaction;
- a criticality accident in a spent fuel assembly storage drum;
- collapse of the hot cells.

The CEA considers the following items to be crucial for the prevention of these feared situations:

- with respect to the risk of sodium containment loss:
 - the primary cold traps situated in the reactor building;
 - the primary containment vessel and its supporting structures (to contain a leak from the first two vessels);
 - the primary sodium storage tanks in the reactor building;
 - the storage drum situated in the storage and handling building (also considered in the context of a criticality accident);
 - the drum purification system drainage tank;
 - the drum cold trap;
 - the secondary sodium storage tanks and the secondary sodium circuit auxiliaries (including the cold traps) situated in the steam generators (SG) building;
- with respect to the risk of hot cell collapse, the irradiated fuel elements compartment and the auxiliary compartment situated in the handling building.

The CEA has also identified the potential threats to the essential equipment, namely :

- the civil engineering structures of the various buildings, and notably those that could cause a potential domino effect;
- the SG caissons, the sodium firewalls and the walkways situated in the SG building;
- crane P1 situated in the reactor building hall;
- cranes P2 and P4 situated in the handling building.

The CEA's list of feared situations considered for the Phénix reactor raises no particular remarks.

Reactor operated by the ILL

The approach implemented by the licensee consisted in identifying the scenarios that could lead to more serious radiological consequences than those considered when establishing the off-site emergency plan (PPI). The scenarios were established considering all the operating phases, even the very short ones such as placing the fuel element stack in a handling cask when unloading it, or changing the water in the handling cask before unloading the spent fuel element into canal 2 (spent fuel pool).

¹ The CEA also assesses the earthquake behaviour of the primary containment cooling system (ultimate backup) insofar as its failure could significantly increase the scale of a sodium-water reaction further to rupture of the primary containment vessel.

The scenarios have been devised on the basis of initiating events such as a "reactivity accident" and "loss of cooling", and seeking the sequences that lead to meltdown of fuel elements under water or in air.

On this basis the licensee retained the following scenarios as having the potential to produce a cliff-edge effect:

- explosive core meltdown (BORAX type accident) further to the rupture of the heavy water inlet manifold in the reactor core;
- in-air meltdown of a spent fuel element in the pile block shortly after reactor shutdown at end of cycle (2.5 h) further to a breach in the primary system or the rupture of a thimble in an experimental channel;
- in-air meltdown of a spent fuel element having cooled for 24 hours after reactor shutdown, during its unloading from the pile block further to a breach in the primary system or the rupture of a thimble in an experimental channel;
- in-air meltdown of a fuel element in the handling cask after 50 days of cooling, during the water replacement operation when the fuel element is exposed to air;
- in-air meltdown of several spent fuel elements stored in canal 2, further to a loss of pool sealing.

These scenarios, which have already been studied in the safety frame of reference, lead to a cliff-edge effect - that is to say radiological consequences exceeding those that trigger the PPI - only if they are accumulated with degradation of the "control of releases to the environment" function. This function is degraded in the event of:

- loss of pressurisation of the annular space between the internal concrete containment and the external metal containment (the pressurisation contributes to static containment);
- loss of the fans and filtration of the gaseous effluents system (which maintains a negative pressure with respect to the environment in the reactor building);
- damage to the internal concrete containment, resulting in direct leakage into the environment.

This leads the licensee to identify the following key SSCs:

- for preventing a BORAX type reactivity accident
 - the heavy water inlet manifold in the core (prevention of the risk of reactivity insertion);
 - the emergency shutdown system;
- for preventing the risk of meltdown in air of the fuel element in the pile block:
 - the primary cooling system (prevention of loss of the water inventory);
 - the thimbles (prevention of loss of the water inventory);
 - the thimble safety valves (isolation of the pile block in the event of thimble rupture);
 - the emergency water system (water make-up in the event of loss of water inventory);
- for preventing the risk of fuel element meltdown in canal 2:
 - the canal 2 civil engineering;
 - the canal 2 liner;
- for preventing the risk of fuel element meltdown in the handling cask:
 - the cask water filling system;
 - the emergency letdown system (system that lowers the fuel element to the bottom of canal 2);
- for the function controlling releases to the environment:
 - the gaseous effluent system and containment vessel isolation;
 - the concrete containment.

For each key SSC, the licensee then identified the equipment items whose failure could lead to a mechanical threat on the SSC (falling load) and the hazards that could affect them in view of their environment (fire, explosion, internal flooding, etc.). The potential sources of threat then undergo an assessment of their robustness to external hazards identical to that to which the key SSCs are subjected.

ASN considers that the procedure adopted by the ILL for the JHR is satisfactory.

Fuel cycle facilities operated by AREVA

AREVA identified the key SSCs on the basis of the feared situations (transposition of the notion of severe accident used for reactors). The key SSCs are those that ensure, in these feared situations, continuing operability of the important safety functions that are necessary to place and maintain the facility in a safe condition.

The feared situations considered for AREVA's facilities correspond to situations of "release of a hazard potential" that can challenge the technical bases of the PUIs and PPIs (on-site and off-site emergency plans respectively). Given the number of feared situations that can be envisaged, based in particular on the accidents considered in the on-site emergency plan (PUI), priorities have been defined according to the hazard potential and its release kinetics.

Thus, for the La Hague site, the analysis is based on the potential source term in accident situations beyond the design basis, the kinetics leading to the feared situation (less than 48 hours save exceptions) and the robustness of the facilities (particularly the stability of the structures and the containment barriers) rendering their failure plausible, even for the extreme hazards studied. The Mélox plant analysis is also based on the potential source term in accident situations beyond the design bases and the kinetics leading to the feared situation.

AREVA identifies the key SSCs as those which, in the feared situations, ensure the important safety functions necessary to achieve and maintain a safe condition after an event. The safety functions concerned are, for example, the stability of civil engineering structures, maintaining containment integrity; the cooling of radioactive substances, dilution of hydrogen from radiolysis. The key SSCs defined in this way are either "structural" (civil engineering elements) or "functional" (essentially active equipment fulfilling specific functions).

Feared situations for the Tricastin site facilities

The Georges Besse I plant

The potential hazard sources for the environment and populations are uranium hexafluoride and hydrofluoric acid (HF) present in:

- the gaseous diffusion cascade;
- the auxiliary building U;
- the Programme Resource Department building (DRP) (REC1: UF₆ container reception and reconditioning unit).

Loss of electrical power supply and cascade cooling have no impact on the safety or the environment.

During the operating phase, the feared situations are:

- for the diffusion cascade (which can contain 800 tonnes of UF₆), opening of breaches leading to the release of hydrofluoric acid (HF);
- for the auxiliary building U and the DRP unit, rupture of numerous pipes and loss of sealing of the metal containments leading to rapid evaporation of the liquid UF₆ (up to 114 tonnes in building U and 40 tonnes in the DRP unit).

The feared situations during the rinsing phase are the same as during operation, but with a reduced source term for UF₆. Eurodif concludes in its report that the radius of the zone of significant hazards for human life is compatible with the envelope radius of the PPI.

ASN considers that the identification of feared situations for the Georges Besse I plant in the complementary safety assessments is satisfactory

Nevertheless, given the development of the facility in the short term, additional information will have to be submitted to take into account the large quantities of ClF_3 that will be used as from the end of 2012. ASN will demand this in the framework of the application to modify the facility operating conditions (BNI authorisation decree modification request currently being examined).

Comurhex

The potential hazard sources for the environment and the populations are:

- at Comurhex I:
 - the storage of hydrofluoric acid (HF) (structure 100 HF);
 - the fluorination of UF_4 into UF_6 (structure 400);
 - the production of fluorine (F_2) (structure 200).
- at Comurhex II:
 - the storage of hydrofluoric acid (HF) (unit 61) ;
 - the fluoridation of UF_4 into UF_6 (unit 64).

The feared situations for Comurhex I are:

- on structure 100 HF, a release of HF following loss of storage tank and building sealing, and spillage of the content of a tanker truck waiting for decanting;
- on structure 400, spillage of liquid UF_6 by sectioning of valve and loss of building sealing;
- on structure 200, release of HF further to loss of tank and electrolysis cell containment and destruction of the building.

For these feared situations, the radius of the zone of significant hazards for human life is smaller than the envelope radius of the off-site emergency plan (PPI), but leads to lethal effects on areas permanently occupied by humans (A7 motorway, activities zone of Saint-Paul Trois Châteaux, NPP and a number of houses in Bollène l'Écluse). It implies the implementation of specific measures on the neighbouring NPP.

The feared situations for Comurhex II are:

- on unit 61, the release of HF following loss of storage tank sealing and a breach in the retention area;
- on unit 64, spillage of UF_6 following rupture of the crystallising container drainage pipes.

By summing all the releases that could result from these feared situations, the radius corresponding to the zone of significant hazards for the human life would be slightly greater than the envelope radius of the PPI but would not impact any permanently occupied areas in the public domain other than the NPP and not either the A7 motorway, for which specific measures are planned.

The key systems, structures and components (SSCs) proposed by the licensee for Comurhex II are:

- the unit structures (civil engineering);
- the equipment containing toxic or radioactive products and the associated retention areas;
- the HF tanks and lines;
- the vent condensates collection tank;
- the electrolysis cells;
- the crystallising containers;
- the reboiler;
- the UF_4 storage silos and the decanting lines;
- the isolation system of equipment containing HF or UF_6 ;
- the equipment involved in seismic detection and cutting off the main electrical power supply further to detection;
- all equipment items that could represent a hazard for an SSC in the event of an earthquake.

ASN considers that the identification of the feared situations for Comurhex must be supplemented by the inclusion of fire as an aggravating scenario.

Socatri

The feared situations are the dispersal of radioactive and chemical material into the environment. Atmospheric releases would not lead to significant consequences off the site. However, spillage of the STEU (Uranium-containing Effluent Treatment Station) tanks into the alluvial water table and hence into the river Gaffière, would have an impact of a few millisieverts over a year if no protection measures are taken.

The following areas of the Socatri site are concerned by the studied accident situations:

- the uranium-containing material storage areas;
- Andra's low-level activity long-lived waste (LLW-LL) storage areas;
- the interim storage areas for waste pending shipment and maintenance equipment for the NPPs;
- the storage of uranium-containing effluents from the STEU.

ASN considers that the identification of the feared situations for Socatri must be supplemented by the inclusion of the flooding and induced effects scenario (criticality risk).

TU5 W

Given the materials and processes implemented, the only substances present in significant quantity that could be disseminated and present a risk outside the site are the HF and the liquid or gaseous UF₆.

With regard to the TU5 and W facilities, the operator indicates that the processes involving the largest quantity of dispersible substances (liquid UF₆ and HF) are located in the "emission" and "HF storage" areas of the W plant. Fire and explosion have not been retained as risks that could cause a feared situation.

For the TU5 and W facilities, ASN considers that the absence of a cliff-edge effect for the fire and explosion scenarios must be substantiated.

For the TU5 unit, which is designed to the SSE (safe shutdown earthquake), the feared situation in a typical SSE ++ scenario would be external spillage of uranyl nitrate (16 m³ at 380 g/L), which would have no immediate consequences on the neighbouring populations but would require the implementation of a soil management plan to treat it.

The feared situations for the W plant are:

- for HF storage, the formation of a slick of HF on the ground following loss of retention area integrity and the impossibility of using the oil spreading system (320 t of HF over 1235 m²) in the event of SSE (tanks not built to this design-basis);
- for the emission building (building used to deice the 48-inch containers and emit UF₆ in gaseous phase to the defluoridation ovens), leakage of gaseous UF₆ from the containers during emission and heating (57 t of liquid UF₆), in case of SSE (area not built to this design-basis);
- for the hydrogen yard, leakage of H₂ with production of ignited jets and H₂ explosion, with domino effect leading to the release of HF or UF₆ or U₃O₈ in case of SSE (risk of hose being pulled out).

For the storage yards

For yard P09 (storage of cubes of depleted U₃O₈), the feared situation is the dissemination of material outside the building as a result of collapse on containers and damage caused to them. The licensee indicates that the updating of the W plant hazard study will take into account a realistic envelope number of damaged containers, and that this scenario will lead to negligible releases.

Finally, the most penalising configurations considered by the licensee are:

- the leakage of 320 tonnes of HF in the HF storage of the W plant;
- the leakage of 57 tonnes of liquid UF₆ from the ovens in the emission area of the W plant.

The licensee has identified the following key SSCs for these feared situations:

Leakage in the "HF storage" area

This area comprises two stores, SHF1 and SHF2, consisting of two separate structural steelwork buildings with a light roof. The structural steelwork supports the service walkways and the pipes.

The two storage buildings each contain:

- HF storage tanks in HDPE (high-density polyethylene) situated in a reinforced concrete retention area;
- an oil spreading system in a retention area to limit HF evaporation in the event of leakage;
- two "tanker truck" and "railway wagon" loading stations.

The key SSCs identified by the licensee in the event of earthquake or flooding are:

- the building structure and foundations;
- the tanks and their anchoring;
- the tank retention areas.

UF₆ leak in the "emission" area

This area comprises 4 defluoridation lines, each comprising three drying ovens connected to a manifold (one oven in emission, one in deicing and one in cooling or unloading).

The key SSCs identified by the licensee in the event of earthquake or flooding are:

- the "emission" building;
- the UF₆ containers;
- the container supporting trolleys;
- the drying ovens.

Key SSCs in the "hydrogen yard" area

The maximum capacity of this yard is six road trailers each carrying 9 or 18 pressurised hydrogen tanks connected in series. The hydrogen is routed from the yard at a reduced pressure of 8 bars to the W plant buildings, where its pressure is further reduced to 3 bars.

The key SSCs identified by the licensee in the event of earthquake or flooding are:

- the trailers of H₂ tanks interconnected in series and equipped with a supply hose,
- the hydrogen pipes,
- the pressure-reducing stations and the supply cut-off valve in the event of leakage.

Georges Besse II plant

The main feared event is leakage of liquid or gaseous UF₆ at above-atmospheric pressure (which could occur further to an earthquake of intensity exceeding the SSE). The identified source terms are the liquid reception and sampling autoclaves of the REC II unit.

In view of the characteristics of the gas centrifugation process (very small quantities of UF₆ used), the consequences of an accident scenario on GB II are identical, whether one considers the design-basis initiating events of the initiating events considered in the complementary safety assessments (CSAs).

ASN considers that the identification of the feared situations for the Georges Besse II plant is satisfactory.

The La Hague site

The feared situations identified by AREVA for the La Hague site are:

- For risks due to thermal releases of radioactive materials:
 - loss of cooling of the fuel assembly pools in the NPH, C, D and E unit (time lapse of 6 days before a dose rate of 2 mSv.h⁻¹ is reached in the pool and 10 days for fuel assembly exposure);

- stopping of rotation of the pendulum type centrifugal decanters in the R1 and T1 units (estimated time lapse before ruthenium release: 50 hours);
- loss of cooling of the storage tanks containing concentrated solutions of fission products from units R2, T2, T2C, T2D, SPF5, SPF6, R7 and T7 (estimated time lapse before solutions boil: between 17 and 35 hours depending on the equipment);
- loss of cooling of the fission product solution concentrating evaporator condensers of units R2 and T2 (estimated time lapse before boiling: 44 hours);
- loss of cooling of the plutonium oxide (PuO₂) container storage areas of the BSI and BST1 units (estimated time lapse before concrete reaches a temperature of 160°C: about 20 hours);
- For the risk of radiolysis hydrogen explosion:
 - loss of the air supply sweeping the tanks storing the solutions of concentrated fines and the alkaline rinsing solutions of units R1, T1, T2, R7 and T7 (lower flammability limit (LFL) of hydrogen reached in 7 to 48 hours);
- For the loss of containment risks:
 - loss of sealing of the so-called "HAO" waste storage silos and the STE2-A unit; these feared situations were not studied in greater depth, as AREVA considers that appropriate means will soon be implemented as part of the "waste recovery and conditioning" operations (water table lift pumps).

The licensee has identified the spent fuel pools and the storage tanks for the concentrated fission products of unit SPF6 as the target perimeter for the feared situations study.

For the La Hague site, AREVA identifies the following as key SSCs:

- the SSCs relating to cooling of the fuel assembly storage pools (outside perimeter of UP2-400 plant) in abnormal situations (safeguard or consequence mitigation mode);
- the SSCs relating to the cooling of the storage areas for fission products from the UP2-800 and UP3-A plants in abnormal situations (the file only examines the robustness of the SSCs associated with the SPF6 unit, as this is considered to be representative of the other units);
- the two backup diesel fuel tanks (necessary for the refuelling of the generator sets).

ASN considers that the feared situations assessment for the La Hague site must be supplemented, in particular to take the possible aggravating factors into consideration (fire, etc.).

Other facilities in the fuel cycle

Mélox

The feared situations analyzed are:

- those described in the safety frame of reference (transport accident of the LR47 tanker truck containing medium-activity (MA) effluents, criticality accident (in the homogeniser), uncontrolled fire in an area containing radioactive material (primary dosing room), loss of containment caused by an earthquake);
- a scenario involving simultaneous loss of the first and second static containment barrier and the dynamic containment of the Powders units in building 500 with maintaining of the third static containment barrier made up by the outer shell of the building (basemat, walls, roof, doors and penetrations);
- a scenario of total loss of the electrical power supply or of the STE fuel rod storage unit cooling leading to a criticality accident due to the deterioration in the storage geometry.

The licensee defines the safe states guaranteeing safety in all situations; they are based on the control of the two major risks, namely dissemination of radioactive materials (corresponding to the Important Safety Function (FIS) relative to the containment of radioactive materials) and the criticality risk (FIS: prevention of the criticality risk). The FIS's are divided into safety functions: the overall stability of the civil engineering structures, maintaining the integrity of the third containment barrier (minor cracking), cooling of fissile material, prevention of the criticality risk and the associated auxiliary functions.

For the feared situations considered, the licensee postulates failure of the successive lines of defence and identifies the barriers whose robustness is examined with respect to the elements in the ASN specifications (earthquake, flooding, extreme climatic events, loss of electrical power supplies or loss of cooling).

A list of key SSCs was established from this, either "structural" (civil engineering and mechanical structures) or "functional" (items fulfilling active functions). The key SSCs analysed were:

- the third static barrier of building 500 and its extension (walls of laboratory premises on the edge of the buildings, doors, filters, ventilation valves and adjustments);
- the backup electrical systems, including the backup diesel generator sets and their fuel supplies;
- the STE storage area and its cooling units, recyclers and chilled water system.

ASN considers that the identification of feared situations for the Mélox plant is globally satisfactory, but must be supplemented to include failure of the seismic detection systems and the mechanisms they control.

FBFC Romans

The licensee took the accidents catered for in the FBFC Romans on-site emergency plan (PUI) as the "feared situations", that is to say:

- a criticality accident in buildings C1, AP2 and R1;
- leakage of HF solution in the HF station;
- fire in buildings C1, AP2 and R1;
- a radioactive material transport accident;
- a chemical transport accident;
- aircraft crash hitting the UF₆ container storage yard (scenario outside the context of the CSAs).

According to the licensee, the processes involving the largest quantity of dispersible material (hot UF₆, that is to say in liquid or gaseous form, and HF) are situated in building C1 (conversion area) and in the HF station (two 20m³ tanks of concentrated HF (50%)).

The feared situations identified by the operator are:

- leakage of UF₆ in the conversion area further to multiple failures leading to the feared situation (loss of the 1st containment barrier (cylinder, hose and internal valve), loss of the 2nd containment barrier (autoclave), malfunction of the ambient environment purification column, structural damage with loss of static containment). The consequences would be a direct discharge of UO₂F₂ and HF into the environment, corresponding to a source term of 6 cylinders each containing 2277 kg of UF₆ (highly pessimistic estimate);
- an HF leak in the HF station further to loss of the containment of the 2 tanks of concentrated HF, malfunctioning of recovery in emergency retention pit, malfunctioning of the ambient environment purification column or loss of containment though serious damage to building. The consequences would be a large release of HF directly into the environment (source term of 34 m³ of concentrated HF).

The key SSCs identified for the feared situation of "*UF₆ leak in the emission area*" are:

- building C1 (earthquake);
- the autoclaves, the hoses and isolation valves and the UF₆ cylinders (earthquake, flooding);
- the potential hazards for the autoclaves (earthquake).

The key SSCs identified for the feared situation of "*HF leak in the HF station*" are:

- the building (earthquake);
- the tanks (earthquake, flooding);
- the potential hazards for the tanks (earthquake).

ASN considers that the identification of feared situations for FBFC is satisfactory, but the licensee must make a complementary study of the potential hazards for the HF station.

Other facilities

ATPu

The licensee has identified the release of plutonium outside the site as being a feared situation. This situation could arise in the event of partial or total collapse of the building further to an earthquake.

The licensee has defined the following as key SSCs: the civil engineering structure of the ATPu, the anchoring devices of the glove boxes and other equipment forming the primary containment system, and the seismic detection system and automatic cut-off of electrical power supplies and water infeeds. The aim of this automatic cut-off, which occurs in the event of acceleration of 0.65 m.s^{-2} or 0.065 g , is to limit the indirect effects of the earthquake, notably fire and internal flooding.

Loss of these "key SSCs" would lead to the dissemination of a larger quantity of radioactive material than that considered in the on-site emergency plan (PUI), which could lead to pollution of the water table.

ASN considers that the identification of feared situations for the ATPu is satisfactory.

Masurca

The CEA takes a feared situation for the facility corresponding to partial or total collapse of the handling and storage building (BSM) containing the nuclear material. This situation could potentially be aggravated by a criticality accident or a sodium fire. Thus, the key equipment items identified by the CEA are the civil engineering of the BSM and the material storage systems in store MG1 (storage compartments, boxes, etc). The CEA considers the overhead travelling stacking crane in store MG1 as a potential hazard for the key equipment.

ASN considers that the identification of the feared situations for Masurca is satisfactory.

1.4 ASN's overall assessment of the identification of the feared situations

ASN considers on the whole that the feared situations have been satisfactorily identified in the initial approach, even if they require supplementing for AREVA's La Hague site to particularly integrate combined accident situations.

After this feared situation identification exercise, ASN considers that the licensees must focus on defining a **hard core of reinforced material and organisational provisions**.

The idea is to give these facilities means for coping with:

- combination of natural phenomena of an exceptional scale, greater than the phenomena considered in the design or the periodic safety review of the facilities;
- severe accidents, particularly very long-duration loss of electrical power supplies or cooling functions that could affect all the facilities on a given site.

ASN will thus instruct the licensees to establish a "hard core" of robust material and organisational provisions, reinforced if necessary, to guarantee the operability of the structures and equipment necessary for controlling the fundamental safety functions in these exceptional situations.

These provisions must ensure an ultimate protection of the facilities, with the following three objectives:

- prevent or mitigate a severe accident;
- limit massive releases in an uncontrollable accident scenario;
- enable the licensee to fulfil the emergency management duties incumbent upon it.

ASN will ask the licensees to submit to it for approval the requirements applicable to this hard core, which must be defined adopting fixed margins that are significantly higher than the current frame of reference.

2. Earthquake

This chapter presents the main elements of the CSA reports relative to earthquakes submitted by the licensees, and the conclusions of ASN after examining them.

The following points were addressed in succession for each facility or group of facilities:

- Design of the facility;
- Measures for protecting the facilities against the seismic risk;
- Conformity of the facilities with the current frame of reference;
- Evaluation of safety margins;
- Envisaged measures to reinforce facility robustness to the seismic risk.

After examining the reports, ASN considered that improvement measures were required for certain facilities. It will therefore demand these measures, in some cases through formal decisions taken by the ASN Commission, which become legally enforceable requirements.

2.1 Design of the facilities

ASN requires that the basic nuclear installations (BNI) be designed to withstand an earthquake of greater intensity than the maximum historical earthquake observed in the last thousand years in the area in which the facilities are located.

To this end the licensees are required to define a design-basis seismic hazard. The rule for determining the seismic hazard is defined in a Fundamental Safety Rule (RFS). The purpose of the RFS's is to set out the regulatory objectives and describe, where applicable, the practices ASN considers satisfactory. They are revised periodically to integrate developments of knowledge in the subject. The first RFS on the subject, called RFS I.2.c², dates from 1981 and was revised in 2001 and became RFS 2001-01³. These RFS's are also used to verify the design of facilities in operation during the periodic safety assessments, and for defining reinforcement measures where necessary.

These rules set two earthquake levels, namely the Maximum Historically Probable Earthquake (MHPE) and the Safe Shutdown Earthquake (SSE), which is the earthquake intensity used to verify that the earthquake finally considered by the licensee for the design of its facility (design-basis earthquake or DBE) complies with the requirement.

The frame of reference for new facilities or for the periodic safety reviews is therefore the RFS 2001-01, relative to determining the seismic risk for the safety of basic nuclear installations with the exception of long-term radioactive waste disposals. For some facilities however, particular rules were taken into consideration in their design and have not been reassessed in the periodic safety reviews. In such cases they are specified for each facility concerned.

2.2 Experimental reactors

2.2.1 Reactors operated by the CEA (Osiris, JHR, Phénix)

Osiris

Facility design and conformity

In 1963, as this site was situated in a tectonically stable zone, it could be considered to be "aseismic". No particular measures were required with respect to earthquakes. In 2004 a study by the CEA led to the defining of characteristic earthquakes for the site of intensity V (MHPE level set at 0.04 g) and intensity VI (SSE level set at 0.08 g). RFS 2001-01 led to a minimum fixed spectrum set at 0.1 g being defined for the Saclay site.

² RFS I.2.c of 1st October 1981 relative to the determining of seismic movements to be considered for the safety of facilities

³ RFS 2001-01 of 31st May 2001 relative to the determining of the seismic risk for the safety of above-ground basic nuclear installations.

The earthquake behaviours analysis of the facility's civil engineering structures is based essentially on an opinion of experts who evaluate a permissible earthquake level by referring to the minimum fixed spectrum (SMF) of RFS 2001-01.

On completion of its analysis the CEA judges that the overall behaviour of Osiris is satisfactory for an earthquake acceleration level equivalent to 1.3 times the fixed earthquake level.

With regard to conformity, the CEA indicates that performance of conformity examinations during preceding periodic safety reviews, combined with periodic inspections and tests, enables this to be checked. These periodic tests and inspections concern the automatic shutdown system on earthquake detection, and the civil engineering (measurement of leakage rate, visual inspection of the condition of the sealed cladding of the reactor coolant pump and heat exchanger bunkers, of the penetrations, and monitoring the development of a number of cracks in the reactor containment dome).

Facility protection measures

The CEA has identified the key structures, systems and components necessary to place and maintain the Osiris reactor in a safe shutdown condition. These SSCs are:

- the Osiris reactor emergency shutdown system;
- maintaining the leak-tightness and the water inventory of the reactor pools and canals, and at least canal No.2, ensuring in this case the availability of sluice gates 1 and 2 and a means of handling them;
- the operation of the natural convection valves of the primary cooling system.

It is noteworthy that in 2010 as part of the Aménophis project, the CEA equipped the Osiris reactor with an automatic shutdown system on earthquake detection system.

Evaluation of the safety margins and measures envisaged to reinforce robustness of the facilities to the seismic risk

Although the CEA considers that the occurrence of earthquakes significantly higher than the site SSE on the Saclay site is not realistic, it thinks that work to improve the stability, particularly of the anchorings, can be envisaged on the metallic structure situated at level +8 m of the reactor building, which can represent a hazard, its stability being guaranteed up to an earthquake of 0.7 SF (fixed earthquake).

According to the CEA, the mechanical equipment items on the whole have significantly higher margins than the civil engineering structures. For example, the margin evaluated for the equipment items varies from 1.3 to 2 whereas that for the infrastructures and superstructures varies from 0.7 to 2. The CEA has evaluated the overall margin relative to radioactive material containment integrity at 1.3.

The CEA has also examined the risk of coolant leakage and loss, and indicated the measures envisaged to counter this type of event (installation of sluice gates, water movements within the facility, external water make-up, etc.).

Measures to improve the safety of the facility, and opinion of ASN

The examination showed that the safety margin coefficients put forward by the CEA required consolidation. Based on the information provided, ASN considers that the CEA must take the following measures, some of which were already identified in the CSA report:

- perform scheduled works to improve the seismic behaviour of the metallic structure at level +8 m with respect to the risk it represents for the pool;
- supplement the analysis of the risk of the pool liner and canal No.2 being damaged by superstructures or equipment items situated nearby;
- ensure seismic qualification of core and spent fuel cooling water make-ups to prevent them becoming uncovered;
- check the operability of the travelling crane (sluice gate movements).

The examination showed that the implementation of these measures should be put into perspective with the forthcoming shutdown of this reactor.

The licensee has also undertaken to assess the robustness of the pile block to earthquake intensities exceeding the design-basis earthquake.

For the Osiris reactor, ASN will require the performance of work to improve the seismic behaviour of the metallic structure and the installation of seismic-qualified systems to maintain or supplement the water inventory.

Jules Horowitz Reactor (JHR)

Design of the facilities

The JHR facility was designed considering a design-basis earthquake (DBE) that is defined as being the envelope of the SSE spectra for Cadarache and the paleo-earthquake established in application of RFS 2001-01.

Measures to protect the facility

The JHR facility is covered by an earthquake monitoring system that monitors the CEA Cadarache Centre as a whole, and not just the JHR (networks monitoring the local and regional microseismicity, accelerometric instrumentation), as well as measuring accelerometers and seismic triggers specific to the JHR BNI. In the event of an earthquake, the licensee is immediately informed so that it can apply the instructions given in the operating documents for such a situation.

The following provisions have been adopted with respect to the seismic risk for the civil engineering structures:

- the presence of reinforced elastomeric parasismic supports mounted on reinforced concrete blocks below the upper basemat that supports the reactor unit building (BUR) and the auxiliary units building (BUA) to filter the horizontal component of the seismic excitation;
- the seismic design of the internal and civil engineering structures of the nuclear unit (UN) made up by the BUR and the BUA, guaranteeing the integrity and stability of these structures, the supporting and protection of the reactor containment and the equipment important for safety (EIS) within these structures and which must withstand the earthquake, the resistance of the containment walls and leak-tightness of the water block, its penetrations and the containment connections, the integrity of the penetrations and civil engineering structures of the nuclear unit, thereby ensuring radiological protection;
- the seismic design of the other safety-classified buildings (safeguard buildings (BAS) containing the diesel generators, protected galleries (BAG) and nuclear unit exhaust stack), the resistance of the premises housing the systems necessary to place and maintain the reactor in safe condition.

Measures have been taken to protect the containment and its penetrations against earthquakes, and more particularly the seismic design of the civil engineering structures of the nuclear unit (UN) guaranteeing the integrity of the third containment barrier, the seismic design of the penetrations (fluids and electrical) associated with the containment guaranteeing integrity during the earthquake of the mechanical parts of the penetrations (sleeve, etc.) and the integrity during the earthquake and post-quake operability of the containment isolation valves.

The electric utilities and the instrumentation and control associated with the control of the containment isolation electric valves and isolation monitoring are designed to withstand an earthquake. These systems are energized by the backup electrical power supply.

The following measures have been taken for reactor earthquake protection: the reactor emergency shutdown system and the associated equipment for controlling reactivity and sub-criticality have been designed to be operational during and after an earthquake. Furthermore, the equipment for the containment of the radioactive substances and for the removal of residual power has been designed to withstand earthquakes.

With regard to the pools and associated systems, the following have been designed to withstand earthquakes:

- the pools themselves;
- the equipment for controlling sub-criticality (devices implemented in the storage of fuel elements such as storage structures and racks; pool water level gauges, particularly that triggering emergency shutdown);
- the equipment contributing to the containment of radioactive materials (pool and canal liners, etc.);
- the residual power removal equipment (backup cooling systems in particular);
- the radiological monitoring equipment.

The licensee has also taken operating measures with respect to the seismic risk that concern the heavy handling means (polar crane, travelling crane, main bridge of the pools), which when not in use are placed in a parked position away from areas housing elements important for safety; a programme for monitoring the parasismic supports; measures for the maintenance of the drains of the nailed wall and limitation of heavy load handling heights.

Conformity of the facility

Conformity of the facility shall be verified as construction progresses, through the qualification of the required materials and the acceptance and commissioning programme.

Evaluation of the safety margins

With regard to the civil engineering structures, the CEA has evaluated the margins by determining the earthquake level beyond which the safety functions would no longer be ensured. The CEA indicated that this approach revealed the weak spots of a facility and allowed the envisaging of measures to improve its robustness and prevent "cliff-edge" effects. This level of earthquake is expressed with reference to the design-basis earthquake (DBE), whose spectrum already encompasses the Cadarache SSE and paleo-earthquake spectra determined by application of RFS 2001-01.

The following JHR civil engineering structures were studied using this procedure:

- supporting of the nuclear unit (UN) consisting of the parasismic supports, the concrete blocks and the lower basemat;
- the reactor pool (RER);
- the intermediate pool (REE);
- the water block bunkers;
- the pools of the nuclear auxiliary building (BUA);
- the safeguard buildings (BAS) and the connection galleries (BAG);
- the BUA roof;
- the potential hazards for the structures whose integrity or stability must be maintained: the locker and changing room building (BAV), the gallery connecting the BAV to the UN, the nailed wall.

The margins were determined with reference to the dimensioning criteria. The CEA also evaluated the margins on the capacity of certain structures (BAS and BAG) to dissipate energy through ductile behaviour.

For the equipment, the CEA examined the electrical power sources, the safeguard systems, the immersed storage baskets, compartments and racks, the pool bridge and the polar crane of the reactor building (BR).

The safety margin factors evaluated by the CEA for these equipment items vary from 1.4 to 2.

For the safeguard pipes, international experience feedback indicates a margin of 3 with respect to the DBE.

From simplified calculations the CEA estimates that the stability of the immersed baskets, racks and compartments is ensured for at least 1.4 DBE. CEA's analysis for the BR polar crane, designed to remain stable in a design-basis earthquake in an unfavourable position with its maximum load, concluded on a margin of more than 2 with respect to the DBE.

As regards containment integrity, the licensee announces an overall margin of 2 with respect to the DBE. The BUA cranes are still to be analysed, as their design is not yet completed.

The licensee estimates that for the JHR facility as a whole the margins with respect to the DBE are between 1.5 and 2, but does not provide any elements for assessing the plausibility of exceeding these seismic margins.

Measures to improve the safety of the facility; opinion of ASN

Apart from the proposals figuring in the CSA report, the CEA has undertaken, further to the CSA review, to take a number of measures to reinforce the robustness of the facilities to the seismic risk:

- consolidate the evaluation of the margins of the safeguard buildings (BAS) and explain the 50% margin evaluation for the nailed wall;
- consider the primary cooling system and the pile block as equipment essential for core cooling by the safeguard circuits or the mixing pump, and evaluate their robustness beyond the DBE accordingly;
- evaluate with respect to the core meltdown risk, the margins beyond the DBE with respect to the risk of neutron-absorbing rods rising under the effect of the vertical acceleration.

Lastly, ASN considers that the licensee must evaluate the design margins of the cranes of the nuclear auxiliary building (BUA) beyond the DBE level, an evaluation that was not carried out in its complementary safety assessment.

ASN will formulate requests on these points to the licensee, some of which will be binding requirements.

Phénix

Design and conformity of the facility

- Two seismic intensity levels of VII and VIII were taken into account in the design of the Phénix facility structures and equipment respectively. The Marcoule site seismicity studies in 1983 led to the following events being retained in application of RFS 81:
- the Châteauneuf earthquake (1873) with an epicentral intensity of VII-VIII brought to beneath the site;
- the Provence earthquake (1909) of epicentral intensity IX, magnitude 6.2 at 35 km from the site;
- the earthquake associated with the Nimes fault, of epicentral intensity VII, magnitude 4.9, at a distance of 10 km from the site.

When the seismic behaviour of the NPP was reassessed in the 1990's to verify the safety of the facility in the event of a MHPE of intensity VII-VIII, the spectra used for the seismic re-evaluation were:

- a so-called "EDF" spectrum set at 0.15 g;
- a spectrum representing the near earthquake RFS 81 set at 0.2 g.

The seismic reassessment of the facility's civil engineering structures was performed considering the envelope of the two spectra representing the reference distant earthquakes for the Marcoule site of MHPE level and one spectrum representing the near earthquake of MHPE in application of RFS I.2. of 1st October 1980. This reassessment led to the implementation of substantial reinforcements, particularly in the buildings and equipment such as the travelling cranes.

With regard to building and equipment conformity, the CEA indicates in its CSA report it can guarantee their conformity thanks to permanent or periodic monitoring of certain parameters in various NPP operating configurations, routine tests of equipment items that do not function permanently, regulatory inspections and verification that the modifications have no impact on the seismic resistance of the equipment and buildings.

Evaluation of the safety margins

To evaluate the robustness of this facility, the CEA identified elementary margins for the structures and equipment.

The CEA determined an overall seismic margin factor for each building which, when applied as a multiplication coefficient with respect to the chosen reference MHPE, enables the earthquake level beyond which a cliff-edge effect could occur to be determined. The overall seismic margin factor is defined as the product of the elementary margins induced by the conservatism of the methods and design-basis criteria, the capacity of the structures to dissipate the energy through ductile behaviour, the loading reductions in certain buildings where circuits have been drained and equipment removed, and the valuation of elements not considered in the seismic reassessment and which could contribute to the resistance of the structures.

The CEA has examined the primary cooling system, the fuel element storage drum, the ultimate backup cooling system, the sodium primary system auxiliaries (tanks, supports, cold traps), the potential hazards (travelling cranes, steam generator caissons, bridges).

The CEA thus obtained an overall seismic margin factor of 4.5 for the primary cooling system, and of up to 7 for the sodium auxiliary systems. The minimum margin is obtained for travelling cranes P2 and P4 (potential hazards) with a factor of 1.8. These values are to be compared with the overall margin factors for the civil engineering which vary from 1.5 to 7.

The licensee considered that these margins were satisfactory and did not require the considering of any particular additional measures with respect to the seismic risk.

Measures envisaged to reinforce the robustness of the facilities to the seismic risk

ASN emphasizes that the risks present in the preparation of decommissioning and during decommissioning result not only from the radioactive inventory of the facility but also from the stored sodium.

On completion of the review, the CEA undertook to consolidate the seismic margin evaluation for cranes P2 and P4 and to evaluate the robustness of crane P6 beyond the design-basis earthquake.

ASN will require CEA to perform an evaluation of the robustness of crane P6 of the Phénix facility beyond the design-basis earthquake, and to propose reinforcements if necessary.

2.2.2. Reactor operated by the ILL

Design of the HFR

The High Flux Reactor (HFR) was designed and produced in accordance with the paraseismic rules PS 67 for an earthquake of intensity VIII. The "RFS 1981" spectra were used for the studies carried out from 1994 to 2002. The procedure for evaluating the seismic hazard adopted on completion of the periodic safety review of 2002 was performed in application of RFS 2001-01. It must be pointed out that in 2004, it was decided to consider only the "RFS 2001-01" spectra for the studies that had not yet been started. The "RFS 1981" response spectra established in accordance with RFS I.2.c and validated by ASN in 1997 were used for certain reinforcements. It should be underlined that further to the periodic safety review of 2002, the ILL undertook major seismic reinforcement work on the facility, some of which remains to be finalised.

In its CSA report, the ILL indicated that the design basis spectra used correspond to either the "RFS 1981" spectra or the "RFS 2001-01" spectra, depending on the key SSCs. More specifically, the earthquake used for the reactor building is the near earthquake defined by RFS 1981; for the frequencies below 4 Hz however, the "RFS 2001" spectrum is more penalising than the "RFS 1981" near earthquake spectrum.

Application of RFS 2001 leads to the defining of a Safe Shutdown Earthquake (SSE) of magnitude 5.7 with its epicentre situated 7 km below the reactor.

Measures to protect the facilities against the seismic risk / design-basis earthquake

In the event of an earthquake, the licensee has indicated that the shutdown status of the facility corresponds to:

- emergency shutdown of the reactor;
- reinforcement of the second barrier containment: closure of all the safety valves and D₂O and H₂O vents;
- containment isolation: closure of all the third barrier valves;

The shutdown command is given when 2 of the 3 triaxial accelerometers positioned at 120° to one another on reactor level B exceed the 0.01 g threshold;

- for emergency shutdown of the reactor, via the reactor safety system;
- for second barrier containment and containment isolation via a 2-out-of-3 voting system and relay circuitry.

Conformity of the facilities with the current frame of reference

At the end of the conformity review conducted as part of the CSA, the ILL identified a number of deviations. Two are particularly important with regard to the CSA: firstly, the safety valves designed to stop loss of the primary cooling water inventory in the event of rupture of an experimental canal flux thimble are not seismic-qualified, and secondly, some of the seismic requirements for the gaseous effluents discharge system are not satisfied.

The ILL proposes to address the conformity deviations taken as a whole by the end of 2012, and some of them during the 2011-2012 winter shutdown, notably as regards the two major conformity deviations mentioned above. The exercise has also shown that the main difficulty lies in verifying that all the work carried out further to the last periodic safety review complies with the specifications. In its CSA report, the ILL gave a commitment to do this by the end of 2012. Lastly, a substantial task remains in defining the safety requirements.

