Stress tests carried out by the Spanish nuclear power plants

Final Report

CSN CONSEJO DE SEGURIDAD NUCLEAR

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1. INTRODUCTION

1.1 Stress tests adopted in the European context

In the wake of the accident that occurred on March 11th 2011 at Fukushima Daiichi Nuclear Power Plant (NPP) in Japan, all European countries initiated actions aimed at verifying the safety measures in place at their plants; however, the advisability of developing a coordinated response within the European Union (EU) very quickly emerged, in order to ensure that all the nuclear power plants in these countries were sufficiently robust to address situations similar to those that occurred at said plant.

In its meeting of March 24th 2011, the European Council agreed on a plan to subject all European nuclear power plants to a homogeneous set of "stress tests" making it possible to assess their capacity to withstand situations beyond their respective Design Bases and identify the safety margins existing with respect to these bases, and the potential measures that might be implemented to improve their safety.

During a meeting held in Brussels on April 15th, with the participation of the European Commission (EC), the regulatory bodies of EU countries and industry representatives, it was agreed that ENSREG should elaborate, with WENRA's technical support, a proposal developing the technical content of the stress tests and defining a method for their performance.

The proposal drawn up by WENRA was approved by ENSREG during its meeting of May 12th and sent to the EC, it being finally approved by the latter on May 25th and subsequently submitted to the European Council held in June 10th.

The Spanish Nuclear Safety Council (CSN) has actively participated at various levels in the discussion and drawing up of these documents, within the framework of both WENRA and ENSREG.

The document finally approved at the European level defines the Stress Tests of nuclear power plants as an additional reassessment of the safety margins of these facilities in the light of the events that took place at Fukushima. In other words, they consider extreme natural phenomena that might jeopardise the safety functions of the facilities and possibly lead eventually to an accident situation entailing damage to the fuel ("severe accident").

As set out in the aforementioned document, these analyses are to be carried out for each site by the licensees of the facilities themselves. The review of the analyses must be performed in a completely independent manner by the corresponding regulatory bodies of each country, their results being consolidated in a national report. Finally, the entire process shall be subjected to a review carried out among all the regulatory bodies (Peer Review), with EC participation. The results of these reviews will be published and discussed in public seminars at the national and international level, to which the stakeholders from different areas, such as the regulatory bodies, the licensees of the facilities and other representatives of the industry, non-governmental organisations, etc., will be invited.

In keeping with the objectives mapped out by the European Council, the document reflects the following schedule: licensee progress reports had to be submitted to each country's regulatory body by August 15th, and the final report containing the analyses performed and proposals for improvement identified throughout the process by October 31st. By September 15th, the regulatory bodies in turn had to submit their respective national progress reports, and by December 31st, their final reports, with a summary of the analyses and conclusions of the licensees and the assessment of the regulator itself. Finally, the aforementioned Peer Reviews will be carried out between January and April 2012.

1.2 Actions undertaken in Spain

In response to the aforementioned Fukushima accident, the CSN immediately initiated a process of gathering all the available information on its evolution, with two objectives: to analyse the possible lessons learnt from the accident and to inform the Spanish public opinion.

Spanish nuclear power plants implemented a series of verifications and reviews to ensure that all existing measures to face up to events within and outside the design basis were operable, in accordance with WANO recommendations. On March 25th, the CSN sent a letter to the licensees of the nuclear power plants to request information on the results of the actions already adopted by them and to require measures complementary to those initially implemented.

On May 25th, the CSN approved and sent to all nuclear power plants a series of Complementary Technical Instructions (ITCs) relating to their Operating Licenses, where they are required to perform the stress tests agreed to within the context of the European Union. The report containing the results had to include a detailed proposal of the planned measures and their corresponding scheduling.

Additionally, and in accordance with the scope proposed at the European level, the CSN sent a similar ITC to José Cabrera NPP, which is currently in the dismantling process and has a temporary storage facility for spent nuclear fuel on site. The content of this ITC is an adaptation of the general stress test programme to the specific circumstances and risks of the plant in question.

On the other hand, and although outside the strict framework established at the European level, the CSN also sent the licensee of the only nuclear fuel manufacturing plant existing in Spain an ITC requiring the performance of stress tests specifically adapted to its design.

Finally, in a process parallel to the one of the Spanish nuclear power plant stress tests and in order to bolster even more the capabilities of these facilities to face up to exceptional situations that might go a lot further beyond the contemplated Design Bases, the CSN subsequently has issued to each of the nuclear power plants in operation ITCs requiring them to perform an analysis to identify those additional measures needed to mitigate the consequences of events caused voluntarily or involuntarily by human intervention which might involve the occurrence of fires or explosions that might lead to the loss of large areas of the plant. The required analyses must be submitted by licensees before December 31st 2012 and include a proposal for a schedule to implement the measures for improvement resulting from said analyses. Given that the information resulting from these analyses may contain information that is sensitive for the facilities, the CSN decided that the documentation generated during this process should be subjected to specific confidentiality restrictions.

2. WORKING METHOD

This report has been prepared with the aim of documenting the assessment performed by the CSN of the information submitted by the licensees of Spanish nuclear power plants in their reports relating to the performance of the so-called "Stress Tests" established at the European level. These tests consist essentially in a complementary safety analysis that includes a reassessment of the safety margins of nuclear power plants in the light of the events that took place on March 11th 2011 at Fukushima NPP in Japan.

In accordance with the requirements, licensees were to analyse for each site the current capabilities of the facility to respond to the following events:

- External events: earthquakes, flooding and other natural events.
- The loss of safety functions due to a loss of the different stages of the electrical power supply and of the ultimate heat sink.
- The management of severe accidents in the Reactor core and accidents entailing a loss of inventory and/or cooling in the Spent Fuel Pools.

In the event of there being any other type of spent fuel storage arrangement at the site, an analysis of robustness thereof with respect to the aforementioned external events and loss of functions had to be performed too.

With a view to harmonising the analyses to be performed by Spanish plants, insofar as possible, and to establishing the contents of the reports to be drawn up, various coordination meetings were held in June and July between the CSN and the licensees – as well as internal meetings of the latter – in which technical aspects related to the scope and the method to perform the required analyses were dealt with. Likewise, two joint meetings were held with plant licensees and the operator of the Spanish electricity grid (Red Eléctrica de España - REE) to review actions and protocols relating to the reliability of the grid and the capacity to recover the power supply in the scenarios contemplated in the stress tests.

Following the schedule set by ENSREG, on September 15th the CSN prepared a first report in which the preliminary analyses (Progress Reports) submitted by the licensees on August 15th were assessed.

Described below are the methodological aspects followed by both the licensees and the CSN in writing their respective reports.

2.1 The process followed by licensees

Licensee analyses have been performed according to the following scheme:

- Verification of the facility's compliance with its design bases as regards the aspects that fall within the scope of the stress tests, assessing the suitability of the design bases in the light of currently available technical know-how.
- Evaluation of each facility's response to a series of extreme situations beyond its design bases, attempting to assess the available safety margins, to identify those cliff-edge situations that might lead to extreme accident sequences and to analyse the facility's expected response.
- Verification of the existence of adequate prevention and mitigation measures and proposing, if necessary, the incorporation of improvements suitable to the identified situations.

The current capabilities of each plant to face up to the proposed events as regards both the design and the organisation have been analysed; the idea was to identify the autonomy (periods of time of availability) to face up to the loss of the safety functions and resources required to prevent a serious accident from having unacceptable consequences for the population.

These evaluations have been tackled by following the defence-in-depth philosophy proposed in the ENSREG document, for the set of situations proposed in said document, assuming, under a deterministic approach, the sequential loss of the existing lines of defense, regardless of their probability of occurrence.

The ultimate objective established by licensees in their reports is to confirm the degree of robustness of the plants when faced with the proposed situations as well as the suitability of the existing accident management measures and, finally, to identify potential applicable improvements to both the (fixed and portable) equipment and the organisation: procedures, human resources, emergency response organisation and use of off-site resources.

The documentation used for the performance of these analyses has been that included in the plant's Safety Analysis Report, Technical Specifications, On-Site Emergency Plan, Operating Procedures (including the Emergency Operating Procedures), Severe Accident Guidelines, Probabilistic Safety Assessments and other design documentation, as well as those specific studies carried out specifically for these stress tests.

Licensees have also carried out several specific checks at each plant and inspections and tests to verify the capabilities reflected in their reports.

In conclusion to their reports, licensees suggest implementing many proposals for improvement regarding the different identified aspects, and propose the following temporary implementation scheme: a short term, when the necessary studies would be started and the planned analysis groups would be formed, considering that they will be completed between June and December 2012; a medium term to tackle diverse design modifications, which would end between 2013 and 2014; and a long term for large-scale design modifications involving new constructions or important changes to the existing systems, which would end between 2015 and 2016 and could even be exceeded in certain justified cases.

2.2 The process followed by the CSN

The CSN is a regulatory body that has its own technical staff. The assessments of the stress tests submitted by the licensees have been dealt with internally, without needing to resort to outside technical support, although assistance has been provided in specific cases by the operator of the Spanish electricity grid (REE), as pointed out above, and by the Centro de Estudios y Experimentación de Obras Públicas (CEDEX), a public body of recognised solvency reporting to the Ministry of Public Works, in the evaluation of the issues relating to external flooding. In this last case, the advice has focused on the analyses submitted by licensees on the bearing capacity of the dams located upstream, in the river basins where the facilities are located, and on the potential consequences of flooding in the areas around the sites.

In order to systematise the assessment process, the CSN has published prepared a specific assessment guide detailing the methodology to be applied, the organisational units responsible for each part of the process, the interactions between them and the planned schedule. Furthermore, in view of the limits regarding available time, weekly coordination meetings have been held during which the preliminary conclusions that were being drawn by the different organisational units have been discussed.

The CSN's assessment has consisted of a review of the documentation submitted by licensees, focusing on the following aspects:

- Verifying that the analyses submitted by licensees cover completely the scope defined in the CSN's ITCs, which required the stress tests to be conducted, differentiating between those aspects in which the licensee says that the planned studies have already been completed and for which the corresponding improvements actions are described and those other which are still pending or still being carried out;. There are also others aspects which are not mentioned in the reports that must be also analyzed by the licensees. All of it in order to guarantee that the analyses of the stress tests of Spanish nuclear power plants are complete and homogeneous insofar as possible.
- Verifying that the analyses have been performed in a coherent and systematic manner with a view to identifying and establishing the significance of potential weaknesses or opportunities for improvement.
- Evaluating the hypotheses and analytical methods used by licensees in their reports, checking the suitability thereof with respect to the scope and foreseen contents of the stress tests.
- Verifying that licensee reports have studied all possible cliff-edge situations for all the aspects that have been analysed. For this verification, those situations which cannot be ruled out even though they have a very low probability of occurrence have been considered applicable.
- Verifying that, for all the aspects that have been studied and in keeping with the results of the analyses, the reports analyse the advisability or the need to reinforce the existing design and organisational capabilities, making sure that a reasoned justification of the conclusions drawn in this respect is provided.
- Evaluating the feasibility and reliability of the recovery and mitigation actions referred to in licensee reports. This means that the performance of specific tests and the writing of written procedures in this respect have been verified in all applicable cases.

The submitted information has been compared with the licensing documentation and other information available at the CSN, as well as with the results of the inspections performed in the past. Given the schedule established for the writing of these reports, it has not been possible to date to review all licensee calculations in a complete and detailed manner.

In addition to the assessment, the CSN has met several times with licensees to discuss technical matters and has performed a total of 24 inspections (4 at each of the 6 nuclear power plants in operation) where different aspects of the contents of the licensee reports have been checked, among them, the capabilities of the plants to face up to:

- Earthquakes (determination of seismic margins).
- Potential on-site flooding caused by earthquakes.
- Events involving a Station Blackout.
- Events involving the loss of the heat sink.
- Severe accidents in the reactor.
- Accidents in spent fuel pools.

The CSN has not been yet able to revise some detail aspects in the time allotted in the stress test programme, so it is going to continue working on these issues and performing those verifications it deems to be necessary. Likewise, licensees will have to conduct some additional studies and design the proposed modifications in detail. Additionally, new information that is gleaned over time about what happened in Fukushima may give rise to new safety improvements to be introduced at the nuclear power plants. This is why this report is not a full stop but only another step in the effort that is being made by both the CSN and Spanish nuclear power plants to improve safety as a result of the Fukushima accident.

After this report is issued, the CSN plans to send each licensee a Complementary Technical Instruction that will collect the conclusions that have drawn, including the acceptance of the proposals for improvement suggested in the reports from the licensees and other aspects identified in the CSN assessment, such as additional analyses or other improvements that it might deem necessary; the associated implementation periods would also be included.

3. GENERAL DATA ON THE FACILITIES AND THE USE OF THE PSA

As is summarised below, the Spanish nuclear fleet in operation currently comprises 6 sites and a total 8 units. There is also a site – belonging to a plant which is currently in the dismantling process – that has a temporary spent fuel storage facility:

- Trillo Nuclear Power Plant (KWU-3 loops).
- Vandellós II Nuclear Power Plant (Westinghouse-3 loops).
- Cofrentes Nuclear Power Plant (GE-BWR6).
- Ascó Nuclear Power Plant (Westinghouse-3 loops, 2 units).
- Almaraz Nuclear Power Plant (Westinghouse-3 loops, 2 units).
- Santa María de Garoña Nuclear Power Plant (GE-BWR3).
- José Cabrera Nuclear Power Plant, in the dismantling phase (Westinghouse -1 loop).

This section includes a general description of each of these facilities.

The use of PSA as part of the Stress Test Process

Spanish nuclear power plants currently have Probabilistic Safety Assessments (PSAs), which are kept updated and whose scope includes:

- Level-1 PSA of internal events at power.
- Level-1 PSA of internal events in other operating modes.
- Level-1 PSA of internal flooding at power.
- Level-1 PSA of internal fires at power.
- Level-2 PSA of internal events at power.
- Assessments of other external events (IPEEE).
- Additionally, some plants have conducted probabilistic assessments of the spent fuel pool with the unit at shutdown conditions.

Since the time when the PSA studies were initially carried out in Spain, and as a result of the most relevant aspects identified therein, licensees have been introducing design modifications and procedures and maintenance practices improvements which have entailed a significant strengthening of the plant´s capabilities to respond to transients and accidents. In addition, PSAs are the basis for the development of several risk-informed applications such as the "Maintenance Rule" or the "Risk Monitor" which is used to support the decision-making process for maintenance activities management.

The use of PSAs as part of the analyses associated with the stress tests is the following:

- Safety margins against earthquakes: the plants have analysed the "seismic margin" from the already-existing analyses of external events (IPEEE), as described in section 4.1 of this report.
- The analysis of flooding due to the failure of non-seismic equipment: licensees have used the analysis of internal flooding PSAs to identify non-seismic components susceptible of generating initiating events and affecting mitigation systems, as described in section 4.2 of this report.
- The analysis of "other extreme natural events": licensees have used the results of their IPEEE to sift through credible extreme events, as described in section 4.2 of this report.

3.1. Trillo Nuclear Power Plant

Trillo NPP is owned by the companies Iberdrola Generación S.A., Gas Natural SDG S.A., Hidroeléctrica del Cantábrico S.A. and Nuclenor S.A.

a) Site

Trillo NPP is located in the area known as "Cerrillo Alto", in the municipality of Trillo (Guadalajara), on the right bank of the River Tagus. The site is 93 km from Madrid and 47 km from Guadalajara as the crow flies and is located East/Northeast with respect to these two cities, the elevation of the plant's general grading level being 832.0 metres with regard to the average sea level at Alicante. It is approximately 300 km from the coast.

b) Description of the unit

A single three-loop pressurised water reactor (PWR) operates at the site, whose nominal thermal power level is 3027.0 MWt, corresponding to a reactor power of 3010.0 MWt. The reactor was designed and supplied by the German company Kraftwerk Union Aktiengesellschaft (KWU). At present the "main vendor" is the French company AREVA. The reactor first reached criticality on May 14th 1988.

- **Reactor Coolant System**

The Reactor Coolant System is made up of the pressure vessel, which houses the reactor core, and three cooling loops, each with a Coolant Pump and a Steam Generator. One of the loops includes the Pressuriser in its hot leg.

- **Other relevant systems**

The main systems which are referenced in these analyses are the following:

- The Emergency Core Cooling System.
- The Emergency Feedwater System.
- The Containment Isolation System.

The first two systems consist basically of four redundant trains, two of which are sufficient to carry out the assigned safety function, and are designed as Seismic Category-I systems, so they can withstand the loads of the Design-Basis Earthquake (Safe Earthquake, SE). These three systems are housed in Seismic Category-I structures that protect them from the external events postulated at the site.

The Emergency Core Cooling System (ECCS) comprises a medium-high pressure injection system (11 MPa-rel), a passive system consisting of 6 low-medium pressure injection accumulators (2.5 MPa-rel), each with a volume of 35 m^3 of borated water, and a low pressure injection system. These systems guarantee the integrity of the fuel in the event of the postulated Reactor Coolant System break accident (LOCA: Loss of Coolant Accident). The actuation of the ECCS and of the Containment Isolation System, which causes the fluid transport lines that go through the Containment to close, also guarantees that the established dose limits will not be exceeded in the event of the postulated accident.

The source of borated water for the active emergency cooling systems is the four Borated Water dual Tanks (BWTs), one per each redundancy, each with a volume of 260 m^3 of borated water.

The Emergency Feedwater System has 4 trains, each equipped with a diesel motor which drives an (emergency) diesel generator and a pump. This system allows to inject water into the steam generators and also to electrically feed all associated loads. Each system train has a pool as an independent water source.

The cooling of the spent fuel pool is carried out by the Emergency Core Cooling System, which has three trains to perform this function, one of them a *dedicated* one.

To operate, these systems require support systems (cooling/power supply), which have also been designed as Seismic Category-I systems.

- **Power supply systems**

For internal plant consumption, Trillo NPP has the following supply paths: from the main 400-kV grid, which remains available following a generator trip thanks to the opening of the “generation breaker”; the main generator, for in-house consumption (“island” mode of operation); and the supply from the 220-kV back-up grid in the event of failure of the two previous supply paths.

In addition to the above, there is another supply path for the safeguard and emergency networks from a third, off-site 132-kV grid, independent from the 400-kV and 220-kV power supplies, and capable of taking the plant to and keeping it in safe condition.

In the event of a Loss of Off-Site Power (LOOP), power is supplied to the internal safeguard and emergency networks by means of the automatic start-up of the four (4) 6130-kVA Safeguard Diesel Generators. These generators are cooled by the essential cooling water system, which discharges its thermal load into the ultimate heat sink. In this situation, there are procedures contemplating the prioritised start-up of the nearby Bolarque, Buendía and Entrepeñas hydroelectric stations.

In the event of a Station Blackout (SBO), i.e. the loss of both the off-site sources and the Safeguard Diesel Generators, the aforementioned four (4) 1500-kVA Emergency Diesel Generators are available to maintain, if necessary, the power supply to different safety-related equipment. These generators are cooled by the Emergency Feedwater System itself.

Both the Safeguard and the Emergency Diesel Generators are designed as Seismic Category-I equipment.

- **Heat Sink**

Trillo NPP’s main heat sink is the circulating water system, which consists in a closed system having two natural draught cooling towers. After a reactor trip, residual heat is removed through the steam generators, which are part of a closed loop that discharges into the condenser.

The ultimate sink for removing the residual heat from the reactor core at shutdown, cooling the spent fuel pool and cooling the auxiliary systems is the essential service water system, which has two water ponds and forced draught cooling towers. The water reserves of the essential service ponds are sized to guarantee cooling for 30 days after the design-basis accident (LOCA: Loss Of Coolant Accident) without any external supply, considering the contents of only one of the two ponds. This sink is designed as Seismic Category I and, like the entire site, is protected against possible flooding of the Tagus due to its being located at an elevation high above the normal level of the river.

- **Containment Building**

The Containment Building is of the so-called Large Dry Containment type, with an approximate free volume of 59000 m^3. The building is made up of a self-supporting steel sphere surrounded by a reinforced concrete structure (“Annullus”), forming a double containment. This last building houses several of the plant’s safety systems. The foundation slab is made of reinforced concrete and has a cavity where the reactor vessel is housed.

The design pressure and temperature of the Containment Building are 0.538 MPa-rel and 145°C respectively. The analyses performed within the framework of the Level-2 PSA have determined that the ultimate capacity of the Containment Building is 0.755 MPa-rel.

- **Spent Fuel Storage Facility**

The plant stores its spent fuel in two locations: the spent fuel pool, located inside the Containment Building, and an Individualised Temporary Storage Facility for Spent Fuel Casks, which is inside the area under the control of the licensee.

- *Spent Fuel Pool*

The walls of the pool are made of reinforced concrete and support an austenitic steel liner. The pool has a storage capacity for 628 fuel assemblies, maintaining an additional capacity equivalent to a complete core (177 fuel assemblies). The storage racks are compact in design and have channels of borated steel. The design of the pool guarantees an effective constant of multiplication no greater than 0.95, provided there is a certain concentration of boron in the pool water, this being lower than that required by the Technical Specifications (2550 ppm).

- *Temporary Storage Facility*

The Individualised Temporary Storage Facility for Spent Fuel Casks belongs to the plant, as well as the fuel stored in the casks, the latter being owned by the Spanish radioactive waste management company (Empresa Nacional de Residuos Radiactivos - ENRESA). When the casks are taken to the future Centralised Temporary Storage (CTS) Facility, the spent fuel stored in them will become the property of ENRESA.

The Temporary Storage Facility has a design capacity for 80 casks. The building where they are housed is designed as Seismic Category I. The passive design of the casks and the building ensures the removal by natural convection of the residual heat generated under the expected storage conditions.

- **Significant safety-related differences between the Units**

Not applicable.

3.2 Vandellós II Nuclear Power Plant

Vandellós II NPP belongs to the electricity utilities Endesa Generación S.A. (72%) and Iberdrola Generación S.A.U. (28%).

a) Site

The Plant is located in the province of Tarragona, on the Mediterranean coast. The site is situated on a strip of land between the AP-7 motorway and the sea and is divided into two by the Valencia-Barcelona railway line and the N-340 highway.

The area has a Mediterranean climate and enjoys the mild weather that is typical of the north-eastern coast of the Iberian Peninsula, although given its proximity to the basin of the River Ebro, which constitutes a channel for the circulation of winds, it is affected by the latter.

There are no permanent watercourses reaching the sea near the site but, rather, small torrents with an intermittent regime that only carry water when storms occur.

b) Description of the unit

At the site there is a single, Westinghouse-design, three-loop pressurised water reactor (PWR) with a rated thermal power of 2940.6 MWt.

The Plant performed its initial loading of fuel in August 1987. Initial criticality was achieved on November 13th 1987 and the declaration of commercial operation was issued on March 8th 1988.

- **Reactor Coolant System**

The Reactor Coolant System is made up of the pressure vessel, which houses the reactor core, and three cooling loops, each with a Coolant Pump and a Steam Generator. One of the loops includes the Pressuriser in its hot leg.

- **Other relevant systems**

The main systems which are referenced in these analyses are the following:

- The Emergency Core Cooling System.
- The Containment Depressurisation and Cooling Systems (Spray and Cooling Units).
- The Containment Isolation System.
- The Containment Combustible Gases Control System.
- The Auxiliary Feedwater System.
- The Control Room Habitability Systems.

All these systems are safeguard systems consisting of two redundant trains, each of which is capable of performing the assigned safety function, and are designed as Seismic Category-I systems, so they are capable of withstanding the loads of the Design-Basis Earthquake (SSE: Safe Shutdown Earthquake). These systems are housed in Seismic Category-I structures that protect them from the external events postulated at the site.

The Emergency Core Cooling System (ECCS) includes a High-Pressure Injection System, a Passive Medium-Pressure Injection System (3 accumulators) and a Low-Pressure Injection System. These systems guarantee the integrity of the fuel in the event of the postulated Reactor Coolant System break accident (LOCA: Loss of Coolant Accident). The actuation of the ECCS, together with the Containment Building and its safeguard systems (Containment Isolation System, Spray System and Cooling Units), guarantees that the established dose limits will not be exceeded in the event of the postulated accident.

The source of borated water for the active emergency cooling systems is the Refueling Water Storage Tank (RWST), the inventory of which amounts to 2891 m^3 (High Level).

The purpose of the Containment Safeguards Systems is to reduce the pressure and temperature in Containment Building following the occurrence of the Reactor Coolant System Break (LOCA) and Main Steam Line Break (MSLB) design-basis accidents, preventing the building's design pressure and temperature from being reached and guaranteeing that the values reached are more than halved within 24 hours. On the other hand, the Containment Isolation System causes the fluid transport lines that go through the Containment to close.

The Auxiliary Feedwater System is designed to inject water into the Steam Generators when faced with any event that causes the Reactor to scram, allowing the sensible and residual heat to be removed from the Reactor core. The System is equipped with two electrically driven pumps and a steam-driven turbine pump. Each of the three pumps is capable by itself of providing the Steam Generators with the flow rate required to remove the residual power from the Reactor core. The preferential source of water for the System is the Condensate Tank (1850 m^3). As an alternative, there is the auxiliary feedwater back-up tank, with a capacity of 4540 m^3.

The plant has a specific system for cooling and cleaning the spent fuel pool.

To operate, the safeguards systems require support systems (cooling/power supply), which have also been designed as Seismic Category-I systems.

- **Power supply systems**

The plant has 3 independent, off-site power supply sources via three power lines that supply power at 400 kV, 220 kV and 110 kV. The 400-kV line is the preferential path to power the auxiliary services of the Plant, and during shutdowns, normal operation and outages, via the Unit Transformer, which feeds all the class-1E and non-class-1E 6.25-kV buses by means of the grouped phase buses, to which the other 2 off-site sources are also connected. The 220-kV grid feeds the External Auxiliary Transformer, which in turn powers the class-1E and non-class-1E 6.25-kV buses. The 110-kV source is used when the 400-kV grid or the 220-kV grid are unavailable, during refueling outages mainly.

In the event of a loss of off-site power (LOOP), the safeguard buses are fed by means of their corresponding 7200-kVA Emergency Diesel Generator. These generators are provided with air coolers that discharge their thermal load into the atmosphere. In these conditions, the 220-kV line, which comes from the nearby Ribarroja hydroelectric station, would allow to feed the normal and safeguard buses in dedicated mode ("island configuration").

In the event of a Station Blackout (SBO), i.e. the loss of both the off-site sources and the aforementioned Diesel Generators, there is a third 2814-kVA Diesel Generator, which is capable of feeding the battery chargers, and the Hydrostatic Test Pump, which allows to maintain the injection to the Reactor Coolant System pump seals or to make up inventory to said system. This generator is also provided with air coolers that discharge their thermal load into the atmosphere.

- **Heat Sink**

The main heat sink of Vandellós II NPP is the Mediterranean Sea. Seawater is boosted by two vertical pit pumps belonging to the essential service water system.

The alternative heat sink (Ultimate Heat Sink, UHS) consists of two forced draught cooling towers, with two redundant cooling water pumping and distribution systems, and a water storage pond that provides autonomy of 30 days. This heat sink is of Seismic Category I and is protected against the possibility of flooding by the sea by its being located more than 20 metres above sea level.

- **Containment Building**

The Containment Building is of the so-called Large Dry Containment type, with an approximate free volume of 62000 m^3. The building is made up of a vertical cylindrical wall (40 metres in diameter), which is closed on top by a semi-spherical dome (with an inner height of 63.40 m), and consists of a reinforced concrete structure with additional pre-stressing of the cylindrical wall and semi-spherical dome by means of a system of post-tensioned tendons. The foundation slab is made of reinforced concrete and has a cavity where the reactor vessel is housed.

The inner wall of the Containment Building has a liner (carbon steel plate) providing leaktightness; admissible leaks must be lower than 0.2% of the volume of the building in a 24-hour period at the peak pressure that would be reached in the worst postulated accident.

The reactor cavity is of the "dry" type, which means that, in order to let water in it, it is necessary to discharge into the containment a volume of water larger than that of the RWST.

The design pressure and temperature of the Containment Building are 0.3796 MPa-rel and 148.9°C respectively. The analyses performed within the framework of the Level-2 PSA have determined that the ultimate capacity of the Containment Building (pressure at which the leaktightness failure would occur) is 0.8667 MPa-rel.

- **Spent Fuel Storage Facility**

The spent fuel is stored under water in the Spent Fuel Pool located in the Fuel Building, which is adjacent to the Containment Building. The structure of the Building, including the Pool itself and its cooling system, has been designed as Seismic Category I. The Spent Fuel Pool is made of concrete and lined with stainless steel, contains borated water and has capacity for 1594 storage positions. The racks are made of borated stainless steel.

- **Significant safety-related differences between the Units**

Not applicable.

3.3 Cofrentes Nuclear Power Plant

Cofrentes NPP is fully owned by the electricity utility Iberdrola Generación S.A.U.

a) Site

The Plant is located on the right bank of the River Júcar, close to the tail of the Embarcaderos reservoir, in the municipality of Cofrentes, in the province of Valencia.

The plant is located on a platform resting to the East on the mountain chain that closes the valley of the Júcar and separated to the West from the river and the tail of the reservoir by a peninsula measuring almost 1 km in length. The elevation of the area immediately around the site is variable (Peña Lisa, Las Rochas, Loma de Serrano) but is more than 45 metres above the maximum level of the water in the river and the reservoir (maximum level: 325.8 m).

The site is located at a distance of 2 km from the village of Cofrentes and more than 3 km from the village of Jalance. There is no dispersed population in the surrounding area. The grading level of the plant has an elevation of 372 metres above sea level and is located at a distance of some 65 km from the Mediterranean coast.

There are 2 large dams upstream from the plant site: the Alarcón dam, 170 km away on the River Júcar and with a 1182-hm^3 storage capacity, and the Contreras dam, 106 km away on the River Cabriel and with a capacity of 852 hm^3. Both dams are of the "gravity" type.

b) Description of the unit

A single BWR-6-type power reactor, designed and supplied by General Electric (GE), operates on the site, its currently licensed thermal power amounting to 3237 MWt.

Construction of the plant began in September 1975. The reactor achieved first criticality in August 1984 and the plant was first coupled to the grid in October of that year, reaching 100% power in January 1985. Cofrentes NPP began commercial operation in March 1985.

- **Reactor Coolant System**

The Reactor Coolant System is made up of the pressure vessel, which houses the reactor core, and two recirculation loops, each equipped with a Pump.

- **Other relevant systems**

The main systems which are referenced in these analyses are the following:

- The Emergency Core Cooling System (ECCS).
- The Containment Spray System, which is part of the LPCI (a subsystem of the ECCS).
- The Suppression Pool Cooling System, which is part of the LPCI.
- The Containment Isolation System.
- The Containment Combustible Gases Control System.
- The control room Habitability Systems.
- The Reactor Core Isolation Cooling (RCIC).

All these systems – except the RCIC – are safeguard systems; they consist of two redundant trains, each of which is capable of performing the assigned safety function, and are designed as Seismic Category-I systems, so they are capable of withstanding the loads of the Design-Basis Earthquake (SSE: Safe Shutdown Earthquake). These systems are housed in Seismic Category-I structures that protect them from the external events postulated at the site.

The Emergency Core Cooling System (ECCS) is made up of the high-pressure core spray (HPCS), low-pressure core spray (LPCS), low-pressure core injection (LPCI) and automatic depressurisation (ADS) sub-systems. The external water source for the emergency cooling systems is the Condensate Storage Tank (CST), which has a minimum capacity of 701 m^3.

The purpose of the Containment Safeguard Systems is to reduce the pressure and temperature in the Containment Building following the occurrence of the Reactor Coolant System break (LOCA) design-basis accidents – including the break of Main Steam Line upstream of its isolation valves, preventing the building's design pressure and temperature from being reached. On the other hand, the Containment Isolation System causes the fluid transport lines that go through the Containment to close. The actuation of the ECCS, together with the Containment Building and its safeguard systems (Isolation System and Spray System), guarantees that the established dose limits will not be exceeded in the event of the postulated accident.

The plant has a specific system for cooling and cleaning the spent fuel pool.

To operate, the safeguards systems require support systems (cooling/power supply), which have also been designed as Seismic Category-I systems.

Furthermore, the plant has the RCIC system, a single-train system equipped with a turbine-driven pump that takes suction from the Condensate Tank and allows the reactor inventory to be maintained.

- **Power supply systems**

The plant has 2 independent off-site power supply sources via the various power lines that supply power at 400 kV and 138 kV and are the preferential power source for plant start-up and shutdown as well as for feeding for the normal 6.3-kV buses (A1, A2, A3 and A4) and safeguard buses (EA1 and EA2) when the unit is shut down.

There is a "generation breaker" that allows the generator to be isolated from the rest of the system, thus making it possible to feed, in the event of a main generator trip, the Plant's electrical services from the 400-kV switchyard via the main transformer (T1) and the auxiliary transformers (T-A1 and T-A2).

In the event of a loss of off-site power (LOOP), the safeguard buses are fed from their corresponding 5509-kVA Emergency Diesel Generator. These generators are cooled by the essential service water system, which discharges its thermal load into the ultimate heat sink. In addition, the preferential restoration of the electrical supply from the nearby Cofrentes, Millares II, Cortes II and La Muela hydroelectric stations, which have an autonomous start-up capacity, is contemplated in the procedures.

In the event of a Station Blackout (SBO), i.e. the loss of both the off-site sources and the aforementioned Diesel Generators, there is a third 3000-kVA Diesel Generator that feeds the Pump of the HPCS, and its auxiliary equipment, which allows the inventory of the reactor coolant system to be maintained. This generator is also cooled by the essential service water system.

- **Heat Sink**

Cofrentes NPP's main heat sink comprises two natural draught cooling towers, which remove heat from the main condenser, and a battery of forced draught towers, which allow the thermal load of the auxiliary systems to be removed during normal operation.

The alternative heat sink (Ultimate Heat Sink, UHS) is made up of a pond and three cooling water pumping and distribution sub-systems; the cooling water is returned via a set of spray nozzles that discharge onto the pond itself, allowing the accident thermal loads to be dissipated. The pond provides autonomy for 30 days. This heat sink is of Seismic Category I and is protected from the possibility of flooding by the River Júcar because it is located at an elevation that is far above the river's normal level.

- **Containment Building**

The Containment Building is of the GE Mark III type, with pressure suppression capacity, and has a double containment with a self-supporting steel structure that is externally surrounded by a reinforced concrete building. The free volume of the primary containment is approximately 36000 m^3.

The design pressure and temperature of the Containment Building are 0.103 MPa-rel and 85°C respectively. The analyses performed within the framework of the Level-2 PSA have determined that the ultimate capacity of the Containment Building (pressure at which the leaktightness failure would occur) is 0.57 MPa-rel.

- **Spent Fuel Storage Facility**

The spent fuel is stored under water in two pools (the East Storage Pool and the West Storage Pool), both located in the Fuel Building that is adjacent to the Containment Building. The structure of the Building, including the pools themselves and its cooling system, has been designed as Seismic Category I. The Spent Fuel Pool is made of concrete, is lined with stainless steel and has a capacity for 5404 storage positions, following two re-racking processes during which the original racks were replaced with other, compact-type racks.

- **Significant safety-related differences between the Units**

Not applicable.

3.4 Ascó Nuclear Power Plant

Ascó NPP's Unit I belongs to the electricity utility Endesa Generación S.A. (100%). On the other hand, Unit II belongs to the utilities Endesa Generación S.A. (85%) and Iberdrola Generación S.A. (15%).

a) Site

The site on which the Plant is located occupies an area of approximately 243 ha and is situated on the right bank of the River Ebro, between the towns of Flix and Ascó, in the province of Tarragona, 110 km from the mouth of the river on the Mediterranean Sea.

The Plant's site is divided in two by a railway line. Most of the Plant's installations are located between the railway line and the main road, with the exception of the cooling water intake and discharge structures, the 380-kV switchyard and several non-safety-related cooling towers.

The surrounding land is mainly devoted to agricultural use, there being also large areas of uncultivated land; the only noteworthy industrial facility in the area is an electrochemical factory located some 4 km from the plant.

The population is very low in the vicinity of the Plant. The population density is considered to be practically zero within a 2-km radius. Up to 4 km from the Plant, the population density reaches a value of 130 inhabitants per km^2, thanks to the towns of Flix, Ascó and Vinebre, but it decreases markedly in a radius greater than 5 km, such that within a 40-km circle it reaches to a value close to 26 inhabitants per km^2. The most important population centre within this 40-km radius is Fraga, with 14539 inhabitants.

The area has a Mediterranean climate, with mild winters and somewhat hot summers. The prevailing winds are warm and humid.

As it flows past the site, the River Ebro measures approximately 150 metres in width; the average flow rate for the 68-year period for which data are available is 500 m^3/s, while the minimum value ever recorded is 100 m^3/s. The river flows along the bottom of the valley and, for more than half its total length (700 km), it forms a flooding basin which limits peak-flow periods; moreover, the dams constructed in its basin increase this effect.

There are three important dams on the Ebro less than 100 km upstream of the site: the Flix dam, with a 11.4-hm^3 reservoir (currently reduced to 6 hm^3) and located some 10 km upstream; the Ribarroja dam, with a 267-hm^3 reservoir and located 30 km upstream; and the Mequinenza dam, with a 1,530-hm^3 reservoir and located 70 km upstream.

b) Description of the Units

There are two Westinghouse-design, three-loop pressurised water reactors (PWR) operating on the site, each having a nominal thermal power of 2940.6 MWt and minor differences of no significance from the point of view of safety.

Unit I first reached criticality on June 17th 1983, and initiated commercial operation on December 10th 1984. On the other hand, Unit II achieved initial criticality on September 11th 1985 and started commercial operation on March 31st 1986.

The following description is applicable to both Units:

- **Reactor Coolant System**

The Reactor Coolant System is made up of the pressure vessel, which houses the reactor core, and three cooling loops, each with a Coolant Pump and a Steam Generator. One of the loops includes the Pressuriser in its hot leg.

- **Other relevant systems**

The main systems which are referenced in these analyses are the following:

- The Emergency Core Cooling System.
- The Containment Depressurisation and Cooling Systems (Spray and Cooling Units).
- The Containment Isolation System.
- The Containment Combustible Gases Control System.
- The Auxiliary Feedwater System.
- The Control Room Habitability Systems.

All these systems are safeguard systems, consist of two redundant trains, each of which is capable of performing the assigned safety function, and are designed as Seismic Category-I systems, so they are capable of withstanding the loads of the Design-Basis Earthquake (Safe Shutdown Earthquake, SSE). These systems are housed in Seismic Category-I structures that protect them from the external events postulated at the site.

The Emergency Core Cooling System (ECCS) includes a High-Pressure Injection System, a Passive Medium-Pressure Injection System (3 accumulators) and a Low-Pressure Injection System. These systems guarantee the integrity of the fuel in the event of the postulated Reactor Coolant System break accident (LOCA: Loss of Coolant Accident). The actuation of the ECCS, together with the Containment Building and its safeguard systems (Containment Isolation System, Spray System and Cooling Units), guarantees that the established dose limits will not exceeded in the event of the postulated accident.

The source of borated water for the active emergency cooling systems is the Refueling Water Storage Tank (RWST), the inventory of which amounts to 1500 m^3.

The purpose of the Containment Safeguards Systems is to reduce the pressure and temperature in Containment Building following the occurrence of the Reactor Coolant System break (LOCA) and Main Steam Line break (MSLB) design-basis accidents, preventing the building's design pressure and temperature from being reached and guaranteeing that the values reached are more than halved within 24 hours. On the other hand, the Containment Isolation System causes the fluid transport lines that go through the Containment to close.

The Auxiliary Feedwater System is designed to inject water into the Steam Generators when faced with any event that causes the Reactor to scram, allowing the residual heat to be removed from the Reactor core. The System is equipped with two electrically driven pumps and a steam-driven turbine pump. Each of the three pumps is capable by itself of providing the Steam Generators with the flow rate required to remove the residual heat from the Reactor core. The preferential source of water for the System is the Condensate Tank (908 m^3); As an alternative, there is the Cooling Tower Make-up Storage Pond (29774 m^3).

The plant has a specific system for cooling and cleaning the spent fuel pool.

To operate, the safeguards systems require support systems (cooling/power supply), which have also been designed as Seismic Category-I systems.

- **Power supply systems**

The electrical power required for start-up and emergency loads is taken from the 110-kV switchyard, which is interconnected to the off-site 220-kV grid and, by means of a 200-MVA transformer, to the 400-kV switchyard. Off-site power for the safeguard systems is taken from the 110-kV grid via the 62-MVA Auxiliary Start-up Transformers (TAAs), of which there are 2 for each unit.

In the event of a loss of off-site power (LOOP), in one unit the 2 safeguard buses are fed by means of their corresponding 5625-kVA Emergency Diesel Generator. These generators are cooled by the engineered safeguard service water system, which discharges its thermal load into the ultimate heat sink. In these conditions, the 220-kV line, which comes from the nearby Ribarroja hydroelectric station, would allow to power the plant in dedicated mode ("island configuration").

In the event of a Station Blackout (SBO), i.e. the loss of both the off-site sources and the aforementioned Diesel Generators, there is a third 2600-kVA Diesel Generator (shared by both groups), which may be connected manually to one of the safeguard buses of each of the nuclear groups. This generator is cooled by a closed system provided with a cooling tower, through which it discharges its thermal load into the atmosphere.

- **Heat Sink**

The main heat sink of Ascó I and II NPP is the River Ebro, there being several pumping systems that provide cooling water for the removal of thermal loads in normal operation.

The alternative heat sink (ultimate heat sink, UHS) for each of the two units of the plant is made up of two cooling towers, two redundant, cooling water pumping and distribution sub-systems and a water storage pond, the latter being common to both units and being capable of providing water for 30 days. This heat sink has been designed as Seismic Category I and is protected from the possibility of flooding of the river Ebro by being located more than 18 metres above the normal level of the river.

- **Containment Building**

The Containment Building is of the so-called Large Dry Containment type, with an approximate free volume of 62000 m^3. The outer structure of the building consist of a straight vertical cylinder (with an inner diameter of 40 metres and an inner height of 59.06 m) and a toroidal-spherical dome with a reinforcing ring, both made of reinforced concrete with tendons for the post-tensioning of the structure. The foundation slab is made of reinforced concrete and has a cavity where the reactor vessel is housed.

The inner wall of the Containment Building has a liner (carbon steel plate) providing leaktightness; admissible leaks must be lower than 0.2% of the volume of the building in a 24-hour period at the peak pressure that would be reached in the worst postulated accident.

The reactor cavity is of the "dry" type, which means that, in order to let water in it, it is necessary to discharge into the containment a volume of water larger than that of the RWST.

The design pressure and temperature of the Containment Building are 0.37 MPa-rel and 148.9°C respectively. The analyses performed within the framework of the Level-2 PSA have determined that the ultimate capacity of the Containment Building (pressure at which the leaktightness failure would occur) is 0.71 MPa-rel.

- **Spent Fuel Storage Facility**

The spent fuel is stored under water in the Spent Fuel Pools, located for each unit in the Fuel Building, located next to the Containment Building. The structure of the Building, including the Pool itself and its cooling system, has been designed as Seismic Category I. The Spent Fuel Pools are made of concrete and lined with stainless steel, contain borated water and have capacity for 1421 storage positions. The racks are made of borated stainless steel.

- **Significant safety-related differences between the Units**

There are minor differences between the Units which, as has already been pointed out, are of no significance as regards safety.

3.5 Almaraz Nuclear Power Plant

Almaraz NPP is owned by the companies Iberdrola Generación S.A.U., Endesa Generación S.A. and Gas Natural SDG S.A.

a) Site

Almaraz NPP is located on the left bank of the Arrocampo brook reservoir in the municipality of Almaraz (Cáceres), 16.4 km west-southwest of Navalmoral de la Mata, 68.8 km east-northeast of the provincial capital, Cáceres, and 180 km west-southwest of Madrid. The plant is located at an elevation of 258 metres above sea level.

There is a dam – Valdecañas – situated halfway down the course of the River Tagus, upstream from the plant's site, having a storage capacity of 1146 hm^3 at its typical maximum level.

b) Description of the unit

There are two Westinghous-design, three-loop pressurised water reactors (PWR) operating on the site, with a rated thermal power of 2,956.6 (Unit I) and 2,955.8 MWt (Unit II) respectively. There are minor design differences between these units which are of no significance from the point of view of safety. Unit 1 reached initial criticality on April 5th 1981, and Unit 2 on September 19th 1983.

The following description is applicable to both units:

- **Reactor Coolant System**

The Reactor Coolant System is made up of the pressure vessel, which houses the reactor core, and three cooling loops, each with a Coolant Pump and a Steam Generator. One of the loops includes the Pressuriser in its hot leg.

- **Other relevant systems**

The main systems which are referenced in these analyses are the following:

- The Emergency Core Cooling System.
- The Containment Depressurisation and Heat Removal Systems (Spray).
- The Containment Isolation System.
- The Containment Combustible Gases Control System.
- The Auxiliary Feedwater System.
- The control room Habitability Systems.

All these systems are safeguard systems, consist of two redundant trains, each of which is capable of performing the assigned safety function, and are designed as Seismic Category-I systems, so they are capable of withstanding the loads of the Design-Basis Earthquake (Safe Shutdown Earthquake, SSE). These systems are housed in Seismic Category-I structures that protect them from the external events postulated at the site.

The Emergency Core Cooling System (ECCS) includes a High-Pressure Injection System, a Passive Medium-Pressure Injection System (3 accumulators) and a Low-Pressure Injection System. These systems guarantee the integrity of the fuel in the event of the postulated Reactor Coolant System break accident (LOCA: Loss of Coolant Accident). The actuation of the ECCS, together with Containment Building and its safeguard systems (Containment Isolation System and Spray System), guarantees that the established dose limits will not exceeded in the event of the postulated accident.

The source of borated water for the active emergency cooling systems is the Refueling Water Storage Tank (RWST), the minimum useful volume of which amounts to 1897 m^3.

The purpose of the Containment Safeguards Systems is to reduce the pressure and temperature in Containment Building following the occurrence of the Reactor Coolant System break (LOCA) and Main Steam Line break (MSLB) design-basis accidents, preventing the building's design pressure and temperature from being reached and guaranteeing that the values reached are more than halved within 24 hours. On the other hand, the Containment Isolation System causes the fluid transport lines that go through the Containment to close.

The Auxiliary Feedwater System is designed to inject water into the Steam Generators when faced with any event that causes the Reactor to scram, allowing the residual heat to be removed from the Reactor core. The System is equipped with two electrically driven pumps and a steam-driven turbine pump. Each of the three pumps is capable by itself of providing the Steam Generators with the flow rate required to remove the residual heat from the Reactor core. The preferential source of water for the System is the Feedwater Tank, which has a minimum volume of 487 m^3; once this is depleted, it can be aligned by hand to the Condensate Tank or to the essential service water system.

The plant has a specific system for cooling and cleaning the spent fuel pool.

To operate, the safeguard systems require support systems (cooling/power supply), also designed as Seismic Category-I systems.

- **Power supply systems**

The electrical power for start-up and emergency situations is taken from the 220-kV switchyard, which is interconnected with the off-site 220-kV grid by means of two lines. An autotransformer links the 220-kV switchyard to the site's 400-kV switchyard, to which 8 off-site lines connect. The 220-kV switchyard has a "ring configuration"; should a fault occur in any of these circuits, it is possible to isolate the damaged line without this affecting the supply of power to the start-up transformers.

In the event of a loss of off-site power (LOOP) in one unit, the 2 safeguard buses are fed by means of their corresponding Emergency Diesel Generator, which has a power of 5507 kVA. These generators are cooled by the essential service water system, which discharges its thermal load into the ultimate heat sink. In these conditions, several lines are available that would allow power to be supplied from the nearby Valdecañas, J. M. Oriol, Gabriel y Galán, Torrejón, Cedillo and Guijo hydroelectric stations.

In the event of a Station Blackout (SBO), i.e., the loss of both the off-site sources and the aforementioned 4 Diesel Generators, there is a fifth 6375-kVA Diesel Generator which may be connected manually to replace any of the other four. All of this generator's services are stand-alone, including the batteries and air cooling, and it has the same capacity, design requirements and qualification as the rest of the emergency diesel generators. Nevertheless, the plant is licensed to be able to respond to a SBO for at least 4 hours without making use of this fifth generator.

- **Heat Sink**

The main heat sink of Almaraz I and II NPP is made up of the condenser and the circulation water system, which is cooled with water from the Arrocampo reservoir. This system does not perform any safety function.

The ultimate heat sink (UHS), which does perform a safety function, consists of the Arrocampo reservoir, the essential service water reservoir and the essential service water system (ESW). Both reservoirs are shared by both units. The Arrocampo reservoir has several pumping systems that supply cooling water for the removal of thermal loads during normal operation, although it may also be used in the event of an emergency, via the ESW, as an alternative to the essential service water reservoir. The latter has spray nozzles in the ESW's return lines. The UHS (including the dams and the components of the ESW) is of Seismic Category I and is located at approximately the same elevation as the rest of the plant's buildings.

- **Containment Building**

The Containment Building is of the so-called Large Dry Containment type, with an approximate free volume of 60000 m^3. The outer structure of the building consists of a straight vertical cylinder and a semi-spherical dome, both made of reinforced concrete. The foundation slab is made of reinforced concrete and has a cavity where the reactor vessel is housed.

The inner wall of the Containment Building has a liner (carbon steel plate) providing leaktightness; admissible leaks must be lower than 0.1% of the volume of the building in a 24-hour period at the peak pressure that would be reached in the worst postulated accident.

The reactor cavity is of the "dry" type, which means that, in order to let water in it, it is necessary to discharge into the containment a volume of water larger than that of the RWST.

The design pressure and temperature of the Containment Building are 0.37 MPa-rel and 148.9°C respectively. The analyses performed within the framework of the Level-2 PSA have determined that the ultimate capacity of the Containment Building (pressure at which the leaktightness failure would occur) is 0.83 MPa-rel.

- **Spent Fuel Storage Facility**

The spent fuel is stored under water in the Spent Fuel Pool, which is located, for each unit, in the Fuel Building, which is adjacent to the Containment Building. The structure of the building, including the Pool itself and its cooling system, has been designed as Seismic Category I. The Spent Fuel Pool is made of concrete and lined with stainless steel, contains borated water and has capacity for to 1,804 storage positions.

The fuel storage racks are high density racks and are designed to ensure that there is an effective multiplication constant (Keff) equal or lower than 0.95, even with the racks completely full of fuel assemblies having the highest estimated reactivity, with the water in the pool having a boron concentration lower than that required by the Technical Specifications and with a temperature corresponding to that of the highest reactivity.

- **Significant safety-related differences between the Units**

The two Units are essentially identical. The differences between them are of no significance as regards safety and are basically as follows:

- In Unit 1 there is a connection to the essential service water system through which it is possible to inject water into the Auxiliary Feedwater System (AFW) or the spent fuel pool by means of external means or by connecting equipment existing at the plant; the same arrangement is planned to be implemented in Unit 2 during the next refueling outage.
- In Unit 2, one of the two Emergency Diesel Generators is of a different design than the other three, and the remote shutdown panels are located in different rooms, although these panels are currently undergoing an important design modification that will affect both units.

3.6 Santa María de Garoña Nuclear Power Plant

Garoña NPP belongs to the electricity utility Nuclenor S.A., a company that is jointly owned in equal proportions by the companies Iberdrola Generación S.A.U. and Endesa Generación S.A.

a) Site

Santa María de Garoña NPP is located on the banks of the River Ebro, on a meander thereof that forms a peninsula measuring approximately 37 ha. This meander is situated at the tail of the Sobrón reservoir, close to the villages of Garoña and Santa María de Garoña, in the northeast of the province of Burgos.

The plant is located at an elevation of 518 metres above sea level, at a distance of more than 100 km from the nearest coast.

The so-called Ebro reservoir, with a capacity of 540-hm^3, is 158 km upstream from the site.

b) Description of the unit

A single BWR-3-type power reactor, designed and supplied by General Electric, operates on the site, its currently licensed thermal power amounting to 1381 MWt.

The plant first reached criticality on November 5th 1970 and began commercial operation on March 2nd 1971.

- **Reactor Coolant System**

The Reactor Coolant System is made up of the pressure vessel, which houses the reactor core, and two recirculation loops, each equipped with a Pump.

- **Relevant systems**

The main systems which are referenced in these analyses are the following:

- The Emergency Core Cooling System (ECCS).
- The Containment Spray System, which is part of the LPCI (a subsystem of the ECCS).
- The Suppression Pool Cooling System, which is part of the LPCI.
- The Containment Isolation System.
- The Control Room Habitability Systems.
- The Isolation Condenser System (IC).

All these systems – save for the IC – are safeguard systems, consist of two redundant trains, each of which is capable of performing the assigned safety function, and are designed as Seismic Category-I systems, so they are capable of withstanding the loads of the Design-Basis Earthquake (Safe Shutdown Earthquake, SSE). These systems are housed in Seismic Category-I structures that protect them from the external events postulated at the site.

The Emergency Core Cooling System (ECCS) consists of the high-pressure core injection (HPCI), low-pressure core spray (LPCS), low-pressure core injection (LPCI) and automatic depressurisation (ADS) sub-systems.

The external water source for the emergency cooling systems is the Condensate Tank, which has a volume of 1550 m^3 of water.

The purpose of the Containment Safeguard Systems is to reduce the pressure and temperature in the Containment Building following the occurrence of the Reactor Coolant System break (LOCA) design-basis accidents – including the break of Main Steam Line upstream of its isolation valves, preventing the building's design pressure and temperature from being reached. On the other hand, the Containment Isolation System causes the fluid transport lines that go through the Containment to close.

To operate, the safeguards systems require support systems (cooling/power supply), which have also been designed as Seismic Category-I systems.

The Isolation Condenser (IC) has a diversity of make-up systems and its function is to remove the residual heat from the Reactor core without losing any inventory thereof.

The plant has a specific system for cooling and cleaning the spent fuel pool.

- **Power supply systems**

The plant has 3 independent off-site power supply sources via the various power lines that supply power at 400 kV, 220 kV and 138 kV; they are the preferential power source for plant start-up and shutdown as well as for feeding of the normal and safeguards buses when the unit is shut down.

In the event of loss of off-site power (LOOP), the safeguard buses are fed via the corresponding Emergency Diesel Generator; each of these generators has a rated power of 2100 kW. These generators are cooled by a closed-circuit water system that discharges its thermal load into the atmosphere through air coolers. In these conditions, the preferential restoration of the electrical supply from the nearby Sobrón, Trespaderne and Quintana hydroelectric stations is contemplated in the procedures.

In the event of a Station Blackout (SBO), there is the HPCI, subsystem of the ECCS-, which is equipped with a turbine-driven pump and that takes suction from the Condensate Tank, which allows the reactor inventory to be maintained, and there is also the above mentioned Isolation Condenser.

- **Heat Sink**

Santa María de Garoña NPP's heat sink is the River Ebro, which allows heat to be removed from the main condenser and auxiliary loads during normal operation and in case of an accident by means of various pumping and water distribution systems. The cooling capacity provided by the river is guaranteed for 30 days, even in the event the dam of the Sobrón reservoir – located downstream from the plant – breaks. The emergency systems that draw water from the river are of Seismic Category I and protected against the possibility of flooding of the river Ebro by being located inside a concrete cubicle designed to protect them in case the water level should rise.

- **Containment Building**

The Containment is of the GE Mark I type, equipped with a double containment and pressure suppression capacity. The primary containment has two separate volumes: the Drywell, which is a steel vessel surrounded by a reinforced concrete structure, and the Wetwell, which houses the suppression pool and is made up of a toroidal enclosure made of carbon steel. The free volume of the containment is approximately 6200 m^3, and it is inerted with nitrogen gas during the reactor is in power operation.

The design pressure and temperature of the Containment Building are 0.43 MPa-rel and 138°C respectively. The analyses performed within the framework of the Level-2 PSA have determined that the ultimate capacity of the Containment Building (pressure at which the leaktightness failure would occur) is 0.53 MPa-rel.

- **Spent Fuel Storage Facility**

The plant's spent fuel is stored in a pool inside the Reactor Building (Secondary Containment) at such a height that it is possible to communicate it directly with the refueling cavity once the latter is flooded. The structure of the Building, including the pools themselves and its cooling system, has been designed as Seismic Category I. The Spent Fuel Pool is made of concrete and lined with stainless steel and has a storage capacity for 2609 assemblies after the 1997 re-racking.

- **Significant safety-related differences between the Units**

Not applicable.

3.7 José Cabrera Nuclear Power Plant (in the dismantling phase)

In February 2010, the ownership of José Cabrera NPP – which is currently in the dismantling phase – was transferred from the electricity utility Gas Natural S.A. to the Spanish radioactive waste management company (Empresa Nacional de Residuos Radiactivos, S.A. - ENRESA).

a) Site

José Cabrera Nuclear NPP is located in Almonacid de Zorita, in the region of La Alcarria, on the left bank of the River Tagus, between the Bolarque and Zorita dams, about 39 km southwest from the city of Guadalajara and about 66 km east of Madrid; the elevation of the plant's general grading level being 604 metres above sea level.

On the site operated until April 30th 2006 a single-loop Pressurised Water Reactor (PWR) with a gross output of 160 electric MW.

There are three important dams less than 100 km upstream of the site: the Entrepeñas, Bolarque and Buendía dams.

b) Description of the facility

The only facility which exists inside the site and is the object to the stress tests contemplated within the context of the European Union is the spent fuel storage facility.

- **Spent Fuel Storage Facility**

The plant has a single spent fuel storage facility, the Individualised Temporary Storage (ATI) Facility for Spent Fuel Casks, which is inside the area controlled by the licensee.

Between January and September 2009, all the spent fuel existing on the site (100.3 tons of heavy metal) was transferred to a dry storage system, in 12 Holtec International HI-STORM 100Z-type casks. The safety functions in this facility are ensured in a passive manner.

This system is made up of a multi-purpose capsule (MPC), with a welded, double lock, having capacity for up to 32 fuel assemblies and designed to be able to passively remove a residual thermal power of up to 30 kW.

These MPCs are located inside an outer shielding module that leaves an annular space with the capsule for the circulation of cooling air. This module has an outer shell and another inner shell made of steel, protecting a 0.7m thick layer of high density concrete. Bearing in mind the progressive cooling of spent nuclear fuel, the residual thermal power per cask as of June 30th 2011 ranged from 8.52 to 12.34 kW, so there is ample margin with regard to the design capacity.

These casks are inside an Individualised Temporary Storage (ATI) facility located at an elevation of 628 metres, which consists of a seismic-design slab where the containers rest. There are no other structures in the vicinity whose collapse might affect the casks.

4. LICENSEE REPORTS AND CSN EVALUATION

On October 31st 2011, the licensees of the Spanish nuclear power plants submitted their final reports to the Nuclear Safety Council (CSN) in response to the Complementary Technical Instructions (ITCs) associated with their operating permits issued by the said organisation, which required the performance of the programme of stress tests agreed to at European level in the wake of the events that occurred at the Fukushima nuclear power plant.

The current Spanish fleet of operating nuclear power plants comprises 6 sites and a total 8 groups. The facilities to which these instructions were addressed are the six nuclear power plants currently in operation and one that, although currently in the dismantling phase, has a spent fuel Individualised Temporary Storage (ITS) facility on site.

As agreed to at European level, the scope of the licensees' assessments was required to include the following:

- Extreme natural events: earthquakes, floods and other natural events
- Events implying loss of safety functions due to loss of different electricity supply resources or the ultimate heat sink
- Management of severe accidents in the Reactor core and accidents involving loss of Spent Fuel Pool inventory and/or cooling. In the event of there being any other type of spent fuel storage at the site, its robustness with respect to the aforementioned events must be analysed.

4.1. Generic aspects

The most noteworthy aspects that the licensees have included in the studies and that are common to all the facilities are first addressed in this section.

4.1.a Extreme natural events

- **Earthquakes:**

In accordance with the practice of application adhered to in the international seismic standards, in the seismic design of the Spanish nuclear power plants, earthquakes have been contemplated on two step levels of severity: a maximum level constituting the '*design basis earthquake*' or DBE, and another lower level corresponding to the '*operating basis earthquake*'. In the NRC standards, these are known respectively as the *Safe Shutdown Earthquake* (SSE) and the *Operating Basis Earthquake* (OBE).

The DBE is the maximum earthquake that, given the historical data and the characteristics of the terrain, it is thought might reasonably occur at a given site, causing the maximum ground movement assumed in the design of the facility. It presents a very low probability of being exceeded during the entire service lifetime of the installation and is associated with maximum safety requirements. In the event of this earthquake occurring, the plant structures, systems and components (SSCs) required to guarantee the integrity of the reactor coolant boundary and the capacity to shut down the reactor and maintain it in a safe condition would remain in operation, as would the capacity to prevent or mitigate accidents potentially causing the uncontrolled release of radioactive effluents.

The operating basis earthquake (OBE) is the largest earthquake that is reasonably expected to occur during the operating lifetime of the plant, and is associated with the safety requirements to be put in place to maintain the facility in normal operation without undue risk. The value typically assigned to this earthquake is half that corresponding to the DBE. In the event of an earthquake exceeding the OBE, the facility would have to be taken to the safe shutdown condition in an orderly manner, in accordance with the action procedures established in the Operating Technical Specifications of each nuclear power plant, in order to be subjected to a specific inspection process ensuring the absence of damage to the plant SSCs.

All the plants have reviewed their SSCs design bases with respect to earthquakes. The conclusions drawn by the licensees indicate that these design bases are adequately fulfilled. In addition, the licensees have reviewed the data on earthquakes that have occurred in the vicinity of the plants since the cut-off date considered in the design basis earthquake definition studies to the first half of 2011, and have concluded that, using the methodology applied in the initial studies, the initially adopted values for Peak Ground Acceleration (PGA), which range from 0.1g to 0.2 g, continue to be valid.

It should be pointed out that, as indicated in the Spanish Standard on Earthquake-Resistant Construction (2002), the calculated seismic acceleration applicable to the sites of the Spanish nuclear power plants is estimated at between 0.05g and 0.08g; however, the value that was used as the DBE at the different Spanish plants ranges from 0.10g to 0.20g.

The plant seismic design bases establish that safety significant SSCs should be designed to withstand the effects of natural phenomena without losing their capacity to perform their safety functions. The seismic classification of safety significant SSCs was carried out in accordance with the criteria of NRC Regulatory Guide 1.29 and ANSI-N 18.2. Seismic Category I (SC I) SSCs have been designed to withstand the effects of the DBE while remaining functional. The SSCs not included in the aforementioned category are known as Seismic Category II (SC II) SSCs and have been designed in accordance with the Spanish seismic resistance standard, with the exception of those whose eventual failure in response to seismic action might affect the function of any of the SC I SSCs, these being known as SC II/I (or SC IIA) SSCs and having been designed to withstand the DBE.

The CSN evaluation considers the content of the licensees' reports to be acceptable as regards their seismic design bases.

In view of the progress made in recent years in site seismic characterisation methods and of the experience gleaned at international level, the CSN is considering initiating a seismic hazard updating programme in accordance with the most recent IAEA standards.

Mention should be made of the fact that the licensees have formal processes to ensure the operability of the SSCs required to reach safe shutdown, among them the OTS surveillance requirements, application of the Maintenance Rule to equipment and structures, In-Service Inspection and seismic and environmental qualification requirements. These processes are regulated by CSN instructions within the framework of the integrated plant supervision and control system in force in Spain.

The licensees' reports include an analysis of the possible indirect effects induced by an earthquake inside the facility; for this purpose consideration has been given to explosions and fires, as well as to internal flooding caused by pipe breaks. The scope expected by the CSN for these analyses, which were transmitted to the licensees during the meetings held, is as follows:

- Fires and explosions: identification of the design basis of the facility as regards protection against fires and explosions caused by an earthquake; identification of combustible or explosive materials stored at the plant, including the performance of an analysis of the corresponding seismic capacity and definition of feasible actions to improve seismic performance where possible. In those cases in which it is not possible to justify an adequate seismic margin, a check is made to ensure that the potential effects do not impact the capacity to reach and maintain safe plant shutdown conditions and that they do not cause any unacceptable radiological consequences off site.

- Internal flooding: identification of the design basis of the facility as regards compliance with the protection against internal floods arising as a result of an earthquake. Analysis of non-seismic category I sources of flooding (tanks and piping), identifying barriers to flooding as a result of ruptures and analysing the performance of the barriers in the event of an earthquake.

  Use of flooding probabilistic safety assessment (PSA) to identify ruptures potentially generating initiating events and affecting mitigation systems, in order to identify sources of flooding and barriers against them, and include them in the seismic margin review walkdowns.

  Identification of possible scenarios of flooding caused the failure of structures or components that, despite being seismic category I, contain or channel large masses of water and that might give rise to effects not previously analysed (such as for example galleries channelling cooling system pipes taking suction from tanks, etc.) and evaluation from the seismic point of view of the protective barriers in place to protect against such flooding.

The CSN evaluation has determined that in certain cases the content of the licensee's analyses is incomplete, as is detailed in the corresponding sections of chapter 4.2 of this report.

Furthermore, as regards the equipment and structures currently available at the plants to respond to flooding, the CSN evaluation considers that all the licensees should adopt additional measures to reinforce their capacity to withstand earthquakes. Among such equipment and structures, consideration should be given to the following: barriers against the effects of flooding (drains, drains check valves, etc.) and instrumentation for their detection, as well as the tripping of non-seismically qualified pumps belonging to systems whose rupture as a consequence of an earthquake might cause flooding.

Finally, as regards the licensing bases against internal flooding caused by earthquakes, the CSN has identified a certain disparity in the reference standards used by the different plants, for which reason the licensees will be required to modify these bases to adapt to the most recently updated international standards, which explicitly include the consideration of earthquakes in the design analyses to protect against the consequences of ruptures.

As regards the margins of safety with respect to the occurrence of earthquakes, considerations have been based on the fact that seismic IPEEE (*Individual Plant Examinations for External Events*) analyses were already available in Spain for all the operating plants. The IPEEE analyses are oriented towards the identification of plant vulnerabilities to external events beyond the design bases. In accordance with the seismic margin methodologies applied (EPRI and US-NRC), the aim is to determine the seismic capacity of the plant known as the "high confidence of low probability of failure" (HCLPF) capacity. For this purpose a Review Level Earthquake (RLE) was established by the CSN in the initial analyses, corresponding to a PGA of 0.3g (with consideration given to an adequate review margin for all the plants independent from their seismic design basis), compliance with this value not being required.

In the IPEEE analyses the licensees had verified whether for two initiating events induced by the earthquake (loss of off-site power and small break LOCA), a seismic margin equal to or higher than 0.3g could be assigned to the SSCs required to reach and maintain safe shutdown (for 72 hours), including the functions of long-term emergency core cooling and containment isolation. Otherwise, the licensees had proposed additional measures to meet this objective.

Within the stress test programme, the scope of the seismic margin analysed has been extended to include the SSCs required to guarantee the integrity and cooling of the spent fuel pool. Also, among the measures aimed at guaranteeing greater plant robustness in response to seismic events, the licensees have revised, or proposed the revision of, the margins of the equipment used to address station blackout (SBO) and severe accident situations. In all these cases, the licensees have verified the possibility of assigning a seismic margin equal to or greater than 0.3g to these SSCs or, otherwise, have proposed the additional measures required for compliance.

In general the CSN evaluation considers the content of the licensees' reports to be acceptable as regards the assessment of the existing seismic margins, with the reservations and specific comments detailed in the corresponding sections of chapter 4.2 of this report.

Where applicable, the licensees include in their reports the results of the analyses performed on the effects of earthquakes on industries in the vicinity of their sites, obtained in the IPEEE's. The CSN has considered these analyses and their conclusions to be valid.

Another aspect analysed by the licensees has been the possible loss of water in the spent fuel pool, or in the heat sink pools where applicable, as a result of the movement caused in the water by the earthquake ("sloshing"), the conclusion being that for the intensity of earthquake considered, both the DBE and the seismic margin of 0.3g, this effect would not in any case be of any relevance.

In those cases in which the plant is located in a river basin with dams upstream of the site, the licensees have carried out an analysis of the structural resistance of these constructions with a view to verifying their capacity to withstand an earthquake of the same intensity as the plant design basis earthquake. In addition, an analysis has been performed to determine whether these dams withstand larger earthquakes and the seismic margins available for each dam have been quantified.

Complementary to the above, the licensees have undertaken analysis of the consequences that the rupturing of these dams would have for the site. In this respect they have assessed the propagation of the flood that might cause such rupturing to the site of the nuclear power plant, in order to determine the maximum credible flood level at the plant as a result of such an event and the time that the maximum peak flow would take to reach the facility.

For the evaluation of these studies, the CSN has been specifically supported by a national centre (CEDEX) of recognised solvency in this type of analysis. The contents of each evaluation are detailed in the corresponding sections of chapter 4.2 of this report.

- **Flooding**

All the plants have reviewed their design bases in relation to flooding as a result of natural off-site events. The conclusions obtained by the licensees indicate that these design bases are adequately fulfilled. In addition, the licensees have assessed their suitability as regards the current understanding of these phenomena, concluding that the magnitude of the design basis flood selected (DBF, *Design Basis Flooding*) continues to be valid.

The CSN evaluation considers the content of the licensees' reports to be acceptable as regards the external flooding design basis.

In addition to the analyses of flooding as a result of the rupturing of dams addressed in the previous section, the review studies contemplate flood caused by other events, such as intense local rainfall, the overflowing of rivers and gullies, tsunamis, wave action and rising sea or groundwater levels, etc.

These analyses include study of the maximum expected event and also of the existing safety margins, as well as the establishment of various proposals for improvement applicable in each case, these being analysed in the corresponding sections of chapter 4.2 of this report, which also contain observations corresponding to the evaluation performed by the CSN.

- **Other natural events**

The analyses performed by the licensees are based on a preliminary probabilistic screening in which use has been made of the available IPEEE results to attempt to establish those external events – other than earthquakes and flooding – that might have a safety impact at each plant. Consideration has been given to the following external events, among others: strong winds, electrical storms, hail, snow storms, extreme temperatures (high and low), freezing, drought and forest fires.

For each of these events the licensees have reviewed the original design basis and have checked that the plant structures and components located in outdoor areas are adequately designed. Furthermore, they have attempted to verify the existence of safety margins beyond the design bases for those events considered to be credible at each site, and have established various reinforcement measures for implementation.

In general the CSN evaluation considers the content of the licensees' reports to be acceptable as regards these events, with the reservations and specific comments detailed in the corresponding sections of chapter 4.2 of this report.

Nevertheless, in the evaluation performed by the CSN, it has been seen that the potential safety impacts of certain possible combinations of the natural events considered at each site, such as damp snow coinciding with strong winds, have not been documented in the final reports submitted. The CSN will require the analyses carried out by the licensees to be adequately completed.

Furthermore, in 2010, prior to the on-going stress tests and with a view to progressing, in keeping with the development of understanding, with the analyses of the potential risks associated with the site meteorological factors, the CSN undertook a specific study in collaboration with the State Meteorology Agency (AEMET) to draw up a *climatology* regarding the occurrence or tornados in the areas surrounding nuclear facilities. This study is currently on-going and points to the fact that in Spain there are very few actual historic records of tornados, these being insufficient for any rigorous statistical treatment. An initial look at the preliminary results shows that the probability of a tornado occurring at the nuclear power plant sites would be 'low' or 'very low', but that it is not yet possible to quantify this for each plant or characterise a possible tornado that might occur at each site. Depending on the final results obtained from this study, the CSN will consider the advisability of requiring additional actions at the plants, with the scope corresponding in each case.

4.1.b Loss of safety functions

- **Loss of power**

The reports submitted by the plants contain a detailed summary of the alternating current electricity supply systems, including the distribution networks and available sources, both on and off site. Also described in detail are the sequences that might occur in the event of a successive loss of off-site power (LOOP) and of the emergency and auxiliary on-site alternating current sources (SBO), the times available for the implementation of actions and the applicable action procedures. In all cases an analysis of battery depletion is also included.

For the design of the electrical systems of plants of American design, the CSN considered the criteria contained in the USNRC standards to be applicable. Among these, and as regards the design of these systems, special mention might be made of General Design Criterion number 17 ("Electric power systems"), Regulatory Guide 1.9 ("Application and Testing of Safety-Related Diesel Generators in Nuclear Power Plants") and IEEE Std 387, Regulatory Guide 1.32 ("Criteria for power systems for Nuclear Power Plants") and IEEE Std 308. For Station Blackout (SBO), the contents of 10CFR50.63 ("Loss of all alternating current power") and of Regulatory Guide 1.155 ("Station Blackout") were applied.

- **Loss of off-site power (LOOP)**

The loss of off-site power is an event that is contemplated in the design basis of the Spanish nuclear power plants. The additional loss of the safeguards diesel generators is also an event contemplated in the design basis of the five Spanish nuclear power plants of American design, since it was included as an extension of the initial design basis during the process of compliance with the regulations on Station Blackout (SBO). As in Germany, the SBO for Trillo NPP was addressed within the general framework of requirements aimed at reducing the vulnerability of the plants to severe accidents.

As regards the resistance capacity of the off-site feed lines, the criteria are equally applicable to all the supply networks of the Spanish plants, in accordance with the information provided by the grid operator (REE). The objective of the hypotheses currently applicable in Spain to the design of pylons, cables and all types of overhead high voltage line accessories is to prevent failure under adverse weather conditions (wind, ice), but not with regard to earthquakes; however, the design with respect to the loads due to wind and ice provides a significant mechanical resistance. In summary, these hypotheses are as follows:

- Loads due to 120 km/h winds (in accordance with the 1968 regulation).
- Loads due to 140 km/h winds (in accordance with the 2008 regulation).
- Loads due to *coatings* of ice.
- Combined loads of wind and ice (in accordance with the 2008 regulation).

The extraordinary meteorological phenomena recorded to date in Spain have had little effect on the transmission network. Furthermore, the existence in Spain of an important meshing of the transmission network and of rigorous operating criteria significantly reduces the risk of loss of power in the event of failure of one of the components of the transmission network.

As regards the reliability of the off-site grid and the lines supplying off-site power to the plants, a process of applying NRC Generic Letter 2006-02, ("Grid reliability and the impact on plant risk and the operability of offsite power") was initiated in Spain, a mixed working group from REE, UNESA (the Spanish electricity utilities association) and the CSN was set up in 2006. The work performed by this group served as the basis for an action plan having the dual objective of establishing a protocol for communication of the status of the grid at all times and of updating the dynamic analyses of grid stability performed for each plant during the 1990's within the framework of the so-called ESCENRED project.

In force at the REE grid Control Centre since January 1st 2008 has been the Protocol establishing the minimum configurations of the external plant connections, within the so-called "network of influence", and the need to notify the plants of any anomaly. In the opposite direction, the procedures of all the plants for communication with the delegate load dispatch centres were adapted to require notification to REE of significant reductions in the reliability of generation.

As a result of the updating work performed within the ESCENRED project, the analyses of grid stability and of interactions with each plant have been revised, with updated models of the components of the plant and the grid, and with the topology and generation distribution forecasts as of 2011. Severe contingencies (nearby three-phase short-circuiting, with protection failures, or grid discharges and losses of generation) have been simulated, with joint analysis by REE and the engineering department of each plant of the behaviour of the grid and off-site feeds, taking into account settings of the protections in the internal systems of the plant. In the analyses performed by each plant, special emphasis has been placed on the behaviour of the preferential sources of off-site feed. The work of this group is expected to be completed in the near future.

As a result of the activities carried out in recent years, there has been an enhancement of the understanding of the situation of the grid and of its dynamic response, this having implied an increase in the reliability of the electrical supply to the plants.

In the event of a situation of zero voltage in the grid, REE has procedures for the recovery of the service in which priority is given to electrical feed for the nuclear power plants. The recovery of the electricity supply to the nuclear power plant switchyards would be undertaken preferentially from the autonomous start-up of hydroelectric stations located in the vicinity of each of the plants.

- **Station blackout (SBO)**

The SBO standards applicable in Spain to plants of American design establish a coping duration that may last 2, 4, 8 or 16 hours depending on three parameters: susceptibility to loss of off-site power (due to characteristics of the weather, the grid and the switchyard), the degree of redundancy of the internal emergency alternating current generators and the degree of reliability of such generators. For this period, consideration was initially given to the suitability of the plant response, taking into account the following aspects: the availability of condensate water, the capacity of the batteries, the availability of compressed air, loss of ventilation, containment integrity and the capacity to maintain primary system inventory. All the above was to be considered after having chosen one of the two following basic options:

– Option 1, non-dependence of alternating current; i.e., by means of systems whose operation does not require alternating current electricity supply, or
– Option 2, availability of an alternative source of alternating current (generally known as the SBO diesel generator) for the feed of certain systems.

In the case of Trillo nuclear power plant, the NSSS of which was supplied by the German company Siemens-KWU, the design includes four "safeguards" diesel generators and four "emergency" diesel generators, and was developed in compliance with the applicable KTA standards and with the later the improvements defined by the German RSK to reduce the vulnerability of the plants to severe accidents. Currently available is the "bleed and feed" capacity of the secondary system; the capacity to perform primary system "bleed" is in the design phase, its implementation being forecast for the year 2013.

In addition to what was required by the CSN in its Complementary Technical Instructions (ITC's), the licensees' reports analyse the scenarios that would arise in the event of depletion of the batteries and complete loss of direct current supply, detailing the manual actions that might be carried out and the improvements proposed to reinforce the response capabilities for this situation.

- **Improvements proposed by the licensees for loss of power events**

All the licensees propose additional measures to improve the robustness of the plants in these scenarios with the priority objective of providing complete autonomy to address SBO type events for at least 24 hours with the equipment existing at the site, and 72 hours with only light equipment provided from off site. Also relevant are the measures proposed to reinforce on-site electricity supply by means of autonomous equipment and to improve the capacity to recover off-site electricity supply from nearby hydroelectric stations.

Another noteworthy aspect is the inclusion of measures to reinforce direct current supply to the controls and instrumentation required to maintain conditions of plant safety in such a situation. Likewise, additional measures are proposed to extend the time to battery depletion and address situations including complete loss of these batteries. The licensees also state that action procedures associated with these improvements will be drawn up and that the personnel will be adequately trained to perform these procedures.

The following proposals for improvement are applicable to all the facilities:

- Improvement of protocols for dedicated electrical supply from hydroelectric stations located in the vicinity of the site and performance of periodic tests in this respect.
- Availability on the site of autonomous electricity generating groups.
- Analysis, and where appropriate testing and proceduralisation, of the capacity to provide water feed for the primary/secondary via the turbine-driven pumps (if included in the design of the plant), even in the event of unavailability of direct current for their control.
- Availability on site of autonomous motor-driven pumps for the injection of water to the primary and/or secondary and be able to perform water or fuel make-up in critical tanks.
- Additional portable instrumentation for performance of the manual control manoeuvres required in the event of complete loss of the batteries.
- Improvements to the communications systems (on and off-site) to address situations implying loss of the corresponding electrical feed systems.
- Improvements to the lighting systems to address prolonged loss of electrical supply events.
- Design modifications required to make available connection points for autonomous electrical and mechanical equipment.

The CSN considers the analyses performed by the licensees and the improvement measures proposed to be basically adequate.

As regards those accidents that might be initiated in the plant shutdown situation, the CSN evaluation has identified the need to generally analyse an additional potential improvement to address situations in which a complete loss of power might occur during the aforementioned shutdown conditions. In this respect, the licensees are required to analyse the capacity to recover containment integrity in those cases in which it its is not established at the beginning of the accident, identifying the possible additional measures required to attempt to guarantee the capacity to recover this integrity.

- **Loss of heat sink**

The licensees' reports first identify the different heat sinks existing at the facilities and their most relevant design characteristics.

The reports then go on to analyse the successive loss of these heat sinks and possible consequences, including the systems in place to maintain the plant in a safe condition and the times available to implement the applicable actions.

The analyses performed by the licensees conclude that these scenarios are bound by the complete loss of alternating current supply (on and off site), for which reason the improvement proposals are the same as those indicated for this event.

The CSN evaluation considers this conclusion to be acceptable.

- **Simultaneous loss of power supply and heat sink**

All the licensees analyse this situation in their reports. The conclusion generally drawn by the licensees is that the situation is equivalent to those covered in the two previous sections, as a result of which the actions for improvement in response to potential limit situations are the same as those described above.

The CSN evaluation considers this conclusion to be acceptable.

4.1.c Accident management

- **Planning for accident management**

The reports submitted by the licensees detail the organisational aspects and the material resources available, in accordance with the respective On-Site Emergency Response Plans (ERP). Each licensee has reviewed the capacity of the plant to respond to emergencies, in relation to both material and human resources; they have also reviewed the contents of their corresponding ERP in order to take on board the lessons learned from Fukushima.

As detailed in section 2 of this report, the reports set out stepwise periods (short, medium and long-term) for the implementation of the different improvement proposals. In this case the proposals seek to increase the robustness of their emergency response organisations in the different relevant areas identified, which were already underlined in the preliminary reports.

The licensees point out that they have set up a working group bringing together all the plants to analyse the human resources required to reinforce their emergency organisations. In this respect they indicate that the following aspects will be taken into account:

- the feasibility of addressing the functions required in scenarios such as those postulated in the stress tests;
- the potential interferences due to duplicated functions among the personnel;
- the personnel required to carry out the new prevention and mitigation strategies;
- the performance of benchmarking activities to analyse the suitability of the current organisation;
- the changes required in the plant documentation (ERP, procedures, etc.); and
- the appropriate means of transport for the effective incorporation of the personnel.

They also state that, on completion of this joint analysis, they will carry out in the medium term the actions deriving therefrom.

The CSN considers the proposal to be adequate, albeit with the following additional considerations:

- plants with more than one group on the site should consider the simultaneous occurrence of the accident in both groups;
- a detailed study should be performed of the feasibility of carrying out the local actions identified in these analyses using portable equipment, taking into account among other things the accessibility of the locations at which the actions are to be performed, the times available for such performance

and the availability of adequate human resources. If such feasibility is not demonstrated, the implementation of fixed equipment should be chosen;

- the feasibility of assigning more than one function to be performed, probably simultaneously, to a specific job post in the emergency response organisation should be reviewed; and
- given the importance of having available adequate human resources for the correct management of an emergency, and especially a severe accident, each licensee should draw up and submit to the CSN for approval a report containing the improvement plans and the strengthening of the emergency response organisation, taking into account the aforementioned considerations, this to be accomplished within one year.

The licensees have decided to reinforce the centres currently available for the management of emergencies with a new on-site Alternative Emergency Management Centre (AEMC), seismically designed and with means for protection against radiations, in order to facilitate emergency operations in extreme situations such as those analysed. For this purpose a working group will be set up, comprising the licensees of all the Spanish nuclear power plants, which will define the characteristics of this centre in the short term. The completion of the construction or the modification of the existing structures is scheduled for the long term (2015-2016).

The CSN considers the proposal to be adequate, although the period for implementation will be the subject of review, with an adequate detailed evaluation of both the importance of this action and the difficulties associated with its complete implementation. In any case, the licensees shall submit to the CSN provisional short to medium-term measures, such that improved capacities, even if only partial, be available prior to the dates for the complete implementation of this modification.

The licensees also propose to set up an Emergency Support Centre (ESC), common to all the plants, with back-up equipment located at a Centralised Stores and available to be deployed and operated by an Intervention Unit ready to act at the sites in 24 hours. The reports indicate that this centre would be operative in the medium term.

The CSN considers this proposal to be adequate and will require the licensees to submit a detailed specification indicating the available resources, the management of these resources and of the ESC, the training of the personnel of the facility and the way in which the centre will be dealt with in their respective SEP's and enacting procedures; this should also include guarantees for its activation and operation. All these aspects shall be defined in the short term, with their resolution, including start-up of the ESC, being performed in the medium term.

The plants already had a mutual assistance procedure for emergency situations; the licensees point out that this procedure will be reviewed and updated in order to bring it into line with the new needs for support and the exchange of human and material resources deriving from these analyses. They also report on the fact that the members of WANO (*World Association of Nuclear Operators*) have decided to promote an integrated world-wide emergency response strategy.

As regards the capacity to access the site, for both people and auxiliary equipment, all the licensees have analysed this issue for the most limiting cases (severe earthquake and flooding), albeit to different extents, establishing the itineraries that would be available under such circumstances. Section 4.2 of this report details the content of the evaluation performed by the CSN on this issue for each plant.

Finally, and in relation to the availability of on and off-site voice and data communications resources in events such as those considered in these "stress tests", the licensees point out that in the short term they will undertake an exhaustive analysis, taking into account criteria such as redundancy, independence and autonomy, with a view to ensuring the availability of the communications systems in the scenarios postulated in the present stress tests. The conclusions of the aforementioned analysis will be coordinated by the plants in order to jointly define the improvements identified, which will be implemented in the long term.

The CSN considers the proposal to be adequate, although the licensees should study and report on the incorporation of provisional measures in the short to medium-term, such that improved capacities, even though they are only partial, be available prior to the dates of implementation of the long-term measures.

As regards the reference dose levels for the personnel intervening in an emergency, the licensees' proposals are not fully homogeneous, some referring to what is set out in the IAEA's TECDOC 953 and the recently approved BSS's, also of the IAEA, while others refer to the reference levels established in ICRP-103 (lower than the former) and, finally, one licensee proposes to maintain the values currently included in his procedures. The CSN considers that, in order to make the individual protection of the workers compatible with the feasibility of performing mitigation actions, a single national value should be established; consequently, the CSN will issue specific requirements harmonising these reference levels.

- **Management of severe accidents (in the reactor)**

The licensees' reports present the different operating procedures currently available at each plant to address accident situations, specifically the Emergency Operating Procedures (EOP's) and the Severe Accident Management Guidelines (SAMGs). The fundamental objective of the EOP's is to attempt to prevent core damage, while that of the SAMGs is to mitigate its consequences, including the maintenance of containment integrity and the prevention and/or mitigation of the off-site release of fission products.

The implementation of the SAMGs at the Spanish plants of American design, both Pressurised Water Reactor (PWR) plants and Boiling Water Reactor (BWR) plants, followed a process that was parallel in time, such that all these plants have had SAMGs since the year 2001. This implementation was performed in accordance with the practices of the country of origin (USA), and then applying the criterion of using only equipment already available at the plants.

In the specific case of Trillo NPP, the only Spanish plant of German design, the implementation of these procedures (Operating Manual and Severe Accidents Manual) was also performed in accordance with the practices of the country of origin of the technology. This has meant that the scope of these manuals focuses more on reinforcing strategies to prevent core damage than on the mitigation of its consequences.

Both the EOPs and the SAMGs have been subject to specific CSN requirements in the past, as a result of which they were already part of the Spanish regulatory system. Among these requirements are those relating to the initial and on-going training of the emergency response personnel, as established in CSN Instruction IS-12 ("Requirements regarding the qualification and training of site and external non-licensed personnel in the area of nuclear power plants"). The development and maintenance of these procedures and guidelines are currently included within the scope of the systematic supervision processes of the CSN.

As regards the control of hydrogen in the containment, the licensees point out that in order to be able to undertake a management of hydrogen that covers the ranges of concentrations expected in the case of a severe accident and improve the robustness of the plant, they will install passive autocatalytic recombiners (PAR's) in those areas of the containment that might present a risk of hydrogen accumulation, with the exception of Trillo NPP, which already has such equipment, and Garoña NPP, whose primary containment is "inerted" with Nitrogen during power operation, for which reason this equipment is expected to be installed in the secondary containment.

Some of the licensees have also analysed the possible accumulation of hydrogen in other buildings annexed to the containment, while others state that they will undertake such analysis in the short term.

The CSN evaluation considers the content of the licensees' reports to be acceptable as regards the control of hydrogen in containment. Section 4.2 of this report details the content of each evaluation.

As regards the prevention of excessive pressure conditions in containment, the licensees of the PWR plants indicate that they are going to install a filtered vent as an additional improvement to protect the containment. The implementation of the filtered vent provides adequate protection against the risk of failure of the containment as a result of overpressure and, in addition, reduces the radiological limitations that non-filtered venting implies.

The BWR plants already have a "hard" venting system that, if accomplished from the Wetwell, includes implicitly the scrubbing of fission products as they pass through the suppression pool (coming from the Drywell or the relief and safety valves). The licensees have also verified that the current systems have a seismic margin of 0.3g and plan to incorporate the modifications necessary to improve their operability under SBO conditions. They also propose to carry out additional actions to study or implement a filtering system on the existing containment vent line.

The CSN evaluation considers the implementation of filtered containment vents at all the operating plants to be particularly advisable, for which reason it values these proposals positively.

In relation to the reduction/mitigation of the off-site release of fission products, and in addition to the filtered venting of the containment, the licensees are analysing the strategy of externally spraying the containment, or any other building that might be affected by significant radioactive leakage, by spraying with water from the outside those points of the structure of the building that constituted the source of the emissions. The final development of this strategy, along with the identification of the resources for the confinement/treatment of the liquid radioactive wastes produced during the accident, is being undertaken within the framework of the response to the CSN Complementary Technical Instruction mentioned in section 1.2 of this report, relating to the development of mitigation measures to respond to beyond design basis events relating to the potential loss of large areas of nuclear power plants.

The licensees also propose various improvements, specific to each facility, to improve the following aspects: the habitability of the control room during severe accidents; the availability of the instrumentation in the event of prolonged SBO's; and to provide alternative measures, based on portable equipment and connections to systems, with a view to being able to inject water into the vessel, the containment and the steam generators (PWR), these being detailed in section 4.2.

As regards the performance of analyses of severe accidents that might begin with the plant in the shutdown condition, the licensees indicate in their reports that they will carry out such analyses within the framework of the probabilistic safety assessment (PSA) updating programmes. The CSN considers the performance of these analyses in the context of PSA to be adequate, on the condition that these be completed before December 31st 2012 (except in the case of Trillo NPP, where the analyses will be integrated in the planned improvement relating to the development of guidelines for the management of severe accidents, which has a specific period for performance). Furthermore, by the said date the licensees should submit an assessment of the analyses including the potential proposals for improvement that might arise.

The detailed CSN evaluation of these aspects may be found in the corresponding sections of chapter 4.2 of this report.

- **Management of accidents involving loss of inventory and/or Spent Fuel Pool cooling**

In this case the licensees identify the resources available, normal and alternative, for cooling of and the supply of water to the spent fuel pools (SFP).

The licensees also present an analysis of the times available prior to boiling and before different levels of water are reached (to uncovering of the fuel assemblies) in the event of total loss of cooling and for different thermal loads in the SFP. Also analysed has been the problem of the possible re-criticality of the fuel, if the pools contain borated water and replenishment had to be performed using non-borated water. The CSN considers these analyses to be acceptable.

The CSN also considers that in order to address accidents involving prolonged loss of the UHS and of electricity supply, the SFP temperature and level instrumentation should have an adequate range (in the case of level, to the bottom of the SFP), should be safety and seismic class and should have an indication available in the control room; furthermore, there should be portable instrumentation available for the case of loss of all power sources. In general, the licensees' proposals fulfil these requirements and are, therefore, considered to be adequate. The licensees should complete their improvement plans in those cases in which any of the aforementioned characteristics is insufficiently covered.

As regards other improvement measures to be implemented, the licensees propose to provide their plants with portable equipment to replace the inventory of water in the pool, along with the portable instrumentation required for adequate control of these manoeuvres. Some licensees also mention that they are studying the possibility of incorporating resources to allow for spraying of the spent fuel assemblies if they were to be left uncovered.

The following section mentions the licensees' proposal in relation to analysis of analysis of fuel degradation phenomena in the pool.

- **Radiological protection issues**

The licensees have performed an estimate of the doses to the personnel in the control room and Technical Support Centre (TSC) in the scenarios analysed in the present stress tests, the objective being to identify the protective measures required to guarantee that the doses received do not exceed the emergency intervention levels.

In all cases, with the exception of Cofrentes NPP, the preliminary estimate of the licensees points to the need to evacuate the emergency support centres other than the control room and TSC in certain severe accident scenarios.

As regards the tracking and control of doses to the workers and of radioactive emissions, the licensees have assessed the resources available, concluding that the procedures and human and material resources available to them are generally adequate, although they feel that it would be appropriate to analyse possible improvements in order to strengthen the response to severe accident scenarios. The analyses will be completed jointly by all the plants and are expected to be finished by June 2012.

Particularly noteworthy among the proposals submitted is the performance of a detailed analysis of the additional radiological protection resources and equipment that it would be advisable to have available to respond to a severe accident, and to construct an alternative emergency management centre (AEMC) on each site with the possibility of radiologically controlling the workers in order to guarantee that they continue to work under suitable conditions.

These proposals are positively valued by the CSN. In relation to the analysis of additional radiological protection resources and equipment, the evaluation performed by the CSN concludes that it is necessary to verify that the scope of the foreseen study on additional resources and equipment to address severe accidents covers the different aspects identified by each plant for the adequate radiological control of the workers, and that alternatives be analysed for the case of a lack of fixed radiological protection instrumentation to monitor the radiological conditions in the plant. As regards the construction of an AEMC, it is concluded that the licensees should develop alternatives for the case of having to evacuate the existing emergency management centres as a result of the radiological conditions during such time as the AEMC is not yet operative.

The CSN considers that the final reports submitted by the licensees represent a step forward with respect to what is indicated in the preliminary reports as regards the identification of situations in which the radiological conditions might prevent the performance of local manual actions. However, there are differences in the approach and in the degree of development of the analyses performed by the different plants which are detailed in the specific sections on each plant.

As a general conclusion of the evaluation, the CSN considers it necessary to unify criteria between the plants regarding the definitive scope of the situations to be analysed (covering the manual actions currently contemplated in the SAMGs and the additional actions arising as a result of these stress tests), the analytical methodology (considering atmospheric releases and, in certain cases, the direct contributions from systems and/or components), and the licensees' strategies, organisation and resources to limit and optimise the doses received during these activities (analysis of possibilities for remote actuations and reduction of the intervention times and personnel required in order to guarantee doses in keeping with the applicable reference levels).

As regards loss of SFP cooling accidents, the licensees have calculated the dose rates at the edge of the pool on the basis of the level of water above the fuel assemblies in order to identify the loss of shielding capacity and its repercussion on accessibility for the performance of recovery actions.

Generally speaking, the CSN will request that – in view of the results obtained – the radiological protection aspects to be considered in the local manual actions foreseen in the event of loss of pool cooling accidents be incorporated in written procedures, that conditions compromising the performance of manual interventions (water level or time) be identified and that specific actuations be contemplated to reduce doses in the local manual actions foreseen.

As regards the phenomena associated with the processes of degradation of the fuel in the pools following its being uncovered, the licensees point out that they will participate in the activities and analyses to be performed by EPRI in relation to this issue during the period 2012 to 2014 in order to gain in-depth insight into the phenomena and the possible releases that would occur following this event. The CSN considers it adequate not to establish any additional improvement in relation to this issue at this time, since it would be advisable first to progress in the analysis of these phenomena.

- **Other spent fuel storage facilities**

There are currently two sites in Spain, Trillo and José Cabrera, that have an Individualised Temporary Storage (ATI) facility for the storage of their spent fuel outside the pools. In both cases these are dry storage installations based on the concept of passive cooling, for which steel casks are used.

In their analyses the licensees identify the design bases applicable to external events and the existing safety margins, as well as the additional measures that might be implemented to improve the safety of these facilities in response to this type of events. These issues are dealt with in greater detail in the description of the specific features of these two facilities, included in the section 4.2.

- **Periods for implementation of improvement actions**

In their reports the licensees propose the implementation of the improvements proposals identified in accordance with the following schedule:

- Short term; training of analysis groups and performance of the foreseen studies. Completion between June and December 2012.
- Medium term; implementation of various design modifications. Completion between 2013 and 2014.
- Long term: implementation of major design modifications implying new constructions or important changes to the existing systems. Completion between 2015 and 2016; these periods might even be exceeded in exceptional cases.

Overall the CSN considers this schedule to be adequate, although certain specific dates in the licensees' proposals might finally be modified. Furthermore, in the specific cases identified in this report, the implementation of short-term improvement actions will be required as a compensatory measure until the long-term measures proposed by the licensees are implemented. These requirements will be included in the Complementary Technical Instructions that the CSN plans to issue as a result of its evaluation of the Spanish nuclear power plant stress tests, and which are mentioned in section 2.2 of this report.

4.2. Specific aspects for each of the facilities

4.2.1 Trillo Nuclear Power Plant

4.2.1.a Extreme natural events

- **Earthquakes**

- *Licensee's position*

The seismic design of Trillo nuclear power plant was performed in accordance with the procedures used by the German standard KTA 2201.1 and the two design earthquake levels established therein: the *safe earthquake* (considered to constitute the DBE) and the *design earthquake* (similar to the OBE in the NRC standards) were obtained using a deterministic methodology. In accordance with German practice, the *safe earthquake* to be adopted was 0.10g; however, as a requirement of the plant construction permit, the component of maximum horizontal acceleration was finally increased to 0.12g, this values being established as the DBE for Trillo. A value equivalent to half the DBE was adopted for the *design earthquake*.

In the seismological study of the plant site consideration has been given also to those earthquakes that might be induced by mining activities and by the accumulation of water by the major dams in the region, such as the Entrepeñas and Buendía reservoirs. The licensee has examined the new seismic events occurring over a wider period than that considered in the original design, this being extended from 1982 to 2011. The earthquakes that have occurred are considerably lower in intensity than those considered in the design and do not modify the DBE. It is deduced, therefore, that the seismic design bases established at the time of licensing of the plant are currently fully valid and conservative.

The protection of the plant against the DBE is based on the Systems, Structures and Components (SSC) seismic design requirements, in accordance with their classification on the basis of criteria equivalent to those of the American regulatory guide RG 1.29, and with the maintenance, through the processes established in the licensing basis, of the seismic qualification and correct status of the SSCs and of their modifications and spares.

The plant is equipped with a seismic surveillance system that fulfils the recommendati.ons of the German KTA 2201.5 standard and of the RG 1.12. The instrumentation of this system, which is included in the plant's Technical Specifications and has associated surveillance requirements, provides information on the accelerations caused by seismic movements in order to determine whether the design earthquake has been exceeded, as required by the established limiting condition for operation. In the event of the said earthquake being exceeded, the On-Site Emergency Response Plan (ERP) would be activated in accordance with the established procedures.

There is also a set of action procedures that allows the potential consequences of an earthquake to be addressed. Nevertheless, as a short-term improvement, the general post-earthquake inspection procedure will be divided into two more specific procedures: one contemplating immediate inspection prior to shutdown and the other covering the inspection activities prior to start-up.

In the event of seismic activity, consideration has been given to loss of off-site power for at least the 72 hours following the earthquake, and it has been determined that there is no need for equipment external to the site. Also analysed has been the feasibility of accessing the site following an earthquake larger than the DBE, and it has been concluded that there are three itineraries allowing for the transport of the necessary emergency equipment.

Compliance with the current licensing basis as regards seismic behaviour is guaranteed through the periodic application of procedures, surveillance requirements and actuations aimed at adequately maintaining the SSCs and seismic surveillance system, as well as their design modifications and associated spares. No portable equipment outside the installations has been included in the emergency procedures for earthquakes.

Trillo nuclear power plant has responded to the CSN requirements and to other recommendations issued in relation to the consequences of the Fukushima accident (WANO SOER 2011-2). Following the verifications performed to date, no significant vulnerability has been detected at the plant.

The licensee assesses the seismic margin of the plant using the work previously performed by means of the methodology developed by the NRC and EPRI (0.3g review earthquake - focused scope), complemented in the context of the stress tests with the performance of new inspections and extension of the scope. The seismic margins study had been updated, identifying the new elements required for safe shutdown that were installed with design modifications during the period 2001-2011, as well as the already existing equipment that had been modified during the said period, confirming their capacity with respect to the DBE and estimating their seismic margin.

In accordance with the seismic margins studies performed, the licensee currently assigns to the plant a minimum HCLPF capacity value of 0.20g, associated with certain components of the safeguards electrical feed network; identifies the plant components with an HCLPF lower than 0.3g and proposes modifications to increase the minimum capacity of the plant to 0.3g. The licensee also determines a minimum seismic margin of 0.24g for the maintenance of fuel cooling and integrity, associated with the pump seal water tanks of the emergency core cooling system, which at the Trillo plant is also in charge of cooling the spent fuel pool, and which will be also upgraded to 0.3g. As regards the integrity of the containment confinement function, the licensee determines a minimum HCLPF of 0.3g.

For the integrity and confinement of the spent fuel in the individualised temporary storage facility (ATI) the licensee determines an HCLPF capacity of at least 0.3g, associated with the possibility of an ENSA-DPT21 cask tipping.

The licensee has estimated that the probability of a 0.20g earthquake occurring on the site is lower than one event every 220,000 years, while that of an earthquake exceeding the margin of 0.3g would be one event every 675,000 years.

In the context of the stress tests it has also been determined whether the seismic capacity of the following equipment, considered in the strategies to address SBO situations and the management of severe accidents coinciding with an earthquake, is higher than 0.3g and, if this is not the case, measures are proposed to reach this value: seismic Fire Protection System (FPS) equipment, secondary bleed and feed (B&F) dedicated pump and adjacent structure, electrical building battery room ventilation systems, main control room filtering and pressurisation system, passive autocatalytic recombiners (PAR) and alternative equipment for spent fuel pool cooling and inventory replenishment.

As regards the possibility of internal effects induced as a result of an earthquake, Trillo points out the following:

- Fires and explosions: Trillo identifies its design basis and points out that the design makes it very improbable that there could be a fire or explosion in the event of an earthquake; furthermore, the components with the highest risk of causing such events in the safety-related buildings are seismic in their design. The licensee identifies the main combustible loads and sources of explosion and confirms that, by design, there are no non-seismically qualified SSCs that by losing their integrity could cause damage in safe shutdown equipment.
- Internal flooding: Trillo points out that it has an analysis of flooding corresponding to the licensing basis, in which consideration is given to the catastrophic rupturing of non-seismic piping and vessels under conservative premises. The cases analysed justify the effects of flooding as being acceptable on the basis of the existence of various barriers. In addition, the licensee has analysed non-seismically qualified piping, tanks and vessels that might cause an initiating event and damage to mitigation systems, identifying rupturing of the FPS in the “annulus” building as a case to be analysed. The licensee describes the instrumentation, isolation actions and barriers in general in place to respond to this case. The scope for the assessment of the seismic margins is that indicated in previous paragraphs, the analysis including those elements that constitute the flood barriers against major water sources whose rupturing might cause the flooding of other areas of the plant. The licensee does not identify the need to implement other additional actions.

In addition, an analysis has been made of the effects of an earthquake with a horizontal acceleration of 0.3g on the free surface of the water in the spent fuel pool and the essential service water ponds. The results have underlined the fact that there is no significant spillage of water from either the pool or the ponds, as a result of which neither the cooling of the spent fuel nor that of any significant equipment is compromised.

Finally, the licensee has also analysed the possible impact of the rupturing of nearby dams as the result of an earthquake and has concluded that this does not imply any risk of external flooding for the plant.

- *CSN evaluation*

The seismic design bases of the plant are the same as those licensed for the original design and are included in the Safety Analysis Report. Their acceptability with respect to the requirements demanded over time by the CSN has been checked as part of the seismic assessment processes undertaken prior to the granting of the successive operating permits, by means of specific analyses performed during the periodic safety reviews, and also through the different inspections carried out, some periodic and others at specific moments in time, within the CSN's supervision and control processes.

In his review, the licensee has given adequate consideration to the seismic surveillance system installed as a means to protect the plant against the occurrence of earthquakes, along with the set of operation and emergency procedures available and actions foreseen to mitigate the consequences of an earthquake. This system, which was previously implemented at the plant, has been reviewed by the CSN with acceptable results.

The HCLPF values estimated by the licensee are considered justified in accordance with the EPRI methodology, although certain values are currently being reviewed by the CSN, for example the value of 0.3g assigned to the irradiated fuel racks. Also pending verification are the corrective actions proposed by the licensee to increase the HCLPF value of the equipment identified with a margin of less than 0.3g.