Assessment of the safety margins

In the complementary safety assessments the licensee assessed the "plausibility" of the ground acceleration levels producing cliff-edge effects for the "RFS 2001" earthquakes and "sediments" soil type conditions in the sense of RFS 2001-01. The licensee then assessed the margin corresponding to the transition from the MHPE to the SSE with respect to the standard deviation σ associated with the seismic movement prediction model used in RFS 2001-01. At the end of its analysis the licensee proposed adopting as the "ultimate plausible" earthquake the SSE + σ level for "sediments" soil type as used in RFS 2001-01.

Regarding the civil engineering, ILL's analysis of the earthquake behaviour of the structures is based on the results of the design studies carried out in the facility reassessment presented to the Advisory Committee in 2002 and a complementary assessment of their behaviour beyond the design-basis conditions. This latter assessment is based essentially on expert opinions.

The seismic behaviour scenario for the HFR building can be summarised as follows:

- up to an earthquake intensity equal to 1.2 SSE, the reactor building behaviour basically remains in the elastic range, and the predictable containment damage characterised by reversible cracking of the wall would in this case result in a very slight loss of leak-tightness;
- up to an intensity of 1.3 SSE, the resistance of the HFR building is maintained. The damage should remain very slight, with a deterioration in leak-tightness of a scale difficult to quantify;
- up to an intensity of 2 SSE, the resistance of the building is maintained. At this stress level the damage should remain slight, but would result in a significant deterioration in leak-tightness of a scale difficult to quantify.

For the reinforced concrete reactor containment, the ILL considers that the containment damage resulting from the SSE and up to 1.3 SSE would correspond to a 10-fold increase in the leakage rate (corresponding to the "small breach in reactor containment" situation). From 1.3 SSE to 2 SSE (also corresponding to SSE + σ), the ILL considers that the containment damage would correspond to a 100-fold increase in the leakage rate (corresponding to the "moderate breach in reactor containment" situation).

For the central core and the canal 2 civil engineering structures, the stability of these two key SSCs would be assured up to an intensity equivalent to 2 times the SSE. This margin is therefore sufficient for these elements not to create a cliff-edge effect below this earthquake intensity. The hot cell would remain stable and would not represent a threat for the equipment situated in the concrete containment.

Regarding the equipment items, the earthquake behaviour analysis of the mechanical structures is based on the results of design calculations presenting the reinforcements carried out between 2003 and 2006 and on the complementary assessment of their behaviour beyond the design-basis conditions. This latter assessment is based essentially on the opinions of experts who estimated the margins for those equipment items that had not been designed to earthquake design standards. This experts' report is to be published.

Consequently, according to the ILL's analyses, the margins for the SSCs lie between values of less than 1 (protection framework, cask maintenance station, reactor coolant pump bunkers, cask reflooding system) and values above 3 (containment isolation source penetrations). The margin for the polar crane is 1.2.

The following are noted with regard to the control of reactivity, cooling and containment.

For the control of reactivity the ILL considers that only a rupture of the heavy water inlet manifold - if it occurs in the light water pool - could cause a BORAX-type reactivity accident. It considers that the heavy water inlet manifold should remain intact up to an earthquake of intensity $SSE + \sigma$. It does however identify elements situated in water inlet manifold environment (such as the cask handling gantry crane) that could constitute threats and jeopardise the integrity of the water manifold at earthquake intensities below the reference earthquake. Furthermore, the "instrumentation & control" part of the emergency shutdown system is not designed to be operational in the event of an earthquake.

Regarding the control of cooling, three cases can be identified: management of the water inventory in the pile block, management of the water inventory in the transfer cask when changing the water, and management of the water inventory in canal 2. Given the scenarios and key SSCs identified by the ILL in its CSA report, the licensee considers that:

- the integrity of the pipes in pools is guaranteed up to an earthquake intensity corresponding to the $SSE + \sigma$;
- the integrity of the pipes outside pools is guaranteed up to 1.5 times the SSE;
- the integrity of the siphon breaker valve situated near the main pipe should be ensured up to an earthquake intensity of $SSE + \sigma$;
- the integrity of the natural convection valves would be guaranteed up to an earthquake intensity of $SSE + \sigma$;
- the integrity of the thimbles and their clamping should be guaranteed up to an earthquake intensity of $SSE + \sigma$;
- the safety valves should be operable during an earthquake of the SSE intensity, but they are not seismic qualified;
- up to an earthquake intensity corresponding to $SSE + \sigma$, the potential threats to the key SSCs should not threaten these key SSCs, except as regards the structural steelwork of the cold neutron source, the experimental equipment, the handling gantry and the handling cask maintenance station;
- the venting and drainage lines, and the safety valves situated at level C could be threatened should the primary coolant pump bunkers collapse;
- the emergency water make-up system (CES), which enables water to be introduced into the pile block, the pool and canal 2, should be operable up to an earthquake intensity of $SSE + \sigma$. Nevertheless, as the CES does not start automatically, it would enter service too late to prevent the meltdown risk in the event of a primary cooling system breach. The licensee therefore proposed in 2008 installing an ultimate reflooding system that can automatically inject water from the reactor cavity into the pile block via three injection lines;
- as regards the transfer cask, the "light water reflooding" and "emergency letdown" functions would be lost in an earthquake of the reference earthquake intensity;
- the leak-tightness of canal 2, with its gates, is ensured up to an earthquake intensity approaching the $SSE + \sigma$.

Lastly, concerning the control of containment with respect to the seismic risk, it must be emphasized that the containment is automatically isolated if an earthquake is detected. This being said, the requirements defined in 2008 for the seismic safeguard gaseous effluents system, which has two filtration lines (THE and PAI) from which discharges could be made to limit the pressure increase in the internal concrete containment (deflation and maintaining negative pressure in the reactor building), should be modified so that this system can withstand the $SSE + \sigma$ earthquake. Moreover, the licensee has noted that the truck door is the only containment penetration that does not have a margin of more than 2 with respect to the SSE, and also identified potential threats to the containment (the fresh air inlet, the cask maintenance station and the level C crane). Lastly, the metal containment will undergo a specific study to substantiate the expert judgement that concludes that its buckling would not cause any significant damage to the concrete containment.

Measures proposed to reinforce the robustness of the facilities to the seismic risk

The ILL has undertaken to solve - during the 2011-2012 winter shutdown, and in any case before the reactor is restarted - the major nonconformities with respect to its previous commitments, notably following the last periodic safety review.

Furthermore, in 2008, as part of the continuous improvement in HFR safety, the ILL proposed installing two new safeguard systems, the ultimate reflooding system (CRU) and the seismic depressurisation system (CDS), which is currently in progress. At the end of its complementary safety assessment procedure the ILL undertook to:

- put in place during the winter 2011-2012 shutdown, the ultimate reflooding system for maintaining the water inventory and therefore core cooling in the event of a breach on portions of the primary cooling system that do not have sufficient margin;
- put in place for the shutdown of winter 2012-2013, the new safeguard system, the CDS for managing the possible depressurisations of the containment after core meltdown (designed to guarantee its operation in the SSE + σ earthquake).

Lastly, the ILL has undertaken to reinforce the equipment identified in its CSA procedure (key SSCs and potential threats to the key SSCs) or to study their reinforcement .

ASN requests to reinforce facility robustness

ASN considers that the ILL's procedure for evaluating the robustness of the HFR facility to the seismic risk is satisfactory. ASN notes that the licensee has undertaken to bring rapidly into conformity the equipment items requiring reinforcement. ASN also underlines the improvements aiming at installing earthquake-resistant systems to guarantee cooling of the fuel elements and limit releases to the environment. ASN considers that these complementary actions must be carried out. It will issue demands regarding these points to the licensee, some of which will be requirements.

2.3 Nuclear fuel cycle facilities (La Hague, Tricastin, Mélox, FBFC)

2.3.1. Tricastin site

Design-basis earthquake

For the Tricastin site AREVA presents an assessment of the expected seismic behaviour of the facilities under the SSE resulting from application of RFS 2001-01.

It was requested in the examination that this site, which - like the Marcoule site - is situated above the Messinian paleovalley, undergo a specific site effects study to evaluate the seismic ground motion to be considered, as recommended in RFS 2001-01.

AREVA retained the following scenarios for the entire Tricastin platform:

- safe shutdown earthquake (SSE) of magnitude 5.5 (scenario 1);
- earthquake of magnitude around 6, called SSE + (scenario 2);
- earthquake of magnitude around 6.5, called SSE ++ (scenario 3);
- flood corresponding to a water flow rate of 300 m³/s in the siphons supplying the river Gaffière, resulting from extreme climatic conditions or a breach in the embankments of the left bank of the canal (scenario 4);
- flooding corresponding to a breach of the embankment of the right bank of the canal (scenario 5);
- SSE ++ earthquake leading to a flood (scenario 6);
- SSE++ earthquake combined with a fire (scenario 7).

Georges Besse I plant

Regarding the seismic behaviour of the enrichment cascade, the licensee considers that:

- the structure of the manifold caissons of plant 120 would remain stable in the SSE with a margin of about 30%; the posts however would crack if the reinforcements were not plasticized;

- the supporting structures of the plant 130 and 140 generator sets would withstand the MHPE;
- the structures of the gallery interlinking the plants would withstand the SSE;
- the structural steelwork would also withstand the SSE.

Resistance to the SSE is globally ensured for the Programme Resource Department (DRP) building. However, the stability of the blocks of annex U cannot be substantiated. Destruction of this building could lead to an criticality accident due to the presence of enriched uranium and hydrogen, and a violent exothermic reaction resulting from with the presence of ClF₃ and hydrogenated compounds.

Comurhex

The majority of the units are not designed to withstand the SSE. The licensee had envisaged several reinforcements but none has been scheduled due to the forthcoming shutdown of the facilities.

Socatri

According to the safety documents, the only equipment items or structures designed to withstand the SSE are:

- building 63B (stockers upstream of STEU);
- the safe-geometry storage of spray unit 19D;
- building 64D (license to operate pending).

The licensee has not assessed their behaviour in the event of an earthquake intensity exceeding the SSE.

TU5 unit

The process building, the facilities in the stripping zone and the effluent storage zone are designed to withstand the SSE in accordance with RFS I.2.c of 1981.

W plant (ICPE)

The licensee indicates that the structures of the buildings and the retention area are designed to withstand the SSE. For tanks SFH1 and SFH2 however, cracking or partial rupture at the joint between the skirt and the bottom of these tanks is to be feared in the event of an earthquake. AREVA points out in this respect that the SSE behaviour of the "emission" zone must be studied, as this part of the facility is unlikely to be stable in the SSE or even the MHPE. AREVA has moreover announced that a project to replace the storage tanks is being studied, and that it plans verifying the earthquake resistance of the emission zone in the first half of 2012.

As regards the behaviour of the W plant in an earthquake exceeding the SSE, AREVA indicates that an earthquake of magnitude 6 would cause major structural damage.

With regard to the storage yards, yards P08 and P09 are not designed to withstand the SSE.

Georges Besse II plant and Comurhex II facility

The Georges Besse II plant (GB II) (civil engineering structures and equipment housing the UF₆ of the North and South Units and of REC II) and the Comurhex II facility have been designed integrating paraseismic measures dimensioned for the SSE in accordance with current design methods.

The measures taken in the studies and construction of the civil engineering structures for GB II, and the verification calculations performed for each building show that the seismic coefficient is greater than 1.5 for deformations remaining within the elastic domain (thereby guaranteeing that the facilities meet the assigned safety requirements) and enable a seismic coefficient of 3 to be retained at the upper limit of the plastic domain. According to the licensee, the verification calculations performed for the equipment items confirm a margin of at least 15% at any point with respect to the elastic limit of the materials. For the Comurhex II facility, the civil engineering structures design integrated a margin of 15% on the reinforcements as a provision.

Measures to protect the facilities against the seismic risk / design-basis earthquakes

Georges Besse I plant

To date, no reinforcement has been scheduled as plant shutdown is planned for 2012.

Comurhex

To date, no reinforcement has been scheduled due to the forthcoming plant shutdown.

Socatri

The licensee has indicated that the seismic behaviour of the facility would be studied as part of the ongoing periodic safety review. Earthquake resistance reinforcements are already planned for the URS building.

TU5 W

The licensee has indicated that a project to replace the HF storage facilities of the W plant is currently being studied.

Georges Besse II plant

No reinforcement is considered necessary at present.

Conformity of the facilities with the current frame of reference and assessment of the safety margins

Georges Besse I plant

For the robustness of the facilities beyond the SSE, AREVA indicates that a magnitude 6 earthquake would lead to rupture of the pipe bellows and major damage in several structures, notably annex U and the DRP building.

Annex U and the DRP building were designed in accordance with paraseismic rules PS 67. The plants, however, were constructed and reinforced to take into account the DSN 75 spectra, which prefigured the content of RFS I.2c.

The licensee has indicated that the weak spot in the cascade is situated at the Low Pressure (LP) and Medium Pressure (MP) connections with the manifolds due to the risk of deformation of the bellows.

Comurhex – Structure 200 (ICPE)

Regarding the seismic behaviour of Comurhex structure 200, AREVA indicates that building 1 built in 1960 was not designed to earthquake design-basis, and building 2 was designed in accordance with the PS 69 rules.

Regarding the robustness of this facility beyond the magnitude 5.5 SSE, AREVA indicates that a magnitude 6 earthquake would lead to major damage to the buildings and total loss of leak-tightness.

Socatri

The licensee's file does not include any information on the earthquake resistance of the key SSCs and the available margins.

TU5 W

The submitted report does not contain any detailed information on this subject.

Georges Besse II plant

The risks associated with the off-site hazards of natural origin were taken into account in the design of the GB II plant for the safety function "containment or radioactive or toxic substances". This safety function has been divided into sub-functions which can be considered as the required functions of the key SSCs.

They are given in the table below:

Risk	Key Structures, Systems, Components	Design requirement	South	North	RECII
Earthquake	South and North unit structures (including buffer yards) and REC II unit	Design of structures and neighbouring equipment to SSE	X	X	X
	Handling machines, UF ₆ container supports	Design to SSE	X	X	X
	AEL autoclave supporting structures	Design to SSE			X
	Needle valves of emission and extraction stations, cold trap isolation valves, circuit breakers and seismic cut-off system	Equipment isolation in event of SSE	X	X	X
	Valves on manifold and pipes (liquid UF ₆ or high-pressure gas transfer circuit)				X
	Vent cold traps, including isolation valves		X	X	X
	Condensers, pipes, valves and instrumentation (sensor) of the liquid UF ₆ or high-pressure gas transfer circuit, PE cylinder drainage system (pipes and valves)	Equipment sealing in event of SSE			X

The effective conformity of the key SSCs is verified from design through to entry into service. SET establishes a "Production conformity file" for this purpose. A technical verification is carried out to ensure that:

- the quality-related actions within the Activities Concerned by Quality (ACQ) have been carried out in accordance with the specified requirements;
- the result obtained meets the specified quality requirements;
- any necessary corrective and preventive actions have been taken.
- furthermore, verifications are made to ensure that:
 - the human and technical means are appropriate for the actions concerned by quality within the ACQs,
 - the technical inspections have been performed.

The licensee indicates that any modification in the facility forms includes the subject of a modification assessment sheet and a modification authorisation file that identifies the risks and guarantees maintaining of the requirements defined at the design phase.

The deviations detected before entry into service commissioning are analysed by ASN in application of the provisions of article 26 of the decree of 2 November 2007.

Considering the scenario of an earthquake of higher intensity than the SSE, in which the enrichment units are in production, transfer is in progress on the unit transfer and decoupling lines, and the ten sampling autoclaves are heating when the seism takes place, the consequences would be:

- a leak at the UF₆ pipes linking the condensers to the containers in the liquid reception autoclave;
- a malfunction of the automatic closure system of the containers needle valve in the autoclaves;
- a leak at the sampling manifold of the liquid sampling autoclaves;
- damage to the building.

The licensee indicates that this would result in successive crossing of the three barriers with:

- a partial leakage of UF₆ from the container into the autoclave;
- a partial leakage of UF₆ from the autoclave into the building;
- a partial leakage of UF₆ from the building to the exterior.

The licensee considers that the dispersal of UF₆ (crystallised or gaseous UF₆) caused by a loss of containment on the sub-atmospheric part would be negligible.

The potential source term is 99 tonnes of liquid UF₆ (coming from seven 48Y containers and five 30B containers). In the event of an SSE + or SSE ++ earthquake, the liquid UF₆ would spread in the autoclaves. Given the loss of leak-tightness of the autoclave door inflatable seal in such a scenario, it is possible that 30 tonnes of liquid UF₆ could leak from the autoclave into the building. Some of the liquid UF₆ would vaporise instantly. This would lead to hydrofluoric acid and uranium hydroxide releases into the environment. The licensee has carried out a study which shows that even without mitigation actions, the radius of the zone of significant hazards for human life is less than the envelope radius of the off-site emergency plan (PPI).

Measures envisaged to increase the robustness of the facilities to the seismic risk

The Georges Besse I plant

On completion of its review of the Georges Besse I plant, ASN considers that the earthquake resistance of the equipment items must be ensured. It will require the licensee to propose measures proportional to the risk of the operations leading up to the shutdown of the facility.

For the specific risks associated with the preparation for facility shutdown, then the phases of final shutdown and decommissioning⁴, ASN will issue the necessary requirements after examining the corresponding authorisation requests.

Comurhex

On completion of its review of Comurhex, ASN considers that the earthquake resistance of the infrastructures, particularly the fluorine production unit and the risks associated with chlorinated and fluorinated compounds, must be addressed specifically. This facility is currently subject to the regulations governing ICPEs (installations classified on environmental protection grounds). ASN will propose the requirements to the competent Authority.

Socatri

On completion of its review of Socatri, ASN considers that the earthquake resistance of the infrastructures, particularly the URS building, must be addressed specifically. It will issue requirements on this subject.

As a general rule for the Tricastin site as a whole, ASN considers that the earthquake resistance of the emergency management rooms must be addressed specifically. It will issue requirements on this subject.

2.3.2. The La Hague site

Design-basis earthquake (DBE)

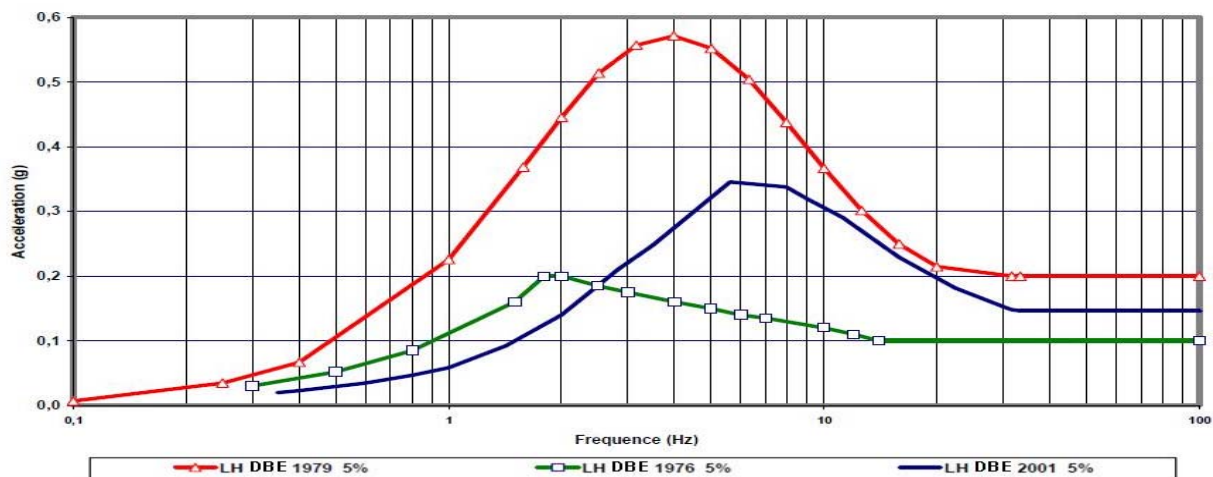
In its complementary safety assessment (CSA) report, the licensee indicated the design-basis spectrum used for each unit (building and equipment), and where applicable the spectrum used for the last periodic safety assessment. Given the year of their construction, many buildings are not subject to earthquake design requirements.

Several spectra are thus considered:

- DBE 1976 for UP2 400, HAO and NPH;
- DBE 1979 for UP2 800, UP3-A, STE2, ACC, EEVSE, fission product storage areas;
- DBE 2001 for the last 10-year safety assessment of UP3-A and STE3.

⁴ Risks not taken into account in the CSA report submitted by the licensee, which in accordance with ASN decision of 5 May 2011, considers the state of the facility on 30 June 2011

LA HAGUE GROUND SPECTRA HORIZONTAL COMPONENTS



*Comparison of the site design-basis earthquakes
and reference earthquake*

For the La Hague site, the DSN79 spectrum (DBE 1979) used for the design of the facilities after that date is higher than that resulting from application of the RFS 2001-01 (reference spectrum for the La Hague site: DBE 2001). However, the DSN 76 spectrum (DBE 1976) used for the design of BNI 33 on the La Hague site is higher than the spectrum determined by application of RFS 2001-01 only for frequencies below 2 Hz.

Measures to protect the facilities against the seismic risk / design-basis earthquakes

The licensee indicates in its report that the foundation soil of the La Hague site was a hard rocky soil (first category envisaged by RFS 2001-01) which it therefore considered very suitable for building earthquake resistance.

Regarding the quality of the parasismic design, concrete buildings are usually braced by face walls with few openings and a gridwork of internal walls that are generally rise from floor to ceiling, subject to low shear stress, and floors forming horizontal webs. They are founded on basemats. The height-to-width ratio is usually low, which means that the walls function predominantly in shear mode. The licensee stated that experience feedback indicated that this category of structure tended to remain stable and only suffered limited structural damage at earthquake intensities higher than that considered in the design.

These buildings have undergone three-dimensional calculation simulations taking into account the ground flexibility to give a good estimate of the natural frequencies and load distributions.

The quality control of the La Hague nuclear constructions was based on technical requirements and a site organisation that complied with quality assurance principles. The licensee considers that the inspections performed by the prime contractor assisted by an approved inspection agency as from the 1980's are worthy of confidence.

Conformity of the facilities with the current frame of reference

As was said earlier, the design-basis earthquakes considered vary from one facility to another on the La Hague site.

The oldest buildings are not designed to earthquake design standards.

Most of the more recent buildings are built to earthquake design standards as from design-basis spectrum DSN 79, and in some cases the DSN 76 spectrum.

The DBE 79 encompasses the reference spectrum of the La Hague site, derived from RFS 2001-01, and the DBE 76 encompasses the reference spectrum up to frequencies of 2 Hz. The most recent buildings therefore comply with the design standards currently in effect.

However, the durability of facility conformity with the design hypotheses, particularly with respect to the effects of aging, has not been truly examined.

Assessment of the safety margins

To assess the robustness of its facilities to the seismic risk, AREVA considers a seismic intensity where the SSE magnitude has been increased. This increase corresponds to $M_{SSE} + 1.5$ for the La Hague site.

For the La Hague site, AREVA has analysed the earthquake robustness of:

- the key SSCs identified for pools NPH, C, D and E, and those identified for the fission product storage areas (SPF6 unit only),
- the Moulinets pond and the West pond that would be used to replenish the backup cooling systems of the tanks and pools (the fixed supply pipes and associated pumps were not analysed),
- the local security organisation (FLS) building housing the emergency centre and certain emergency management resources,
- the diesel fuel backup tanks (post-earthquake leak-tightness),
- the "pendulum-type centrifugal decanters" (DPC) of the R1 and T1 units (robustness analysis of the decanter tanks and their tappingsnozzles, ground attachments of the electric cabinetsranks, decanter rotor, pressurised water tanks).

For the above-mentioned pools - and the pond shells in particular - AREVA's analysis of the buildings concludes on high robustness, with the risk of serious damage occurring with earthquakes of magnitude exceeding 6.4 at 15 km (the magnitude of the current SSE for the site is 5.8 at a distance of 15 km).

In AREVA's opinion, this level of robustness renders relatively implausible the occurrence of a seismic event that could jeopardise the civil engineering stability and hence the water inventory of the ponds. Likewise, the robustness study of the key SSCs ensuring the cooling functions concludes that their robustness is equivalent or higher than the minimum level of the abovementioned buildings.

In the case of fission product storage facilities, AREVA concludes that the robustness of the civil engineering of the buildings corresponds to a risk of significant damage occurring with earthquakes of magnitude exceeding 7.3 at 15 km. Furthermore, the robustness of the key SSCs ensuring the cooling and dilution of hydrogen from radiolysis corresponds to a magnitude of 6.8 at 15 km.

According to AREVA, the civil engineering robustness of the facilities that could be affected by feared situations results essentially "from the conservatism of the design-basis methods, due in particular to the design in the linear elastic range which is not required in standard buildings". In the case of the UP2-800 and UP3-A plant units, designed to earthquake design-basis and built between 1982 and 1994, the study methodologies and the work inspection procedures applied by the prime contractor assisted by an approved inspection agency were implemented in globally similar manners.

In AREVA's opinion they should lead to a minimum level of robustness similar to the results evidenced on the buildings mentioned earlier (units BSI, DEDS, T0, T1, T2, T3, T4 and T7 of BNI 116, Extension BST1, R1, R2, R7, SPF5 of BNI 117, STE3A, STE3B, STE3T, MDSA, MDSB and DEEB of BNI 118).

For the units built as from the second half of the 1990's, AREVA points out that it had changed its method of integrating margins in the studies in order to obtain greater flexibility in taking potential modifications in account during the project. These changes lead to a higher level of robustness for the units concerned (units ACC, ECC of BNI 116 and R4 of BNI 117), according to AREVA.

Likewise, for the mechanical and fabricated equipment in the UP2-800 and UP3-A units, similar in design (operating principles, choice of materials, construction classes, designed to earthquake design-basis by calculation and associated requirements) and production, AREVA carries over the conclusions of its robustness analyses.

The review identified the following values as being among the lowest robustness coefficients presented:

Site	Location	Structure	Component	Margin with respect to reference spectrum of the site considered	Seismic spectrum in acceleration or earthquake of magnitude	Assessment of margins
La Hague	NPH pools	Sealing between blocks A1, A2, A3 and A4	Interpond bellows (containment)	2	6.4	Substantiated by tests
	NPH pools	Stainless steel lining, risk of piercing	Falling of the spent fuel mast bridge	2	6.6	
	Main building SPF6	Fission product storage areas	Backup electrical equipment	2.3	6.8	Tests on vibrating tables
	Backup diesel fuel tanks		(Containment) Vertical tanks on skirt	1.4	6.2	Justification by finite elements.

Robustness coefficients for the La Hague facilities

AREVA concludes that the leak-tightness of the backup diesel fuel tanks would be maintained up to an earthquake of magnitude 6.2 at 15 km, without being able to quantify any damage beyond this. For the West pond and the Moulinets dam, AREVA concludes on robustness up to earthquake intensities of 7.3 and 6.6 respectively at 15 km. The robustness study of the FLS building led AREVA to judge that the building's behaviour would be satisfactory up to the MHPE (magnitude of 5.3 at 15 km), which is lower than the current SSE for the site. Lastly, with regard to the earthquake robustness of the DPCs, AREVA considers that the unplugging function remains operational up to an earthquake of magnitude 6.6 at 15 km, without being able to say whether or not a cliff-edge effect would occur beyond this level.

With regard to the safety margins evidenced above, ASN underlines that the simplified approach adopted by the licensee to assess these safety margins does not enable the robustness of the identified key SSCs to be assessed with a sufficient degree of confidence.

Qualitatively, it must be noted that the earthquake stability of old structures - insofar as they were not built to earthquake design standards complying with current codified practices - is often justified retrospectively considering local mechanisms of adaptation to the stresses (by the redistribution of loads in the structural elements for example, or methods enabling a ductile capacity to be taken into account).

As such cases rely on adaptation mechanisms that already draw on the non-linear behaviour reserves of these structures, their intrinsic robustness is forcibly limited. Conversely, for the structures designed following the current conventional approach mentioned above and for which additional design margins have been allowed for, the robustness is increased. This robustness can nevertheless be challenged when neighbouring structures constitute potential threats because they do not give the same seismic behaviour guarantees (for example, because they were designed in accordance with parasismic codes applicable to normal-risk structures with limited requirements).

Moreover, given that it is impossible to consider that the identified margins can be uniform for all the structures, and the fact that the overall method presented by AREVA does not enable the specific characteristics of each structure to be taken into account and does not consider the vertical earthquake effects, it is impossible to guarantee as a matter of course the robustness levels determined for the civil engineering structures concerned by the complementary safety assessments.

Regarding the equipment, it can be considered that the margins presented by AREVA are acceptable insofar as they are based on the analysis of stresses evaluated in the event of an earthquake with respect to the design criteria. It must nevertheless be noted that sensitive points such as systems of attachment to supporting structures, assemblies, certain welds, tappings sensitive to equipment movement, buckling of tank skirts, are not addressed.

Measures envisaged to reinforce robustness of the facilities to the seismic risk

Structures resting on elastomeric supports

The behaviour of these structures (ponds of pools C, D and E, cooling towers of pools and fission product storage areas) is governed by that of the elastic supports which provide great flexibility in the horizontal directions. Consequently the robustness of the structures resting on these supports should be evaluated not by considering the ductility of the structure itself, which behaves like a "rigid body", but by a specific analysis of the behaviour of the supports considering their distortion for the horizontal earthquake effects and the vertical earthquake effects, which they do not attenuate.

For the La Hague site structures resting on neoprene supports, ASN will ask the licensee to make a specific analysis of their behaviour beyond the design-basis level, considering the vertical earthquake effect and examining their conformity with respect to the aging phenomenon.

Furthermore, constructing pools on elastomeric supports favours sloshing phenomena (formation of waves on the free surface) in the pools (influence of the structure's low frequency response), which can lead to significant water overflows.

ASN considers that the licensee must assess the consequences of the risks of pool water overflowing depending on the earthquake levels considered. It will issue a request in this respect.

Auxiliary structures

The backup structures ensuring the cooling of the pools and fission product storage tanks feature several civil engineering structures (cooling tower supporting structure, diesel generator set buildings, electrical rooms, etc.) and are linked by trenches or racks to the buildings containing the spent fuel pools or fission product storage tanks.

AREVA has not presented an analysis of the earthquake behaviour of these racks and trenches, nor has it analysed the effects of differential movements of the structure in an earthquake, particularly with regard to the routing of pipes and cables.

ASN considers that the licensee must analysis the robustness of the connecting structures designed to earthquake design standards (racks, trenches, etc.) and the equipment items they support, considering all the induced effects (inertial and kinematic effects). It will issue a request in this respect.

Structures that have been reinforced and/or justified by redistributing seismic loads

Some structures, such as the NPH and T4 buildings, required reinforcement, considering areas of cracking with load redistributions determined by an elastic calculation to ensure their stability in an earthquake considering the DSN 79 spectrum.

These reinforcements, while preserving the resistance of the structure, do not confer robustness comparable with that of a structure built from the outset to earthquake design standards.

ASN considers that the licensee must analyse the seismic behaviour of the T4 workshop using the methodology applied in the CSA report, considering the areas that have been justified by load redistribution. It will issue a request in this respect.

2.3.3 Other facilities in the fuel cycle (Mélox, FBFC)

Mélox

Design of the facilities

The functions important for safety are:

- maintaining the containment of radioactive materials,
- preventing the criticality risk.

The equipment and structures whose loss further to an earthquake could lead directly or indirectly to either an unacceptable dispersal of nuclear substances into the environment, or to a criticality accident, are designed to earthquake design-basis methods. Similarly, the equipment items likely to damage, following an earthquake, an equipment dimensioned to earthquake are also dimensioned to earthquake.

Paraseismic design rules have been applied to the Mélox buildings and civil engineering structures.

The initial design of the structures used the spectra established in application of RFS 1981:

- a fixed spectrum (type I) PGA 0.3 g corresponding to a near earthquake,
- two spectra (types II.1 and II.2) PGA 0.21 g corresponding to two distant earthquakes of intensity VIII MSK.

These spectra taken as a whole are called "DBE 1981 Mélox" (RFS 1981 design-basis spectrum of Mélox).

The modifications to building 500 were justified with the spectra established in application of the provisional 1998 version of RFS 2001-01:

- a spectrum corresponding to a near earthquake of magnitude 5.3 and focal distance of 7 km, PGA 0.25 g,
- a spectrum corresponding to a paleo-earthquake of magnitude 6.5 and focal distance of 13.5 km.

These spectra taken as a whole are called "DBE 1998 Mélox" (design-basis spectrum of the 1998 version of RFS 2001-01 of Mélox).

The update of the Definitive Safety Report revision B in 2003, approved by ASN, consolidated the justification of the encompassing nature of the spectra used for the design of the structures with respect to the RFS 2001-01 spectra.

Measures to protect the facilities with respect to the seismic risk / design-basis earthquakes

The civil engineering essentially fulfils a containment function, but it also contributes to criticality risk prevention, particularly by helping support the equipment necessary for maintaining storage area geometry.

The structural elements have been designed to bring together all the conditions necessary to preserve their condition with respect to:

- the general balance of the building;
- the stability of form of the building;
- the integrity of the walls (little cracking).

Nuclear buildings tend to have a low height-to-width ratio to minimise their mechanical stresses in the event of an earthquake.

Furthermore, the surface layers of the ground on which the buildings are located has been replaced by noble foundation materials resting on consolidated gravelly-sandy alluvial deposits. The various inspections carried out in the substitution backfill put down after excavation revealed satisfactory overall uniformity and high compactness with, on the whole, mechanical characteristics equal to or higher than the subjacent gravelly-sandy alluvial deposits.

Conformity of the facilities with the current frame of reference

Industrial commissioning of the Mélox plant was declared in May 2000, and the licensee has carried out the first periodic safety review of the facility. It submitted the corresponding report to ASN at the end of September 2011, in accordance with the regulations.

The conformity review, for which the licensee can be held liable, is based on the analysis of the Elements Important for Safety (EIS), and consisted in verifying the conformity of:

- the facility with respect to its design requirements, considering questions of equipment aging and obsolescence,
- the operating practices with respect to the applicable frame of reference.

On completion of the verification of conformity of the facility with the design requirements, the licensee confirms:

- the good general condition of the civil engineering structures;
- the satisfactory behaviour of the mechanical equipment, particularly with regard to the aging mechanisms (ionising radiation, fatigue, corrosion);
- the adaptation of the maintenance programme to the monitoring of equipment conformity relative to the ventilation systems;
- that this approach has enabled the robustness of the provisions associated with control of the criticality risk to be improved.

Regarding equipment aging and obsolescence, the licensee has upgraded its monitoring procedure by instituting a global cross-facility process covering all the facilities in the plant.

The licensee indicates that the deviations found when verifying conformity of the operating practices with the applicable frame of reference were systematically analysed. The large majority of them were dealt with immediately. The remaining deviations were entered in the plan of actions resulting from the review. These elements will nevertheless be included, along with the review file, in the scope of the appraisal that ASN will demand of the advisory committee of experts for laboratories and plants.

The analyses carried out to verify the conformity of operating practices with respect to the applicable frame of reference enabled:

- the understanding and applicability of the operating instructions to be improved,
- the operating documentation to be simplified.

The safety re-evaluation

The re-evaluation of safety carried out during the period safety review was based on:

- the main regulatory changes occurring over the 1999-2009 period;
- the operating and monitoring results for the facility (production balance, discharge balance, waste balance, accumulated dose) and the results of the modifications made to the facility over the 1999-2009 period;
- the results of internal deviations concerning safety occurring over the 1999- 2009 period and the corresponding experience feedback, particularly the significant events notified to ASN;
- the national and international experience feedback (REX) acquired on facilities other than Mélox);
- the development of the state of the art, knowledge and analysis methodologies (criticality, thermal design, organisational and human factors);
- the conclusions of the conformity review;
- the foreseeable changes on the facility;
- the requests formulated by ASN.

According to the licensee, this work does not call into question the safety and operating provisions in effect, but enabled it to identify a series of improvements whose application should help reinforce the lines of defence.

On completion of the ongoing review, ASN will give its opinion on the results of the periodic safety review at the beginning of 2013.

Furthermore, ASN has inspected the facility on the theme of conformity. This inspection revealed no major deviation from the safety frame of reference applicable to the facility.

Assessment of the safety margins

The facility robustness analysis focused on the civil engineering of the buildings that enabled static containment to be obtained on the buildings 500, extension 500 and 501, and guaranteeing the stability of buildings 504 and 506, and the sensitive equipment necessary for placing the facility in a safe state.

It is noteworthy, as appears clearly in the following summary table of mechanical equipment robustness, that the margin on the backup diesel generator sets is low.

Mechanical equipment	Minimum Earthquake level without cliff-edge effect (magnitude at distance of 7 km)
Storage module STK	7.00
Pellet interim storage areas PSK PSR and PST	7.00
Ventilation system	6.20
Pellet interim storage areas PSA and PSB	6.20
STE storage modules	6.40
STE cooling units	6.6 on ground and 5.8 on flat roof
STE recyclers	6.60
Backup ventilation cabinet	6.40
STE chilled water system	6.60
Extraction Storage ventilation duct	6.40
Backup diesel generator sets	5.50

The design-basis earthquake (DBE) is an earthquake of intensity 5.30 at a distance of 7 km. The backup diesel generator sets risk being unusable in the event of an earthquake of intensity of 5.50 or more (at a distance of 7 km). Loss of the backed-up cooling systems (fans, cooling units and recyclers) engages the risks of criticality and loss of confinement. The temperatures that would be reached in the fissile material storage areas, particularly of STE fuel rods, could very rapidly jeopardise the storage area geometry, within time lapses that seem poorly compatible with the intervention times.

Measures envisaged to reinforce robustness of the facilities to the seismic risk

The review showed that it was necessary for the licensee to study the site effects (lithological and/or geometrical) and evaluate any margin increases to be made to the chosen spectra. The licensee was also recommended to verify the seismic behaviour of the galleries, trenches and loft of building 500 and of the chimney stacks of buildings 500 and 501. The licensee has undertaken to carry out this verification for the gallery of the extension, the loft and the stack of building 500 in order to reinforce the civil engineering robustness.

ASN considers for the Mélox facility that it is important to carry out studies to verify the resistance of certain equipment items to earthquake, combined earthquake and fire, or other accident situations beyond the frame of reference, so that the necessary reinforcements can be planned where necessary. It considers that the risk of a cliff-edge effect associated with the loss of the last filtration level (DNF) (further to an earthquake aggravated by a fire in the "powders" unit) must be taken into account in particular.

For the seismic detection system and the identified associated controls, ASN considers that provisions must be made to counter the failure of all or part of this system.

ASN will issue requests on these various points to the licensee, some of which will be made requirements.

FBFC Romans

Design

The design of the buildings constituting BNI 98 dates back to the end of the 1970's, and for some of them was based on the PS69 parasismic rules.

During the periodic safety review of BNI 98 carried out in 2003, the characteristics of the maximum historically probable earthquakes (MHPE) and the safety shutdown earthquakes (SSE) to be adopted for the Roman site were validated. These characteristics, obtained by application of RFS 2001-01 and the preceding RFS (RFS I.2.c), which encompass the spectra resulting from strict application of RFS 2001-01, are as follows:

- MHPE specific to the seismotectonic domain of the site: magnitude = 4.5; depth = 8 km; intensity at the site = VI-VII on the MSK scale;
- MHPE attached to the associated East seismotectonic domain (including the Vercors region), called "distant MHPE": magnitude = 5.3; focal distance to site = 21 km;
- near SSE: magnitude = 5; focal depth = 8 km;
- distant SSE: magnitude = 5.8; focal distance = 21 km.

Measures to protect the facilities with respect to the seismic risk / design-basis earthquakes

Further to the 2003 safety review of BNI 9, the two main buildings housing fuel production (buildings C1 and AP2) were reinforced in order to withstand the SSEs validated in 2003.

The other structures of BNI 98, apart from the HF station, were not reinforced further to the 2003 periodic safety review. Their resistance to the MHPE and SSE defined in 2003 is not guaranteed.

The HF station was put into service in 2005 and designed to withstand the SSEs defined in 2003.

Conformity of the facility

Conformity of the BNI 98 buildings with the current frame of reference for the facility is not confirmed because the licensee has not verified it exhaustively. The licensee nevertheless specifies the following: the HF station was judged in conformity with its design file when commissioned in 2005 and the reinforcements of building C1 are in conformity with the reinforcements file produced after the safety review of 2003.

The next periodic safety review of BNI 98 is to be carried out in 2013. The file to be submitted by the licensee must include an examination of conformity of the entire BNI with the exception of building R1, which is to form the subject of a renovation file that will be submitted at the end of 2012.