The actions proposed are generally considered to be efficient to improve the robustness of the plant in relation to the occurrence of beyond design basis earthquakes. The foreseen periods for the implementation of these actions are also considered to be reasonable.

In addition to the generic conclusions dealt with in section 4.1.a, the following conclusions are drawn as regards the possibility of effects being induced as a result of an earthquake:

- Fires and explosions: the CSN evaluation considers the scope of the analyses performed, identifying the possible sources of explosions or fires, to be adequate.
- Internal flooding: the CSN evaluation considers that the licensee has carried out an ample analysis, including the proposal to increase the seismic margin of certain items of equipment.

- **Flooding**

- *Licensee's position*

The altitude of the plant grading level is 832.0 m., and the maximum flood level for a return period of 10,000 years at the Ermita dam on the river Tagus would reach elevation 725.57 metres. In view of this large difference in elevations, the possibility of flooding of the site as a result of the river swelling has not been considered. Nevertheless, new analyses have been performed by the licensee using updated data, and it is confirmed that the maximum level of floods with return periods of one million years would remain far below the elevation of the plant esplanade (margin greater than 100 m).

As there are no cliff-edge situations for flooding caused by swelling of the river, no possible improvements are identified to increase the robustness of the facility against flooding.

As regards the possibility of external floods as a result of obstructions by ice, Trillo concludes that it is highly unlikely that sufficient ice to produce an obstruction or flooding could be formed.

In relation to the event of local flooding as a result of torrential rains, the design of the plant rainwater drains (roads and roofing) was performed in accordance with the Spanish standards in force when these were constructed. The licensee has carried out a new analysis to take into consideration the meteorological data available up to 2010 and the new standards currently in force. The site drains network has three independent evacuation points, with a capacity of more than 170% of the maximum probable value of precipitation. Consequently, there are ample margins with respect to potential flooding due to torrential rains. Nevertheless, the licensee indicates that improvements are to be made in order to prevent the possibility of minor local flooding in specific areas.

The licensee has also analysed the drainage capacity of the roofs of the plant buildings, but includes the results obtained in the next section, on "other extreme natural events".

As regards the effect of possible rises in the water table, according to the plant surveillance programme the upper perched level is located below the elevation of the foundations of the main buildings of the plant. These are protected by a weatherproofing system and are fitted with a drainage network. The deepest underground galleries are located at an elevation higher than the water table and have a drainage channel in their floor. Bearing in mind the above, an eventual rise in the water table would have no impact on the buildings, since any possible in-seepage would be collected by the drainage system.

In order to avoid the possible effects of adverse meteorological phenomena, the plant has surveillance procedures associated with the drainage systems. These procedures establish the visual inspections to be performed, their frequency and the associated administrative actions. Furthermore, the ERP is activated in the event of rainfall with an hourly intensity of more than 150 l/m^2, measured by the plant meteorological tower, this carrying with it the execution of the previously established procedures.

The standards currently included in the licensing basis relating to external floods are met, without deviations having been identified.

A study is available on the feasibility of accessing the site in the event of flooding as a result of rainfall of exceptional intensity and of the rupturing of dams that might affect access routes to the plant. The conclusion drawn is that unaffected routes would in all cases be left open and that any routes affected could be rehabilitated in a relatively short period of time, through the use of provisional routes.

- *CSN evaluation*

The flooding design bases are the same as those for the original design and have been accepted by the CSN. Furthermore, the protections existing for these phenomena, both the drainage systems and the actuation procedures, have been periodically inspected as part of the CSN supervision programmes.

The licensee has analysed the effect of a possible rise in the water table on the buildings, underground galleries and other SSCs, verifying that this would have no significant impact on safety, since the possible in-seepage would be collected by the drainage systems. The CSN evaluation has identified that the licensee has not documented the analysis of the effects due to a possible failure of the drainage systems, for which reason the CSN will require the licensee to provide complementary information on this analysis.

The robustness of the plant with respect to external flooding is considered to be reasonably justified and the measures proposed to improve the removal of water resulting from torrential rains will contribute to increasing this robustness. The implementation of these measures is considered acceptable. As regards the feasibility of accessing the plant in the event of flooding, its evaluation is included in the section on "Planning of accident management".

- **Other extreme natural events**

- *Licensee's position*

At the Trillo plant the natural events that have passed the screening process with the IPEEE methodology, used to rule out those whose impact was negligible, have been: torrential rains, snow loads and strong winds. In addition to these the licensee has reviewed other events that are credible at the site even though they were previously discarded, these being electrical storms, rising groundwater levels, forest fires, hail and extreme temperatures (maximum and minimum).

As regards torrential rains and the drainage of rainwater from the roofs of buildings, the evacuation capacity is higher than that demanded by the current Spanish building technical code. The licensee has reviewed the calculations of the drainage capacity of the main buildings using updated meteorological data for a return period of 10,000 years. In view of the number of evacuation elements on the roofs and the fact that the plant has established a programme of revision and maintenance works to guarantee their state of conservation, the licensee concluded that the Trillo plant has no vulnerability to the flooding of roofs as a result of heavy rainfall.

Considerations regarding drainage of the site and the effects of rising groundwater levels have been addressed above in the section on "flooding".

The design considers a snow load on a horizontal surface of 100 kg/m^2. The load that might affect the structural capacity of the roofs is higher than 184 kg/m^2, which is equivalent to a layer of snow measuring 1.53 m, a value that the licensee considers unthinkable at this site.

As regards strong winds, the wind speed considered in the design of the plant buildings and structures was 144 km/h. The load due to winds has been re-evaluated using updated meteorological data and the standards currently in force, the conclusion being that there are margins of more than 100% in the case of the safety-related structures.

Both the occurrence of strong winds and intense snowfalls are contemplated as initiating events in the ERP, which would be activated in accordance with the established action procedures to minimise the possible effects of an emergency.

The design conditions and associated maintenance actuations have been reviewed in relation to electrical storms, forest fires, hail and drought, and it has been concluded that they are adequate according to the applicable standards and ensure ample margins with respect to credible events at the site.

The licensee has also reviewed the treatment given to ambient temperatures in relation to the ultimate heat sink and the rest of the plant SSCs, evaluating the requirements of the applicable standards and the historical records provided by the plant weather station.

The final conclusion of the analysis indicates that Trillo nuclear power plant has available ample design margins with respect to potential extreme natural events, since it is capable of withstanding meteorological situations far in excess of those that have historically taken place at the site.

- *CSN evaluation*

The screening of external events performed to establish the design basis is based on a very low probability of occurrence (10^{-5} per year), in accordance with the probabilistic methodologies included in the applicable IPEEE standards.

The analyses performed by the licensee have seen their scope extended with respect to those carried out previous to the stress tests, and even to those documented in the licensee's preliminary report. In general, the results are considered to be adequately justified. The design criteria applied and margins estimated are reasonable, albeit with the two following reservations:

- The CSN has not yet concluded the evaluation of the margins with respect to extreme temperatures, a task that is currently on-going.
- As has been indicated in the previous section, the CSN will require the licensee to provide complementary information on the analysis of effects due to the possible failure of the drainage systems.

The licensee has actuation procedures for the occurrence of severe meteorological conditions at the site, these having been inspected within the framework of the CSN supervision and control programmes.

With the exception of the improvements already mentioned to prevent possible local flooding in specific areas of the site, the licensee does not propose other potential reinforcement measures for the external events dealt with here. When the CSN has completed its on-going evaluation of the points indicated the advisability or otherwise of adopting additional measures will be determined.

4.2.1.b Loss of safety functions

- **Loss of off-site power (LOOP)**

- *Licensee's position*

Trillo nuclear power plant describes the interconnections with the grid and the available electrical feed paths (and the possibility of operating in "island configuration"), concluding that these provide a high degree of robustness and reliability and of confidence in the capacity to quickly recover from a loss of the off-site grid.

The plant references the procedures of the operator of the national electricity grid for the recovery of power in the event of a zero voltage condition in the grid, these giving priority to power supply for the nuclear power plants, in particular for Trillo.

In a LOOP situation, the electrical supply for the safeguards and emergency equipment is provided by the automatic start-up of the four safeguards diesel generators. As a back-up measure there are a further four emergency diesel generators that allow electrical feed to be provided to the equipment required to take the plant to safe shutdown. All these diesel generators are designed as Safety Class and Seismic Category I.

The safeguards diesel generators are located in the diesel building, with physical and functional separation in four trains; the emergency diesel generators are located in the emergency feedwater building and are also physically and functionally separated in four trains.

The two buildings are separated by a distance of approximately 200 metres, with other buildings located between them. The support systems required for the operation of the diesels are independent, with no support systems being shared by the safeguards and emergency networks.

The operating autonomy of the safeguards diesel generators, without the need for support from outside the plant, is longer than the 72 hours considered in the standards.

As regards the emergency diesel generators, their specific fuel storage capacity allows them to be operated for 24 hours while, by transferring fuel from the redundant safeguards diesel tank, this would be extended to some 25 days.

The plant has lubricating oil stored for the simultaneous operation of all the diesel generators for around three days. This period is much longer when only the emergency diesel generators are operated.

The cooling of the safeguards generators is accomplished by way of the essential services water system, the reserves in the reservoirs allowing for the performance of the safety functions for a period of considerably longer than seven days. In the case of the emergency generators, this is accomplished by means of water reserves (for at least 10 hours) in the pools located inside the emergency feedwater building. There are connections for water make-up to the pools from other plant internal systems which would guarantee the generator cooling function, and consequently the removal of residual heat via the steam generators for a lengthy period of time.

- *CSN evaluation*

The LOOP situation is within the plant design basis, with a coping time of at least three days, which is the autonomy required by the standards for the diesel generators.

The off-site lines have different points of origin and runs, this independence providing reliability in supply. The transfers between feeds have operated satisfactorily. The grid operator has procedures for recovery by areas that take into consideration the preferential feed to be provided to the nuclear power plants.

The four safeguards diesel generators and the four emergency generators, all designed seismically and without apparent common mode failures, provide a highly significant level of security.

The licensee provides a detailed justification of the autonomy of the diesel generators, as regards both gasoil and lubricating oil and cooling, which demonstrates satisfactorily that this would extend beyond the three days considered. Assuming operation with the emergency generators, this period would exceed seven days.

The plant has a programme for the maintenance of diesel generator availability and reliability that is managed as part of the Maintenance Rule.

The aspects indicated by the plant and summarised above are included in the applicable licensing documents and have been repeatedly inspected by the CSN throughout the lifetime of the plant, as a result of which there are no regulatory objections in this respect.

- **Station blackout (SBO)**

- *Licensee's position*

In the event of loss of off-site power (LOOP) and of the normal back-up sources (safeguards diesel generators), the capacity to supply power to the internal emergency network would be maintained by the emergency diesel generators. This ensures the availability of the alternating and direct current consumers assigned to the emergency network, as well as of the safeguards direct current consumers and uninterrupted service, guaranteeing the necessary safety functions.

In the scenario proposed, the depletion of the batteries of the safeguards network would not imply any change in the cooling conditions, since the latter is guaranteed by equipment assigned to the emergency network.

In the hypothetical case of a loss of off-site power (LOOP) with the loss of the normal back-up sources and of any other additional back-up source (i.e. the four emergency diesel generators), the electrical feed sources that would remain available would be the safeguards and emergency +/- 24 V batteries and the 220 V safeguards batteries.

This allows feed to be maintained to the 48/24 V safeguards and emergency network direct current distribution systems, the 220 V safeguards direct current distribution systems and the 380 V uninterrupted service alternating current safeguards distribution network.

The autonomy studies performed without consideration given to the disconnection of loads determine the battery discharging times, which for the safeguards trains are between three hours and five hours twenty minutes, for 220 V, and between approximately three and ten hours for 24 V. In the case of the 24 V emergency batteries, these times range between approximate limits of three and six hours. With a procedure for the disconnection of unnecessary 220 V loads, the discharge times of these batteries would increase significantly.

From the point of view of core cooling, the main characteristic of a situation such as the one considered would be the loss of the steam generator feed function. Available in the procedures to prevent this evolution of the event is the possibility of quickly recovering this function by depressurising the secondary side of the steam generators by discharging via one of the main steam dump stations (this achieves the partial recovery of cooling by using the water existing in the main feedwater lines) and, in parallel to the above, by connecting a diesel-engined pump permanently installed alongside the emergency feedwater building at previously established points via the lines of the emergency feedwater system.

Depressurisation of the steam generators to below approximately 12 bar allows for injection by means of this motor-driven pump, which would initially take water from the emergency feedwater system pools.

It has been estimated that with the available plant internal resources it is possible to perform the necessary actions within around 25-30 minutes as from initiation of the event.

The licensee monitors/tracks the operational performance of the secondary circuit diesel-engined pump by means of the Maintenance Rule.

The limitation of primary coolant leaks via the lines connecting to the circuit is accomplished by means of the following:

- Self-actuating closure of the pressuriser relief valves.
- Automatic closure on initiation of the event of the volume control system extraction by means of the high pressure reducer station regulating valves.
- Automatic closure of containment isolation valves, on minor sampling system lines, on activation of the so-called emergency cooling criteria (ECC), i.e. low pressuriser level, low primary pressure and, where applicable, high activity in containment, which would be fulfilled prior to depletion of the batteries.
- Closure of other lines connecting to the primary circuit by means of checking devices.

Following the above, leakage might continue via the outlet lines from the reactor coolant pump seals (estimated at 0.22 kg/s per pump) and via small diameter lines in the equipment drains system. This leakage would be confined inside containment as a result of closure of the isolations provided by valves actuated from the uninterrupted service busses.

Available for replenishment of the primary coolant, such that the leakage and corresponding contraction of the cooling are compensated in part, is the content of the accumulators, which will be provided when the RCS pressure decreases sufficiently. The licensee's thermohydraulic analyses indicate that, in order to maintain adequate core cooling via the steam generators and by means of natural circulation in the primary, it would not be necessary to inject using active systems or isolate the accumulators in order to prevent the entry of N2 in the primary circuit, which might compromise heat transfer across the steam generators.

Once secondary circuit B&F operation has been stabilised, to address the possible depletion of the batteries, the operation of the steam generator feed motor-driven pump is not compromised since this component is fully autonomous.

The motor-operated valves on the make-up line to the steam generators would remain in the position they were in at the moment feed from the batteries was lost (isolation valves open, regulating valves in intermediate position), the possibility of manually operating these valves from the annulus building being maintained.

As regards limiting situations, the plant indicates that the temperature of 500 ºC at the outlet from the fuel assemblies in the reactor core, which is the criterion validated as the limit for the initiation of steam generator depressurisation in secondary B&F operation, would be reached in t ≈ 103 minutes into the scenario, in a situation of SBO with failure of the emergency diesel generators, if no corrective measures were implemented.

In relation to the possibility of extending the autonomy of the 220 V d.c. batteries, the licensee considers three possible proceduralised levels of load disconnection; with the highest level the available times would be between 16 and 18 hours.

As regards the effects of loss of ventilation, the instrumentation can operate without ventilation for at least 10 hours. As improvement actions, the use of a portable diesel generator in the emergency feedwater building is contemplated.

In the case of the 24 V d.c. feed, attempting to disconnect loads to extend the autonomy of the batteries is not considered feasible since I&C cabinets are involved and assessing the effects of their disconnection is a complex issue. It has been decided that it would be appropriate to rely on improvement actions allowing electrical supply to be maintained.

- *CSN evaluation*

The total loss of off-site alternating current power and the on-site safeguards diesel generators (SBO) is within the plant design basis. The design basis for the emergency diesel generators is considered in the applicable licensing documents and has, therefore, been evaluated previously and inspected on previous occasions.

In the highly improbable event of joint loss of the safeguards end emergency diesel generators, direct current batteries would be available, with extended autonomy values that would be adequate to allow for the start-up of the alternative feed to the steam generators.

Prior to the stress tests, the CSN performed an inspection to verify that the times indicated for the alignment and operation of the diesel-engined pump for alternative steam generator feed were as contemplated by the plant. Likewise, and subsequent to the issuing of the preliminary report, an inspection was performed at the plant on aspects of that report considered to be relevant. The CSN considers that the possibility of operating the diesel-engined pump in manual is a strong point in the case that, following the alignment of this pump, the batteries were to be depleted prior to connection of the portable generators contemplated in the improvement actions.

The CSN has no observations to make regarding the information provided by the plant and, following the verifications performed, considers this information to be acceptable.

- **Improvements proposed by Trillo nuclear power plant in response to loss of power events**

The plant describes a series of planned actions that may be summarised as follows:

- Incorporation of a portable diesel generator, with a connection to the 380 V a.c. emergency supply for the feed of batteries, ventilation and valve actuators.
- Incorporation of a portable electrical pump for injection to the primary and spent fuel pool, plus another portable electrical pump for water transfer manoeuvres and a portable diesel generator to feed the corresponding pumps.
- Improvement of the seismic resistance of the steam generator alternative feed diesel-engined pump in order to achieve a margin of 0.3g.
- Incorporation of portable lighting and communication resources.
- Incorporation of portable feeds for the instrumentation.
- Incorporation of diesel generator lubricating oil reserves.
- Incorporation in the procedures of periodic testing of hydroelectric stations and a special test of the steam generator alternative feed diesel-engined pump under absence of d.c. conditions.

In the current stage of development, the forecasts provided by the plant are considered to be valid, although the feasibility of using portable equipment will be subject to the results of the specific analysis of personnel availability required in section 4.1.c of this report.

With the implementation of these measures, the cliff-edge situation times would be extended and would depend on the autonomy of the portable equipment.

- **Loss of ultimate heat sink (UHS)**

- *Licensee's position*

The main heat sink is made up of the circulating water system, which is a closed system with two natural draught wet towers. Following a reactor scram, the residual heat is removed in a closed circuit configuration via the steam generators, with discharge to the main condenser.

Loss of the condenser function leads to cooling in an open circuit configuration via the secondary circuit, with dumping of the main steam to the atmosphere, this being the alternative to the main heat sink for residual heat removal. In this operating mode, the feed to the steam generators is still by means of the start-up/shutdown pumps taking suction from the feedwater tank. It should be pointed out that the equipment involved in this function is able to take electrical feed from the safeguards diesel generators. The water reserves available in this operating mode (water reserves in the feedwater tank plus reserves in the demineralised water distribution system pools) allows for cooldown of the plant to the conditions for start-up of the residual heat removal systems or, if necessary, allow the removal of residual heat via the steam generators to be prolonged.

In the event of unavailability of feed to the steam generators with the start-up/shutdown pumps, the pumps of the emergency feedwater system, driven mechanically by the emergency diesel generators, may be used.

The ultimate heat sink for the removal of residual heat from the reactor core in shutdown, the cooling of the spent fuel pool and the cooling of the auxiliary systems consists of the essential service water system (VE), which is equipped with two pools of water and forced draught cooling towers. The reserves of water in the essential service ponds are dimensioned to guarantee cooling for 30 days without the need for external make-up following the design basis accident (LOCA), considering the contents of one only of the two ponds.

The system has equipment assigned to the safeguards power distribution network, and also includes equipment assigned to the emergency power distribution network. Both the safeguards and the emergency equipment is capable of guaranteeing the removal of residual heat from the reactor core under cold shutdown conditions and the removal of residual heat from the spent fuel pool. To accomplish this, the operation of a single train is sufficient for each of the two functions and, in extreme cases, there is an alternating cooling mode by means of which, with a single train, it would be possible to cover both cooling functions (core and pool).

The two ponds and their respective water intake structures for the system pumps are physically and functionally separate, as a result of which with the loss of one of the ponds the ultimate availability of a residual heat removal chain is still guaranteed by means of the safeguards network equipment.

Considering only equipment assigned to the emergency network, and with this same situation of loss of function in one of the two reservoirs, it is possible to maintain the function of one residual heat removal chain.

The complete failure of this system during power operation would not have any repercussions on the capacity to cool the reactor core. All the safety functions relating to cooling of the core would be guaranteed with the operation of emergency systems independently from this system, the only exception being the fact that it would not be possible to reach cold shutdown, heat removal continuing via the steam generators. For this reason no improvements additional to those indicated in the section on SBO are foreseen.

For shutdown situations:

- The plant has analytically studied a simultaneous primary and spent fuel pool (SFP) cooling mode (known as the “tandem” mode) for cases in which a single safeguards or emergency residual heat removal chain is available and the primary is open and communicating with the SFP, this having provided satisfactory results. The necessary operating procedures detailing this manoeuvre will be drawn up.
- If the capacity to remove residual heat via the UHS is completely lost, several situations might arise:
  - If the primary system is closed and full or with a low level, cooling of the core might be accomplished via one steam generator (natural single-phase circulation or, for low level, reflux by condensation of steam in the tubes).
  - If the primary system is open with a low level, loss of the UHS would lead to boiling of the water in this system. It would be possible to replace inventory from the accumulators (this would provide for around 13 hours) or from the borated water storage tanks (this would provide for around 70 hours).
- The availability of alternative resources (improvements for SBO) is foreseen for the injection of borated water to the primary circuit.

- *CSN evaluation*

Refer to the evaluation in the following section.

- **Loss of ultimate heat sink combined with SBO**

- *Licensee's position*

The scenario of loss of ultimate heat sink with SBO, occurring during operation at power, is analogous to the one described for SBO, with the difference that the possible recovery of off-site electricity supply via the third network, depending on the prevailing ambient conditions and especially in the rooms of electronics related to the safeguards equipment, would only allow feed to be re-established to the steam generators by means of the start-up/shutdown pumps, recovery of the operation of the essential services water system being necessary to make it possible to reach cold shutdown and normalise the cooling of the spent fuel pool.

In any case, if as a result of the ambient conditions affecting the rooms containing safeguards electrical or electronic equipment in the long term it were not possible to recover feed to the steam generators by means of the start-up/shutdown pumps, it would still be possible to maintain core cooling via the steam generators by providing feed using the emergency feed pumps or the autonomous motor-driven pump.

In the event of loss of UHS with SBO during shutdown, with the primary open, there would be no pumps available to inject the content of the borated water storage tanks. Only the accumulators could be used for this purpose, but to accomplish this it would be necessary to open the isolation valves manually from inside the containment. In order to allow these valves to be opened remotely, it would be necessary to provide them with an alternative supply of electricity. If the water in the accumulators were used, the RCS could be cooled for 13.4 hours.

Trillo considers that the improvement measures analysed and proposed for SBO are valid and adequate for this scenario and also identifies the following additional improvements:

- Use of other sources of water in the event of loss of the essential service water system (VE) by means of flanged connections, portable pumps and hoses (VC, UC3, DAA, information centre tanks).
- Supply of essential service water (VE) to the emergency feedwater pools (RS) by means of portable motor-driven gasoil pump.
- Inclusion in the procedures of the possibility of locally operating the inlet valves to the steam generators, located in the rooms of the annulus building, ZB, at elevation +6.0.
- Design modification to keep the piston check valve bypass valves closed during RHR operation, in order to prevent potential leakage in the RHR suction line.
- Alternative electrical supply for the accumulator valves from the uninterrupted services busses.
- In order to guarantee the opening of the main steam dump isolation valves at low pressures, without current available for the operation of the corresponding pilot valves, the existing back-up pneumatic system will be improved in order to allow for the injection of air from independent compressed air bottles.

- *CSN evaluation*

This section evaluates loss of the UHS with and without SBO.

The licensee has provided an adequate description of the features included in the design to avoid the loss of the UHS, and has analysed the situation that would lead to such loss with and without SBO with an adequate scope.

The information relating to the UHS design basis has been evaluated and licensed by the CSN in previous stages. In addition, the equipment and corresponding procedures have been inspected by the CSN on numerous occasions.

The licensee has performed realistic calculations to estimate the depletion time of the sources of water currently available for the emergency feed water system (RS). The result is that the time available with the RS pools is greater than 24 hours in injection mode with the diesel-engined steam generator injection pump. The manual motor-driven pump actuation manoeuvres will be tested by the licensee when the relevant portable instrumentation for secondary bleed and feed is available. Likewise, a test should be performed of the manual actuation of the steam generator relief valves.

The proposals for improvement presented by the licensee are considered acceptable.

4.2.1.c Accident management

- **Planning of accident management**

- *Licensee's position*

The licensee of the Trillo plant points to specific improvements in the area of communications to strengthen the capacity of the plant in this respect and plans to implement these improvements in the medium term. In keeping with the start-up of the new Alternative Emergency Management Centre (AEMC), the licensee also plans a series of further-reaching communications improvements, which will be analysed in the short term and are expected to be implemented in the long term.

As regards routes for access to the facility, the licensee points to the existence of three feasible accesses to the site in the event of a severe earthquake, and also analyses the way in which the access routes to the site would be affected by floods of different types.

The licensee establishes new reference dose levels for the personnel intervening in an emergency, pointing out that these would be voluntary workers and would be informed. These dose levels correspond to those established in ICRP-103.

- *CSN evaluation*

The licensee's proposal regarding the communication capacity of the plant is considered acceptable, although the licensee should study the incorporation of provisional short to medium-term measures providing improved capacities, even if only partial, prior to the dates for implementation of the long-term measures, informing the CSN.

In relation to the access routes to the facility, the analyses performed by the licensee for cases of earthquakes are considered acceptable, although the licensee should complete these studies for flooding, analysing the time during which the accesses to the plant would be unusable and indicating what compensatory measures are foreseen during this period.

As regards the reference dose levels for the personnel intervening in an emergency, and as has been mentioned in section 4.1.c of this report, the CSN considers that homogeneous reference levels should be established for all the Spanish nuclear power plants. Nevertheless, in the short term the licensee should consider a framework guaranteeing both individual protection and the feasibility of undertaking emergency mitigation actions, as contemplated in the IAEA TECDOC 953 and BSS's.

- **Measures for the management of accidents in the reactor**

- *Licensee's position*

Like the rest of the plants, the licensee describes the measures in place at the level of equipment, procedures and personnel to prevent, mitigate and manage severe accidents. In this respect the licensee analyses the different strategies contained in his Operating Manual and Severe Accidents Manual aimed at maintaining or recovering the function of core cooling. Furthermore, the Trillo plant points out that it is currently in the design phase for the implementation of a primary depressurisation system allowing for the performance of the *Bleed&Feed* action. Trillo has a system of passive hydrogen recombiners installed inside containment.

In addition, Trillo proposes a series of different actions to increase the robustness of the facility in response to severe accidents. In this respect, and in addition to what is indicated in the general section regarding a new AEMC, the licensee will reinforce the human resources of the plant's emergency response organisation and analyse the communication systems, taking into account criteria such as redundancy, independence and autonomy in the event of SBO.

The following additional measures, which are mentioned in the sections on loss of safety functions, will also improve the robustness of the facility in response to severe accidents:

- Provision of the following portable equipment:
  - A portable diesel generator for feed of equipment such as batteries, ventilation and valve actuators.
  - A portable electric pump located in the annulus building and fed from an external portable generator, for injection to the primary from the borated water tanks (BWT's) of the emergency core cooling system. This pump could also inject to the spent fuel pool.
  - A second portable electrical pump fed from an external portable diesel for the replenishment of inventory to the BWT's from the primary coolant storage and treatment systems.
  - A diesel-engined pump to take water from the demineralised water pools to the BWT's, following depletion of the reserves of borated water. The licensee points out that a reserve of boric acid is available, in sacks of approximately 900 kg in the auxiliary building, plus more than 5,000 kg in the general stores.
- Use of portable feeds for the relevant instrumentation and control for feed and bleed of the secondary, reactor and primary system.
- As regards the strategy of secondary bleed and feed to address situations of loss of feed to the steam generators as a result of SBO, Trillo proposes the following:
  - Improvement of the seismic resistance of the diesel-engined pump providing make-up to the steam generators.
  - Inclusion in the procedures and performance of a special test on make-up to the secondary using the steam generator supply diesel-engined pump, simulating loss of d.c. power conditions (manual control).
  - Supply of essential services water to the emergency feedwater pools by means of the portable diesel-engined pump.
  - Improvement of the back-up system for opening of the main steam dump isolation valves.

The specific actions proposed by Trillo to improve the robustness of the facility in relation to severe accidents are as follows:

- Development of symptom-based severe accident management guidelines for mitigation of the consequences of severe accidents and maintenance of containment integrity. Within the framework of the above, the Trillo plant will analyse the possibility of all the instrumentation and systems required to undertake the strategies included in these guidelines withstanding the ambient conditions arising as a result of the severe accident. Likewise, it will analyse the possibility of the mitigation and I&C systems credited in these guidelines, including their support systems, withstanding earthquake loads.
- Implementation of filtered containment venting as a final measure to prevent containment overpressure conditions.
- Improvement of the instrumentation for the monitoring of containment status during severe accident conditions.

In addition, Trillo has verified that the seismic margin of the passive catalytic hydrogen recombiners is 0.3 g.

The licensee has carried out the same exercise for the control room filtering system, concluding that with improvements to its supports the seismic margin of 0.3 g would be achieved. Furthermore, the Trillo plant proposes that feed for this system be provided from the electrical safeguards network.

In order to estimate the potential accumulations of hydrogen outside containment in the event of a severe accident, Trillo NPP has used as a basis the maximum quantity of hydrogen that may be generated and has taken into account the maximum leakage rate allowed by the Operating Technical Specifications, extrapolated from the design pressure to the ultimate containment pressure. In the calculation, the licensee has not considered the action of the PAR's. Trillo NPP concludes that under these conditions the margin between the maximum quantity of hydrogen released to the annulus (8 kg/day) and the typical quantity of hydrogen necessary for there to be a risk of combustion (100 kg) is high and, therefore, that the leaked mass is far from typical values of combustion risk.

The licensee includes in his report the times in which certain events (cliff-edge situations) would occur for severe accident sequences. The calculations have been performed using the RELAP5 and MAAP-3 codes. For the extreme scenario of SBO with no cooling or core make-up system available from the onset of the event, exposure of the core would take place after 1.45 hours and rupturing of the vessel after 3.3 hours. If the alternative steam generator feed diesel-engined pump were available (and following depressurisation of the steam generators via the relief valves), adequate core cooling conditions would be guaranteed for more than 24 hours.

As regards the management of severe accidents occurring from shutdown operating conditions, Trillo claims that it will undertake studies of this issue within the framework of integral PSA performance.

- *CSN evaluation*

Both the Operating Manual, which contains strategies for accidents within the design basis, and the guidelines or instructions contained in the Severe Accidents Manual have been checked by the CSN through inspections and assessments, and are considered to be adequate for the performance of their accident-related functions.

In the additional reinforcement measures the licensee has included those relating to portable equipment for alternative injection to the primary in order to prevent or minimise damage to the fuel. All these improvement measures are considered positive, since they allow for a response to situations such as a prolonged SBO with greater guarantees.

The measures proposed by the Trillo plant in relation to secondary depressurisation (bleed) and feed are considered positive, since they allow for a response to prolonged SBO situations with greater guarantees.

The installation of a filtered containment venting system as a final measure against containment overpressure conditions is considered to be a positive step, since it strengthens the capacity of the facility to prevent containment failure and to minimise the release of radioactive products in the event of an accident.

Furthermore, within the framework of the severe accident management guidelines development programme, Trillo will analyse the possibility of all the instrumentation and systems required for the performance of the strategies included in these guidelines withstanding the ambient conditions arising as a result of a severe accident and earthquake loads. This measure is considered adequate since it improves the capacity of the facility to respond to severe accidents.

As regards the development of symptom-based severe accident management guidelines, this is considered to constitute a positive step. As this is an improvement to be implemented in the long term, it is considered necessary for the licensee to develop the project schedule in detail and submit it to the CSN in the near future.

In relation to the Trillo calculation to estimate the potential accumulations of hydrogen outside containment in the event of a severe accident, the hypotheses used by the licensee determine the maximum amount of hydrogen generated are considered *a priori* to be adequate; however, for extrapolation of the leakage rate to the ultimate containment pressure, the licensee should also take into account the influence of the conditions generated by a severe accident on containment isolation (deterioration of penetration and valve seals, possible venting of containment when the system is available, etc.). This analysis should consider the dynamics of propagation in the different rooms of buildings adjacent to containment, taking into consideration their geometry, in order to estimate possible local concentrations that, despite their short duration, might lead to hazardous concentration values being exceeded.

As regards the management of severe accidents occurring from shutdown operating conditions, Trillo proposes to undertake studies of this issue within the framework of integral PSA performance. The CSN considers that it is reasonable to link this task to PSA performance but that in any case these studies should be integrated into the severe accident management guideline development project.

In addition, it is considered that the licensee should include on his list of improvements the analysis of the leaktightness capacity of the containment isolation valves and penetrations under the pressure, temperature and radiation conditions of the severe accident. It is considered that Trillo should analyse this issue in order to obtain an estimate of leakage and, where appropriate, identify and implement potential improvements.

The measures proposed by the licensee to improve the control room filtering system (improvement of supports to achieve the seismic margin of 0.3 g and electrical feed from the safeguards network) are considered positive.

- **Loss of fuel pool inventory and/or cooling**

- *Licensee's position*

The function of cooling the spent fuel pool, located inside containment, is covered in the design by the availability of three independent cooling trains equipped with pumps fed from the safeguards network, two of these also being equipped with pumps fed from the emergency network. This same configuration of trains exists in the support systems, including the ultimate heat sink constituted by the essential services water system.

In addition, there is a procedure for the supply of water to the fuel pool by means of the fixed fire protection system (FPS) pumps. Make-up to the SFP with non-borated water from the FPS would be performed cyclically, between 10 and 11 metres, in accordance with the corresponding operating instruction. Among other objectives, this prevents overflowing of the SPF, the edge of which is located at 12.65 metres, and possible dilution of the Boron in the coolant. Any new alternative SFP injection strategy with non-borated water that might be designed should take this factor into account, such that if overflowing of the SFP is allowed to occur, the pertinent criticality analyses have been performed.

The location of the spent fuel pool inside containment makes it possible confine the release of fission products and hydrogen as a result of possible exposure and damage to the spent fuel inside this building. As regards hydrogen generation, the PAR system incorporates sufficient design margins for the recombination of the hydrogen released as a result of damage to the fuel in the core and in the SFP.

The origin of a scenario implying the complete loss of SFP cooling and make-up capacity must necessarily be based on the loss of all the mitigating systems in this situation, none of the scenarios contemplated in the design bases being able to produce this situation alone. Only scenarios beyond the design basis, or a combination of such scenarios, could give rise to the complete loss of the capacity to prevent degradation of the fuel in the pool. In the worst case, the SFP heat removal function is guaranteed, without actions being taken, for more than 24 hours.

The monitoring instrumentation available consists of SFP water temperature and level instruments, part of the post-accident instrumentation, qualified from the seismic and environmental points of view for design basis accident conditions (large break LOCA), with indication/recording in both the main and emergency control rooms. This requires direct current supply from the emergency network for operation.

In his report the licensee includes calculations of the times available before boiling occurs, and different water levels are reached (to exposure of the fuel assemblies) in the event of total loss of cooling. Using as input the minimum level in the pool established in the plant's Technical Specifications (11.85 m) and with unfavourable conditions as regards initial temperature and the residual heat to be removed (refuelling situation with the entire core in the spent fuel pool and the latter isolated from the reactor cavity), times of 4.5 hours for boiling and 37 hours to exposure of the active part of the fuel are obtained. Furthermore, a limit time of 45 minutes is available from the onset of boiling for accessibility to the containment interior, where the SFP is located. In the case of the thermal load corresponding to the end of a typical refuelling outage, the time to boiling would be 23.5 hours and the time taken by the level to reach the upper part of the fuel assemblies would be 193 hours.

The licensee has analysed the phenomenon of sloshing in the SFP and has reached the conclusion that the spillage caused by an earthquake would be negligible and would not imply any relevant decrease in the level of the storage installation.

As regards the possible accidental drainage of the spent fuel pool:

- The inflatable seals and corresponding pneumatic system (to the isolation valve) have an HCLPF capacity of 0.3 g.
- The arrangement of the pipes on the walls means that in the event of rupturing of the most unfavourable line, the water level necessary for shielding is conserved.

With a view to improving the execution of the alternative pool cooling strategies and increasing its robustness, the Trillo plant proposes to carry out the following design modifications:

- Establishment of a path for the supply of water to the spent fuel pool independent from the FPS pumps by means of an autonomous portable pump (diesel-driven pump) taking suction from the seismic FPS or the demineralised water pools in the case of SBO or loss of ultimate heat sink along with LOOP.
- Availability of alternative means for injection to the SFP and spraying of the spent fuel assemblies with borated water by means of the following:
    - Portable electrical pump in the annulus building and hose connections to the residual heat removal system for injection or spraying of the SFP (by means of the existing sprays for cleaning of the SFP liner, belonging to the ECCS system). The detailed analysis of this modification will underline the suitability of these sprays for performance of the new function or, otherwise, the need to install new spray headers. The pump will be fed from the exterior by means of a portable diesel generator.
    - Availability of a portable generator for the recovery of emergency direct current supply and part of the alternating current supply to ensure the availability of the SFP instrumentation and allow for remote operation of the valves.
    - Provision of feed from the uninterrupted power supply to the SFP cooling system third loop valve providing isolation with respect to the auxiliary systems.
    - Availability of portable instrumentation for SFP monitoring (temperature, level) by means of battery trolleys and a digital display.

In addition, the licensee mentions that the plant will participate in the tracking of EPRI work on the study of phenomena associated with the most severe phases of degradation of the fuel in the pool.

- *CSN evaluation*

The licensee includes information on the design basis of the SFP and its associated cooling systems. These issues have been evaluated and licensed during previous stages of the plant. Furthermore, the equipment and related procedures have been inspected by the CSN on numerous occasions.

The licensee describes the measures currently available to address loss of SFP cooling scenarios; in the case of the Trillo plant, the pool is located inside containment. The measures proposed by the licensee, aimed at strengthening the cooling capacity in the event of SBO and loss of the ultimate heat sink, are considered positive and necessary.

The CSN considers the conclusion drawn by the licensee with respect to the phenomenon of sloshing in the SFP to be acceptable.

- **Radiological protection issues**

- *Licensee's position*

The design of the Trillo nuclear power plant control room allows for habitability in the event of an accident and is equipped with protection equipment for the personnel manning this room. The alternative to the control room is the emergency control room. In view of its location and characteristics, the Technical Support Centre (TSC) has the same radiological conditions as the control room in the event of an accident.

The control room is equipped with a ventilation system that can operate in recirculation mode, isolated from the exterior, fed from safeguards busses and designed to operate following the safety earthquake.

The emergency control room also has a ventilation system with similar characteristics, but fed by emergency current.

As part of the improvements introduced at the plant for the management of accidents beyond the design basis, a control room envelope air filtering system was implemented as a complement to the above, with a view to facilitating longer operating personnel residence in the control room and the TSC. This filtering system is currently connected to the normal electrical feed network and its components have been designed only to guarantee stability following an earthquake.

In order to increase the robustness of the plant, Trillo plans to provide the control room filtering system with safeguards electrical feed in the medium term, this allowing it to operate in the event of LOOP, and to improve its supports to achieve a seismic margin of 0.3 g.

The licensee has analysed the advisability and feasibility of implementing a filtering system for the emergency control room similar to that already existing in the main control room, although in his report no definitive decision has been included regarding it.

Trillo has estimated the dose that would be received by the personnel in the control room and emergency control room in a severe accident scenario with prolonged loss of power and with the need for filtered venting of the containment. The analysis underlines the fact that with personal protection equipment used, the estimated doses are lower than the emergency intervention levels.

The Trillo plant has also determined that the conditions of habitability in the Operative Support Centre (OSC) are limited in the event of accidents involving the atmospheric release of activity since the centre is not equipped with an adequately filtered ventilation system, and has proposed as an alternative that the stand-by personnel be redirected to the TSC. The licensee proposes to construct an Alternative Emergency Management Centre (AEMC) on the site, to be available in 2015, with the possibility of radiologically controlling the workers in order to guarantee their residence under adequate conditions. This proposal will be addressed conjointly by all the licensees.

As regards the resources available for the monitoring and control of radioactive emissions in the event of an accident, the Trillo plant has a Radiation Surveillance System, including post-accident sampling and monitors, an Emergency Radiological Surveillance Plan and procedures to determine the activity released.

The licensee has analysed the post-accident radiological surveillance and sampling systems, taking into account the range of the instrumentation and its seismic and electrical qualification, and has concluded that these systems would be available up to depletion of the batteries in the severe accident scenarios contemplated in the present report, and that with the improvement measures that will be implemented for the consideration of SBO, the availability of this surveillance instrumentation would be guaranteed in the long term.

The licensee also has available personal protection resources, dosimeters and portable equipment for the radiological control of the workers and of radiation and contamination levels.

With a view to increasing the resistance of the plant in the scenarios studied, Trillo has identified the need for improvements and resources for the performance of the Emergency Radiological Surveillance Plan under adverse conditions.

In addition, an analysis will be carried out along with the rest of the licensees of possible additional equipment and improvements to the current radiological protection resources to bring them into line with the conditions potentially existing in the scenarios analysed. This analysis is scheduled for completion in June 2012, and from that moment on it will be necessary to implement the improvements identified.

As regards the identification of radiological conditions that would prevent the performance of local manual actions, Trillo has estimated the doses that would be received, the performance times and the protection resources that would be required for the actuations planned in its Severe Accidents Manual and associated with the proposed improvements, as well as the doses that would be received in post-accident sampling (non-degassed liquid samples). In all cases it is concluded that the intervention levels established would not be exceeded. Trillo proposes the future development of severe accident management guideline (SAMGs) and the establishment in the emergency procedures of instructions for action in cases involving high radiation, signposting the itineraries for local actions.

In relation to the SFP, the licensee has established a limit of 3 metres above the fuel assemblies as the success criterion for flooding, indicating that this would provide sufficient shielding for the performance of short duration local actions not initially foreseen (maximum dose at the most unfavourable point 1 Sv/h). The Trillo plant identifies as the limit situation the need for the recovery actions to have been taken within 45 minutes of the onset of evaporation, since in the event of an accident in the reactor and pool, access to containment is conditioned more restrictively by lack of core cooling. In the alternative pool cooling strategies, the need to take local actions in the vicinity after the water level has dropped significantly is not contemplated.

- *CSN evaluation*

The radiation exposure of the personnel in the control room and emergency control room of the Trillo plant during any design basis accident does not exceed the dose limits for professionally exposed workers set out in the Regulation on the Protection of Health against Ionising Radiations.

The CSN considers the improvement of the control room filtering system planned by Trillo to be positive. The aim of this improvement is to provide the system with safeguards electrical feed in the medium term and to improve the system supports to achieve a seismic margin of 0.3 g.

The CSN considers that the analysis of habitability in the event of a severe accident performed by the licensee presents important uncertainties (containment leakage, characteristics and efficiency of the filtered venting to be implemented, atmospheric conditions, control room air inlet flow, residence times, etc.). Consequently, in order to reinforce the plant, the licensee should analyse in the short term the implementation of a system to provide an alternative power supply to the control room filtering system in the event of SBO. In this same respect, and taking into account that for the scenarios analysed the operators may possibly have to remain in or go to the emergency control room for the performance of certain operations, the licensee should analyse in greater depth the implementation of a filtering system for this room, available also in the event of SBO.

The proposal to construct an AEMC is positively valued. The conclusion indicated in this respect in section 4.1.c is applicable.

As regards the resources available for the monitoring and control of radioactive emissions, it is considered advisable for Trillo nuclear power plant to implement in the medium term a continuous surveillance network with the automatic reception of data in the control room, TSC and CSN emergency response room.

The CSN values positively the analysis that is to be carried out jointly by all the plants on the radiological protection resources and equipment that it would be advisable to have available in the scenarios analysed, and the improvement measures identified by the licensee. In the case of the Trillo plant, the analysis should contemplate at least the availability of the sampling system in prolonged SBO scenarios and the correct operation of the post-accident radiation monitors in severe accident conditions. Also applicable is the conclusion indicated in section 4.1.c.

As regards the analysis of impedimenta resulting from radiological conditions to the performance of local manual actions, the analysis performed by Trillo (on the basis of normal plant operating conditions), is not valid in the case of an accident with core damage. The improvement proposal consisting of establishing instructions in the emergency procedures for actions in the presence of high radiation is positively valued, and the CSN will request that these be associated with each of the SAMGs depending on the foreseen doses. Section 4.1.c includes a series of general conclusions regarding the analysis of impedimenta resulting from radiological conditions to the performance of local manual actions.

The methodology, calculation codes and input data used by the licensee to calculate dose rates on the basis of the level of water in the pool are considered to be adequate. The licensee will be requested to incorporate in the procedures the radiological protection issues to be considered in the foreseen local manual actions. Section 4.1.c includes general conclusions in this respect. Trillo should revise the criterion of the water level above the fuel assemblies that would prevent the performance of actions in the vicinity of the pool.

- **Individualised Temporary Storage (ATI) of spent fuel**

The Trillo plant has an individualised temporary storage (ATI) facility for Spent Fuel Casks, located in the zone controlled by the licensee. The licensee's report includes study of the ATI facility within the framework of his general analyses.

4.2.2 Vandellós II Nuclear Power Plant

4.2.2.a Extreme natural events

- **Earthquakes**

- *Licensee's position*

The maximum horizontal acceleration of the terrain for the design basis earthquake (SSE) adopted in the design of Vandellós II nuclear power plant is 0.20g, calculated using a deterministic methodology. Consideration has also been given in the design to a lower level of seismic demand, corresponding to the Operating Basis Earthquake (OBE), whose maximum horizontal acceleration of the terrain is 0.10g. The basis process to establish the DBE has been to assess the maximum historical earthquake impacting the site and to then increase this by a certain margin estimated to define the maximum possible seismic intensity and corresponding local ground acceleration.

In order to analyse the current validity of the DBE earthquake, a review was made of the earthquakes occurring in an area of 300 km around the plant from the year 1981, which is the limit date of the catalogue used in defining the DBE, to May 17th 2011 using the catalogue of the Instituto Geográfico Nacional (IGN). It has been concluded that there has been no earthquake during that period of time and within that radius that exceeded the maximum seismicity associated with the seismogenic areas considered for determination of the DBE, as a result of which the seismic design bases initially considered continue to be valid.

Protection of the plant against the DBE is based on the seismic design requirements of the structures, systems and components (SSCs), in accordance with the classification included in NRC RG 1.29, and on the maintenance practices for the seismic qualification and correct status of the SSCs, and their modifications and spares, through the processes established in the licensing basis.

For the detection of earthquakes the plant has a specific instrumentation system that meets the requirements of NRC regulatory guide RG 1.12, consisting of six triaxial accelerometers, one located in the free field and the other five at different elevations in the containment and control buildings. Whenever any of these accelerometers detects an acceleration in excess of 0.015g, recording of the event is initiated and the seismic monitoring system is activated. In addition to diagnostic alarms, this system generates an OBE exceeded alarm with a signal in the control room. If exceeding of the OBE is detected, the plant's On-Site Emergency Response Plan (ERP) is activated and a series of actions are implemented, such as analysis of the records of the seismic instrumentation and plant equipment inspection procedures, all of this with the aim of verifying the availability of the equipment required to take the plant to safe shutdown, guaranteeing the functions of reactivity control, control of primary pressure, control of primary inventory and the capacity to remove residual heat.

The licensee has assessed the seismic margin of the plant on the basis of the work already performed for the seismic IPEEE, by means of the methodology developed by the NRC (0.3g review earthquake- full scope), complemented in the context of the stress tests with extension of the original scope and the performance of new inspections, considering the functions of fuel confinement in the seismic margin analyses.

Since the performance of the first analyses of the margins in 1994 to the latest revision of the seismic IPEEE in October 2009, including the design modifications incorporated during operation of the plant, the licensee has carried out actions that have provided as a final result a seismic margin for the plant overall with an HCLPF value of 0.3g. A seismic margin of 0.3g is also assigned for the integrity and isolation function of the containment, determined by the capacity of the isolation valves as the components most sensitive to seismic activity.

As regards the integrity of the containment, in relation to the fuel in the spent fuel pool, and in the wake of the new analyses and inspections performed and pending confirmation of the results of certain on-going analyses, an HCLPF capacity of 0.3g is assigned. Given that the spent fuel pool cooling system was not included within the scope of the original IPEEE, it has been the subject of a new analysis and specific inspection walkdown to be able to assign it an HCPLF of 0.3g.

In order to increase the robustness of the plant, the licensee proposes to perform an analysis of the seismic vulnerability of the SBO equipment and of the most relevant equipment involved in the Severe Accident Management Guidelines and not contemplated in the current IPEEE, with a view to determining suitable actions guaranteeing a seismic margin of at least 0.3g for all required SSCs.

The licensee has used three alternative methods to analyse the loss of inventory ("sloshing") from both the spent fuel pool and the engineered safeguards reservoir in response to an earthquake of up to 0.30g, concluding that in both cases the loss of inventory is irrelevant and that there would be no impact on safety-related systems.

Compliance with the current licensing basis regarding seismic performance is guaranteed through the periodic application of procedures, surveillance requirements and actuations aimed at adequately maintaining the SSCs and the seismic monitoring system.

In relation to the possibility of internal effects arising as a result of an earthquake, the Vandellós II nuclear power plant report indicates the following:

- Fires and explosions: Vandellós identifies its design basis and points out that compliance with, along with the protections and extinguishing resources in place, provides barriers for the control of fire events at the site. As an additional measure for seismic events, the licensee has performed an inventory of inflammable or explosive products in storage and plans to perform a seismic analysis of the SSCs.
- Internal flooding: Vandellós points out that a PSA of internal flooding is available, identifying those pipes that might be the point of origin of flooding and that during the IPEEE analysis a check is made of the condition of the piping in areas containing safe shutdown equipment. The licensee proposes a new scope for seismic resistance inspections, including non-seismically qualified piping that might cause an initiating event and loss of mitigation systems. Of these pipes, the effects of rupturing will be analysed for those that might affect safety-related equipment.

As regards effects on nearby industries, the potential effects of seismic action on industries in the vicinity had already been analysed prior to these stress tests, in the context of the IPEEE studies for Other External Events. Vandellós has analysed the Plana del Vent Combined Cycle Thermal Power Station, located at a distance of some 800 metres from the plant. The conclusion is that for the most limiting rupture and overpressure condition induced by the deflagration of the inflammable cloud at the distance at which this were to occur, the most limiting of the events analysed would have no effect on Vandellós II. As regards the risk of toxic products being released from that plant, it was determined that in the event of an accidental release only ammonium hydroxide might reach relevant concentrations at the air inlets to the control room; however, the maximum quantity in storage would mean that the concentration at these inlets would be below the toxicity limit, even under the most unfavourable meteorological conditions.

- *CSN evaluation*

The seismic design basis of the plant is the same as that licensed at the origin. Its acceptability with respect to the requirements set out by the CSN over time has been checked during the seismic evaluation processes undertaken prior to granting of the successive operating permits, by means of specific analyses carried out during the periodic safety reviews and also the different inspections performed as part of the CSN supervision and control processes.

The seismic monitoring system was already in place at the plant prior to the stress tests and had been reviewed by the CSN with favourable results. A limiting condition for operation beyond the OBE, with its corresponding actions, surveillance requirements and actuation procedures, is included in the plant's Technical Specifications.

The HCLPF capacity values estimated by the licensee are considered justified in keeping with the NRC and EPRI seismic margins methodology, although the value of 0.3g assigned to the irradiated fuel racks is currently being reviewed by the CSN. Also pending verification are the analyses of certain anchoring devices and the possible corrective actions that the licensee might propose in order to increase the HCLPF value, if equipment having a margin of less than 0.3g were identified in the studies proposed to increase the seismic robustness of the plant.

No limiting situations are identified as regards the behaviour of the plant in response to earthquakes. As the seismic margin resulting from the analyses coincides with the review earthquake value adopted, the analysis methodology does not allow a greater margin to be quantified. If other review methods were applied, a seismic margin of more than 0.3g might be achieved.

The actuations already proposed are efficient to improve the robustness of the plant in response to beyond the design basis earthquakes. Certain additional measures might be advisable on conclusion of the analyses under way and being completed by the licensee.

As regards the possibility of there being induced effects as a result of an earthquake, and in addition to the generic conclusions included in section 4.1.a, the following conclusions are drawn:

- Fires and explosions: the CSN evaluation considers the scope of the analysis performed to be adequate as regards both the identification of possible sources of fires or explosions and the action proposed.
- Internal flooding: the CSN evaluation considers that the scope of the analysis planned by the licensee should be extended to include non-seismically qualified piping whose rupturing might give rise to an initiating event and loss of mitigating systems in scenarios not covered by those already analysed. Furthermore, the Vandellós plant should determine whether there are effects due to floods caused by other major sources of water potentially generating floods and, in this case, the barriers available to them.

Effects on nearby industries: the CSN evaluation considers that the analyses performed by Vandellós NPP within the framework of compliance with analyses deriving from the IPEEE and their conclusions are acceptable in the context of the evaluation included in this report.

- **Flooding**

- *Licensee's position*

The events considered in the design of the plant that might give rise to flooding on the site are the following: intense local rainfall, maximum probable flood) in water courses and gullies, waves and rises in sea level, seaquakes in the Mediterranean and rising groundwater levels.

The design value adopted for intense local rainfall is 140 mm/h for 10 minutes, this being higher than the maximum rainfall calculated on the basis of the meteorological data recorded on the site. It has been verified that the evacuation capacity of the site drains is capable of withstanding a rainfall intensity of 266 mm/h.

The protections against intense local rainfall consist basically of the site drains network, the building roof drains, the seals of the penetrations between outdoor galleries and buildings and the height above the elevation of the site of the accesses to buildings. It has been verified that in the case of the design basis precipitation, none of these protections are breached, as a result of which they are adequate and fulfil the design basis.

In addition to the physical barriers and the characteristics of the site, maintenance activities, tests and inspections are carried out. The periodic review of the IPEEE entails the updating of the maximum probable rainfall values, which in turn implies walkdowns to check for the correct conservation of the protections. The On-Site Emergency Response Plan (ERP) is activated in the event of intense rainfall measured at the plant meteorological tower, this implying the execution of the already established procedures.

The water level that would be reached at the point closest to the site as a result of the maximum probable flood would not reach the elevation of the site (elevation 100 m), as a result of which it would not be affected (this level is equivalent to elevation 89.5 m, with a margin of 10.5 m with respect to the elevation of the site). The methodology used to determine the design wave gives a maximum value of

5.6 m and, taking into account the location of the engineered safeguards system as the heat sink, the wave height required for a potential tsunami to affect the installation would have to exceed 23.25 m, which is not considered credible on the site.

As regards the groundwaters, no noteworthy alterations of the water table are to be expected, since this depends basically on the sea level. A maintained rise in sea level of approximately the 11-metre margin existing between the maximum water table and lowest elevation of the foundations of the buildings is not considered credible. Furthermore, there is a groundwater monitoring system by means of which the levels in various boreholes are periodically measured.

No limit situations are identified as a result of flooding events on the site. The licensee concludes that an ample margin is available over and above the maximum flood height under the conditions corresponding to the design basis and that there is a sufficient margin above the flood height in the worst credible scenario beyond the design basis.

Notwithstanding the above, and in order to increase the robustness of the plant with regard to external flooding, the licensee identifies the following actuations:

- The evacuation capacity of the drainage network to withstand rainfall of an intensity of 260 mm/h for 1 hour has been verified.
- A model of the site drainage network has been developed to verify the capacity of the said network and the characteristics of the site to withstand rainfall with an intensity of 620 mm/h for 10 minutes.
- The development of a model covering the surface drainage capacity of the site has been initiated, with a view to determining the need or otherwise of actions to increase the robustness of the plant with respect to the phenomenon of intense local rainfall.
- A campaign for the review of all seals in galleries connecting to buildings containing safety-related equipment has been carried out. These seals are being provided with a hydrostatic resistance suitable to guarantee their leaktightness.
- The design of a reinforcement for the wall channelling the Malaset gorge is under way, the aim being to ensure that in no case can water enter the site.

- *CSN evaluation*

The information included by the licensee on events that might give rise to on-site flooding is a summary of what was included in the Vandellós II Safety Analysis Report, which is an official operating document. The set of design bases described is considered reasonable and suited to the characteristics of the site.

Since the final heat sink was modified and the new engineered safeguards system was implemented, a Tsunami has been ruled out as the design basis, since it is not an event that could credibly affect the safety-related systems.

The estimates of the maximum capacity of the site drainage network submitted by the licensee will be reviewed by the CSN by means of the established evaluation and inspection processes.

The robustness of the plant with respect to external flooding is considered to be reasonably justified. The actions proposed to increase this robustness are considered to be correct and pertinent. The results of the on-going measures will need to be suitable checked by the CSN, by way of the established evaluation and inspection processes.

- **Other extreme natural events**

- *Licensee's position*

In addition to the external events relating to flooding dealt with in the previous section, the licensee has reviewed the following events: strong winds, hail, extreme temperatures, forest fires and electrical storms.

In accordance with the licensee's analyses, the only significant extreme natural event is that involving strong winds, the design basis being a wind speed of 204 km/h for safety-related SSCs. During the latest IPEEE review (2009), an analysis of the degree of danger implied by winds was performed using the available data for the period 1968 to 2008, the hazard curve obtained corresponds to a degree of confidence of 97.7%. According to this curve, the frequency with which the design wind might be exceeded amounts to some 500 years. The margins of both the structures and tanks located outdoors have been assessed, the conclusion being that strong winds do not constitute a significant risk at the site. No limit situations are identified and no measures are proposed to increase the robustness of the plant.

The response of the plant to hail and electrical storms has been analysed, the conclusion being that these phenomena do not imply any significant risk for the site. Also evaluated has been the response to forest fires, the conclusion in this case being that the plant is adequately protected by the action procedures in place. In none of the cases described above are additional protective or reinforcement measures required.

As regards extreme temperatures, statistical analyses are under way of the records for the site; the need or otherwise for additional protective measures will be established depending on the results obtained. One way or another, the operating experience of the plant shows that the risk of freezing and of extremely high temperatures possibly affecting the cooling safety function is extremely improbable.

- *CSN evaluation*

The analyses performed by the licensee have seen their scope extended with respect to those carried out prior to the stress tests and the results are considered to be satisfactory, except in the case of extreme temperatures, the study of which is currently being performed by the licensee.

The licensee has action procedures for severe meteorological conditions on the site which had already been inspected within the framework of the CSN supervision and control programmes.

The CSN considers the design criteria applied and the margins estimated to be reasonable.

4.2.2.b Loss of safety functions

- **Loss of off-site power (LOOP)**

- *Licensee's position*

Vandellós II nuclear power plant describes the interconnections with the grid and the off-site electrical feeds available, concluding that the off-site supplies provide high levels of robustness and reliability and confidence in the capacity to quickly recover from a loss of off-site power.

The plant references the procedures of the operator of the electrical system for the recovery of voltage in the event of zero grid power, these procedures giving priority to the nuclear power plants, in particular to the Vandellós plant, the preferential feed for the plant being in stand-along or island configuration from the Ribarroja hydroelectric station. There are three possible modes for formation of the island (automatic, remote control and manual), which are tested periodically.

The on-site electrical supply for the safeguards systems is made up of the emergency diesel generators, the direct current system batteries and chargers and the inverters for class 1E vital services and instrumentation busses. Furthermore, there is an additional diesel generator, GD-N, which is described in the section on SBO.

In the event of LOOP, the feed for the safeguards systems is accomplished by the start-up, connection and automatic load sequencing of the two emergency diesel generators (EDGs), which are Class 1E and Seismic Category I and are located in separate Seismic Category I rooms in the Diesel Building.

The autonomy of the EDGs operating at 100% load is longer than seven days, considering fuel, lubrication and cooling, such that a LOOP situation may be withstood for more than seven days without any additional means of support. The fact that the EDGs are cooled by air-coolers, independently from the ultimate heat sink systems, is considered an additional strength.

As regards the supply of auxiliary feed water to the steam generators, it is concluded that with the inventory in the condensate tank and the support of the auxiliary feedwater this is also guaranteed for more than seven days.

The licensee mentions the on-going project for the installation of a third emergency diesel generator with the same design and qualification requirements as the two already in place and with the capacity to replace either of them.

The plant includes an analysis of the loss of safety functions in all plant operating modes, considering the operational status of primary system and containment and describing the operational evolution and mechanisms and response strategy.

- *CSN evaluation*

The LOOP is within the plant design basis, with a coping time of at least seven days, and has, therefore, been evaluated and licensed in previous stages of the plant lifetime, its different aspects having been inspected by the CSN.

The descriptions submitted by the licensee are considered to be correct. The off-site feeds have different points of origin and follow different paths, this independence providing reliability in supply with respect to events such as the one postulated here (LOOP). The transfers between feeds have operated satisfactorily. The grid operator has procedures for recovery by zones that take into account the preferential feed for the nuclear power plants. The performance of periodic off-site power recovery tests from the Ribarroja hydroelectric station increases the reliability of the off-site supply from this source.

The CSN evaluation considers that the response expected from the plant in the event of LOOP is safe and in keeping with expectations, and that the plant could withstand this scenario without additional support for more than seven days, considering the autonomy of the EDGs and the inventory of water for injection to the steam generators.

The plant has a programme of diesel generator availability and reliability maintenance that is managed as part of the Maintenance Rule.

The installation of a third diesel generator, planned prior to the stress tests, will imply an improvement of the availability and reliability of the emergency feed.

In the case of events in other operating modes, and as a measure to increase robustness, it is expected that the refuelling water storage tank might be filled from alternative water sources by means of mobile pumping equipment.

- **Station blackout (SBO)**

- *Licensee's position*

The analysis performed by the licensee points out that as a result of the regulatory requirement associated with the Station Blackout (SBO) Rule, an additional diesel generator (GD-N) is available, with the capacity to feed the loads required for this scenario. This generator is located in a building designed to Seismic Category I, separated from the EDGs, with different support systems and cooled by air-coolers. As regards the seismicity of this GD-N, an analysis is on-going to identify vulnerabilities and provide it with a greater seismic capacity.

With the increase in the monitored level in the gasoil storage tank from which the GD-N day tank is fed, the autonomy of this generator is for more than seven days.

The plant has calculated the evolution of the temperature in the rooms in the event of loss of ventilation for 24 hours, without considering passive mitigation measures. It is concluded that the results demonstrate that temperatures implying a limit situation for the equipment are not reached.

In this scenario the plant is capable of withstanding the situation for more than seven days without any additional support.

The plant describes the resources available to respond to events occurring in other operating modes, in which the plant safety response demands are less limiting; nevertheless, the plant mentions its plans to make available a portable pump for make-up of water to the Refuelling water Storage Tank (RWST).

In the event of loss of all the normal sources and the additional back-up sources (GD-N), only the batteries would be left as a source of electricity supply.

By design, each of the five class 1E batteries (two associated with each train and one with the control of the Turbine-driven auxiliary Feedwater Pump, AFWTP) having a function in the scenarios analysed has sufficient capacity to provide electric supply for the associated necessary loads for at least two hours.

The autonomy of the batteries has been re-analysed, the result pointing to autonomies of more than 24 hours. This autonomy springs mainly from the ample capacity margin available, consideration of the current loads, more realistic consideration of consumptions and a new strategy for the selective disconnection of non-essential loads in 1 hour.

Likewise, for this case of additional loss of the GD-N, the plant also analyses the response in operating modes other than power operation.

The conclusion is that, for certain situations, if improvement actions were not incorporated it would not be possible to maintain primary circuit inventory in the long term, due to leakage across the seals of the primary coolant pumps.

The licensee includes the times in which limit situations would occur: battery depletion (24 hours), dryout of the steam generators (31.9 hours), core uncover (32.6 hours), vessel failure (35 hours) and failure of the containment (more than three days), if no corrective actions were taken to address these situations. Taking these analyses into account, the licensee proposes to bring in portable electricity-generating equipment to increase the autonomy of the batteries to more than 72 hours and provide feed to other loads, make available an alternative steam generator injection strategy and allow for alternative high and low pressure injection to the primary.

As regards measures to prevent the failure of the vessel and the containment, the plant refers to the section on Severe Accidents.

As regards situations in which the batteries are lost in addition to the supply from alternating current sources, the licensee indicates that a remaining possibility would be the manual operation of the AFWTP and steam generator relief valves. It is pointed out that, as in the previous scenario, the evolution of the incident would be governed by the cooling and depressurisation capacity via the secondary and by the leakage across the primary coolant pump seals; these seals would determine the moment of the core uncover even though the capacity to remove residual heat via the secondary were maintained.

The licensee plans to test the manual operation of the AFWTP during the 2012 refuelling outage, and periodically thereafter, and mentions that the manual actuation of a steam generator relief valve has been tested at the workshop.

- *CSN evaluation*

The complete loss of on and off-site alternating current supply (SBO) is an event that was incorporated in the Licensing Basis following the publication of regulation 10CFR50.63, developed in Regulatory Guide 1.155. The SBO coping time at the Vandellós plant is eight hours; the situation licensed is LOOP and loss of the emergency diesel generators, the availability of the GD-N being maintained.

As a result of that, the capacity to feed train A by means of GD-N, and consequently the capacity to feed the loads required to address the situation of LOOP and loss of the EDGs, was incorporated, with which the train A direct current and 120 V alternating current would be available.

The CSN evaluation concludes that the essential diesel generator GD-N is a strength, since it is located separately from the EDGs, with different support systems, and is air cooled.

In order to increase to seven days the time that the plant is capable of withstanding an SBO situation, it is necessary only to increase the reserve of fuel in the storage tank (with the current monitored level the autonomy is for 4.1 days).

As regards the primary inventory function, in the SBO situation the hydrostatic pump taking suction from the RWST makes it possible to replace the inventory lost across the seals of the reactor coolant pumps (RCPs) for more than 10 days.

The alternative low pressure injection to the primary and the refilling of the RWST for the events identified as possibly occurring in other operating modes are adequate measures. It is also expected that the hydrostatic test pump, if not injecting to the seals, would be used for injection to the primary.

The measures proposed to achieve an autonomy of more than seven days for generator GD-N, consisting of procedural modifications, are considered adequate.

In the event of additional loss of the essential diesel generator, GD-N, the plant would respond to the situation with the help of those systems that require only direct current electrical supply (steam generator feed by means of the AFWTP and depressurisation of the steam generators by means of the steam generator relief valves). The plant has described the analyses performed for this scenario, which are considered to be adequate, and proposes improvement actions providing an additional strength to address such situations.

The battery autonomy calculations have been reviewed by the CSN in relation to their general aspects of approach, hypothesis and calculation method, the results being satisfactory.

The licensee includes the times by which the limit situations (exposure of the core and failure of the vessel and the containment) would occur in this situation.

Subsequent to the issuing of the preliminary report, an inspection has been performed at the plant covering those aspects of that report that were considered relevant.

The manual operation strategy (AFWTP and relief valves) will be subjected to an additional check by the CSN once the licensee has performed the foreseen test.

In view of the actuations carried out, the CSN concludes that the plant's forecasts and proposals are acceptable.

- **Improvements proposed by Vandellós II nuclear power plant in response to loss of power events**

With a view to improving the robustness of the plant in relation to this type of situations, the licensee proposes to undertake the following actuations:

- Incorporation of diesel groups for the feed of battery chargers, the hydrostatic test pump and other loads.
- Incorporation of motor-driven pumps for injection to primary and steam generators and replenishment of the RWST.
- Drawing up of procedures for the performance of the foreseen plant and portable equipment manual operations.
- Performance of periodic AFWTP tests, incorporation of portable equipment (instrumentation) to ensure the availability of the information required for the manual operation of this pump.
- Implementation of a new type of seal in the primary coolant pumps (if their adequate development and qualification are finally demonstrated).
- Incorporation of whatever design modifications might be required for the use of the portable equipment: definition of equipment location and reinforcement of lighting and communications with the new portable groups.
- Completion of GD-N seismic response analysis.

In the current stage of development the improvements proposed by the plant are considered to be valid, although the feasibility of using portable equipment is subject to the results of the specific analysis of the availability of personnel required in section 4.1.c of this report.

With the implementation of these measures, the cliff-edge situation times would be extended and would depend on the autonomy of the portable equipment.

- **Loss of ultimate heat sink (UHS)**

- *Licensee's position*

Vandellós II nuclear power plant has available the heat sink provided by the Mediterranean Sea (for the purposes of this report this is known as the primary heat sink). The drive of the seawater may be accomplished by means of two vertically mounted pit pumps belonging to the essential services water system (EF) and located downstream of the moving screens of the plant general intake structure, this preventing the risk of the ingress of foreign materials that might threaten the correct operation of the pumps and heat exchangers or cause the speedy deterioration of their circuits. The two pumps are located in separate and independent chambers in the pump house (elevation 77.6, at 1 m above sea level).

The EF system, which is made up of independent circuits with a capacity of 100%, in turn cools the component cooling water system (EG). The EG system is made up of two trains of 100% capacity each, is located in the Seismic Category I components building and has class 1E components. This system in turn cools the safeguards systems that protect the core, the integrity of the containment and the spent fuel pool.

Furthermore, Vandellós II NPP has an ultimate heat sink (UHS), EJ system, which consists of a pumping system, two cooling towers and a water pond that provides a cooling autonomy for 30 days without external contributions. The alternative sink is Seismic Category I and is protected against the possibility of flooding from the Mediterranean by having all the related equipment located at elevation 100 of the site, approximately 24 m above normal sea level. Likewise, the source of water for this alternative sink is the safeguards reservoir, a structure designed as Seismic Category I and also located at elevation 100 m, far above any credible level caused by events in the sea.

The EJ system is made up of two independent trains. Each train is equipped with two pumps, located in parallel, each capable of supplying 100% of the necessary flow. The cooling towers dissipate the thermal power absorbed in the heat exchanger to the atmosphere.

Vandellós II nuclear power plant considers the existence of two heat sinks with their corresponding residual heat removal chains to be a strength. Also considered to constitute a strong point is the fact that the essential chilled water systems (GJ system), the function of which is to supply cold water to the cooling units located in rooms housing safeguards equipment and emergency diesel generators (KJ system), have the atmosphere as a heat sink, with an independent water system equipped with air-coolers located on the roof of the TSC-Diesel building (elevation 114, located 37.40 m above sea level).

The licensee has analysed the impact of loss of the different heat sinks in both normal operation and other operating modes, and for this purpose has established three differentiated groups of statuses, which are based on the plant's Technical Specifications operating Modes:

- Group 0: this encompasses Modes 1, 2, 3, 4 and 5 with the RCS and containment closed and inventory in the steam generators with make-up and atmospheric steam dump capacity.
  - Loss of the primary heat sink, with the availability of off-site power, will cause turbine trip, reactor scram, start-up of the AFW system and start-up of the two trains of the EJ system.
  - In this situation, the Vandellós II plant considers that there are no limit situations to be taken into account. As an actuation to increase the robustness of the plant, the licensee has an on-going analysis aimed at improving the management of the inventory in the tanks, in order to maintain this at the maximum effective capacity, to the extent possible, with a view to increasing water reserves.
  - In the event of loss of the ultimate heat sink during normal plant operation, and in application of the plant's Technical Specifications, the plant may be taken to cold shutdown since there would be availability of the steam generators and of the RHR system, cooled by the EF system. The procedures used in this situation are those corresponding to normal shutdown. Vandellós II does not identify cliff-edge situations for this event and does not consider additional actions

to be necessary to increase the robustness of the plant. Calculations have been performed to estimate the depletion time of the two sources of auxiliary feedwater, the conclusion being that this would occur in a period of longer than 10 days.

  - In the event of simultaneous loss of the primary and ultimate heat sinks (these two heat sinks are physically separated), the AFW system and steam generator relief valves would be available for the removal of residual heat from the core and reduction of primary pressure. Also available is the hydrostatic test pump for RCP seal injection. Vandellós II nuclear power plant is capable of maintaining adequate conditions without any additional means of support for more than seven days in this situation.

- Group 1: this corresponds to Mode 6 with the RCS open and the containment closed.
  - In the event of loss of either the primary or the ultimate heat sink, the replenishment of primary inventory continues to be possible since the RHR is maintained. Draining of the RWST would be a limiting situation, with sufficient time available to initiate refilling or alternative injection to the primary. There are sufficient sources of water available on the site to ensure supply for more than seven days. As a measure to increase the robustness of the plant in response to this event, reserves of boric acid will be made available, along with mobile pumping equipment on site for the strategies of RWST refilling or alternative injection to the primary, such that the necessary boron concentration is guaranteed.
  - In the event of simultaneous loss of the primary and ultimate heat sinks, no heat removal capacity would be available via the RHR system. Primary make-up would be possible from the RWST by gravity. In this case, because of the elevations of the RWST and the RCS, it would be possible to inject approximately 58% of the volume of the tank. Subsequent primary make-up, if required, could be performed using the future alternative injection mobile pump or the RWST refill strategy, in which case boric acid reserves would be available on site to guarantee subcriticality. The motor-operated valves located on the injection path fail in position and may be opened using the flywheel if necessary. The cliff-edge situations and actions to increase the robustness of the plant are the same as those mentioned in previous paragraphs.

- Group 2: this corresponds to Mode 5 with the primary sufficiently open and the containment closed, with the pressuriser manhole open.
  - In the event of loss of the main or ultimate heat sink, the operational evolution would be analogous to that of Group 1, with the difference that the surplus primary make-up water would be released via the pressuriser to the containment sumps instead of to the refuelling cavity. The limit situations and the measures proposed are the same as those indicated above for Group 1.
  - In the event of both heat sinks being lost, what has been indicated for Group 1 is valid, with the exception that, given the existing elevations, the gravity-based RWST refilling process will be less effective as regards its possible duration, and it will be necessary to opt for the alternative primary injection strategy. The cliff-edge situations and the measures proposed are the same as those indicated above for Group 1.

- *CSN evaluation*

Refer to the evaluation of the following section

- **Loss of ultimate heat sink with SBO**

- *Licensee's position*

For this scenario, in all situations (Groups 0, 1 and 2) the operational evolution, limit situations and actuations proposed to improve the robustness of the plant are the same as those presented in the sections on LOOP and complete loss of alternating current.

- *CSN evaluation*

This section evaluates loss of the UHS, with and without SBO.

The licensee has provided an adequate description of the provisions existing in the design to prevent loss of the UHS and has analysed the situation that would lead to such loss, with and without SBO, with an adequate scope.

The information relating to the UHS design basis has been evaluated and licensed by the CSN in previous stages. In addition, the equipment and related procedures have been inspected by the CSN on numerous occasions.

The licensee identifies and proposed improvements to increase the robustness of the plant for cases of loss of UHS with and without SBO. These measures are the same as those identified in the section on loss of power, since loss of the UHS would lead to a situation in the plant in which the systems available to protect the safety functions would be the same as for the loss of power situation.

The licensee has performed realistic calculations to estimate the depletion time of the two sources of auxiliary feedwater (condensate storage tank and auxiliary feedwater system back-up tank), the result being a period of more than 10 days. It is considered that the AFWTP and steam generator relief valve manual actuation manoeuvres should be tested during the next refuelling outage.

The CSN considers the improvement proposals submitted by the licensee to be adequate.

As regards the habitability of the AFWTP room, the licensee has submitted a calculation for the dimensioning of the entry and exit of air for natural ventilation in the event of SBO that demonstrates that a temperature of 40 ºC is maintained inside the room. It is considered that the licensee should justify that in the event of prolonged SBO (24 hours) the room will not see temperature values preventing manual AFWTP control actuations.

4.2.2.c Accident management

- **Planning of accident management**

- *Licensee's position*

In addition to the analysis committed to by all the plants regarding the human resources required to respond to an emergency, the licensee of Vandellós II nuclear power plant proposes to incorporate an additional fixed shift auxiliary operator in 2012, who will undertake the auxiliary operator supervisor functions.

The licensee proposes specific improvements in the area of communications to strengthen the communications capacity of the facility through the extension of the currently available system, which will provide coverage throughout the entire site and that is planned for implementation in the short term.

In keeping with the start-up of the new Alternative Emergency Management Centre (AEMC), the licensee sets out another series of further-reaching improvements in communications, the analysis of which will be completed in the short term, which are planned for implementation in the long term.

As regards access routes to the facility, the licensee had already pointed out in his preliminary report that there were two feasible accesses to the site in the event of a severe earthquake, and at least two feasible routes in the event of flooding.

The licensee establishes new reference dose levels for the personnel intervening in an emergency, indicating that they will be voluntary informed workers. These dose levels correspond to those established in ICRP-103.

- *CSN evaluation*

The licensee's proposal to incorporate a new auxiliary operator in 2012 is considered adequate as a short-term action to reinforce the emergency response capacity.

The licensee plans to analyse additional measures in the short term to increase robustness in the area of communications, this being considered acceptable. The implementation of the additional measures identified should be undertaken in the medium term. As regards the further-reaching improvements that will be associated with the start-up of the new AEMC, these are considered to be acceptable, although the licensee should study the incorporation of provisional short to medium-term measures report on them to the CSN, such that improved capacities, even though only partial, be available prior to the dates for implementation of the long-term measures.

As regards access routes to the facility, the analysis submitted is considered acceptable.

In relation to the reference dose levels for the personnel intervening in an emergency, and as already mentioned in section 4.1.c of this report, the CSN considers it necessary to establish homogeneous reference levels for all the Spanish nuclear power plants. Nevertheless, the licensee should consider in the short term a framework guaranteeing both individual protection and the feasibility of undertaking emergency mitigation actions, as contemplated in the IAEA's TECDOC 953 and BSS's.

- **Measure for the management of accidents in the reactor**

- *Licensee's position*

Like the rest of the plants, the licensee describes the measures in place at the level of equipment, procedures and personnel to prevent, mitigate and manage severe accidents.

Vandellós II also analyses the different strategies contained in its severe accident management guidelines (SAMGs) and their capacity to protect containment and mitigate off-site releases, concluding that with the resources already in place measures will be taken to recover equipment or functions allowing the consequences of accidents to be mitigates or palliated.

The licensee indicates that with the measures currently contemplated in the SAMGs and the improvements proposed in previous chapters, a sufficient capacity is available to respond to severe accidents. Thus, although the initial objective of the improvement measures proposed for SBO is to avoid degradation of the core, if this were not possible part of these measures will allow severe accident strategies to be addressed.

Specifically, with a view to increasing the robustness of the facility, the licensee also points out that portable equipment will be provided at the plant which, by enabling suitable connections to the available systems, will make it possible to respond to severe accident scenarios in the hypothetical event of complete and simultaneous loss of all the measures currently implemented. In addition, and as indicated in the general section, the availability of a new centralised Emergency Support Centre (ESC) is planned.

Along with other improvement measures aimed at controlling hydrogen and overpressure conditions in containment, this will allow the plant to be provided with greater equipment redundancy for the performance of the strategies defined in the SAMGs. The measures proposed by the licensee (some already described in the section on loss of safety functions) are as follows:

- Make available diesel groups for the feeding of some specific loads, among them the hydrostatic test pump and battery chargers.
- Make available motor-driven pumps for injection to the primary and steam generators and for RWST replenishment.
- Make available an additional capacity, by means of portable equipment, for injection to containment, either for feed of the containment spray system or for injection via the recirculation system.
- Analysis of alternative electric supply for the control room filtering units.
- Make available the capacity to spray the containment and other buildings from the outside in order to mitigate the release of fission products.

The plant plans to also provide the plant with PARs (passive autocatalytic recombiners) to improve hydrogen control, even in the event of prolonged SBO.

As regards the accumulation of hydrogen in other buildings, the plant announces in its report that it will carry out an analysis in the short term to determine hydrogen concentrations in enclosures annexed to the containment, in which consideration will be given to the possibility of the leakage of gases from the containment, in order to determine the existing risks of inflammability.

With regard to possible improvements in the control of containment pressure, and with a view to providing the plant with different alternatives capable of mitigating a severe accident with pressurisation of the containment, Vandellós II will install a filtered containment venting system, announcing previously the performance of an analysis covering the technological alternatives available for containment venting and specification of the solution adopted.

Likewise, as regards the implementation of the reactor cavity flooding strategy, the licensee indicates that an analysis will be submitted at the end of the year to determine the advantages and disadvantages, a decision being taken regarding application depending on the results (this possibly implying a physical design modification).

The Vandellós II plant indicates that none of the relevant SAMG items of equipment would be affected for the flooding elevation established in the equipment environmental qualification study for design basis accidents.

As regards the instrumentation, the licensee points out that in order to increase the robustness of the plant, and in addition to the portable instruments necessary in the strategies currently being developed, there are additional specific guidelines for the recovery of the variables considered to be most significant in the prevention phase: steam pressure, steam generator level, primary pressure and core exit thermocouple temperatures.

The licensee has analysed the times to certain events (cliff-edge situations) for a series of severe accident sequences. The calculations were performed using MAAP-4. In the event of the direct current batteries being available for 24 hours (allowing for core cooling by means of the AFW system), core uncover would take place after 32.6 hours and vessel failure after 35 hours.

- *CSN evaluation*

Both the emergency operating procedures (EOPs) and severe accident management guidelines (SAMGs) have been incorporated at this plant on the basis of the standards of the Westinghouse owners group (PWROG). These are considered adequate for the performance of their function and have been checked by the CSN by means of inspections and assessments.

The licensee includes among the additional reinforcement measures those relating to the portable equipment aimed at preventing or minimising fuel damage. All these improvement measures are considered positive since they allow prolonged SBO situations to be addressed with greater guarantees.

As regards prevention with respect to core damage sequences with high primary pressure, the manual main steam dump strategy is considered positive. In addition, it is considered that the licensee should analyse and, if necessary, implement an improvement regarding the possibility of actuating the pressuriser relief valves in the scenario of a severe accident coinciding with an earthquake and complete loss of electricity supplies (including the d.c. sources).

The measures proposed by the licensee for severe accidents and relating to hydrogen control (installation of PAR's) and the depressurisation of containment (installation of a filtered venting system and measures to inject water to containment by means of portable equipment) are all considered to be positive.

The alternative containment injection strategy that the licensee is currently developing is based on the use of water from the safeguards reservoir by means of portable equipment. Furthermore, the Vandellós II plant has not given credit to alternative injection under gravity from the RWST since this ceases to be feasible for a containment pressure of 1.50 kg/cm^2. The licensee's approach is considered to be adequate.

As regards the flooding of equipment and instruments as a result of injecting to containment, the plant indicates that, according to its analysis for design basis accidents, no item of equipment of relevance for the SAMGs would be affected. It is considered that the licensee should re-analyse this issue taking into account the possible flooding levels that might be reached through current and future SAMG strategies, and taking into account also the current injection media and those mentionedas improvements.

In relation to injection to the reactor cavity prior to vessel failure, an analysis is currently on-going to value the positive and negative aspects of such injection and be able to take a decision in this respect. On the basis of the conclusions of this analysis, the licensee will determine whether the balance between the positive and negative issues makes it recommendable to implement the capacity to inject to the cavity (which might involve a design modification). This approach is considered to be positive.

The containment venting strategies currently present in the plant SAMGs are last resort measures since the most efficient paths (from the point of view of containment depressurisation) have a low design pressure and the low efficiency paths are neither filtered nor channelled to the stack. This is, as has been pointed out, a last resort measure to protect against rupturing of the containment in response to an imminent threat in this respect. The venting capacity will improve substantially with the installation of a new filtered venting system.

Additionally, and as regards the instrumentation, the licensee indicates that portable electricity-generating groups will be made available to maintain, among others, the functions required to ensure insight into the status of the plant. Furthermore, Vandellós II has identified the instrumentation necessary to manage severe accidents (contained in the SAMGs) and has assessed both whether an indication of this parameter exists on the Remote Shutdown Panel and the feasibility of local data acquisition. For each variable the aspects necessary to recover its indication when required is detailed. In this respect, Vandellós II plans to draw up specific guidelines. The licensee claims in the report that there are plans to incorporate these improvements. However, neither this measure nor a list of the instruments affected by the improvement is included in the table summarising the list of improvements. The licensee should complete this issue.

Vandellós II indicates that an analysis will be performed of the potential risk of hydrogen in buildings annexed to the containment. In the context of the analysis of the risk of hydrogen in such annexed buildings, the licensee should analyse the possible hydrogen leakage paths (venting, failure of venting lines, leakage across high pressure penetrations inside containment) and the dynamics of propagation in the different rooms annexed to containment, taking into account their geometry, in order to estimate those possible local concentrations that, although short-lived, might lead to hazardous concentrations being exceeded.

The improvement measure proposed to assess the need to provide the plant with a connection to a portable electric generator for the control room emergency filtering units, in order to guarantee the habitability of the control room in the event of a severe accident, is considered positive.

In addition, it is considered that the licensee should incorporate on his list of improvements the analysis of the following aspects (the conclusions of which might lead to design modifications in the plant procedures):

- Management of severe accidents arising from shutdown operating conditions.
- Capacity of the instrumentation associated with parameters critical for the severe accident strategies to provide reliable information under severe accident conditions in containment (for example, containment pressure, RCS pressure or hydrogen concentration in containment).
- Leaktightness capacity of the containment isolation valves and penetrations under the pressure, temperature and radiation conditions of the severe accident. It is considered that the plant should analyse this issue in order to obtain an estimate of leakage and, where appropriate, identify and implement potential improvements.

- **Loss of fuel pool inventory and/or cooling**

- *Licensee's position*

Cooling of the spent fuel pool (SFP) is accomplished by means of the spent fuel pool cooling and purification system (EC system), which is a class 1E system designed to remain functional during and after a safe shutdown earthquake (SSE) or other postulated risks such as fires, internal missiles or pipe breaks.

Each of the EC system trains has a capacity of 100% and is fed from the safeguards busses that receive voltage from the off-site energy sources and the emergency diesel generators in the event of LOOP. The EC system heat exchanger is cooled by the EG system, which in turn may be cooled by both the EF system (primary heat sink), during normal operation, or by the EJ system (ultimate heat sink) in emergency operation.

Assuming the operation of a single loop, the system is capable of maintaining the temperature of the water in the irradiated fuel pool at 60 ºC maximum with the thermal load defined as the maximum temporary heat load.

In the event of total loss of SFP cooling, water would be supplied from the three available sources to maintain the inventory in the SFP: by gravity from the RWST, the condensate storage tank and the reactor coolant make-up water storage tank. The Failure Operating Procedure POF-03, "Failure in Spent Fuel Pool cooling" is being revised to include the fire protection system (FPS) as an alternative source. Reserves of boric acid will be made available on site for use in the event of the water source used for make-up not being of borated water.

In the control room there is SFP water level and temperature indication and alarm. The level instrumentation has a range of 1.80 m and the temperature instrumentation a range of 0 to 100 ºC.

The licensee has analysed the loss of inventory that would occur as a result of seismic action in the SFP ("sloshing") and concludes that this phenomenon would cause spillage of 0.22 m^3 of water, this not affecting the conclusions of the scenarios analysed.

In his report the licensee includes calculations of the times available to boiling and different levels of water (up to exposure of the fuel assemblies) in the event of total loss of cooling and for different thermal loads in the SFP. The most unfavourable case is that of the maximum thermal load (all fuel assemblies in the SFP), initial level 7 m above the fuel assemblies and initial temperature in the pool 60 ºC; in this case times of 5.1 hours to boiling and 51.95 hours to exposure of the fuel assemblies are obtained. In the case of the thermal load corresponding to the end of a typical refuelling outage, the time to boiling would be 14.33 hours and the time for the level to reach the upper part of the fuel assemblies would be 114.38 hours.

As regards the possible accidental drainage of the SFP:

- The inflatable joints and corresponding pneumatic system (tubing and check valves) have an HCLPF capacity of 0.3g.
- The piping of the suction and return cooling system has an HCLPG capacity of 0.3g. The pool is designed such that inadvertent drainage is avoided below a height of approximately 5 metres above the fuel assemblies.

The licensee proposes the following improvements in relation to loss of the fuel pool cooling and inventory replenishment capacity:

- Procedures: development of guidelines for the implementation of alternative SFP injection strategies and spraying from the outside.
- Analysis of potential improvements to the SFP instrumentation.
- Acquisition of portable equipment on the site for SFP injection and spraying.
- Design modifications: improvements to the SFP instrumentation.

- *CSN evaluation*

The licensee includes information on the design basis of the SFP and associated cooling systems. These aspects have been evaluated and licensed in previous plant stages. In addition, the equipment and related procedures have been inspected by the CSN on numerous occasions.

The licensee describes the measures currently available to address scenarios of loss of SFP cooling. The current cooling and make-up alternatives would not be available in the event of SBO, except for the FPS, which has a diesel pump (currently not seismic). The improvement proposed by the licensee regarding the acquisition of portable equipment for SFP injection and spraying is considered positive and necessary.

The licensee has analysed the loss of inventory that would occur in the SFP ("sloshing") as a result of seismic action and concludes that there would be spillage amounting to 0.22 m^3 of water as a result of this phenomenon. As this loss of volume is around 0.017 % of the total volume of the pool, the effect is not considered to be significant.

- **Radiological protection issues**

- *Licensee's position*

The control room envelope at the Vandellós II plant, in which is located the TSC, is equipped with an emergency ventilation system that ensures habitability conditions in the event of a chemical and/or radiological accident. These centres are equipped with an adequate number of items of protection equipment for the personnel working in these areas.

The licensee has estimated the dose that would be received by the personnel in the control room envelope in the event of a severe accident coinciding with a prolonged loss of electrical power in which containment venting were necessary. The analysis shows that under the assumption of the venting being filtered, with shifts established and with personal protection equipment used, the estimated doses are lower than the emergency intervention levels. Furthermore, in order to increase the robustness of control room habitability, the licensee has short-term plans to analyse the alternative supply of electric power by means of portable equipment to the control room emergency filtering units and to the heating battery to maintain the effectiveness of the filters.

As regards the radiological conditions in other emergency support centres, Vandellós II has estimated the limitations regarding residence times and necessary personal protection for different core damage situations, determining that it would be necessary to evacuate the Operative Support Centre (OSC) in the event of containment venting. The licensee proposes to construct an Alternative Emergency Management Centre (AEMC) on the site, to be available in 2015, with the possibility of radiologically controlling the workers and guaranteeing residence under adequate conditions. This proposal will be addressed conjointly by all the plants.

As regards the resources available for the monitoring and control of radioactive emissions in the event of accidents, Vandellós II has a radiation monitoring system that includes post-accident monitors and sampling, the on-line environmental radiological monitoring network (RVRAC), the emergency radiological surveillance plan (PVRE) and procedures for calculation of the activity released.

In addition to the actions foreseen to increase the robustness of the plant in response to SBO, the plant is undertaking an exhaustive analysis of its communication systems, among them the RVRAC and those used by the PVRE, in order to ensure their availability in the scenarios postulated in the present stress tests.

In addition, and along with the rest of the licensees, the plant will analyse possible additional equipment and improvements to the current radiological protection resources to adapt them to the conditions potentially existing in the scenarios analysed. This analysis is expected to be completed in June 2012, as from when the improvements identified will need to be implemented.

As regards identification of the radiological conditions that would prevent local manual actuations, Vandellós II has estimated the residence time limitations and protections at the different areas from which the manual recovery actions identified in these stress tests would be performed, for different core and containment damage situations. The estimate has been carried out taking into account releases of activity to the air. Strict time controls would be required in the event of core damage, the maximum performance times being just minutes in the case of containment venting. These conditions would improve, allowing for residence times of several hours, once the filtered containment venting were implemented.

- *CSN evaluation*

The current design of the control room envelope at the facility has been evaluated and accepted by the CSN and guarantees that the radiation to the personnel located there during any design basis accident would not exceed the limits of General Design Criterion 19, of Appendix A of NRC 10 CFR 50.

The CSN considers that the habitability analysis performed by the licensee for severe accident cases presents important uncertainties (containment leakage, characteristics and efficiency of the filtered venting system to be implemented, atmospheric conditions, control room air inlet flow, residence times, etc.). In this respect, the licensee's proposal to analyse in the short term an alternative power supply to the control room emergency filtering units and the heating battery (to maintain the effectiveness of the filters) by means of portable equipment, is considered positive.

The proposal to construct an AEMC is valued positively. Section 4.1.c includes general conclusions in this respect.

In relation to the means available for the monitoring and control of radioactive emissions, it is considered a strength that Vandellós II has available a on-line environmental radiological surveillance network, with the automatic reception of data in the control room, the TSC and the CSN emergency response room.

Also considered positive is the analysis that all the licensees of the Spanish nuclear power plants will perform jointly and in coordination with respect to the radiological protection resources and equipment that should be available in the scenarios analysed. In the case of Vandellós II, the analysis should contemplate at least the availability of the post-accident sampling system and radiation monitors in prolonged SBO scenarios and their correct operation in severe accident conditions. The conclusion drawn in section 4.1.c is also applicable.

As regards the analysis to identify the radiological conditions that might prevent the performance of local manual actions, the plant should extend the study to include certain manual actions currently contemplated in the SAMGs. The general conclusions in this respect are included in section 4.1.c. The CSN will require the development of actuation guidelines for each of the SAMGs with the radiological protection issues to be taken into account depending on the foreseeable doses.

The licensee will be requested to review the dose rate calculations depending on the level of water in the SFP, since the hypotheses used are not conservative and the calculation methodology could be more accurate. The licensee will be requested to incorporate in the procedures the radiological protection issues to be considered in the foreseen local manual actuations. The general conclusions in this respect are included in section 4.1.c.

4.2.3 Cofrentes Nuclear Power Plant

4.2.3.a Extreme natural events

- **Earthquakes**

- *Licensee's position*

The Design Basis Earthquake (DBE) adopted for the seismic design of Cofrentes nuclear power plant has a horizontal free field acceleration of 0.17 g, calculated using a deterministic methodology. Also considered in the design is another lower level of seismic demand corresponding to the Operating Basis Earthquake (OBE), whose horizontal acceleration is half the DBE.

The licensee has reviewed the seismic design basis of the plant to determine its current validity. In this respect, the cut-off date originally considered (1972) has been extended to June 30th 201, in application of the catalogue of the Instituto Geográfico Nacional (IGN), checks being performed to ensure that the maximum seismicity associated with seismogenic zones used to determine the DBE has not been exceeded. Consequently, the conclusion is that the seismic design basis continues to be valid.

Protection of the plant against the DBE is based on the requirements applicable to the seismic design of the SSCs in accordance with the classification included in NRC RG 1.29, and maintenance, by way of the processes established in the licensing basis, seismic qualification and the correct condition of the SSCs, along with the corresponding modifications and spares.

For the detection of earthquakes the plant has a seismic surveillance system that fulfils the recommendations of NRC RG 1.12 and RG 1.166. The instrumentation supplies an immediate indication in the control room whenever the established accelerations are exceeded. The system is made up of six triaxial sensors for strong movements, located in different parts of the site, the associated reproduction and recording system and spectrum analysis.

The licensee assesses the seismic margin of the plant on the basis of the work already performed using the methodology developed by the NRC and EPRI (with a RLE of 0.3g and full scoped). During the 2011 refuelling outage an IPEEE review was performed, this having been undertaken to evaluate the new equipment related with plant design modifications and confirm the maintenance of the seismic margins of the initial study. The IPEEE has been complemented in the context of the stress tests with the performance of new inspections and extension of the scope to include consideration of the confinement function relating to the spent fuel in the pool.

In accordance with the studies performed, the licensee assigns to the safety functions required to reach and maintain safe shutdown a minimum HCLPF capacity value of 0.28g. This value is limited by a series of relays for which it was not possible to justify a higher HCLPF during the 2011 outage. A seismic margin of 0.3g is identified for the integrity of the spent fuel stored in the pool, and a margin of 0.5g for the integrity of the containment, this being considered by the licensee to constitute an additional plant robustness.

The licensee has evaluated the seismic margin available for a series of items of equipment used in the management of Station Blackout (SBO) and in the severe accident management guidelines (SAMGs). The scope has been as follows:

- Piping and valves for injection to the vessel and pool by means of the Fire Protection System (FPS).
- RCIC turbine-driven pump and suction and discharge valves.
- Valves and piping for manual actuation of primary containment venting.

An assessment has been performed of the capacity of the plant to withstand simultaneously an earthquake exceeding the DBE and off-site flooding exceeding the design basis flood, as analysed in the chapter on flooding.

The plant Safety Analysis Report includes an evaluation of the simultaneous failure of the Alarcón and Contreras dams as a result of an earthquake, the conclusion being that this event is not considered credible in view of the distance between them and the seismicity of the area, among other things. This conclusion was verified by means of a study of the probability of the two dams rupturing simultaneously for any reason, such that the flood waves were superimposed at the site, the probability obtained amounting to 10^{-12}/year. The section on flooding included below includes additional assessments of this event.

Compliance with the current licensing basis as regards seismic behaviour is guaranteed through the periodic application of procedures, surveillance requirements and actions aimed at adequately maintaining the SSCs and seismic surveillance system, along with the corresponding design modifications and associated spares.

As regards the possibility of there being induced effects as a result of an earthquake, the plant report indicates the following:

- Fires and explosions: the licensee verifies compliance with the current design basis. Compliance with the protective measures for the storage of combustible materials inside the plant, the measures for protection against fires and the evaluations performed to analyse fire risk indicates that in the event of an explosion or fire, the safe shutdown of the facility would not be affected. The licensee also points out that the possible sources identified in the fire protection study have been reviewed during inspection walkthroughs, concluding that those that might affect the safe shutdown path present a margin of more than 0.3g.
- Internal flooding: the licensee identifies the current design basis, in which no consideration is given to circumferential breaks in non-seismically qualified piping, although the safe shutdown paths for the sizes requested in the design basis are analysed. With the drawing up of the Protection Manual for internal flooding, the existence of barriers, surveillance measures and measures for the maintenance of barriers guaranteeing low levels of risk in the event of flooding is justified. The licensee plans to analyse the non-Seismic Category I piping identified in the flooding PSA as being susceptible to generating initiating events and affecting the mitigation systems, from the point of view of seismic behaviour. Furthermore, the licensee has analysed beyond the design basis scenarios covering possible breaks in the systems on site containing large sources of water and has concluded that the existing barriers are adequate and that in none of the cases would the safe shutdown of the facility be prevented, although the need to implement additional measures with respect to the FPS pump house is identified, in order to address the potential rupturing of the essential service water pond.

- *CSN evaluation*

The seismic design basis of the Cofrentes plant is that licensed in the original design of the facility, is included in the Safety Analysis Report and has been periodically inspected and evaluated by the CSN.

The HCLPF values estimated by the licensee are considered to be justified in accordance with the EPRI methodology, although certain values, such as the value of 0.3g assigned to the racks, are currently being reviewed by the CSN. Also pending verification are the corrective actions proposed by the licensee to increase the HCLPF value of the equipment identified as having a margin of less than 0.3g, as well as the evaluation of the margins of certain systems used in SBO and SAMG scenarios.

The licensee has analysed the seismic performance of the upstream Alarcón and Contreras dams, verifying that both have a resistance capacity beyond the plant DBE. The licensee has also estimated the seismic capacity of each of these dams, concluding that the Alarcón dam could withstand an earthquake of 0.26g and the Contreras dam an earthquake of up to 0.44g. These results are considered valid as regards the seismic margins assessment performed; nevertheless, additional comments are provided in the CSN's evaluation in the section on flooding included below.

The actuations proposed are considered to be adequate to improve the robustness of the plant in response to beyond the design basis earthquakes.

As regards the possibility of induced effects occurring as a result of an earthquake, and in addition to the general conclusions included in section 4.1.a, the following conclusions are reached:

- Fires and explosions: the analysis performed by the licensee is considered to be adequate and complete.
- Internal flooding: the CSN evaluation considers that with the analyses available and the proposal regarding analysis and the review of margins for items identified in the PSA, the plant covers the scope required for the analysis of potential flooding effects. The licensee's proposal regarding the FPS pump house is considered to be adequate, although this proposal has not been included among the improvement proposals identified in chapter 6 of his report.

- **Flooding**

- *Licensee's position*

The design basis regarding flooding considers the catastrophic rupturing of the Contreras dam (located 106 km upstream on the river Cabriel), coinciding with a flood caused by torrential rainfall of a magnitude equivalent to half the Maximum Probable Precipitation (MPP) and taking into account the effect of winds of 65 km/h causing waves in the mass of water. With this combination of events, the maximum height of the surface of the water would reach elevation 367.41 m, which is below the elevation of the plant grading level (372 m), as a result of which even in these conditions it would be possible to take the reactor to cold shutdown and maintain fuel pool cooling.

Also calculated has been the level of flooding due to the instantaneous rupturing of the Contreras dam, assuming the corresponding reservoir to be filled to its maximum level. The maximum height of the water reached at the site is 361.99 m and, considering the waves formed by the wind, would reach 363.49 metres.

In all cases the 400 kV switchyard located on elevation 348.7 m would be lost, which would cause the plant to shut down as contemplated in the design, without the SSCs located on the elevation of the plant grading level being affected. The 138 kV switchyard is located on elevation 372 m, as a result of which it would not be affected. Likewise, the off-site route followed by the 138 kV lines reaching the plant has been analysed, the conclusion being that these would remain available even in the event of the maximum flood contemplated by the design.

As regards the situation of the water table and its possible rising as a result of rainfall and flooding, the maximum design level is 362 m. It has been estimated that for the water table located below the buildings to reach the foundations due to in-seepage caused by the design flood, it would be necessary for the flood level to remain for six months. The water table is monitored monthly.

The cliff-edge situation postulated is a flood of unknown origin that reaches the plant grading level (372 m). In this situation, off-site power would be lost due to flooding of the 138kV switchyard, the plant then depending on the emergency diesel generators. The reactor could be taken to cold shutdown and cooling of the spent fuel pools could be maintained, since the flooding height of the safety-significant buildings is at least elevation 372.2 m. The duration of a flood is not expected to compromise the margins foreseen for the plant to maintain its safety functions with only on-site power supply.

The licensee describes the actions established in the Site Emergency Plan for flooding as a result of river swell or rainfall. The ultimate conclusion is that the natural layout of the site, along with the protections existing by design, guarantees the protection of the buildings, galleries and outdoor equipment against intense rainfall. The building roofs have been designed such that they are capable of withstanding the maximum loads due to rainfall and also prevent water from seeping into the inside of the building. The roofs are included in a periodic maintenance programme aimed at permanently guaranteeing their suitable condition.

- *CSN evaluation*

The design bases relating to the different events that might cause flooding of the site are included in the plant Safety Analysis Report and have been evaluated and accepted by the CSN. The CSN has also performed specific inspections to verify what is established in the aforementioned bases.

As regards the effects of rupturing of the dams located upstream of the site, the licensee's analyses present hypotheses different from those contemplated in the emergency plans for dams within the framework of Spanish practice, since the possibility of the combined catastrophic rupturing of the two dams in considered highly improbable. However, as the licensee's proposals differ from those postulated in the dam emergency plans, the actions required to bring the two approaches into line should be adopted. As a result of these actions, the licensee should review the studies performed and adopt the measures deriving therefrom.

The licensee states that the duration of the flood considered as constituting the "limit situation" is not expected to compromise the margins foreseen for the plant to maintain its safety functions only with on-site power supply. In view of the information provided, this conclusion is considered to be reasonable, although certain aspects, such as the local effects of the increase in the water table and the improvement measures for the removal of water from galleries without drains, require additional checks by the CSN, these currently being under way.

- **Other extreme natural events**

- *Licensee's position*

The plant has analysed the possible occurrence of events caused by other phenomena of external origin, identifying strong winds as being the only relevant such events. The design wind speed for the plant is 150 km/h, calculated on the basis of studies of the maximum winds in the area with a recurrence time of 1000 years and applying the criteria of the Spanish MV-101 building standards. The maximum wind speed measured to date at the site has been 119 km/h. The resistance capacity of the structures exceeds 150 km/h, due to the conservatism involved in this type of load calculations and to the consideration of other criteria in the design (e.g., seismic criteria).

In addition, the potential impact of other extreme meteorological situations that might occur at the site (lightning strikes, freezing of the river, landslides, freezing and extreme temperatures, forest fires, snow, high river levels, drought, tornados, hail) has been assessed. It is concluded that the plant has adequate protections to respond to such events.