Assessment of the safety margins

The licensee only performed the robustness analysis on the HF station and building C1, and reached the following main conclusions:

- for the HF station: it can be considered robust to an earthquake of intensity exceeding that of the SSE + 1;
- for building C1:
 - Block 4 containing the conversion autoclaves: the resistance of the block was substantiated by an experts' review for an earthquake of magnitude exceeding that of the SSE + 0.5;
 - Vaporisation unit: margins are reportedly available (not precisely quantified) owing to the margins intrinsic to the design codes used to substantiate the stability of the unit structures. According to the licensee, these margins cover an increase in the seismic loading by a factor of 2;
 - HF condensation: margins are reportedly available (not precisely quantified) owing to the margins intrinsic to the design codes used to substantiate the stability of the unit equipment. According to the licensee, these margins cover a 4-fold increase in the seismic loading of the structures and a 2-fold increase in the seismic loading of the attachments and anchor points.

Measures envisaged to increase the robustness of the facilities to the seismic risk

FBFC announces the renovation of building R1 (recycling of manufacturing discards), for which the file should be submitted at the end of 2012.

For FBFC, ASN considers that the licensee must carry out work to reinforce building R1 used for recycling uranium materials, and the equipment it houses. It will issue a requirement on this subject to set the work schedule.

ASN considers that the licensee must implement an automatic system for cutting off the electrical power supplies, closing the UF₆ emission valves and isolating the on-site hazardous gas infeed lines on detection of an earthquake.

2.4 Other facilities (ATPu, Masurca)

2.4.1. ATPu

Design of the facility

This facility, which was built in 1959 with no particular anti-seismic provisions, essentially consists of blocks A, B, C, D, E and F comprising 3 levels separated by construction joints. The basement houses the radioactive materials storage and conditioning rooms, production cells and technical premises. The ground floor contains most of the manufacturing and inspection cells and storage areas for fuel elements and waste. The first floor accommodates cubicles, technical rooms and offices. The CEA indicates that blocks A and B constituting the "powder block" underwent seismic reinforcements in 1977 in accordance with the PS69 rules. Studies performed in 1994 demonstrated the need for additional seismic reinforcements. CEA however opted for closure of the facility which is currently under decommissioning.

The safety functions to be guaranteed for the ATPu unit are the containment of radioactive materials and control of sub-criticality.

Conformity of the facilities with the current frame of reference

With regard to the civil engineering structures, CEA underlines that in an earthquake corresponding to 50% of the MHPE, the main building could collapse, which would lead to the dissemination of quantities of radioactive substances exceeding those quantified in the on-site emergency plan (PUI) and pollution of the water table, thereby leading to very serious radiological consequences.

Evaluation of the safety margins

The ATPu, currently under decommissioning, has no margin with respect to a seismic intensity corresponding to the MHPE.

Measures envisaged to reinforce robustness to the seismic risk

The licensee proposes no measures for reinforcing robustness of the facilities to earthquakes. This is because the essential measure to reduce the radiological risk associated with the ATPu consists in finalising as quickly as possible the operations to remove the radioactive substances still present and decommission the facility.

These operations are governed by final shutdown and decommissioning decree No.2009-262 of 6 March 2009, which sets a time scale of fifteen years for completing facility decommissioning.

Given the state of the ATPu, ASN considers that no earthquake resistance reinforcement is to be required of the licensee (requests will be made for emergency situation management).

2.4.2. Masurca

Design

The MASURCA facility was designed in accordance with the provisional "PS 62" parasismic rules. This facility is currently shut down and will be renovated as from 2015. The licensee considers that its stability is globally ensured for an SSE that is established taking into account the true distance between the site and the Middle-Durance fault.

Measures to protect the facilities against the seismic risk

The design measures concern the civil engineering of the storage and handling building (BSM) and the storage compartments of the fissile materials storeroom, which were designed to the reference spectrum applicable in 1964 when the facility was built.

The operating measures implemented to mitigate the consequences of an earthquake are described in a specific procedure concerning the post-earthquake actions. The main measure is to cut off the supplies of electricity, water, diesel fuel, argon-CO₂ to avoid the risks of indirect effects following an earthquake. The identified indirect effects considered in the analysis are the loss of all the electrical power supplies, damage to the electrical systems that could produce a short circuit and start a fire, and rupture of the water pipes in the BSM, causing water to flow around the fissile materials. The CEA indicated that these indirect effects were not such as to generate an additional cliff-edge effect.

The analysis of the earthquake behaviour of the civil engineering structures is based essentially on an opinion of experts.

On 30 June 2011 the reactor was unloaded and only the BSM building contained nuclear materials. A facility renovation project is currently in progress, with the planned construction of a new storage building to replace the BSM (entry into service planned for 2017).

Conformity of the facilities with the current frame of reference

The CEA reports a diagnosis revealing that the current design of the BSM does not meet the safety requirements in the event of the SSE earthquake defined per RFS 2001-01 for all the Cadarache site facilities.

Evaluation of the safety margins

In view of the foregoing, the facility in its current state has no safety margin.

With regard to the stability of the storage and handling equipment (storage compartments and overhead travelling stacking crane) in the event of an earthquake, the CEA points out that they are not directly involved in the containment but can play a role in the prevention of the criticality risk. According to the CEA they display margins significantly higher than those of the civil engineering. Consequently, the main risk feared is the destruction of the BSM building, which would lead to destruction of the equipment and loss of containment. The risk of instability of the storage and handling equipment items in themselves is not feared.

Measures to improve the safety of the facility - Opinion of ASN

The CEA points out that a specific complementary assessment of the renovated facility configuration will be presented as part of the renovation project file review.

Pending availability of this new building, the measures envisaged consist in limiting the quantity of water that could be spread over nuclear materials following a break in the water pipe supplying the BSM by:

- shutting off the municipal water feeder supplying a shower and wash-hand basin (the equipment in the locker/changing room building can be used);
- shutting off and draining of the air-conditioning chilled water system.

The quantity of water that could reach nuclear materials would thus be limited to the volume of the heating hot water system, that is to say 0.5 m³.

In the interim, the CEA specifies that part of the fissile material inventory is going to be transferred to the new Magenta facility.

Apart from the abovementioned provisions, the CEA has undertaken in the framework of the complementary safety assessment to examine, and if necessary take various measures to transiently reinforce the robustness of the facility:

- plug the openings in the facade walls of the BSM;
- install a coaming at the sodium store entrance to prevent the ingress of any water runoff at ground level;
- give a gradient to the external platform.

On completion of the complementary safety assessment review for Masurca, ASN considers that the licensee must remove the fissile materials from the BSM into a facility built to earthquake design standards in application of RFS 2001-01.

ASN will issue a requirement in this respect, setting the completion deadline.

2.5 General provisions relative to the seismic risk

As a general rule, the licensees must continue the initiatives to better assess the uncertainties inherent to the databases and prediction models, and to characterise the site effects.

Moreover, further to the CSAs, and in order to increase the robustness of the facilities, ASN will ask the licensees to define the requirements applicable to **the hard core of reinforced material and organisational provisions defined in paragraph 1.3 above**. When defining the earthquake resistance requirements for these hard core provisions, the licensees will have to adopt significant fixed margins with respect to the current frame of reference (RFS 2001-01 in particular).

ASN will be issuing requests in this respect, some of which could become requirements.

3. Flooding

This chapter presents the main findings drawn from the CSA reports relative to flooding submitted by the licensees, and ASN's conclusions after examining these reports.

The following points were addressed in succession for each facility or group of facilities:

- Design of the facility;
- Measures to protect the facilities against the flood risk;
- Conformity of the facilities with the current frame of reference;
- Evaluation of the safety margins;
- Measures envisaged to reinforce the robustness of the facility to the flood risk.

After examining the reports, ASN considered that improvement measures should be implemented on certain facilities. It will therefore request this. Some of these requests will be formal decisions taken by the ASN Commission, issued as legally enforceable requirements.

3.1 Design of the facilities

ASN's rule No.I.2.e of 12 April 1984 for taking into account the risk of flooding applies to nuclear power plants (NPPs) operating a pressurised water reactor (PWR). It is therefore not strictly applicable to other facilities. Nevertheless, lacking another frame of reference, this rule can be considered for these other facilities.

The draft guide relative to the protection of the facilities against external floods, currently under preparation and which was the subject of consultation in 2010, will apply to all basic nuclear installations (BNI), whatever their type.

3.2 Experimental reactors

3.2.1 Reactors operated by the CEA (Osiris, JHR, Phénix)

Osiris

Design of the facility

With regard to the risk of flooding resulting from rainwater inflows, the CEA indicated in its CSA report that the site's storm water drainage system was designed for 10-year storm events. It points out moreover that the facility's drainage system is not designed for 100-year storm events at the bounds of the 70% confidence interval, but that the overflows that could occur under these circumstances would run towards the Corbeville stream below the site, and would therefore have no impact on the facility.

With regard to the risk of flooding resulting from ground water infiltrations into the buildings, the CEA excluded the risk of flooding by ground water rise, as the water table is situated at a depth of more than 30 metres.

Whatever the case, according to the CEA the flood risk is not such as to create a cliff-edge affect.

Measures to protect the facilities against the flood risk

Several constructional measures have been implemented to protect against a large infiltration of water into the Osiris reactor, such as:

- the situating of the general foundations inside a circular impermeable lining in reinforced concrete;
- the application of a multilayer bituminous coating under the basemat and rising 2 metres up the external wall of the containment;
- the presence of drains under the multilayer coating, leading to sumps and pumps installed in the annular space between the enclosure and the reinforced concrete lining;
- 10-cm high walls around the pipe passageways giving access to level -4 m from level 0.

Constructional measures have also been implemented in the hot workshop building to limit the risk of water infiltration.

The CEA therefore considers that the design measures taken, as much for the arrangement of the electrical equipment qualified as important for safety as for the routing of the water pipes, preclude the risk of a flood being the cause of simultaneous loss of the Osiris reactor's protection channels (the CEA specified that the most penalising consequences for the facility in case of flooding were the total loss of the electrical power supplies, with the exception of the lines supplied directly by the ultimate backup generator set (GUS) (extraction fans), and the loss of nuclear ventilation).

Furthermore, the licensee indicates that operating provisions for firstly alerting to the imminence of a flood, and secondly mitigating its consequences, have been defined, and comprise:

- monitoring the alert given by Météo France (the French Met Office) or the Centre;
- performing inspection patrols;
- level sensors that can start a lift pump or send an alert to the control room;
- the presence in the facility of mobile pumping means, and immersible and motor-driven pumps on the site that can pump up the water and direct it to outlets.

Conformity of the facilities with the current frame of reference

As a general rule the CEA considers that the conformity of the essential equipment and the potential threats is confirmed by the periodic inspections and tests, the maintenance operations and the actions carried out further to the periodic safety reviews.

For Osiris in particular, and with respect to the flooding risk, the licensee states that conformity is ensured by applying the following measures:

- performing daily inspection rounds to monitor the premises where there is a risk of water ingress;
- taking three-monthly measurements in the external drain manholes to monitor any water inflows in the immediate vicinity of the facility buildings. The CEA specifies that no leaks through the basemat have been detected;
- taking samples from the sumps collecting the water from the drains situated under the multilayer coating of the Osiris reactor in order to monitor the sealing against a water table rise and leaks from the water block. The CEA indicates that the last televisual inspection concluded that the general condition of the pipes and grids was good;
- every 10 years, performing leak tests of the multilayer coating covering the lower part of the containment and the basemat;
- inspection of the drain situated under the canal by video camera, cleaning and testing its operation. The licensee considers its overall condition satisfactory;
- 4-monthly testing of automatic starting of the lift pumps situated in the annular space sumps.

It can be pointed out that the targeted conformity review carried out in 2009 as part of the Osiris facility's periodic safety review revealed no major nonconformities.

Evaluation of the safety margins

To estimate the safety margins with respect to a 100-year storm event, the CEA reviewed its 2005 study relative to the risks of saturation of the facility's storm water drainage systems further to a 100-year flood situation. It considered a 100-year storm event corresponding to the upper bound of the 95% confidence interval. The results show that with these rainfall levels it is always the drains situated to the south, south-east of the facility's buildings that would become saturated. The volume of water resulting from the overflow of these drains was estimated at 221 m³ for intense rainfall periods lasting 30 minutes.

Given the flatness of the land near the facility, the CEA considers that such an overflow volume would lead to a water wavefront of less than 50 cm height and could lead to water ingresses in the retention areas of certain tanks, as well as in the diesel generator room, then to the -4 m level of the crown gallery before reaching the annular space. The CEA does not consider that this event could produce a cliff-edge effect. It nevertheless plans measures to reinforce the robustness of the facility, particularly to limit the impact of water ingress into the non-fixed tank retention areas and the gallery.

The CEA also indicates that no cliff-edge effect occurs and no essential element is threatened as long as the -4 m level is not flooded to a depth exceeding 60 cm of water, which would represent a volume of more than 5000 m³ in the facility basements.

The CEA considers that flooding of the facility cannot lead to the failure of an essential equipment item and that the main flood risk comes from heavy rainfall. The storm water drainage systems, whether for the facility or the whole Centre, were designed for a 10-year storm event. According to the abovementioned study of 2005, a 100-year storm would produce minor drainage system overflows, which would run towards the Corbeville stream situated to the south of the Centre. The CEA thus considers that there is no risk of a cliff-edge effect. It states moreover that to lose the nuclear ventilation and the electrical cabinets situated at the - 4 m level, 5000 m³ of water would have to infiltrate the facility, a volume that vastly exceeds that expected in the event of drainage system overflow further to a 100-year storm (less than 250 m³).

Measures envisaged to reinforce the robustness of the facilities to the flood risk

The CEA envisages the following improvements:

- extend the creation of low walls around all the passageways giving access to the -4 m level from the 0 m level;
- isolate a gallery linking the Pierre Süe laboratory (external to the facility, not specifically protected against flooding) to the annular space of the Osiris reactor (gallery situated around the basemat);
- implement provisions preventing the lifting of the tanks of acid, sodium hydroxide and fuel, or preventing the water from entering their bunkers;
- protect the pulsed ventilation suction inlet situated on the exterior of the facility at the 0 m level, against water ingress.

ASN has no particular remarks concerning the licensee's proposals to reinforce the robustness of the Osiris facility to the risk of flooding.

JHR

Design of the facility

When designing the Cadarache site facilities, the CEA calculated a flood safety margin level of 265 m NGF (French datum level system) based on the bursting of the Serre-Poncon dam. The Cadarache site is moreover crossed by the Ravin de la Bête stream, which is at an elevation 297 m NGF at the JHR, then channelled at the ATPu in an oval drain dimensioned to discharge the 100-year storm flow estimated for this part of the watershed. Given the margins available between the levels of the platforms and of the two watercourses (which can reach several tens of meters), or between the extreme flow of the stream and the discharge capacity of its channel, the CEA has ruled out flooding of the Cadarache facilities by the River Durance or overflowing of the Ravin de la Bête stream.

The reference rainfall levels considered for the design are the 100-year storm events, as defined in the experience feedback (REX) from the Blayais site.

As regards an extreme rise in the water table, the CEA considered a level corresponding to the 100-year flood for the JHR, where the extreme level of the water table would reach the 316 m NGF elevation at the JHR nuclear reactor.

Measures aiming to protect the facilities against the flood risk

The following design measures were taken:

The JHR storm water drainage system is designed to cope with a 100-year storm to which a safety factor of 1.5 has been applied.

In addition to the storm water drainage system, measures have been taken to prevent the ingress of runoff water into the structures:

As regards water ingress into the nuclear unit (UN):

- The access doors (truck airlock, new systems airlock, emergency door) are on a gradient so that the flow is directed towards the exterior;

- The roof is angled to prevent water accumulating on the buildings; it has downpipes conveying storm water to the drainage system, an overflow guaranteeing water discharge if the pipe gets blocked, and a sealed coating. Roof-mounted equipment items are situated at height and the ventilation openings are protected against infiltrations. The ventilation penetrations are raised above the roof slab;
- In the connecting galleries, the fluid pipe and electric cable penetrations with the UN are raised above the ground surface of these galleries and sealed to prevent infiltrations. The Nuclear Materials Building (BMN) gallery has a gradient and a low wall perpendicular to the gallery allowing water to flow towards the BMR building which has a retention capacity of 200 m³. The BAGs are equipped with coamings and sumps. The upper slab of the BAGs and BMN, which acts as a roof, is on a gradient and has overhangs with a drip groove.

With regard to water ingress into the safeguard auxiliary buildings (BAS) A and B, these buildings are raised and at different elevations on platforms with gradients that direct the runoff water towards the storm water drainage systems. The floors of the BAS buildings are raised by between 0.1 and 0.6 m with respect to the external finished ground surface. The diesel tanks supplying the backup generators are installed in pits protected by concrete slabs that prevent water infiltration.

Lastly, the CEA underlines that no drainage channel can create a communication between the two BAS buildings (geographical separation):

- the storm water drainage channels of BAS A discharge to the Eastern edge of the site;
- the storm water drainage channels of BAS B discharge to the Western edge of the site;

Regarding water ingress by water table rise and exceptional storm water infiltration, the UN is protected against flooding by:

- the sealing of the internal surface of the UN basemat (-3 m level) and of the primary bunkers;
- the lower basemat of the UN which supports the paraseismic supports designed to withstand the uplift in an accidental rise of the water table;
- the reinforcement of the excavations (passive nailing of the bedrock, pneumatically placed reinforced concrete walls, bored drains and barbicans);
- the UN drainage system, which is independent of the storm water drainage system, collects the water table rise water and rain infiltration water and discharges it to the Ravin de la Bête.

As regards the buildings other than the UN, some are situated at higher elevations than the 100-year water table rises (BAS B and BAG B), and are therefore protected against water ingress. The other buildings have peripheral drainage systems capable of draining to the storm water drainage system an envelope value equivalent to a 100-year water table rise.

Regarding the operating measures for alerting to the imminence of a flood and mitigate its consequences, the ground water level is periodically checked by the piezometers situated near the facility. The frequency of these inspections can be increased according to the evolution of the water table level.

Flood detectors carried over to the control room alert the operator to the infiltration of water in the buildings BAS A and B, BAG A and B, and the lower basemat of the UN.

Conformity of the facilities to the current frame of reference

The CEA specifies that the storm water drainage system is inspected periodically and cleaned as required to remove any material that could block the channels. Periodic inspection rounds are carried out in the lower basemat to check the condition of the system draining the water to the Ravin de la Bête. Cleaning is carried out if necessary.

If a flood significantly higher than a 100-year flood were to cause water ingress in the lower basemat, the following measures would be taken:

- inspection of the condition of the structures and mechanical parts of the inter-basemat space;
- inspection of the condition of the foundation basemat.

Evaluation of the safety margins

The licensee has considered the cases of an extreme flood of the river Durance, bursting of the dams situated near the Cadarache centre (EDF dam of Serre-Ponçon, dams of Sainte-Croix and Esparron-sur-Verdon) and bursting of the Canal de Provence.

The calculations have shown that the rise in pond water resulting from the most pessimistic dam-break flood wave would correspond to a breach in the Serre-Ponçon dam situated more than 95 km from Cadarache. The dam-break flood wave would result from the gradual but total destruction of the dam caused by deep seepage. It was calculated that this flood wave would reach Cadarache 5 h 40 min after the dam burst and result in a peak flow of the order of 60,000 m³/s with a mid-height width of a few hours. The cases of a simultaneous 100-year flood would represent an additional flow of 5 000 m³/s, which would not significantly change the maximum elevation reached by the flood wave, this being 265 m NGF.

The licensee considers that a no nuclear facility on the site would be concerned and that the Centre would remain accessible via the auxiliary gates.

The licensee presents the risks of storm water drainage system overflow in the event of rainfall exceeding the design-basis levels. The CEA considers that the storm water runoffs not collected by the drainage system would have no impact on the JHR buildings on account of the small area of the upstream watershed, the access sills which are raised with respect to the roads, or the steep external slopes directing the runoffs downstream to the Ravin de la Bête.

With regard to the effects of a gradual rise in the water table beyond the levels considered for the design of the facilities, the licensee highlights either the protection measures that enable - in the same way as for the storm water - the water to be discharged towards the Ravin de la Bête, or the margins before the low points of the sensitive buildings are reached.

Measures to improve the safety of the facility - Opinion of ASN

Although there is no identified cliff-edge effect, the CEA proposes reinforcing design robustness by taking measures to facilitate pumping of a water build-up in the parasismic support area following flooding of the containment.

ASN considers that the licensee's proposals to increase the flood risk robustness of the JHR facility are satisfactory. It will instruct the licensee to install, in the bottom section of the concrete wall of the parasismic supports area, means to facilitate management of a containment flood.

Phénix

Design of the facility

The CEA has calculated a flood safety margin level (CMS) of 38.54 m NGF, resulting from bursting of the Douglas dam combined with the 100-year flood of the river Rhone. Level 0 of the Phénix reactor is situated 16 cm above the CMS.

The design reference rainfall is the 100-year storm event at the upper bound of the 95% confidence interval. The CEA indicates that the storm water drainage system can evacuate rainfall representing about 100 mm/h, which is comparable with a 100-year storm for the region. The CEA underlines that the drainage system has functioned satisfactorily in the past, notably in the heavy rainfall episode of 2002.

The platform would be immersed upwards of the 38.70 m NGF level.

Measures to protect the facilities against the flood risk

In its CSA report the CEA presents several design measures to protect the Phénix reactor against the flood risk, and notably:

- the level 0 of the reactor which is situated at elevation 38.70 m NGF, for a CMS of 38.54 m NGF;
- the various structures of the Compagnie Nationale du Rhône (CNR) that would regulate the flow of the Rhone and lead its overflow towards the left bank. The water level at the facility, which is situated on the right bank, would therefore be limited even though it is not protected by an embankment;
- the presence of fixed pumping means, notably in the auxiliary building, the inspection-offices building and the steam generator (SG) building.

The CEA also presents operating provisions for alerting to the imminence of a flood:

- monitoring of the river Rhone (level, flow rate, height, flood risks) via the "Vigicrues" web site;
- the alert given by Météo France if extreme weather conditions are forecast.

The situation of the site nevertheless reveals weaknesses in the supervision-office building (BCB) and the pumping station which suggest that beyond the 38 m NGF level there is a flood risk for the reactor building basements, the reactor pit, the SG building and the handling building, but it would be limited to water infiltrations from the auxiliary building penetrations.

Conformity of the facilities with the current frame of reference

The CEA indicates that the main measures for guaranteeing the conformity of the facility are:

- verification of lift pump operation by performing two-weekly tests;
- verification, as part of the CSAs, of the condition of the roofs and storm water downpipes. The CEA also envisages scheduling periodic inspection of the storm water drainage systems.

Consequently, the CEA considers that for the Phénix facility the main flood risks come from heavy rainfall and flooding of the nearby river Rhone. The risk of a cliff-edge effect exists in the event of a sodium-water reaction induced by the displacement of the secondary sodium storage tanks which are simply placed on skids in the basement of the handling and SG building.

Evaluation of the safety margins

The CEA has presented the effects of a rise in the level of the river Rhone, particularly beyond the CMS, then beyond the elevation of the facility platform (38.70 m NGF), leading to flooding of the buildings. The licensee points out however that overflows above the left-bank embankment opposite the facility would limit the increase in water level. It therefore considers that to reach the platform it would require flood flows much higher than those associated with the CMS.

The licensee rules out any significant risk resulting from an extreme rise in the water table, on account of the means of protection implemented in the buildings containing essential equipment and the absence of cliff-edge effects in the event of infiltrations into the auxiliary buildings.

The CEA indicates that rainfall exceeding the capacity of the drainage system could lead to a flash flood on the facility platform inducing a risk of flooding the buildings. The licensee proposes a complementary study in this respect to evaluate the ability of the plant's storm water drainage system to evacuate the water from very intense rainfall episodes.

Measures envisaged to reinforce the robustness of the facilities to the flood risk

Considering all these elements, CEA envisages:

- Remedying the facility's weak spots by:
 - installing isolating devices on the overflow lines linking the main diesel generator set cooling system tanks to the tank situated in the BCB basement;
 - evaluating the resistance of the fire barrier penetrations between the basements of the auxiliary, handling, SG and reactor buildings to a height of water, and study their reinforcement if necessary;
- Favour the overflow of the water towards the IPE (area adjacent to the SG building containing the hall of shut down turbines) by means of openings made in the connection gallery between the BCB and the auxiliary building;
- Procure means for limiting water ingress (inflatable tubes, etc.) and establish a procedure for preparing mobile pumping means in case of an announced rise in water level or heavy rainfall;
- Study the dimensioning of the plant storm water drainage system with respect to its capacity to evacuate the water from very intense rainfall episodes, exceeding those already encountered;
- Perform periodic inspections of the plant storm water drainage systems;
- Render watertight an opening giving access to a sodium tank situated at the low point of the reactor building.

The CEA has moreover undertaken to:

- Evaluate the margin on the river Rhone flow rate before reaching the Phénix platform;
- Supplement its study to take into account scenarios of rainfall combined with the risk of unserviceability of the storm water drainage system, areas of local water build-up resulting from the site configuration and the location of the accesses to buildings containing equipment that must be protected;
- Specify the measures adopted to protect the sensitive premises in the event of flooding of the platform caused by a flood of the river Rhone and the schedule for implementing these measures.

The main risk the Phénix reactor presents with respect to the extreme situations studied in the CSA is linked to flooding, in view of the risk of sodium / water interaction. The ASN will issue requirements relative to the necessary to work to increase the facility's robustness to this risk, and the sensitive premises in particular.

3.2.2. Reactor operated by the ILL

Design of the facility

The high flux reactor is situated upstream of the confluence of the Isère and the Drac, on the right bank of the Drac and the left bank of the Isère. These two rivers have relatively different flow regimens, the first being supplied with rainwater associated with oceanic disturbances, the second by rainfall associated with Mediterranean disturbances. The result is that it is relatively rare for the two rivers to become flooded simultaneously.

In its CSA report, ILL indicates that the HFR is designed to withstand a flood at the maximum elevation of 210.50 m NGF, which covers the elevation of all the floods of the Isère and the Drac, but not that resulting from bursting of the Monteynard dam.

Measures to protect the facilities against the flood risk

The first protection measures against flooding of the Isère and the Drac are the ILL site embankments.

Anti-flood devices are also provided in the cooling system water intakes and by the installation of flood gates.

A system protecting against bursting of the Monteynard dam, which would result in a flood wavefront on the site, can also be deployed with respect to the external metallic containment which risks not resisting such a load. The principle of this system would be to depressurise the annular space by opening it at two points to let the water rise on either side of the enclosure thereby preventing any damaging load build-up.

Conformity of the facilities to the current frame of reference

The ILL indicates in its CSA report that the design of the HFR does not comply with RFS I.2.e. This is because:

- as the thousand-year return flood is not known, the safety margin corresponding to this flood + 15% is not defined;
- the design does not take into account the loss of the most constraining retention structure (Monteynard dam) combined with the highest flood in history or the 100-year return flood if this is higher.

Bringing into compliance is planned as part of the next update of the safety report planned for 2012. The ILL indicates that this level is nevertheless already taken into account and integrated in the emergency management procedures for site flooding. As regards the key SCCs, the licensee has identified the necessary reinforcements (see below).

Evaluation of the safety margins

The ILL has examined a scenario involving the bursting of the four dams situated on the river Drac further to an earthquake. It considers this scenario extremely improbable and emphasizes the penalising natures of the calculated elevations (216.2 m) and after adding the safety margin (218 m). The reference level taken to evaluate the robustness of the facility is the 216.2 m NGF level. This choice is explained by the conservative

nature of the hypotheses used for the calculation. The flow rates are similar to those calculated for the Monteynard dam burst scenario.

The licensee has therefore assessed the risks of water entering the reactor building taking 216.2 m NGF as the reference water height. It indicates that at this height of 216.2 m NGF, the consequences on the facility would be:

- flooding of level C of the reactor building via the large doors (truck door and courtyard door),
- loss of all the electrical power supplies. For information, the normal operations control room is situated on the 4th floor of building ILL4, above the 216.20 m NGF level. Yet operation from this room requires the off-site electrical power supplies or, the backup diesel generators situated at level 210.50 m NGF or the batteries situated on the 1st floor of building ILL4, i.e. at the level 214.20 m NGF.
- loss of the emergency control station (PCS), which allows control of the gaseous effluents (EG) system and the emergency water make-up system (CES); the associated electrical power supply consists of a backup diesel generator that is watertight up to the level 210.50 m NGF.

Given this information it can be considered that monitoring and control of the facility is only maintained up to level 210.50 m NGF.

The ILL points out that these failures do not however lead to an accident, as the reactor core and the fuel elements cooling in the pool are always correctly cooled by natural convection. It is important to underline the fact that in the event of a risk of site flooding, safe reactor shutdown can be carried out very rapidly, since the moment the reactor is shut down the residual power can be removed by simple natural convection which is established completely passively (via three natural convection valves, the opening of just one of them being sufficient) from the moment the cooling pumps that provided a forced downward flow stop functioning.

On this basis it can be considered that, on condition that there is an effective flood risk alerting system, the licensee will be capable of shutting down the facility.

Proposed measures to reinforce the robustness of the facility to the flood risk

In view of which is presented above, the ILL has undertaken:

- during the winter 2013-2014 shutdown, to reinforce all the enclosure penetrations and openings situated below the level 216.20 m NGF. The items concerned are: the courtyard door, the truck door, the level C airlock, the penetration opening D2O and the secondary water penetration opening. During the examination ILL undertook to examine the possibility of starting work to reinforce the water-tightness of the reactor building openings as of the winter 2012-2013 shutdown, with priority being placed on the courtyard door which is situated at the lowest level (207 m NGF).
- put in place, during the winter 2011-2012 shutdown, a diesel generator set outside the floodable zone to energise the systems that guarantee reactor monitoring after flooding and deployment of initial aid means, such as a motor driven pump.

It has also undertaken to build a new control station called PCS that can implement and control all the backup systems (CES, CRU, CDS, CEN) up to a water height reaching the 216.20 m NGF level. This point is developed in the "Severe accident management" section.

Requests from ASN to reinforce the robustness of the facility

On completion of its review of the ILL's CSA report, ASN considers the licensee's procedure satisfactory. In the coming months it will perform an in-depth examination of the licensee's proposed improvements, some of which could become requirements.

3.3 Nuclear fuel cycle facilities (La Hague, Tricastin, Mélox, FBFC)

3.3.1 Tricastin site

Design

AREVA indicates that the site flood protection level is set at 51.1 m NGFO (French orthometric datum system).

The Georges Besse I plant

The floor of the BNI is situated at level 49.50 m NGFO. No equipment items containing radioactive materials are installed below the 53.50 m NGFO level. Only the UF₆ containers could be reached by a flood.

Comurhex

The land covered by the Comhurex facility is situated at an elevation equal to or higher than 51 m NGFO, the buildings having a slightly higher elevation and the retention areas being protected against rainwater runoff by low walls. The environmental consequences of a flood are therefore limited to leaching of the soils, representing about 900 grammes of uranium.

The minimum elevation of the floors of Comurhex II is 51.40 m NGFO, which guarantees that the facility is kept out of water.

Socatri

The licensee's file presents no particular information on the consequences of a flood on the facility. Nevertheless, previous studies (safety review, safety options file of the TRIDENT project) show that the facility is floodable with respect to the current frame of reference.

An increased 100-year return storm could create a flash flood of about 20 cm height and loss of certain electrical power supplies and information feedback (the minimum elevation of the effluent treatment stations is 47.70 m NGFO).

This aspects is studied in the ongoing periodic safety review.

TU5 W

The sensitive areas that could be impacted by a flood are:

- "HF storage" area of the W facility
- "emission" area of the W facility

"HF storage" area

The risk considered by the licensee in the event of flooding is the lifting of tanks.

The licensee indicates that the design of the HF storage tanks is based on two different principles:

- Storage SHF1: The tanks are installed on concrete blocks placed in retention tanks protected by a low surrounding wall. In this case, above a filling factor of 71% (the licensee states that the tanks are either empty or filled to more than 75%), the tanks cannot be lifted by the water, whatever the height it reaches. Lifting an empty tank has no impact.
- Storage SHF2: The tanks are anchored on a concrete foundation, placed in retention tanks, protected by a low surrounding wall. In this case the anchoring of the tanks totally excludes the risk of them being lifted by the water, whatever the height it reaches.

"Emission" zone

The risk considered by the licensee in the event of flooding is the lifting of the containers and the pulling out of pipes.

The containers of solid-phase UF₆ are placed on handling trolleys whose low point is 96 cm above the unit floor. They are connected to drying ovens by needle valves situated 2 m above the ground. The first manual

shutoff valves at the oven exits are 3 m above the ground (the remotely controllable valves are installed upstream). Furthermore, the drying ovens are sealed and anchored to the concrete foundation.

The Georges Besse II plant

The installation platform is situated at an elevation (51.94 m NGFO for the south unit, 54.05 m NGFO for the north unit, 53.00 m NGFO for the REC II unit) that should maintain the sensitive facilities above water in the event of flooding (of level 51.10 m NGFO). The walls and basemats situated below the platform level are made from water-repellent concrete and designed to withstand the hydrostatic pressure of the water table. The backup generator sets and the compressors for producing the compressed air necessary for preserving the centrifuges are also above water.

The crystallizing containers, cold traps and equipment other than containers 30B and 48Y of GB II are installed at least 4 m above the level of the platforms.

Measures relative to the risk of extreme rainfall events have also been taken at the design stage. Each buffer yard has a storm water retention area. The storm water from the south unit retention area is directed to the storm water tank and the storm water from the north unit and the REC II unit is directed towards the intermediate tank. The storm water tank, which discharges into the river Gaffière, collects the storm water from the roofs and roads of the south unit. The intermediate tank does likewise for the north unit and the REC II unit, discharging the water into the AREVA NC storm water drainage system.

Measures to protect the facilities against the flood risk

The site systematically receives the meteorological bulletins from Météo France, which represent a pre-alert threshold for all the platform licensees. A local tripartite agreement between the Compagnie Nationale du Rhône (CNR), EDF and AREVA provides for the mutual communication of information in the event of unfavourable climatic situations or a rise in water levels.

Georges Besse I plant

The licensee's file does not contain any information on the measures to protect the facility against flooding.

Comurhex

A vertical screen associated with three pumping wells has been installed along the river Gaffière, raising its banks to an elevation of 52.39 m NGFO along the first 200 metres after it enters the site. The licensee indicates that the land is to be further levelled to reach the same elevation over another 200 m. This will give the facility an additional protection barrier.

Furthermore, in the event of rainfall of higher intensity than the 100-year return storms, the facilities are shut down and placed in safe condition and the effluents present in the pits are disposed of.

Socatri

The licensee's file gives no information on the consequences of a flood on the facility. The safety frame of reference for the facility, however, plans for it to be placed in safe condition as soon as the 47.8 m level is reached, with the installation of flood gates at building entrances and raising of the materials above floor level with the units.

TU5 W

The licensee indicates that the following measures are taken for this facility

- "HF storage" area: a protective wall surrounds the retention tanks (48 cm for SHF1 and 20 cm for SHF2);
- "Emission" area: the shutoff valves are closed preventively and production is stopped in the event of flooding.

Georges Besse II plant

Protection of the facility against the flood risk relies on the elevation of the different key constituents.

Conformity of the facilities with the current frame of reference

The licensee has not yet performed a periodic safety review of its facilities. It bases its assessment of SSC conformity on its internal inspection and maintenance system. It indicates that implementation of this organisational procedure has revealed no nonconformities. This is not sufficient to assess the conformity of the SSCs, which must undergo a proper conformity review in the short term. This review has begun for one facility, the Socatri BNI.

For the Georges Besse II plant, effective conformity is verified from design through to commissioning.

Evaluation of the safety margins

The licensee examined the safety margins with respect to the initial design of the facilities. It concludes from the studies that a number of facilities would not withstand a Fukushima-type event.

More detailed information is provided for the Georges Besse II plant.

Georges Besse II plant

The complementary safety assessment considers two hazard events on the Tricastin site:

- flow of water from the siphons of the river Gaffière attaining 300 m³.s⁻¹ per loading on the left bank: in this case the facilities remain above water;
- flooding by a break in the canal embankment on the right bank between the TGV (high-speed railway) line and the NPP: in this case, according to the water heights given in the impact study conducted by SNCF TGV Méditerranée, the equipment involved in safety functions remains above water, except for the pumps and the emergency drainage system cold traps or chemical traps. The sub-criticality of these equipment items is guaranteed in case of immersion.

Measures envisaged to reinforce the robustness of the facilities to the risk of flooding

Additional measures were identified in the complementary safety assessments, in particular to further knowledge relating to the flood risk for the facilities in the event of increased rainfall scenarios considering the risk of the storm water drainage system being unavailable, water build-up areas due to the site configuration and the location of accesses to building containing equipment to protect, or to reinforce the measures to take in the event of flooding (operating instructions relative to stopping production in the W plant for example, implementing security measures to limit flooding of the premises and to contain the consequences of the flood within the bounds of the facility).

On completion of its review, ASN considers that for the Tricastin site facilities, the specific risk of flooding of the enriched material storage areas is a particular aspect that must be taken into account. Furthermore it considers that the licensee must further reinforce the measures taken in the event of flooding. It will issue requirements on this subject.

More particularly, ASN considers that AREVA must provide it with additional information concerning the available margins for the flood accident sequences considered, taking into account all site developments that could influence the water heights attained.

The different nuclear licensees on the platform must also assess the margins available for the flood accident sequences considered (upstream dam burst, failure of the Donzère canal embankment, etc.) and propose any necessary reinforcements, taking into account all the site developments that could influence the water heights attained.

For Socatri, ASN considers that the licensee must take the necessary measures to prevent the risk of criticality in the event of flooding of the enriched material storage areas. It shall issue requirements on this subject.

3.3.2. La Hague site

Design of the facilities

Owing to its location and environment (high elevation with respect to the sea, situated on the high point in the area), the La Hague site is not subject to tsunamis, dam burst or flood risks.

Flooding of the buildings could only result from a rise of the ground water tables or extremely heavy rainfall.

The licensee has estimated that the rates of water rise before reaching the mean low level of the units is 10 days if there is no ground water pumping, which is not guaranteed in an earthquake situation.

When designing the plants, AREVA used the 10-year return rainfall (precipitation of 2.1 mm per for 10 minutes) as the design flood hazard.

Conformity

Although the licensee has not performed a proper conformity review, it has assessed the capacity of the storm water drainage systems to evacuate the volumes of water created by a 100-year return storm and any possible alternative run-off routes the water would take. Of the fourteen buildings examined, seven have drainage systems that are too small to evacuate the volumes of water considered (24 mm rainfall in 6 min).

Furthermore, the risk of the storm water drainage system being unavailable is not retained by the licensee, who considers that this can be avoided through regular maintenance of the network.

Measures to protect the facilities against the flood risk

The site has a pumping system that lowers the water table levels.

Evaluation of the safety margins

The majority of the La Hague site is situated at the summit of the Jobourg plateau, more than one hundred meters above sea level. To the south, below the plateau and close to the sea, the site also has a connecting area comprising the Moulinets dam in particular. The base of the dam and the adjacent facilities are situated at an elevation of about 28 m NGF, i.e. 33 m above the marine charts 0 datum level. These facilities are situated more than 10 m above the highest envisageable waters (high water of spring tide + thousand-year storm surge + strong swell).

Consequently the licensee considers that any risk of flooding associated with a tsunami combined with an earthquake can be excluded, even in an extreme scenario.

The licensee presented an assessment of the flood risk associated with water table rises. Considering the dynamics of the water table risk phenomenon to be sufficiently slow, the licensee ruled out the risk associated with loss of the pumping that lowers the water table levels.

The licensee also presented an assessment of the flood risk associated with maximum high intensity rainfall (PFI). The PFI values used were evaluated referring to the "REX Blayais" (Blayais site experience feedback) methodology and the impact assessment was modelled taking account of the storm water drainage system evacuation capacities, the predicted overflows and the possible paths taken by surface runoff water. The water heights estimated using this procedure were between 0 and 13 cm at the access points to the buildings containing the key SSCs.

Measures envisaged to reinforce the robustness of the facilities to the flood risk

The licensee concluded that it was necessary to raise the access sills of two of the 14 buildings studied in the flood risk assessment associated with the PFI.

Proposed studies to supplement the procedure

For the La Hague facilities, ASN considers that the licensee must supplement its procedure by analysing at least the risks of flooding of the key SSCs with respect to the design-basis storm scenarios and perform a sensitivity study with respect to partial blocking of the pipes and the risks of multiple breaks in systems and structures further to an earthquake, taking account of the site configuration and the location of access points to the buildings containing equipment to be protected. It will make requests in this respect.

3.3.3. Other facilities in the fuel cycle (Mélox, FBFC)

Mélox

Design of the facility

To define the means of flood protection when designing the plant, the licensee used RFS I.2.e to determine which data to consider. These data were then provided by Compagnie Nationale du Rhône (CNR). They concern the following levels:

- the maximum 1000-year flood (CMM), represented by the 1000-year return flood flow increased by 15%;
- the 100-year flood combined with failure of the Vouglans dam.

The flow of the thousand-year flood increased by 15% is retained as the most penalising with respect to the rise of the river Rhone. In event of the CMM, the Rhone can in fact only exceed the 37.5 m NGF level (elevation of the left bank embankment) by a small amount, but without exceeding the level of the right bank. The height difference between the embankments of left and right bank of the Rhone favours overflowing on the left-bank side.