- *CSN evaluation*

The screening of off-site events performed to establish the design basis is based on a very low probability of occurrence (10^{-5} per year), in accordance with the probabilistic methodologies included in the applicable IPEEE standards.

The licensee has extended the scope of his analyses with respect to what was documented in the preliminary report and has addressed other credible events at the site in a reasoned manner. The conclusions drawn are generally considered to be reasonable, although the CSN has not yet concluded its detailed evaluation of extreme temperatures, this still being under way.

4.2.3.b Loss of safety functions

- **Loss of off-site power (LOOP)**

- *Licensee's position*

Cofrentes describes the existing interconnections with the grid and off-site power sources, concluding that they provide a high degree of reliability and confidence in the capacity to quickly recover from a loss of the external grid.

The plant references the procedures of the electricity grid operator for the recovery of supply in the event of a zero grid voltage condition, these giving priority to feed for the nuclear power plants and in particular for Cofrentes NPP. In the case of this plant the replacement power comes preferentially from the nearby Cofrentes, Millares II, Cortes II and La Muela hydroelectric stations, all with an autonomous start-up capacity, some of which have been tested.

The on-site electrical feed for the safeguards systems of each of the divisions is made up of a diesel generator and a direct current battery. There are three electrical divisions; divisions I and II are totally redundant, the design guaranteeing safe shutdown in the event of LOOP with one only of these divisions in service; division III corresponds to the high pressure core spray system (HPCS).

In the event of LOOP, the feed for the safety-related equipment is performed automatically through the start-up, connection and load sequencing of the division I and II diesel generators, either of these being sufficient to maintain electrical feed for the equipment required to take the plant to safe shutdown. The third diesel generator (GD-HPCS) will not be necessary in the event of LOOP.

The three diesel generators are designed as Safety Class and Seismic Category I, and the structures containing them are designed to withstand the effects of the SSE earthquake without losing their capacity to perform their safety function. They are also protected against the effects of other natural phenomena such as winds, flooding, etc. by the building in which they are housed.

The plant lists the periodic and preventive maintenance tests performed on the diesel generators to check their reliability.

By design, the autonomy of each of the three diesel generators is seven days, considering fuel, lubrication and cooling. Cooling is accomplished by means of the essential service water system.

- *CSN evaluation*

The descriptions provided by the licensee are considered to be correct. There is a basis for considering the off-site feed system as being reliable, since the feeds have different points of origin and runs and this independence brings reliability to the supply in response to events such as that postulated (LOOP), in addition to which both the generation breaker and the switches between feeds have operated satisfactorily. The reliability of the off-site electrical feed is reinforced by the fact that the grid operator has procedures for recovery by geographical areas, which take into account the preferential feed for the nuclear power plants and the performance of tests on recovery from nearby hydroelectric stations. The proposal that these tests be performed periodically will increase the reliability of the off-site power supply.

The LOOP is within the design basis of the plant, with a coping time of at least seven days. Consequently, the situation considered in this sub-section has been evaluated and licensed in previous stages, its various aspects having been inspected by the CSN.

In the event of external flooding, the plant might lose the availability of the 400 kV switchyard but maintain the 132 kV switchyard, for which reason the LOOP situation would not be reached.

There are no observations as regards the response of the plant in the event of loss of the off-site feeds. The CSN considers that the foreseeable response of the plant in the event of LOOP would be safe and as expected, since in this situation the plant has available three emergency diesel generators, which start up on loss of voltage on the emergency busses and automatically feed the loads necessary for safe shutdown. The plant may withstand this scenario for more than seven days without any additional means of support.

The measures mentioned by the plant to prolong the autonomy of the diesel generators, allowing for the transfer of gasoil from the auxiliary boilers sub-system, will bring additional autonomy.

The forecasts regarding the recovery of off-site electrical feed and those relating to the periodic testing of the feed from nearby hydroelectric stations are worthy of special mention.

- **Station blackout (SBO)**

- *Licensee's position*

As regards the event of station blackout (LOOP) and loss of the normal back-up sources (DG-A, DG-B), the licensee had previously provided a justification of the safety of the plant for the SBO situation considered at the time, with a coping time of four hours, with electricity available from the batteries and without the need for support from HPCS system and its diesel generator.

The safety-related direct current system is organised in three divisions, each with a battery and two battery chargers (one in stand-by). Each sub-system is located in an area physically and electrically separate from the other sub-systems. The calculations have demonstrated a battery autonomy of more than the four hours considered.

The licensee includes a description of the sequence of events that would take place after the occurrence of an SBO event, along with the systems available to guarantee compliance with the required functions.

Although not a design basis situation, for a situation of SBO extending beyond the aforementioned four-hour period the electrical feed provided by the third generator referred to previously and assigned to safety-related equipment division III would be available. Connection of generator DG-HPCS, which would be aligned to divisions I or II, in accordance with the procedure in place for this purpose, would also make available the HPCS system, with high pressure injection (the RCIC system also being available) and make it possible to feed the electrical loads required for the operation of the systems, including the battery chargers and the batteries themselves, the latter not therefore having any limitation as regards autonomy.

The condensate storage tank (CST) is the preferential source of water for injection to the vessel by both the HPCS and RCIC systems.

In the event of station blackout (LOOP) and loss of the normal back-up sources (DG-A, DG-B), plus the loss of any additional back-up source of alternating current feed (DG-HPCS), i.e., a situation of SBO in which – as regards alternating current sources - failure of the division III diesel generator is also assumed, core cooling would be accomplished by means of the turbine-driven RCIC pump, with steam discharged to the suppression pool (SP), as a result of which heat removal from this pool would be accomplished through the controlled opening of containment venting.

The availability of direct current would be maintained, fundamentally for the control of RCIC system operation, actuation of the Safety and Relief Valves (SRVs) when vessel depressurisation is required and feed for the instrumentation, during such time as this were guaranteed by the autonomy of the battery (and no supply were forthcoming from a portable generator). The plant procedures for SBO list the direct current loads that should be disconnected to stretch out the depletion time of the batteries. As batteries A and B have been replaced with others of higher capacity, new autonomy calculations have been performed, the results being 20 h 46 min for battery "A" and 25 h 4 min for battery "B".

In the event of failure of the RCIC system, the primary system would be depressurised by means of the SRVs, the FPS then remaining available for injection to the reactor vessel once aligned for this function, the primary system being depressurised previously by means of the SRVs in accordance with the procedures in place.

The licensee states that the limit time for injection to the vessel, in the event of failure of the HPCS and RCIC systems and following depressurisation by means of the SRVs, is 30 minutes. The limit time for containment venting to remove heat from the SP under these conditions would be 30 hours.

For the extreme case of a scenario with failure of all the alternating current sources and loss of the batteries without portable generators having been connected, the plant is developing a procedure for the completely manual operation of the RCIC system, i.e. without direct current. The availability of flywheels for the manual actuation of the containment vent valves in this situation has been checked.

- *CSN evaluation*

As has been mentioned in section 4.1.b, Station Blackout (SBO), defined as the complete loss of on and off-site alternating current, is an event beyond the design basis of the operating plants that was incorporated in its day into the plant licensing basis.

As regards the two options established as being possible in RG 1.155 (independence with respect to alternating current, availability of an alternative source of alternating current), the Cofrentes plant opted for the first, based on the use of d.c. sources as electrical feeds. The SBO coping time then considered for the purposes of the applicable analyses was four hours. The evaluation has verified that the division III diesel generator (DG-HPCS) was not considered with regard to compliance with the SBO standard.

The forecasts regarding alignment for an SBO beyond four hours (up to 72 hours) of DG-HPCS and of the loads to be fed are considered correct in the current context. The autonomy of this generator is at least seven days.

The CSN has reviewed the calculations of battery autonomy performed by the plant for the event of the SBO being complete (additional loss of DG-HPCS) and considers them to be correct.

The description provided by the plant of the sequence of events that would take place following an SBO event, in the current context (both complete and prolonged) and of the systems that would be available to guarantee compliance with the required functions is adequate.

The limit times presented by the plant refer to a situation of joint unavailability of all the safety systems, this corresponding to severe accident situations. The limit times referred to in the complementary technical instructions would be those corresponding to depletion of the batteries taking into account their extended autonomy.

The plant has calculations of the autonomy of batteries in SBO that justify the values included in the report. The new calculation performed for current batteries A and B has been reviewed, with satisfactory results.

As regards heat removal from the Suppression Pool (SP), the CSN considers that the plant should perform a complementary analysis considering the feasibility of an alternative other than containment venting to reduce SP temperature.

The plant has installed flanges on the lines of the essential service water system, close to the ultimate heat sink, to allow for the connection of portable pumps, the water being used for different purposes, among them cooling of the diesel generators in the event of unavailability of the pumps of the essential service water system. This is considered to constitute a positive measure.

As regards the development of a procedure for the manual operation of the RCIC system and in view of the difficulties involved – including the associated radiological risk – the plant should demonstrate its feasibility, contrasting it with equivalent plants where possible, and assess the possibility of performing a design modification and a verification based on a real test under conditions not implying any radiological risk for the operators.

Two aspects for which the plant should submit complementary documentation are those relating to the possible effects of loss of ventilation in total SBO events extending beyond 4 hours and to forecasts regarding the use sources of water complementary to the CST in the HPCS and RCIC systems.

It is concluded that, in view of the considerations included in this section, the plant's analysis are adequate. The CSN has performed an inspection for the review of issues relating to loss of power, loss of heat sink, spent fuel pool and severe accidents.

- **Improvements proposed by the Cofrentes plant in response to loss of power events**

The plant sets out proposals for improvement that are summarised below:

- Development of a procedure for feed of divisions I or II from DG-HPCS
- Extension of divisional battery autonomy by means of an electricity-generating group.
- Addition of compressors to extend the availability of SRVs, containment vent valves and spent fuel pool gate seals.
- Development of a procedure for the manual operation of the RCIC in the event of unavailability of electrical power.
- Incorporation of pumping groups using the different existing sources of water to be able to inject to the vessel, suppression pool, containment sprays and alternative fuel pool supply.
- Incorporation of a electricity-generating group to ensure the operation of the division I and II hydrogen ignitors and maintain control room pressurisation.
- Planned performance of periodic tests on the recovery of power supply from the nearby hydroelectric stations.
- Installation of a seismic FPS.
- Improved communications.
- Procedure for the reading of critical plant parameters in the event of complete loss of power.

In their current stage of development the improvements proposed by the plant are considered valid, with the reservations and/or considerations set out in the previous sections. Particularly significant in this respect is the consideration relating to the submittal of a complementary analysis of the possibility of incorporating an alternative method for heat removal from the SP and the possible improvements necessary to give credit to the manual operation of the RCIC turbine-driven pump. Furthermore, the feasibility of using portable equipment is subject to the results of the specific personnel availability analysis required in section 4.1.c of this report.

With the implementation of these measures, the cliff-edge situation times would be extended and would depend on the autonomy of the portable equipment.

- **Loss of ultimate heat sink (UHS)**

- *Licensee's position*

During normal power operation of the plant, the heat sink for the turbine cycle consists of a condenser cooled by the circulating water system, which constitutes the primary heat sink. By means of this system the reactor may remain in the hot shutdown operating condition. During reactor shutdown (cold shutdown and refuelling), the heat is removed to the ultimate heat sink (UHS) pond via the essential service water system (P40).

In the event of loss of off-site power (LOOP) and other transients, the residual heat from the reactor is removed either directly or through cooling of the suppression pool (SP) to the UHS via system P40. This system is also designed to remove heat in the event of a design basis accident (LOCA), postulated to include a LOOP.

In the event of failure of the P40 system or of the capacity to remove heat from the reactor to the UHS, the heat would be released to the SP, which would lead to an increase in containment pressure and temperature. In such cases the heat may be transferred to the atmosphere via the dedicated venting system that couples to atmosphere of the containment to the environment. In the medium term, operation of the vent may require water make-up to the suppression pool in order to prevent an excessive decrease in level in this zone.

As regards the spent fuel storage pools, under normal conditions the residual heat from the fuel is given off via the corresponding cooling system to the plant service water system (P41), which is equipped with an active method for heat transfer (forced draught towers). This system constitutes the primary heat sink for the residual heat generated in the storage pools. This system is Non Safety Class and Non Seismic Category and is provided with emergency electrical feed in the event of LOOP and other transients. In the event of a design basis accident (LOCA) coinciding with LOOP, or in the event of failure of the P41 system itself, the residual heat from the fuel is transferred to the UHS via system P40. In the event of a LOCA, the cooling is transferred automatically to the P40 system.

In keeping with the Design Basis, the P40 system is designed to provide cooling water for the removal of heat from the equipment required to achieve and maintain safe plant shutdown and is designed with sufficient redundancy in order for its safety function to be performed assuming a single failure coinciding with LOOP. Both the system and its containing structures are designed to withstand the effects of an earthquake without losing the capacity to perform their safety function. The system is protected against the effects of other natural phenomena, such as winds, external flooding, etc.

The system is made up of a pond for cooling by spraying (UHS) and three independent cooling systems, one per division. The cooling water taken from the UHS by the pumps located at the pond water intake structure will be distributed to the essential components by means of the three aforementioned circuits. After cooling the components, the system water returns to the pond via three separate headers, the final sections of which are equipped with a series of spray devices with coupled nozzles.

Loss of the UHS directly affects to the fuel cooling function, and indirectly to loss of the radioactivity confinement capacity. Described below is the impact of this event on the aforementioned safety functions:

- Impact on cooling of fuel in the reactor
  - During power operation, loss of the UHS as an initiating event does not affect the normal heat sink since they are completely independent: the P40 system that transfers the heat to the UHS pool is a stand-by system and does not cool systems required for power operation of the plant. For this reason, its loss has no short-term impact. Its coincidence with an earthquake, flood, loss of off-site power or any other event disabling the normal heat sink would lead to a situation in which the residual heat would be removed to the atmosphere via the dedicated containment venting system.

    Loss of this containment vent during normal operation at power has no impact since it is completely independent of the normal heat removal system.
  - Under normal refuelling operation conditions, heat removal is accomplished by means of one of the two loops of the RHR system to the UHS. In the event of loss of the UHS, there would be a total loss of heat removal which would lead to heating of the coolant up to boiling, which would occur after 9 h 50 min in the most probable situation of the cavity and the vessel being filled and inter-communicated (1 hour and 8 minutes in the most limiting situation, corresponding to the initiation of opening of the reactor vessel). As from this moment, cooling of the fuel would be achieved by make-up of coolant as evaporation occurs. The systems capable of providing make-up to the vessel are the HPCS, LPCS and LPCI, seismic systems with electrical feed from the diesel generators, and the FPS and condensate distribution system, non-seismic and with normal feed. In addition, the FPS is equipped with a diesel-engined pump making it independent from electricity supply.
  - If the loss of the UHS were to occur in an accident or transient situation in which the plant depended on its operation, this would lead to loss of the three diesel generators as a result of lack of cooling.
  - If the plant were in a LOOP situation, this would evolve into SBO: no ECCS system would be available to inject coolant to the vessel. The capacity of the RCIC, which does not depend on alternating current feed, is sufficient to cool the fuel but is limited in time by the conditions in the SP, into which the corresponding turbine discharges its exhaust steam. In accordance with the EOPs, the conditions in the suppression pool and primary containment should be relaxed by using the dedicated containment vent, which would in principle allow for the continued operation of the RCIC. The dedicated vent path does not depend on a.c. power and its isolation valves are equipped with dedicated direct current batteries and drive air. If the origin of the LOOP has been an earthquake, the operability of the vent path is guaranteed by the manual operation of its valves; it would act as an alternative UHS and water could be provided to the SP by means of the FPS, manually aligned and with water driven by the diesel pump.
  - If the loss of the UHS does not coincide with LOOP, the impact would be much slighter, since all the essential plant systems would be fed from the off-site feed sources, the battery chargers would be in operation and any phenomenon associated with loss of cooling (equipment cooling, ventilation system, etc.) would be much slower.
- Impact on cooling of the fuel in the spent fuel pools
  - Loss of the P41 system, normal heat sink for the spent fuel pools (SFPs), with forced draught cooling towers, makes it necessary to transfer heat removal to the RHR system, this in turn transferring the heat to the UHS via the essential service water system (P40), which is capable

of performing this function indefinitely. Coincidence of this loss with an earthquake, loss of off-site power or flood does not aggravate the situation.

- If for any operational reason heat were being removed from the SFPs to the UHS and the latter were lost, cooling would be accomplished using P41, except in the event of an earthquake. Nevertheless, the licensee points out that this is not a limit situation since a period of between 10 hours and several days, depending on initial conditions, is available before boiling of the SFP coolant occurs, this providing time for alignment of the coolant make-up systems (FPS, condensate distribution and demineralised water distribution systems).

- *CSN evaluation*

Refer to the evaluation in the following section.

- **Loss of ultimate heat sink combined with SBO**

- *Licensee's position*

A characteristic of the Cofrentes plant is the fact that the emergency diesel generators are cooled by means of the P40 system, the heat being transferred to the UHS. The P40 system pumps are fed by the generators in the event of loss of off-site power. For this reason, coincidence with loss of the UHS does not aggravate the SBO situation.

This plant considers that the improvement measures analysed and proposed for SBO are valid and adequate for this scenario, as a result of which no additional measures are identified.

Some of these proposals are aimed at making available additional residual heat removal capacities, from both the SFPs and the vessel.

- *CSN evaluation*

This section evaluates loss of the UHS, with and without SBO.

The licensee has provided an adequate description of the design features in place to prevent loss of the UHS and has analysed the situation that would result from loss of the UHS with and without SBO with an adequate scope.

In both cases (loss of UHS with and without SBO) the licensee identifies improvements to increase the robustness of the plant. These measures are considered positive and are the same as those identified in the section on loss of power, since the loss of the UHS would lead to a situation in the plant in which the same systems as for loss of power would be available to protect the safety functions.

The design modification performed on the essential service water system (installation of flanges downstream of the system pumps) would make an additional way available in the short term for water make-up to the vessel, cooling of the diesel generators or the injection of water to the spent fuel pools. This modification is considered positive.

With the plant in the shutdown situation, loss of the UHS with LOOP (which would lead to SBO in the case of Cofrentes) will lead to a situation of loss of cooling to the vessel in which water must be provided within a period of between approximately 8 hours and 75 hours (times for core uncover depending on the initial level of water in the vessel-cavity). In its description the plant details the system or systems that would be used to attempt to cool the core in this situation. It does not, however, point out which of the improvements proposed would provide an alternative cooling capacity for this case. It is considered that at least the following measures (identified by the licensee) might strengthen the performance of the plant in this situation: seismic FPS, portable pumping groups to inject into the vessel taking suction from the UHS, electricity-generating group for the pump of condensate distribution system to inject to the vessel from the CST. The licensee should take the shutdown situation into account in the development of future procedures making use of the systems to be implemented.

The licensee has not included in his report realistic calculations to estimate the depletion times of the sources of water currently available for the cooling system in closed circuit configuration (RCIC). The manual actuation of the turbine-driven RCIC pump proposed by the licensee poses the difficulties in performance commented on above, for which reason it has not been tested by the licensee; furthermore, the licensee indicates that he has no evidence of industry operating experience in this respect. The plant should analyse possible improvements to the RCIC system facilitating manual actuation, as well as the possibility of undertaking some type of test in the most realistic situation possible without compromising plant safety and radiological protection.

4.2.3.c Accident management

- **Planning of accident management**

- *Licensee's position*

For the case of prolonged SBO the licensee of the Cofrentes plant indicates specific improvements in the area of communications that are currently being evaluated and that would increase the coping times of the currently existing communications systems, but does not indicate any term for implementation.

Likewise, the licensee plans to reinforce the centres currently available for the management of emergencies with a new centre on site that, except for its being known as the Emergency Response Centre (ERC), coincides in all respects with the AEMC planned by the rest of the licensees.

In keeping with the start-up of this new centre, Cofrentes is planning another series of more in-depth improvements in the area of communications; analysis of these improvements will be completed in the short term and their implementation is proposed in the long term.

As regards routes for access to the facility, the licensee concludes that there is a feasible route in the event of an earthquake of lower intensity than the SSE that includes a structure over the river Jalance (bridge number 3) with spans of less than 1 metre. The graphic information on this structure and the rest of the information provided by the licensee indicates that the structure does not fulfil seismic resistance criteria. The licensee claims that in the event of flooding caused by rupturing of the Contreras dam, coinciding with the rainfall corresponding to ½ Maximum Probable Precipitation and the effect of waves of 1.5 m, there would be a feasible route but that its recovery would be slow.

The licensee establishes that for the professionally exposed workers participating in emergency tasks to mitigate the initial consequences of the accident, save lives or mitigate deterministic effects or prevent catastrophic conditions possibly affecting the population or the environment, the doses will be limited to below 500 mSv. This limit corresponds to what is set out in the IAEA's TECDOC 953 and recently approved BSS's.

- *CSN evaluation*

The licensee's proposal as regards specific improvements in the area of communications is considered to be acceptable, although specific periods for their implementation should be established. As regards the further-reaching improvements that will be associated with the start-up of the new ERC, these are considered to be acceptable, although the licensee should study the possible incorporation of provisional short to medium-term measures such that improved capacities, even though they be partial, be available prior to the dates for long-term implementation, informing the CSN in this respect.

As regards access routes to the facility, the CSN evaluation considers that no feasible itinerary has been identified for severe earthquake events. Neither has a feasible route to the site been identified for the case of flooding caused by rupturing of the Contreras dam, coinciding with the rainfall corresponding to ½ MPP and the effect of waves of 1.5 m, for which reason the licensee should analyse and propose improvements for both cases. The analysis should include the times during which the access routes remain unusable as a result of the earthquake or flooding and the compensatory measures foreseen during this period.

As regards the reference dose levels for the personnel intervening in an emergency, and as has been pointed out in section 4.1.c of this report, the CSN will establish a set of homogeneous reference levels for all the Spanish nuclear power plants. Nevertheless, and as the value proposed guarantees both individual protection and the feasibility of undertaking emergency mitigation actions, they are considered acceptable in the short term.

- **Measures for the management of accidents in the reactor**

- *Licensee's position*

The licensee describes the measures at the level of equipment, procedures and personnel to prevent, mitigate and manage severe accidents, also specifying the strategies to be followed in the guidelines and procedures as the plant conditions degrade. In concluding its analysis, the plant proposes different actions to increase the robustness of the plant in response to this type of events, through the incorporation of a series of improvements.

As regards hydrogen in the containment, in both the Emergency Operating Procedures (EOPs) and the Severe Accident Management Guidelines (SAMGs) this is managed by monitoring hydrogen concentration in the drywell and containment and ensuring that it is kept at values that do not imply any threat for the containment. The mechanisms for the control of hydrogen in the drywell are based on the hydrogen mix and on its venting and purge. As regards the containment, they are based on the use of hydrogen recombiners and ignitors, as well as on the dedicated containment venting system.

The hydrogen igniters (two divisions) control the amounts of hydrogen generated during a severe accident by means of controlled combustion at low concentrations, thus minimising the threat for containment integrity. In SBO, operation is ensured by the fact that the division II has an alternative feed from a miscellaneous services UPS. In order to ensure operation of the igniters beyond the lifetime of the battery dedicated for the UPS, the plant will be equipped with an electricity-generating group. As an additional measure to improve the robustness of the plant, passive autocatalytic recombiners (PARs) will be installed in those areas of the containment and drywell that might present a risk of hydrogen accumulation.

In relation to the potential for hydrogen accumulation in other buildings outside containment, the licensee indicates that values typical of the risk of combustion would not be reached (more than 100 kg according to IAEA document TECDOC-1661). According to the results obtained with MAAP-4, in a severe accident scenario with failure of the vessel and the generation of hydrogen with containment pressurisation to the maximum value permitted for venting, 3.21 kg/cm^2, the amount leaking from containment would not exceed 5 kg in 24 hours and would not be channelled to only one building. The licensee does not propose any measure in this respect.

As regards last resort measures to prevent the possibility of damage to the fuel in high pressure sequences, in his report the licensee has specified the measures available for depressurisation of the vessel during management of the accident in this scenario. In addition the licensee proposes a series of improvement measures relating to the safety and relief valves (SRVs) in order to guarantee prolonged operation in the event of long-lasting SBO, which would consist of the acquisition of an electricity-generating group allowing for energisation of the solenoids, the seismic qualification the nitrogen bottles in order for them to be operable in the event of an earthquake and the acquisition of an air compressor group for alternative pneumatic drive.

The ultimate capacity of the containment of the plant is 5.81 kg/cm^2, a value that exceeds the design pressure by more than five times. In a scenario with loss of cooling of the suppression pool and without any make-up to- it, the level in the pool would be maintained for more than 24 hours above the first line of vents, isolating the drywell from containment and the discharge of the SRVs would remain covered beyond 72 hours, maintaining the suppression pool filtering function.

As regards prevention against overpressure conditions in containment, in addition to venting via the normal systems and drywell spraying, there is the dedicated containment venting system that has a preferential line from the containment, with two air-operated isolation valves. This vent path makes it possible to take advantage of the retention of possible radioactive products in the suppression pool, preventing them from being released to the exterior. It is capable of removing a maximum saturated steam flow of up to 20 kg/s without exceeding the containment design pressure, at a height of 52.4 metres, this facilitating the dispersion of emissions and preventing concentrations of radioactivity and hydrogen at ground level, removing potential threats to the plant installations. In a limiting pressure scenario, the time limit for venting actuation might be reached before 24 hours.

The licensee is going to modify the elevation of the venting system suction in order to allow for the flooding of the containment to the upper part of the active fuel (TAF) in the event of a severe accident; this modification had been requested by the CSN. In addition, the possibility of installing a filter complementing the fission product scrubbing action performed by the suppression pool will be analysed, limiting off-site releases and doses in other plant buildings, as long as this does not hinder the functionality of the existing vent system throughout the range of pressures and strategies established in the EOPs / SAMGs. The licensee also proposes to carry out modifications to improve the operability of the venting in loss of d.c. feed situations. In this respect, a procedure will be developed for the manual opening of the valves on the dedicated containment venting line. Other improvements are the redesign of the nitrogen supply to the containment vent valves in order for it to be functional in the event of an earthquake, and the acquisition of an air compressor group allowing the vent valves to be opened in the event of prolonged SBO leading to the total consumption of the nitrogen bottles. The licensee also plans to undertake the improvements arising as a result of the work performed jointly with the BWR owners group (BWROG) in this area.

As regards the prevention of recriticality, the licensee presents the strategies currently available to confirm the shutdown of the reactor, among which are considered the methods consisting of additional boration, replenishing the stand-by control liquid system tank with borated water and adding boron to the condensate storage tank for injection into the vessel by means of the HPCS system. For this purpose there are 3220 kg of boric acid and 5500 kg of borax available in the plant stores.

In relation to the prevention of the corium penetrating the containment foundation slab, the licensee indicates that the supply of water to the reactor pedestal subsequent to the relocation of the molten core would not provide effective cooling if more than 20% had dropped. Consequently, with the vessel intact, the SAMGs require the flooding of the containment to an elevation allowing for at least flooding of the pedestal. With the vessel failed, the containment flooding process continues to an elevation above the TAF (Top of Active Fuel), for which the CST and FPS tanks must be refilled.

The licensee has drawn up several proposals for improvement aimed at guaranteeing supplies of water for both cooling of the vessel and the flooding of containment and cooling of the spent fuel pool. For this purpose, flanges and connections were installed downstream of the P40 pumps during the 2011 refuelling outage for connection to a mobile pumping group or the transfer of water from the different sources located on the site to ensure make-up in the event of prolonged SBO.

As regards the feasibility and effectiveness of the existing accident management measures under conditions of extreme risk, the licensee claims that the determination of seismic margins performed in the section of the final report corresponding to external events guarantees the availability of two safe shutdown paths in the event of an earthquake in excess of the SSE. There is also a margin as regards the operability of the RCIC and containment venting systems through their manual actuation. As regards flooding scenarios, the licensee claims that there are ample margins between the level of water that might be reached on the site in the event of occurrence of the design basis flood and the level at which the equipment and systems required for performance of the planned accident management measures would begin to be affected.

Regarding the suitability and feasibility of the instrumentation, the licensee plans to develop a procedure for the reading of the critical plant parameters in the event of complete loss of electrical feed.

In relation to the design of the control room, and as an additional measure to improve the robustness of the plant, an electricity-generating group will be made available to guarantee the continued pressurisation of the control room in the event of prolonged SBO.

As regards critical times in loss of core cooling scenarios, Cofrentes includes a detailed study of the critical times of the vessel and containment in the event of SBO, by means of simulation using the MAAP-4 code. For the extreme case of there not being any cooling system or make-up to the core from the onset of the event, severe damage due to core meltdown would occur after 1.26 hours and rupturing of the vessel after 3 hours. If the d.c. batteries were available, adequate core cooling conditions would be guaranteed for around one day via the RCIC and venting of containment (autonomy of battery "A" 20 hours 46 minutes and of battery "B" 25 hours 4 minutes).

As regards the analysis of accidents in other operating modes, the licensee refers to the strategies available for the different operational states existing during refuelling outages. The EOPs, except for EOP-1-RC, are replaced with the refuelling contingencies once loosening of the vessel bolts has begun (operating condition 6, refuelling). The SBO procedure continues to be applicable. Four contingencies are established, dealing with the following issues:

- Control of residual heat removal from the vessel and refuelling platform pool under refuelling conditions.
- Control of vessel and refuelling platform pool inventory.
- Flooding or primary containment during refuelling: the aim is to flood the containment if the water level cannot be maintained above the TAF (with irradiated fuel in the vessel).
- Control of inventory of and residual heat removal from the Fuel Building pools.

- *CSN evaluation*

Both the Emergency Operating Procedures (EOPs) and the Severe Accident Management Guidelines (SAMGs) have been incorporated at this plant on the basis of the standards of the BWROG. They are considered adequate for the performance of their function and have been previously checked by the CSN through inspections and evaluations.

As regards last resort measures to prevent the possibility of fuel damage during high pressure sequences, the licensee has specified in his report the measures available for the depressurisation of the vessel during management of the accident in this scenario. The improvements relating to the SRVs proposed by the licensee are considered appropriate.

In relation to the control of hydrogen in containment, the measures to install passive autocatalytic recombiners in those areas of the containment that might pose a risk of hydrogen accumulation and to provide electrical feed to the igniters in the event of prolonged SBO are considered positive.

As regards the current dedicated containment venting arrangement, the improvements proposed by the licensee are considered positive (measures to increase the robustness of actuation of the venting and design modification relating to changing the elevation of the vent suction, for which consideration should be given to the difference in pressures that might exist between the containment and the drywell and the corresponding difference in water level between the two during the containment flooding phase). This modification will be carried out prior to the end of the 2013 refuelling outage, as established by requirements issued previously by the CSN.

Among the improvement measures, the plant plans to perform an additional analysis to assess the advisability of installing a filtered containment venting system, and would consider its subsequent installation depending on the results obtained.

The CSN considers that, in addition to the filtering capacity provided by the suppression pool during a severe accident, the existence of a complementary containment filtering capacity (independent from the suppression pool) oriented towards the ultimate protection of the containment and the minimisation of radioactivity releases in the event of a severe accident, is a highly positive measure for the optimised management of this type of accidents, for which reason the licensee should perform this analysis and submit it to the CSN for approval before June 30th 2012.

As regards prevention of foundation slab penetration, it is considered that the strategies already defined, along with the future design change of the elevation of the dedicated containment venting system, should allow for better management of the containment flooding strategy and, therefore, for prevention of foundation slab penetration.

In relation to the availability of instrumentation, the licensee plans to develop a procedure for the reading of critical plant parameters in the event of complete loss of power. This improvement is considered positive. In implementing this improvement the licensee should take into account the critical parameters throughout all the phases of the accident (including severe accidents), considering the possible design modifications that might be required.

As regards the potential accumulation of hydrogen in other buildings outside containment, the calculation described by the licensee in his report is considered to be an acceptable method as an initial approach to the problem; however, the licensee should analyse in greater depth the possible paths for hydrogen leakage (venting, failure of the venting lines, leakage across high pressure penetrations inside containment), taking into account the high pressures in the containment and the dynamics of propagation to the different rooms of the buildings affected, including their geometry, in order to estimate possible local concentrations that, despite their being short-lived, might lead to hazardous concentrations being exceeded.

The improvement measure proposed in relation to the electrical feed for the control room filtering and air-conditioning system is considered positive, since it brings an additional strength to the plant in response to complete loss of power.

As regards the analysis performed by the licensee for other operating modes, this is considered adequate in relation to the strategies already available in the EOPs and shutdown contingencies. Although many of these strategies are those that would be attempted in a severe accident, the analysis is considered to be incomplete since it does not contemplate all the characteristics associated with a severe accident (for example the phenomenology relating to hydrogen or the availability of instrumentation during severe accident sequences). Consequently, it is considered that the licensee should extend his analyses of the management of severe accidents occurring from shutdown operation conditions.

In addition, it is considered that the licensee should incorporate on his list of improvements the analysis of the following issues (the conclusions of which might lead to design modifications in the plant procedures):

- Capacity of the instrumentation associated with parameters critical for the severe accident strategies to provide reliable information under severe accident conditions in containment (for example, containment pressure, RCS pressure or hydrogen concentration in containment).
- Leaktightness capacity of the containment isolation valves and penetrations under severe accident pressure, temperature and radiation conditions. It is considered that the Cofrentes plant should analyse this issue in order to obtain an estimate of leakage and, where appropriate, identify and implement potential improvements.

As regards the feasibility of the manual actions proposed, through the use of portable equipment, the results of the specific analysis of personnel availability required in section 4.1.c of this report are applicable.

- **Loss of fuel pool inventory and/or cooling**

- *Licensee's position*

The basis method for the cooling of the irradiated fuel assemblies consists of forced circulation of the pool water via heat exchangers, which may be cooled by various systems, and maintenance of seven metres of water above these assemblies, with monitoring of the temperature of the water. The systems used in cooling may be the following:

- Fuel pool cooling and clean-up system
- Residual heat removal system, RHR
- Essential service water system
- Condensate distribution system

The following are contemplated as additional alternative cooling systems:

- Demineralised water distribution system, via service connections available in the pool areas.
- Fire protection system (FPS) by means of connections and hoses for make-up and/or spraying from the fire hydrants in the fuel pool area.
- Portable fire protection equipment via the access gate from the exterior to the Fuel Building.

If it were not possible to maintain the seven metres of water above the racks, the fuel building ventilation system would be isolated, the stand-by gas treatment system (safeguards system equipped with high efficiency filters) would be started up and the pool would be sprayed in order to minimise the impact of iodines.

If the water level in the fuel pool continued to decrease and approached the racks, the supply of a solution of pentaborate would be initiated by means of hoses from the stand-by liquid control system (SBLC) make-up tank, which would constitute a preventive measure to address potential criticalities.

The failure of the spent fuel pool cooling system is dealt with via an operating procedure that identifies management measures from the initial phase of the accident. The plant has updated this procedure, improving and extending the accident management measures to the beginning of exposure of the racks. This change has been performed recently through the application of a proposal by the BWROG.

In addition, the application of strategies for the distribution of the assemblies stored in the spent fuel pools implies achieving a storage configuration such that, in the event of a loss of storage pool cooling accident, the time to boiling of the water contained in the pools, and therefore to exposure of the fuel assemblies, is delayed as long as possible.

The licensee includes in his report calculations of the time available before boiling occurs and different water levels are reached (to fuel assemblies uncover) in the event of complete loss of cooling and for different thermal loads in the SFP. The most unfavourable case is the beginning of refuelling (all assemblies in the SFP); in this case times of 9.10 hours to boiling and 80.64 hours to fuel uncoverare obtained. In the case of the thermal load corresponding to the end of a typical refuelling outage, the time to boiling would be 29.12 hours and the time taken for the level to reach the upper part of the fuel assemblies would be 256.43 hours.

As regards the possible accidental draining of the SFP, the following measures are available:

- The inflatable joints and pneumatic system (tubing and check valves) have an HCLPF seismic capacity of 0.3g.
- The piping of the suction and return cooling system has an HCLPF seismic capacity of 0.3g. The return piping to the fuel is protected against the siphon effect that might drain the pool in the event of pipe break by means of redundant vacuum breakers at the highest points of this piping.

Cofrentes proposes the following measures to increase the robustness of the plant:

- Acquisition of a compressor for the supply of air to the inflatable seals of the spent fuel pools.
- Increased robustness of the spent fuel pool level, temperature and radiation instrumentation.
- Implementation of a system allowing for the spraying of water over the SFPs in the event of total loss of shielding.
- Development of a procedure for the distribution of the fuel assemblies in the spent fuel pools, such that the thermal load in the different areas of the pool is balanced.

- *CSN evaluation*

The licensee includes information on the design basis of the SFPs and associated cooling systems. These aspects have been evaluated and licensed in previous stages of the plant. In addition, the equipment and related procedures have been inspected by the CSN on numerous occasions.

The licensee describes the measures currently in place to address loss of SFP cooling scenarios. The current alternatives for cooling and water make-up to the SFP would not be available in the event of SBO, with the exception of the fire protection system, which is equipped with a diesel pump (non-seismic). The design modification carried out in the essential service water system will provide an additional source in the short term that will allow water to be supplied to the vessel, cooling of the diesel generators or the injection of water to the spent fuel pools.

As regards critical times, the licensee has not taken into account the decrease in level due to sloshing (20 cm for an earthquake of 0.3 g). Considering this loss of cooling, the times to boiling and exposure of the fuel would be shorter. Given that this loss of level amounts to around 1.5% of the total pool height, the effect is considered to insignificant.

Among the improvements mentioned by the licensee in his report is the provision of an alternative means to maintain the leaktightness of the SFP gates, an improvement that is considered positive since it would reduce the probability of pool drainage. The rest of the measures proposed are also considered to be positive.

- **Radiological protection issues**

- *Licensee's position*

The control room envelope at Cofrentes includes the Technical support Centre (TSC), and is equipped with an emergency filtering system that, in the event of a design basis accident, maintains habitability and ensures that the dose to the personnel operating in this area remains below the permissible limits. These centres are equipped with a suitable number of personal protection systems for the personnel working in the area.

The licensee has estimated the dose that would be received by the personnel in the control room envelope in the event of a severe accident scenario with prolonged loss of power and requiring the operation of the currently available containment venting system. The study concludes that it would not be necessary to evacuate the control room for radiological reasons if emergency filtering for the room were available prior to venting.

Consequently, as an additional measure to improve the robustness of the plant, the licensee plans to make available an electricity-generating group to maintain the pressurisation of the control room in the event of a prolonged SBO.

As regards the radiological conditions in other emergency support centres, the Cofrentes plant claims that the safest areas could be detected and potential routes and areas for meeting and preparation of recovery tasks established, in addition to the TSC, by means of the area radiation monitors and processes of the radiological surveillance system. The licensee proposes to construct an Emergency Response Centre (ERC) on the site, which coincides in all respects with the AEMC planned by the rest of the licensees, to be available by 2015, with the possibility of radiologically controlling the workers and the alternative capacity to house emergency centres. The proposal will be jointly addressed by all the plants.

As regards the means available for the monitoring and control of radioactive emissions in the event of an accident, Cofrentes has a radiation monitoring system that includes post-accident sampling and monitors, the emergency radiological surveillance plan (PVRE) and procedures to determine the activity released.

The licensee also has personal protection resources, dosimeters and portable equipment for the radiological control of the workers and levels of radiation and contamination, and details additional needs in detail.

The plant is undertaking an exhaustive analysis of the communications systems, including those used by the PVRE, with a view to ensuring their availability in the scenarios postulated in the present stress tests.

In addition, an analysis will be undertaken, along with the rest of the licensees, of possible additional equipment and improvements to the current radiological protection resources in order to bring them into line with the conditions potentially existing in the scenarios analysed. This analysis is scheduled to be completed in June 2012, as from when the improvements identified will needs to be implemented.

The licensee refers to the different strategies to address a severe accident without mentioning whether the actuations and alignments required imply local manual actuations and without referring to whether or not the radiological conditions would prevent their performance.

As regards accidents involving loss of spent pool cooling, this plant establishes that in the most unfavourable situation (unloading of the complete core between days 2 and 8 of a refuelling outage), more than three days would be available before exposure of the fuel assemblies occurred, sufficient time for the initiation of measures aimed at recovering the cooling. Cofrentes has reviewed the fuel pool cooling failure procedure that contemplates the manual actuation of valves and prompt manual preparation of the equipment and hoses of the alternative systems, prior to reaching values requiring evacuation as a result of radiation in the building, which are identified as ¾ of the initial water layer. Access would be prohibited when the water level is below 600cm (dose rate higher than 100 mSv/h). The plant has a low radiation area behind the structural wall of the pools in which the dose rates would be lower than 25 microSv/h, even if the fuel assemblies were uncovered.

- *CSN evaluation*

The current design of the control room envelope at the Cofrentes plant had been previously evaluated and accepted by the CSN and guarantees that the exposure of the personnel working in this area to radiation during any design basis accident would not exceed the limits set out in the NRC's 10 CFR 50.67.

As regards the habitability of the control room in the event of a severe accident, the CSN positively values the licensee's improvement proposal consisting of the acquisition, in the short term, of an electricity-generating group providing the feed required in the event of a prolonged SBO to ensure an exterior air filtering unit and a conditioning unit to maintain control room overpressure and prevent the infiltration of non-filtered air.

The CSN values positively the proposal by the licensees to construct an AEMC (called ERC in the Cofrentes case). The generic conclusion indicated in section 4.1.c is applicable in this respect.

As regards the measures available for the monitoring and control of radioactive emissions, it is considered advisable for the Cofrentes plant to implement a continuous surveillance network in the medium term, with the automatic reception of data in the control room, the TSC and the CSN emergency response room.

The CSN positively values the analysis that the plant are going to undertake jointly regarding the radiological protection resources and equipment that it would be advisable to have available for the scenarios analysed. In the case of Cofrentes, the analysis should contemplate at least the availability of radiation monitors and the post-accident sampling system in prolonged SBO scenarios and their correct operation under severe accident conditions. The conclusion indicated in section 4.1.c is also applicable here.

The plant should undertake a study of the analysis of those radiological conditions that might prevent the performance of local manual actions for both the cases contemplated in the SAMGs and the new recovery actions by means of portable resources and sampling activities. Section 4.1.c includes general conclusions in this respect. The CSN will require the development of actuation guidelines for each of the SAMGs with the radiological protection issues to be taken into account depending on foreseeable doses.

The input data used by the licensee to calculate dose rates depending on the level of water in the pool are considered to be adequate; nevertheless, the calculation code used should be more precise. The licensee will be requested to incorporate in procedures the radiological protection aspects to be considered in whatever local manual actions are foreseen. Section 4.1.c includes general conclusions in this respect.

4.2.4 Ascó Nuclear Power Plant

4.2.4.a Extreme natural events

- **Earthquakes**

- *Licensee's position*

The seismic design of both units at Ascó NPP is based on a safe shutdown earthquake (DBE or SSE) with a maximum horizontal acceleration at the surface of the terrain of 0.13g, obtained using a deterministic methodology. Also considered in both units is another lower level of demand corresponding to the operating basis earthquake (OBE), the maximum horizontal acceleration of which is 0.07g. The basic process used to establish the DBE has been to assess the maximum historic earthquake impacting the site and then increasing it by a margin estimated to define the maximum possible seismic intensity and corresponding local acceleration of the terrain.

In order to determine the current validity of the DBE earthquake over time, from the point of view of seismicity, the earthquakes occurring within 300 km of the site from 1978, the cut-off date in the catalogue originally used, to May 17th 2011 were obtained using the catalogue of the Instituto Geográfico Nacional (IGN). The resulting conclusion is that no earthquake has occurred within that radius and during the period considered that has exceeded the maximum seismicity associated with the seismogenic areas considered in obtaining the DBE, as a result of which the seismic design basis initially considered continues to be valid.

The protection of the plant against the DBE is based on the seismic Systems, Structures and Components (SSCs) design requirements, in accordance with the classification included in the ANSI-N 18.2-1.973 standard, and with what is stipulated in NRC regulatory guide RG 1.29. Also contributing to the protection of the plant are the maintenance practices applied for the seismic qualification and correct status of the SSCs, through the processes established in the licensing basis, as well as for the corresponding modifications and spares.

The plant is equipped with a specific instrumentation system for the detection of earthquakes, common to both units, that meets the requirements of NRC RG 1.12. The system consists of six triaxial accelerometers, one located in the free field and the others at different elevations in the containment and control buildings. Registration is activated when any of these accelerometers detects an acceleration in excess of 0.015g. This seismic surveillance system generates diagnostic alarms and a specific alarm indicating that the OBE has been exceeded, with signals sent to the control rooms of both units. In the event of an earthquake beyond the OBE being detected, the plant On-Site Emergency Response Plan (ERP) is activated and as series of activities are initiated, such as analysis of the records of the seismic instrumentation, the declaration of an emergency and the execution of the plant equipment inspection procedures, all of this oriented towards verifying the availability of the equipment required to take the plant to safe shutdown, guaranteeing the functions of reactivity control, the control of primary pressure, the control or primary inventory and the heat removal capacity.

The licensee assesses the seismic margin of the plants using the work already performed for the seismic IPEEE by means of the methodology developed by the NRC and EPRI (0.3g review earthquake - full scope), complemented, within the context of the stress tests, with the performance of new inspections and the extension of the original scope to consider the confinement function in relation to the spent fuel in the pool (SFP) and also certain SSCs used to address SBO and severe accident management situations.

Since the first analyses of margins were performed in 1998, the appropriate corrective actions have been carried out, allowing a seismic result to be obtained for Ascó nuclear power plant with an HCLPF value of 0.3g for structures and components allowing the safe shutdown of the plants to be achieved. In the latest review of the seismic IPEEE, in October 2010, the implementation of the corrective actions previously proposed has been verified and it has been confirmed that the seismic margin has not been altered with the design modifications introduced during plant operation.

A seismic margin of 0.3g is also assigned for the integrity and function of containment isolation, this being determined by the capacity of the isolation valves as the components with the smallest margin with respect to earthquakes. As regards the seismic margin for fuel confinement integrity, an HCLPF capacity of 0.3g for the spent fuel pool and its liner, this also being the case for the gates and spent fuel racks, although the results of a specific on-going analysis of the effects of the racks sliding on the liner and possible interactions between them as a result of an earthquake remain to be confirmed.

The spent fuel pool cooling system at the plant is Safety Class 3 and Seismic Category I, this implying that the design provides guarantees as regards its capacity to withstand the DBE. Nevertheless, in the context of the stress tests, and as this system is not included within the scope of the original IPEEEs, it has been subjected to a new analysis and a specific inspection walkdown in order to be able to assign to it an HCPLF value of de 0.3g; although the analysis of the anchor bolts of certain items of equipment to determine whether any improvements are required is still to be completed.

Three alternative methods have been used to analyse the possibility of a loss of inventory from both the spent fuel pools and engineered safeguards reservoir, and its consequences, in response to a seismic event of 0.3 g. It has been concluded that in all cases the loss of inventory would be irrelevant and that there would be no significant impact on safety-related components.

Also performed has been an evaluation of the potential effect of upheaval of the terrain on the increased seismic capacity of the plant (0.3g), the conclusion being that such an event would not reduce this seismic margin as long as the limits established in the plant Surveillance Manual were fulfilled, this having been practically applied since the start-up of Ascó II.

The licensee has analysed the capacity to withstand beyond DBE earthquakes of two major dams, Mequinenza and Ribarroja, located on the river Ebro upstream of the site. In the first stage of analysis it has been determined that both dams are capable of withstanding the DBE for the Ascó site (0.13g). The seismic capacity of each dam was then calculated and the margin above the DBE determined; the capacity of the Mequinenza dam corresponds to an earthquake of 0.175g and that of the Ribarroja dam to an earthquake of 0.144g. Finally, consideration was given to the hypothesis of chain rupturing of the upstream dams, with analysis of the flood that would occur and of the maximum flood level at the site; it was concluded that this level would correspond to elevation 45.45 m, below the elevation of plant grading level and not, therefore, affecting any safety-related SSCs.

Compliance with the current licensing basis of the plants in relation to seismic behaviour is guaranteed through the periodic application of procedures, surveillance requirements and actuations aimed at suitably maintaining the SSCs and the seismic surveillance system.

In order to increase the seismic robustness of the plant, and pending conclusion of the specific analyses referred to above, the licensee proposes to analyse the seismic vulnerability of the SBO equipment and the most relevant items of equipment involved in the Severe Accident Management Guidelines (SAMG) not contemplated in the current IPEEE, in order to determine suitable actions guaranteeing a seismic margin of at least 0.3g in all the necessary SSCs.

As regards the possibility of there being induced effects as a result of an earthquake, the licensee indicates the following:

- Fires and explosions: the plant identifies its design basis and points out that compliance with it, along with the protections and extinguishing measures, provides barriers for the control of fire events on the site. As an additional measure against events of seismic origin the licensee has drawn up an inventory of inflammable or explosive products in storage and plans to perform an analysis of these SSCs from a seismic perspective.
- Internal flooding: the plant indicates that a PSA of on-site floods is available, identifying those pipes that might be the origin of flooding, and during IPEEE analysis the condition of piping in areas housing safe shutdown equipment is verified. The licensee proposes a new scope of inspection from the point of view of seismic margins, including non-seismically qualified pipes susceptible to causing an initiating event and the loss of mitigation systems, selecting those that may affect safety-related equipment.

Effects on nearby industry: The potential effects of seismic action on nearby industries had already been analysed prior to these stress tests, in the context of the IPEEE studies for other external events; the only relevant facility is the Erkimia Electrochemical Plant, located in Flix at a distance of some 4 km from the plant. Consideration was given in the study to the risk deriving from an explosion and it was concluded that explosions at this plant could be ruled out as a source of risk for Ascó NPP. As regards the risk of toxic releases, it was determined that under the most unfavourable meteorological conditions chlorine would not reach the toxicity limit for the operators, even without the isolation of the control room; nevertheless, in the case of chlorine control room isolation occurs the operating personnel is required to use the autonomous breathing equipment in place.

- *CSN evaluation*

The seismic design basis for both plant units is the same as that licensed for the original design. Its acceptability with respect to the requirements established by the CSN over time has been checked as part of the seismic evaluation processes carried out prior to granting of the successive operating permits, by means of specific analyses performed within the framework of the periodic safety reviews and also through the different inspections performed as part of the CSN supervision and control processes.

The seismic surveillance system that had been implemented prior to the stress tests was reviewed by the CSN and found to be acceptable. The operating technical specifications of each plant include a limiting condition on operation for the event of the OBE being exceeded, with the corresponding actions, surveillance requirements and actuation procedures.

The HCLPF values estimated by the licensee are considered to be justified in accordance with the EPRI seismic margins methodology, although the value of 0.3g assigned to the irradiated fuel racks is currently under review by the CSN. Also pending verification are the analyses of certain anchoring devices and possible corrective actions that the licensee might propose to increase the HCLPF value in the event of equipment being identified with a margin of less than 0.3g in the studies proposed to increase the seismic robustness of the plant.

No limit situations are identified in the performance of the plant in response to earthquakes. As the seismic margin resulting from the analyses coincides with the review earthquake value adopted, the analysis methodology does not allow a larger margin to be quantified. If other review methods were applied, a seismic margin of more than 0.3g might be obtained.

As regards earthquakes exceeding the DBE and the floods that they may cause, the licensee has calculated the seismic capacity of the two dams located upstream whose rupturing might have an impact on the site. The reports submitted indicate that both dams withstand the design basis earthquake of the plant and have a certain margin with respect to it (the seismic capacity of the Mequinenza dam is 1.20 times the DBE and that of the Ribarroja dam is 1.08 times this value). Furthermore, the licensee has analysed the hypothesis of the successive rupturing of the upstream dams, obtaining a maximum level of flooding on the site below the elevation of the plant grading level. Although the analyses provided are considered to be valid as regards the justified estimate of margins beyond the design basis, and although the occurrence of the events implied in the hypothesis is considered to be highly improbable, the scenarios proposed differ from those contemplated in the emergency plans of dams in Spanish practice. Consequently, the CSN considers that the actions required to bring both approaches into line should be undertaken, the licensee then revising his analyses and adopting the measures deriving therefrom.