The 100-year flood combined with failure of the Vouglans dam is more penalising with respect to the rise in the water of the secondary canal situated behind the right-bank embankment. In the event of a 100-year flood concomitantly with Vouglans dam failure, the level would reach 36.65 m NGF at the Marcoule site (KP 209.5). This value has been adopted as the flood safety margin level (CMS) since the design data were re-evaluated.

The Mélox plant is installed on a platform at elevation 40 m NGF. This gives a margin of more than 2 m with respect to the CMM and more than 3 m with respect to the 100-year flood combined with failure of the Vouglans dam. The pits of building 500, which are dug below the 40 m NGF level, are designed to withstand the hydrostatic thrust corresponding to the CMM.

These pits are designed for a rise in the water table. All the plant structures are watertight up to the basemat, to which is added the height of the door sills. The margin is 9.73 m with respect to the average height of the water (30.57 m NGF), and 6.93 m with respect to the maximum level recorded over 10 years (33.37 m NGF).

As the quantity of water inside the process premises is very limited, the risk of internal flooding has not been considered.

The plant has been designed (with the installation of a network of pipes and the dimensioning of the openings, connecting galleries, passageways, cooling units and flat roofs) from the reference rainfall levels indicated in the table below and taken from the graph of heights/durations/frequencies of the national meteorological service of Nîmes-Courbessac.

Return period (years)	Duration			
	6 min	15 min	30 min	1 h
10	16 mm	28 mm	45 mm	68 mm
100	24 mm	41 mm	68 mm	105 mm

*Nîmes-Courbessac rain-gauge station -
Maximum adjusted precipitation over the 1964-1992 period*

Measures to protect the facilities against the flood risk

The target key SSCs in the event of flooding are the cooling units (situated externally), the emergency diesel generator sets (situated in external containers) and the backup diesel generator sets (situated in different rooms within building504) that enable the safeguarded functions to be maintained. The plant has been designed to protect these key SSCs against a reference flood .

Conformity of the facilities with the current frame of reference

It is noteworthy that the licensee performed an elevation measurement study in 2009 which revealed that the settling has slowed down since 1996 and that the maximum settling value does not call into question the existing margins with respect to the reference floods.

Evaluation of the safety margins

The licensee has studied the robustness of the facilities and in particular the key SSCs mentioned above (cooling units, emergency and backup generator sets) with respect to floods beyond the reference level. The margins were evaluated with respect to the maximum design flood level (CMS). The following table summarises the results of the licensee's study

Key systems and components	NGF level	Margin with respect to maximum design flood level (CMS)
2 provisional emergency diesel generator sets(*)	> 38 m(*)	> 1.35 m (*)
2 backup diesel generator sets (train A/train B)	41 m	4.35 m
2 safeguard electrical rooms	40.60 m	3.95 m
2 safeguard control stations (train A/train B)	40.30 m	3.65 m
2 STE cooling units (train A/train B)	41.05 m	4.4 m
	51.46 m	14.81 m
2 TAS cooling units (train A/train B)	40.70 m	4.05 m
	40.80 m	4.15 m

(*) The replacement of the provisional emergency diesel generator sets is planned for early 2012 after obtaining regulatory authorisation. The final generator sets will be situated at 40.05 m NGF, i.e. with a margin of 3.4 m with respect to the maximum design flood level (CMS)

In the framework of the CSAs, the licensee envisaged a progressive flood of a level exceeding:

- firstly, that of the 100-year flood combined with failure of the Vouglans dam;
- secondly, that of the platform (40 m NGF) on which the plant is built.

According to the licensee, the first equipment impacted would be the provisional emergency diesel generator sets; their loss has no impact on placing the facility in safe condition. In the definitive configuration (2012) of emergency diesel generator sets (40.05 m NGF) would also be the first to be impacted. The safeguard control stations would be the next impacted (40.30 m NGF), but local operations still remain possible. Upwards of a flood level of 40.40 m NGF, the criticality risk prevention conditions are modified. Nevertheless, criticality risk prevention is ensured as long as the fuel assemblies and rods remain in place. From level 40.80 m NGF, fuel assembly cooling is no longer ensured, and upwards of level 51.46 m NGF, cooling of the fuel rod storage area is no longer ensured. The backup diesel generator sets are flooded upwards of the flood level of 41.00 m NGF.

To summarise, the flood levels necessary to damage the key SSCs are very difficult to reach given the width of the plain. Consequently the licensee considered that only the loss of the emergency diesel generator sets should be taken into account.

With regard to the risk relating to torrential rain events, the values updated by Météo France are:

Duration	6 mn	15 mn	30 mn	1 h
Reference rainfall (mm)	21.5	41.7	67.0	112.1

Nîmes-Courbessac rain-gauge station - Maximum adjusted precipitation over the 1964-1992 period

The licensee indicates that they differ little from the design-basis values. Furthermore, experience feedback from the "Cevenol episodes" (tragic floods in the Hérault and Gard départements) in 2002 and 2003 showed that there was no impact on the premises above water and led to reinforcement of the watertightness of the alleyway in building 500 and the creation of a drain channel in the alleyway.

Measures envisaged to reinforce robustness of the facilities to the flood risk

For the reasons mentioned above, the licensee does not envisage reinforcing the robustness of the facility to the flood risk. In its opinion, the aggravating elements considered lead to the conclusion that it is pointless reinforcing the robustness of the facility, including with respect to combined earthquake and flooding.

The extreme weather conditions (torrential rainfall of higher intensity than that of the design-basis storms events and rising of the water table) were also considered. The licensee recently updated its reference rainfall values referring to the draft flood guide. The new values are currently being appraised by the IRSN. The evaluation must take into account unavailability of the storm water drainage system, local water build-up areas and the location of accesses to buildings containing equipment to be protected.

On completion of the review, ASN considers that there is no specific need for the licensee to increase the Mélox facility robustness to the flood risk.

FBFC

Design of the facility

Two rivers, the Joyeuse and the Isère, run along the south side of the industrial site on which the FBFC facility is installed. The site elevation is higher than that of both these rivers. The risk of flooding caused by either of the 2 rivers bursting their banks is nil given the large difference in height between the ground elevation of BNI 98 and the normal water level of each river: +19 metres for the Joyeuse and +24 metres for the Isère. Even in the event of a 100-year flood of one of the rivers, the FBFC site would not be flooded.

There are two water tables below the FBFC site:

- a deep water table dating from the tertiary situated at a depth of 150 to 200 m below the ground elevation. There is absolutely no risk of flooding from this water table;
- a large-scale surface water table accompanying a watercourse and crossing the FBFC site from east to west over a width of several kilometres. The depth of this water table ranges from 5 to 30 metres in general, and is more precisely at 12 metres under the FBFC site. The water table is below the level of the foundations of the FBFC buildings. Its level is stable even in the event of floods of the Joyeuse or the Isère, which shows that there are no direct exchanges between the water table and the two rivers. The risk of flooding of the FBFC facilities by a rise in this near-surface water table is therefore ruled out.

The risk of flooding by rainfall, and notably the 100-year storm events is currently being studied by FBFC. The results should be submitted to ASN in mid-2012 along with the appropriate protection measures where necessary.

Measures to protect the facilities against the flood risk

The licensee's complementary safety assessment does not provide for measures to protect its facilities against the flood risk. This being said, the results of the above-mentioned study on the flood risk from rainfall could lead it to propose protection measures.

Conformity of the facilities with the current frame of reference

In the same way as for the seismic risk, conformity of the facility is not guaranteed.

Evaluation of the safety margins

The licensee's report contains no specific study of the safety margins with respect to the flood risk.

Measures envisaged to reinforce robustness of the facilities to the flood risk

On completion of its review, ASN considers that the FBFC facility requires no reinforcement of its robustness to flood risks other than those caused by rainfall on the site.

ASN will however demand reinforcements in the protection of any buildings identified in the periodic safety review as being vulnerable to the risk of flooding by rainfall further to the results of the study due in mid-2012.

3.4 Other facilities (ATPu, Masurca)

3.4.1 ATPu

Design of the facilities

The majority of the Cadarache Centre is located on the watershed of the Ravin de la Bête, a perennial stream fed by springs in its "downstream" section, and which flows into the river Durance.

The flood situations considered by the licensee are:

- flooding from the upstream watershed

The watershed upstream of the ATPu facility covers a small surface area and is entirely vegetated. The 100-year flow rate provided by this watershed is less than 1m³/s. The storm water drainage infrastructure situated on the periphery of the ATPu facility protects it against the risk of flooding from the upstream watershed.

- storm water

The large majority of the Cadarache Centre storm water drainage system was built in the 1960's – 70's on the basis of the conventional design rules for urban environment road and utility networks. The design model of the drainage systems is the Strickler flow model that takes the roughness of the pipes into account, and is conventionally used in open channel hydraulics. This model enables the evacuation capacity of systems to be evaluated by associating them with a filling rate.

- rise of the water table

The highest level recorded at the ATPu facility reached 273.5 m NGF (1993-1994). The basement of the main building is at level 275.5 m NGF. The building has a waterproof lining. The ground floor is at level 280 m NGF.

- overflow of the Ravin de la Bête

The ATPu facility is situated near the Ravin de la Bête stream in an area where it is entirely channelled in an oval drain with a capacity of about 40 m³/s, which is subject to special maintenance and periodic inspection after each rainfall event. Its capacity is consistent with the 100-year flow adopted for this part of the watershed. The licensee therefore considers that the ATPu facility is protected against the risk of flooding caused by overflow of the Ravin de la Bête stream.

- damage to hydraulic structures.

The licensee considered the case of an extreme flood of the Durance and failure of the dams situated near the Cadarache Centre (EDF dam of Serre-Ponçon, dams of Sainte-Croix and Esparron-sur-Verdon) and breaching of the Canal de Provence.

The calculations showed that the most pessimistic dam break flood wave in terms of height of the reservoir surface would correspond to failure of the Serre-Ponçon dam situated more than 95 km from Cadarache. The dam break flood wave would result from the total but progressive failure of the dam. It was calculated that this wave would reach Cadarache 5 h 40 min after dam failure and lead to a peak flow of some 60,000 m³/s with a mid-height width of a few hours. The case of a simultaneous 100-year flood would represent an additional flow of 5,000 m³/s, which would not significantly alter the maximum level reached by the dam break flood wave. The maximum level reached would be 265 m NGF.

The licensee considers that no nuclear facility would be concerned and that the Centre would remain accessible via the auxiliary doors.

Measures to protect the facilities against the flood risk

The main design measures to protect against the risk of external flooding are as follows:

- the building has a waterproof lining in the basements, supplemented by a peripheral drain connected to the storm water drainage system, allowing partial lowering of the storm water;
- in the areas likely to be flooded in heavy rainfall events or by a rise in the water table to the 280 m NGF level, appropriate gradients (or steps) have been provided at the building access points, which are therefore raised with respect to the outside ground level.

The storm waters are collected by downpipes, gutters, ditches and area drains, then channelled towards the Ravin de la Bête stream into which they are discharged.

These design measures are supplemented by other actions such as maintenance and servicing of the storm water drainage system, inspection and monitoring (periodic inspection of the leak-tightness of the roof, walls, openings, monitoring of piezometric levels, flood alarm) and interventions (pumping, positioning of inflatable tubes, etc.) with the aim of limiting water ingress into the premises in the event of a flood.

The licensee points out that no significant rainfall event has jeopardized the safety of the ATPu facility since it was built.

Conformity of the facilities with the current frame of reference

The licensee indicates that conformity of the facilities with the frame of reference is regularly checked through the facility's periodic inspection and test program. More specifically, this includes annual testing of probe remote alarm transmission and annual maintenance of the sump pumps that pump water up to the tanks.

Evaluation of the safety margins

The equipment present in the basement of the main ATPu building essentially comprises one of the two electrical power supply stations and the facility ventilation and filtration systems. A flood in this basement would cause total loss of the electrical power supplies and shutdown of the facility's entire ventilation system. The licensee considers that these events are not such as to induce a cliff-edge effect.

Likewise, the radioactive materials present in the basement of the main ATPu building have several containment barriers, thereby preventing the risk of dissemination and of criticality in the presence of water. Consequently, there is no risk of a cliff-edge effect associated with the flood risk.

The licensee considers that as the basement of the main ATPu building has a waterproof lining, the facility can withstand a flood level of 280 m NGF - the level of the ground floor of the building - without losing containment integrity.

Above this level the water would infiltrate by the facility's ground floor access points. The flood alarm detectors on the basement of the building would be activated, triggering calling of the response teams.

Measures envisaged to reinforce robustness of the facilities to the flood risk

Given that there is no significant risk associated with flooding, the licensee does not propose any measures to reinforce ATPu robustness to the flood risk.

On completion of its review, ASN considers that it is not necessary to reinforce the ATPu facility's robustness to the flood risk.

3.4.2 Masurca

Design of the facility

When designing the Cadarache site facilities, the CEA calculated a flood safety margin level of 265 m NGF, based on failure of the Serre-Ponçon dam. The Cadarache site is moreover crossed by the Ravin de la Bête stream, which is at level 297 m NGF at the Masurca facility, then channelled at the ATPu in an oval drain dimensioned to discharge the 100-year storm flow estimated for this part of the watershed. Given the margins available between the levels of the platforms and the two watercourses (which reaches several tens of meters), or between the extreme flow of the stream and the discharge capacity of its channel, the CEA

has ruled out the risk of the Cadarache facilities being flooded by the River Durance or overflowing of the Ravin de la Bête stream.

The reference rainfall levels considered for the design are the 100-year storm events, as defined in the "REX Blayais" (Blayais site experience feedback). The dimensioning of the BNI's storm water drainage system for these rainfall events was examined during the last periodic safety review of the facility (2006).

As regards extreme rises in the water table, the CEA considered a level corresponding to the 100-year flood, where the extreme level of the water table would reach the 317 m NGF elevation for Masurca.

Measures to protect the facility against the flood risk

The licensee concludes in its CSA report that no particular measures are required to ensure a safe condition after flooding.

It specifies that in the event of immersion of fissile materials, the safety of the facility would not be jeopardised.

To prevent the risk of water infiltrating into the facility, building watertightness is ensured at construction. The facility also has a drainage system external to the buildings. Drainage grids and channels and a network of pipes collect the storm water (water runoff from impermeable surfaces) and drainage water (infiltration through permeable surfaces) and channel it to the Centre's storm water drainage system. Maintenance of the systems evacuating the water from the drain channels is ensured either by Autumn/Winter servicing by the Centre's specialist services, or at the request of the licensee if found necessary during inspection rounds, for example.

Gallery GA1 has 4 sumps which collect water resulting from a rise in the water table or infiltration of water into the facility. Each sump is equipped with a lift pump that is started automatically by a float mechanism if the water reaches a given level. The pumps evacuate the water from the sumps to the storm water drainage network. This system thus detects and mitigates the consequences of such a situation.. A flood detector in the highest sump is linked to the Centre's remote alarm network. If the alarm is triggered, the local security organisation (FLS) intervenes using mobile pumps to evacuate the rising water. Furthermore, the fissile materials store is equipped with five water detectors, one in each storage cell. The information from these devices is processed by the remote alarm network and transmitted to the Centre's safety control station.

Conformity of the facility with the current frame of reference

The conformity of the facility is determined by the periodic inspection and, where necessary, cleaning of the storm water drainage system, the drainage grids and inspection chambers, the run-off water collection channels and the associated grit chambers.

Furthermore, in the follow-ups to the facility's periodic safety review, a reassessment of the external flood risk analysis based on *in situ* recording of the storm water drainage system and the drainage channels is in progress. Any works and developments necessary to guarantee collection and evacuation of the storm water corresponding to the design-basis rainfall event will be carried out to guarantee conformity of the facility with respect to the external flood risk.

Evaluation of safety margins

The CEA does not consider a more severe scenario than a flood caused by the river Durance (flood and/or dam failure). The CEA rules out the risk of the Masurca facility being flooded by an overflow of the Ravin de la Bête stream. The licensee puts forward risks of the storm water drainage system overflowing in the event of rainfall events exceeding the design basis rainfall. The CEA considers that the storm water not collected by the drainage system would not have an impact on the buildings due to the small surface area of the upstream watershed, and the steep slopes downstream favouring water runoff towards the Ravin de la Bête. This being said, the truck manoeuvring area to the north of the storage and handling building BSM building, slopes downwards towards the BSM in front of the delivery hall.

Regarding the effects of a gradual rise in the water table beyond the levels considered for the design of the facility, the licensee highlights firstly the protection measures which, as is the case with the storm water, evacuate the flows towards the Ravin de la Bête, and secondly the margins before the low points of the sensitive buildings are reached. Typically, in the case of the BSM, the level of 317 m NGF is to be compared with level 321.6 m NGF of the low point of the nuclear material storage area, which represents an additional margin on a rise in the water table of almost 5 m, and corresponds to a rise return period of more than 50,000 years. Furthermore, if the water were to rise beyond the level of the BSM building basement slab (321.3 m NGF), the topographic configuration of the facility and the area around it favours passive defence. This is due to the fact that the "basement" of the facility opens directly onto the external ground level via the delivery hall door. Subject to a slight alteration in the truck manoeuvring area gradient, water will run off naturally by gravity towards the Ravin de la Bête as of an elevation of approximately 321 m. On condition that the doors are opened to allow water evacuation, and given the geometry of the storage areas, the water could not reach the fissile materials for which the low point is 25 cm higher than the coamings (5 cm high) of the loading hall access doors.

Measures to improve the safety of the facility - Opinion of ASN

Apart from the proposals and commitments associated with the flood risks, such as the reversing of the gradient of the truck manoeuvring area and giving it a diamond-like shape, the CEA proposes upgrading the storm water collection and drainage systems if this should be revealed necessary by the external flood risk reassessment currently in progress on the basis of the on-site measurements taken in July and August 2011, and the design-basis "flood" hazard.

ASN considers that licensee's proposals to reinforce the robustness of the Masurca facility to the flood risks must be applied. ANS will give the proposals formal request status.

4. Other extreme natural phenomena

4.1 Design of the facilities

The facilities' structures were designed in accordance with the Snow and Wind 65 (NV 65) rules for the oldest ones and the amended versions in effect at the time of their design. At each periodic safety review, the licensees check that the IPS (important for safety) buildings, and the buildings housing IPS systems or equipment (also called EIS - elements important for safety) can withstand the climate conditions defined in the latest rules in effect.

4.2 Experimental reactors

4.2.1. Reactors operated by the CEA (Osiris, JHR, Phénix)

Osiris

In addition to the flood risk analysis presented earlier, the CEA assessed the risk of localised blockage of the water drainage system induced by debris carried by a very strong wind or hail, associated with a rainfall event. The CEA estimates that the risk of blockage induced by wind is very limited due to the configuration of the site and the drains, and that the risk of flooding due to hail is covered by the flood risks associated with rainfall events exceeding the 100-year storm levels or with the breach of neighbouring infrastructures.

Furthermore, the CEA indicates in its CSA report that hail combined with strong winds could cause damage to the cooling tower airfoils, in which case manual reactor shutdown would be necessary when ineffectiveness of the secondary cooling system was observed. Consequently, with regard to natural phenomena, the CEA proposes establishing an instruction requiring the shutdown of the cooling tower and therefore of the reactor in extreme meteorological events such as hail storms that induce a loss of secondary cooling system effectiveness, and at the latest before the safety thresholds of the core inlet temperature probes are reached.

Regarding the risk of occurrence of an earthquake exceeding the design-basis earthquake followed by an induced flood, the CEA considers that in the event of an earthquake exceeding 1.5 times the fixed earthquake level applicable at Saclay, localised flooding could occur, particularly with failure of the Saclay site water tower, of the BNI 40 and 101 (the nearest BNI) cooling towers, and rupture of a water pipe coming from the Centre.

Given the water volumes involved (3,000 m³) and the flow rate in the water pipe coming from the Centre (150 m³/h), the CEA considered that no impact was expected on the facility. By way of comparison, the volume of water necessary to flood the first EIS's, namely the nuclear ventilation and the electrical cabinets situated at the -4 m level of the facility, is greater than 5,000 m³. The CEA also points out that in this case the backup ventilation system would remain available to maintain negative pressure in the reactor building .

In the framework of the complementary safety assessments, the CEA nevertheless proposed implementing the following measures:

- Using the GUS (ultimate backup diesel generator set) to power the backup ventilation placed at a height of 2 m and the equipment allowing the ventilation to be configured on the Osiris reactor hall in order to filter the ventilation discharges;
- Using the GUS to back up the annular space lift pumps;
- Back up the hot layer pump to provide biological protection in the hall;
- Close the technical gallery proving the link between the purification room at -4 m in the crown gallery, and the cooling towers, to prevent any water ingress resulting from a breach in the ponds;
- Extend the use of low walls around all the passageways giving access to the - 4 m level from the 0 m level.

The CEA's analysis of the impact of extreme meteorological conditions on the Osiris facility raises no particular remarks from ASN.

JHR

The CEA assessed the risk of localised blockage of the water drainage system induced by debris carried by a very strong wind or hail, associated with a rainfall event. The measures implemented for such an event are described in part 4. The CEA concludes that these events cannot lead to a cliff-edge effect. The CEA also considered the possibility of lightning strike, and decided that its consequences would have no impact on the management of the external flood insofar as the implementation of active means is not necessary in the short term. It adds that the JHR lightning protection takes into account the applicable standard NF EN 62305-2.

In its study of extreme natural phenomena, the CEA assessed the risk of flooding resulting from failures of the Sainte-Croix and Esparron/Gréoux dams on the river Verdon, less than 30 km from the Cadarache site. It calculated the maximum levels at the site for independent failures of the dams, and found them to be lower than the level reached with failure of the Serre-Poncon dam. Consequently it ruled out the risk of flooding induced by failure of a dam on the river Verdon. The CEA also studied the risk of flooding resulting from a breach of the Provence Canal situated near the site. The most penalising breach would be failure of the underground water intake called the "puits du médecin" (the doctor's well). The CEA calculated the induced water levels along the length of the valley de la Bête up to the site, and concluded that there was no risk of flooding for the JHR.

Measures to improve the safety of the facility - Opinion of ASN

The CEA envisages adapting the roads and utility networks (VRD) so as to improve water drainage. It also envisages moving the standby diesel generator set (DS) outside the water run-off zone.

ASN considers that the licensee's proposals will improve the robustness of the facility, especially moving the standby diesel generator set outside the zone of possible water run-off in the event of flooding in the coolants building. ASN will formally request this of the CEA.

ASN also notes that the adaptation of the roads and utility networks will be examined in the complementary safety analysis of the Cadarache site, for which the submittal date is 15 September 2012.

Phénix

The CEA has assessed the risk of localised blockage of the water drainage system induced by debris carried by a very strong wind or hail, associated with a rainfall event. The CEA estimates that the risk of blockage induced by the wind is very limited due to the site configuration, but identifies risks of flooding caused by hail combined with exceptional rainfall events, through breaks in the storm water downpipes inside the buildings and infiltrations further to the formation of a pool of water on the ground. The licensee considers that the risks of flooding of the buildings would be similar to those induced by a river flood, but with much lower water flow rates.

Combination of an earthquake exceeding the DBE and induced flooding

The CEA estimates that failures of the Donzère and Bollène dams on the river Rhône, although much closer to the site than the Vouglans dam, would lead to water levels much lower than the flood safety margin level (CMS) in view of the significantly lower capacities and the scenario chosen for the CMS. The licensee therefore rules out the risk of Phénix being flooded by failure of these dams.

The CEA analysed the risk of a leak in the water tower (semi-buried tank of 1300 m³) situated about 200 m to the west of the facility on the slopes of the Dent de Marcoule. Assuming that 50% of the volume of the water tower spills out entirely at level+0.00 m of the Steam Generator building, then runs into its basements before being discharged to the exterior, the CEA estimates that water depths of 75 cm and 45 cm maximum could form on the ground floor and basement. In this case, after operating the two raw water pumps supplying the water tower for one hour, the water level in the auxiliary buildings would reach the level of the penetrations with the reactor building, the handling building and the steam generators (SG) building. The CEA estimates that this is sufficient time to detect the leak and stop the pumps.

It nevertheless envisages establishing an instruction for shutting down the raw water pumps further to an earthquake. If the rupture takes place in the gallery outside the buildings, the pressure could raise a manhole cover plate situated in the SG building hall entrance. The CEA therefore envisages modifying this cover plate to guarantee it remains closed.

As regards the Pascal pond (2 500 m³), the licensee considers that any leaks would tend to flow southward without having any significant impact on the site.

The CEA also presents envelope scenarios for rupture of all the water systems inside the reactor and handling buildings, leading to maximum water depths of 5 cm and 10 cm. Two pipe rupture cases in the peripheral buildings were also studied, one concerning the link with the water tower, the other with the Rhône. The operator concluded that there was no cliff-edge effect regarding the flooding of the buildings.

In this context the CEA proposed the following improvement measures in its complementary safety assessment report:

- Study the creation in the reactor building of a preferential flow path channelling water towards the basemat recesses and avoiding contact with the sodium equipment;
- Seal an opening giving access to sodium tank situated at the reactor building low point;
- Establish an instruction for shutting down the raw water pumps further to an earthquake.

ASN considers that the licensee's proposals to reinforce the Phénix facility's robustness to the risks presented by other extreme phenomena (meteorological phenomena and combined earthquake and flooding) are acceptable. ASN may give them formal request status (some are already concerned by the flooding aspect).

4.2.2. Reactor operated by the ILL

The worst-case flood would result from failure of the Monteynard dam, which is totally independent of, and unaffected by, even extreme meteorological conditions.

This paragraph is therefore not applicable to the HFR once the case of a flood further to failure of the most penalizing dam - the Monteynard dam - has been taken into account and used as the design basis (see "flood" section).

4.3 Facilities in the nuclear fuel cycle (La Hague, Tricastin, Mélox, FBFC)

4.3.1 Tricastin site

All the facilities on the Tricastin site, with the exception of Comurhex, were designed in accordance with the Snow and Wind 65 (NV 65) rules.

According to the licensee, no extreme snowfall, wind or temperature events would lead to a more severe accident than those mentioned before. Furthermore, the kinetics of these events would be sufficiently slow to allow the facilities to be placed in safe condition.

AREVA has also undertaken to consider in its analysis of extreme meteorological phenomena due for submittal in the 1st quarter 2013, the consequences of exceptional wind speeds defined on the basis of local experience feedback, evaluating all the related effects (negative pressure, resistance of chimney stacks, etc.) and the impact of any induced projectiles on the key SSCs.

TU5 W

The risk associated with tornadoes or very strong winds lies in possible "missile" effects that could damage sensitive structures where there is an explosion risk. In this case it concerns the hydrogen storage yard and racks of the W facility which, given its location, could cause two types of accident:

- hydrogen leak creating a cloud of hydrogen gas which subsequently explodes;
- hydrogen leak with production of an ignited jet that heats a nearby gas tank causing it to explode.

The licensee considers that neither of these two scenarios is likely to cause a severe accident, therefore it does not envisage implementing additional measures.

ASN considers that, given AREVA's commitment to study the effects of very strong winds, the procedure it has adopted is satisfactory. ASN may ask the licensee for targeted reinforcements, depending on the results of this study.

4.3.2. La Hague site

With regard to the risks associated with snow and wind, the licensee indicates in its complementary safety assessment that the facilities were designed on the basis of estimated envelope values for the loads induced by snow and wind.

It considers that projectiles picked up by a tornado would be unlikely to damage the reinforced concrete structures housing functions important for safety, as these structures are designed to withstand the impact of a projectile such as a light aircraft engine. It also indicates that the chimney stacks and their anchoring systems are designed to withstand extreme winds.

ASN considers that the licensee must supplement its analysis of extreme meteorological phenomena for the La Hague facilities on the basis of experience feedback, taking into consideration a tornado and evaluating all the associated effects (negative pressure, resistance of chimney stacks, impact of any projectiles on the metal structures and external utilities, etc.). ASN will issue requests in this respect.

4.3.3. Other facilities in the fuel cycle (Mélox, FBFC)

Mélox

Stronger than design-basis winds and tornadoes were considered in the complementary safety assessment. Extreme winds can cause chimney stacks to collapse, which would not affect the third containment barrier (designed to withstand the impact of a light aircraft engine), but would lead to loss of control of discharges. By engineering judgement, the licensee estimates that a tornado would progress along the Rhône valley and bypass the Mélox building.

ASN has no particular remarks concerning the licensee's analysis of the Mélox facility in this respect.

FBFC

With the exception of the risk of flooding by rainfall, the licensee considered that no climatic event capable of generating an accident situation needed to be analysed.

ASN has no particular remarks concerning the licensee's analysis of the FBFC facility in this respect.

4.4 Other facilities (ATPu and Masurca)

4.4.1. ATPu

In view of the measures taken in the design (application of the snow and wind rules in effect on the date of construction, lightning protection) and operation of the facility (monitoring and intervention in the event of flooding), the licensee considers that there is no risk of a cliff-edge effect being caused by meteorological conditions.

ASN has no particular remarks concerning the licensee's analysis of the ATPu facility in this respect.

4.4.2. Masurca

The CEA assessed the risk of localised blockage of the water drainage system induced by debris carried by a very strong wind, or hail, associated with a rainfall event. The CEA also considered lightning strike, highlighting the presence of a mesh cage on the roof, the external walls of the storage and handling building BSM and a protection system against electric power grid overvoltages. The CEA concludes that the extreme meteorological conditions associated with flooding do not risk causing a cliff-edge effect.

In view of the planned measures to reinforce the robustness of the Masurca facility, ASN has no particular remarks concerning this complementary analysis.

5. Loss of the electrical power supplies and cooling systems

5.1 Experimental reactors

5.1.1. CEA reactors (*Osiris, JHR, Phénix*)

Osiris

Loss of off-site electrical power supplies

In the event of loss of the off-site electrical power grid, two diesel generator sets are automatically brought into service to supply the Osiris reactor with electrical power.

Loss of the off-site electrical power supplies and the conventional emergency supplies

Loss of a diesel generator set would cause:

- shutdown of the primary coolant pumps and therefore emergency shutdown of the Osiris reactor. Primary coolant pump shutdown would also lead to passive opening of the natural convection valves after about one minute (making the primary cooling system communicate with the reactor pool) and the establishing of a natural convection flow in the core;
- loss of the pools and channels cooling system. In this situation it is possible to compensate for evaporation through water make-ups via the pools and channels filling system (flow rate of 30 m³/h) which is connected to the public water supply and supplied by the diesel generator set that is still available.

If both diesel generator sets are lost, an ultimate backup diesel-generator set (GUS) dedicated to the facility is put into service manually. However, at present the GUS supplies no pool cooling system or water make-up system. Consequently, the time lapses before the irradiated fuel elements become exposed are as follows:

- 255 days if the reactor pool communicates with the spent fuel storage channels (nominal situation);
- more than 230 days for channel 2 if it is isolated;
- 43 days for the Osiris reactor pool if it is isolated from the spent fuel storage channels by a gate, and assuming that the initial level in the reactor pool is low (exceptional maintenance situation that occurs once a year).

The CEA considers this time lapse sufficient to deploy external electrical power supply or water make-up means (the Saclay centre also has two mobile generator sets).

In the event of loss of the two diesel-generator sets, power for monitoring the facility is provided by batteries for one hour, a period judged sufficient to start the GUS, which powers the equipment necessary for facility containment management as well as for monitoring the facility.

Loss of the off-site electrical power supplies and the conventional emergency supplies and all other on-site electrical power sources

In the event of loss of the GUS, the batteries would be available for a limited time. The Centre's mobile generator sets could be brought to the Osiris facility within one to four hours according to the CEA.

In the event of loss of the batteries, no electrical power supply is available in the facility. As CEA points out, this means that the radiation protection systems (particularly the permanent irradiation measurement in the reactor building) are no longer powered. To avoid reaching a cliff-edge effect, the CEA indicates that it is necessary to monitor the water level in the tanks and to be able to provide make-ups. The slow kinetics of the phenomenon means that the water levels can be monitored by inspection patrol personnel equipped with mobile radiation detectors.

Measures envisaged to reinforce robustness of the facilities to the loss of electrical power supplies and proposed studies

The CEA indicates that the study of electrical power supply loss reveals good robustness of the facility and a large number of backup means (3 diesel-generator sets at the facility and 2 at the Saclay centre).

The CEA nevertheless proposed the following measures to improve the robustness of the facility in its complementary safety assessment:

- Establish a control procedure to optimise management of the generator sets in the event of prolonged loss of the off-site electrical power supply, in order to extend the autonomy of the emergency electrical supplies (currently limited to 35 hours), and in particular specify that it is necessary:
 - to use the GUS in priority, as it consumes less than the other two diesel generator sets;
 - maintain a minimum reserve of diesel fuel and oil and draw up a formal procedure for topping up a diesel generator with fuel and oil in operation.
- Carry out a feasibility study for powering the filling system pump via the GUS;
- Define the actions to take in the event of prolonged loss of the EDF power grid and the two main emergency diesel generator sets when the Osiris reactor is at low level, and study the feasibility of using the GUS to supply the pumps for transferring water from the drainage tank to the Osiris reactor pool;
- Connect the pool and channel water filling system pump and the hot layer pump (to reinforce biological protection in the Osiris hall) to the electrical network supplied by the GUS;
- Examine the possibility of powering at least one fan of the backup ventilation system by the GUS or another mobile electrical power source, in order to guarantee permanent filtration of any releases via the ventilation system.

Measures envisaged to reinforce the robustness of the facilities to the loss of the ultimate cooling system / heat sink

As regards the loss of the main cooling sources (core primary cooling system in the case of Osiris), the CEA has considered an unfavourable initial situation that consists in starting the transient with the Osiris reactor pool at low level. The time allowed to add water, if possible demineralised, is about one month. The numerous possibilities of making water make-ups in the required volumes have led the CEA not to plan for additional measures at this stage.

As regards the risk of loss of the main and emergency cooling systems, the CEA indicates that the only unfavourable initial situation in this case is also a low level in the Osiris reactor pool at the start of the transient. It states that as long as the electrical power supplies are available, it is possible to transfer 130 m³ of water from the drainage tank to the reactor pool.

The licensee underlines that the Osiris facility contains a large quantity of water in the pools and channels (about 2000 m³), which leaves a comfortable margin (more than 40 days) for deploying external water make-up resources. Moreover, even in the event of loss of sealing of the plug separating the reactor pool from the control mechanisms room which is part of the water block, the time lapse before the core becomes exposed exceeds 16 days. This still leaves sufficient time to deploy the necessary external water make-up resources.

It is specified that water make-ups could be made from the fall-back centre situated 300 metres from the facility, by means of an emergency water make-up system (flow of 90 m³/h) connected to the public water supply. If the water make-up systems (normal and emergency) - which are not designed to earthquake design standards - are out of service, the local security organisation (FLS) will have to be called to the site to place a hose in the pool or channel concerned. The means of action available to the FLS are chiefly:

- the centre's fire-fighting water supply (flow rate of 150 m³/h);
- pumps that can be connected to the reserve pond, the Villiers pond or the Saclay ponds (flow rate of 120 m³/h).

In this context, the CEA envisages the following improvements:

- study a modification for disabling the system that automatically stops raising of the bridges. This is because if the water level in the pools and channels were to drop, it could be necessary to install gates in a radiological environment that exceeds the threshold activating automatic stopping of raising of the bridges. The CEA specifies that the FLS could carry out the required water make-ups using a remotely controlled robot if necessary.
- constitute a stock of sand bags that could be used to block a crack in the bottom of a pool or channel.

Loss of the main cooling system combined with total loss of the off-site and on-site (electrical power supplies

Loss of the off-site electrical power supplies and the on-site emergency supplies deprives the facility of the pumps used to make water transfers, particularly the drainage tank pump and the filling system pump. The emergency water make-up system should however be available, as should the centre's mobile backup means. The CEA indicates from its analysis that core exposure would occur after 43 days, and judges this leaves sufficient time to deploy the external water make-up means.

The licensee nevertheless envisages the following improvement measures in addition to those presented earlier:

- Reflect upon supplementing the procedure to apply if the pool water level drops, in order to integrate the penalising case of combined events (total loss of electrical power supplies, loss of water make-up possibilities, simultaneous leaks in several of the water block rooms). More particularly, if the combined loss of leak-tightness of a channel and loss of electrical supplies is considered, the gates for isolating the break must be handled using a crane powered by a normal diesel generator set (manual electrical connection) or by an emergency mobile generator set, that is complementary to the existing GUS;
- Provide a backed up electrical power supply from a mobile source for the filling system pump and the pump for transferring water from the drainage tank to the pool (130 m³) in order to keep the fuel elements under water and thereby push back the risk of a cliff-edge effect.
- Back up the electrical power supply of the backup fan placed at a height of 2 m, and the equipment for configuring the backup ventilation to ensure permanent filtration of the ventilation discharges.

The analysis presented by the CEA assumes that in the event of loss of the electrical power supply and/or the heat sink:

- emergency reactor shutdown is performed;
- the natural convection valves open;
- the pools and channels remain watertight;
- water make-ups are possible.

The CEA has already identified these equipment items as essential items, which is satisfactory. Nevertheless, in an accident situation it is necessary to have information on the state of the core and the pools. The CEA has undertaken to assess the robustness of the instrumentation considered important for monitoring the situation in this respect, that is to say:

- the position of the natural convection components;
- the core outlet temperature or the reactor pool temperature;
- the reactor pool level.

ASN considers that the improvement proposals presented by the CEA for Osiris are such as to reinforce the robustness of the facility in the event of loss of the electrical power supplies and the cooling systems.

ASN also considers that it is necessary to revise the procedure to follow in the event of a drop in the Osiris reactor pool water level.

Pursuant to ASN's request, the CEA will submit before the end of 2011 a document describing the measures it intends implementing in view of reactor shut down scheduled for 31 December 2015 at the latest. ASN will analyse this document and make the necessary requests where applicable.

JHR

Loss of the electrical power supplies

The JHR receives its electrical power from the CEA Cadarache on-site power network via two substations (PDL A and B).

If the normal 15kV network is lost, the following networks are automatically activated:

- The standby diesel generator set (DS) provides an emergency supply for part of the priority power network (MEPA);
- The 2 backup diesel generators (DAS) each supply one train (trains A and B) of the backup power network (MEQ);
- The 2 ultimate backup sources (SUS A and B) comprising inverters and batteries, each supplying one train of the ultimate backup power network (MEU).

If the off-site power supply is lost, the backup power network (MEQ), designed to the JHR design basis earthquake (DBE) presented in part 2 of this report (all the equipment items constituting this network must be operational during and after an earthquake), is automatically activated. It comprises two geographically separate trains ensuring redundancy of the actions necessary to place and maintain the reactor and experimental systems in safe condition. Each train is supplied by a backup diesel generator (DAS) with an estimated autonomy of 4 days.

If the backup electrical power supply is lost, the facility has an ultimate backup power network (MEU), designed to the DBE (all the equipment items constituting this network must be operational during and after an earthquake), which for at least 2 hours supplies more particularly the equipment that removes residual power from the core in the short term (RUC, RUP, mixing pump, natural convection valves), and their support functions (ventilation, lighting, etc.). It comprises two trains (A and B), each energised by a system of batteries/inverters (ultimate backup sources SUS A and B). Nevertheless, these two trains do not provide complete functional redundancy, since particularly the natural convection valves are supplied by train A only and the mixing pump by train B only. Furthermore, the backup instrumentation and control has its own internal power supply providing an autonomy of at least 6 hours.

Moreover each backup diesel generator can be replaced up by a mobile generator set via connections external to the buildings that house them. A mobile generator set can be available in less than 8 hours, or less than 4 hours if it comes from Cadarache Centre's own inventory.

Measures envisaged to reinforce the robustness of the facilities to loss of the electrical power supplies

The CEA envisages design changes to reinforce the availability of the backup electrical power supplies, such as:

- Use the standby diesel generator set (DS) to replace one of the two backup diesel generators (DAS). In this context, for an effective and rapid response (few hours) to the failure of a DAS, it is envisaged to:
 - reinforce the DS by classifying it as SI/O (Integrated System during earthquake/Operational after earthquake) so that it can also supply one of the backup trains;
 - move this DS (renamed GUS - ultimate backup diesel generator set) to a raised platform to protect it against any risk of flooding from the BMR building;
- Give the two ultimate backup sources (SUS) the same power capacity. To increase the autonomy of the equipment powered by train B, the licensee proposes increasing the capacity of SUS B by increasing its autonomy from the current 2 hours to 6 hours, making it identical to that of SUS train A.

ASN notes the improvements envisaged by the licensee to reinforce the robustness of the JHR facility in the event of electrical power supply loss. It will issue requests to the licensee to reinforce the availability of the backup electrical power sources.

Loss of the cooling systems / heat sink

If the core inlet temperature is high, the reactor coolant pumps are stopped, emergency shutdown is initiated and the safeguard cooling systems - which are redundant and designed to earthquake design standards - are started. They comprise the RUC (A and B) systems, which branch from the main primary cooling system (RPP) and are cooled by the RUP (A and B) systems. The RUP (A and B) systems, which function in closed circuit on the pool, are cooled by the RUS (A and B) systems which are cooled in turn by two cooling towers in the safeguard buildings (BAS A and B).

The two backup cooling towers installed on either side of the nuclear unit have a dedicated water reserve of 30 m³; once this water reserve has been used up, the low level of power remaining to be removed (less than 700 kW) means that the cooling tower can switch to dry operation.

The starting command for the core safeguard cooling system (RUC) and the pools safeguard cooling system (reactor pool and intermediate pool) (RUP) in the reactor building, is accompanied by the starting command for the primary cooling system mixing pump. This pump temporarily ensures sufficient cooling if the two trains of the RUC system fail to start. The licensee indicates that to transfer the residual power from the core system to the reactor pool, it is planned to open the two natural convection valves located upstream and downstream of the core after 20 minutes, and to stop the mixing pump later on.

According to the licensee, 1 hour and 20 minutes after reactor shutdown, the natural convection valves alone are sufficient to cool the core.

In the ultimate case where the above means are not sufficient to cool the core, the facility has systems for resupplying water to the pools, including one ultimate system for resupplying the BUR pools from outside the nuclear buildings, by an external mobile means and quick-connect coupling (bleed skimmer, BUR pools make-up and filling circuit, REW system). It should be noted that the BAN pools do not have an equivalent ultimate system but the CEA does not consider this situation prejudicial: given the cooling time of the stored fuels, the total residual power of the fuels is 80 kW or less. It nevertheless proposes an improvement in this respect.

Conclusion on the measures taken to protect the facilities against the risk of loss of the ultimate cooling system / heat sink

The CEA concludes in its CSA report that loss of the heat sink is catered for by design. Management of this situation is based on redundant and independent backup means designed to earthquake design standards.

To cope with loss of the backup means, the CEA concludes that improvements can be made to facilitate cooling by external backup means.

Measures envisaged to reinforce the robustness of the facilities to loss of the ultimate cooling system / heat sink

To cope with ultimate situations, the CEA envisages:

- creating 2 tapplings on the secondary safeguard cooling systems of the core and the reactor building pools (RUS). These tapplings will enable external means (tanker truck with stand-alone pump) to supply the RUS system with cold water without using the system pump and cooling tower;
- extending the capacities of the water make-up circuit (REW system) for resupplying the pools of the BUA.

ASN notes the improvements proposed by the licensee to reinforce the robustness of the facility in the event of loss of the heat sink. It will issue requirements for the licensee to create tapplings that will allow the supply of water by on-site means and take measures to have an on-site water supply capacity.

Simultaneous loss of the cooling systems and the electrical power supplies

In the event of simultaneous loss of the core cooling systems (normal and safeguard) and of the off-site and backup electrical power supplies, the mixing pump supplied by the ultimate backup battery (SUS B) ensures forced convection in the core for the time necessary (less than 2 hours) for the core residual power level to

be compatible with the changeover to natural convection achieved by opening the two natural convection valves situated upstream and downstream of the core.

Without water make-up via the skimmer BUR pools filling and water make-up circuit (REW system) from outside the nuclear auxiliary building (external mobile means and quick-connect coupling) as envisaged by the CEA, water evaporation from the pool results in the following time lapses before the fuel elements become exposed:

- 35 days after reactor shutdown if it was operating at maximum power,
- 18 days in exceptional maintenance situation (5 days after shutdown of the reactor having operated at maximum power, authorised pool level at -4.5 m),
- several months in the case of the nuclear auxiliary building spent fuel pools.

Measures envisaged to reinforce the robustness of the facility to loss of the main cooling system combined with total loss of the off-site and backup electrical power supplies

In addition to the measures envisaged by the CEA further to the study of the loss of both the electrical power supplies and cooling systems, the CEA proposes permanently storing a volume of water in one of the drainage tanks of the Nuclear Unit pools (these tanks are situated in the nuclear auxiliary building, BUA) so that the BUA pools water can be replenished by the pool water make-up system of the water block, connected to the backup power network, after resupplying the train A or B backup electrical panels.

Measures to reinforce the robustness of the facilities to the risk on which the CEA has given undertakings under the CSA review and the proposed studies

In its CSA report, the CEA highlighted the reactor emergency shutdown function and a number of items of equipment that could guarantee removal of sufficient residual power to prevent core meltdown. The items of equipment are:

- the mixing pump and the ultimate backup battery SUS B, with an autonomy of two hours;
- the natural convection valves and the ultimate backup battery SUS A, with an autonomy of six hours.

The licensee indicates that these items of equipment were selected because it estimates that by mixing the primary cooling water for 1 hour 20 minutes after reactor shutdown, and opening the natural convection valves 20 minutes after reactor shutdown, the reactor is maintained in a thermohydraulic condition that leaves a substantial time lapse before there is a real meltdown risk. However, no substantiating study was provided for the CSA review.

During the review, the CEA undertook to examine in greater depth the possibility of defining a "hard core of severe accident prevention measures" focused on the primary cooling system mixing pump compared with a hard core focused on the safeguard cooling systems. This procedure lies within the framework of the more general request to define a hard core of material and organisational provisions mentioned earlier.

Furthermore, with regard to accident situation management, the CEA has undertaken to evaluate the robustness of the instrumentation considered important for monitoring the situation in this respect, that is to say the position of the natural convection components (valves), the core outlet temperature or the reactor pool temperature and the reactor pool level.

The ASN considers that for the JHR facility there are no additional demands with respect to the combined situations of loss of the electrical power supplies and the cooling sources compared with the two situations taken individually.

Phénix

Loss of the electrical power supplies

The CEA indicates that in the event of an accident and in the case of the previously examined risks, supplying the following systems with electrical power can enable facility condition monitoring to be maintained:

- the health chain, which covers the radiological monitoring of the facility;
- the Ultimate Situation Measurement Acquisition System (SAMU) and its electrical power source.

Loss of the off-site electrical power supplies

In the event of loss of the off-site electrical power supplies, that is to say the 225 kV supply and the two 20 kV supplies, the site relies on two diesel generator sets, D1 and D2, for the supply of electrical power. Each diesel generator set can supply all the auxiliaries necessary to safeguard the equipment and ensure the permanence of the monitoring sources. The licensee states that the estimated operating time of the generators exceeds 3 days.

Loss of the off-site electrical power supplies and the conventional emergency supplies

If diesel generator sets D1 and D2 are lost, electrical power must be supplied by the ultimate backup diesel generator sets DE and DW, which are earthquake qualified.

Their estimated operating time exceeds 8 days.

Some safety auxiliaries are powered by dedicated storage batteries.

In the event of total loss of the off-site and on-site power supplies, one or more generator sets from outside the facilities can be procured and connected at generator sets DE and DW level.

The impact of a total loss of the electrical power supplies (failure of the normal and inverted power supplies and non-starting of the diesel generator sets) on the safety functions is presented below.

Removal of residual power

According to the CEA, loss of the current means of removing the residual power remaining in the reactor, the drums or the cells in which the fuel assemblies transit, has no impact given the current residual power levels.

Containment of radioactive and hazardous materials

In the event of loss of the electrical power supply, the general and process ventilation systems ensuring dynamic containment are stopped. Containment of the materials is then guaranteed by the static containment barriers.

With regard to the risk of deterioration of the barriers if the sodium in the reactor and the drum freezes, the CEA states that the temperature levels reached do not call into question the long term integrity of either the tubes or the reactor block structures, and particularly the structures supporting the core.

Control of reactivity and sub-criticality

According to the CEA, total loss of the electrical power supplies has no impact on the control of reactor reactivity, given the definitive shutdown of the reactor (rod drop being in any case assured passively by gravity if the electrical power supply fails).

Moreover, the CEA indicates that the loss of the electrical power supplies has no impact on the geometry, the moderation or the mass in the places where a criticality accident risk is identified. The method of monitoring fissile environments is not modified by loss of the electrical power supplies. Likewise, the lines of defence implemented to ensure equipment sub-criticality are also maintained in the event of electrical power supply loss.

Specific risks associated with sodium

Regarding the specific risks associated with sodium, the "nitrogen production and distribution" functional assembly remains operational in the event of a total power supply loss.

Monitoring of the facility

The radiation protection equipment that permanently monitors the radiological environment of the premises is connected to battery-backed busbars. In the event of loss of the off-site electrical power supplies or generalised loss of power, the CEA indicates the power supply to this equipment remains ensured by diesel generator sets DE or DW. If these generator sets should be lost in turn, the equipment would be supplied by batteries for about 8 hours.

The CEA indicates that the Ultimate Situation Measurement Acquisition System (SAMU) delivers sufficient information on the condition of the primary cooling system to different places in the facility, particularly further to accident situations adversely affecting transmission of this information to the control room, or loss of the control room, such as:

- a large sodium fire in the Reactor building;
- an earthquake that has destroyed the Reactor Building / Supervision-Office Building connecting passageway;
- loss of the control room;
- loss of the data logger distribution frame (RCM).

The SAMU can be consulted via:

- a transportable consultation computer in the fall-back room,
- three transportable computers installed:
 - in the control room;
 - in the emergency room in the Supervision-Office Building;
 - in the handling building at level + 0.0 m.

The CEA specifies that the processing unit, the racks and the frames supporting these equipment items are earthquake resistant. All the system connections and power supplies are made in earthquake-resistant cableways specific to the SAMU system.

It is possible to obtain different types of information concerning the "relevant" measurements further to reactor shutdown at each of the SAMU consultation stations, particularly information relating to core reactivity, primary sodium temperature, condition of the ultimate backup system, etc.

The SAMU is connected to a set of battery-backed busbars supplied by the ultimate backup diesel generators DE or DW in the event of a general loss of power. It also has an independent battery power supply with an autonomy of 6 hours.

Consequently, the CEA considers in its CSA report that total loss of the electrical power supply would not lead to a cliff-edge effect. The electrical power supplies do nevertheless play a role in the monitoring of the condition of the facility in degraded situations (earthquake, flood in particular)

The licensee's analysis of the risk of loss of electrical power supplies for the Phénix facility raises no particular remarks from ASN.

ASN does nevertheless consider it necessary to conduct a complementary study to verify that freezing of the sodium does not jeopardize the integrity of the reactor vessel and the spent fuel storage drum. The CEA has undertaken to consolidate the analysis concluding that there is no risk of a cliff-edge effect if the sodium in the vessel and drum freezes.

ASN will take this commitment up in a formal request.

Loss of the cooling systems / heat sink

In view of the state of the facility, which is in the decommissioning preparation phase, and the low residual power level of the fuel assemblies, the operator identifies no risk of a cliff-edge effect in the event of loss of equipment cooling or loss of the heat sinks.

Combined loss of the electrical power supplies and the heat sink

The CEA considers that loss of the electrical power supplies combined with loss of the heat sink would not lead to a cliff-edge effect given the state of facility.

These conclusions regarding the loss-of-cooling-source risk for the Phénix facility raise no remarks from ASN.

5.1.2. *Reactor operated by the ILL*

Loss of the electrical power supplies

The HFR is supplied from the HTA 20 kV power system managed by Gaz et Electricité de Grenoble. Loss of the 20 kV power system causes loss of the two pumps of the main primary system (reactor coolant pumps) and those of the associated main cooling system; stopping of the reactor coolant pumps causes automatic reactor shutdown. In this situation, two 1800 kVA diesel generator sets situated in building ILL 3 start automatically. These generator sets supply backup power to the CRAB (rod shutdown cooling system) pumps, the associated cooling system pumps (auxiliary backed-up) and the reactor protection system (as well as power for the radiation protection network, the air supply and extraction fans in the reactor building and the safety lighting). The two diesel generator sets each have an autonomy of 40 hours and are fully redundant. If neither of the two diesel generator sets should come into service after loss of the 20 kV system, the three CRAB pumps would be supplied for one hour by three groups of 400 V/50 Hz batteries each delivering 50 kVA. At the end of this period, the residual power is removed by natural convection.

The natural convection cooling of the fuel elements in channel 2 and in the handling cask is not affected by loss of the electrical power supplies.

Conclusion on the planned measures to protect the facilities against the risk of loss of the electrical power supplies

The ILL indicates that by design, core cooling is ensured by natural convection as soon as the reactor is shut down. The shutdown cooling system (CRA) is however supplied by a battery with an autonomy of one hour to ensure cooling by forced convection. It considers that the loss of all the electrical power supplies has no impact on the control of cooling. According to the licensee, the facility could ensure satisfactory cooling of the core and the spent fuel elements (SFE) further to loss of the off-site electrical power supplies and the emergency power sources, without external intervention and with no time limit. The facility is relatively insensitive to electrical power supply losses, on condition that the reactor is shut down and the natural convection valves which ensure passive cooling of the fuel in the reactor are opened. It must be noted however that the ILL does not formally identify these equipment items as "key" SSCs.

The ILL indicates in its report that containment isolation and leak-tightness are guaranteed if the emergency power sources are lost. However, in the event of loss of the electrical power supplies and aggravating circumstances, the operability of the gaseous effluents (EG) system in order to maintain the reactor building under negative pressure and thereby guarantee the absences of direct leaks, is not ensured from the emergency control room (PCS). Containment would therefore be degraded due to the loss of annular space pressurisation and loss of the static containment provided by the gaseous effluents system, without any impact in the absence of a nuclear accident, according to the ILL.

Measures proposed to reinforce the robustness of the facilities to the loss of the electrical power supplies

With regard to the last point concerning the operability of the gaseous effluents system to keep the reactor building under negative pressure, the licensee proposes a modification to the control of the gaseous effluents system which is not entirely taken up by the diesel generator set of the emergency control room (PCS). This modification is scheduled for when the HFR is restarted at the beginning of 2012.

The licensee also proposes drafting a specific operating instruction (CPE) for loss of the off-site electrical power supplies, in order to optimise the existing procedures and improve the organisational provisions.

In its CSA report the licensee also undertook - in accordance with an earlier analysis - to set up an intermediate system that automatically triggers rod drop if the 20 kV supply is lost for more than 2 seconds.

In addition, pending creation of the new PCS (PCS3, see the "accident management" section), the ILL plans installing a new emergency diesel generator set (at a higher elevation than 216.2 m NGF – see flood risk) to supply the reactor monitoring equipment.

Lastly, it has undertaken to consider the emergency shutdown system as a "key" SSC on account of its role in serious accident risk prevention in the event of loss of the electrical power sources.

On completion of the review of the ILL's complementary safety assessment, ASN considers that the measures proposed must be implemented. It will issue requests to the licensee in this respect.

Loss of the cooling systems / heat sink

Design measures taken to prevent loss of the ultimate cooling system or the heat sink

The cooling water used to remove the power transmitted by the reactor's heavy water and demineralised water system heat exchangers is river water drawn from the river Drac, into which it is also discharged after use. The temperature of the water drawn varies from 5°C to over 15°C depending on the season. The water necessary for the needs of the reactor is routed from the pumping station by three separate networks, each with its own pumps.

In the event of loss of the heat sink, the reactor would be stopped by the emergency shutdown function associated with the core inlet water temperature (37°C). According to the operating rules, the shift personnel would activate shutdown of the main reactor coolant pumps and leave the pumps of the shutdown cooling system (CRA) in operation for one hour before switching to natural convection cooling mode. Under these conditions, the heavy water temperature at the fuel element outlet would reach about 61°C maximum before stabilising, because the power transmitted to the pool water (440 m³) by the pile block structures and the pipes is then of the same order as the residual power of the core.

The ILL evaluates the drop in the pool water level at 40 cm/day. It has calculated that the pool water would not boil. Under these conditions, the ILL would have more than 15 days to restore the pool water inventory.

With regard to channel 2 and the transfer cask, the drop in level would be less than 40 cm/day (for 400 kW of spent fuel element (SFE) power). The absence of any intervention for 4 or 5 days would have no impact on the fuel elements because the stored SFEs have more than 6 metres of water above them and the top of the cask heat exchanger (operating in natural convection) is covered by more than 3 metres of water. Nevertheless, the level of activity above channel 2 could significantly increase. By lowering the fuel elements, the ILL would have more than 15 days to restore the channel 2 water inventory.

The ILL indicates that it has the emergency water make-up system (CES), designed to earthquake design standards (see "earthquake" section), to provide the necessary water make-up by pumping water from a 120 m³ tank or by pumping the water from room A11 with another pump if the water level in this room is sufficient. The CES can only be put into service from the PCS. Water make-up is also possible from the exterior via a seismic containment penetration situated beside the truck door, by means of a motor-driven pump and a flexible hose between the motor-driven pump and the containment penetration.

Conclusion on the planned measures to protect the facilities against the risk of loss of the ultimate cooling system or the heat sink

The facility is relatively insensitive to loss of the heat sink, therefore it can be considered acceptable that the HFR has just one heat sink. The ILL has nevertheless undertaken to implement the improvements mentioned below.

Measures envisaged to reinforce the robustness of the facility to loss of the ultimate cooling system or the heat sink

The ILL has undertaken to apply the following measures:

- install the ultimate reflooding system (CRU), designed to earthquake design standards (mentioned on the "earthquake" section). The safety injection will be ensured passively by gravity as long as the pool water level is sufficiently high. The reserve of water in the pool is sufficiently large to guarantee the water inventory in the short term, allowing the CES to be brought into service;
- in addition to the CRU, install two wells in the water table in the immediate vicinity of the reactor building to reinforce the robustness of the facility to an earthquake exceeding the DBE, which will also give greater robustness in the management of the total loss of heat sinks scenario. This is because it will enable external water to be injected into the pool and channel 2 at a much higher flow rate, i.e. 250 m³/h per well, and with total redundancy. This system will be designed to operate up to an earthquake intensity of DBE + σ and a water level of 216.20 m NGF;
- install an intermediate system that triggers rod drop automatically if secondary flow is lost for more than 10 seconds, in accordance with a previous study proposed by the ILL;
- during the next periodic safety review, consolidate demonstration of the capacity to remove the residual power immediately after reactor shutdown using the natural convection valves alone, taking into consideration the problems that could affect the reactor coolant pump flywheels and the primary and secondary cooling systems in an earthquake of intensity DBE + σ . In this context, the

ILL will examine the possibility of performing tests on the reactor with appropriate instrumentation, in addition to the computer simulations. If demonstration difficulties should arise, the ILL will examine the benefits of considering the shutdown cooling system (CRA) and its electrical power supply as a "key" SSC;

- consider the emergency shutdown system as a "key" SSC, on account of its role in serious accident risk prevention in the event of heat sink loss.

On completion of its review of the ILL's complementary safety assessment, ASN considers that the improvement proposals presented by the licensee, and in particular the installation of two wells to draw water from the water table in the immediate vicinity of the reactor building to reinforce the robustness of the facility to the loss of the heat sink, are satisfactory.

ASN will issue formal requests with respect to these proposals.

Loss of the main cooling system combined with total loss of the off-site and emergency electrical power supplies

For the HFR, loss of all the electrical power supplies forcibly means loss of the primary heat sink, as none of the secondary pumps are powered any more. This scenario is therefore exactly the same as those described previously for loss of the electrical power supplies and loss of the heat sink.

The core is cooled by forced convection for about one hour by the CRAB pumps, thanks to the autonomy of their batteries.

After this the core is cooled by natural convection, the ultimate heat sink being the reactor pool. This totally "self-sufficient" cooling can continue for at least two weeks.

The point raises no particular remarks from ASN.

5.2 Facilities in the nuclear fuel cycle (La Hague, Tricastin, Mélox, FBFC)

5.2.1. Tricastin site

Loss of the electrical power supplies

Although the electrical power supply is not a safety function for the facilities on the AREVA Tricastin platform, its reliability does contribute to the overall safety of the facilities.

The Georges Besse I plant

The facilities of the GB I plant are supplied from 5 independent 225kV sub-assemblies supplied by the NPP and RTE. Each normal train is designed to be able to satisfy, alone, all the power demands of the consumers that can be connected to it.

Eurodif Production also has an uninterruptible power supply by batteries and inverter to supply the control stations (autonomy 1 h), electrical cabinets of the security network (autonomy 12h), safety lighting (autonomy 1h30), local diesel generator set control station (autonomy 5h) and sensors and control loops of annex U (autonomy 10h).

Comurhex

The plant is supplied from the distribution substation of AREVA NC Pierrelatte via 2 redundant 15kV lines, each of which can provide the necessary power alone.

Comurhex also has an uninterruptible power supply by batteries and inverter to supply the control stations (autonomy 1h), the automatic fire detection (DAI) safety networks (autonomy 12h) and the safety lighting (autonomy 1h).

Total loss of the electrical power supply automatically leads to the process equipment being placed in safe position. Prolonged loss of power would lead to slow heating up of the storage building of the 100HF structure. If the temperature of 20°C were to be exceeded, the tank pressure would rise. The licensee nevertheless considers that the 3 days necessary for this rise in pressure (high and very high thresholds at 100 mbar and 1 bar respectively) would leave it sufficient time to deploy a mobile diesel generator set. Furthermore, the tanks are equipped with pneumatic and manual valves connected to the vents manifold.

The risks associated with a total loss of electrical power supply on Comurhex II and the procedure adopted are basically the same as for Comurhex I.

Socatri

The licensee's file presents no information on the consequences of a loss of electrical power supply for the facility.

TU5W

The electrical power supply is not considered a safety function for the TU5 and W facilities, because they are placed in safe shutdown condition if electrical power is lost. This being said, the mobile diesel generator sets at the disposal of the local security organisation FLS (local security organisation) enable the safety networks and, if necessary, the inverter batteries to be resupplied.

Georges Besse II plant

In the event of loss of the off-site electrical power supplies, the actuators automatically move to their safety position and the facilities is automatically placed in safe condition. This event has no impact on safety.

Loss of the cooling system / heat sink

Loss of the heat sink has no impact on safety for the Eurodif, Comurhex, Socatri, GB II and TU5W facilities.

Loss of the main cooling system combined with total loss of the off-site and emergency electrical power supplies

The combined loss of the electrical power supply and cooling and the associated consequences would not lead to a feared situation for the Tricastin site facilities.

The information presented by the licensees concerning the risk of loss of the electrical power supply and cooling for the Tricastin site raise no particular remarks from ASN.

5.2.2. La Hague site

Loss of the electrical power supplies

In the event of total loss of the electrical power supply, the following feared situations could arise:

- loss of the "commanded" rotation system of the pendulum-type centrifugal decanters (DPC);
- loss of the safeguard cooling function leading to a rise in the temperature of the stored high thermal power solutions (fissile product [FP] tanks) and the water in the pools;
- loss of the function for diluting the hydrogen from radiolysis when it is ensured by active systems (air superchargers).

Design measures taken to prevent loss of the electrical power supplies

The site electrical power supply comprises three sources:

- the normal power supplied from the RTE grids (EDF) and supplying the units via the "electrical distribution sub-stations" (SSRE) and the "utilities buildings sub-stations" (SSBU);
- the emergency power, supplied by the 15 kV backup power house for the UP2-400 plant and the 20 kV stand-alone power house for the BNIs in operation (also via the SSREs and SSBU);
- the backup power for the BNI's in operation and the ultimate backup power for the UP2-400 provided by the diesel generator sets specific to the units that need to have an electrical power supply permanently available, particularly for the dilution of hydrogen from radiolysis and the cooling function.

Conclusion on the measures planned to protect the facilities against the risk of loss of the electrical power supplies

According to the operator, the robustness of the electrical power supply is ensured by:

- the multiplicity of the power supply sources (redundant trains or off-site sources (RTE), multiple independent on-site sources);
- the multiplicity of the mutually interconnectable physical routing paths;
- the performance of preventive maintenance and periodic and regular inspections;
- the robustness of the backup diesel generator sets in the event of an earthquake.

ASN considers that loss of the electrical power supplies on the La Hague site must not lead to a reduction in process safety (ventilations, pool cooling, FP tanks, etc.). Consequently this loss must be compensated by the implementation of robust manual reinjection means or passive protection means. This demand will be issued as a requirement.

Loss of the cooling systems

Feared situations in the event of loss of the cooling system

Loss of the cooling systems could lead to a rise in the temperature of the stored high thermal power solutions (FP tanks) and the water in the pools.

Design measures to prevent loss of the ultimate cooling system / heat sink

The BNIs in operation are permanently cooled by:

- the systems associated with the NPH, C, D and E pools (each pool has its own cooling circuits);
- the cooling unit of the T2 unit supplying the units of the UP3-A plant (units T1, T2 and T7);
- the CNRS cooling unit supplying the units of the UP2-800 plant (units R1, R2 and R7).

Although cooling of the UP2-400 plant facilities does not appear in the CSA report, the CRS3 cooling plant cools the units of the UP2-400 plant and the SPF4 unit of BNI 117.

The cooling systems comprise:

- an "internal" loop specific to each unit, consisting of a demineralised water circuit;
- an "external" loop consisting of a demineralised water circuit allowing cooling of the internal loop via a system of "water/water" heat exchangers and removal of thermal power to the exterior via a system of cooling tower-type "water/air" heat exchangers.

These systems include "active" equipment items such as motor-driven pumps that require electrical power to function.

In a degraded situation, depending on the equipment items:

- their operation is ensured by one of the various electrical power sources presented in the preceding paragraph (particularly the backup electrical power supply: diesel generator sets),
- their design allows operation in "passive" mode, following the thermosiphon principle, as is the case with the "Nymphéas" heat exchangers of the pools and the cooling towers.

The key components of these cooling systems are designed and verified to be able to withstand potential external hazards and in particular a design-basis earthquake exceeding the seismic hazard.

Conclusion on the measures planned to protect the facilities against the risk of loss of the ultimate cooling system

The licensee considers that the degree of equipment redundancy and the earthquake robustness study are sufficient to conclude that the cooling systems of the pools and the SPF5 and SPF6 units (cases that were studied) have good overall robustness. According to the licensee, the conclusions can be transposed to the

other fission product concentrate storage tanks in the R7/T7 unit that have cooling circuits similar to those of the SPF5 and SPF6 units .

For the La Hague site, ASN considers that even if the pool heating kinetics are relatively slow (about one week), the site must have robust means for resupplying the pools with water.

ASN will require AREVA to take the necessary measures to have robust means of resupplying water to the pools and units housing the storage tanks containing concentrated fission product solutions, using the existing means as a basis if necessary. It will also require AREVA to have means for putting the pool and storage tank cooling systems back into service as rapidly as possible.

With regard to the units in which the spent fuel elements are stored, ASN will require the licensee to conduct a study relative to the control of the hydrogen risk in the pools building, and the resistance of the pool civil engineering in conditions of loss of pool cooling or loss of water inventory leading to exposure of the fuel elements

ASN also considers that if new pools are built on the La Hague site, they must have:

- reinforced provisions with respect to containment, equally well for the reactor containment in the event of a hydrogen explosion risk, as for maintaining integrity of the pool tank in the event of fuel element exposure or boiling of the water;
- a high level of protection against external hazards,
- robust water resupply means for ensuring the necessary make-ups.

Loss of the main cooling system combined with total loss of the off-site and emergency electrical power supplies

The licensee has identified the following three situations as feared situations that could occur:

Loss of the "commanded" rotation system of the pendulum-type centrifugal decanters (DPC):

Loss of the DPC rotation system would, if no remedial means were employed, lead to evaporation of the dissolution solution followed by heating of the solid particles that could lead to a release after about 50 hours in realistic operating conditions.

Loss of the cooling function of the spent fuel pools and of the storage tanks for solutions of fission products and fines

The loss of the cooling function for the pools would lead to:

- an increase in the pool water temperature;
- attainment of the pool water boiling temperature;
- a reduction in the pool water level by evaporation;
- a gradual reduction in the radiological screen that this water constitutes;
- exposure of the fuel assemblies;
- deterioration of the cladding of the fuel elements, leading to dispersal of the gaseous and volatile radioactive products they contain.

The times estimated by the licensee to reach the significant stages in the accident sequence starting from the total loss of the electrical power supplies and cooling are summarized in the following table:

Estimated time to reach (hours)			
Start of boiling	Water surface at the level of the top of the fuel assemblies	Fuel cladding temperature at 500°C (start of deterioration)	Total evaporation
52 hours	253 hours	>310 hours	>500 hours

Times associated with the transients of total loss of electrical power supplies and cooling for the pools

The loss of the cooling function for the fission product tanks would lead to:

- an increase in the temperature of the solutions contained in the tanks;
- attainment of the boiling temperature of these solutions;
- entrainment of the radioactive drops by the vapour produced;
- release of radioactive materials.

According to the licensee, the times for the solutions contained in the identified equipment to reach boiling point in the feared situations can be estimated as follows:

Unit	Equipment	Time before boiling
T2	Concentrated FP solution storage and transfer tanks	17 hours
SPF5 and SPF6	Concentrated FP solution transfer tanks	17 hours
T7	Concentrated FP solution storage tanks	25 hours
SPF5 and SPF6	Concentrated FP solution storage tanks	25 hours
R7	Concentrated FP solution storage tanks	28 hours
T2	FP condenser evaporator	44 hours
R2	FP condenser evaporator	65 hours

Times to reach boiling point in the event of loss of cooling for the FP tanks

Loss of the function for diluting the hydrogen from radiolysis by stopping ventilation of the buildings housing the pools or by stopping the superchargers producing the air sweeping the fission products and fines storage tanks.

According to the operator, the times to reach the Lower Flammability Limit (LFL) of hydrogen (4%) in the equipment identified in the feared situations can be estimated as follows:

Unit	Equipment	Time
R1	Fines transfer tanks	8 hours
T2	Fines storage tanks	13 hours
T2	Fines transfer tanks	20 hours
R1	Fines storage tanks	23 hours
T1	Fines recovery tanks	23 hours
R1	Fines recovery tanks	25 hours
T7	Alkali rinsing tank (not acidified)	25 hours
R7	Alkali rinsing tank (not acidified)	28 hours
R7	Fines suspension tank	48 hours

Times to reach the LFL of hydrogen in the event of loss of radiolysis hydrogen dilution

Furthermore, the cooling of the plutonium oxide storage pits in the BSI units for BNI 116, BST1 and its extension for BNI 117, is ensured by forced ventilation of the concrete pits containing these storage pits. The possibility of supplying power from backup generator sets designed to earthquake design standards is planned for in the design.

In the event of loss of the forced ventilation of the pits, natural draft operation is provided for in the pits of the BST1 extension, which is of more recent design. With regard to the PuO₂ storage pits in the BSI and BST1 units, which do not have natural draft cooling, the time for the concrete to reach a temperature of 160°C is estimated at 20 hours in the event of loss of cooling.

The storage areas for vitrified fission product containers (T7 and R7 unit buffer storage areas, EEV/SE storage) have cooling systems that function by forced convection or, in the event of loss of the electrical power supplies, by natural draft.

Measures taken to prevent these feared situations

The measures to prevent these situations have been detailed in the preceding paragraphs. They are based on the multiplicity of electrical power sources and supply paths, the redundancy of the equipment ensuring the cooling of the pools and FP tanks on the one hand, and the dilution of hydrogen from radiolysis on the other, and the robustness of these equipment items in the event of an earthquake.

Moreover, a study postulating the prolonged and joint outage of the electrical power supply and the cooling function revealed margins with respect to the times to attain the phenomena that could lead to radiological releases (heating of solid particles in the DPC, degradation of the cladding of spent fuel elements stored in pools, boiling of FP solution tanks, hydrogen explosion).

Measures envisaged to reinforce the robustness of the facilities to the loss of the main cooling system combined with total loss of the off-site and emergency electrical power supplies

The licensee has undertaken to submit a complementary study integrating the robustness to the loss of the natural convection of the PuO₂ and glass storage pits, within one year.

ASN considers that the equipment ensuring cooling of the pools and FP tanks must be rendered robust to external hazards to ensure their operability in accident conditions. It will issue a requirement on this subject.

5.2.3. *Other facilities in the fuel cycle (Mélox, FBFC)*

Mélox

Electrical power is distributed to the Mélox buildings by three networks:

- the "normal" network, connected to the RTE grid by two redundant trains;
- the "redundant" network comprising two redundant trains, each supplied by a diesel generator set (GE);
- the "backup" network, designed to earthquake design standards and comprising two redundant trains, each supplied by a specific diesel generator set (different GE to the redundant network).

In the event of loss of the off-site power grid, switchover to the redundant network occurs automatically. If the normal automatic mechanisms should fail, safeguard automatic mechanisms start the backup generator set (at the end of 2012, two permanent fixed generator sets will be installed) and the supply of the emergency and backup electrical panels. Several measures have been taken to ensure the starting (automatic or manual) of the emergency diesel generator set(s): redundant fuel supply pumps, redundant starting systems, control panel on batteries, etc. The licensee indicates that these measures enhance the reliability of the emergency electrical power supply for the Mélox facility.

Loss of the off-site electrical power supplies and the conventional emergency power supplies

In the event of loss of the off-site and emergency power supplies in a non-earthquake situation, the consumers whose shutdown could jeopardise the integrity of the first containment system are taken over by the backup network. In the event of an earthquake, the consumers whose shutdown could have consequences on the environment are taken over by this network.

Automatic mechanisms start the backup diesel generator sets and the supply of the backup electrical panels. The backup network is designed to the DBE.

Loss of the off-site electrical power supplies and the conventional emergency power supplies and any other on-site emergency electrical power source

Total loss of the electrical power supplies leads to loss of the following safeguarded functions: safeguarded dynamic containment (stopping of fans), cooling (stopping of fans, cooling units and recyclers) and safeguard operating control of the facility.

In the event of total loss of the power supplies, radioactive material containment is maintained by the key SSCs associated with static containment. Damage to the key SSCs further to an earthquake or a rise in temperature can lead to feared situations.

Conclusion on the measures planned to protect the facilities against the risk of loss of the electrical power supplies

The licensee considers that the loss of the normal and emergency electrical power supplies does not lead to feared situations. However, the total loss of electrical power supplies in an earthquake situation and the impact of the associated loss of the cooling function must be examined (see below). The feared situations are loss of containment and criticality accidents.

The safety of the Mélox facility in the event of loss of the electrical power supplies is dependent on its capacity to maintain containment of the materials. These are fail-safe systems. ASN judges these systems sufficient to ensure the safety of the facility in electrical power supply loss situations.

ASN will issue formal demands concerning the licensee's capacity to manage the loss of the cooling function, further to loss of the electrical power supply or not (see following section).

Loss of the cooling systems / heat sink

The thermal risk is due to the heat released by the fissile materials, which can induce degradation of the constituents of the first containment barrier, of the radiological protections or neutron-absorbing screens. This risk is high in the fissile material storage areas and in the homogenisation facilities.

Design measures taken to prevent loss of the ultimate cooling system or heat sink

The chilled water production for the storage area ventilation loop heat exchangers is connected to the redundant electrical power supply. In the event of electrical supply by the backup network or loss of the process secondary chilled water circuit of building 500, the ventilation of the containments enters safeguard mode: heat removal is ensured by the safeguard air intake and by the THD (very high flow) extraction. When post-earthquake safeguard mode is entered, containment ventilation stops and cooling is ensured by natural convection through the walls of the glove boxes.

Cooling of the STE rod storage area is ensured by the HD (high flow) ventilation, by the safeguard fresh air intake and by a specific ventilation system via two independent loops each ensuring 100% of the thermal load to remove, designed to earthquake design standards and safeguarded; these loops each comprise two air/water heat exchangers and a refrigerating unit integrating redundant equipment.

The prevention measures against chilled water loss (process and ventilation) in building 500 (primary loop) are:

- protection against freezing ensured by an electrically backed-up low output pump;
- redundancy of the production equipment;
- maintaining of cooling of the backed-up and emergency equipment of the ventilation loop in the event of electrical power supply loss by a combined generator set/pump unit in the process primary chilled water loop.

To guard against loss of the process cold water supply of building 500 (secondary loop), the primary loop/secondary loop heat exchangers are doubled and the circulation pumps are trebled.

Conclusion on the measures planned to protect the facilities against the risk of loss of the ultimate cooling system / heat sink, possibly combined with aggravating factors

If the cooling function is lost, the integrity of the STE storage geometry is jeopardised when the air temperature reaches 160°C, that is to say 11 hours after cooling stops. Restoring the function within less than 11 hours would seem difficult in a generalised post-earthquake emergency management situation. Moreover, the degradation of the neutron decoupling screens and a change in the geometry of the stacks of fuel rod trays could occur simultaneously and jeopardise control of the sub-criticality of the storage area before reaching 160° C.

If the cooling function in the storage areas outside the STE is lost, the temperature that jeopardises the integrity of the geometry is reached after 5 days, if there are no added aggravating factors. The licensee considers that an external intervention to perform mechanical repairs on the ventilation system or the diesel generator sets, or to restore the electrical power supply using an external mobile generator set, can be carried out within this period of time .

In the event of loss of cooling that could induce a criticality accident in the STE storage area, the licensee envisages adding boron to avoid a criticality accident. The boron would be mixed with water in a buffer tank, pumped to the storage area and sprayed over the fuel rod trays.

ASN considers that the licensee must prove its capacity to restore then maintain the cooling function in the Mélox facility within a time compatible with the rise in temperature , that is to say:

- less than 11 hours for the STE storage station;
- less than 5 days for the other fissile material storage areas;
- and taking aggravating factors into account.

ASN also considers that the licensee must substantiate the feasibility and effectiveness of spraying the fuel rod trays taking the intervention conditions into account (mist, temperature, radiation protection). It will issue a requirement on this subject.

Loss of the main cooling system combined with total loss of the electrical power supplies

Simultaneous loss of the cooling system and all the electrical power supplies leads to the same feared situation as in the previous section. It is the loss of cooling that requires the fastest response due to the rise in temperature in the fissile material storage areas.

FBFC

The FBFC site is supplied with electricity by 2 external trains:

- One 20 kV line that is buried from the Pizançon dam (line dedicated to FBFC);
- One emergency 20 kV overhead line, coming from the Saint-Paul-lès-Romans substation.

BNI 98 has the following on-site emergency power supply means:

- 3 fixed diesel generator sets with an autonomy of 24 hours: 2000 kVA generator set G05 in the U2 building, 1250 kVA generator set G07 situated near the U3 building, and 1250 kVA generator set G08 situated in building U1. It is possible to connect a mobile generator set to the electrical connection panel of each of these diesel generator sets if one of them should fail;
- 1 mobile generator set of 630 kVA, for which FBFC has a reservation contract with an outside company;
- Inverters, to provide the electricity necessary to place the facilities in safe condition in the event of loss of the BNI's off-site electrical power supplies (guaranteed autonomy of 10 mn): 2 inverters of 200 kVA each in AP2, 2 inverters of 200 kVA each in building U2, and 1 inverter of 40 kVA in building U3.

The backed-up electrical power supplies of BNI 98 primarily supply:

- In building C1: the process ventilation; certain equipment items in building C1: pneumatic transfers of uranium powder, conversion ovens, Granex system, freight elevator, backup scrub column (for HF releases);
- In building AP2: the 2 general ventilation and process ventilation trains; the BTU sintering furnaces and their cooling circuit (including the cooling tower);
- In building R1: the ventilation;
- In the HF station: certain equipment items, including the ambient environment scrub column (scrubbing of HF releases);
- Building U1, which contains the inverters and the air compressors;
- The supply for the batteries of the criticality detection and alarm unit (EDAC);
- Safety equipment such as the breathable air supply, site fencing or gates;
- The process ventilation functions in the buildings not mentioned above.

The backed-up electrical power supplies do not supply systems such as radiological monitoring, automatic fire detection (DAI, which has its own batteries), or the PPI (on-site emergency plan) sirens (which also have their own batteries).

It must be pointed out that the earthquake resistance of the site's electrical power supplies - normal or emergency - is not guaranteed.

Feared situations in the event of loss of the electrical power supplies

In the event of loss of the normal or emergency electrical power supplies, production is stopped and the facilities are placed in a safe condition. The licensee waits for a normal electrical power supply to be restored to assess the state of the facilities and attempt to put them back into operation.

In the event of total loss of the electrical power supplies:

- the fans stop. Containment of radioactive or hazardous materials is ensured by static containment (tanks, walls of rooms and buildings);
- the criticality monitoring mode is maintained, because it does not depend on an electrical power supply and is not linked to fail-safe components in the event of power supply loss (valves that close automatically, etc.);

- three particular cases must nevertheless be noted, as they require electrical power for a few minutes to place the equipment items concerned in safe condition:
 - the conversion autoclaves (building C1): in the event of loss of the electrical power supplies, autoclave heating is stopped. The fluid supply valves (nitrogen, compressed air) and the solenoid valves of the UF6 circuit are fail-safe valves and should therefore close automatically on loss of power. The injection of steam into the conversion ovens is stopped automatically by the valves moving to the closed safety position;
 - the sintering furnaces (building AP2): these furnaces serve to "bake" the uranium pellets, a process that produces hydrogen. It is absolutely vital that this hydrogen gas be burned at the furnace outlet to avoid any risk of explosion, and this is achieved by flares. Consequently, in the event of loss of the electrical power supplies while the sintering furnaces are functioning, these furnaces are placed in shutdown position by automatically introducing an inerting gas (nitrogen), while maintaining a minimum gas flow inside the furnaces to ensure sufficient internal pressure, by closing the furnace doors, and guaranteeing combustion of the hydrogen by maintaining a hot wire supplied by an inverter at the flare outlets. Lastly, the furnaces are cooled by a water cooling circuit which is energised by the backed-up electrical network. The transient phase of furnace cooling stoppage lasts about 3 minutes;
 - the HF station: in the event of loss of the electrical power supplies, the HF station must continue to scrub the HF discharges from the conversion autoclaves, until the autoclaves are completely stopped. The duration of this operating transient is not estimated in the CSAs.