It is considered that the actuations proposed are effective as regards improving the robustness of the plant in response to beyond the design basis earthquakes. Certain additional measures might be advisable on conclusion of the analyses currently being undertaken by the licensee.

As regards the possibility of there being induced effects as a result of an earthquake, and in addition to the generic conclusions set out in section 4.1.a, the following conclusions are drawn:

- Fires and explosions: the CSN evaluation considers the scope of the analyses performed to be adequate as regards both the identification of possible sources of explosions or fires and the action proposed.
- Internal flooding: the CSN evaluation considers that the scope of the analysis planned by the licensee should be extended to include non-seismically qualified piping whose rupturing might cause an initiating event and the loss of mitigation systems in scenarios not covered by the analyses performed to date. Furthermore, the Ascó plant should perform an analysis to determine whether there are effects due to floods caused by other major sources of water capable of causing flooding and, in this case, the barriers available with respect to them .

Effects on nearby industries: the CSN evaluation considers that the analyses performed by Ascó within the framework of compliance with the IPEEE analyses and their conclusions are acceptable as regards the evaluations included in this report.

- **Flooding**

- *Licensee's position*

The external events considered in the design of Ascó nuclear power plant and capable of causing flooding on the site are as follows: maximum probable flood (MPF) in the river Ebro and in streams and gullies, intense local rainfall, rising of groundwater levels and seismically induced rupturing of upstream dams.

The elevation of the plant grading level from which access is gained to the safety-related SSCs is 50.0 m, around 20 m above the normal level of the river Ebro. There are no safety-related systems at the intake structure.

The results of the flooding analyses contemplated in the design basis, and included in the plant Safety Analysis Report, indicate that in the most unfavourable of the hypotheses analysed the water would reach a level of 47.7 m, which is the highest reached by the river Ebro as a result of any of the flood hypotheses and the value adopted as the Design Basis Flooding Level.

The most limiting flooding event is the successive rupturing of the dams located on the river Ebro upstream of the site. This event has already been analysed in the previous section from the point of view of rupturing caused by earthquakes. The licensee has undertaken additional analyses of dam rupturing as a result of both earthquakes and flooding and concludes that the maximum level that would be reached on the site would be 48.11 m, with a margin of almost 2 metres with respect to the plant grading level elevation.

As is established in the plant Safety Analysis Report, the maximum probable flood has been calculated on the basis of the maximum flows recorded in the river Ebro between 1903 and 1997, considering a maximum return period of 1,000 years. In the updates of the MPF the concept of Maximum Probable Precipitation (MPP) has been used, in both the statistical and the hydrometeorological sense. This same concept has been applied to calculate the MPF associated with streams and gullies, a return period of 1000 years also being adopted in this case.

In order to avoid flooding by groundwaters as a result of seepage from the river Ebro, the plant is equipped with an impermeable screen that surrounds the site and extends from the impermeable zone to elevation 46.0 m. It also has a deep drainage network around each unit and superficial drainage networks and weatherproofing to protect the site. These design characteristics make it possible to maintain the level of the water table at around elevation 32.0 m, such that the safety-related structures are not affected. Likewise, within the framework of the Ground Movement Surveillance Programme there is a Hydrology Manual to facilitate the rigorous control of the evolution of the water table, the fluctuations of which are normally phenomena of very gradual evolution.

In addition to the physical barriers and characteristics of the site that constitute the basis for protection against flooding, a series of maintenance, inspection and testing activities are carried out at the plant to guarantee that the condition of these barriers and characteristics is kept as expected. There are actuation procedures for the different activities. Furthermore, the IPEEE is periodically reviewed to update the values of the MPP in accordance with the latest data available and the removal capacity of the drainage systems is reviewed.

Furthermore, the plant On-Site Emergency Response Plan (ERP) is activated in the event of rainfall of severe intensity, as measured by the site meteorological station, this implying the execution of the already established procedures.

No limit situations identified with the phenomenon of rainfall have been identified at the site of Ascó nuclear power plant. Nevertheless, the 400kV switchyard is located at elevation 38; consequently a reasonable hypothesis is that if this elevation were exceeded, all the feeds provided by this switchyard would be left out of service, causing the plant to trip and quite probably leading to a complete loss of off-site power. The plants are designed for this event.

The licensee points out that the following actions are currently being performed with a view to increasing the robustness of the plant with respect to external floodings:

- Detailed analysis of the channelling of gullies coming together in the ARMCO pipe and of the site drainage network, in order to determine potential improvement actions.

– Review of trench seals in order to provide them with an adequate hydrostatic resistance, exceeding even the elevation of the site and guaranteeing watertightness.
– Inspection of drains in the Diesel and Auxiliary Feedwater buildings and connecting to the rainwater network. This inspection has been already completed with no vulnerabilities detected, for which reason no additional actuations are foreseen.

- *CSN evaluation*

The information provided by the licensee on the design bases relating to events potentially leading to external floods is included in the plant's Safety Analysis Report and complementary documents. The data and analyses have been updated subsequent to the initial plant license and have been evaluated and inspected by the CSN within the framework of the habitual supervision and control processes.

The set of design bases described is considered reasonable, in accordance with the applicable standards requirements, and adequate for the characteristics of the site.

As regards consideration of the rupturing of upstream dams, this has been addressed in the previous section and assessment conclusions have been issued.

The measures proposed to increase the robustness of the facility in response to flooding are considered to be adequate, although they refer basically to on-going studies to determine potential improvement actions. The conservation of the margins already justified will determine the advisability or otherwise of adopting additional measures.

- **Other extreme natural events**

- *Licensee's position*

In addition to the events analysed in the previous sections, the licensee includes here analyses of the following events: extreme winds, forest fires, electrical storms, snow, drought and upheaval of the terrain.

The conclusion drawn is that, given the current situation as regards the conditions of the site and the results of the analyses, as well as the on-going measures adopted, none of the events analysed here implies any risk for the plant.

The only natural event that has passed the screening process, after ruling out those whose impacts were negligible, is strong winds, the design basis for which is 144 km/h. In the analysis performed with respect to outdoor safety-related structures and tanks, the licensee concludes that a safety margin of more than 2.6 times the design wind speed is available.

The licensee points out that the analyses relating to hail and extreme temperatures are still being performed, as a result of which no conclusions are provided in this respect.

- *CSN evaluation*

The screening of off-site events performed to establish the design basis is based on a very low probability of occurrence (10^{-5}), in accordance with the probabilistic methodologies included in the applicable IPEEE standards.

The licensee has extended the scope of the analyses performed with respect to those documented in the progress report, evaluating the extreme events credible at the site and complementary to those dealt with in previous sections. The conclusions drawn as regards design requirements and the estimation of margins are considered acceptable in the case of the events analysed by the licensee.

However, the analyses of two events: hail and extreme temperatures, remain to be completed by the licensee, as a result of which the CSN evaluation cannot value their results.

The licensee has procedures for action in the event of severe meteorological conditions on the site, which have been inspected within the framework of the CSN's supervision and control programmes.

The CSN evaluation of this section will be completed when the licensee finishes his studies.

4.2.4.b Loss of safety functions

- **Loss of off-site power (LOOP)**

- *Licensee's position*

Ascó nuclear power plant describes the interconnections with the grid and the available off-site electrical connections and concludes that the off-site power sources are extremely robust and reliable and that they instil confidence in the plant's capacity to quickly re-establish a loss of the exterior grid.

The plant makes reference to the electrical grid operator's procedures for restoring voltage in the event of zero power in the grid that gives priority to the supply of the nuclear power plants. For this plant, the preferred mode planned is to supply the plant using the "island" configuration provided by the nearby Ribarroja hydroelectric power station, which can be operated using three modes (automatic, remote control and manual), with these modes being periodically tested.

In each of the units, the internal electricity supply for the safety systems is constituted by the emergency diesel generators (EDGs), batteries and chargers of the direct current system and the inverters for vital bus bars and of 1E-class instrumentation. There is also an additional alternative diesel generator (DG-3), which serves both units and is described in the SBO section.

In the event of LOOP, the safety systems are supplied via the start-up, connection and automatic loading sequence of the two EDGs, which are Class 1E and Seismic Category I; the diesel generators of each unit are housed in separate rooms of the Diesel Building.

The autonomy of the EDGs operating at 100% load is longer than seven days, bearing fuel, lubrication and cooling in mind, meaning that the plant can withstand more than seven days of a LOOP situation without any means of additional support. The EDGs are cooled by the safeguards cooling system, while the EDG uses the dry coolers.

With respect to the supply of auxiliary feedwater, the licensee concludes that this is also guaranteed for longer than seven days by the quantity of water held in the condenser tank and the safeguards cooling system reservoir.

The plant includes a loss of safety functions analysis with respect to all of its operating modes that encompasses the primary and containment operative status by describing the operational development of the response mechanisms and strategies.

- *CSN evaluation*

The LOOP forms an integral part of the design basis of the plant, which can withstand at least seven days and, therefore, has been evaluated and licensed during previous phases of the life of the plant, and the various aspects thereof have been inspected by the CSN.

The descriptions provided by the licensee are deemed correct. The off-site power supplies reach the plant from different sources via different routes and this independence makes the supply reliable should events such as that being analysed here (LOOP) occur. The safeguards busses are permanently supplied by the preferential off-site power supply, meaning that in the event of a plant trip transfer is not necessary. The grid operator has zonal recovery procedures taking the preferential supply of the nuclear power plants into account. The running of periodic off-site power recovery tests from the Ribarroja hydroelectric station, proposed by the licensee, increases the reliability of the external supply from this source.

The plant runs a diesel generator availability and reliability maintenance programme that is managed within the Maintenance Rule.

In the event of incidents in other operating modes, and as a measure to increase coping times, it has been planned that the refuelling water storage tank (RWST) can be refilled from alternative water sources using mobile pumping equipment.

The CSN evaluation considers that the expected response of the plant in the event of LOOP is safe and as planned, and that it can withstand this scenario without having to resort to any additional support aids for over seven days in light of the autonomy of the EDGs and the reserve of water for feeding the steam generators.

- **Station blackout (SBO)**

- *Licensee's position*

The analysis carried out by the licensee shows that, as a result of the regulatory requirement associated with the Station Blackout (SBO) Rule, there is an additional alternative diesel generator (DG-3), serving both units, capable of supplying the loads necessary for this scenario (of one of the two units). DG-3 has its own support systems, does not depend on the ultimate heat sink for cooling, and is housed in an independent building. DG-3 and its building are not Seismic Category I (not required by the SBO regulations), and there is an on-going analysis to identify vulnerabilities and provide them with greater seismic capacity.

The plant has reanalysed the autonomy of DG-3 and indicated the measures for extending it to seven days and provide the generator with the capacity to connect it to both units simultaneously. The result is that the power is sufficient for connection of the minimum loads required by the two units and the alternated connection of additional loads (safeguards services water pump, component cooling water pump, pool cooling, and venting). In order to increase the autonomy, all that is needed are the actions that are already on-going.

The plant has available calculations for charting temperature development in rooms in the event of a loss of venting for 24 hours, without considering passive mitigation measures. The conclusion is that the results show that temperatures do not reach equipment danger limits.

In this scenario the plant is capable of withstanding this situation, without any additional support, for longer than seven days.

The plant is capable of responding in cases of events that may occur in other operating modes that involve less limiting plant safety response demands, although the plant does mention having a mobile pump for refilling of the RWST as a backup.

In the event of loss of all the normal power supply sources and the additional back-up source (DG-3), only the batteries would be left as an electricity supply source.

Each unit is equipped with 3 Class 1E batteries (one for each train and the third for the control of the AFWTP) designed to function in the scenarios analysed, which are capable of supplying the associated required loads for at least two hours.

The autonomy of the batteries has been reanalysed and the results have shown autonomies of longer than 24 hours. This autonomy is mainly the result of the large margin of capacity available, the consideration of the current loads, consideration of more realistic consumptions, and a new strategy of selective non-essential loads disconnection, within the period of one hour.

Likewise, for this case of the additional loss of DG-3, the licensee has also analysed the response in operating modes other than power operation.

The conclusion is that, for certain situations, if improvement actions are not incorporated, it would not be possible to maintain the primary inventory in the long term due to the leaks across the seals of the primary coolant pumps.

The licensee includes the times after which limiting situations would occur: depletion of batteries (24 hours), drying out of steam generators (30.6 hours), core uncover (31.4 hours), vessel failure (34.3 hours) and containment failure (more than three days), in the event of corrective actions not being taken in the aforementioned situations. Bearing these analyses in mind, the licensee is proposing the acquisition of portable equipment for generating electrical power to increase the autonomy of the batteries to over 72 hours and supply to other loads, implement a steam generator alternative feeding strategy and make the alternative injection of the primary possible at high and low pressure.

For the vessel and containment failure measures, the plant refers to the severe sccidents section.

Faced with a situation involving not only the loss of the supply of the alternating current sources, but also that of the batteries, the licensee indicates that the possibility would remain of operating the AFWTP and operating the steam generator relief valves manually. As in the previous scenario, the development of the incident would be governed by the cooling and depressurisation capacity via the secondary and by the leak across the seals of the primary coolant pumps, with these leaks determining core exposure time, although the capability of removing residual heat via the secondary would be maintained.

The licensee points out the already proven capability of manually operating the AFWTP and also that of being able to depressurise the steam generators by manually activating the relief valves, as well as the running of periodic tests that ensure the reliability of this manoeuvre.

The licensee includes the times within which the limiting situations would occur (exposure of the core, vessel failure and containment) in this situation.

- *CSN evaluation*

The total loss of on-site and off-site alternating current (SBO) is an event that was included in the Licensing Basis following the publication of regulation 10CFR50.63, developed in Regulatory Guide 1.155. The SBO coping time at the Ascó plant is eight hours; the licensed situation is that of the LOOP and loss of the EDGs whilst still having the alternative diesel generator DG-3 available.

As a result of the above regulations, the aforementioned DG-3 was installed as an alternative alternating current supply source for SBO capable of supplying either of the two units and, consequently, capable of supplying the loads required to counteract a LOOP situation and loss of the EDGs, meaning that the 120 V direct and alternating current of train A would be available.

The CSN evaluation concludes that DG-3 is a strength because it is housed in a building separate from the EDGs, has different support systems and is air cooled. Moreover, there are no objections to the plan of the two units sharing the aforementioned DG-3 in the situation in question. During the CSN Inspection it was verified that the licensee is in possession of a power demand calculation with respect to the GD-3 in the event of a simultaneous connection to both units, which has given satisfactory results.

In order to increase the autonomy of DG-3 to seven days and have the capacity to supply the two units, minor design modifications and procedural modifications are necessary, and are considered adequate by the CSN evaluation.

With respect to maintaining the inventory function of the primary during an SBO situation, the hydrostatic test pump taking suction from the RWST allows the inventory lost across the seals of the Reactor Coolant Pumps (RCPs) to be replenished for longer than 10 days.

The low pressure alternative injection to the primary forecasts and the refilling of the RWST for identified events that may occur in other operating modes are adequate. It is also forecast that were the hydrostatic test pump not to be injecting to the seals it would be used for injecting into the primary.

In the event of the additional loss of the GD-3, the plant would tackle the situation with the help of the systems which, electrically speaking, only require a direct current supply (feeding the steam generators via the AFWTP and depressurisation of the steam generators by way of theirrelief valves). The plant has described the analyses carried out for this scenario, which the CSN considers to be adequate, and proposes improvement actions that provide additional robustness when combating these situations.

The general calculation approach, hypothesis and method aspects of the plant's battery autonomy calculations have been reviewed by the CSN and found to be satisfactory.

Once these measures have been implemented, the times in which the cliff-edge situations would occur will be determined by the autonomy of the planned portable equipment.

With respect to the loss of direct current scenario, the licensee has proved, during the 2011 refuelling shutdown of unit I, the capability of operating the AFWTP manually, and the plant plans to test it soon in unit II and repeat it periodically.

Subsequent to the issue of the preliminary report, an inspection was carried out at the plant regarding aspects that this report considered to be relevant.

Following the actions performed by the CSN, it is concluded that the plant proposals are acceptable.

- **Improvements proposed by Ascó nuclear power plant regarding loss of power**

With the purpose of improving the robustness of the plant with respect to this type of situations, the plant lists its projected improvements, which are summarised below:

- Provision of diesel generators for powering battery chargers, hydrostatic test pump and loads.
- Provision of motor-driven pumps for primary and steam generator injection and refilling of RWST.
- Preparation of procedures for performing planned manual operations using both plant and portable equipment.

- Periodic testing of the AFWTP turbine-driven pump; provision of portable equipment (instrumentation) to provide the information required for the manual operation of said pump.
- Introduction of a new type of seal on the primary cooling pumps (if it can finally be proved that it has been suitably developed and classified).
- Provision of the design modifications that may be required for the use of the mobile equipment; definition of the location of this equipment; and strengthening of lighting and communications by means of the new mobile generators.
- Completing the analysis of the seismicity response of DG-3.

The projected improvements proposed by the plant are deemed valid with respect to the current development phase, although the feasibility of using mobile equipment is subject to the results of the specific personnel availability analysis required in section 4.1.c of this report.

With the implementation of these measures the cliff-edge situation times would be increased and depend on the autonomy of the mobile equipment.

- **Loss of ultimate heat sink (UHS)**

- *Licensee's position*

The Ascó plant heat sink, which for the purposes of this report is called the primary heat sink, is the River Ebro. From here several pump systems provide cooling water for the removal of all the thermal loads during normal operation. These systems are designed to function in all of the plant operating modes except in emergencies, although they could perform their function of cooling the components in the event of conventional electrical power being available. They have redundancies in all the active equipment, such as the component and service cooling water pumps, the component heat exchangers, as well as the rest of the associated elements, meaning the systems can continue to operate if one piece of equipment fails. This is achieved by activating the train that is in stand-by. All the equipment in question is designed in accordance with Seismic Category II.

The component cooler heat exchangers and the component cooling water system cooling pumps (system 42) are located 50 metres above the flood level calculated for the River Ebro. The component services water system pumps (system 41) are located 32 metres above the flood level.

The plant also has an ultimate heat sink (UHS), which consists of a pumping system, cooling towers (two per unit) and a water storage reservoir, common for both units, capable of providing cooling water for 30 days without external support. This UHS is Seismic Category I and Safety Class and is protected from any possible flooding of the River Ebro as all the related equipment is located on the 50-metre level of the site, approximately 18 metres above the normal level of the River Ebro. Moreover, the water source for this UHS, the safeguards reservoir, is a Seismic Category I designed structure located 106.80 metres above the normal level of the River Ebro and well above any possible flooding.

The engineered safeguards services water system (system 43) is supplied from the pools of the towers and consists of two entirely separate redundant trains each with 100% capacity, meaning that each of them will be capable of performing everything from normal shutdown of the unit, any operating mode including the loss of off-site power to cold shutdown. Its purpose is to transfer the thermal load extracted from the engineered safeguards cooling water system (system 44) to the atmosphere.

System 43 also supplies the flow necessary for cooling the circuits of the emergency diesel generator of each train, the discharges of which are also sent to the forced draught cooling tower.

The licenseeconsiders the existence of two heat sinks and their respective residual heat removal chains as strengths, as it does the existence of a safeguards reservoir which enables a guaranteed gravitational supply of water in any scenario without the need for any pumping element, both to the auxiliary feedwater system and the spent fuel pool.

The licensee has identified the presence of macrophyte blooms and algae in the River Ebro, which have over the years caused the occasional trip of the reactor of unit I and unit II, as a potential cause for the loss of the primary heat sink. Ascó nuclear power plant and the Ebro Water Authority (CHE) have initiated studies and implemented actions to determine the causes of the growth of macrophyte blooms and minimise their impact on the safe operation of the Plant. The ambient parameters that affect the development of macrophyte blooms are: the temperature of the river, its flow, conductivity, the pH and hardness of the water, nutrients and the level of oxygenation. As a result of the presence of biomass in the river, the mobile and fixed screens systems installed are effective at trapping quantities of biomass that are continuously entering the watercourse. At certain times huge interlinked masses of macrophytes (blankets) form that make these less effective. The CHE is proposing certain macrophyte control measures that are being put into practice by the plant, which include: visual control, sample taking and laboratory analysis, bathymetries of the river, removing macrophytes at the Flix Hydroelectric Station, surveillance and mechanical removal of macrophytes from the river, cyclical rises of water level, increasing the flow of the river twice a year and a study by the CHE into the possibility of including the harvesting of macrophyte blooms to counteract their increase. Other existing techniques, such as the use of biocides, cannot be implemented due to their potential impact on the flora and fauna of the river.

The licensee has analysed the impact of the loss of the different heat sinks both in normal operating conditions and in other plant's Technical Specifications operating modes, and two different status groups have been established to do this:

- Group 0: covers modes 1, 2, 3, 4 and 5 with the RCS closed and closed containment and inventory in the steam generators with replenishment capacity and release of steam into the atmosphere.
  - The loss of the primary heat sink, with availability of off-site electrical energy, is an initiating event that will cause the turbine and reactor to trip. Safety equipment (systems 43 and 44) will be available to deal with the situation.
  - In this situation, the plant considers that there are no limiting scenarios to be taken into account. To increase the robustness of the plant the licensee is performing actions such as continuing with its analysis for improving the way the inventory of the tanks is managed, whether these are in the Technical Specifications or not, in order to keep them, as far as possible, at their maximum working capacity in such a way as to increase the water reserves.
  - In the event of the ultimate heat sink being lost during normal plant operation, the Technical Specifications are applied and the plant must be taken to cold shutdown. As long as the off-site electricity supply, the AFW system and the primary heat sink are available, the equipment needed for shutdown can be kept in service and the cold shutdown situation can be achieved. This situation is unusual given that it depends on conventional systems (systems 41 and 42).
  - If the loss occurs from the mode 4 or 5 operational statuses, the RHR would already be connected and there would be no limitation.
  - The procedures used in this situation are those of a normal shutdown and the efforts must be channelled into recovering the UHS within the minimum possible time.
  - The Ascó plant does not identify cliff-edge situations in this scenario nor does it consider that additional actions are necessary to increase the robustness of the plant.

    - If the primary heat sink and the ultimate heat sink are simultaneously lost (both sinks are physically separated), the AFW system and the release of steam from the steam generators are available for the removal of residual heat from the core and the reduction of pressure in the primary. There is also the hydrostatic test pump for injection to the seals of the RCP's. The plant is capable of maintaining suitable conditions without any additional means of support for more than seven days in this situation.
- Group1: corresponds to mode 6 with the RCS open and containment closed.
    - In the event of the primary heat sink being lost, the replacement of inventory to the primary continues to be available due to injection capacity being maintained with the RHR being cooled by the UHS. Total drainage of the RWST would be a cliff-edge situation, with there being enough time either to begin refilling it or the alternative injection of the primary. There are enough water sources on the site to ensure more than seven days of supply. In order to strengthen the plant's capacity to respond to an event of this nature, reserves of boric acid and mobile pumping equipment will be available on site to implement the strategies of refilling the RWST or carrying out the alternative injection of the primary so as to guarantee the required concentration of boron.
    - In the event of the ultimate heat sink being lost, the replenishment of inventory to the primary is still available due to injection capacity being maintained with the RHR being cooled by the primary heat sink. The RHR pumps will be supplied from the RWST. The depletion of the RWST after approximately 8.5 hours would be a cliff-edge situation, with two additional hours being available for initiating the refilling of the tank, and for this reason the plant is developing a specific RWST refilling strategy that is seen as being a means of increasing the plant's capacity to respond to this event.
    - In the event of a simultaneous loss of the primary heat sink and of the ultimate heat sink, it will not be possible to run the emergency diesel generators as they depend on the UHS. The replenishment of inventory to the primary under gravity of the entire content of the RWST continues to be available as its lowest point is above the RCS. The subsequent replenishment, if necessary, can be carried out using either the future alternative mobile primary injection pump or the RWST refilling strategy, in which case reserves of boric acid will be available on-site to guarantee subcriticality. The motor-driven valves deployed along the injection route fail in position and they can be opened by flywheel if necessary. The cliff-edge situations and the actions for increasing the robustness of the plant are the same as those described in the two previous paragraphs.

- *CSN evaluation*

See the evaluation of the following section.

- **Loss of ultimate heat sink combined with SBO**

- *Licensee's position*

For this scenario, both in group 0 and group 1 situations, the operational development, the limiting situations and the actions proposed for improving the robustness of the plant are the same as those presented in the "Loss of Off-site Power (LOOP), of the normal backup sources and of the alternative diesel generator".

- *CSN evaluation*

In this section the loss of the UHS, with and without SBO, is evaluated.

The licensee has provided a suitable description of the existing provisions in the design for preventing the loss of the UHS and has analysed, with sufficient scope, the situation that would result from the loss of the UHS, with or without SBO.

The information regarding the UHS design basis had previously been evaluated and licensed by the CSN. Furthermore, the related equipment and procedures have been inspected by the CSN on numerous occasions.

In the event of loss of the UHS, with or without SBO, the licensee identifies and proposes improvements to upgrade the robustness of the plant. These measures are the same as those described in the loss of electrical power section given that the loss of the UHS would lead to a situation within the plant in which the same systems used for the loss of electrical power situation would be available to protect the safety functions.

The licensee has calculated the time it would take to deplete the water sources currently available for the AFW system (condensate tank and safeguards reservoir) and has found that time to be longer than seven days. The manual actuation manoeuvres with respect to the AFW turbine-driven pump (AFWTP) and steam generator relief valves have been successfully tested in unit II, and will be tested in unit I during the next refuelling outage.

The CSN evaluation considers the improvement proposals presented by the Ascó plant to be adequate.

In relation to the habitability of the AFWTP room, the licensee has presented a calculation for the sizing of the air inlet and outlet for natural venting in the event of SBO that shows that the temperatures inside the room would be 50 ºC. It is considered necessary that the licensee provides proof that the temperature inside the room will not reach values that prevent the AFWTP from being manually actuated in the event of prolonged SBO (24 hours).

4.2.4.c Accident management

- **Planning of accident management**

- *Licensee's position*

The licensee of Ascó NPP is planning to analyse the organisation and means available for managing emergencies, and to size the organisational changes in the medium-term. Furthermore, he is proposing to incorporate, sometime in 2012, an additional auxiliary operator on a single shift basis who will perform assistant supervisory duties and work for both units.

The licensee proposes specific improvements for strengthening the plant's communications capacity by expanding the so-called TETRA system, which will provide coverage for the entire site, and is proposing to install it in the short term for unit I and in the medium-term for unit II. The licensee is also planning to analyse, in the short term, additional means for increasing robustness in the communications area.

In line with the start-up of the new Alternative Emergency Management Centre (AEMC), Ascó NPP is planning another series of more significant communications improvements, the analysis of which will conclude in the short term, and proposes to install them in the long term.

As regards the plant's access routes, the licensee had provided information about the existence of a feasible access route to the site in the event of a major earthquake; this route is identified that coincides with the feasible route in the event of flooding of the River Ebro to an elevation not exceeding 48.11metres.

The licensee establishes new reference dose levels for the personnel involved in an emergency, indicating that these will be voluntary workers who have been briefed. These dose levels correspond with those established in ICRP-103.

- *CSN evaluation*

The licensee's proposal to analyse the organisation and means with respect to emergency management will require broadening the studies and adopting the resulting organisational solutions regarding events such as those proposed which could simultaneously affect both units. The proposal to contract the services of a new auxiliary operatorin 2012 is deemed adequate as a short-term action for strengthening the plant's capacity with respect to an emergency.

In the short term the licensee is planning to analyse additional means for strengthening the communications area, which is considered acceptable. The installation of the additional resources identified will have to be carried out in the medium term. With respect to the more significant improvements which will be associated with the start-up of the new AEMC, these are considered acceptable, although the licensee will have to study and notify the CSN of the incorporation of the provisional short and medium-term measures, which will ensure the availability of improved capacities, albeit partial, prior to the long-term implementation dates.

In relation to the site access routes, the analysis presented is deemed acceptable, although the licensee will have to analyse the time that the access route remains unusable due to flooding above the 48.11metre elevation and what compensatory measures are planned for this deadline.

As far as the reference dose levels for the personnel taking part in an emergency are concerned, and as has already been mentioned in section 4.1.c of this report, the CSN deems it necessary to establish standardised reference levels for all the Spanish nuclear power plants. However, the licensee will have to consider, in the short term, a framework that not only guarantees individual protection, but also the feasibility of tackling the emergency mitigation actions as stated in the TECDOC 953 and in the Basic Safety Standards (BSS) of the IAEA.

- **Measures for the management of accidents in the reactor**

- *Licensee's position*

Like all the other plants, the licensee describes the measures in place at equipment, procedure and personnel levels for preventing, mitigating and managing severe accidents. He also describes the use of the guidelines and procedures to be used in accordance with the deterioration of the conditions of the plant, bearing in mind the equipment currently available and the support systems necessary for its operation.

Furthermore, the Ascó plant is proposing a number of actions to strengthen the plant's response capacity with respect to severe accidents:

- In relation to the capacity of the equipment considered in the Severe Accident Management Guidelines (SAMGs) to withstand earthquakes, the plant indicates it is going to carry out an analysis to determine its seismic margins with the objective of reaching a value of 0.3g.
- In order to prevent damage to the core, the plant is proposing, as an additional measure, the implementation of measures that enable alternative injection into the steam generators and into the primary (acquisition of mobile equipment, making the design modifications necessary for the installation of connection points and developing guidelines and procedures). These measures are already described in the loss of safety functions section.

- To prevent damage to the core at high pressure, the plant is proposing, as an additional measure, the development of a strategy for the manual depressurisation of the steam generators (this measure is already described in the loss of safety functions section in combination with the manual control of the auxiliary feedwater turbine-driven pump).
- For the prevention of the risks derived from high concentrations of hydrogen, the Ascó plant indicates that it will be installing passive autocatalytic recombiners (PARs).
- Likewise, this plant proposes the development of a strategy for the alternative injection of water into the containment, which would be carried out either via the piping of the containment spray system or the recirculation lines, using the Fire Protection system or a mobile pump taking water from the pools of the safeguards towers.
- The plant indicates that none equipment used within the SAMG would be affected with respect to the flood elevation established in the environmental classification of equipment study for the design basis accidents.
- Likewise, with the aim of not only preventing excessive pressure in the containment vessel, but also of limiting off-site radioactive emissions, the plant will install a filtered containment venting system.
- For the prevention of a return to criticality, the licensee has not proposed specific improvements. In addition, Ascó NPP indicates that all the sources of water considered in the SAMG provide water with boric acid and that, nevertheless, these guides generically consider it to be preferable to inject water, even if it does not contain boric acid, than not to inject.
- In order to prevent the concrete of the containment building slab from being attacked, Ascó NPP is carrying out an analysis to evaluate the positive and negative aspects of the strategy of reactor cavity injection, the conclusions of which will enable them to decide whether or not to install it. The licensee indicates that the results of this analysis will be available before the end of 2011 and that depending on these the decision will be taken whether or not to implement the strategy (which might involve a number of physical design modifications).
- With respect to the reduction or mitigation of the releases of fission products, the plant is considering the development of a new strategy for external spraying in the event of leakage, be these from the containment building or from any other building susceptible to radioactive leaks.
- In relation to the accumulation of hydrogen in other buildings outside the containment area, the licensee indicates that a specific analysis will be carried out to assess the risk of hydrogen explosions.
- With respect to the habitability of the control room, the Ascó plant is going to carry out an analysis into the alternative power supply to the control room filtering units.

The plant indicates that with respect to the aforementioned mobile equipment, both for pumping and for supplying electrical power, it is planning to develop its specifications, identify the planned connection points, carry out the design modifications needed to install these connection points, acquire the equipment in question and identify a safe location for it.

In addition, some of the improvements identified by the licensee in the loss of safety functions section improve the plant's capacity to deal with severe accidents.

With respect to a severe accident sequence, the licensee includes the times in which certain events (cliff-edge situations) would occur. These calculations have been made using MAAP-4. In the event of the direct current batteries being available for 24 hours (thereby enabling the core to be cooled using the AFW system), the core would become exposed after 31.4 hours and the pressure vessel would rupture after 34.3 hours.

- *CSN evaluation*

Both the Emergency Operating Procedures (EOPs) and the SAMGs have been incorporated into this plant using the standards of the Pressurised Water Reactor Owners Group (PWROG). These are considered suitable for performing their function and have been verified by the CSN via inspections and assessments.

The licensee's additional strengthening measures include those related with mobile equipment for preventing or minimising fuel damage. All these improvement measures are considered positive as they enable a prolonged SBO situation to be tackled with greater chances of success.

With respect to safety in the event of core damage with high pressure in the primary, the manual main steam relief strategy is considered positive. Furthermore, it is considered that the licensee should analyse and, if necessary, improve the plant's capacity to actuate the pressuriser relief valves in a severe accident scenario combined with an earthquake and a total loss of electrical power sources (including direct current).

The measures proposed by the plant with respect to severe accidents involving hydrogen control (installation of PAR's) and containment depressurisation (the installation of a filtered venting system and measures for feeding the containment spray system using mobile equipment) are all considered positive.

As far as the strategies involving flooding the containment area are concerned, the analysis presented by the licensee refers to the flood level in the event of a design basis accident. It is considered that the licensee will have to reanalyse this aspect bearing in mind the possible flood levels that could be achieved via the present and future SAMG strategies and taking the current injection means and those mentioned in the improvements into account.

Regarding the flooding of the reactor cavity, the licensee is planning to analyse the advantages and drawbacks of this strategy and take a final decision (which might involve a design modification). This approach is deemed suitable.

The containment venting strategies currently contained in the SAMGs are last resort measures, given that most effective routes (from the point of view of containment depressurisation) have a low-pressure design and the low efficiency routes are neither filtered nor channelled to the stack. This is, as has already been indicated, a last resort measure to protect the containment against an imminent risk of rupture. Venting capacity will be significantly improved with the installation of the new filtered venting system proposed by the licensee.

In relation to the instrumentation of the important severe accident management parameters, the licensee indicates that mobile generators will be made available to maintain, among others, the instrumentation functions needed to gain insight into the status of the plant (reactor, primary circuit, secondary circuit, spent fuel pool, etc.). Furthermore, the licensee's report includes a list of the instrumentation needed for the management of severe accidents without indicating whether the mobile generators will supply all of this instrumentation or only a part of it. The licensee will have to clarify this aspect by identifying, where appropriate, which instrumentation is planned to be supplied by these mobile generators.

In addition to the above, the Ascó report indicates plans for the incorporation of the mobile instrumentation necessary for implementation of the alternative primary injection and manual steam generator depressurisation strategies, which are currently in the development phase. The licensee has not included this measure in the table that summarises the list of improvements.

Likewise, in its report the plant indicates that it will analyse the potential hydrogen risk in other buildings. This analysis will have to consider in detail the possible escape routes for the hydrogen (venting, venting line failure, leaks across penetrations under high-pressure conditions inside containment) and the dynamics of propagation in the different rooms of the buildings adjoining the containment area, bearing in mind their geometry, in order to estimate possible localised concentrations which, although short-lived, might lead to dangerous concentrations being exceeded.

The improvement measure proposed for evaluating the need to make a mobile electrical generator available as a back-up for the control room emergency filtering groups to guarantee the habitability of the control room in the event of a severe accident is deemed positive.

In addition to the aforementioned, it is considered that the licensee must add the analysis of the following aspects to his list of improvements (the conclusions of which may result in modifications to the design and procedures of the plant):

- Management of the severe accidents that initiates at shutdown conditions.
- The capacity of the instrumentation associated with SAMG-used critical parameters to provide reliable information under severe accident conditions in containment (for example, containment pressure, RCS pressure or the concentration of hydrogen in containment).
- The leaktightness capacity of the containment isolation valves and of the penetrations under the pressure, temperature and radiation conditions of the severe accident. It is considered that the licensee will have to analyse this aspect in order to be able to estimate the leak and, where appropriate, to identify and implement potential improvements.

- **Loss of fuel pool inventory and/or cooling**

\- *Licensee's position*

The Spent Fuel Pool (SFP) is cooled using the spent fuel pool cooling and purification system (System 17), which is a Class 1E system that is designed to remain operational both during and after a safe shutdown earthquake (SSE) or other postulated risks such as fire, internal missiles or pipe ruptures.

Each of the system 17 trains is of 100% capacity and is supplied via the safeguard busses that receive their voltage from the off-site electrical power sources or, in the event of LOOP, from the emergency diesel generators. The System 17 heat exchanger is cooled by the engineered safeguards cooling system (system 44) or by the component cooling system (system 42), the latter without safety functions.

The water temperature of the SFP must, at all times, be kept lower than or equal to 65.5 ºC in accordance with the plant's Technical Specifications.

In the event of the pool cooling system failing, in order to keep the SFP inventory this would be fed using the three available water sources: the reactor coolant make-up tank, which is the preferred source of support if the loss of inventory is due to the water of the SFP evaporating; the RWST, when the loss of inventory is due to leaks in the system, which guarantees that the concentration of boron is maintained within the established limits; and the safeguard water storage reservoir in the event of an emergency if none of the other support sources are available. The licensee indicates that the Failure Operation Instruction IOF-03, "Loss of spent fuel pool cooling", is under review to consider the inclusion of other possible alternative sources such as the tanks of the water treatment plant and of the fire protection system. Reserves of boric acid will be available on site to be used in the event of the water source being used for replenishment not being borated.

The control room is equipped with a SFP water level and temperature indication and alarm. The level instrumentation has a range of 1.93 metres (level) and 0 ºC to 120 ºC (temperature).

The licensee has analysed the loss of inventory that would occur as a result of seismic action on the SFP (sloshing) and reached the conclusion that no water would be spilled from the pool as a result of this phenomenon.

The licensee's report includes calculations of the times available until the onset of boiling and changes in water levels (until the fuel assemblies uncover) in the event of a total loss of cooling and for different thermal loads in the SFP. The most unfavourable situation is that of a maximum temporary thermal load (all of the fuel assemblies in the SFP), initial level 7 metres above the fuel assemblies and an initial pool temperature of 60 ºC; in this case it would take 3.45 hours to reach boiling and 41.71 hours to fuel assemblies uncover. If the initial temperature considered is 65.5 ºC, the available times are reduced by around three hours in the event of maximum normal thermal load. In the event of the thermal load corresponding to the end of a standard refuelling outage, the time to boiling would be 11.58 hours, and it would take 97.5 hours for the level to fall to the top of the fuel assemblies.

The following measures are in place in the event of the SFP being accidentally drained:

- The HCLPF capacity of the inflatable seals and their pneumatic system (piping and check valves) is 0.3g.
- The suction and return tubing of the cooling system has an HCLPF capacity of 0.3g. The inlets for the cooling system are close to the normal level and the return piping includes anti-siphon holes to prevent water exiting due to siphoning under any circumstances. These devices make it impossible for the level to sink below the 48.190 elevation, in other words 1.223 metres below the normal level (this level is more than 8.023 metres above the active part of the fuel assemblies stored in the pool).

The licensee proposes the following improvements with respect to the loss of fuel pool cooling and inventory replenishment capacity:

- Procedures: the development of guidelines for implementing alternative SFP injection strategies and the external spraying thereof.
- Analysing the potential improvements of the SFP instrumentation.
- The acquisition of on-site mobile equipment for SFP injection and spraying.
- Design modifications: SFP instrumentation improvements.

- *CSN evaluation*

The licensee includes information relative to the SFP design basis and its associated cooling systems. These aspects had been evaluated and licensed during previous exercises carried out by the plant. Furthermore, the equipment and procedures in question have been inspected by the CSN on numerous occasions.

The licensee describes the measures currently in place for tackling the loss of SFP cooling. The current alternative SFP cooling and water replenishment measures would not be available in the event of SBO with the exception of the fire protection system which has a diesel pump (currently non-seismic) and the safeguards reservoir (UHS). The improvement proposed by the licensee regarding the acquisition of mobile equipment for injecting and spraying the SFP is considered positive.

The licensee presents an analysis of the times available until the onset of boiling and changes in water levels (until the fuel assemblies are exposed) in the event of a total loss of cooling and for different thermal loads in the SFP, which is considered adequate except with respect to the initial temperature, given that 60 ºC was considered instead of that currently in force in the plant's Technical Specifications (65.5 ºC), which would result in lower boiling and exposure times. It is considered that the licensee must complete his analysis starting from the latter initial temperature.

- **Radiological protection issues**

- *Licensee's position*

The control room and the Technical Support Centre (TSC) of each of the two units of the Ascó plant are equipped with an emergency venting system that guarantees the conditions of habitability in the event of a chemical and/or radiological accident. These facilities are provided with enough protection equipment to cover the number of people who work in them.

The licensee has estimated the dose that would be received by the personnel inside the control room in the event of a severe accident in the two units following a prolonged loss of electrical power and when it is necessary to vent the containment area. The analysis shows that in the event of the venting being filtered, by establishing shifts and using personal protection equipment, the estimated doses are lower than the intervention levels during emergencies. Furthermore, in order to strengthen the habitability of the control room, the licensee has a short-term plan to analyse the alternative supply of electrical power to the emergency filtering units of the control room, including the heating battery, in order to maintain the effectiveness of the filters using mobile equipment.

In relation to the radiological conditions in other emergency support centres, the plant has estimated, for different core and containment damage situations, the period of residence limitations and personal protections required, and identified that it would be necessary to establish the evacuation of the Operative Support Centre (OSC) in the event of containment venting. The licensee proposes the construction, within the site, of an Alternative Emergency Management Centre (AEMC) to be available in 2015 in which it will be possible to submit the workers to radiological controls, which will guarantee they remain in suitable conditions. This proposal will be tackled conjointly by all the plants.

With respect to the means available for the monitoring and control of radioactive emissions in the event of an accident, the Ascó plant is equipped with a Radiological Surveillance System that includes post-accident monitors and sampling, the on-line environmental radiological monitoring network (RVRAC) , the Emergency Radiological Surveillance Plan (PVRE) and procedures for the calculation of radioactivity releases.

The licensee is also equipped with the personal protection means, dosimeters and portable equipment for the radiological control of the workers and of radiation and contamination levels.

As well as the actions planned for increasing the plant's capacity to respond in the event of an SBO, the plant is implementing an exhaustive analysis of its communications systems, which include the RVRAC and those used by the PVRE, in order to ensure their availability during the scenarios used in the present stress tests.

In addition, an analysis is going to be carried out together with the rest of the licensees of possible additional equipment and improvements of the current radiological protection measures in order to adapt them to the potential conditions found in the scenarios analysed. This analysis is forecast to conclude in June 2012, and as of that time the improvements identified will have to be implemented.

In relation to the identification of radiological conditions that would hinder the performance of local manual actions, the Ascó plant has estimated, for different core and containment damage situations, the period of residence limitations and protections in the diverse locations in which the manual recovery actions identified in these stress tests would be carried out. The estimate was made bearing atmospheric radioactivity releases in mind. Strict time controls would be required in the event of damage to the core, and inaccessible areas identified (period of stay limited to minutes) in the event of containment venting. These conditions would improve, enabling periods of residence of several hours, once the filtered containment venting system has been installed.

In relation to accidents involving the loss of SFP cooling, the licensee identifies that for the maximum normal thermal load (at the initiation of a operating cycle and with the core loaded in the reactor), and starting from the water level established in the plant's Technical Specifications, the plant would have more than 42 hours after the occurrence of the accident before the dose rates prevent access to the pool, which is considered to be sufficient time for carrying out the compensatory measures necessary for re-establishing the level of water in the pool and after which accessing the pool zone would be inadvisable (dose rates equal to or greater than 100 mSv/h). The licensee proposes reviewing the procedure applicable to the loss of SFP cooling.

- *CSN evaluation*

The current design of the control rooms of each of the Ascó plant's two units has been evaluated and accepted by the CSN and guarantees that the radiation to which the personal working in them is exposed during any design basis accident in one of the two units does not exceed the limits of General Design Criterion 19, of Appendix A of the NRC's 10 CFR 50.

The CSN considers that the habitability analysis carried out by the licensee in the event of a severe accident presents significant uncertainties (containment leaks, characteristics and efficiency of the filtered venting to be installed, atmospheric conditions, control room air inflow, residence periods, etc.). However, the licensee's proposal to carry out a short-term analysis of the alternative supply of electrical power to the control room emergency filtering units, and to the heating battery which maintain the filters effectiveness, using mobile equipment is deemed positive.

The proposal to build an AEMC is positively valued. The conclusion in this respect and indicated in 4.1.c is applicable here.

In relation to the means available for the monitoring and control of radioactive emissions, the fact that Ascó nuclear power plant has a continuous environmental radiological surveillance network, with said levels being automatically received in the control room, TSC and CSN emergency response room, is considered as a strength.

Likewise, the analysis that the plants are going to jointly carry out regarding the radiological protection measures and equipment that it would be convenient to have available in the scenarios analysed. In the case of Ascó, this analysis will have to include at least the availability of the post-accident radiation monitors and sampling systems in prolonged SBO scenarios and their correct operation under severe accident conditions. The conclusion in this respect indicated in 4.1.c is also applicable here.

In relation to the analysis for the identification of radiological conditions that would impede the carrying out of local manual actions, Ascó NPP will have to extend its study to include certain manual actions currently contemplated in the SAMG. Section 4.1.c includes general conclusions in this respect. The CSN will request the development of action instructions for each of the SAMG with each of the radiological protection aspects to be taken into account in accordance with the foreseeable doses.

The licensee will be requested to review his dose rate calculations in accordance with the water level in the pool given that the hypotheses used are not conservative and the calculation methodology should be more precise. The licensee will be requested to incorporate the radiological protection aspects to be considered in the local manual actions foreseen. Section 4.1.c includes a preview of the general conclusions in this respect.

4.2.5 Almaraz Nuclear Power Plant

4.2.5.a Extreme natural events

- **Earthquakes**

- *Licensee's position*

The seismic design of the two units at Almaraz is based on a safe shutdown earthquake (DBE) with a free field horizontal acceleration (PGA) of 0.10 g, this having been calculated using a deterministic methodology. Essentially the DBE is based on increasing the maximum historic earthquake that has occurred in the region situated around the site by a degree. Also considered in the design of each group is another lower level of seismic demand, corresponding to the operating basis earthquake (OBE), the horizontal acceleration of which is half the DBE.

The analysis of the faults that might affect the Almaraz site concludes that the two long faults that run in the SW-NE direction on either side of the site are inactive with respect to the design criteria of nuclear power plants, confirming the quantification of the DBE indicated. Consideration has also been given to possible earthquakes induced by the Arrocampo reservoir, the conclusion being that the associated intensity would be much lower than that due to earthquakes of natural origin, this allowing consideration of such induced tremors to be omitted.

The licensee has reviewed the seismic design basis of the plant to determine its current validity. Seismicity was investigated in an area of 300 km around the plant, the original cut-off date has been now extended to May 17^{th} 2011 through application of the catalogue of the Spanish National Geographic Institute (IGN), checking that the maximum seismicity associated with the seismogenic zones used to determine the DBE has not been exceeded and, consequently, concludes that the seismic design basis continues to be valid.

The protection of the plant against the DBE is based on the seismic SSC design requirements, in accordance with the classification included in ANSI-N 18.2-1973, the maintenance practices through the processes established in the licensing basis, the seismic qualification and the correct status of the SSC as well as their modifications and spares.

The plant is equipped with a seismic monitoring system, the design of which meets the requirements of American regulatory guides RG 1.12 and 1.166. The system supplies measurements, permanent recording and analyses of seismic response at various locations around the plant. The system instrumentation provides an immediate indication in the control room whenever the previously established accelerations are exceeded. The plant also has operating procedures for earthquakes, which contemplate, among others, the following actuations: actions to be performed in the event of an earthquake, criteria regarding the operating basis earthquake (OBE) being exceeded and actions to be taken in the event of rupturing of the Arrocampo dam. The On-Site Emergency Response Plan (ERP) is also activated in the event of a confirmed earthquake having a magnitude equal to or greater than the OBE and the actuations contemplated in the procedures for such events are carried out.

Furthermore, as a result of the accident that took place at the Fukushima nuclear power plants, a series of recommendations have been issued at international level (in particular, WANO SOER 2011-2) aimed at guaranteeing, in the short term, that each plant is able to respond to both events included in the design basis and others beyond the design basis. Almaraz NPP has replied to these recommendations and to the requirements of the CSN, reporting on the checks performed and their results. To date, no significant vulnerability has been identified in either of the plant units.

The licensee assesses the seismic margin of the plant using the work already performed by means of the methodology developed by the NRC and EPRI (0.3g review earthquake - "focused scope"), complementing them in the context of the stress tests through the performance of new inspections and extension of the scope. The study of seismic margins was updated by identifying the new elements required for safe shutdown that were installed with design modifications during the period 2001-2010, along with the existing equipment modified during this period, confirming their capacity with respect to the DBE and estimating the corresponding seismic margin.

In accordance with the seismic margin studies performed, the licensee assigns to the plant a minimum HCLPF capacity value of 0.21g, associated with the chemical and volume control tank, and identifies the components of the plant with a HCLPF lower than 0.3g. The licensee points out that the seismic capacity of Almaraz NPP for safe plant shutdown is 0.27g for Unit I and 0.24g for Unit II, considering that the chemical and volume control tank is not strictly required for safe shutdown and that in any case a modification of this component is planned that will allow a margin of more than 0.3g to be assigned to it. The licensee also identifies a seismic margin of 0.3g in both units for the integrity of the fuel in the spent fuel pool and for the integrity of containment. These results were confirmed following the inspection walkdowns expressly carried out, in which a series of interferences between components were detected whose resolution will make it possible to achieve a HCLPF capacity of 0.3g.

The equipment for which the analysis of margins has been extended, in the context of the stress tests, are the containment isolation valves not included in the original seismic IPEEE and the equipment installed on the different alternative paths for SFP cooling and water make-up available in the event of failure of the normal cooling system, which had been assessed previously and that had been assigned a HCLPF of > 0.3g. Also determined has been the seismic capacity of the equipment belonging to the auxiliary feedwater system and containment spray system, considered in the strategies to address SBO and the management of severe accidents coinciding with an earthquake.

The movement of water in the fuel pool caused by a 0.3g earthquake was analysed, determining whether this might lead to spillage ("sloshing") of the water contained in these pools and the impact it would have on the pool itself (reduction of cooling capacity) and externally (flooding of other installations). In the worst case there would be total spillage amounting to some 13.3 m^3, which implies a reduction of 10 cm in pool level, which would not compromise the cooling of the spent fuel or affect safety significant equipment in the fuel building, given the configuration of this building.

Compliance with the current licensing basis in relation to seismic behaviour is guaranteed through the periodic application of procedures, surveillance requirements and actuations aimed at suitably maintaining the SSCs and seismic monitoring system, along with the corresponding design modifications and associated spares. Furthermore, the licensee indicates that no off-site resources are required to respond to the potential consequences of an earthquake within the design basis.

As regards the possibility of there being effects induced as a result of an earthquake, the Almaraz NPP report indicates the following:

- Fires and explosions: the licensee considers that compliance with the current design basis, along with the assessments performed of possible explosions in hydrogen stores and as a result of fires in stores housing combustible material, indicates that the risk of a fire induced by an earthquake that might affect the safe shutdown capacity may be considered negligible. The licensee identifies an action to be carried out in the short term to include hydrogen line isolation actions in procedures.
- Internal flooding: Almaraz points out that it has available an analysis of floods corresponding to the updated licensing basis in which consideration is given to circumferential breaks in non-seismically qualified piping. In addition, the licensee has analysed non-seismically qualified pipes and tanks identified in the PSA that might cause an initiating event and damage to mitigation systems, and also analyses multiple breaks in areas with safety-related equipment, identifying in all cases instrumentation, isolation actions included in procedures and general barriers against flooding. The scope for the evaluation of seismic margins is that indicated in previous paragraphs. The licensee does not indicate any other additional actions.