Conclusion on the measures planned to protect the facilities against the risk of loss of the electrical power supplies

The licensee estimates that the measures it has provided for are sufficient.

The foregoing raises no particular comments from ASN.

Loss of the cooling systems / heat sink

The licensee indicates that only a few equipment items in BNI 98 require cooling:

- In building AP2:
 - the grinding machine wheels – cooling with demineralised water;
 - the BTU sintering furnaces – cooling water in closed circuit, which is itself cooled by 2 cooling towers – backup water supply from public water system;
 - the DEGUSSA sintering furnaces – cooling with recycled water;
 - the exit area of the roasting furnaces, called "Ripoche furnaces" - cooling with recycled water;
- In building R1:
 - calcining / reduction furnaces – cooling with recycled water.

The only cooling functions whose loss could impact the safety are those of the BTU and DEGUSSA sintering furnaces. According to the licensee, their loss would lead to:

- possible slight contamination in the environment of the furnace concerned;
- very slight hydrogen leaks in the furnace hall during the furnace inerting time.

The licensee identifies no feared situation in the event of loss of the ultimate cooling system.

Likewise, it identifies no feared situation in the event of loss of the main cooling system combined with total loss of the off-site and emergency electrical power supplies

The foregoing raises no particular comments from ASN.

5.3 Other facilities (ATPu, Masurca)

5.3.1 ATPu

Loss of the electrical power supplies

The ATPu is supplied by two 15 kV looped three-phase lines passing via the facility's 2 transformer stations. Each of these lines can supply the entire loop. The transformer stations are equipped with cut-off means upstream of each HV/LV transformer. If the building's main electrical substation should fail, all the ATPu facilities can be taken over by the second substation, subject to load-shedding.

In the event of a loss of power lasting more than 2 seconds further to a voltage drop of more than 15% at the main transformer station, a relay control gives the diesel generator set starting command. The backed-up circuits are energised about 15 seconds after start-up.

The two 1000 kVA diesel generator sets are located in an auxiliary technical building. The supply and storage tanks are linked by an overflow tube.

Furthermore, mobile generator sets can be made available from the Centre's general resources, to resupply certain parts of the electrical distribution network depending on the context. One of these generator sets is intended for power supply redundancy of the fixed generator sets' electrical panel, during maintenance in particular. A second generator set is intended to backup the facility monitoring systems, the auxiliaries of the substations and of the fixed diesel generator set plant, and the safety lighting circuits. A third and final generator set is intended to resupply the normal system coming from the PU2 station.

The remote alarm, interphone, criticality, radiation protection and emergency shutdown networks, powered with low voltage (24 V or 48 V), are backed up by a 100 kW group of dry batteries permanently connected to charging units.

Feared situations in the event of loss of the electrical power supplies

In the event of loss of the off-site electrical power supplies, without off-site backup, electrical power is supplied by two fixed diesel generator sets of 1000 kVA each, located in an auxiliary technical building. Each generator set is fuelled from a 500-litre diesel fuel tank, supplied by pump from two external tanks of 8,000 litres. If one of the two diesel generator sets should fail, the generator set remaining in service is capable of taking over powering of the facility, subject to load-shedding.

The equipment that supplies the power for all the functions important for the safety of the ATPu facility requires 1,250 kVA of power. Considering the hourly fuel consumption of the diesel generator sets and the quantities of fuel present on the Centre at all times, the licensee estimates that these generator sets have 37 hours of autonomy.

If the facility's ventilation is shut down, the diesel generator sets can supply the other equipment of the facility for 225 hours.

Loss of the off-site electrical power supplies and the conventional emergency power supplies

If the two fixed diesel generator sets are lost, the licensee places the ATPu facilities in safe condition, stops any glove box activity and evacuates the cells. If the ventilation is not taken over by the emergency system, the sealed doors upstream of the exhaust stacks are intentionally closed. If there is a total loss of electrical power for more than one hour, the personnel is ordered to evacuate the main building.

In the event of loss of the off-site electrical power supplies and the conventional emergency supplies (fixed generator sets), the remote alarm, interphone, criticality, radiation protection and emergency shutdown networks are backed up by dry batteries permanently connected to charging units. The autonomies of the chargers and inverters supplying the different equipment items vary between 10 minutes and 5 hours, depending on the equipment. There is also a mobile emergency battery/battery charger unit located in an auxiliary technical building that can be connected to and supply the consumers.

Loss of the off-site electrical power supplies, and the conventional emergency power supplies, and any other on-site emergency electrical power source

The licensee indicates that the loss of the ATPu electrical power supply would not lead to any cliff-edge effect situations.

This is because in the event of total loss of the electrical power supplies (off-site, fixed diesel generator sets, batteries), the different networks, including the criticality monitoring and fire detection systems, would no longer be active. This situation would nevertheless not lead to a sudden degradation in the accident sequences. After complete discharging of the batteries, the facility would remain in a static state, all the operations performed in the facility having been stopped.

In the event of total loss of the electrical power supplies (external, fixed diesel generator sets, batteries), inspection rounds are scheduled during and outside opening hours.

Conclusion on the measures planned to protect the facilities against the risk of loss of the electrical power supplies

Insofar as the consequences of the loss of the electrical power supplies would be limited for the ATPu, the licensee does not propose any additional provisions to protect the facilities against this risk.

Measures envisaged to reinforce the robustness of the facilities to the loss of the electrical power supplies, and proposed studies

Insofar as total loss of the electric power supplies would not be likely to result in situations leading to a cliff-edge effect for the ATPu, the licensee does not propose any measures to reinforce the robustness of the facilities to the risk of loss of the electrical power supplies.

The foregoing raises no particular comments from ASN, in view of the ongoing decommissioning of the facility.

Loss of the cooling systems / heat sink

The licensee considered that this subject was not relevant for the ATPu.

Effectively, none of the ATPu equipment requires a cooling system.

The foregoing raises no particular comments from ASN.

5.3.2. Masurca

The ventilation circuits (electric supply and extraction fans) represent the main cooling system of the storage and handling building (BSM). Loss of this system is equivalent to loss of the electrical power supplies.

In the event of loss of the electrical power supplies, the licensee indicates that the EDAC (criticality detection and alarm unit) is independent, as it has its own batteries with an autonomy of 8 h. Furthermore, the potential consequences of loss of the electrical power supplies are due to:

- the stopping of the extraction fans in storeroom MG1, and in the storage compartments in particular. The studies relative to the thermal conditions show that if this "process" extraction ventilation is stopped in the BSM fuel storage areas, the temperature levels reached are not such as to jeopardise the resistance of the cladding of the fissile elements and of the storage compartments themselves. Thus, according to the CEA, loss of cooling of the fuel and storage compartments in fissile material storeroom MG1 would have no impact on the containment of these materials or the sub-criticality of the storage area;
- the loss of dynamic containment of the BSM, which, given the leakage rates considered in the design, puts the BSM premises in equilibrium with the atmospheric pressure as soon as the extraction ventilation is lost. However, as the integrity of the fuel cladding (1st barrier) is maintained, loss of the second barrier would be of no consequence;

- the loss of radiological monitoring - locally and from the control room (SCO) - of the ambient atmosphere in the loading room (SCM), and loss of radiological monitoring of the air extracted from the storage compartments(MA08) due to loss of the supply of their respective air flow pumps. However, as there is no extracted air flow from the storage compartments and no ventilation in the SCM, these measurements are not necessarily representative of possible radiological emissions.

Moreover, the total loss of the electrical power supplies can be remedied by deploying the 390 kVA mobile generator set (GEM) or the 25 kVA GEM provided by the Centre within 4 hours.

The licensee indicates that for the MASURCA facility, loss of the electrical power supplies does not lead to the risk of a cliff-edge effect and no cooling is required given the current status of the facility.

Given the current status of the Masurca facility, the foregoing raises no particular comments from ASN.

6. Severe accident management

6.1 Emergency management organisation and general provisions

6.1.1. CEA facilities (experimental reactors, Masurca et ATPu)

Overall assessment

ASN Decision 2011-DC-0224 of 5 May 2011 required the CEA to perform Complementary Safety Assessments (CSAs) of the following BNIs for 15 September 2011: JHR, Masurca, ATPu, Phénix and Osiris.

As emergency management is a cross-organisation subject, the provisions specific to each BNI cannot be examined independently of the general provisions organised for the CEA centres of Cadarache, Marcoule and Saclay as a whole. This section relative to the CEA's management of severe accidents constitutes the ASN's intermediate appraisal based on the analysis of the CSA reports submitted in 2011. It will be supplemented by the analysis of the CSA reports for the Cadarache and Marcoule centres, due on 15 September 2012. **ASN will moreover require the submittal of a report relative to emergency management at the Saclay centre in 2013.**

In spite of the Advisory Committees' recommendation No.5 of 6 July 2011 to "submit an initial assessment of the availability and accessibility of the resources common to the sites and of use to the facilities examined on 15 September 2011, which will be supplemented in the file due for submittal in September 2012", the CEA presents the general organisation and inventory of the resources common to the centres but without specifying their availability or accessibility.

The assessment has, on the whole, been satisfactory for the Phénix and Osiris facilities. The robustness and availability of the organisation and material provisions specific to these BNIs, have been examined in accordance with the specifications. The assessment of the Cadarache BNIs (JHR, Masurca, ATPu) however, is incomplete, as the reports only mention the organisation and general resources of the centre.

ASN will ask CEA to supplement the future studies, particularly for the Marcoule and Cadarache centres, by examining and detailing the robustness and availability of the organisation and material provisions:

- that are implemented in each of the centres,
- that are specific to each BNI, including those examined incompletely in 2011.

ASN will issue requests in this respect for the report that will be required to be produced for the Saclay site in 2013.

More generally, ASN points out that pursuant to article 20 of decree No. 2007-1557 of 2 November 2007, "the on-site emergency plan (PUI) defines, on the basis of the design study figuring in the safety report, the organisational measures, the methods of intervention and the necessary means implemented by the licensee in an emergency situation to protect the personnel, the public and the environment from ionising radiation, and to preserve or restore the safety of the facility". The PUI must therefore detail the provisions specific to each BNI.

Consequently, even if the CEA has a PUI common to several of its BNIs, ASN will ask it to define the provisions specific to each BNI, in line with the presentations and justifications provided in the reports due in 2012 (Marcoule and Cadarache) and 2013 (Saclay).

ASN also considers that insufficient attention has been devoted to coordination in the event of a severe accident affecting all or part of the BNIs of a given site simultaneously.

ASN will therefore require the CEA licensees to reinforce their material and organisational provisions to take into account accident situations affecting all or part of the facilities of a given site simultaneously.

Licensee's accident management organisation

With regard to the JHR, Masurca and the ATPu (CEA Cadarache), the CSA reports give no details on the specific organisation of the emergency management unit that would be implemented within the stricken facility. For Phénix (CEA Marcoule) and Osiris (CEA Saclay), these emergency management units are called the Facility Command Post (PCI) and the Local Command Post (PCL) respectively.

ASN considers that coordination between these emergency management units is vital for the collection and transmission of the information necessary to assess the condition of the facility. ASN will therefore issue demands to address coordination between the emergency management units (description of existing organisation, presentation of the necessary improvements) in the future reports from the CEA Cadarache, Marcoule and Saclay centres.

As regards CEA Marcoule, at present it is planned that in the event of an accident, the centre will provide assistance to the nuclear licensees Mélox and Socodei by making available for example its emergency management rooms, its local security organisation (FLS) and its Radiological Protection Service (SPR).

ASN considers that the CSA report for the CEA centres must include an assessment of their capacity to support the neighbouring licensees in hazard situations - as defined in the CSA specifications - and affecting all or part of the site facilities simultaneously as defined in the CSA specifications. ASN will require all the licensees to reinforce coordination between licensees on a given site.

Possibility of using existing equipment in the event of a severe accident

The CSA reports draw up an inventory of the general resources available in each centre (emergency management rooms, communication means, mobile intervention means, emergency power supplies, etc.). The CEA points out that their availability and functionality in the event of a severe accident will be assessed for the reports due in 2012. With regard to the inventory of means specific to a given facility, this has only been drawn up for Osiris and Phénix. The CSA report for Phénix is the only one that provides an assessment of the availability and robustness of the facility's own means for the extreme situations envisaged.

Osiris

If the control room is unavailable, the facility has a fall-back centre that must communicate with the technical team at the Strategic Management Command Post (PCD). However, the report does not indicate the dedicated communication means in the fall-back centre. Furthermore, the Osiris facility has a specific electrical power supply whose availability and autonomy have not been assessed.

Phénix

The CEA's report provides information on the robustness of the premises used by the local emergency management organisation with respect to some of the hazards considered in the CSA, particularly the earthquake hazard. The notable point at the Phénix facility level concerns the fall-back room that would be used if the facility was unavailable. The fall-back room, which provides data on the reactor condition, is situated in premises protected from radiation by 50-cm thick concrete walls, but which would be flooded by the process waters in the event of an earthquake.

ATPu and Masurca

As the ATPu would not withstand an earthquake of MHPE (maximum historically probable earthquake) intensity (in the sense of RFS 2001-01), this would result in *"a loss of containment and dissemination of radioactive substances in the environment [...], leading to potential pollution of the water table around the facility"*. Furthermore, the accessibility of the site after an earthquake is not proven, given that the main entrance gate and the security gates would be automatically blocked. In addition to this, the updated inventory of the materials remaining in the ATPu does not detail their distribution per building, therefore the risks relating to the degradation of one or more buildings in the event of an emergency situation cannot be precisely assessed.

ASN considers that the CEA must ensure that the inventory of radioactive materials per building is known at all times in order to facilitate emergency management. ASN may issue a requirement in regarding this point.

With regard to the Masurca facility, the CEA indicates that an earthquake of the DBE (design basis earthquake) intensity would lead to total or partial collapse of the Storage and Handling Building (BSM), which would lead to substantial dissemination of radioactive material in the environment, preventing human intervention. The licensee specifies that pending entry into service of a building that meets current earthquake design standards (RFS 2001-01), which is scheduled for 2017, it plans transferring the fissile material to the MAGENTA facility for interim storage, but without setting a date.

ASN considers that the transfer of the fissile material currently stored in the BSM should be effectively carried out in the short term. ASN will issue a requirement on this subject to set the deadline.

Measures envisaged to reinforce accident management capabilities

As regards the Marcoule centre, the CEA undertakes in its CSA report to make the following reinforcements:

- construction of a new building housing the Marcoule centre's emergency management premises, outside floodable zones, built to the DBE and having an autonomy of 96h in the event of electrical power supply loss;
- parking of intervention vehicles and positioning of the mobile pumping and electrical power supply means in a place that will not be impacted by the effects of an earthquake;
- reinforcement of the Phénix facility's resources: means for limiting water ingress, preparation procedures for the mobile pumping equipment;
- study of the possible reinforcements for Phénix: inerting and extinguishing means on premises containing sodium, use of a buffer volume for storing potentially contaminated water.

The Cadarache and Saclay centres do not envisage reinforcement measures at this stage of the study.

The information presented by the CEA to date is incomplete and does not enable a conclusion to be drawn regarding the robustness of the material and organisational provisions in the JHR, Masurca, ATPu, Phénix and Osiris facilities in terms of emergency management. The CEA has decided to push back the assessment of the provisions specific to each BNI to the site reports due in 2012 and 2013.

ASN will demand that the availability of the organisational and material provisions in the event of a severe accident, including the provisions specific to each BNI, be assessed in the reports submitted by the CEA centres in 2012 and 2013. Particular attention shall be paid to the following information: emergency management premises, means of intervention and communication, instrumentation, means of radiation protection, technical and environmental instrumentation.

6.1.2. The reactor operated by the ILL

ASN considers that the ILL has carried out the CSA to its satisfaction, by proposing a complete appraisal of the availability and robustness of the means necessary for emergency management in the event of an earthquake, flooding, and the two events combined.

Licensee's accident management organisation

The organisation such as it is described in the on-site emergency plan (PUI) of the ILL Grenoble enables some 150 people to be mobilised by full-scale deployment, with a possible complement of 50 more people. As the personnel have multiple skills, details of their possible assignments to the different emergency teams are provided.

ASN considers that the ILL's deployment capacity for a severe accident situation is adequate. Nevertheless, full-scale deployment of the emergency teams raises personnel management questions, notably the extra personnel present on site (potential exposure to risk, on-site sleeping capacities). During the review, the ILL undertook to examine the operability of the mode of alerting and deploying its emergency teams in the external hazard scenarios studied in the CSAs.

ASN will examine the ILL's mobilisation capacity in its review of the ILL's on-site emergency plan (PUI).

Possibility of using existing equipment in the event of a severe accident

The robustness of the general material resources for emergency management have been analysed with respect to the risks of earthquake, flooding, and the two events combined.

It should be noted that the existing premises used for emergency management were not designed to withstand an earthquake situation compounded by other accident events.

As regards the information and communication means in an emergency, the site has a PPI (off-site emergency plan) siren in accordance with the regulations in effect (*Decree No.2005-1269 of 12 October 2005*). Nevertheless, its earthquake qualification and autonomy in the event of electrical power supply loss remain to be verified. Furthermore, the ILL does not have an automatic population alerting system which allows a faster response time when PPIs are triggered in the reflex response phase.

In the event of a severe accident, loss of the hard-wired telephone network would make it impossible to raise the national alert with the competent authorities (ASN and the prefecture). The ILL indicates that it has ordered satellite telephones to overcome loss of the telephone network. In the interim, an assistance contract has been signed with the CEA to make CEA satellite telephones available.

The ILL has independent and rechargeable radio transmission resources (5 frequencies) designed to the DBE. They have a range of about 10 km. A study is underway to increase the seismic resistance of the radio relays between the interior and exterior of the reactor building.

With regard to the radiological and environmental equipment used in emergencies, the ILL generally has portable equipment. However, the ILL does not address the availability or autonomy of this equipment in its study.

Lastly, the general intervention means that could be deployed would be provided by the CEA Grenoble: emergency diesel generator sets, motor-driven pumps, fire-fighting and rescue vehicles. However, the coordination between the ILL and the CEA to guarantee the availability of the means in an emergency affecting these two sites simultaneously is not formally addressed.

Measures envisaged to reinforce accident management capabilities

The ILL Grenoble envisages the following emergency management reinforcements:

- construction of a new emergency operations control centre (PCS) equipped with redundant backup means, for managing combined extreme scenarios;
- acquisition of satellite telephones.

ASN considers that the reinforcements proposed for the ILL are necessary but insufficient, and that they must be supplemented particularly with regard to:

- *the robustness of all the emergency premises (PCD and associated PC) to the combined extreme scenarios: their integration in the new PCS could be envisaged on this account;*
- *coordination with the neighbouring licensees;*
- *the availability of meteorological and environmental radiological monitoring data.*

ASN will issue specific demands concerning these aspects, some of which will be requirements.

6.1.3. Facilities of the nuclear fuel cycle

Overall assessment

The CSA reports submitted by the AREVA group present an appraisal of the planned material and organisational measures for severe accident situations. Their availability and robustness to certain hazards considered in this context, and notably earthquakes, have been described in a global manner.

The general finding is that the current human, material and organisational resources are not sufficient to guarantee the availability and functionality of all these resources in a severe accident situation.

The licensees present reinforcement provisions that would possibly be envisaged, but without giving any commitments or decisions regarding their deployment. Apart from the creation of a local security organisation, (FLS) at the FBFC Romans facility, the only commitment from the licensees is to perform

numerous studies relating to emergency management in order to decide on the necessary material and organisational reinforcements.

With regard to emergency management, ASN considers that the AREVA group licensees have established a summary inventory of resources and not drawn the practical conclusions from their findings.

On completion of its review, ASN emphasises the importance of the following recommendation, made in the meeting of the advisory committee of experts: *"AREVA must take measures to equip each site with robust means for managing an emergency situation, emergency management premises and places for storing these means. The technical and human resources must be capable of managing a situation resulting from hazard levels higher than the facility design-basis hazards"*.

ASN will issue requirements on this subject, focusing in particular on the emergency management premises, the material resources and the means of communication.

The Tricastin site

Licensee's accident management organisation

The organisation as it is described in the on-site emergency plan (PUI) for the Tricastin site facilities enables a total of 113 people to be mobilised for the entire site during working hours, and 47 people outside working hours. Some resources are common to Eurodif Production and SET. The report moreover states that a project for joint organisation of emergency situation management is currently being studied, particularly concerning the accident impact assessments.

ASN considers that:

- any agent who could be deployed on different facilities must obligatorily be trained for each PUI concerned (utilisation of reflex sheets, scenarios, etc.);
- in the event of a severe accident affecting several facilities on the Tricastin site simultaneously, the availability of resources common to several facilities would not be guaranteed.

The Tricastin site report underlines that "in accordance with the convention applicable since 14 April 2011, the site director ensures , [...] alerting of the prefectures of the Drôme and the Vaucluse, the coordination, the communication and the feedback of information on the situation and its development to the prefectural authorities and to the PCD-N AREVA [...]". ASN points out that on the Tricastin site, the holders of the operating license, that is to say the directors of the companies Eurodif Production, Comurhex, SET, Socatri and AREVA NC, act as licensees and as such are responsible for the implementation of their PUI.

ASN considers that the consistency of the organisation described in the CSA report must be verified with respect to the national emergency organisation, notably the decision circuit involving the licensee, the préfecture and ASN. AREVA must thus clarify the respective roles and responsibilities of the site director and the holders of the licenses to operate.

ASN shall issue requirements regarding these points.

Possibility of using existing equipment

The report draws up an inventory of the intervention means figuring in the site licensees' PUIs and the off-site emergency means that might be called upon. Their availability and robustness in the event of an earthquake, flooding, or the two combined have been partially assessed.

With regard to the means of alert, notably the PPI (off-site emergency plan) siren and the automatic population alerting system, AREVA provides no information that confirms their availability in the event of a severe accident.

Regarding the means of communication, the report indicates that the multiplicity of the networks and the site's good coverage increases its capacity for both internal and external communications in the event of a severe accident. On the other hand, unlike the other entities, Socatri has neither access to the RIMBAUD network nor satellite telephones.

Regarding environmental monitoring, AREVA has drawn up the inventory of the fixed and portable instruments available on the site

With regard to the emergency management premises, the Local Strategic Management Command Posts (PCDL) of each entity are designed to the DBE, with the exception of the Comurhex premises, whose robustness was not studied.

Moreover, the emergency management premises have a limited autonomy in the event of loss of the electrical power supply.

ASN observes that the SET does not have its own PCDL, and would use the PCDL of Eurodif in the event of a severe accident. However, the availability of this PCDL in the event of an accident affecting Eurodif and SET simultaneously is not guaranteed. ASN will issue a requirement concerning this point.

Fall-back premises designed to the DBE are also planned for should the control rooms be unavailable. However, the licensee does not specify in its report whether the fall-back premises will be equipped with filtration systems in the same way as the control rooms.

ASN considers that the control of the facilities on the Tricastin site must be ensured from the control or fall-back premises until a lasting safe condition is reached. It will issue a requirement to this end.

With regard to the intervention means, the site's personnel and material resources are geared to meet two simultaneous accidents in standard situations and three in exceptional situations, whereas the complementary safety assessment led to the envisaging of up to 6 simultaneous accident situations.

ASN will issue requirements for the Tricastin site licensees to reinforce their material and organisational provisions to include accident situations affecting all or part of the site facilities simultaneously.

Measures envisaged to reinforce the accident management capabilities

AREVA states that the availability and functionality of the technical and human resources necessary for interventions in severe accident situations cannot be fully guaranteed in the event of a DBE-type earthquake. Emergency management such as it is planned in the PUI would very likely be disturbed by such lack of availability. The situation would be the same in the event of flooding, except that the slower kinetics of the event would allow the facilities to be made safe. Lastly, the combination of an earthquake and flooding would make intervention extremely difficult or even impossible, depending on the rate of rise of the water.

The licensees plan conducting various studies relating to emergency management in the extreme situations studied for the CSAs, and concerning the following points in particular: alerting and communication means, coordination means necessary for emergency management, installation of emergency resources and new wells, mitigation means available to the FLS.

On the other hand, the licensees do not decide on or make any commitments regarding the implementation of reinforcement provisions.

ASN considers it essential that the Tricastin licensees reinforce their organisational and material provisions for severe accident situations. It considers that these reinforcements must take into account the consequences of any hazardous phenomenon that could occur on the Tricastin site and the neighbouring facilities, notably the Tricastin NPP (explosive, thermal, toxic, radioactive release phenomena, etc.).

ASN will issue requirements regarding these points, focusing in particular on the emergency premises, material resources, means of communication and coordination between neighbouring licensees, including EDF.

With regard to the joint emergency organisation project, AREVA envisages grouping safety/environment departments and skills and reinforcing the professionalisation of the emergency teams for the "shareable" functions (human resources, logistics, accident impact assessment, etc.).

ASN considers that the people involved in emergency management, particularly with regard to the individual PUIs of the Tricastin site (reflex response sheets, scenarios, etc.), must have the necessary competence before they take up their function. The ASN inspectors will endeavour to verify this point during their field inspections.

The La Hague site

Licensee's accident management organisation

The licensee AREVA NC indicates that human resource management in severe accident situations would rely on the deployment of the facility personnel, personnel associated with the emergency organisation as planned for in the PUI, including the intervention agents (FLS) and on-call personnel. If necessary these resources could be reinforced on an alternating basis.

Possibility of using equipment existing on the site

The licensee has drawn up an inventory of the intervention means figuring in the PUI and the off-site emergency means that can be called upon. Their availability and intervention capacity in the event of a severe accident have been partially assessed.

With regard to the alert means, particularly the PPI (off-site emergency plan) siren and population alerting system if the PPI is triggered in the reflex response phases, AREVA NC provides no information that confirms their availability in the event of a severe accident.

The autonomy of the means of communication would be limited to a few hours. Beyond this AREVA NC envisages using carrier frequency transmission or a battery power supply.

AREVA has drawn up an inventory of the fixed and portable environmental monitoring instruments available on the site.

With regard to the crisis management premises, the robustness of the FLS building housing the PCDL (Local Strategic Management Command Post) and the PCS (Security Command Post) is limited to an earthquake of magnitude 5.3. This building is equipped for the management of a lasting emergency situation, with fixed beds, emergency electrical power supply, autonomous water supply, filtered positive pressure and radiological monitoring instruments. The hall grouping the First-Line Command Posts (PCA) for each facility is built to withstand the DBE.

Measures envisaged to reinforce the accident management capabilities

AREVA NC envisages reinforcing the human resources, particularly the intervention resources, by sharing with the group's other sites, but without detailing the conditions.

For the material resources, various crisis management-related studies will be carried out. Avenues considered noteworthy by ASN are:

- the creation of resistant premises to accommodate the emergency organisation, ensuring redundancy with the premises normally provided for the PCDL;
- the reinforcement of the pumping means and the evaluation of the radiological impact around the site (trucks);
- the reinforcement of the internal and external communication means to ensure their availability.

AREVA NC does not decide on or make any commitments regarding the implementation of reinforcement provisions.

ASN considers that it is essential for AREVA NC to reinforce its material and organisational provisions for severe accident situations. ASN will issue requirements in this respect, more particularly concerning the emergency premises, the material resources and the means of communication.

Mélox Marcoule

Licensee's accident management organisation

In its CSA report, Mélox makes reference to the emergency organisation described in its PUI. It provides details on the organisation of the permanence of PUI functions and supervision. Supervision permanence covers facility monitoring and detection in order to determine the nature and location of an event.

The emergency organisation and means that would be implemented if an accident occurred on the Mélox facility are based on several resources at CEA Marcoule (CEA Marcoules PCD-L premises, FLS and SPR).

Possibility of using equipment existing on the site

The licensee has drawn up the inventory of the intervention means figuring in the PUI and the off-site emergency means that can be called upon. Their availability and robustness in the event of a severe accident have been partially assessed, essentially with respect to an earthquake situation.

The emergency premises are housed in a building with a backed-up electrical power supply but which is not built to earthquake design standards and not protected against a toxic or radioactive cloud. The envisaged fall-back possibilities are either in CEA Marcoule's PCD, or in another Mélox building, both earthquake resistant and with containment.

ASN considers that Mélox must consider the conditions of transfer to the fall-back premises on the Marcoule site in the event of a toxic or radioactive cloud. Moreover, the functionality of the fall-back premises must be ensured with respect to the current organisation of the PCDL. ASN will ensure that these points are addressed to its satisfaction in response to the emergency management requirements.

With regard to the internal and external communication means, Mélox indicates that their diversity should ensure the operability of at least one of them. For internal communications, Mélox envisages carrier frequency transmission as a backup means.

ASN considers that the working conditions (irradiating or toxic environment, etc.) associated with carrier frequency transmission must be analysed and the feasibility of these measures demonstrated. More generally, ASN will issue a requirement concerning the intervention conditions of emergency management personnel.

The technical instrumentation is installed in a building built to seismic standards.

Measures envisaged to reinforce the accident management capabilities

Implementation of emergency management as provided for in the PUI could be disrupted by problems of material and human resource availability. At organisational level, the deployment of alternating reinforcement personnel would improve emergency management in a lasting situation. As for the material resources, Mélox proposes a preliminary inventory of the possible reinforcements, without giving an implementation schedule. It mentions in particular:

- the emergency premises: pre-equipped, positive-pressure sealed tent, deliverable within 48 hours;
- acquisition of additional satellite telephones;
- reinforcing of the pumping, cooling and emergency electrical power supply means.

Mélox does not decide on or make any commitments regarding the implementation of the reinforcement provisions.

ASN considers it essential for Mélox to reinforce its material and organisational provisions for severe accident situations. These reinforcements must take into consideration:

- the need for coordination between Mélox and CEA Marcoule to ensure the availability of the shared means in the event of a severe accident affecting the two licensees simultaneously;
- the consequences of any induced hazardous phenomenon that could occur on the Mélox facility and any neighbouring facility, notably CEA Marcoule (explosion, fire, toxic leak, radioactive releases, etc.).

ASN will issue requirements concerning these points, and in particular the emergency premises, the material resources, the means of communication and coordination between neighbouring licensees.

FBFC Romans

Licensee's accident management organisation

FBFC sets out the emergency management organisation described in its PUI. The human intervention resources specific to FBFC are based on the multi-skilled Site Intervention Teams (EIS), with intervention, medical, environmental and radiation protection skills. FBFC points out that their availability would not be guaranteed after an earthquake.

To date, FBFC does not have any heavy emergency equipment dedicated to the site and present at all times. Recourse to the off-site resources of the Romans Fire Brigade is therefore vital.

Possibility of using equipment existing on the site

The licensee has drawn up an inventory of the intervention means figuring in the PUI and the off-site emergency means that can be called upon. Their availability and robustness in the event of a severe accident have been partially assessed, essentially with respect to an earthquake situation.

With regard to the alert means, the PPI siren is located in a building designed to withstand the safe shutdown earthquake (SSE), but without a backed-up electrical power supply. Furthermore, the installation of an automatic population alerting system in the event of PPI triggering in the reflex response phase is currently underway, FBFC being one of the few hitherto unequipped sites.

With regard to the means of internal and external communication, FBFC provides no information to confirm their availability in a severe accident situation.

With regard to the site's emergency intervention means, FBFC states that they are stored in a building that is not designed to seismic standards.

As for the emergency management premises, their earthquake robustness is not confirmed. FBFC only confirms the resistance of a control room to the SSE+ 0.5, but it is not equipped with air filtration means.

To conclude, FBFC indicates that the availability and functionality of the technical and human resources necessary for a post-earthquake intervention are not guaranteed. The implementation of crisis management as planned for in the PUI would very likely be disrupted by such availability shortcomings.

Measures envisaged to reinforce the accident management capabilities

FBFC acknowledges the need to reinforce the existing organisational provisions. It has undertaken to set up a local intervention team on the FBFC site available 24h/24h and 7d/7d.

ASN considers this reinforcement measure to be satisfactory on condition that the capacity and skills of the FBFC Romans local intervention team are adapted to the specific needs of the site, and that these resources are operational for the hazards defined in the CSA. ASN will issue a complementary technical requirement on this subject.

With respect to the material resources, FBFC proposes initiating a project addressing "emergency management in degraded post-earthquake situation" with the aim of defining the technical and organisational measures to implement.

The following are mentioned in particular:

- seismic qualification and autonomy of the PPI siren;
- acquisition of additional satellite telephones;
- reinforcement of monitoring/diagnostic, electrical power supply and water supply means.

Apart from the setting up of a Local Safety Organisation (FLS) on its Romans site, FBFC does not decide on or make any commitments regarding the implementation of the reinforcement provisions.

ASN considers it essential for FBFC to reinforce its organisational and material provisions for severe accident situations. These reinforcements must take into account the consequences of any induced hazardous phenomenon that could occur on the FBFC site (explosion, fire, toxic leak, radioactive releases, etc.)

ASN will issue requirements concerning these points, and in particular the emergency premises, the material resources and the means of communication.

6.1.4. Conclusion

With regard to the general emergency management provisions for severe accident situations, the reports submitted by the licensees in 2011 meet the initial specifications to varying extents.

The ILL has clearly identified the necessary reinforcements and undertaken to implement them. The CEA and AREVA have not made a decision or given a commitment to the implementation of reinforcement provisions, even those that could be achieved rapidly.

- for the CEA, these provisions will be identified and prioritised after submitting the reports for the centres due in 2012 (CEA Marcoule and CEA Cadarache) and 2013 (Saclay);
- for AREVA, the licensees undertake to carry out various studies relating to emergency situation management.

With regard to the CEA, ASN considers that the centres' reports must assess the availability of the organisational and material provisions for severe accident situations, including the provisions specific to each BNI.

With regard to AREVA, ASN considers that the summary inventory drawn up in the CSA reports is just a first step and that the licensees must reinforce the means and facilities.

Further to the review of the CSA reports, ASN will issue technical requirements concerning the following points:

- the emergency management premises;
- the emergency intervention equipment;
- the active dosimetry means, radiation protection measuring instruments, personal and collective protective equipment;
- the technical and environmental instrumentation;
- the means of communication;
- the functionality of the command or fall-back premises;
- coordination further to an accident affecting all or part of the facilities operated by a given licensee on a given site simultaneously;
- coordination between neighbouring licensees with respect to accident events and induced effects that could hinder the deployment of the emergency response teams.

6.2 Severe accident management per facility

6.2.1. Experimental reactors

Osiris

The feared severe accident is core meltdown (see § 1).

Licensee's accident management organisation

A core meltdown accident would be managed from the fall-back centre which enables the safeguard ventilation system and the emergency water make-up circuit to be controlled, and the following elements to be monitored:

- detection of the low position of the Osiris control rods;
- the Osiris reactor pool water level;
- the Osiris reactor pool water temperature;
- the pressure in the containment;
- the operation of the nuclear ventilation equipment;
- the radiological measurements of exhaust stack discharges;
- the dose rates measured by the radiation protection monitors in the facility.

In the event of core meltdown, the "normal" nuclear ventilation would be stopped manually and the safeguard ventilation would take over (by static containment), enabling the reactor containment to be kept at slight negative pressure. The safeguard ventilation is designed to withstand the reference earthquake.

The CEA has examined the potential risks of containment degradation after core meltdown. It considers that there is no risk of containment damage by hydrogen explosion, even if ventilation is lost. Moreover, the pressure rise in the reactor vessel would be very slight and would not lead to its destruction. The CEA rules out the risk of a criticality accident, even in the event of an earthquake.

In addition, it has evaluated the dose rate in the facility in the event of exposure of the fuel elements. If channel 2 were to become exposed, the dose rate would be 13.5 Sv/h at the edge of the channel and 0.7 Sv/h at 1 metre from the edge. The CEA indicates that if necessary, the FLS will be able to make the required water make-ups using a remotely-controlled robot.

It should also be noted that the availability of the means necessary for the intervention of the FLS on the facility for the management of a severe accident will be analysed in 2012.

Identification of the factors potentially hindering accident management and of the resulting constraints

With regard to the fire risks induced by an earthquake, the CEA takes the envelope case of a fire in the equipment room affecting one of the electrical power supplies to the reactor. Yet it does not indicate whether the fire protection means are designed to seismic standards, nor does it indicate the vulnerability of the essential equipment items to fire.

The licensee has undertaken to assess the induced hazards internal or external to the facility (global CEA commitment).

Conclusion on the planned organisational measures for accident management

The licensee has proposed replacing the FLS equipment shed doors with flexible doors to facilitate access to this equipment for post-accident operation.

Existing severe accident management measures

The CEA has undertaken to assess the robustness of the instrumentation considered important for monitoring the situation of the facility, namely:

- the position of the natural convection valves;
- the core outlet temperature or the reactor pool temperature;
- the water level in the reactor pool.

Conclusion on the planned measures to mitigate the consequences (radioactive or chemical releases) in the event of a severe accident

ASN will request the submittal of a complementary safety assessment for the Saclay site in which the question of environmental instrumentation can be addressed.

JHR

The feared severe accidents studied in the CSA report for the JHR are those corresponding to loss of fuel cooling leading to fuel meltdown. Such situations can be initiated in different ways (loss of off-site and on-site electrical power supplies, loss of cooling flow, breaches, etc.) and be compounded (loss of containment, criticality, fire, etc.)

Prevention measures for managing a severe accident resulting from loss of cooling.

The CEA highlights the following existing severe accident prevention measures:

- the water block bunkers and the pools that help keep the core under water. Design measures allow balancing of the water levels between the pools and the bunkers in the event of a breach in order to exclude the risk of core exposure;
- the following means for supplying the reactor building pools with water:
 - the EPV tanks and the EPL circuit supplied by the normal electrical power network. The EPL circuit transfers the water stored in the EPV tanks to the nuclear unit pools;
 - the ultimate recirculation system for leaks collected in the water block bunkers (REU) designed to seismic standards and supplied by the normal electrical network. If a breach occurs, it enables the water collected in the water block bunkers to be directed to the pools of the Reactor Unit Building (BUR). This system is powered by the off-site electrical network.

The CEA envisages the following complementary measures to increase the robustness of the facility:

- permanent filling of one EPV tank of the Auxiliary Unit Building (BUA) with a few hundred cubic metres of water: creation on an internal stock of water so that the pools can be resupplied without bringing in water from outside sources;
- extension of the function of the ultimate recirculation system to the areas adjacent to the water block: collection followed by pumping of the leakage water from the areas adjacent to the reactor pool;
- design to seismic standards of the section of the EPL system that supplies the reactor pool: increase the robustness of the make-up system;
- installation of specific sensors to allow monitoring of the water level in each pool from the control room and the fall-back station (in addition to the existing threshold overshoot alarms), unless the equipment already planned for can fulfil this function.

Measures for mitigating the consequences of a severe accident

The CEA indicates that to mitigate the consequences of a severe accident, the JHR has the reactor containment and associated systems.

Containment management is based on total isolation of the reactor containment and the putting into service of a post-accident ventilation system that is independent of the other ventilation systems, situated in the ZRF and equipped with HEPA filters and iodine traps. This ventilation system can collect any leaks in from the containment penetrations and depressurise the containment if necessary. The equipment necessary for containment management is designed to seismic standards and controlled from the control room or, as a last resort, locally.

These actions are triggered automatically if there is an increase in activity in the reactor building, or manually by the shift team from the control room. The licensee can also manage the risk of overpressure in the reactor building hall from the control room by opening a decompression line connected to the post-accident ventilation system. This can also be done locally.

Analysis of an extreme scenario of total loss of cooling leading to fuel meltdown

In its assessment the CEA postulates a severe accident situation of meltdown under water with fast kinetics (less than 15 minutes) with the penalising build-up of failures of all the redundant active backup means and closing of the valves when the coolant pumps discharge as soon as the speed of their flywheel becomes too low.

In this case the natural convection valves must be opened manually as soon as possible.

With regard to this highly improbable scenario, it must be pointed out that the natural convection valves, the mixing pump and their respective sets of batteries - SUS A and SUS B - are designated by the CEA as key equipment items because they enable cooling and removal of residual power to be ensured in the event of loss of the normal electrical power supply (EDF) and the backup power supply (diesel generator sets of the MEQ network). This extremely penalising scenario enables the kinetics of the hypothetical accident scenario of meltdown under water to be assessed, if it were to happen in spite of the planned prevention measures (ultimate backup pump, natural convection valves, all supplied by the SUS batteries).

With regard to the radiological conditions in the reactor building hall, under the conditions of this scenario, the height of water in the pool would provide radiological protection. An intervention in the reactor building is therefore, in principle, not impossible.

If water containment was no longer ensured in spite of the robustness of the pool (designed for a BORAX-type explosive reactivity accident), the containment function would be ensured by the last barrier formed by the reactor building containment. On this account the review concluded that the monitoring means and the actions required to control environmental releases would have to be particularly robust to earthquakes.

Assessment of the risks associated with the industrial environment

The risks associated with the industrial environment were examined. The general approach adopted by the CEA was firstly to identify - through the Cadarache PGSE (general presentation of the site and facility) and the safety frame of reference in effect - the industrial facilities, hazardous material pipelines and communication routes (road, rails and river) around the site and at the JHR (including those present on the site itself). In a second phase the CEA assessed the potential risks associated with the hazard sources on the basis of the existing studies for the BNIs in question.