Additionally, and in relation to the effect that an earthquake beyond the plant design basis might have on the Valdecañas dam, located on the river Tagus in the vicinity of the plant, the licensee has performed a structural analysis, the result of which indicates that the dam would maintain its integrity following an earthquake with an intensity of 0.3g. Although the results of the structural calculation show that for this earthquake there is no collapse of the structure or rupturing or loss of functionality, the possibility of flooding as a result of rupturing of the dam with the reservoir full to its maximum normal level (elevation 315 m) has also been analysed. It is concluded that the plant's grading level (257.5 m) would not be reached in either of the two rupturing hypotheses considered (instantaneous simultaneous rupturing of the dam spillway gates and partial notch-shape rupturing of the dam with a total surface area of 2530 m^2), the flood reaching elevation 255.40 m in the worst case.

In order to increase the seismic robustness of the plant, the licensee proposes to carry out the pertinent reassessments and design modifications to obtain a HCLPF value as close as possible to 0.3g in all SSCs required to perform safe shutdown functions and respond to the postulated accidents. Likewise, those points at which possible seismic interferences with other components have been identified will be resolved. In addition, the plant procedures have been updated to contemplate the results of the analyses performed, or are being updated in this respect, including among other things multiple rupturing and analysis of the Valdecañas dam.

- *CSN evaluation*

The Almaraz NPP seismic design bases are those licensed in the original design of the facility; they are included in the plant's Safety Analysis Report and have been repeatedly evaluated and inspected by the CSN.

The licensee provides an adequate description of the seismic monitoring system in relation to the measures in force to protect the plant against the DBE and also of the improvement implied by its being interrelated with the On-Site Emergency Response Plan (ERP) for the case of an earthquake as an initiating event. This system, which was previously implemented at the plant, had been reviewed by the CSN and is considered acceptable.

The HCLPF values estimated by the licensee are considered to be justified in accordance with the EPRI methodology, although the value of 0.3g assigned to the irradiated fuel racks is currently being reviewed by the CSN. Also pending verification are the corrective actions proposed by the licensee to increase the HCLPF value of the equipment identified as having a margin of below 0.3g.

As regards the possibility of there being effects induced as a result of an earthquake, and in addition to the generic conclusions set out in section 4.1.a, the following conclusions are reached:

- Fires and explosions: the CSN evaluation considers the scope of the analysis performed to be adequate as regards both the identification of possible sources of fires and explosions and the improvement action proposed.
- Internal flooding: the CSN evaluation considers that the licensee has performed an ample analysis; furthermore, the licensee proposes to perform reassessments to obtain a seismic margin value adequate to respond to the postulated accidents. The CSN evaluation considers that these reassessments should also cover those pipes that might generate an initiating event in addition to the loss of mitigating systems, and that these be scenarios not covered by the analyses already performed.

As regards the studies performed by the licensee to verify the integrity of the Valdecañas dam, located upstream from the plant, this has been analysed for an earthquake having a horizontal acceleration of 0.3g and a vertical acceleration of 0.2g with water up to the maximum elevation of the reservoir, 315 m; the conclusion being that the integrity of the dam is maintained, the studies consequently being acceptable. The analysis of stability in response to the occurrence of extraordinary floods contemplates the collapse of the dam due to subsidence of the foundations, which reach a depth of 20 m into the ground, and rupturing of the crown, the result being that there are ample margins to flooding of the plant in both cases. These analyses are considered valid by the CSN and give a justified estimate of the margins beyond the design basis; however, the following section on flooding provides additional comments in the CSN's evaluation.

By way of a general conclusion for this section, the CSN considers the improvement actions proposed to increase the robustness of the plant to be generally effective since they would allow a seismic margin of 0.3g to be achieved.

- **Flooding**

\- *Licensee's position*

The flooding design basis considered has been a flood with a return period of 10000 years, combined with the corresponding wave height and its breaking over the slopes of the plant esplanade level and the essential service water pond dyke. Under these conditions, the flood level obtained would be located at elevation 256.53, the plant grading level being at elevation 257.50. The safeguards and purge treatment buildings, which have doors communicating with the exterior and which the water might also reach via communicating areas by way of the rainwater drainage network, if this were to be flooded, are also located above the maximum flooding level calculated.

The calculation of flooding levels has been updated with the meteorological data recorded at the site up to 2010 and has confirmed the validity of the flooding level and wave height values considered in the design basis.

All the safety-related SSCs remain available following the flood, including the essential services water intake structure and the emergency alternating current supply system, made up of the diesel generators and the associated gasoil system. There would be no impact on the cooling capacity of the spent fuel pool.

Almaraz NPP has procedures to respond to flooding by means of which a check is made of the correct operation of the watertight seals, coverings and sumps are inspected and cleaned, preventive actions against the risk of flooding are established and compensatory actions are defined for cases of malfunctioning or unavailability of the equipment required in the plant's flooding protection manual. Furthermore, the On-Site Emergency Response Plan (ERP) would be activated in the event of rainfall of severe hourly intensity, as measured by the plant meteorological tower, in accordance with the already established procedures.

Compliance with the licensing basis is guaranteed by the periodic performance of the procedures and actuations carried out at the plant, in accordance with the established monitoring requirements and the conditions set out in the instructions issued by the CSN.

Almaraz NPP has a margin over and above the maximum estimated flooding height. Furthermore, the licensee indicates that the flooding elevation for a return period of ten million years would also be lower than the elevation of the plant grading level and that the possibility of the buildings located below this elevation sustaining damage would be very low for a return period of one million years, as a result of which the available margins are considered to be adequate.

The plant is equipped with a water table control system that consists of two control wells, with two automatic (start-up and shutdown) pumps in each that discharge to the rainwater drainage network. The objective of this system is to prevent seepage and damp in the plant buildings, mainly the safeguards buildings, and guarantee the stability of the terrain with respect to possible settling of the fuel buildings. An analysis is made of the effects that the total and continuous loss of electric supply to the control well pumps would have in two scenarios: 72 hours and 7 days. The results indicate that in the worst case the water table would rise to elevation 252.50 m after 7 days. It has been estimated that this rise would cause seepage to the inside of the safeguards building that would give rise to a depth of water of between 17 and 43 cm, this being below the critical height of 62 cm estimated for the equipment affected by flooding in this room. Furthermore, 3 months would be required for the water table to reach the elevation of the reservoir (255.0). As regards the stability of the terrain, water table rise tests lasting 90 days were performed in 1985 and no increase was observed in the settling of the buildings and structures.

As regards local flooding as a result of torrential rains, the maximum admissible intensity drainage capacity of the nuclear island headers is 284 $l/m^2/h$, this being far above the intensity for 10 minutes for return periods of up to 10000 years; consequently, it is deduced that the probability of occurrence of floods on the plant site is practically zero. The plant would not be affected by extreme rains of up to 275 l/m^2 in 24 hours (occurrence once every 10 million years). Above this value there would be the possibility of water accumulating in certain areas of the plant, which might affect the safety equipment located in such areas.

External flooding due to the potential rupturing of the Valdecañas dam has already been analysed in the previous section (earthquakes above the DBE and flooding). The only issue to be underlined here are the available response times according to the calculations, from the moment of rupturing of the dam to the moment in which the flood reaches the site. The maximum level of flooding at the Arrocampo dam would be reached after 7 hours and 43 minutes. The maximum level in the Arrocampo reservoir (elevation 255.40) would occur after 15 hours and 24 minutes.

With a view to further improving the capacity of the plant to respond to external flooding beyond the design basis, the licensee proposes to implement a design modification to increase the capacity of the Arrocampo dam drains, plus another to make the access doors to the safeguards and purge treatment buildings watertight. The licensee also states that an analysis is being made of the possibility of improving the watertightness of the rest of the installations housing safety-related equipment and of increasing the drainage capacity of the roofs and terraces of buildings and the site overall.

- *CSN evaluation*

The design basis relating to the different events that might cause flooding of the site is included in the plant's Safety Analysis Report and has been evaluated and inspected periodically by the CSN.

The licensee has carried out a detailed review of the possible effects of flooding caused by the entry of water via paths located below the elevation of the plant grading level, such as a rise in the water table or ingress via the rainwater drains. The licensee has also analysed possible cliff-edge situations, adopting the hypothesis of an external flood reaching the elevation of the plant esplanade (257.50). The results are satisfactory and are considered to be reasonably justified. Nevertheless, in certain cases, such as loss of the water table control systems, additional checks will be made by the CSN using the evaluation and inspection processes established.

As regards the effects of the potential but highly improbable rupturing of the Valdecañas dam, the structural capacity of which has been analysed in the previous section, the most unfavourable hypothesis contemplated by the licensee in his analysis is less demanding than the rupture criteria adopted in the dam emergency plans in Spanish practice. The consequence is that the maximum flood level estimated by the licensee is lower than that assumed in the emergency plan of the Valdecañas dam. In view of these results, the CSN considers that the actions necessary to bring the two approaches into harmony should be undertaken: i.e., the approach adopted by the licensee and that postulated in the emergency plans. As a result of this harmonisation, the licensee should review his analyses and adopt whatever measures might arise as a result.

The margins calculated with respect to the different causes of flooding are considered to be justified in general.

As regards the measures proposed to improve the robustness of the plant in response to potential flooding, they are all considered to be adequate to contribute to strengthening the plant response to external floods, although in certain cases, such as improvement of the leaktightness of the accesses to safety-related areas or increasing site drainage, the actions proposed by the licensee should be more detailed in their scope and as regards implementation times.

- **Other extreme natural events**

- *Licensee's position*

An additional process of analysis and screening has been carried out on the basis of the extreme natural events included in NUREG/CR-2300 and in accordance with the individual evaluation of the plant with respect to external events already performed by Almaraz NPP (IPEEE). The events not ruled out in the screening process are: drought, heavy rainfall, wind and snow loads, electrical storms, hail, external fires and extreme temperatures (freezing and high temperatures).

In his analysis the licensee concludes that sufficient margins are available in all cases. In this respect it is pointed out that the plant would not be affected by rainfall having a frequency of occurrence of once every ten million years, that the plant structures were designed to withstand wind speeds of 144 km/h, and that the maximum annual gust of wind in the period analysed was 136 km/h, as a result of which the wind speed established in the design criteria has not been exceeded at any time. The safety factors applied in the design of the structures imply available margins of almost 50% for non-seismic buildings and higher than 100% for seismic buildings.

As regards potential improvements relating to other external events, and in addition to those already indicated for earthquakes and flooding, the licensee points to the advisability of undertaking certain improvements to the plant buildings in order to strengthen their external protection against atmospheric discharges, the installation of these being planned with design modifications.

- *CSN evaluation*

The screening of external events performed to establish the design bases is based on a very low probability of occurrence (10^{-5} per year), in accordance with the probabilistic methodologies included in the applicable IPEEE standards.

The analyses carried out by the licensee seen their scope extended with respect to those performed previous to the stress tests, and the results are considered to be satisfactory. The design criteria applied and the margins estimated are reasonable, although in certain cases, such as the margins with respect to extreme temperatures, the results submitted are still being reviewed by the CSN.

The licensee has procedures for action in response to the occurrence of severe weather conditions at the site, these having been inspected within the framework of the CSN's supervision and control programmes.

The improvements proposed to increase protection against atmospheric discharges should be specified by the licensee in greater detail and a timeframe should be established for their implementation.

4.2.5.b Loss of safety functions

- **Loss of off-site power (LOOP)**

- *Licensee's position*

Almaraz NPP describes the external electrical feed sources available, concluding that they provide high levels of availability and reliability and a high degree of security as regards their capacity to rapidly recover from a loss of the off-site grid, considering that the national electricity grid operator (REE) has available procedures for the recovery of power in the event of a zero condition in the grid, which give priority to feed for the NPP's and in particular to Almaraz, and in which the recovery of supply from the hydroelectric stations in the vicinity of the plant sites is established as the preferential method. This has been checked on several occasions by way of different tests to feed Almaraz NPP guaranteeing the availability of electrical energy in a very short space of time.

In the event of LOOP, the feed for the safeguards equipment is re-established by starting up and automatically connecting the two redundant diesel generators in each unit and through the corresponding automatic loading sequence; the existence of a 5th diesel generator (5DG) capable of replacing either of the two generators for each unit is also noteworthy.

The licensee submits the results of the analysis of the autonomy of the diesel generators, concluding that this is limited only by the capacity to supply fuel and the consumption of lubricating oil, with no need to supply water to the closed cooling circuit, and that this autonomy is longer than 7 days. Specifically, the volume of gasoil in the storage tanks, monitored by the plant's Technical Specifications, is sufficient for the operation of one diesel generator per unit for more than 10.5 days (more than 7 days if the passive failure of one of the tanks is postulated). The oil storage capacity of the motor sumps provides an autonomy of more than 11 days. As regards cooling (removal of thermal load), for generators 1DG to 4DG this is accomplished by means of the essential services water system (to the ultimate heat sink) while the shared diesel generator, 5DG, is cooled by air.

As an improvement associated with this scenario, the plant proposes the performance of periodic tests of the capacity to recover feed from the two hydroelectric stations considered to be preferential sources in the procedures of the electricity grid operator.

- *CSN evaluation*

The LOOP is within the design basis of the plant and the measures to address this scenario have been evaluated and inspected frequently by the CSN.

The fifth diesel generator, which may replace either of the two in each unit, with all its autonomous auxiliaries, improves the reliability of the emergency feed system.

By design, the autonomy of the diesel generators is 7 days. The plant has performed tests confirming this autonomy.

The reliability and availability of the DG's is overseen/monitored within the scope of the Maintenance Rule.

The lines providing feed from the grid have different points of origin and runs, this providing the supply with diversity and reliability.

The grid operator has procedures for recovery by zones that take into account the preferential feed for the nuclear power plants.

The proposal regarding the performance of periodic tests of the capacity to provide off-site feed from the hydroelectric stations will improve the reliability of the recovery of off-site power supply.

The aspects indicated by the licensee and summarised above are contained in the applicable licensing documents and have been evaluated and inspected by the CSN throughout the lifetime of the plant. There are no regulatory objections in this respect.

- **Station blackout (SBO)**

- *Licensee's position*

For cases of loss of off-site power and of the normal back-up a.c. sources, the plant currently has a fifth diesel generator (5DG) with complete autonomous services and the same capacity, design requirements and qualification as the other four. It is designed to act as a replacement for any of those four generators and is equipped with an interconnection system that allows it to be quickly connected to any medium voltage emergency bus.

With a single unit in the SBO condition, diesel generator 5DG would be aligned to it and the emergency electricity supply would be recovered. Both units could then be taken to safe shutdown and kept in this situation in the long term.

With both units in SBO, diesel generator 5DG would be aligned alternately to one and then the other, which would allow the safeguards systems to be used and batteries to be kept charged in one unit while in the other d.c. feed would be available for control of the auxiliary feedwater turbine-driven pump (AFWTP) and of the steam generator (SG) relief valves.

In the event of loss of off-site power, loss of the normal back-up a.c. sources and loss of the additional back-up sources (diesel generator 5DG), the plant is licensed to respond to this situation for at least 4 hours with only direct current. To accomplish this, the affected units would initiate cooling of the primary system by using the SG relief valves and the AFWTP. The plant includes a summary of the licensing basis and of the analyses performed for compliance with the standards governing SBO.

The plant has analyses of loss of ventilation in the turbine-driven pump rooms, of d.c. distribution and of batteries from which it is concluded that the ventilation is not a critical element in the response to SBO.

By design the safety-related batteries have an autonomy of 4 hours. Taking into account the existing overdimensioning and the instructions regarding the disconnection of unnecessary loads, the autonomy of the general use batteries is extended to 8 h 40 min. For the control of the AFWTP there is a dedicated battery with an autonomy of 7 hours and 20 minutes that is connected when the train B battery is depleted (8 h 40 min), as a result of which there is direct current available for the operation of the turbine-driven pump for 16 hours.

In the scenario considered there would be leakage across the Reactor Coolant Pump (RCP) seals, for which reason the plant states that it will be necessary to inject to the primary circuit to maintain a controlled inventory.

The plant has included a statement regarding the sequences and time limits: depletion of the batteries for the control of the AFWTP (16 hours), availability of water in the preferential source (30 hours), steam generator dryout (37 hours) and core uncovering (40 hours), if no corrective actions are taken to address these situations.

The analysis of SBO initiated in "other operating modes" (other than power operation) has been included, the conclusion being that the improvement actions for SBO at power, in particular for the control of Reactor Coolant System (RCS) inventory and residual heat removal, allow SBO to be addressed or mitigated in other modes.

In addition to the scenarios whose analysis was required in the CSN Complementary Technical Instruction which required the stress tests fulfilment, the plant has analysed the event of a total loss of alternating current power in which, in addition, the d.c. sources are eventually lost.

This would imply the unavailability of practically all the plant equipment except the AFWTP and the manual SG relief. There is the possibility of operating the AFWTP without direct current, and of carrying out steam generator relief manually by means of the flywheel of the valves. In this respect a test was performed in unit I during the 2011 refuelling outage and a procedure is being developed for plant cooldown and control with a complete loss of electricity supply.

Portable stand-alone lighting and communication resources are currently available in the control room for plant cooldown by means of the AFWTP and SG relief without electricity supply. The acquisition of portable equipment to electrically feed the SG wide range water level transmitters is currently on-going.

It has been calculated that the water available in the auxiliary feedwater and condensate tanks would allow adequate core cooling to be maintained for 30 hours, SG dryout occurring after 37 hours and uncovering of the core after 40.

- *CSN evaluation*

The Station Blackout (SBO) scenario was originally incorporated in the Licensing Basis of Almaraz NPP assuming that the total loss of alternating current supply occurred in only one of the two units and considering a coping time of 4 hours. The analyses performed justified the capacity to respond to

SBO with only electrical feed coming from batteries. Diesel generator 5DG was installed subsequent to compliance by Almaraz NPP with the SBO regulations.

At present, in the event of a single unit being in the SBO condition, 5DG will be aligned to it; in the event of both units being affected by SBO, the licensee foresees the alignment of 5DG alternately to each of the two units.

The CSN evaluation sees Almaraz NPP's 5DG diesel generator as being strength, since it is separated physically from the other diesel generators, has different support systems and is cooled by air. The incorporation of this 5DG was the subject of a specific licensing process.

The plant has analysed the feasibility of coupling generator 5DG to both units simultaneously, ruling out the possibility of providing feed to one redundancy in each unit because of the difficulty involved in removing the interlocks incorporated in the design to guarantee the criterion of independence and separation of trains. The decision has been taken to align 5DG alternately to both trains in each unit, which allows the scenario considered to be addressed satisfactorily.

The licensee considers increasing the autonomy of the batteries through the proceduralised disconnection of unnecessary loads, having carried out the corresponding calculation. The CSN has reviewed the calculation of the autonomy of the batteries as regards the approach and hypotheses adopted and the calculation method used, with satisfactory results.

Off-site floods would not affect the plant safety-related equipment, as referred to in section 4.2.5.a. However, the plant plans to reinforce the doors of certain buildings for the case of the hypothetical extreme rupturing of dams being considered.

As regards the feasibility of AFWTP operation with manual control and manually controlling the SG relief valves, the fact that this has been tested in one unit and that the test provided satisfactory results should be considered a strong point. The plant proposes to carry out this test in the other unit during the next refuelling outage and to repeat it periodically.

The licensee provides adequate information on the analyses of limit times.

Subsequent to the preliminary report, the CSN has performed documentary checks of these turbine-driven pump and steam generator relief manual control tests performed at unit I during the course of inspections, with satisfactory results, and has also carried out other relevant verifications.

In the wake of the actions performed, the CSN evaluation concludes that it has no additional observations regarding the information provided by the plant.

- **Improvements proposed by Almaraz NPP in response to loss of power events**

With a view to improving the robustness of the plant in relation to this type of situations, the licensee proposes to undertake the following actions:

- Performance of periodic testing of off-site feed from the hydroelectric stations.
- Tracking of the state of the art in relation to new RCP seals, appraising their implementation at other plants and their capacity in accident situations.
- Proceduralise and perform periodic tests on the operation of the AFWTP with manual control.
- Train the plant personnel on the local operation of the steam generator relief valves and control of the AFWTP in the lighting and communication conditions encountered during SBO.

- Provide the plant with an additional capacity, by means of portable equipment, to: replenish RCS inventory from the refuelling water storage tank, and to take suction from the ESW pond and discharge to the steam generators, or to the tank, or the suction side, of the AFWTP.
- Provide the plant with a portable electricity generator to feed control of the AFWTP and for supply to the hydrostatic test pump, with the capacity to feed a battery charger and two motors simultaneously.
- Make available additional portable instrumentation, and improve that currently in place, for control of the AFWTP and SG level and for other actuations to address the events considered.
- Improvements in the availability of communications, such as connection of the public address system to a portable diesel, the implementation of a wireless communications system throughout the plant, increased capacity of the battery of the telephone exchange and reinforcement of training on communications with the control room. Actions to improve the autonomy of the lighting systems are also included.

The improvement measures identified by the plant in the current stage of development are considered valid, although the feasibility of using portable equipment will depend on the results of the specific analysis of the availability of personnel required in section 4.1.c of this report.

With the implementation of these measures, the cliff-edge situation times would be extended and would depend on the autonomy of the portable equipment.

- **Loss of Ultimate Heat Sink (UHS)**

- *Licensee's position*

The main heat sink is made up of the condenser and the circulating water system that cools it with water from the Arrocampo reservoir. This system has no safety function, as a result of which it is not considered to be safety class. The ultimate heat sink (UHS), which does perform a safety function, is made up of the Arrocampo reservoir, the essential service water pond and the essential service water system (ESW). The corresponding dams, as well as the components of the essential service water system, are capable of withstanding the safe shutdown earthquake (SSE) and also have a seismic margin of 0.3g.

The ESW system supplies water for the cooling of emergency diesel generators 1DG to 4DG and allows for removal of the heat load from the components, or support systems, required to take the plant to a stable condition. It also allows for removal of the heat load from the spent fuel pool cooling system.

The ESW water intake structure is located on the seismic category I dyke that separates the Arrocampo reservoir from the essential services water pond, such that the water may enter from both sides via spillways that are normally below water level. If loss of the capacity of the intake structure is postulated, the ESW would be lost.

The ESW may discharge to the following:

- The Arrocampo reservoir via the circulating water discharge tunnel, calculated to withstand the safe shutdown earthquake (SSE).
- The essential services water reservoir, either via the spray nozzles located in the headers above the thermal separation screen or directly via the spillway existing for this purpose.

Each of the reservoirs is licensed to guarantee by itself the removal of heat from both units; for this reason, the loss of one would not imply the loss of the ultimate heat sink:

- Loss of the Arrocampo reservoir: the plant ultimate heat sink is guaranteed by the essential services water reservoir for more than 30 days. In addition, there are measures to protect the essential services water reservoir, including the tripping of the two reactors and the initiation of shutdown procedures.
- Loss of the essential services water reservoir: the Arrocampo reservoir is maintained as the ultimate heat sink, the plant being shut down in an orderly manner in accordance with the plant's Technical Specifications.
- Loss of the essential services intake: the five pumps of the essential services water system would be lost and the situation would be similar to that described for SBO, with the difference that the fifth diesel generator (5DG) would be available to guarantee the supply of regulated direct and alternating current supply for the instrumentation required for shutdown and for control of the AFWTP, aligned alternately to each of the two units.

The main potential cause of an event of these characteristics would be the obstruction of the screens. However, a very high percentage of the intake structure obstruction events that may occur at nuclear power plants could not occur at Almaraz NPP because of the type of cooling by means of a reservoir, the physical location and the meteorological conditions that have occurred historically in the area. In the remaining cases (obstruction by brushwood and fish), although they might be applicable, experience has shown that the measures adopted by Almaraz NPP are effective in preventing this type of problem. These measures consist basically of the following:

- Almaraz NPP has a procedure for the "Control of thermo-ecological conditions in the Arrocampo reservoir".
- In 1993 a plan for the monitoring and control of submerged microphytes was set up.
- A design modification has been implemented that has improved the control and operation of the screens. From being continuously in operation, they have switched to an automatic start-up every 8 hours and another whenever there is a difference in level between the two sides of the screen.
- Contacts are maintained with other Spanish nuclear power plants via the Radiological Protection and the Environment department, and information is provided on events relating to this issue through the exchange of operating experiences with the rest of the plants.

The actions to be taken in the event of loss of the essential services water intake would be as follows:

- Manual tripping of the reactor and of the RCP's due to loss of cooling.
- Primary cooldown and depressurisation to reduce the risk of RCP seal failure. The cooldown would be carried out using the AFWTP and the turbine bypass to the condenser or the steam generator relief valves.
- Supply to the auxiliary feedwater and condensate tanks from the water plant tanks.
- The limit for this situation would be the same as in the LOOP scenario with loss of diesel generators 1DG to 4DG. The leak occurring across the seals of the RCP's leads to the need for water to be supplied to the RCS, in order to replenish inventory.

Almaraz NPP considers the improvement measures analysed and proposed for SBO to be valid and adequate for this scenario, for which reason no additional measures are identified.

- *CSN evaluation*

Refer to the evaluation in the following section

- **Loss of heat sink combined with SBO**

- *Licensee's position*

The possible situations that might arise in relation to a loss of ultimate heat sink along with SBO are as follows:

– Loss of Arrocampo reservoir with SBO: the ultimate heat sink of the plant is guaranteed with the essential services water reservoir for more than 30 days. The situation is identical to that existing in the event of SBO.

– Loss of essential services water reservoir with SBO: the Arrocampo reservoir is maintained as the ultimate heat sink. The situation is identical to that existing in the event of SBO.

– Loss of essential water intake with SBO: The situation is identical to that existing in the event of SBO.

In the scenarios analysed, the situation is identical to that described for SBO, except that by aligning diesel generator 5DG alternately to the two units, the batteries may be charged and, as a result, the instrumentation and control of the auxiliary feedwater turbine-driven pump may be kept in service for a prolonged period.

Almaraz NPP considers the improvement measures analysed and proposed for SBO to be valid and adequate for this scenario, for which reason no additional measures are identified.

- *CSN evaluation*

This section evaluates loss of the UHS with and without SBO

The licensee has provided an adequate description of the provisions existing in the design to prevent loss of the UHS and has analysed the situation that would arise as a result of loss of the UHS, with and without SBO, with an adequate scope.

The information relating to the UHS design basis, which includes the loss of either of the UHS reservoirs, has been evaluated and licensed by the CSN during previous stages. Furthermore, the related equipment and procedures have been inspected by the CSN on numerous occasions.

In the cases of loss of UHS with and without SBO the licensee identifies and proposes improvements to increase the robustness of the plant. These measures are the same as those identified in the section on loss of power supply, since loss of the UHS would lead to a situation in which the systems available to protect the safety functions would be the same as in the loss of power situation.

The design modification performed on the essential services water system of Unit II, and which will be carried out in Unit I during the next refuelling outage (preparations for the connection of portable pumping equipment), will make an additional source available for cooling of the steam generator secondary system for more than 24 hours. This modification is considered to be adequate.

The licensee has performed realistic calculations to estimate the depletion times of the sources of water currently available for the auxiliary feedwater system. The result is that the time available with the AFW and condensate tanks is longer than 24 hours. The manoeuvres consisting of manually operating the auxiliary feedwater system turbine-driven pump and steam generator relief valves have been successfully tested in Unit I (they will be tested in Unit II during the next refuelling outage).

The CSN considers the proposals for improvement presented by Almaraz NPP to be adequate.

The licensee has submitted a calculation of the temperature that would be reached in the AFW turbine-driven pump room with the door closed. The conclusions of this calculation are that the temperature reached after 24 hours of operation of the said pump would be 74ºC and that this value is lower than that which might affect the operation of the equipment. However, it is considered that this calculation gives values that would hinder the local operation of the turbine-driven pump. Consequently, the licensee should include a proposal for improvement to guarantee conditions of habitability making it feasible to operate the turbine-driven pump manually.

4.2.5.c Accident management

- **Planning of accident management**

- *Licensee's position*

The licensee of Almaraz NPP proposes to analyse the organisation and resources available to address the management of emergencies and to dimension organisational changes in the medium term.

The licensee indicates specific improvements in the area of communications aimed at strengthening the communication capacity of the plant, which it is proposed will be implemented in the medium term. In keeping with the start-up of the new Alternative Emergency Management Centre (AEMC), the licensee proposes another series of improvements in areas relating to communications; the analysis of these improvements will be completed in the short term and implementation is proposed in the long term.

As regards access routes to the site in the case of extreme events, the licensee had already identified the existence of twelve feasible routes for access to the site in the event of a severe earthquake in his preliminary report. In this report, the licensee points out that there are five feasible routes for access to the site by conventional vehicles in the event of flooding due to the partial rupturing of the Valdecañas dam and three feasible routes in the case of maximum flooding.

The licensee establishes new reference dose levels for the personnel intervening in an emergency, indicating that they will be voluntary and informed workers. These dose levels correspond to those established in ICRP-103.

- *CSN evaluation*

The licensee's proposal to analyse the organisation and resources to address emergency management should extend the studies and adopt whatever solutions relating to organisational issues might be derived in relation to events such as those proposed and simultaneously affecting both units.

The licensee plans to incorporate additional measures in the short term to increase robustness in the area of communications, this being considered acceptable. As regards the further-reaching improvements that will be associated with the start-up of the new AEMC, these are considered to be acceptable, although the licensee should study and report to the CSN on the incorporation of provisional measures in the short to medium term, such that improved capacities be available, even if only partial, prior to the dates of implementation of the long-term measures.

As regards the access routes to the facility, the analysis submitted is considered acceptable.

As regards the reference dose levels for the personnel intervening in an emergency, and as has been pointed out in section 4.1.c of this report, the CSN considers it necessary to establish homogeneous reference levels for all the Spanish nuclear power plants. Nevertheless, in the short term the licensee should consider a framework guaranteeing both individual protection and the feasibility of undertaking actuations mitigating the emergency, as contemplated in IAEA TECDOC 953 and BSS's.

- **Measures for the management of accidents in the reactor**

- *Licensee's position*

As in the case of the rest of the plants, the licensee describes the measures in place at the level of equipment, procedures and personnel to prevent, mitigate and manage severe accidents.

Almaraz NPP also analyses the various strategies contained in its SAMGs and their capacity to protect the containment and mitigate off-site releases, concluding that with the existing resources measures will be taken to recover equipment or functions allowing the consequences of accidents to be mitigated or palliated.

The licensee points out that with the measures currently contemplated in the SAMGs and the improvements proposed in the previous chapters sufficient capacity is available to respond to severe accidents. In this respect, although the initial objective of the improvement measures proposed for SBO events is to avoid degradation of the core, if this is not possible part of the said measures will allow severe accident strategies to be addressed.

Specifically, with a view to increasing the robustness of the facility, and in addition to what is indicated in the general section regarding a new centralised Emergency Support Centre (ESC), Almaraz NPP also indicates that portable equipment will be available at the plant which, along with the necessary portable instrumentation and with adequate connections to the available systems enabled, will allow for a response to severe accident scenarios in the hypothetical case of complete and simultaneous loss of all the measures currently implemented.

Along with other improvement measures aimed at controlling hydrogen and excessive pressure conditions in containment, this will allow for greater plant equipment redundancy for the performance of the strategies defined in the SAMGs. The measures proposed by the licensee are as follows:

- To provide the hydrostatic test pump with an additional electrical feed from one generator and have available a portable pump with the capacity to inject into the primary. The licensee indicates that with this improvement action it will be possible to address the following severe accident strategies: "RCS injection", "Injection to containment" and "Containment flooding".
- Availability of an additional capacity, by means of portable equipment, to replace inventory to the auxiliary feedwater tank and supply water to the suction side of the AFWTP. The licensee indicates that with this improvement action it will be possible to address the following severe accident strategy: "Inject water to the steam generators".
- Availability of an additional capacity, by means of portable equipment, to feed the steam generators. The licensee indicates that with this improvement action it will be possible to address the following severe accident strategy: "Inject water to the steam generators".
- Availability of an additional capacity, by means of portable equipment, to feed the containment spray system. The licensee indicates that with this improvement action it will be possible to address the following severe accident strategies: "Injection into containment", "Reduction of fission product releases", "Control of conditions in containment", "Containment flooding", "Mitigation of fission product emissions" and "Containment depressurisation".
- Evaluation of the advisability of providing the plant with a connection to a portable generator for feeding the control room emergency filtering units.

Almaraz NPP also plans to provide the plant with PAR's (passive autocatalytic hydrogen recombiners) aimed at improving the control of hydrogen, even in the case of prolonged SBO. The licensee indicates that with this improvement action it will be possible to address the following severe accident strategies: "Reduction of hydrogen concentration in containment" and "Control of hydrogen inflammability in containment".

As regards the accumulation of hydrogen in other buildings, Almaraz NPP has submitted a calculation of the concentration of hydrogen in the safeguards and fuel buildings. The conclusion of this calculation, performed using the MAAP-4 code, is that a concentration of 4% would not be exceeded.

In relation to possible improvements in containment pressure control, and with a view to providing the plant with different alternatives capable of mitigating a severe accident with pressurisation of the containment, Almaraz NPP will install a filtered containment venting system, having previously assessed the different alternatives existing and ensuring that the possible risks associated with this system are eliminated or reduced to acceptable levels.

As regards the instrumentation, the licensee points out that, in order to increase the robustness of the plant, the measurement of the necessary variables might be performed by means of a portable system that Almaraz NPP plans to acquire for the plant. This portable system would be connected to the terminals of the signals in the control room cabinets or in local cabinets.

In his report the licensee includes the times in which certain events (cliff-edge situations) would occur, for a set of severe accident sequences. The calculations were performed using MAAP-4. In the event of the AFW system being available for 30 hours (the time guaranteed on the basis of the inventory of water in the AFW and condensate tanks), core uncovering would occur after 41 hours and rupturing of the vessel after 49 hours.

- *CSN evaluation*

Both the emergency operating procedures (EOP's) and Severe Accident Management Guidelines (SAMGs) have been incorporated in this plant from the standards of the Westinghouse owners' group, PWROG. They are considered to be adequate for the performance of their functions and have been checked by the CSN by means of inspections and evaluations.

As regards additional reinforcement measures, the licensee includes those relating to portable equipment aimed at preventing or minimising damage to the fuel. All these improvement measures are considered to be positive, since they allow a prolonged SBO situation to be addressed with greater guarantees and have been discussed in the corresponding section of this report.

As regards prevention in relation to core damage sequences with high pressure in the primary, the manual steam generator relief strategy is considered positive. In addition, it is considered that the licensee should analyse and, where necessary, implement some improvement as regards the actuation capacity of the pressuriser relief valves in the severe accident coinciding with earthquake and complete loss of power sources scenario (including loss of d.c. sources).

The measures proposed by Almaraz NPP for severe accidents relating to hydrogen control (installation of PAR's) and containment depressurisation (installation of a filtered venting system and measures for feed of the containment spray system by means of portable equipment) are all considered to be positive.

In relation to the containment and reactor cavity flooding strategies, in his final report the licensee has analysed the important equipment and instrumentation that would be lost in the event of the containment being flooded. From the analysis performed the licensee concludes that the equipment intervening in certain of the alternative paths for water make-up to the containment might be affected, but that the main make-up paths would not. As regards the instrumentation, containment pressure transmitters PT-50-TMI and PT-51-TMI (wide range: -0.33 to 12.65 kg/cm^2) would be submerged, with pressure transmitters PT-6315 to PT-6318 (narrow range: -0.28 to 4.57 kg/cm^2) remaining above the level of the flooding. Also possibly affected would be 2 of the 4 hydrogen detection sensors on each train and 2 of the 5 containment air temperature elements. In relation to this issue, the licensee should analyse the possibility of relocating or protecting the aforementioned instrumentation, taking into account its possible use in the SAMG strategies. Likewise, it is considered that it would be advisable to specify in the SAMGs the important items of equipment that would be submerged depending on the level reached in containment and also to analyse the impact of the loss of this equipment on the SAMG strategies.

In relation to the containment venting strategy, the licensee's analysis concludes that not all the alternatives currently included in the SAMGs are effective. The only effective alternatives, as regards their providing a significant flow for compliance with the required function, would be the containment purge system and the hydrogen purge system; however, for these two systems it is not possible to guarantee that the vented flow would be channelled to the stack, since the design pressure of the ducts inside the fuel building and of the equipment (filtering unit, fans) is very low. The licensee is going to modify the SAMGs such that this limitation is adequately contemplated. The venting capacity will be substantially improved with the installation of a future filtered venting system.

As regards the portable instrumentation for the important parameters in severe accident management, the licensee indicates in his report that the incorporation of improvements is planned. However, the table summarising the list of improvements does not include this measure or the list of instruments that would be affected. The licensee should complete this.

Likewise, Almaraz NPP has estimated the accumulation of hydrogen in the safeguards and fuel buildings, to which leakage from the containment might reach in the event of a severe accident. For these calculations the licensee has used the MAAP-4 code, and submits a hydrogen concentration value for each building. The calculation is considered to be an acceptable approach as an initial approximation to the problem; however, the licensee should analyse in greater detail the possible hydrogen escape paths (venting, failure of vent lines, leakage across high pressure penetrations inside containment) and the dynamics of propagation in the different rooms of the safeguards and fuel buildings, taking into account their topology, in order to estimate possible local concentrations that, although short-lived, might lead to hazardous concentrations.

As regards the availability of boron to address possible returns to criticality, Almaraz NPP will establish a precaution in its procedures in order to ensure that only borated water is supplied to the RCS. Furthermore, having reviewed this strategy, the licensee has detected that the alternative of providing non-borated water from the essential services water system in order to replenish the level in the RWST and provide make-up to the RCS is not adequate, for which reason the decision has been taken to remove it from the SAMG.

The licensee has analysed the availability of equipment to address the strategies included in the SAMGs in the event of an earthquake and flooding; it is guaranteed that at least one SAMG strategy would remain available.

The improvement measure proposed to evaluate the need to provide the control room emergency filtering units with a connection to a portable generator, in order to guarantee the habitability of the control room in the event of a severe accident is considered positive.

In addition, it is considered that the licensee should extend the improvements proposed with an analysis of the following aspects (the conclusions of which might lead to design modifications or modifications to plant procedures):

- Management of severe accidents started from shutdown operation conditions.
- Capacity of the instrumentation associated with parameters critical for severe accident strategies to provide reliable information under the conditions corresponding to severe accidents in containment (for example, containment pressure, RCS pressure or containment hydrogen concentration).
- Leaktightness capacity of the containment isolation valves and penetrations under severe accident pressure, temperature and radiation conditions. It is considered that Almaraz NPP should analyse this issue in order to obtain an estimate of the leakage and, where appropriate, identify and implement potential improvements.

• **Loss of fuel pool inventory and/or cooling**

- *Licensee's position*

The spent fuel pool (SFP) cooling system is a safety-related system and as such is Safety Class 3 and Seismic Category I. In the event of a LOCA or loss of off-site power, the SFP cooling system pumps enter the manual sequence of connection of loads to the diesel generators. Although they close on a phase "A" isolation signal, the valves supplying component cooling water to the SFP heat exchangers could be opened manually to allow for their cooling.. The temperature of the water in the pool must be kept at all times at or below 60ºC (140ºF).

The following alternative cooling possibilities are available in the event of failure of the pool cooling system:

- Fuel pool heat removal systems. The SFP heat removal function may be performed by means of the following:
  - The refuelling water purification system (RW), by transferring water from the refuelling water storage tank to the fuel pool and vice versa.
  - If the loss of pool cooling is due to loss of the component cooling water system of the affected unit, the heat removal function may also be performed using the heat exchangers of the pool cooling system belonging to the other unit.
- Fuel pool inventory replenishment systems. The function of replenishing SFP inventory may be performed by means of the following:
  - Water may be pumped either demineralised to the SFP or from the reactor make-up system, which is seismic category I.
  - Emergency water make-up to the pool would be performed from the essential services water reservoir (Seismic Category I) by means of a connection to the RW system pumps discharge line. Both the essential services water system and the RW pumps and corresponding discharge line are classified as safety class 3 and seismic category I.
  - Water make-up by means of the hoses of the fire protection system (FPS). As a back-up arrangement there is also an alternative water supply from the hose connections located in the fuel building, in the area close to the pool, the water coming from the fire protection system distribution ring. The sources of supply in this case are the Arrocampo reservoir and the essential services water reservoir. The FPS is equipped with a diesel pump that would be available in the event of SBO.

These alternatives for SFP cooling and water make-up are contemplated in the corresponding plant failure operating procedure and auxiliary instructions.

The SFP is equipped with level instrumentation (two local indicators, range 10.6 to 14.6 metres) and temperature instrumentation (two local indicators that send a signal to the plant computer and generate an alarm in the control room, range 0 to 100 ºC).

As regards the risk of re-criticality in the SFP, the licensee has performed an analysis using the SCALE-4.4/KENO V.a programme. The conclusion of this analysis is that the fuel assemblies stored in the pool would not return to criticality, even in the event of the evaporated water being replaced with non-borated water, as a result of which the strategies contemplating replenishment with non-borated water are valid.

In the report the licensee includes calculations of the times available prior to boiling and to different water levels (to uncovering of the fuel assemblies) in the event of complete loss of cooling and for different heat loads in the SFP. The most unfavourable case would be at the initiation of the refuelling outage (all the fuel assemblies in the SFP); in this case the times obtained are 5.4 hours to boiling and 58.3 hours to uncovering of the fuel assemblies. In the case of the thermal load corresponding to the end of a typical refuelling outage, the time to boiling would be 14.8 hours and the time taken for the level to reach the upper part of the fuel assemblies would be 160.1 hours.

As regards the possible accidental draining of the SFP:

– The gate inflation joints have an HCLPF capacity of 0.3g.
– The cooling system suction and return piping has an HCLPG capacity of 0.3g. The return line contains an anti-siphon orifice measuring 1.27 cm (1/2 inch) in diameter close to the surface of the water to prevent the pool from draining by siphon action.

The licensee proposes the following improvements relating to loss of fuel pool cooling and inventory replenishment capacity:

– Design Modifications:
    - Installation of new Category I SFP water level sensors, with a range covering from the bottom of the pool to the surface.
    - Provision of pool temperature indication in the control room.
    - Seismic qualification of the FPS diesel pump, in order to increase the pool make-up capacity.
    - Availability of portable equipment for pool water inventory make-up.
    - Provide the capacity to replenish fuel pool inventory from the new seismic FPS.
    - Availability of portable instrumentation for the monitoring of pool temperature and level.
– Additional analyses:
    - Analysis of the possibility of equipping the plant with a pool spray system to simultaneously reduce fission product emissions and replace inventory.

The licensee also mentions tracking of the work performed within the framework of EPRI on the phenomena associated with the most severe phases of fuel degradation, as well as reevaluation of the procedure "Purification and Cooling of the Fuel Pool and Purification of the Refuelling Water Storage Tank and Reactor Cavity" as a result of work carried out in response to a CSN requirement and the recommendations of WANO SOER 2011-2.

- *CSN evaluation*

The licensee includes information relating to the design basis of the spent fuel pool (SFP) and associated cooling systems. These aspects have been evaluated and licensed during previous phases of the plant life. In addition, the equipment and related procedures have been repeatedly inspected by the CSN.

The licensee describes the measures currently available to respond to loss of SFP cooling scenarios. The current SFP cooling and water make-up alternatives would not be available in the event of SBO, except the fire protection system, which is equipped with a diesel pump (currently non-seismic). The measures proposed by the licensee to strengthen the cooling capacity in the event of SBO and earthquake are considered positive and necessary. The rest of the measures proposed are also considered to be positive.

As regards time limits, the licensee has not taken into account the decrease in level as a result of sloshing (10 cm for a 0.3 g earthquake). Considering this loss of coolant, the times available before boiling and uncovering of the fuel would be shorter. In view of the fact that this loss of level is around 1% of the total height of the pool, the effect is considered not to be significant.

- **Radiological protection issues**

- *Licensee's position*

The licensee indicates in his report that Almaraz NPP has an ample margin to respond to a design basis accident, from the point of view of the control room operators, with the habitability system operable. Even assuming that this were not available, adequate protection against radiation is ensured, the series of measures contemplated in this respect including the availability of masks and autonomous breathing equipment.

Almaraz NPP has estimated the dose that would be received by the personnel located inside the control room envelope in the event of a severe accident in both units following a prolonged loss of power and requiring containment venting. The results of the analysis show that assuming the vent to be filtered, establishing shifts and using personal protection equipment the estimated doses are lower than the emergency intervention levels. In addition, the licensee plans to evaluate in the medium term the advisability of equipping the plant with a connection to a portable electric generator for the control room emergency filtering units.

In relation to the radiological conditions in other emergency support centres, the preliminary estimate performed by Almaraz NPP points to the conditions being compromised, in the current situation, in the case of accidents involving core damage. The licensees proposes the construction of an Alternative Emergency Management Centre (AEMC) on the site, to be available in 2015, with the possibility of controlling the workers radiologically in order to guarantee their presence under adequate conditions. This proposal will be addressed conjointly by all the plants.

As regards the resources available for the monitoring and control of radioactive emissions in the event of an accident, Almaraz NPP can make use of the area and process radiation monitoring system, which includes post-accident monitors and sampling, of the environmental radioactivity alert network, of the emergency radiological surveillance plan (PVRE) and of procedures for calculation of the activity released.

The licensee also has personal protection resources, dosimeters and portable equipment for the radiological control of the workers and of levels of radiation and contamination.

The analysis performed by the licensee of the resources available in the scenarios studied has allowed the following improvement measures to be identified:

- Modification of the containment atmosphere emergency sampling system, making it independent from the electrical supply.
- Provision of additional resources for the performance of the emergency radiological surveillance plan under adverse conditions.

- Study of the possibility of installing batteries and/or solar panels at the environmental radioactivity alert network measuring stations.

In addition, an analysis will be performed, along with the rest of the licensees, of possible additional equipment and improvements to the current radiological protection resources to adapt them to the conditions potentially existing in the scenarios analysed. This analysis is expected to be completed in June 2012, as from when it will be necessary to implement the improvements identified.

As regards identification of the radiological conditions that might prevent the performance of local manual actuations, Almaraz NPP has made a preliminary estimate of the cubicles that would be affected by each of the strategies defined in the SAMGs currently in force following the occurrence of core damage, and has determined that for the local actuations contemplated in the SAMGs compromising radiological situations would arise. The licensee identifies the need to delve further into this issue. In this respect, the licensee plans to develop actuation guidelines for each of the SAMGs with the radiological protection issues to be taken into account depending on the expected doses.

As regards the spent fuel pools, the licensee has determined that loss of the shielding capacity, in the most unfavourable situation corresponding to the beginning of a refuelling outage, would occur with the water level 3 metres above the upper part of the fuel assemblies, and estimates the time taken to reach this situation at 38.2 hours. The licensee points out finally that under these conditions local interventions lasting 15 minutes could be performed with the currently established reference levels. In relation to the above, Almaraz NPP also proposes to perform a revision of the applicable procedure for spent fuel pool (SFP) cooling.

- *CSN evaluation*

The current design of the Almaraz NPP control room envelope has been evaluated and accepted by the CSN and guarantees that the exposure to radiation of the personnel located in the control room during any design basis accident in one of the two units will not exceed the limits of General Design Criterion 19 of Appendix A of the NRC's 10 CFR 50.

The CSN considers that the severe accident habitability analysis carried out by the licensee presents important uncertainties (containment leakage, characteristics and efficiency of the filtered venting to be installed, atmospheric conditions, control room air inflow, residence times, etc.). In this respect, the licensee's proposal regarding the evaluation of the advisability of providing the plant with a connection to a portable electric generator for the control room emergency filtering units is considered positive, although the analysis should be performed in the short term.

The proposal to build an AEMC is positively valued. A series of general conclusions in relation to this is included in section 4.1.c.

As regards resources for the tracking and control of radioactive emissions, the fact that Almaraz NPP has an environmental radioactivity alert network with indications in the control room and TSC is considered a strong point. Nevertheless, it would be advisable to improve this network in order to allow for the automatic reception of data in the control room and TSC in the medium term and their subsequent transmission to the CSN emergency response room.

Also considered positive are the improvement measures identified by the licensee and the analysis to be performed jointly and in coordination by all the licensees of the Spanish nuclear power plants in relation to radiological protection resources and equipment that it would be advisable to have available in the scenarios analysed in the present stress tests. In the specific case of Almaraz NPP, the analysis should contemplate at least the availability of the post-accident radiation monitors in prolonged SBO scenarios and their correct operation under severe accident conditions. The generic conclusions indicated in section 4.1.c are equally applicable.

The proposal to develop actuation guidelines for each of the SAMGs with the radiological protection issues to be taken into account depending on the expected doses is valued positively. Almaraz NPP should extend the analysis of impedimenta to the performance of local manual actions to include the new recovery actions (use of portable and sampling resources). The general conclusions in this respect are included in section 4.1.c.

As regards the methodology, calculation codes and input data used by the licensee to calculate dose rates depending on the level of water in the pool, these are considered to be adequate. Also considered appropriate is Almaraz's proposal to revise the procedure applicable for SFP cooling. In this respect, the general conclusion indicated in section 4.1.c is applicable.

4.2.6 Santa María de Garoña Nuclear Power Plant

4.2.6.a Extreme Natural Events

- **Earthquakes**

- *Licensee's position*

The original seismic design of the plant, defined using a Design Basis Earthquake (DBE) with a peak ground acceleration (PGA) of 0.20g, was completed prior to the seismic regulations which have since become part of common practice in the design of plants in Spain . Subsequently, under the so-called Systematic Evaluation Programme (SEP, 1983), a value of 0.10g was established for the safe shutdown earthquake (SSE or DBE). In the context of these stress tests, the earthquake data considered have been extended to include those occurring between 1st January 1983 and 31st July 2011, which has confirmed the validity of the SSE previously established.

The plant has a digital earthquake surveillance instrumentation system which complies with NRC RG 1.12 for the detection, plotting and analysis of seismic movements on site, and is fitted with a specific operational procedure should an earthquake take place, POA-751-001 "Action in the event of an earthquake".

The protection of the plant against the DBE is based on the seismic design of the Systems, Structuresand Components (SSCs) in accordance with their classification and maintenance, through the processes established under the licence, seismic classification and the correct SSC status, in addition to modifications and spares. Over the course of the Garoña plant's lifetime a number of different schemes have been implemented to alter the seismic classification of the SSCs, adapting them to current regulation and CSN requirements. The most significant of the aforementioned programmes are as follows:

- Project Mark I: the CSN issued a requirement (according to the NRC practice) regarding the re-assessment of the structural capacity of the Mark-I containment system, in consideration of new hydrodynamic loads in the suppression pool.
- Systematic Evaluation Programme (SEP): in relation to this issue the purpose of the programme was to review the codes previously used with the requirements in force at the time.
- USI A-46 (SQUG): as a result of the NRC Unresolved safety Issue (USI) A-46, all mechanical and electricalequipment (including relays) in operation at nuclear power plants not covered under SEP due to lack of methodology, were assessed from a seismic perspective.

The licensee assesses the seismic margins of the plant, using the work already completed using the methodology developed by the NRC and EPRI (review earthquake of 0.3g and full scope). In the latest IPEEE review, in July 2010, the HCLPF value was updated for a series of items of equipment and some new values were included, re-assessing the seismic margin for the plant. In the context of the stress tests the IPEEE has been complemented through the completion of new inspections and the extension of the scope to encompass all the functions for fuel confinement.

In accordance with the studies completed, the licensee assigns a minimum HCLPF capacity of 0.28g to the safety functions required to attain and maintain safe shutdown. This figure is limited by the capacity of the minimum voltage relay switch for the emergency assemblies BUS-E2-4C and BUS-E2-4D. It also identifies a seismic margin of 0.3g both for the integrity of spent fuel pool (SFP) and containment.

The licensee has assessed the available seismic margin in a range of items of equipment used for managing Station Blackout (SBO) and the Severe Accident Management Guidelines (SAMG). In all the systems analysed, a seismic margin of 0.3g has been attained, except in the Fire Protection diesel pump (only classified for DBE). The condensate transfer line to the SFP and the drainage pipe from this pool to the suppression pool remain pending of the EPRI methodology inspection; the licensee has suggested completing these inspections in the short term as an additional action in order to check their ability to withstand seismic events.

The effects of an earthquake with an acceleration of up to 0.3g on the movement of water in the SFP have been analysed. In no case would any significant loss of inventory occur, and the water spillage would not have an impact on the surrounding safety equipment.