As concerns the identification of the hazard sources associated with the industrial environment (internal and external), the review found that the CEA did not always indicate the maximum quantities of hazardous materials involved. Indeed, the CEA mentions the presence of ICPEs (installations classified on environmental protection grounds) within the Cadarache site (MADERE, TOTEM, etc.) without demonstrating that these facilities do not present a risk. Moreover the CEA does not give an assessment of the impacts of the dangerous phenomena associated with these hazard sources - possibly compounded in the event of an earthquake or flooding - on the BNI which may have been rendered more vulnerable by the earthquake or flood event.

With regard to the industrial facilities off the BNI site, the review highlighted that the CEA lacked sufficient information on their robustness to earthquakes and flooding.

The CEA has therefore undertaken to provide an assessment of the induced risks associated with the industrial environment both on and off the sites targeted by the CSAs. This risk assessment will present:

- a deterministic identification, from hazard studies, of all the hazard situations associated with the industrial environment that can impact the BNIs targeted by the CSAs;
- an assessment of the impacts of these situations on the BNI, given its condition after an earthquake or flood;
- a verification of the robustness of the emergency management means for such situations.

This is a generic commitment from the CEA for all its BNIs.

Assessment of the risks induced by an earthquake

Considering earthquake-induced risks, the licensee has studied the following:

- the risk of internal fire induced by an earthquake;
- the risk of explosion induced by an earthquake;
- the risk of flooding induced by an earthquake.

With regard to the study of earthquake-induced risks internal to the BNI, the CEA has specified a requirement that "elements important for safety (EIS) that have an earthquake-resistance requirement" should not be vulnerable to fire, explosion or jets of fluid; this results in having design rules for the electrical equipment, nitric acid systems and fluid pipes crossing the electrical rooms, when these elements are situated in "safety-classified" premises. With respect to the DBE, requirements to conserve the integrity or operability of the fire-protection means (automatic fire detection, dry risers, sectorisation) have been specified, as has the preventive inertia of the liquid metal handling cubicle. To limit the effects of a post-earthquake explosion, the gas storage yards will be designed to direct the blast and fragments from an explosion towards an area free of elements important for safety. In the "battery" rooms of safety-classified buildings, the H2 detectors and load cut-off devices must remain operational after an earthquake.

With regard to the risk of flooding induced by an earthquake, the CEA concluded that the rupture of the normal, secondary and tertiary cooling systems - which are not built to seismic standards - would not create a

cliff-edge effect, as their consequences are limited to possible problems with light vehicle movements, isolation of the planned diesel generator set on the platform in front of the BMR, and potential water ingresses in the BMX building. Although it has not identified any cliff-edge effect, the CEA proposes additional measures to prevent and mitigate the consequences of the risk, which are described in the section dedicated to the analysis of other extreme natural phenomena, namely:

- movement of the standby diesel generator set to an area outside the water runoff area;
- local adaptations of the second-phase roads and utilities networks in order to improve water discharge towards the le Ravin de la Bête.

Other risks

The following risks have also been examined:

- the risk of containment degradation after core meltdown by hydrogen explosion or basemat melt-through, the exclusion of which is substantiated in the CSA;
- the re-criticality risk, even though it is excluded in the safety frame of reference. With regard to the management of this risk, the CEA puts forwards a system of emergency poisoning by injecting soluble neutron poison via a line of the core backup cooling system (RUC) which can be manoeuvred from the auxiliary building and energised by the normal electrical power network;

The CEA has also assessed the radiological conditions in the premises with a potential requirement for operator inputs (control room, fall-back centre, quick-connect coupling external to the nuclear unit, diesel generator premises) and considering that the nuclear materials stored in the auxiliary building are exposed. These conditions confirm those set for "controlled areas in the sense of the labour code".

For the JHR, with regard to mitigating the consequences of severe accidents, ASN will ask the CEA to examine the possibility of including the equipment items involved in the "control of environmental releases" in the hard core of reinforced provisions, and to verify their robustness to an earthquake exceeding the reference earthquake for the facility.

Phénix

The feared serious situations are:

- loss of sodium containment that could lead to a sodium fire or a sodium-water reaction;
- a criticality accident in the spent fuel assembly storage tank;
- collapse of the hot cells.

The CEA therefore analysed in its CSAs the robustness of the means available in the following situations that could lead to a cliff-edge effect:

- cumulated leaks of the main vessel, of the double-walled vessel and the primary containment vessel, which could lead to a sodium fire;
- a leak in the fuel storage tank vessel combined with failure in integrity of the fuel storage tank vessel pit lining, which could lead to a sodium fire;
- a sodium fire affecting the in-service primary cold trap;
- a large-scale sodium-water reaction;
- an accident mobilising the radiological source term of the cells.

Licensee's accident management organisation

The CEA's means for detecting a sodium fire include monitoring the oxygen content and atmospheric relative humidity, as well as televisual monitoring of the primary containment vessel. The CEA specified that if the normal sodium fire detection systems malfunction, and given the scale of the fires considered for cliff-edge effects, the quantity of fumes released would be such that fire would be detected visually. In the event of a sodium fire, some premises can be inerted, and the facility has appropriate means for this (Marcalina powder). If a sodium fire occurs in the fuel storage tank vessel pit or in the primary cold trap, only inerting of the

premises could be effective insofar as the chemical or radiological environment will not permit on-site intervention with the extinguishing powder.

Consequently, the CEA envisages firstly providing a rapidly deployable nitrogen tank, and secondly creating a dedicated access to the rooms so that the extinguishing powder can be introduced via a dry riser-type connection. It does not envisage additional means in the event of a concomitant leak of the double-walled main vessel and the primary containment, considering that the earthquake robustness of the primary containment vessel is amply sufficient (estimated safety factor of 25). The CEA also proposes parking the two FLS fire-fighting trucks (one filled with Marcalina powder) in a place that will not be impacted by the possible effects of an earthquake.

In the event of a sodium-water reaction, the licensee plans venting the hydrogen produced. Nevertheless, if a large-scale sodium-water reaction takes place, the intervention possibilities will be very limited, and perhaps inexistent.

In an earthquake occurs, only sodium leaks in the double-walled vessel and the fuel storage tank vessel can be detected by the SAMU (Ultimate Situation Measurement Acquisition System) which has an autonomy of 8 hours and can be resupplied by a diesel generator set. It should be noted that the CEA has undertaken to detail its action plan relative to additional sodium fire extinguishing means as envisaged in the ECS report.

In the event of flooding, a sodium-water reaction could be detected with the portable hydrogen detection instruments of the FLS.

Identification of the factors potentially hindering accident management and of the resulting constraints

In its CSA report the CEA analyse the possible consequences of an earthquake or flood on the availability of the emergency intervention means, and notably:

- total loss of electrical power supplies and fluid supplies;
- a secondary accident due to a fire, explosion or a criticality accident;
- damage to the access road to the centre;
- potential contamination of water in the event of flooding;
- atmospheric contamination;
- the presence of propane in the northern area of the centre;
- the presence of hydrogen in the NPP;
- the presence of corrosive water (sodium hydroxide) in and near the NPP;
- uncertainty of the availability of the technical intervention means owing to their potential damage further to the earthquake.

The licensee has given a commitment regarding the assessment of the induced hazards external and internal to the facility (global CEA commitment).

Conclusion on the planned organisational measures for accident management

The CEA indicates in its CSA report that the availability and functionality of the technical and human resources necessary for the intervention might not be fully guaranteed after an earthquake of exceptional intensity: the implementation of emergency management such as it is planned for in the PUI risks being disrupted by shortcomings in equipment and personnel availability. The CEA nevertheless underlines the ongoing construction of a building designed to seismic standards, situated outside the floodable zone, and accommodating the emergency command post in particular. Moreover, the CEA indicates in the CSA dedicated to the Phénix facility that further measures are planned to improve the situation, such as having vehicles stationed in appropriate places out of range of the impacts of an earthquake: a vehicle equipped with portable radiation protection equipment, two FLS fire-fighting vehicles, pumping gear and a diesel generator set. A satellite telephone will also be provided in the centre's FLS security command post.

The CEA has envisaged the following measures (some of which were mentioned earlier in this report) to reinforce the accident management capabilities of the Phénix facility in particular:

- procuring means to limit the ingress of water into the buildings (inflatable anti-flood tubes);
- establish a preparation procedure for the mobile pumping means in the event of forecast river flooding or rainfall events;
- have a buffer volume for storing potentially contaminated water before treatment and discharging into the environment;
- study the setting up of argon or nitrogen tanks and injection means to ensure the inerting of certain sodium-containing areas;
- study the implementation of means of injecting Marcalina power into the sodium-containing areas to extinguish a fire;
- specify its plan of action relative to complementary sodium fire extinguishing means.

These measures chiefly target the means of fighting floods and sodium fires.

In addition, in the framework of the centre's CSA that will be submitted in September 2012, the licensee has undertaken to examine the environmental instrumentation necessary for emergency management.

ASN considers it necessary for the CEA to implement additional measures for managing the situations that can lead to sodium fires. ASN will issue a requirement for CEA to submit a plan of action relative to the setting up of complementary means for extinguishing sodium fires.

6.2.2. Reactor operated by the ILL

As indicated earlier, the feared severe accidents are meltdown in air and BORAX (explosive type of reactivity accident).

The ILL has thus presented in its CSA report the accident management measures aiming at guaranteeing:

- core cooling before and after the fuel becomes damaged;
- cooling of the spent fuel elements in the pool ;
- containment after fuel damage, that is to say control of environmental releases.

Identification of the factors potentially hindering accident management and of the resulting constraints

The ILL considers that the following factors can aggravate accident management:

- an earthquake, which could have an impact on the means of communication (the current PCS is designed to the SSE earthquake);
- flooding to a level of 216.2 m NGF, which would render the current PCS unavailable, as it is designed to a level of 210.5 m NGF;
- combined earthquake and flooding.

The ILL indicates that it has particular operating instructions dedicated to the management of the facility in the event of an earthquake or flooding.

The analysis of the resistance of the structures and equipment in the event of an earthquake, flooding or the two combined is presented in the "earthquake" and "flooding" sections of the present report.

The ILL has undertaken to assess the possible impact of the industrial environment and the communication routes on the emergency management means.

Existing severe accident management measures

As mentioned above, severe accident management requires management of cooling and containment.

ILL considers that the management of core cooling before damage occurs relies on:

- controlling the water inventory in the pile block above the natural convection valves;

- controlling the level of water in the pool, above the pile block, with the pool acting as the ultimate cooling source.

The loss of heavy water inventory in the pile block can be detected from the control room, the PCS, or the reactor building. The safeguard actions consist firstly in isolating the pile block (in an earthquake situation, the isolation function would not be available) and secondly in resupplying the pile block with water from the emergency water make-up system (CES), which can only be controlled from the PCS. The time required to resupply the pile block with water is estimated at 60 minutes if external means (motor-driven pump) are deployed.

With regard to core cooling management after damage has occurred, it must be noted that the core could be situated in the reactor pool further to failure of the pile block. In this extreme hypothesis, control of the facility would still consist in maintaining the pool water level by using the CES. The resupply procedure is similar to that used for the pile block. The pool water level can be monitored from the control room and the PCS. After an earthquake, the information would only be available in the PCS, and it would be lost if the PCS became flooded. The licensee carried out a study which it qualifies as highly conservative and which concluded that the molten core cannot melt through the pool bottom lining (particularly in view of the difference in melting temperature between the aluminium matrix of the fuel and the steel of the pool). The licensee moreover considers that the risk of recriticality does exist but would not significantly aggravate the consequences of core meltdown, given the depth of the pool and the thickness of the concrete walls.

With regard to the control of spent fuel element cooling in channel 2, the ILL considers that it relies on:

- controlling the water inventory in channel 2;
- controlling the "emergency rod drop" function for the fuel element present in the transfer cask.

The information on the channel 2 water level is available in the control room and the PCS, and water make-up is carried out using the emergency water make-up system (CES) from the PCS.

The licensee also indicates that water loss from the cask can be detected from the control room, the PCS or in the reactor building. The cask water temperature can also be monitored. If there is a confirmed drop in the cask water level, the shift supervisor can perform make-ups with heavy water or light water. If the water level cannot be restored, emergency dropdown is carried out; this can be done from the control room or the PCS. These dropdown systems are tested regularly. Emergency dropdown using the system takes 10 minutes. In the event of loss of the backed-up electrical power supplies, dropdown can be performed manually in 30 minutes in the reactor building.

Lowering of the water level in channel 2 or the cask is detected by an alarm associated with the measurement of dose rate above channel 2. The diagnosis can be confirmed by two other sensors. These measurements are available in the PCS but would be lost in the event of an earthquake or flooding.

With regard to containment management, the HFR has a double-walled containment: an inner containment in reinforced concrete and an outer containment consisting of a metal wall. The annular space between them is kept at a positive pressure of 135 mbar to prevent any direct leakage from the inner containment to the exterior. Management of environmental releases in these cases consists:

- maintaining positive pressure in the annular space between the inner concrete containment and the outer metal containment, associated with the static containment. The overpressure value is defined according to the risk of combustion of the cold and hot neutron sources: 15 mbar if combustion has already occurred, 75 mbar if it can be excluded;
- or limit the pressure rise in the inner concrete containment by making discharges through the EG (gaseous effluents) circuit equipped with two HEPA and PAI (Iodine trapping) filtration lines.

The pressure rise in the inner containment can be due to a possible BORAX-type explosive reactivity accident, to the combustion of cold and hot neutron sources or the heating of the air in the hall by the residual power of the spent fuel elements, to heat transfers through the double-walled containment, or to leaks from the pressurised annular space and evaporation of water from the pool.

Detection of an abnormal radiological environment in the reactor hall or the detection of an earthquake causes automatic isolation of the containment.

Provisions for improving the robustness of the facility with respect to containment management in the event of an earthquake have been adopted in the CSAs. They are presented in the "earthquake" section.

In addition, the licensee has also assessed the hydrogen risk due primarily to the "cold neutron sources". The conclusion is that the average hydrogen concentration in the hall would not exceed 0.3%, that is to say one tenth of the lower explosive limit (LEL) of hydrogen in air. However, the means of detection and management of a deuterium leak would be rendered unavailable in the event of an earthquake or flood.

Facility monitoring measures (required instrumentation)

Control of the facility in an earthquake situation is ensured from the PCS, which constitutes the fall-back centre, situated 170 metres from the reactor. This control centre is supposed to amply withstand an earthquake of the SSE intensity and the explosion of a tanker truck on the A480 motorway. It has an air purification and pressurisation system to protect against any external pollution of the air. In the event of an earthquake, the PCS allows:

- monitoring of the water levels in the pile block, the reactor pool and channel 2;
- the CES to be put into service and monitoring of the level of the associated water sources;
- monitoring of the radiological environment in the reactor building and at the bottom of the chimney stack (dose rate measurements);
- energising of the emergency fan housed by the PCS, which enables positive pressure to be maintained in the annular space;
- passive depressurisation of the reactor building hall. Reminder: on completion of the nonconformity processing planned in the near future, an active depressurisation function will be available after an earthquake.

Nevertheless, the information available at the PCS does not allow the "residual power removal" function to be properly diagnosed. This is because the licensee has no information on either the temperature of the heavy water in the core or the position of the natural convection valves which are supposed to fulfil the function when the reactor is shut down. The ILL will examine the possibility of having information concerning the most relevant physical parameters of the reactor relative to the objective, instead of information on the status of the systems responsible for fulfilling the function.

Likewise, the information available in the PCS does not allow a true diagnosis of the state of the "control of environmental releases" function. This is because the licensee only has a measurement of the dose rate at the bottom of the chimney.

The PCS power supply is delivered from one of the non-backed up auxiliary panels of the reactor. It is backed up by a 100 kVA earthquake-qualified diesel generator set that is started manually. This diesel generator set has an autonomy of 20 hours under full load. The ILL nevertheless estimates that in practice the autonomy would exceed 40 hours since the high-power equipment items will function intermittently or even not at all (gaseous effluent heaters, emergency water make-up system). Furthermore, the fuel can be replenished from the fuel available in the 2 main tanks of the facility's diesel generator sets. If necessary, an external mobile diesel generator set can be deployed to supply the PCS with power, but in this case the ILL would have to count on the mobile means of the CEA.

Measures envisaged to reinforce the existing measures and proposed studies

With regard to a severe accident situation and given the analysis carried out for the ILL's CSA, the licensee's major improvement commitment is to build, for the planned restarting in 2014, a new emergency operations control centre (PCS) called PCS3, meeting the following requirements:

- earthquake design basis: SSE with margins higher than 2 to cover the "ultimate plausible earthquake", SSE + σ ;
- flood design basis: 216.2 m NGF - the maximum water level physically possible on the site;
- explosion design basis: 80 mbar, corresponding to the explosion of a 20-tonne LPG tanker truck on the A480 motorway;

- radiation design basis: taking core meltdown in air when hot as the reference scenario;
- redundancy of all the backup means, including the necessary utilities (electrical power supplies in particular).

For this new PCS, the ILL has undertaken to:

- provide an uninterruptible power supply (UPS) for the equipment items involved in facility monitoring from this PCS 3;
- detail the design of the PCS 3 with respect to hazards associated with the industrial environment and the communication routes, and specify its functional requirements.

The ILL underlines that the PCS 3 will be permit the management of all types of emergency (nuclear, seismic, flood, combined hazards) and will be designed so as to allow the utilisation of all the new backup systems presented earlier in this report (CRU, CES, CDS, CEN).

Pending PCS 3's entry into service, and to improve the current situation, the licensee has planned to install, during the winter 2011-2012 shutdown, an additional emergency diesel generator set. In the event of site flooding, this generator will be capable of resupplying the normally backed-up electrical power supplies, allowing monitoring of the reactor and deployment of emergency means such as a motor-driven pump. The ILL has undertaken to specify the functional requirements of this additional emergency diesel generator set. It has also undertaken to examine the possibility of emergency takeover of the electrical power supply necessary for monitoring the facility from the PCS to cope with a starting failure of the dedicated diesel generator set after an earthquake.

The ILL has moreover undertaken to:

- add a fixed earthquake-qualified neutron detector in the pool that will deliver information to the future PCS 3 to inform operators of the critical state of the core should it be damaged in the pile block or the pool;
- install two passive autocatalytic hydrogen recombiners at the top of the containment and the top of the structural steelwork of the cold neutron source;
- install instrumentation that provides reliable information on residual power removal in the event of an earthquake exceeding the SSE (for an earthquake equal to $SSE + \sigma$);
- install earthquake-qualified instrumentation (qualified to a level at least equal to $SSE + \sigma$), enabling an accurate characterisation of the radiological activity of environmental releases in an accident situation,
- take measures to ensure the availability of the meteorological and environmental radiological monitoring data;
- supplement its demonstrations concerning the impact of an earthquake-induced fire or explosion.

It has also undertaken to:

- continue its reflection on the integration of the organisational and human aspects in accident situations;
- examine the operability of the method of alerting and deploying its emergency teams in the extreme external hazard scenarios studied in the CSAs
- take measures to guarantee the reinforcement of the emergency organisation with means from outside the BNI

The ILL has also planned buying satellite telephones.

ASN considers that the proposed measures must be implemented, the major improvement being the creation of a new PCS (PCS 3) taking into account the hazard risks studied in the CSA. ASN will issue requests to the ILL in this respect.

6.2.3. *Facilities of the nuclear fuel cycle*

Tricastin site

The licensee has presented the measures implemented on the Tricastin site in its CSA report. These measures are presented in the preceding sub-chapter.

La Hague site

The feared situations identified by the licensee for the La Hague site are:

- With regard to the risks due to releases of heat from radioactive material:
 - loss of cooling of the spent fuel pools of units NPH, C, D and E;
 - stopping of rotation of the pendulum-type centrifugal decanters (DPC) of units R1 and T1;
 - loss of cooling of the concentrated fission product storage tanks in units R2, T2, T2C, T2D, SPF5, SPF6, R7 and T7;
 - loss of cooling of the fission product concentration evaporator condensers of units R2 and T2;
 - loss of cooling of the plutonium oxide (PuO₂) container storage areas in units BSI and BST1;
- With regard to the risk of explosion of hydrogen from radiolysis:
 - loss of the supply of air sweeping the storage tanks of concentrated fines solutions and alkali rinsing solutions from units R1, T1, T2, R7 and T7;
- With regard to the loss of containment risks
 - loss of tightness of the HAO and 130 waste storage silos, and of unit STE2-A.

Identification of the factors potentially hindering accident management and of the resulting constraints

The dimensions of the site can hinder severe accident management, resulting in long delays in the implementation of consequence-mitigation actions.

The limited robustness of certain support buildings (FLS, infirmary, administration building and building 148) is also a factor that could hinder accident management by creating material disorders or loss of human life.

In an earthquake-induced fire situation, the build-up of fumes in the premises could hinder the emergency intervention actions in addition to the possible disruptions caused by the earthquake.

A failure in the civil engineering of the pools (breach) or serious disorders around the pools further to an earthquake are factors that could hinder accident management, and notably the implementation of the planned means to mitigate consequences.

Existing severe accident management measures

In addition to the means presented in the preceding paragraph, the licensee has specific means for each feared severe accident.

Loss of cooling:

According to the licensee, the site currently has water supply sources it considers robust to an earthquake and providing sufficient autonomy to restore the cooling systems:

- the West pond with a capacity of between 30,000 and 55,000 m³;
- the Moulinets dam, holding between 250,000 and 410,000 m³;
- the Froide Fontaine dam holding a maximum of 5,000 m³ of water.

The licensee plans deploying the following means to manage a cooling loss:

- supplying water to the equipment (pools, FP tanks, etc.) using motor-driven pumps and a network of fire-fighting-type pipes installed in the emergency management process and supplied from the sources presented above;

- powering, by a diesel generator set, a fan for the PuO₂ storage pits. As the diesel generator sets have an autonomy of several hours, the licensee plans refuelling them with diesel fuel brought in transportable tanks from the site's safeguard fuel stock.

Loss of rotation of the DPCs in units T1 and R1:

Assuming the loss of the electrical power supply to the pendulum-type centrifugal decanters (DPC), including the backup supply in an aggravated scenario, return to the ultimate safe condition involves unclogging amalgamated solid particles to cool them down, which requires:

- manually rotating the decanter bowl;
- then injecting water under pressure from a tank provided for that purpose.

These operations are planned for in the emergency organisation in place on the La Hague site.

Loss of dilution of hydrogen generated from radiolysis:

For the management of a severe accident associated with the loss of dilution of radiolytic hydrogen, the licensee plans supplying air from compressed air cylinders. The connections between the tank sweeping pipes can be made with connecting hoses.

Measures envisaged to reinforce the existing measures and proposed studies

Loss of cooling:

In addition to the means existing on the site, the licensee plans studying:

- installing quick-fitting couplings on certain internal loops of the cooling systems of equipment requiring remedial action within 48 hours;
- increasing the inventory of motor-driven pumps and associated accessories in order to cater for the compounded nature of the scenario and distribute the water necessary for the facilities to attain the ultimate safe condition;
- adapting the ventilation systems of the BSI and BST1 storage areas to allow a minimum level of passive cooling.

The licensee also envisages drilling wells to establish a water supply from the water table.

Loss of dilution of radiolytic hydrogen:

In addition to the means already present on the site, the licensee plans studying the installation of compressed air cylinder racks in certain buildings were remedial action with respect to radiolytic hydrogen sweeping is required within less than 48 hours.

Proposed studies to complete the procedure:

The licensee has undertaken to submit a cross-site emergency management study (coordination and intervention means), integrating:

- the consideration of potential compounding factors (fire, explosion, load fall, criticality, hazardous substances, installations classified on environmental protection grounds (ICPEs)) that could speed up the occurrence of feared situations or disturb remediation actions;
- assurance of the operability of the emergency means in the context of an overall assessment of the status of the site and its environment, for all the hazards considered in the CSAs, including those associated with the communication routes and the industrial environment, induced effects included;
- the impact of potential transport accidents on the La Hague site on the feasibility of the emergency management actions.

The licensee has undertaken to integrate in this cross-site study:

- the means for returning the cooling systems of the pools and concentrated fission production solution storage tanks to service as rapidly as possible;
- the sizing of the site's water supply resources so that they can cope with the cooling water needs of the accident-stricken units and the fire-fighting needs, and give justifications for how the different water contributions will be prioritised.

The licensee has also undertaken to enhance the robustness of the means of resupplying water to the pools and the units accommodating the concentrated fission product solution storage tanks to ensure the rapid resupply of these units with water brought from a relatively invulnerable place, particularly with respect to the possible site disruptions (collapsed building, ICPE-type accident, etc.), releases of radioactive substances or chemicals and increase in radiation levels, without excluding:

- the installation of pipes between the units housing the concentrated fission production solution storage tanks on the one hand, and the West pond on the other, in view of its situation, which is relatively unaffected by the general state of the site;
- the pre-positioning of the pumps for collecting water from the retention pits of pools C, D and E accumulated in the building and the multiplying of the points for injecting water into the pools (C, D, E and NPH). The case of the fission production solution concentration evaporators will be examined.

ASN considers that the means for resupplying the pools and units housing the concentrated fission product solution storage tanks must be rendered more robust to ensure fast resupply of water.

For the legacy waste storage silos (BNI 33, 38 and 80), ASN will ask AREVA to give it a schedule for proceeding with recovery of the effluents contained in the silos as rapidly as possible, along with all the elements justifying its proposal.

ASN will also ask AREVA to propose the reinforcement of silo monitoring, of the technical provisions, and of the type of geotechnical containment or equivalent, with the aim of enhancing environmental protection by preventing and mitigating the consequences of a leak from these silos.

Others (Mélox, FBFC)

Mélox

The planned intervention means for each accident situation considered are described in the PUI. Operation is ensured by teams working continuous shifts. These teams are capable of diagnosing the situation and carrying out the actions to help secure the facilities; they can call upon the on-call teams. Moreover, the FLS and SPR (Radiological Protection Service) of the CEA Marcoule, and possibly the SDIS (Departmental Fire and Emergency Service), can provide reinforcement.

The emergency management premises are situated in building 502 (non-nuclear). This building dates from before 1992 and has not been designed to current seismic standards or designed to protect the teams against a radioactive or toxic cloud. The licensee has therefore planned for fall-back solutions, either in other Mélox buildings, or within the CEA Marcoule emergency command post.

Measures envisaged to reinforce the existing measures and proposed studies

In the complementary safety assessment the licensee analysed the consequences of a severe accident affecting the entire Marcoule site and beyond. From this analysis it established a list of the technical means necessary to remedy insofar as possible the consequences of different accident situations:

- total loss of the water sources;
- loss of cooling in a storage area;
- loss of confinement.

This list comprises:

- pumping means (one pump with a capacity of 15 m³/h and one with a capacity of 5 m³/h);
- electrical power supply means (one 100 kVA generator set, two 20 kVA mobile generator sets, 2 transportable fuel tanks);
- cooling means (a reserve stock of boron in bags, a refrigeration unit and auxiliaries: 52 kVA);
- handling and storage means (one all-terrain truck, maritime containers, 2-m pierced steel planks);
- communication means (satellite telephones);
- emergency premises (pre-equipped, positive-pressure sealed tent).

Conclusions on the planned measures to mitigate the consequences (radioactive or chemical releases) in a severe accident situation

The emergency organisation and means implemented in an accident situation at the Mélox facility are based on several resources of CEA Marcoule (PCD-L premises, FLS and SPR).

It is important that the licensee's cross-site study into emergency management should clearly identify the availability of these means for the hazards defined in the CSA and which would impact simultaneously the Mélox facility and other facilities on the CEA Marcoule site.

If availability turns out to be insufficient, the licensee must acquire its own emergency management means that give it intervention autonomy with respect to CEA Marcoule.

In the inventory mentioned earlier, AREVA plans sharing certain resources with other facilities belonging to the group.

ASN considers that for the Mélox facility the licensee must take into account the risk of a cliff-edge effect associated with loss or deterioration of the last filtration level further to a fire in one of the powders unit rooms concomitantly with an earthquake. It considers that the licensee's ability to implement the appropriate measures to limit the rise in temperature within the required times remains an essential parameter. ASN will issue a requirement on this subject.

ASN considers that the licensee must demonstrate that, whatever the extent of sharing of means, it will have the necessary means to intervene on its facility in an accident situation.

ASN moreover estimates that the licensee must clarify the conditions of the intervention agreement signed with the CEA Marcoule so that it is guaranteed immediate access to the information of importance for control of the plant: weather alerts, incidents occurring on the other facilities on the site and their consequences. ASN will issue a request to the CEA in this respect.

FBFC

The licensee identifies two feared severe accidents

- in the conversion building C1: loss of containment of the 6 cylinders of UF₆ and the associated autoclaves heating in the emission zone with loss of containment in the building as well, leading to the release of UO₂F₂ and HF into the environment;
- in the HF station: loss of containment of the 2 tanks of concentrated HF at 55% installed in the station, leading to a large release of HF directly into the environment.

Identification of the factors potentially hindering accident management and of the resulting constraints (countermeasures that already exist):

Generally speaking, for the 2 accidents mentioned above the main factors that could hinder accident management are:

- loss of tightness of a system containing UF₆ (cylinder, autoclave) or HF (system discharging the HF produced by the conversion of UF₆, HF tanks), which could create a UF₆ leak in the autoclave room or an HF leak in the HF station;
- loss or malfunctioning of the UF₆, uranium or HF detection system, which would prevent rapid detection of the problem;

- loss or malfunctioning of the transmission of alarms to the control room, which would prevent rapid detection of the problem;
- non-starting of the systems for scrubbing the HF present in the air in the premises, which would generate HF releases directly into the environment;
- failure of static containment or of the conversion building ventilation filtration system, which would cause releases of radioactive substances directly into the environment.

The mitigation means proposed for a gaseous HF release into the environment is spraying from the exterior with the aim of knocking down the HF cloud.

For the two feared accident situations, the weak point for which no solution is proposed at present is the fact that the alarms are not integrally transmitted to the control rooms or emergency management premises, and moreover the existing transmission systems are not designed to seismic standards.

Existing severe accident management measures

The emergency management means are not specific to the feared severe accidents but applicable to any emergency management situation.

Facility monitoring measures (required instrumentation):

As a general rule the licensee considers that once the facilities have been placed in safe condition, nothing more is to be done inside them. The important factors are therefore:

- the reliability of the transmission of alarms to the control room;
- the reliability of the automatic systems for placing the facilities in safe condition, or the accessibility under all circumstances of the manual systems for placing the facilities in safe condition.

ASN has no particular remarks concerning FBFC.

6.2.4. Other facilities

ATPu

Feared severe accidents

The severe accidents considered by the licensee for the CSAs would result from an earthquake of greater intensity than the "safe shutdown" earthquake or a flood beyond the flood safety margin level.

Identification of the factors potentially hindering accident management and of the resulting constraints

The licensee does not identify any particular factor that could hinder accident management. The Cadarache centre is situated far from large built-up areas and other industrial facilities. The nearest pressurised gas pipe is 1.5 km away and the pipe supplying the centre presents no particular risk. In the event of a flood or earthquake, the centre would remain accessible from the off-site public road network.

Existing severe accident management measures

The licensee identifies the following potential intervention means for a severe accident such as an earthquake or a flood:

- The devices for cutting off the facilities' industrial water supply and the electrical power supply;
- The means of communication (satellite telephones, microwave transmission network);
- The emergency diesel generator sets;
- The mobile radiation protection equipment;
- The pumping equipment, etc.

Measures envisaged to reinforce the existing measures and proposed studies

The licensee proposes no measures to reinforce the existing provisions, as decommissioning is in progress.

ASN has no particular remarks concerning the ATPu.

Masurca

Loss of the electrical power supplies for the Masurca facility does not lead to the risk of a cliff-edge effect, and no cooling is necessary given the current status of the facility. Only the post-earthquake management is handled by the CEA.

The review conducted by the IRSN, ASN's technical support organisation, put forward that - contrary to the conclusions of the licensee - there is apparently a real toxicity risk in the event of fire due to the presence of sodium on the facility. This risk could complicate management of an accident situation.

Existing severe accident management measures

The CEA specifies that a procedure specific to Masurca has been put in place to define the initial actions to take in the event of an earthquake, the aim being to reach a shutdown state immediately after the earthquake and conduct investigations to assess the situation and take conservative measures to lastingly maintain the facility in safe condition.

The actions to take depend on the intensity of the earthquake. In the case of a "weak" earthquake, that is to say in which the BSM (storage and handling building) remains intact and the functions are operational, the actions will consist in verifying the assumption of "good behaviour" of the facility through inspections targeting the points judged to be sensitive. In the case of a "strong" earthquake (substantial damage to the BSM and many functions out of service), safeguard actions shall be implemented to prevent possible aggravation of the situation (fire, explosion, collapse, leaks, etc.).

Among the recommended actions, the CEA plans cutting off the supplies of electricity, water, diesel fuel and argon-CO₂ to avoid risks of an indirect effect further to an earthquake.

The CEA also indicates that depending on the nature and severity of the damage suffered by the facility, measures would be taken to prevent or mitigate environmental contamination.

With regard to the fire risk, the fact that sodium is present in the facility means that the risk of a sodium-water reaction when fighting a fire must be considered. The CEA has specified in this respect that the use of water for fighting fires in the Masurca facility is prohibited by the emergency intervention instructions.

The CEA plans for manual cut-off of the electricity, water, diesel fuel and argon-CO₂ supplies in the event of an earthquake. The intervention instructions underline that the security duty watch (PMS) is ensured by a single person outside working hours.

Due to the risk of the BSM collapsing in an earthquake, the CEA has decided to temporarily store the fissile material from BSM storeroom No.1 - the main contributor to the radioactive material inventory of the BNI on 30 June 2011 - in the MAGENTA facility, until the new BSM designed to seismic standards enters service in 2017.

ASN considers that the currently stored fissile material must be removed in the short term. ASN will issue a requirement to set the deadline in this respect.

In addition, the licensee has not specified the concrete measures envisaged to mitigate the radiological consequences on the environment.

It has nevertheless developed the description of post-earthquake management. In the event of an earthquake causing partial or total collapse of the BSM and leading to a cliff-edge effect, the centre's own means will be called upon, along with external means if necessary. In this latter situation, emergency management will be coordinated by the Crisis Coordination Centre (CCC), which will be able to deploy the human and material resources of GIE INTRA (group deploying robot intervention on accident sites). This group is capable of getting its teams and equipment to the site within 24 hours at the most.

The review has revealed that the CEA has no means of limiting environmental contamination.

With regard to the study of the risks associated with the industrial environment, the general approach adopted by the CEA is initially to identify - through the Cadarache PGSE (general presentation of the site and facility) and the safety frame of reference in effect - the industrial facilities, hazardous material pipelines and communication routes (road, rails and river) in the vicinity of the Masurca site. In a second phase the CEA assesses the potential risks associated with the hazard sources on the basis of the existing studies for the BNIs in question. With regard to the risks from outside the CEA Cadarache site (industrial environment and communication routes), the CEA concludes that there is no potential source of risk. With regard to the on-site industrial environment, the CEA concludes that the BNIs and ICPEs situated in the vicinity of the Masurca facility has no impact or only a "negligible impact " on its safety.

Measures envisaged to reinforce the existing measures - Opinion of ASN

No measures have been proposed by the licensee.

To conclude, ASN considers that the licensee must clearly define the measures to implement on the Masurca facility in an earthquake situation, particularly to limit environmental contamination, taking account of the toxic risk associated with the presence of sodium and the ambient environment conditions associated with the risks of material dissemination and criticality.

On this account ASN considers that in its report on the Cadarache site due in September 2012, the CEA must present its assessment of the means that could mitigate the environmental consequences of situations leading to total or partial collapse of the Masurca facility BSM building in the event of an earthquake. The accessibility of the facility and consideration of the induced effects such as a fire or a criticality accident must be included in the assessment. The means of ensuring radiological monitoring of the environment and releases shall also be considered.

7. Conditions for use of outside contractors

The Fukushima accident showed that the ability of the licensee and, as applicable, its contractors, to organise their work in severe accident conditions is a key factor in managing such situations. This ability to organise is also a key factor in facility maintenance, the quality of operations and thus the prevention of accidents. The conditions for resorting to subcontracting are thus of particular importance and should enable the licensee to retain complete control of and full responsibility for the safety of its facility. This importance was also underlined by the stakeholders, particularly the HCTISN, as of the beginning of the process to draft the ASN specifications for the CSAs. The ASN specifications thus asked the licensees to analyse the conditions for the use of outside contractors.

Furthermore, and more generally, ASN considers that incorporating socio-organisational and human factors into the safety approach is fundamental and this aspect is covered both in the inspections conducted by ASN and on the occasion of the periodic safety reviews of the facilities. The experience feedback from the Fukushima accident will also be taken into account.

ASN reviews the conditions for the use of subcontracting in nuclear facilities during the meetings of the advisory expert committees for reactors and for laboratories and plants, which thus examined CEA's safety and radiation protection management strategy in 2010, and that of AREVA in 2011. It is also carrying out targeted inspections on this topic.

7.1 AREVA

Scope of activities concerned

The ASN specifications for the CSAs ask AREVA to describe and justify the scope of activities concerned by subcontracting and to demonstrate that this scope is compatible with the licensee's full responsibility for nuclear safety and radiation protection.

In its complementary safety assessment, AREVA did not clarify its definition of contractor, nor the acceptable number of subcontracting tiers it considers to be manageable. The licensee does however point out that the chapter of the CSAs report devoted to subcontracting does not concern companies which simply supply equipment or consumables to the nuclear sites, without actually having to intervene on these sites.

The AREVA group has defined a list of activities it considers preferable not to outsource. These are the following:

- production;
- management of utilities necessary for production;
- maintenance of the "core process";
- maintenance of utilities;
- project ownership;
- safety and radiation protection services on each site.

With regard to subcontracting, one particularity of the AREVA group is that it has subsidiaries specialising in engineering, provision of services, supply of equipment and performance of special work. The activities outsourced for each of the nuclear sites operated by an entity of the AREVA group can thus be split into two categories:

- activities subcontracted internally within the AREVA group, representing between 40 and 50% of all the activities subcontracted, depending on the site, and generally concerning the following:
 - transport of radioactive materials;
 - management of radioactive waste;
 - engineering, in particular "core process" engineering;
 - washing of work clothes;
 - IT services;

- the activities entrusted to contractors outside the AREVA group, representing between 50 and 60% of all the activities subcontracted, depending on the site, and which generally concern the following:
 - management of effluents;
 - management of non-radioactive waste;
 - maintenance outside the "core process";
 - design or consultancy services;
 - inspections and periodic tests.

These general principles do not take account of the aspects specific to each site. Therefore,

- the operation and maintenance of certain nuclear activities are subcontracted on the La Hague and Mélox sites;
- the Mélox facility has another particular contractor, the licensee of the CEA Marcoule site, which manages the services common to the entire site, such as medical or security services;
- the La Hague, Tricastin and Mélox sites chose to subcontract all or part of the "core process" maintenance.

In its CSA reports, AREVA presents the volume of activities subcontracted in terms of costs, but without comparing this with the cost of the activities not subcontracted. It is not therefore possible to evaluate the scale of subcontracting on the sites operated by an entity of the AREVA group.

However, the costs of the subcontracted activities are presented. They can be broken down on the sites generally as follows:

- engineering: between 16 and 40%;
- maintenance: between 18 and 24%;
- construction, networks, upkeep of buildings: between 6 and 20%;
- transport of radioactive materials: between 1 and 24%;
- equipment, components: about 10%;
- clean-up or decommissioning of equipment, facilities or premises: between 2 and 7%;
- support activities (utilities, laundry, etc.): between 1 and 12%;
- waste management: between 2 and 4%;
- ISO certification, quality, inspections and periodic tests: 1%;
- others: between 3 and 6%.

In addition to these activities, AREVA states that subcontracting of the operation of some nuclear activities (La Hague and Mélox sites) represents between 3 and 6% of the total cost of the subcontracted activities.

Management of subcontracted activities

Contractor selection methods

The ASN specifications for the CSAs ask AREVA to describe how the contractors are selected: requirements concerning the qualification of outside contractors (in particular the nuclear safety and radiation protection training of the staff), formal specifications and types of contracts, methods for placing of contracts, steps taken to give subcontractor companies and their employees medium-term visibility of their activities.

With regard to the contractor selection procedures, the AREVA group has a general doctrine, which is a "buying" process implemented on the sites to take account of the specificities of each one.

This doctrine is applied through various site procedures concerning the following general topics (the title of the corresponding "site" documents varies from one site to another):

- drafting of specifications for calls for bids or requests for services;
- monitoring and receipt of a purchase order;
- evaluation of contractors or suppliers;

- contractor working conditions.

Each site also has its own "**contractor**" database with data supplied from a general information sheet for each contractor and from evaluation sheets drawn up following the performance of work. This database is used for pre-selection of the contractors (or a priori evaluation) when the site has to place an order or a contract. It would however appear that there is no pooling of the site's databases, in particular for the evaluation of contractors intervening nationwide throughout France.

It should be noted that among the contractors, AREVA identifies those it considers to be "strategic", who are the subject of particularly close monitoring:

- contractors performing work with an impact on safety, security, health, radiation protection or environmental aspects;
- contractors performing work entailing a proven technical risk;
- contracting representing a proven financial risk (turnover, degree of dependency);
- contractors representing a proven legal risk (monopoly situation, etc.).

The **contractor selection process** is common to all the entities of the AREVA group: the buyer (in other words the site Buying department) and the client (that is the site department which needs the service) evaluate the replies to the calls for bids or requests for orders, on the basis of a table of technical choices involving the following criteria:

- the contractor's compliance with its undertakings during previous contracts placed with the site;
- conformity with the specifications;
- the quality of compliance with safety, security, health, radiation protection and environmental requirements;
- the lead-times and schedule proposed in conformity with the requirements of the client;
- dosimetry optimisation (when this criterion is applicable);
- optimisation of the waste generated (when this criterion is applicable).

These are supplemented by commercial selection criteria, which are usually the following:

- the total amount of the bid;
- the costs breakdown;
- the quality of the commercial proposal;
- the contractor's degree of dependency.

Some sites also apply a criterion regarding the long-term stability of the contractor.

The contractor selection criteria presented above naturally take account of both technical and commercial aspects of the responses proposed by the candidates for the contracts. However:

- there is no clear criterion regarding management of several cascaded subcontracting tiers;
- during the course of previous inspections, ASN often observed that commercial criteria could carry more weight than technical criteria in the final selection.

Steps taken to ensure satisfactory intervention conditions for outside contractors

In its CSAs, ASN asked AREVA to describe the steps taken to ensure satisfactory intervention conditions for the outside contractors and to describe the organisation put into place for the radiation protection of their workers.

With regard to the doctrine and procedures managing the use of contractors, their conditions for access to the various sites and their working conditions on these sites, AREVA stated that there is a group level doctrine, which comprises:

- the values charter, in which the contractors are identified as stakeholders and which promotes a sustainable partnership relationship to ensure the best possible level of services;
- the "nuclear safety" charter, which promotes identical treatment of the employees of the group and those of the contractors, with regard to safety and radiation protection;
- a sustainable development commitment applicable to the suppliers, requiring that a high level of safety, health and security be achieved in the subcontracted interventions;
- the "safety, security, health, radiation protection and environment" directive for contractor working conditions;
- the acceptance procedure for radioactive clean-up contractors;
- the instruction concerning the placing of contracts comprising radioactive clean-up and decommissioning services.

On each site, this "group" doctrine is implemented through operating procedures or documents (the titles of these documents varies from site to site) covering the following general topics:

- safety;
- health and safety;
- radiation protection;
- what is expected of the contractors in terms of training, qualification, operational documents, working clothes, equipment, etc.;
- establishment of the work permit, which must be obtained prior to the beginning of the interventions.

With regard to **contractor training**, AREVA stated in its reports that the competence, training and qualification requirements are stipulated in the technical and other specifications, but without checking to ensure that there is exhaustive verification of these skills, training and qualifications.

AREVA stated that each site provides "visitor security" training to each new arrival on the site and, as applicable, takes steps to ensure awareness of or provides specific training for particular operations (glovebox work for instance).

Only the Mélox report indicates that the training given by the site is mandatory in order to obtain a work permit on the site.

Methods for monitoring subcontracted activities

The ASN specifications for the CSAs asked for a description of the methods for monitoring the subcontracted activities, in particular how the licensee continues to guarantee its responsibility for nuclear safety and radiation protection.

The main steps in contractor monitoring within the AREVA group are as follows:

- the work kick-off meeting;
- the progress checkpoints stipulated in the contract;
- the closure meeting which goes over feedback data;
- filling out of the licensee's internal contractor evaluation sheet.

Contractor monitoring comprises three levels of surveillance:

- technical surveillance (level 0);
- independent evaluations specific to each licensee (level 1);
- independent evaluations by the group's general management (level 2).

The AREVA reports give figures for the surveillance visits carried out in 2010, but they are not complete. In particular, only the level 1 surveillance is mentioned by all the sites (except Tricastin). Moreover, a comparison of these figures shows that the same number of level 1 visits was carried out in 2010 on sites of completely different sizes and risk levels.

However, the reports do not indicate how the contractor surveillance results were used and in particular whether or not each licensee analyses experience feedback concerning each contractor, when it holds several contracts, and whether or not there is overall experience feedback with regard to this surveillance.

AREVA states that it carries out a subsequent evaluation of its contractors, through the contract assessment form (FAM) which is used to input data into the "contractors" database mentioned in the "Contractor selection methods" chapter above. This FAM is based on the following criteria:

- the quality and conformity of the response to the call for bids;
- the organisation of the worksite or the service;
- the personnel involved (qualifications, training, experience, etc.);
- the quality of the design studies produced;
- the inventory and final condition of the worksite;
- compliance with the technical requirements or the applicable safety, security and environment requirements;
- the inspections carried out;
- the quality of performance;
- the quality of the documents provided.

Experience feedback is shared among the licensee and the contractors during meetings that are in principle annual, the general content of which is not specified in the reports and which would not seem to be actually held on all the sites. This sharing of feedback also takes place during the expanded CHSCT meetings, but in a format not specified in the CSA reports.

Conclusions on the conditions for use of outside contractors

Only two of the four CSA reports (for Mélox and La Hague) comprise conclusions. These however remain extremely general and indicate that the licensee has decided to keep in-house those activities referred to as "core business or expertise" and to choose specialist contractors for specific works, who can provide references in the nuclear sector and who are well-established locally. Thus, in the event of a severe accident situation, the licensee would be able to call on contractors who are well-familiar with the facilities, with expertise in safety, security, health, radiation and environmental protection for intervention on the facilities and who are capable of rapid mobilisation.

In the light of the above, ASN is not able to make a full assessment of subcontracting management within the AREVA group, as the data provided are incomplete.

In particular, AREVA fails to specify the steps taken to follow-up the ASN requests and observations made on the occasion of previous inspections, especially:

- the selection criteria and the consideration of financial aspects as opposed to technical safety and radiation protection criteria;
- the steps taken to ensure satisfactory contractor surveillance;
- the lack of inspections by the group general management on the topic of subcontracting;
- the absence of experience feedback on the basis of level 0 or 1 contractor surveillance.

ASN also noted that AREVA proposed no measures to tighten up the requirements concerning the conditions for use of outside contractors.

AREVA recently submitted a report on the group's subcontracting policy, in particular analysed in terms of nuclear safety, radiation protection, occupational safety and maintaining and developing skills. AREVA thus identified various areas for improvement aiming to:

- limit to 3 the subcontracting tiers for its operation and service activities;

- pursue its goal of gradually reducing the maximum doses delivered;
- deploy an action plan for increasing subcontractor participation in analysing and sharing experience feedback;
- define and implement social certification for the subcontracting companies.

ASN will examine this report and decide on the relevant steps to be taken subsequently.

7.2 CEA

Scope of activities concerned

CEA stated that it calls in outside contractors to *"provide services or perform work necessary for it to continue to carry out its duties and its activities or continue to function and for which it does not have the particular in-house skills necessary, or those which it does possess are not available when required for the envisaged mission"*.

The scope of activity concerned by subcontracting varies according to the BNIs concerned. Depending on the BNI, it in particular covers maintenance of various equipment items, in-service monitoring of certain equipment items, design studies for projects and their modifications, project management for particular works, project ownership for particular works, quality monitoring of the facility, performance of safety analyses or quality control of subcontracted operations. Project management of clean-up/decommissioning operations on the ATPu (BNI 32) is performed by AREVA NC Cadarache. Furthermore, for design and construction activities concerning the Jules Horowitz reactor (JHR), CEA calls on specialist suppliers (engineering, industrial firms, construction and erection contractors).

It would however seem that in some facilities, activities cannot be subcontracted. For example in BNI 39 (Masurca), *"some skills specific to operation of the Masurca facility are not subcontracted (e.g. reactor operation, warehouse management, etc.)"*. Furthermore, no provision is made for Osiris (BNI 40) *"to call on outside contractors for crisis management or accident situation recovery operations"*.

Contractor selection procedures

CEA states that *"each service is the subject of specifications defining the unit's requirements, the conditions placed on awarding of the contract, the stipulated requirements, particularly with regard to safety, and the expected results"*.

CEA also specifies that the methods chosen by the bidders to meet the safety obligations pursuant to the Labour Code (regarding occupational health and safety, in particular radiation protection) and the Defence Code (particularly regarding the protection and monitoring of nuclear materials) are part of the contractor selection criteria.

CEA has two tools for preliminary evaluation of the suppliers:

- the supplier evaluation procedure consists in collecting data to identify *"the characteristics of the contractors in the legal, financial, technical (areas of expertise, human and technical resources), organisational (quality, safety) and commercial (contracts concluded with CEA and with other customers) fields"*. The data collected enable an evaluation to be made of the work (services, supplies and works) done by the contractors under a contract, on the basis of technical conformity with the specifications, compliance with costs and deadlines, compliance with the regulations (environment, security, radiation protection and safety), provision of the documentation stipulated in the contract and the quality of customer service;
- for radioactive clean-up and decommissioning operations, the Acceptance Commission for Nuclear Site Clean-up Contractors (CAEAR) is a system for qualifying outside contractors. It is based on the contractor's professional experience, management of the contractor personnel's skills and how the subcontracting company takes account of safety and criticality, enabling CEA to make a *"pre-selection of contractors on the basis of safety, technical expertise and operator competence criteria"*. Following the various steps in this arrangement, which in particular comprises an evaluation audit, acceptance may be given for a maximum of three years and for clearly defined fields. CEA stated that a review is currently being conducted on the possible extension of the fields concerned by CAEAR to include facility operations.

The contracts are awarded on a best-bidder basis, consisting in *"selecting the proposal which provides the best guarantees of satisfactory completion, while remaining economically advantageous"*, in other words, that which conforms most closely to its needs and which, at reasonable cost, is best able to meet the stipulated requirements,

especially in terms of security and safety". The contractor is therefore chosen taking account of price, the contractor's technical capability, quality and safety results and organisation.

Steps taken to ensure satisfactory intervention conditions for outside contractors

CEA is responsible for general coordination of the preventive measures it takes and those taken by the head of the outside contractor. In this respect, it defines the rules and steps taken for risk prevention and ensures that they are implemented.

CEA indicates that an inspection is carried out on the workplace, the facilities and the equipment contained therein, prior to any intervention by workers from outside contractors, in particular to present the radiological risks specific to the facility and to the activities concerned.

With regard to radiation protection, CEA specifies that the head of the facility *"calls on the technical expertise of the department with competence for radiation protection at CEA (SCR/CEA) and coordinates the interactions between the SCR and the outside contractor"*. Moreover, the outside contractor's person competent in radiation protection (PCR/EE) *"acts under the responsibility of his or her employer and has responsibility for implementing the measures relating to radiation protection, in particular as defined in the specifications, the contract, the prevention plan and, as applicable, the agreement signed with CEA"*.

The SCR/CEA ensures that the persons in charge of radiation protection at the outside contractor *"have assimilated the radiation protection frame of reference requirements mentioned in the specifications and the prevention plan and, with the agreement of the Head of the facility, carry out the necessary spot-checks (sampling checks) (...)"*. The SCR/CEA may *"suspend the work of the outside contractor at any moment if it observes a real risk"*.

Finally, CEA recalls that *"the radiological protection measures and the level of personnel surveillance are the same for all exposed workers (CEA and outside contractors)"*.

With regard to management of the competence of the staff involved, CEA stipulates various measures according to the BNIs. Thus, for Osiris, CEA stipulates that *"measures to promote a safety culture are put into place for outside operators or workers in the facilities (...)"*. For Phénix, *"there is a specific training module for contractors who are to work in the facility (...)"*.

Methods for monitoring subcontracted activities

CEA states that monitoring of the contracted services is carried out *"in all fields concerning performance of the contract (safety, security, legal, technical, social, etc.) and, as necessary, involves the support units in the centres"*.

CEA ensures that the contractor and any subcontractors *"have set up an organisation appropriate to the nature of the contracted work and able to meet the safety and security objectives"*.

The surveillance provisions implemented vary according to the BNIs, but in general a CEA operative is designated for each contracted service. They monitor and exercise surveillance of the activities subcontracted and ensure compliance with the safety and security frames of reference. For the Phénix facility it is stipulated that *"the surveillance of a contractor is performed by the project management and directly by CEA or by an external inspection organisation (designated and monitored by CEA)"*.

ASN opinion on the conditions for use of outside contractors

Generally speaking, it would appear that the files transmitted by CEA comply structurally with the ASN specifications, presenting the steps taken for the four topics requested; scope of activities subcontracted, contractor selection procedures, conditions for intervention by the contractors and surveillance of subcontracted activities.

However, the information actually transmitted leads us to make the following remarks.

With regard to the scope of activities subcontracted, it would appear that the information forwarded by CEA only partially complies with the ASN request. Furthermore, a recent generic instruction showed that CEA does not have any formal tools for anticipating the skills requirements that would necessitate resorting to subcontracting.

CEA describes the provisions governing the intervention conditions for outside contractors, particularly in the safety and radiation protection fields. With regard to training, the arrangements for evaluating what was actually learned during the training are not described.

Concerning the surveillance of subcontracted activities, the elements presented comprise few actual details of the skills and responsibilities associated with the contractor surveillance duties and the methods for training the personnel in charge of these duties.

ASN notes that CEA envisages taking no particular steps to reinforce its requirements on this subject, after pointing out that it had not identified any particular difficulties when reviewing the conditions for resorting to the use of outside contractors.

CEA recently submitted a report on its subcontracting policy. ASN will review this report and decide on what steps are to be taken subsequently.

7.3 ILL

Scope of activities concerned

The ILL indicates that its policy for operation of the RHF is based on management of the core professions and know-how needed to guarantee the safety and availability of the required scientific operations. Consequently, the ILL performs the following operations with its own personnel:

- all RHF operational activities;
- all major maintenance operations (regular thimble replacements, replacement of the reflective tank, the RHF vessel);
- the majority of inspections and periodic tests (CEP);
- activities related to site and environment radiation protection (under the responsibility of the ILL radiation protection safety and environment department).

The following activities are subcontracted:

- very particular tests (such as the tests of the HEPA filters and the PAI (iodine trapping), performed by specialist contractors who generally intervene on the entire nuclear fleet);
- certain "conventional" maintenance and troubleshooting operations,
 - design studies;
 - manufacturing;
 - certain activities defined or chosen according to an annual programme.

The ILL specifies that for management of a crisis, CEA could assist it by making premises and crisis management resources available in the event of a site evacuation, and by providing aid to the injured and in the event of a fire (pending intervention by the Departmental Fire and Emergency Service (SDIS)).

To summarise, the ILL indicates that the use of contractors is limited to those fields of activity which do not risk leading to a loss of responsibility and autonomy.

Contractor selection procedures

For contractor selection, the ILL refers to a quality assurance note (NAQ n°12) which details the steps involved in the contractor selection process: creation of the call for bids file, transmission of the call for bids file and examination of responses to it. This examination takes account of quality assurance criteria such as the supplier's organisation and how it processes nonconformities.

Steps taken to ensure satisfactory intervention conditions for outside contractors

Given the nature of the work involved and the management system in place, entailing compliance with the prevention plans and application for and then granting of work permits, the ILL does not require any particular safety qualifications of its contractors. The ILL mentions two principal arrangements governing management of the conditions for intervention by outside contractors on the site:

- a security memo "Steps to be taken concerning outside contractors" based on Decree 92-158 of 20/02/1992 and articles R 237-1 to 28 of the Labour Code;
- Quality Assurance Note NAQ N° 34 "Work permit procedure".

Monitoring of operational dosimetry is governed by the "provisions of the prevention plan for the contractor(s) and of each work permit issued to the contractor."

With regard to radiation protection training, the ILL has created its own training module which is presented to any new intervention staff prior to issue of the authorisation for access to a controlled zone. These requirements are specified in the Quality Assurance Notes (NAQ) and radiation protection and security instructions.

Methods for monitoring subcontracted activities

The ILL specifies that "as stipulated in NAQ N° 34, any subcontracted intervention carried out on the site is supervised by the ILL manager who requested the works, as need be in association with persons from ILL acting as inspectors or providing assistance, for example for measures relating to radiation protection. Each service may be the subject of a quality audit during the course of the intervention and an evaluation of the subcontractor. These arrangements are specified in the work permit issued. NAQ N° 45 "Quality audit and evaluation of subcontractors" specifies the performance methods".

In this way all manufacturing or maintenance work on Equipment Important for Safety and Monitored Quality Equipment (EISMQS) performed off the site or on the site is supervised by an ILL manager and carried out in accordance with the requirements of the Quality Organisation Manual.

The ILL underlines the fact that the subcontracted tests and maintenance operations (in particular concerning the HEPA filters and PAI) remain supervised by the ILL operations, safety and radiation protection teams.

Steps envisaged for tightening the requirements concerning the conditions for the use of outside contractors

Following the investigation, the ILL undertook to continue to review its organisation of the surveillance of contractors performing monitored quality activities.

In the light of the above, the steps already taken and ILL's undertaking to continue its review of its organisation of the surveillance of contractors performing monitored quality activities, ASN has no particular remarks.

8. Conclusion

In 2011, the complementary safety assessments, extended to cover facilities other than power reactors, concerned 20 basic nuclear installations that varied widely, in terms of both their type (fuel cycle plants, experimental reactors) and their situation: under construction, undergoing commissioning, in service, in preparation for shutdown, or finally shut down.

Even though the framework defined at the European level concerns only power reactors, ASN made the decision to accord high priority to these facilities as of 2011, in the light of the potential safety implications.

As the CSAs approach was defined on the basis of the European stress test specifications designed for power reactors in service, adaptations were therefore necessary so that this approach could be applied to facilities which do not represent the same risks. These adaptations meant that choices had to be made in order to optimise the way these 20 facilities were processed, within the allotted time.

In this respect, it is essential to recall that the evaluation carried out in 2011 is simply the first step in the process to integrate the experience feedback from the Fukushima accident, which will be a lengthy one. It led ASN to examine the robustness of the facilities beyond the hazard levels considered in the design, and to request the first safety improvements. This approach will be continued in the coming years.

8.1 General evaluation

Following examination of these CSAs, ASN issued the following evaluations of the reports submitted to it for the facilities other than power reactors.

Concerning AREVA, the facilities targeted in 2011 are for the most part old, extremely diverse and inherently very different from the PWRs. Following its examination, ASN recognises that the CSA process, which was carried out in a very short period of time, on a wide variety of facilities and according to specifications originally defined for PWRs, does pose a number of difficulties for the fuel cycle plants.

Having said this, ASN nonetheless considers that AREVA did not complete the process and that it must be continued in order to finalise the safety improvements to be made to the facilities.

For CEA, ASN considers that the CSA approach to safety is on the whole satisfactory. CEA thus identified a number of areas for improvement that it could implement. In 2012, this approach will be supplemented by an analysis of the common resources on the Cadarache and Marcoule sites in particular, in compliance with the ASN decision of 5th May 2011.

With regard to the high-flux reactor operated by the Laue-Langevin Institute, ASN underlined the quality of the report submitted. The ILL conducted a highly detailed assessment of the margins and also proposed a large number of improvements.

8.2 Safety implications

Subsequent to the CSAs, ASN considers that the priority facilities examined offered a level of safety that is sufficient to warrant no request for immediate shutdown of any facilities. For information, the shutdown decision had already been made for the following facilities: ATPu, Phénix, Comurhex Pierrelatte, the old installations on the La Hague site, Eurodif, Osiris. The fissile material stored in the Masurca storage and handling building (BSM) also needs to be removed from storage.

For the other facilities, ASN will be asking the licensees to take a number of steps to reinforce their robustness. Some of these requests could concern facilities currently undergoing decommissioning, given the duration of the operations and the associated risks.

They will in particular concern reinforced seismic resistance, reinforced protection of the facilities against the risk of off-site flooding and crisis management measures.

8.3 Improving the robustness of facilities and forthcoming works

General requirements applicable to all the licensees

Definition of a hard core

Following the CSAs of the nuclear facilities conducted in the aftermath of the Fukushima accident, ASN considers that the nuclear facilities need to be made more robust to risks that are highly unlikely but not as yet considered in the design of the facilities or following their periodic safety review.

This entails providing the facilities with the means to enable them to deal with:

- a combination of natural phenomena of an exceptional scale and in excess of the phenomena used in the design or the periodic safety review of the facilities;
- severe situations, in particular long-duration loss of electrical power or cooling, which could affect all the facilities of a given site.

Therefore, by 30th June 2012, ASN will require that the licensees identify and justify a "hard core" of robust material and organisational measures, reinforced if necessary, to guarantee the operational nature of the structures and equipment enabling the fundamental safety functions to be performed in these exceptional situations.

These measures will ensure ultimate protection of the facilities, with the following three objectives:

- prevent a severe accident or limit its progression;
- limit large-scale releases in an accident scenario which could not be controlled;
- enable the licensee to perform its duties in the management of a crisis.

Continued action to ensure the conformity of the facilities

The diversity of licensee situations with regard to conformity means that each one has to be individually assessed.

Concerning AREVA, given the past history of the sites and the considerable diversity of the facilities, ASN underlines the fact that periodic safety reviews have not yet been carried out on all the facilities, but that they will have to be carried out soon. ASN will thus issue a requirement in this respect, leading to a review of the frame of reference. It considers that the situation needs to be improved and will closely monitor the steps taken accordingly, stipulating performance requirements and the corresponding deadlines. ASN will issue requirements for all the conformity reviews to be submitted no later than 31st December 2014.

Concerning CEA, since the 1990s, the BNIs have been the subject of conformity examinations on the occasion of the periodic safety reviews. CEA is taking the necessary steps to remedy any deviations observed. ASN considers that the steps taken by CEA are on the whole satisfactory, even if the lead-times could be improved.

Concerning the ILL, the conformity review is considered by ASN to be satisfactory. The licensee performed this exhaustively as part of the CSA approach. Most of the anomalies are related to delays in the processing of nonconformities identified during the previous periodic safety review. The licensee proposed a short-term action plan for dealing with them.

Crisis management

In order to perform its duties in an emergency situation, the licensee must have a robust organisation, in particular with regard to the extreme situations covered by the CSAs. ASN will thus be requiring that the licensees include organisational and material measures in their hard cores, which are elements essential for crisis management, in other words crisis management premises, material resources needed for crisis management, means of communication and technical and environmental instrumentation. ASN will also be asking that the licensees include in this hard core operational dosimetry resources, measuring instruments for radiation protection and individual and collective protection equipment, because initial experience feedback from crisis management at Fukushima shows that these were lacking.

The crisis management premises must be designed for hazards in excess of the current frame of reference. They will have to be accessible and habitable during long-duration crises and designed to accommodate the teams necessary for long-term site management. The control rooms are also crucial for crisis management and their accessibility and habitability must ensure that all the facilities on a given site can be operated and monitored in the event of releases of hazardous or radioactive substances.

The Fukushima events showed that an off-site hazard can affect several facilities on a given site at the same time. In the CSA reports, the licensees stated that the current organisation did not take account of this possibility. ASN will thus be asking the licensees to supplement their crisis organisation, so that they are able to manage a "multi-facility" event. For multi-licensee sites, it is also important that the licensees coordinate their crisis management and mitigate impacts on neighbouring facilities. This point will be the subject of a requirement for reinforced coordination between the licensees of nuclear, but also non-nuclear facilities.

Finally, during the inspections carried out in 2011, ASN observed that the sites have concluded agreements with external entities for management of a crisis situation. The site agreements with hospitals are frequently very old, with some of them dating back to 1989. ASN will thus be asking the licensees to regularly update these agreements and regularly test them.

Integrating organisational and human factors and use of contractors

ASN considers that additional steps must be taken regarding emergency situation management and the training of the personnel involved. It will thus be asking the licensees to define the human interventions required to manage the extreme situations studied by the CSAs and take account of crisis team shift changes and the intervention logistics necessary.

ASN will also be asking the licensees to send it the list of skills required for crisis management, stipulating whether or not these skills are liable to be provided by the outside contractors. The licensees shall prove that their organisation ensures the availability of the skills necessary in the event of a crisis, in particular if outside contractors could be used.

Finally, ASN will be asking the licensees to provide training and preparation for their personnel liable to intervene in extreme situations, to guarantee that they can be mobilised during such a situation and ensure that the outside contractors liable to intervene in crisis management adopt similar preparation and training requirements for their own personnel.

The Fukushima accident showed that the ability of the licensee and, as applicable, its contractors, to organise their work in severe accident conditions is a key factor in managing such situations. This ability to organise is also a key factor in the prevention of such accidents, facility maintenance and the quality of operations. The conditions for the use of subcontracting are thus of particular importance and should enable the licensee to retain complete control and full responsibility for the safety of its facility. Based on the CSAs, ASN considers that the monitoring of subcontractors performing activities important for safety needs to be strengthened and that this monitoring must in particular not be delegated. ASN has included a requirement to this end in the draft order setting out the general rules concerning BNIs. ASN also considers that the proposal by EDF, CEA and AREVA to limit subcontracting to tier 3 is an interesting suggestion worth examining. It recommends that research programs on these subjects be engaged, both nationally and at a European level. Finally, ASN will propose setting up a working group on these subjects, comprising the licensees, trades union organisations, the HCTISN, the Ministry for Labour and the ministries responsible for nuclear safety.

Furthermore, ASN considers that the renewal of the licensees' workforces and skills, at a time when there is major generational turnover combined with considerable work subsequent to the CSAs, is a fundamental point to which ASN will be paying very close attention.

Special requirements

The diversity of activities carried out in the fuel cycle facilities leads to the identification of specific feared accident situations that are different from those considered for the reactors. The licensees had to identify accident situations beyond the scenarios hitherto considered and to integrate them into the CSA approach.

Fuel cycle facilities - AREVA

Identifying the feared situations

In its selection of feared situations, AREVA chose those with the most demanding kinetics in terms of crisis management.

ASN considers that the analysis of feared situations needs to be supplemented to take account of accident situation combinations and problems with access to certain facilities, owing to the site context.

ASN will be asking AREVA to supplement its identification of feared situations by justifying the selection criteria used and by taking account of potential aggravating factors.

Increasing facility robustness to earthquake and flooding risks

As the facilities were all designed at different periods, they all have different seismic resistance levels. A distinction therefore needs to be made between facilities for which shutdown is already scheduled in the near future and those which are to continue with long-term operations.

For the facilities the licensee wishes to keep in service, ASN will be requesting the necessary reinforcements to guarantee at least the ability to withstand the safe shutdown earthquake SSE. This requirement concerns the TU5/W, Comurhex, Eurodif, FBFC facilities and certain units at La Hague. For the units for which shutdown is already scheduled, in particular on the La Hague site, ASN will be asking the licensee to implement compensatory measures.

For the Tricastin site, the licensee will have to reassess the consequences of flooding on the site and propose any necessary measures to take account of the various developments and changes made since the previous studies.

Improving risk management

For the Tricastin and Romans sites, ASN will be asking the licensee to study and implement effective means of reducing toxic gases, in particular a leak of hydrogen fluoride (HF) gas, uranium hexafluoride (UF₆), chlorine (Cl₂) and chlorine trifluoride (ClF₃).

For the Tricastin site, ASN will be asking the platform licensees to take the necessary steps to ensure that they coordinate well in the event of a crisis (consideration of the risks inherent in neighbouring activities, protection of the various crisis management premises, adequacy of the crisis management resources).

For the La Hague site, ASN will be asking AREVA to deploy additional, robust means of resupplying water to the pools and the units housing storage tanks for concentrated fission product solutions, as well as means of rapidly restoring cooling of the pools and storage tanks to service.

For the silos storing the legacy waste from the La Hague site, ASN will be asking AREVA to submit a schedule for recovery of the legacy effluents as rapidly as possible. ASN will also be asking it to initiate feasibility studies for the deployment of technical arrangements, such as a geotechnical containment or system with equivalent effect, to protect ground and surface waters in the event of a leak from these silos.

Research facilities and facilities undergoing decommissioning operated by CEA

Reinforcing the robustness of the facilities to the earthquake and flooding risk

The CSAs confirmed the elements concerning the seismic risk and resulting from the recent periodic safety reviews, demonstrating that the ATPu facility and the Masurca reactor fissile materials store were not designed to deal with this risk.

ASN therefore considers that:

- decommissioning of the ATPu must be completed as rapidly as possible. As at 30th June 2011, about half the glove boxes had already been processed;
- the fissile material stored in the Masurca reactor warehouse must be relocated soon to a facility designed in compliance with current seismic standards.

In the particular case of the Jules Horowitz reactor (JHR), it should be noted that margins are already designed into this facility in compliance with the most recent requirements. However, its current situation - under construction – led the licensee to propose additional improvements.

For the other facilities, ASN will submit requests to CEA regarding the few nonconformities or missing design studies that need to be addressed.

The flooding risks are minor for the CEA facilities examined in 2011. However, given the particular vulnerability linked to the presence of large quantities of sodium, ASN will be asking that additional studies be conducted on this risk and that improvements be made to the Phénix facility.

Improving risk management

For the ATPu facility and the Masurca reactor fissile materials store, the main risk concerns the possible dissemination of materials in the event of destruction of the buildings. The risk of criticality or fire could also make crisis management more difficult.

Given the current state of the facilities, ASN will be asking the licensee:

- concerning ATPu, to provide an operational estimate of the quantities of radioactive material present per area and to take the necessary steps to ensure that this estimate is available at all times, to allow effective management in an accident situation;
- for Masurca, to relocate the fissile material as rapidly as possible to a facility designed in compliance with seismic standards, at a time to be set in an ASN requirement. CEA has already made a previous commitment to ASN to carry out this relocation no later than at the end of 2013.

For the reactors (Jules Horowitz, Phénix and Osiris), the main risk is the loss of cooling. However, a considerable time would elapse before the occurrence of any cliff-edge effects.

ASN will be asking that the improvements identified for the RJH be implemented, in order to reinforce the ultimate backup cooling in the event of the most extreme situations involving multiple loss of redundant equipment.

Finally, ASN will be asking that additional steps be taken so that, in all circumstances, essential technical and environmental data be transmitted to a centre allowing management of the accident situation.

Research facility operated by ILL

Reinforcing the robustness of the facilities to the earthquake and flooding risk

Seismic behaviour nonconformities were identified. Most are the result of delays in processing the follow-up to the last periodic safety review. ASN will be asking for conformity work to be initiated in the very short term; some steps are already in progress.

The flooding risk was examined conservatively by the licensee; it would be a major risk in the event of multiple dam bursts on the Drac, especially with regard to crisis management, given the loss of several means of information and intervention. The licensee proposed building a new crisis PC, with information and intervention resources, designed in compliance with seismic standards and protected from flooding, even in an extreme situation. In the meantime, ASN will be asking for interim improvements to be put into place.

Improving risk management

With regard to the loss of cooling, it would appear that a considerable time would elapse before the occurrence of any cliff-edge effects, except in the event of significant breaches following an earthquake. The main risks are linked to the effect on the facility of extreme off-site hazards (flooding, earthquake). ASN will be asking for the planned improvements to be implemented in the near future, as proposed by the licensee, in particular concerning the resources for managing an accident situation. Additional measures will in particular need to be taken so that in all circumstances, essential technical and environmental data can be transmitted to a centre allowing management of the accident situation.

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- MÉLOX 2011-DC-0223
- CEA: RJH, Masurca, ATPu, Osiris and Phénix 2011-DC-0224
- ILL: 2011-DC-0216

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- CEA: MR/DPSN/SSN/2011 N°091/JC of 31/05/2011
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GLOSSARY

ACQ	Quality-related activity	CP1	CPY reactors 1st train: Tricastin, Gravelines, Dampierre and Blayais
AMT-C	Thermal Maintenance Agency – Centre (EDF)	CP2	CPY reactors, 2 nd train: Saint-Laurent B, Chinon B and Cruas
ANCCLI	National Association of CLIs	CPY	900 MWe series, 2 nd generation (28 units)
APR	Refuelling shutdown	CRF	Circulating water system (raw water)
AREVA	Industrial group active in the nuclear fuel cycle and construction of nuclear installations	CSA	Complementary safety assessment
ASG	Steam generator auxiliary feedwater system (EFWS)	CSM	Manche waste repository (ANDRA)
ASN	Autorité de sûreté nucléaire (French nuclear safety authority)	CVCS	Chemical and volume control system (primary system)
BAN	Nuclear auxiliary building	DAI	Automatic fire detection
BAS	Safeguard auxiliary building	DBE	Design basis earthquake
BDS	Security block (EDF)	DCH	Direct Containment Heating
BK	Fuel building	DCL	Control room and electrical building conditioning
BL	Electrical building	DI	Intervention request / Internal directive
BNI	Basic nuclear installation	DP	Particular directive
BORAX	Explosive type of reactivity accident	DPC	Primary cause diagnosis
BR	Reactor building	DRS	Design response spectrum
BWR	Boiling water reactor	DT	Technical Directive
C3	Last exit gates for the NPP personnel	DTG	General Technical Department
CAEAR	Acceptance commission for nuclear site clean-up contractors	DUS	Ultimate backup diesel generator
CCI	Corium-concrete interaction	DVC	Control room ventilation
CCWS	Component cooling water system	EAS	Containment spray system
CEFRI	French committee for the certification of companies for the training and supervision of personnel working with ionizing radiation	EAU	Containment instrumentation system for seismic monitoring and measurement
CEP	Inspection and periodic tests	ECI	Irradiated fuel elements
CERCA	Compagnie pour l'Étude et la Réalisation des Combustibles Atomiques (French atomic fuel research company)	EDAC	Criticality detection and alarm system
CFI	Circulating water filtration system	EDF	Electricité De France
CHSCT	Committee for health, safety and working conditions	EFWS	Steam generator auxiliary feedwater system
CIA	Incident/accident operation	EIS	Element Important for Safety
CIESCT	Inter-company committee on safety and working conditions	EL4D	Heavy water reactor situated in Brennilis, decommissioning in progress (EDF)
CLI	Local information committee	ELC	Local Emergency Team
CMM	Maximum thousand year flood	ELPI	Local initial response teams
CMS	Flood safety margin level (or CBMS)	EN	European Norms
CNRS	Centre National de la Recherche Scientifique (French National Center for Scientific Research)	EPR	European Pressurized water Reactor
CNR	Compagnie Nationale du Rhône	EPS	Probabilistic safety assessment
COGEMA	Compagnie GÉNÉrale des MATières nucléaires (AREVA group, now AREVA NC)	ERDF	Electricité Réseau Distribution France
CP0	900 MWe series, 1st generation (6 units)	ESRF	European Synchrotron Radiation Facility (in Grenoble, France)
		ESS	Significant Safety-related Event
		ESWS	Essential service water system
		ETY	Hydrogen recombination system
		EUR	European Utilities Requirements
		EVU	Reactor building ultimate heat removal system
		FARN	Nuclear Rapid Intervention Force

FEP	Contractor evaluation form	JPP	Fire-fighting water production system
FIS	Function important for safety	KRT	Plant radiation monitoring system (radiation protection)
FPC(P)S	Reactor cavity and spent fuel pool cooling and treatment system	LDP	Pressuriser relief line
FRAMATOME	Nuclear steam supply system manufacturer (now AREVA NP)	LII	Lower flammability limit
GAEC	Emergency team intervention guide	LLS	Backup turbine generator
GCA	Grand Canal of Alsace	LOOP	Loss of off-site power
GCT-a	Turbine bypass system - - atmosphere	LTC	Emergency technical room
GE	Generator set	MCCI	Molten Core Concrete Interaction,
GEF	Static generator set	MDC	Complementary domain equipment
GEM	Mobile generator set	MHPE	Maximum Historically Probable Earthquake
GES	Backup generator set	MMS	Mobile safety equipment
GIAG	Severe Accident Intervention Guide	MOPIA	EDF project acronym meaning "Implementing an attractive industrial policy"
GIE INTRA	Company deploying robot intervention on accident sites	MOX	Mixed OXide: fuel based on mixed uranium and plutonium oxide
GMPP	Reactor coolant pump set (see RCP)	MSK	A seismic effect measurement scale named after its inventors: Medvedev, Sponheuer and Karnik
GP	Advisory committee of experts (reporting to ASN)	N4	1450 MWe series (4 units)
GPR	Advisory committee of experts for nuclear reactors (reporting to ASN)	NAQ	Quality assurance memo
GUS	Ultimate backup generator set	NC	Not Classified
H1	Situation of total loss of heat sink on a PWR	NDT	Non-Destructive Tests/Testing
H3	Situation of total loss of backed-up electrical power supplies on a PWR	NF	French standard
HCTISN	French High Committee for Transparency and Information on Nuclear Security	NGF	French general datum system
HERCA	Head of European Radiation Control Authorities	NGFN	French normal general datum system
ICPE	Installation classified on environmental protection grounds	NGFO	Orthometric datum system
ICPE A	ICPE subject to authorisation	NPP	Nuclear Power Plant
ICPE AS	ICPE subject to authorisation with public protection restriction	NRC	Nuclear Regulatory Commission (U.S. nuclear safety authority)
ICPE D	ICPE subject to declaration	ORSEC	National emergency response plan
I-LHT	Inter-plant unit backup procedure	P4	First series of the 1300 MWe nuclear reactors (8 units)
IPS	Important for safety	P'4	Second series of the 1300 MWe nuclear reactors (12 units)
IPS-NC	Important for safety - Not classified	PAR	Passive autocatalytic recombiner
IRSN	Institut de Radioprotection et de Sûreté Nucléaire (French Institute for Radiation Protection and Nuclear Safety)	PBMP	Basic preventive maintenance programme
IRWST	In-Containment Refuelling Water Storage Tank – EPR reactor borated water tank situated in the reactor containment	PC	Command post
ISO	International Standard Organisation	PCD	Strategic management command post
ITS	Temporary safety instruction	PCL	Local command post
JAC	Classified fire-fighting water production system	PCS	Emergency control station (ILL – RHF)
JPD	Indoor fire-fighting water distribution system	PF	Fission products
JPI	Nuclear island fire protection system	PFI	High-intensity rainfall
		POLMAR	MARitime POLLution
		PPI	Off-site emergency plan
		PPRT	Technological risks prevention plan
		PSGE	General presentation of the facility safety
		PTR	Reactor cavity and spent fuel pool cooling and treatment system (FPC(P)S)
		PUI	On-site emergency plan

PUI SR	On-site emergency plan - radiological safety	SEO	Plant sewer system
PV	Volumetric protection	SEPTEN	Service d'études et projets thermiques et nucléaires (Thermal and nuclear studies and projects service)
PWR	Pressurised water reactor	SER	Conventional island demineralised water distribution system (including storage)
RCD	Reactor completely unloaded	SEVESO	"Seveso II" directive: name given to Directive No.96/82 on the control of hazards associated with major accidents involving hazardous substances (in reference to the place of an accident that occurred in 1976 in a chemicals plant)
RCP	Reactor Coolant Pump	SG	Steam generator
RCV	Primary system chemical and volume control system (CVCS)	SHOM	Service Hydrographique et Océanographique de la Marine (French naval hydrographic and oceanographic service)
REA	Reactor boron and water make-up system	SMA	Seismic margin evaluation
REB	Dam burst or collapse	SMUR	Service Mobile d'Urgence et de Réanimation (Mobile emergency and intensive care service)
RECS	Complementary safety assessment report	SOER	Significant Operating Experience Report
REX	Experience feedback	SPE	Permanent surveillance document
RFS	Fundamental safety rule	SPR	Radiological Protection Service
RGE	General operating rules	SRU	Alternate heat sink (EPR)
RHRS	Residual Heat Removal System (RRA)	SSE	Safe shutdown earthquake
RIS	Safety injection system (PWR)	TA	Auxiliary transformer
RIS-BP	Safety injection system, low pressure	TAC	Combustion turbine
RPC	Special operating rules	TAM	Equipment (access) hatch
RRA	Residual heat removal system (RHRS) (PWR)	TPS ASG	Turbine-driven auxiliary feedwater pump
RRI	Component cooling system (CCWS) (PWR)	TS	Step-down transformer
RTE	Electricity transmission system	TSN	TSN Act: Act of 13 June 2006 on transparency and security in the nuclear field
SA	Severe Accident	U2	Continuous monitoring of containment integrity
SAMU	Service d'Assistance Médicale d'Urgence (Emergency Medical Assistance Service)	U5	Containment venting-filtration procedure and system
SAPPRE	Population address system in reflex response phase	UPS	Uninterruptible power supply
SAR	Instrument compressed air distribution system.	VD	10-year in-service outage inspection
SBNI	Secret basic nuclear installation	VDA	Atmospheric steam dump valves
SBO	Station Black Out (total loss of electrical power supplies)		
SC1	Seismic class 1		
SCR	Service competent in radiation protection		
SEA	Demineralisation plant water supply system (pre-treatment)		
SEBIM	Pressuriser valves		
SEC	Essential service water system (ESWS)		
SED	Nuclear island demineralised water distribution system		
SEI	Industrial water system		



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