The licensee has also analysed the possibility of an earthquake stronger than that used as the design basis affecting the Arroyo dam (Ebro reservoir), located some 70 km as the crow flies from the plant. This analysis concluded that the dam would remain intact during seismic activity of 0.358g which justifies the assumption that damage to the dam need not be taken into consideration as a design basis event for the plant.

Notwithstanding the above, a hydraulic analysis of the dam rupturing was completed using realistic hypotheses, the conclusion being that floodwater would not exceed a level of 515.75 m above sea level, and would not, therefore, affect the vital areas of the plant (plant grading level 518.0 m, and intake structure level 516.5 m). The time elapsed before the maximum level is reached would be more than 26 hours (the course of the river flows some 158 km from the dam to the plant) which would allow, in the hypothetical case of rupturing of the dam, sufficient time for appropriate preventive measures to be taken.

Compliance with current licensing conditions with regard to seismic resistance is ensured with the regular application of procedures, surveillance requirements and actions directed at correct maintenance of the SSCs and the seismic surveillance system, together with design alterations and related spares.

With regard to possible induced effects as the result of an earthquake, the report on the plant states the following:

- Fires and explosions: the licensee identifies the design basis for fire and explosions, indicating the fire risk assessment as the source used for establishing these parameters. Compliance with the design basis ensures protection of the power plant against the risk of fire; however, the licensee has identified the main inflammable material and explosive products in storage. In these cases, the seismic margin has been assessed, identifying measures to increase resilience to earthquakes to 0.3g, and the licensee indicates that a margin of 0.3g will also be checked in the hydrogen injection circuit.

– Internal flooding: the licensee identifies the current design basis, which does not consider the circumferential rupturing of non-seismic pipes. The licensee has completed an analysis of seismic margins in areas with safe shutdown equipment, presenting damage both from immersion and spraying, and has also completed spurious actions on the Fire Protection System. The licensee has also completed an analysis of flooding caused by large water sources for which a seismic margin cannot be guaranteed and an instrument analysis for flood detection. The licensee has identified lines requiring actions for adjustment of the seismic margin.

- *CSN evaluation*

The current licensing conditions for the seismic design of Garoña have been assessed and accepted by the CSN and have been inspected on numerous occasions by the CSN under its supervision programmes. The review, which takes into consideration seismic activity occurring between 1st January 1983 and 31st July 2011 confirms the established SSE value and deems it to be acceptable.

The HCLPF values estimated by the licensee are considered to be justified in accordance with the EPRI methodology. The CSN has yet to check the corrective action put forward by the licensee in order to increase the HCLPF value of the identified equipment with a margin of less than 0.3g, as well as an assessment of margins for some of the systems used in SBO and SAMGs.

As regards the rupturing of the Arroyo dam as a result of an earthquake, the licensee assigns a seismic margin (as capacity prior to rupturing) of 0.378g. These analyses are considered valid and are a justified estimate of the margins beyond the design basis; however, under the next section on *flooding* there are additional comments in the CSN evaluation.

With regard to possible induced effects as the result of an earthquake, and in addition to the generic conclusions in section 4.1.a, the following conclusions are drawn:

– Fires and explosions: the analysis completed by the licensee is considered correct. The proposed line of improvement is also considered appropriate, without making a full assessment of the specific measures to be taken as these have not been detailed.
– Internal flooding: the CSN evaluation considers that the licensee has completed a full analysis, identifying equipment which may be at risk of causing flooding, in order to assess seismic margins. However, the assessment concludes that these margin reassessments should cover pipelines which may cause an initiating event, as well as the loss of damage limitation systems, and therefore the licensee must complete the relevant studies. As regards possible flooding caused by large water sources, the CSN evaluation considers it to be appropriate to implement improvements for the intake structure in order to ensure greater resistance in case of the bursting of the circulating water pipe which, while considered a structure with a seismic margin of 0.3g, its failure would result in a scenario which has not been assessed within the framework of the stress tests.

The improvements proposed by the licensee in order to increase the robustness of the plant are considered effective, as they would allow for a seismic margin of 0.3g.

- **Flooding**

- *Licensee's position*

The design of the plant presents a Probable Maximum Precipitation (PMP), with an increased flow of water in the River Ebro which may reach up to 2502 m3/s, which would reach an elevation of 515.72 m, which would not affect the safe shutdown equipment (plant grading level: 518.0m and intake structure level: 516.5 m). An analysis is also made of the full and instantaneous rupturing of the dams upstream from the power plant. The estimated flows obtained, combined with 50% of PMP, result in flood levels not exceeding 516m, thus not affecting any vital elements of the plant. The licensee remarks that a chain reaction rupturing of these two dams has not been taken into account, as the total drainage capacity of the reservoir closest to the plant is greater than the flood wave.

Within the scope of the stress tests, and in order to identify the existing safety margins for these tests, Garoña indicates that a reassessment of the issue has been completed, with up to date methods and more accurate models, obtaining figures for the flow of water on site below those obtained in the design basis.

Finally, regarding the possible rupturing of the Arroyo dam, Garoña NPP has completed an analysis of the consequences of this, with realistic hypotheses, drawing the conclusion that the flood levels would not surpass 515.75 m and therefore not affect vital areas of the plant, and that the time taken to reach maximum levels would be more than 26 hours; (the course of the river runs 158 km from the dam to the plant) which would allow preventative measures to be adopted in the case of dam rupturing.

The licensee indicates that all the systems required to perform safety functions, both for the prevention and mitigation of severe accidents, are always available in the event of flooding.

The analysis of the clogging of the intake structure in the case of flood water resulting from rupturing of the Arroyo dam concludes that there would be minimal effect on the operability of the intake. No subsidence of the intake structure foundations or widespread clogging by sludge or mud is foreseeable. Consequently, this would not compromise water intake operation and cooling of the plant would be guaranteed.

A study was made of the variation in the water table levels on the site as a result of heavy rainfall, comparing the levels which may be reached with the foundations of the main buildings. The first level which would result in any impact, as a result of external flooding, on the equipment required in order to maintain the correct operation of the plant is 516.5 m (LPCI service water pumps and Fire Protection System (FPS) diesel pump). This level is not reached in either of the hypotheses presented, meaning that the level of safety against this phenomenon is adequate.

The reaction of the site and drainage systems of the plant to extreme rainfall has been analysed, identifying some improvements to be made to drains and drainage pipes, as well as the leaktightness of doors and buildings, which would provide additional robustness. These improvements form part of the programme presented.

With regard to heavy local showers, it is considered recommendable to fit check valves at the end of fall pipes, drains and drainage lines connected to the rainwater network in the turbine and service buildings.

- *CSN evaluation*

The design basis relating to the different events which may result in flooding of the site are summarised in the plant's Safety Analysis Report and have been assessed and inspected on several occasions by the CSN.

Regarding the effects of possible dam rupturing upriver from the site, the licensee's analysis differs from those contemplated on the emergency plans in practice in Spain. Consequently, the CSN considers that the actions required to bring both approaches into line should be undertaken, the licensee then revising his analyses and adopting the measures deriving therefrom.

The licensee has procedures for use in case of external flooding and severe meteorological conditions on site, which have been inspected under the CSN supervision and control schemes.

The measures proposed by the licensee in order to increase the plant's resilience to external flooding are considered appropriate.

- **Other extreme natural events**

- *Licensee's position*

A determining reassessment had been completed on external risks under the Systematic Evaluation Programme (SEP) at Santa María de Garoña in the 1980's. A probability assessment was later carried out on external natural events, ruling out the majority of these as they present a sufficiently low risk level.

In the context of the stress tests, the licensee has assessed the possibility of events caused by other natural phenomena of an external nature, identifying wind loads and low river levels as a result of the rupturing of the Sobrón dam as the most significant of these. Having assessed the maximum foreseeable wind loads, it was concluded that the design of the structures at the plant uses figures higher than those obtained. As regards the low river level, the licensee stated that it was found that due to the layout of the water intake, the removal of residual heat was not compromised in the long term, as the LPCI service water remained operable.

The licensee has also analysed snow loads, concluding that the probability of exceeding the limitations of the roofs is so low that no further analysis is necessary. As regards drought and high temperatures, and after the design modifications completed in 2007, which separated the pump room cooling from river water, the plant concludes that these do not affect the safety of the facility.

Other natural phenomena have also been analysed, such as lightening, hail, extreme temperatures and forest fires, establishing that adequate protection has been provided against these.

A procedure is in place for action in the event of severe meteorological conditions, which presents certain actions in order to deal with prolonged situations of isolation and outside electricity supply on site in the best conditions possible. These situations may be caused by: strong winds (pre-alert levels in the On-Site Emergency Response Plan, ERP), severe storms (orange alert from the Spanish Meteorological Agency, AEMET), intense rain (orange alert from AEMET), and heavy snowfall (red alert from AEMET).

The alterations made with regard to external events are:

- Review of the lightening conductors existing on plant building and drawing up of the appropriate preventative maintenance procedures.
- Inclusion of cleaning of the intake structure pool under a regular cleaning procedure.

- *CSN evaluation*

The filtering out of external events used to establish the design basis was drawn from the extremely low probability of these occurrences (10^{-5} per year) has been done in accordance with the probability methodologies covered under the applicable IPEEE regulations.

The analysis completed by the licensee has increased scope compared to those completed prior to the stress tests. Other credible events on the site have been addressed within reason, such as, amongst others: electrical storms, high temperatures, freezing, hail, and external fires. The results are considered satisfactory in general; although in some cases, such as the margins for extreme temperatures, these are still under examination by the CSN.

4.2.6.b Loss of safety functions

- **Loss of off-site power (LOOP)**

- *Licensee's position*

The licensee of Garoña nuclear power plant describes the off-site power supply resources, concluding that these are highly reliable and provide an optimum level of confidence with regard to their ability to recover off-site power swiftly.

As regards internal sources, for a LOOP situation, safety equipment is supplied by the automatic switch to the two emergency diesel generators, either of which allows a continuous supply of electricity to the equipment required to take the plant to safe shutdown. The generators are designed as Safety Class and Seismic Category I.

The direct current supply is divided into two systems, each with a battery and battery charger, with a third battery charger available to provide a third floating battery for alternate use as back up for the other two.

The gasoil system for the diesel generators consists of a storage tank, shared by the two generators, with a capacity to supply one generator for seven days and both generators in simultaneous operation for the first 24 hours.

In the event of zero voltage on the grid, the Spanish grid operator has recovery procedures in place organised by zones, which prioritise the recovery of power supply to nuclear power plants. In the case of this plant, this means priority reconnection from the nearby hydroelectric power stations of Sobrón and Aguayo which are equipped for autonomous start-up. Tests have been completed from the Sobrón hydroelectric station.

The preferred method for fuel cooling in a LOOP situation is the Isolation Condenser (IC), which starts automatically if pressure remains at least eight seconds at, or above, the system start-up set point. Should it not start up automatically, the operator will start the system manually. The use of the IC prevents residual heat from entering the suppression pool (SP). In order to keep the IC running, the water in the shell must be replenished after an hour of operation.

The water supply for the IC systems are the condensate transfer system and the fire protection system (FPS), the latter being seismic qualified in those sections safety related.

There are other cooling methods, with safety systems available, which may be used as an alternative to the aforementioned method, in case of loss of off-site power: the High Pressure Core Injection (HPCI) and the Safety and Relief Valves (SRV) with subsequent use of low pressure injection systems.

- *CSN evaluation*

The LOOP situation falls within the design basis of the plant, with a coping time of at least seven days. The situation considered in this subsection had therefore been assessed and licensed on previous occasions during the lifetime of the plant, and the different aspects of the procedure have been inspected by the CSN.

The external mains lines have different sources and routes; this independence provides reliability to the supply in this event (LOOP).

The procedures indicated by the plant to extend the autonomy of the diesel generators (transfer of gasoil from the auxiliary boiler system, supply from tanker truck to day tanks by force of gravity) provide an additional guarantee .

As regards the autonomy of the internal back-up supply, the diesel generators are cooled by air, and are therefore not dependent on the heat sink (river water); they are located over two metres above the maximum flood level identified in chapter 4.2.6.a of this report.

The preferred cooling method, the IC, draws on surplus water supplies. The other cooling methods with safety systems would likewise be available.

Regular testing of off-site power supply recovery from nearby hydraulic power stations is favourable, and it is considered appropriate to implement this shortly.

Based on all the above, the CSN considers that the foreseeable response of the power station in case of LOOP would be safe and in line with expectations.

- **Station Blackout (SBO)**

- *Licensee's position*

The licensee indicates that long term SBO does not form part of the current licensing basis. In order for a long term SBO to occur, in addition to the loss of external power supply for several days, these power lines must be fully disabled and with no possibility of recovery of the supply during the time the two diesel generators can continue to operate. As mentioned, these generators do not depend on the water supply from the UHS as they are cooled by air.

The plant indicates that no additional back-up alternating current supply has been required to be included in the design, given that the plant has systems fed by direct current which can guarantee the removal of residual heat. While initially an SBO coping time of just four hours was considered, the existing systems allow safe operation to be maintained for a prolonged period.

The preferred systems for fuel cooling in this case are the Isolation Condenser (IC) and the High Pressure Coolant Injection (HPCI). Both systems run on direct current.

The IC has a passive response, only requiring a motor-driven valve to be opened (automatically or manually) on the condensate return line; the water supply to the IC shell is guaranteed for at least 24 hours due to the autonomy of the fire protection diesel pump (refuelling can be done using fuel from the diesel generator storage tank).

The pressure in the reactor would gradually reduce in keeping with the residual heat. The use of the IC for residual heat removal minimises the thermal load passed on to the suppression pool.

The plant includes a detailed description of the IC system, and states that should fully manual start up be required, this operation is made possible with the use of a fixed ladder and a operation platform. The design has already been altered in order to allow for the partial opening of the aforementioned valve from the control room. Details are given of the regular tests performed on the system to confirm its capacity for heat removal.

As regards the HPCI, this system draws water preferably from the condensate storage tank (CST), which would compensate for the loss of inventory in the vessel with intermittent start-ups, of short duration well spaced out in time. The use of the HCIP to maintain the Reactor vessel level can be replaced with injected water via the fire protection diesel pump, having first depressurised the vessel.

The plant provides an assessment of how the temperature evolves in the HPCI turbine-driven pump room, confirming acceptable results.

The plant includes a list of systems which would remain available in the event of SBO: hydraulic system for control rod fast insertion (*Scram*); Batteries A, B and C and 125 V d.c. distribution system; essential 120 V AC assemblies; relief valves (RVs) and safety relief valves (SRV); IC; HPCI; condensate storage tank (CST); fire protection system diesel pump; primary containment venting valves; and instruments.

The instruments necessary for monitoring the main Reactor vessel and primary containment parameters are fed from Uninterrupted Power Systems (UPS)with direct current backup batteries, with an autonomy of seven hours; after which time the power supply for the associated ondulators would be transferred manually to the divisional batteries.

In case of SBO the loss of venting in the essential UPS rooms leads to an increase in temperature, which however does not affect the operation of this equipment. This consideration is based on results obtained from a test completed under a greater thermal load than that which would exist in case of SBO. The opening of the front and rear doors of the UPS cabinets would allow the temperature to be kept at acceptable values for the operation of these equipments.

The design and dimensions of the 125 V d.c. batteries allows them to last for longer than the four hours initially considered, by disconnecting unnecessary loads. These procedures permit an autonomy of 17 hours for battery A and 20 hours for battery B, while the duration for battery C coupled to train A would be 16 hours, and coupled to train B would be 19.5 hours; consequently, the resulting minimum autonomy would be 33 hours, connecting battery C to Train A.

Should neither the IC nor the HPCI be available, the procedures include instructions which require the reactor to be depressurised manually. The control of levels in the reactor, and therefore of cooling conditions, is done by injection using the Fire Protection System and venting of the containment atmosphere in order to keep control of the temperature in the Suppression Pool (SP). It has been estimated that the applicable time limit in case of joint unavailability of the safety systems from the start of an SBO event (IC, HFP, depressurisation and Fire Protection) is 1.5 hours; this time refers to a severe accident situation.

The time limits referred to in the CSN Complementary Technical Instructions (ITC) are those for depletion of the aforementioned batteries; the plant also gives, as a more restrictive deadline, 42.2 hours for core damage, without taking into consideration the proposed improvements.

The plant has also considered the eventuality of a hypothetical situation in which the 125 V d.c. batteries have fully run down, and the power supply has not yet been recovered, and provides considerations on the effect of this in each division; the IC system would remain available, for which it is sufficient to monitor the level on the shell side, the last can be done using a gauge not requiring electricity supply. The reactor level could be monitored using column instruments not requiring electricity.

The licensee also proposes an analysis of the possible manual operation of the HPCI should the d.c. power supply be lost.

- *CSN evaluation*

A four-hour SBO was effectively included in the Licensing Conditions for the plant. The assessment of the plant regarding prolonged SBO is considered to be basically correct, fundamentally based on the fact that the IC system is practically passive, as indicated above; furthermore, the HPCI system only depends on d.c. electricity supply in order to operate. The list of systems which would remain available in a SBO situation is considered correct.

After completing the reports for the preliminary phase, an CSN inspection in the plant was performed on all aspects considered relevant for the information provided in this section. Among others, the calculations were reviewed for prolonged autonomy of batteries, diesel generators, and details of the IC system.

The current features of the plant (not counting the planned improvements) present a number of strengths, as the two diesel generators are cooled using air and located above the maximum expected flood level, together with the batteries and d.c. buses. It is also worth noting the possibility of manual valve regulation for the IC condensate return line (this avoids unnecessary valve cycling to control reactor cooling rate); easy access to this valve for fully manual operation has been confirmed.

It is considered that, based on the characteristics of the IC system, a safe situation could be reached, even in the event of complete unavailability of electrical power.

The CSN considers that, despite the strengths described above, which allow for the use of the IC in an SBO scenario, the plant should complete a full complementary analysis which examines the feasibility of an alternative means of reducing the SP temperature, other than by containment venting. In addition, and as a means of improvement for increasing the plant strengths in these scenarios, and for the particular case of high pressure in the reactor vessel, the licensee should analyse the possibility of reinforcing the capacity for injection and depressurisation of the vessel.

The CSN evaluation, with the considerations indicated above, considers acceptable the assessments made by the licensee at this stage.

With regard to a procedure for manual operation of the HPCI system, given the difficulties this entails and including the associated radiological risk, the plant must demonstrate its feasibility, wherever possible contrasting it with similar plants, and evaluating the possibility of making design alterations and establishing some kind of real test in conditions which pose no risk of radiological exposure for workers.

- **Improvements proposed by Santa María de Garoña NPP regarding loss of power**

In order to improve the resistance of the plant in this kind of situation, the licensee proposes undertaking the following actions:

- Availability of a motor generator to feed a condensate transfer pump, the essential bus A, and the 125 C d.c. chargers “A” and “C”.
- Availability of an independent motor-driven pump taking suction from the CST with the capacity to supply the IC shell, the Reactor vessel and the SFP.
- Availability of a portable motor-driven pump taking suction from the river, supplying the Fire Protection System and connecting it to the IC shell, vessel and SFP.
- Fulfilment of regular off-site power supply recovery tests from nearby hydroelectric power stations.
- Analysis of HPCI and containment venting fully manual operation under loss of direct current conditions.

The planned improvements presented by the licensee are considered valid at this stage although the feasibility of using portable equipment is subject to the results of a specific analysis of the availability of staff required under section 4.1.c of this report.

With the implementation of these measures, the cliff-edge situation times would be extended and would depend on the autonomy of the portable equipment.

- **Loss of ultimate heat sink (UHS)**

- *Licensee's position*

The ultimate heat sink at the Garoña plant is the River Ebro. Water from the river is pumped up using motors located in the intake structure, and is used by the plant's cooling systems. A loss of Ultimate Heat Sink (UHS) is understood to be the loss of the connection between the cooling systems and the river.

There are systems in the plant which do not depend on the river as a heat sink, as they transfer heat to the air, such as: emergency diesel generators; Isolation Condenser (IC) and the essential chilled water systems for cooling of the control room, electrical equipment rooms and LPCI and CS (core spray system) rooms. This equipment remains operative in case of loss of UHS.

Under a hypothetical loss of UHS, one of two situations may arise: a) the loss of the intake structure is due to on-going events, which may be identified in time, before they affect the plant and allow the preparation tasks established in the relevant procedures to take place, such as commencing a shutdown of the plant and the stockpiling of water in the Plant's tanks; b) the loss of the intake structure occurs suddenly.

In the event of loss of the intake structure, the service water system pumps are tripped, thus losing cooling for the turbo generators, condensate and water supply pumps, recirculation motor generator, control rod drives (CRD) and heat exchangers in the closed circuit cooling system, affecting, among others the cooling of the spent fuel pool (SFP). In this case, the reactor is cooled using the IC, which can remove residual heat from the reactor, preventing heat from reaching the suppression pool.

The water collected in the plant's tanks allows the core to be cooled using the IC. The tanks can be refilled using the condensate transfer system pumps. 1550 m3 are required to keep cool the core using the IC for seven days. The condensate tank has that capacity. As an alternative to using the tank and condensate transfer pumps to supply water to the IC shell, a portable motor suction pump could be provided, with the discharge connected to the fire protection system. From this system, water can be fed into the IC and where necessary, to the reactor, if pressure has been lowered to a level compatible with injection into this system.

Should the IC not be available for the removal of residual heat, the following method, described in the section on SBO can be used: injection into the reactor (HPCI or low pressure ECCS having first depressurised the reactor) and removal of heat from the Suppression Pool (SP) using the containment dedicated venting system.

As the CRDH pumps are not operative, there is no water supply to the recirculation pump seals, this resulting in possible leakage across these seals; if this occurs and the isolation valves to the re-circulation pumps cannot be closed, this leak can be compensated using intermittent HPCI injections, in short bursts and at long intervals.

The licensee has not identified additional extreme situations for this scenario to those presented in the section on SBO, and therefore neither are any necessary improvements for reactor cooling identified.

- *CSN evaluation*

See assessment of next section

- **Loss of ultimate heat sink combined with SBO**

- *Licensee's position*

Should a situation of SBO coincide with a loss of UHS there will be no cooling methods drawing water from the intake structure or alternating current pumps which can supply water to the IC shell or the reactor vessel.

The sequence of events in such a case would be as follows:

1. Removal of residual heat using IC for the first hour. After this time, the system will remain out of service as it will no longer have a water supply to the shell. Operation can be resumed if alternative supply measures are fitted (motor-driven pump taking suction from the condensate tank drawing water through the condensate transfer system, or motor-driven pump taking suction from the river to the Fire Protection System header). If no other supply methods are available, the reactor must be continued to be cooled using the following method.

2. Injection to the reactor with HPCI to maintain the inventory and removal of heat from the SP using the containment venting. The start-up of the IC at any point in this sequence would stop heat from being transferred to the SP.

3. Depressurisation of the reactor using the relief valves and/or safety relief valves until a pressure is reached which allows water to be injected into the reactor at low pressure. In a situation of SBO with loss of the intake structure the fire protection diesel pump is not available, meaning that this strategy can only be used if there is a motor-driven pump connected to the fire protection system or the condensate transfer system, with a supply line to the vessel through CS system lines or LPCI. Removal of heat from the SP would be done via containment venting.

If the only means of removing heat is to use the HPCI with primary containment venting, the loss of direct current division "A", which would occur 33 hours after the onset of SBO, would render the HPCI, the containment venting inoperable, without the capacity to depressurise the reactor (because of the loss of safety and relief valves).

The manual start-up of the IC with a supply from alternative methods, at any time prior to the loss of the direct current division "A" or even within seven hours of the loss of direct current, alters this evolution, interrupting the heat discharge to the containment and ensuring the cooling of the core. During this 40-hour period there are no radiological conditioning factors for access to the reactor building other than those found in normal operation.

Another option for the removal of residual heat is the recovery of HPCI operation, together with containment venting. In this regard, the possibility of activating this means of residual heat removal after loss of direct current should be studied.

The planned modifications for the case of SBO, described in the section on the loss of electrical power, try to ensure the availability of d.c. power supply and the water feeding for the IC shell in the long term.

The licensee has also analysed compliance of the safety functions in different stages of a scenario of loss of cooling functions in other modes of operation. In order to do this, up to nine operational phases during a refuelling outage have been studied, the conclusion reached being that the most critical phase is the one from operation condition 5 (cold shutdown) to the start of the process of refilling the reactor cavity, in terms of the time available for taking action.

- *CSN evaluation*

The information regarding the design basis of the UHS has been assessed and licensed by the CSN in the past. Furthermore, the related equipment and procedures have been inspected by the CSN on repeated occasions.

The licensee has provided an adequate description of the provisions made in the design for dealing with loss of the UHS, and has analysed the situation which would result from loss of the UHS with and without SBO, with sufficient scope.

In the case of loss of the UHS with and without SBO, the licensee has identified and proposed improvements in order to increase the resistance of the plant. These measures are the same as those identified in the section on loss of power supply given that loss of the UHS would lead to a plant situation where, in order to protect the safety functions, the same systems would be used as for the loss of power.

There are no time limits for the case of loss of UHS, given that there is the capacity to replenish the IC as electricity is available. In the case of loss of the UHS with SBO, water cannot be supplied to the IC, but there is the possibility of injecting water into the vessel using the HPCI and removing residual heat through the containment dedicated venting. It is considered that the licensee should analyse the feasibility of operating the venting valves and the HCIP manually, and, where necessary, test this capacity. Furthermore, the licensee should analyse the habitability of the rooms affected in case of SBO.

The planned improvements proposed by the licensee are considered appropriate.

4.2.6.c Accident management

- **Planning of accident management**

- *Licensee's position*

The licensee proposes an analysis of the organisation and resources available for the management of emergencies in accordance to the proposals of the other Spanish power plants.

In keeping with the start-up of the new Alternative Emergency Management Centre (AEMC), the plant licensee proposes a series of more in-depth improvements in the area of communications, whose analysis will be completed in the short term and whose implementation is proposed in the long term.

In relation to the site access routes, the licensee reports the existence of at least one feasible access route in the event of a severe earthquake; accordingly, the licensee proposes the possibility of using air transport for human resources from Miranda de Ebro and Medina de Pomar and considers reinforcing the main access bridge to the power plant, which will be implemented in the mid-term. In the case of floods caused by rupturing of the Arroyo dam, the licensee points out that it has 14 hours before the site access roads would be affected; the licensee considers this to be sufficient time for transporting the required personnel and resources to the site.

The licensee maintains the reference dose levels for personnel intervening in an emergency as provided in the current On-Site and Off-site Emergency Response Plans (ERPs).

- *CSN evaluation*

The report submitted by the licensee does not include actions for reinforcing the plant's communications in the event of a prolonged SBO. Therefore, the licensee must analyse this issue and report on the measures for improvement and the term for implementation proposed. In the other side, the most important improvements in communications which will be associated with the start-up of the new AEMC, and are considered acceptable; however, the licensee must study and report on the incorporation of provisional measures in the short to medium term to ensure improvements to capacities, albeit partial, before the long-term implementation dates.

In relation to the access routes to the facility in the event of earthquakes or floods, the analysis submitted by the licensee is considered generally acceptable; however, it must be completed with an analysis of the time the accesses might be out of use in the said cases and, more specifically, in the event of flooding caused by rupturing of the Arroyo dam and the compensation measures in place for said periods.

With regard to the reference dose levels for personnel intervening in an emergency, as already mentioned in section 4.1.c of this report, the CSN considers it necessary to establish consistent reference levels for every Spanish nuclear power plant. However, in the short term the licensee must consider a framework that guarantees individual protection and the feasibility of carrying out actions designed to reduce the emergency level, as provided in TECDOC 953 and the BSS's of the IAEA.

- **Measures for the management of accidents in the reactor**

- *Licensee's position*

The licensee describes the measures in place in terms of equipment, procedures and human resources to prevent, mitigate and manage severe accidents; it also specifies the strategies that are to be applied in guides and procedures as the conditions of the plant worsen. As a conclusion to its analysis, Garoña proposes various actions for increasing the plant robustness in such an event through the incorporation of a number of improvements.

With regard to preventing hydrogen hazards in containment, one of the main characteristics of the Garoña primary containment is the fact that the atmosphere is kept inert. Consequently, there is no risk of hydrogen explosions. There are equipments available for detecting hydrogen and oxygen concentrations in the containment. Should specific values be reached, the primary containment would be vented and purged with nitrogen.

In relation to possible accumulations of hydrogen in other buildings, the areas with accumulation hazards will be identified and passive recombiners will be installed.

With regard to preventing overpressure in the containment, besides venting using normal systems and spraying of the dry well, the power plant has containment dedicated venting. This venting has a preferential line from the suppression pool (SP) chamber, with a pneumatic valve and another motor-driven valve in series and dependent on direct current. This venting channel allows for use of the SP radioactive products retention capacity, preventing them from reaching the exterior.

The licensee indicates that modifications will be made to improve the operability of the venting system in situations involving the loss of direct current and the development of a procedure for manual opening of the venting line valves.

The licensee will install a filtered containment venting system, taking into account the radiological analyses that have been made and their possible interference with venting capacity through overpressure.

With regard to the prevention of a possible reactor core return to criticality, the licensee provides two strategies at the present time, which consider the preferential use of the Standby Liquid control System (SBLC) to shut down the reactor and avoid core recriticality, and mentions that to have recriticality situation in a BWR reactor (in sequences not started by ATWS), it would be necessary to have a loss of almost all the control rods without loss of the fuel geometry. The plant has an alternative method for injecting boron into the reactor vessel using the reactor water cleanup system (CU) pumps (the source of boron solution would be the SBLC tank or, alternatively, the cleanup system pre-layer tank; in the latter case, the boron solution would need to be prepared previously, for which there is at least 600 kg of boric acid and 600 kg of borax at the site.

In relation to preventing containment foundation slab penetration, the licensee has SAMG strategies such as flooding the drywell when there is a risk of reactor vessel failure, or spraying the dry well after this failure has been determined for the direct cooling of the molten core. The long-term aim is to flood the containment as soon as possible until the molten material is covered.

The emergency depressurisation of the vessel would be carried out by the relief and safety-relief valves (RVs and SRVs). For the RVs to operate, it would only be necessary to connect their solenoids to direct current. For the SRVs valves the pneumatic supply is also necessary. In the event of a loss of the pneumatic supply, each valve has a nitrogen accumulator tank. With regard to the requirement for direct current, evidence is given of its availability for a period of 33 hours in the corresponding chapter. As a measure for improvement, the installation of a diesel generator is proposed to supply electricity to a division-A power bus, which would supply both 125 V d.c. electrical divisions. The licensee is also analysing the possibility of using portable batteries to open the RVs.

If necessary, the containment would be vented through the dedicated venting line, preferably via the suppression chamber (there is another venting channel from the dry well). The venting system has a motor-driven valve supplied by direct current, which can be opened manually using a flywheel, and two pneumatic valves (operated by the instrument air system or, as a back-up, with bottles of N_2, which are controlled by direct-current solenoid valves). The aforementioned proposed improvement of installing a diesel generator to feed a power bus of division A would make it possible to actuate the aforementioned valves. Furthermore, as a proposal for improvement, there would also be a procedure for the manual opening of said valves.

In relation to the feasibility and effectiveness of the existing measures for accident management under extreme conditions, the licensee reports that the results corresponding to the external flooding analysis show that the level reached for the maximum flood does not compromise the availability of the required systems. In the event of an earthquake, the preferential systems are generally classified on a seismic basis, whereas the alternatives may not be classified.

The licensee indicates that, for the LOOP, SBO and loss of UHS scenarios, there is seismically classified equipment available that would not be affected by floods with regard to implementing the SAMG strategies. The improvements proposed for the SBO coincident with loss of the UHS scenario would be as follows: installation of a diesel generator with the capacity for supplying a division-A electrical power bus, which would make it possible to supply one of the condensate transfer pumps, and the installation of a fixed diesel pump taking suction from the condensate storage tank and with the capacity to inject to the SFP and/or the reactor vessel.

In relation to the adequateness and feasibility of the instrumentation, the licensee includes specific information on the instruments used for monitoring and managing an accident in accordance with the classification criteria of Regulatory Guide 1.97, and states that it has been verified that, for the instruments classified as Category 1, the radiological conditions present during the severe accident are compatible with the environmental classification criteria of said instruments. It also states that it will also have the capacity for a direct reading of selected variables from the control room, remote shutdown panel or reactor building through the use of portable calibrators, which will guarantee their reading in conditions involving a total loss of power.

The licensee also analyses the effects of the flooding required in the severe accident affecting the equipment/instruments of the primary containment, identifying the main equipment and instruments that would be affected during the primary containment flooding process defined in the SAMGs. It concludes that, during this process, no equipment or instruments required for operation according to the applicable SAMG strategy are affected.

The licensee includes proposals for ensuring feeding capacity to the IC shell, the suppression pool and the reactor vessel in SBO and loss of the UHS conditions, as described in the section on the loss of safety functions.

The licensee will analyse the minimum lighting required to ensure access to areas with equipment that needs to be operated in accident situations. With the conclusions of this analysis, it will review the corresponding procedure and assess the possibility of separating the lighting circuits or replacing certain lighting for a lower-consumption technology.

In his report, the licensee includes a table with limit times for the case of SBO under power. According to this table, the core damage would occur at 1.5 hours after the start of the accident in the extreme case of the direct current not being available from the first moment when the accident starts. For the case in which the direct current is available for 33 hours, enabling the operation of the HPCI system, damage to the core would occur at 42.2 hours.

In relation to the analysis of accidents in other operating modes, the licensee gives the strategies available for the different phases of a refuelling outage. It states that the procedures in place for dealing with refuelling accidents are abnormal operating procedures (in some cases, they refer to the use of Emergency Operation Procedures, EOPs, strategies). It also sets up limit times to the beginning of fuel uncover in the core and in the in the spent fuel pool. The licensee states that the planned improvements (diesel generator, portable pumps and fixed diesel pump) will enable a reduction of alignment times and guarantee water supply to the reactor vessel before reaching boiling conditions.

- *CSN evaluation*

Both the EOPs and the SAMGs have been implemented by the plant on the basis of the General Electric owners group standards, BWROG. They are considered appropriate for the corresponding function and have been checked by the CSN through inspections and assessments.

With regard to last resort measures for avoiding the possibility of damage to fuel in high pressure sequences, the licensee has specified in his report the measures in place for depressurising the vessel during accident management in such a scenario. The improvements related to the electricity supply of the RVs and SRVs solenoids are considered appropriate. However, it is considered that the licensee should analyse the capacity of the current nitrogen supply to the SRVs in the event of a prolonged SBO and, if necessary, consider improvements for reinforcing and guaranteeing this supply.

The measure involving the installation of passive recombiners proposed by the licensee in relation to possible accumulations of hydrogen in other buildings is considered appropriate.

With regard to containment venting, the measures indicated by the licensee are considered positive, especially the installation of the filtered venting. Furthermore, it is considered that the licensee should analyse the capacity of the current nitrogen supply to the system valves in the event of a prolonged SBO and, if necessary, consider improvements for reinforcing and guaranteeing this supply.

In relation to preventing containment slab penetration, the strategies defined in the SAMGs are considered appropriate.

As regards the instrumentation reading capacity in the event of complete loss of power, the licensee indicates improvements that are considered positive. When implementing this improvement, the licensee should take into account the critical parameters throughout the phases of the accident (including severe accidents).

The analysis performed by the licensee for other operating modes is considered appropriate with regard to the strategies already in place in the abnormal operating procedures and EOPs. Although many of these strategies would be attempted in the event of a severe accident, the analysis is considered incomplete because it does not cover all the characteristics associated with this type of accidents (e.g. the phenomenology related to hydrogen or the availability of instruments in severe accident sequences). Consequently, it is considered that the licensee should complete the analysis of the management of the severe accidents that occur from shutdown operating conditions.

Furthermore, it is considered that the licensee should incorporate into its list of improvements the analysis of the following issues (their conclusions could require plant modifications or procedures changes):

- Capacity of the instruments associated with critical parameters for severe accident strategies with regard to providing reliable information under severe accident conditions in the containment (for example: containment pressure, RCS pressure or hydrogen concentration in containment).
- Leaktightness capacity of the containment isolation valves and penetrations under severe accident radiation, temperature and pressure conditions. It is considered that the plant needs to analyse the issue to obtain an estimate of the leak and, where applicable, identify and implement potential improvements.

- **Loss of fuel pool inventory and/or cooling**

\- *Licensee's position*

The fuel pool filtering and cooling system (FPC) comprises two identical trains; both share the pool discharge and suction line. The cooling water for the heat exchangers is supplied by the reactor building close cooling water system. The FPC pumps are fed by emergency alternating current and each pump is supplied from an independent electrical division.

The FPC system can be complemented by the shutdown cooling system (SHC), which comprises two identical cooling trains; each one has a centrifugal pump operated from the control room and a heat exchanger. Each system pump is powered by emergency alternating current.

There are also two alternative cooling systems that allow for the removal of the maximum thermal load in the pool under the different operating conditions of the plant. The seismic design of its components guarantees availability even in the event of an earthquake. They are also electrically powered from the emergency busses, covering any situation of loss of off-site power. These systems are as follows:

a) Alternative system (CST-based):

- This enables the water supply from the Condensate Storage Tank (CST) with one of the condensate transfer pumps and the drainage of said water, from the pool overflow tanks, back to the CST.
- This alignment can be used in the event of a loss of normal cooling after an earthquake during the first 72 hours, giving time for the availability of other alignments of the alternative cooling system.

b) Alternative fuel pool cooling system (LPCI-based):

- The second alignment for alternative cooling uses a discharge line from the overflow tanks to the suppression pool, trough the discharge of the LPCI 'B' loop test line.
- This second alignment enables the cooling of the pool indefinitely, since the suppression pool can be cooled by the LPCI service water system.
- An additional alignment is possible, consisting of using an LPCI pump aspirating from the CST and discharging into the spent fuel pool. This alignment can be used in cases in which the SP is not available.

In the event of failure of all the cooling systems, the plant has the following methods for the supply of water to the pool: from the CST using any of the condensate transfer pumps; the LPCI system in pool injection mode; the demineralised water transfer system; the fire protection system (FP) via the hose posts and the hoses located in the refuelling plant. The water can be supplied in complete absence of electrical current through the use of the FP diesel pump. This supply system (diesel pump and FP pipes to the hose post) are seismically qualified.

Furthermore, in a situation of a refuelling outage, with the cavity flooded and the SFP doors removed, any system for injecting water into the vessel can be used as a system for supplying water to the pool.

The control room has SFP water temperature and level alarms and indicators. The level instrument has a range of 2.2 m, and the temperature instrument has a range of 0°C to 200°C. As a proposed improvement, the current level instrumentation will be replaced by other that covers the entire range up to the top of the fuel assemblies.

The licensee has analysed the loss of SFP inventory that would occur as a result of the seismic action (sloshing) and has drawn the conclusion that 26.3 m^3 of pool water would be lost as a result of this phenomenon.

In his report, the licensee includes calculations of the times available up to boiling in the event of total loss of SFP cooling and for different thermal loads. The worst-case scenario is the maximum temporary thermal load (pool gates in position and all the fuel located in the pool), initial level of seven metres above the fuel assemblies and initial water temperature of 65.5°C; in this case, times of 5.5 hours are obtained for the onset of boiling and 75 hours until the fuel assemblies are uncovered. Considering the sloshing phenomenon and taking into account the volume lost, the times available in this situation would be reduced by approximately three hours. In the case of the thermal load corresponding to the end of a standard refuelling process, the time to the onset of boiling would be 21.5 hours, with 288 hours before the level reaches the top of the fuel assemblies.

In relation to the possible accidental drainage of the SFP, the following measures are available:

- The passage between the SFP and the refuelling cavity, positioned above the reactor vessel, is fitted with two sealed gates with monitored drainage between the gates; This system enables the detection and repair of leaks.
- The aspiration and return pipes of the SFP cooling system have an HCLPF capacity of 0.3 g. To avoid unintentional drainage of the pool, it has no penetrations below a safe storage level and the pipes submerged in the pool are fitted with an anti-return siphon that prevents the inversion of the flow.

- *CSN evaluation*

The licensee includes information on the design basis of the SFP and its associated cooling systems. These issues have been evaluated and licensed in previous stages of the plant life. Furthermore, the related equipment and procedures have been inspected by the CSN on repeated occasions.

The licensee describes the measures that are currently available for scenarios involving SFP cooling loss. The current alternatives for cooling and replacing water in the SFP would not be available in the event of SBO, except for the fire-fighting system, which has a seismically classified diesel pump, but is located in the river intake structure. Accordingly, it would be inoperative in the event of UHS loss. To solve this situation, the licensee proposes using the independent and portable water supply motor-driven pumps described in the sections on SBO and UHS loss with SBO. Said measures are considered positive.

In relation to the SFP level and temperature instruments, the licensee proposes increasing the level range up to the top of the fuel assemblies stored in the pool. In keeping with the considerations included in the general section of this report, the CSN considers that the level instrument range should cover up to the bottom part of the fuel assemblies.

The licensee has analysed the loss of inventory that would occur as a result of seismic action in the SFP (sloshing) and has drawn the conclusion that 26.3 m^3 of pool water would be lost as a result of this phenomenon. It is considered that the effect is significant since the times available for taking emergency supply measures are reduced by three hours in the worst-case scenario (and 13 hours for the case of the thermal load corresponding to the end of the refuelling process), whereby the licensee should be required to perform a more detailed analysis of this situation.

In his report, the licensee includes the design provisions for avoiding unintentional drainage (doors and anti-return siphons), but does not include the seismic capacity of the doors and devices for guaranteeing their leaktightness. The licensee should complete its analysis on this issue.

- **Radiological protection issues**

- *Licensee's position*

The envelope of the Santa María de Garoña plant control room, in which the Technical Support Centre (TSC) is located, has an independent air venting, recirculation and filtration system that guarantees habitability conditions in the event of a design basis accident. The centres are fitted with an appropriate number of protective equipment for the personnel working there.

The licensee has analysed the radiological impact on the control room envelope during a severe accident, with a prolonged loss of power and with containment venting. The study concludes that, during a period of more than 72 hours, the estimated doses are lower than the emergency intervention levels, without the need for recovery of the functionality of the control room habitability system or using special protection.

In relation to the radiological conditions in other emergency support centres, the plant has performed a preliminary analysis of the radiological impact on the Operative Support Centre (OSC) and has concluded that in some phases of the accident evacuation would be recommendable for radiological reasons. The licensee proposes the construction of a new Alternative Emergency Management Centre (AEMC) on the site, available in 2015, with the possibility for the radiological control of workers to guarantee their permanence under appropriate conditions. This proposal will be afforded conjointly by all the plants.

In relation to the resources available for monitoring and controlling radioactive emissions in the event of an accident, Garoña has a radiation monitoring system that includes post-accident sampling and monitoring, the Emergency Radiological Surveillance Plan (PVRE) and calculation programmes and procedures for determining the activity released.

The licensee also has personal protective resources, dosimeters and portable equipment for the radiological control of workers and radiation and contamination levels.

In order to improve the overall capacity in emergency situations, the licensee proposes improvements to the means of radiological protection for workers and to those related to the impact on the exterior. Accordingly, all the Spanish plants will constitute a joint working group to analyse possible additional equipment and improvements to adapt current equipment to the potential conditions that may exist after the events that have been analysed. Said analysis will be completed before 30 June 2012 and the improvements that have been identified will then need to be implemented.

The plant has performed a preliminary estimate taking into account air activity emissions, doses in some locations (reactor building, suppression pool (SP), turbine building and outdoor areas), identifying that, after core damage the SP zone is not accessible, time control is required in the reactor building and the turbine building and exteriors are not accessible in the case of containment venting. So as not to lose the alternative for manual venting from the suppression chamber, the licensee proposes developing a specific procedure for the remote opening of the suppression chamber venting valve .

In relation to an accident involving the loss of SFP cooling, and based on the calculations that have been performed, the licensee establishes that in the worst-case scenario corresponding to the start of the refuelling process, with water levels of one metre above the fuel assemblies, access and permanence in places near to the pool should be restricted. With a level of two metres above the fuel assemblies, there would be no restriction to permanence. There is a term of nine days from when the accident begins to reach a water level of two metres above the elements.

The licensee states that, from when the SFP water starts to boil, there is a risk of emissions into the circulating air, which would require the isolation of the secondary containment. As a proposal for improvement related to the pool level instrumentation, the licensee proposes replacing said instruments with others that cover the entire range up to when the elements are uncovered.

- *CSN evaluation*

The current design of the control room envelope of the plant has been assessed and accepted by the CSN and guarantees that the exposure to radiation of the personnel working in it during any design basis accident does not exceed the limits of the NRC's 10 CFR 50.67.

The CSN considers that the habitability analysis performed by the licensee in the case of a severe accident contains important uncertainties (containment leaks, retention in the suppression pool, specifications and efficiency of the filtered venting that is to be implemented, atmospheric conditions, incoming airflow into the control room, residence times, etc.). Consequently, in order to strengthen the plant capacities in the event of SBO, the licensee must perform in the short-term an analysis of the implementation of a system for providing alternative electricity supply to the control room emergency filtering units.

The proposal for the construction of an EAMC is considered positive. The conclusion drawn on this issue is applicable, as provided in 4.1.c.

In relation to the resources available for monitoring and controlling radioactive emissions, it is considered appropriate for Garoña NPP to implement, in the mid-term, a on-line monitoring network with automatic data reception in the control room, TSC and CSN emergency response room.

The CSN supports the analysis that is to be performed in conjunction with other power plants on the radiological protection equipment and means that should be available for the scenarios covered by these stress tests. In the case of this plant, the analysis must include at least the availability of the radiation monitors and the post-accident sampling system monitors in prolonged SBO scenarios and their correct operation under severe accident conditions. The general conclusion provided in section 4.1.c of this report is also applicable.

With regard to the analysis for identifying radiological conditions that would prevent local manual actions, the plant should extend its study to incorporate not only the actions provided in the SAMG, but also those provided in the new recovery actions through portable and sampling means. Section 4.1.c contains the general conclusions drawn on this issue. The CSN will request the development of action guidelines for each SAMG with the radiological protection issues that must be considered depending on the foreseeable doses. Accordingly, the CSN supports the licensee's proposal of drawing up a specific procedure for the remote opening of the suppression chamber vent valve.

The CSN considers appropriate the methodology, calculation codes and initial data used by the licensee to estimate the dose rates according to the SFP water level, and the modelled situation is considered conservative. The licensee will be requested to ensure that the plant procedures incorporate the radiological protection issues that are to be considered in the local manual actions anticipated. Section 4.1.c contains the general conclusions drawn on this issue.

4.2.7 José Cabrera nuclear power plant (in dismantling phase)

José Cabrera Nuclear Power Plant is currently in the dismantling phase and all its spent fuel is located in an Individualised Temporary Storage (ATI) facility, located on the site itself and comprising 12 dry storage casks with an inert atmosphere (HI-STORM 100Z cask system), positioned on a reinforced concrete slab.

The storage system has the appropriate safety margins and does not need active systems or components for the corresponding safety functions; in particular, it does not need electrical power sources for operation or monitoring systems to guarantee said functions. The system provides confinement, protection from radiation, criticality control and passive heat removal from the spent fuel.

4.2.7.a Extreme Natural Events

- **Earthquakes**

- *Licensee's position*

The original seismic design of the José Cabrera nuclear power plant was defined by the safe shutdown earthquake (SSE) of 0.07 g and, therefore, the design basis earthquake value of the ATI could have been the same. However, the structural assessments of the ATI were performed by taking into consideration an earthquake of 0.25g as the DBE.

The methodology used to establish the DBE of the ATI facility has been deterministic and comes from the standard alternative allowed by the 10CFR72.103 for sites with relatively low seismicity, to which the ATI corresponds.

The most recent studies on the activity of the faults near the site are not yet conclusive and the representation of the seismic activity in the area with a seismotectonic province has been considered appropriate. The seismicity has been reviewed in a radius of 320 km around the facility, extending the time period initially considered to 30 June 2011 and using the catalogue of the Instituto Geográfico Nacional (IGN). The estimate of the effects of an earthquake of a magnitude of 6.0 on the site, with two hypotheses on the seismogenic source, corresponds correctly to the acceleration of 0.25 g adopted as the DBE in the facility design.

During the power plant dismantling phase, the capacity for recording the previously installed seismic monitoring system is maintained, which makes it possible to obtain a quick response regarding the scope of the seismic event if it were to occur. In addition, the facility has the resources and procedures for inspecting, monitoring and recovering the status of the casks under accident conditions.

In the proximity of the ATI there are no structures, equipment or components that might give rise to indirect derivative effects from the DBE that may affect the safety of the facility. The storage system is classified as safety-significant, but not so the support slab on which the casks stand.

The support slab determines partial safety margins that vary between 1.13 and 2.44 and guarantee a very conservative design. The loss of adherence would occur with a horizontal acceleration of 0.28 g, which is when the casks would start to slide. The possibility of the casks turning over would be reached with the combination of a horizontal acceleration of 0.55g and a vertical acceleration of half the horizontal acceleration. The structural analysis of the slab identifies a guaranteed seismic capacity of more than 0.25g, which enables the evaluation with a minimum value equal to that given for the loss of friction, i.e. 0.28g. Although the results are not yet available, the licensee has performed a quantitative study to determine the seismic margin of the slab.

In relation to the seismic behaviour of the three dams located upstream from the plant site, the studies performed under seismic excitation loads corresponding to the design earthquake of the power plant concluded that the elastic security of the structural model was guaranteed for the three dams, discarding the flooding of the facility site as a result of the seismic rupturing of any of the dams. The licensee has not analysed the resistance of the dams to larger earthquakes, since, with the conservative-deterministic hypothesis of the joint rupturing of all the dams, the flooding caused would not affect the safety of the facility.

With regard to earthquakes, the licensee indicates that the following improvement actions have already been taken:

- Review of the test and inspection procedures related to: earthquakes, equipment for monitoring earthquakes, floods and other extreme events.
- Establishment of a communications protocol between the facility and the Bolarque dam for the event of the rupturing of the dam or for a large river flow (incoming supply to the Bolarque reservoir of more than 2000 m^3/s).
- Relocation, aside of the potential flooding, of the equipment provided for cleaning the duct venting pipes. Furthermore, the licensee will review the correct operation of said ducts on a regular basis.

- *CSN evaluation*

The Safety Analysis Report shows that the standard earthquake indicated in the 10 CFR 72.103 has been considered as the DBE for the facility; in other words, the storage system support slab has been designed with standardised USNRC RG 1.60 spectra at an acceleration of 0.25 g, which had already been checked by the CSN in the licensing process.

The licensee has identified the weak points and limits that may apply in an earthquake situation with the possibility of the casks turning over. This situation has an estimated safety margin that is clearly higher than the horizontal acceleration adopted for the DBE. In addition, the licensee anticipates feasible solutions for solving the situation in which a cask turns over and makes a justified estimate of required response times.

With regard to the rupturing of dams caused by an earthquake, the extreme consideration submitted by the licensee with regard to the simultaneous rupturing of all the dams, and the simultaneous nature of flood wave peaks generated by each one, would appear to be a very pessimistic and not easily imagined scenario, as analysed in the following section.

The improvement actions taken by the licensee are considered reasonable. The CSN will make the corresponding checks during its normal supervision and control processes.

- **Flooding**

- *Licensee's position*

The normal level of the River Tagus as it flows past the power plant corresponds to 599.8 m and the design basis flood (DBF) can be considered at 604 m. The ATI stands at 628 m, far above the level associated with the DBF and also above the maximum level that can be reached in the case of rupturing of the dams positioned upstream from the site, which would reach a level of 623 m or 626 m, depending on the conservative nature of the calculation model used in the analyses that have been performed.

As an extreme case, in a deterministic way, the rupturing of the dams upstream from the facility has been assumed and analysed, not simultaneously, but rather with a time difference whereby the wave produced by the combination of floods would reach a maximum total flow volume of 134,000 m^3/s. The analysis has been made using a simplified model (conservative). In this case, a level of 629 m would be reached in the facility zone, affecting it with a maximum depth of 1 m. In view of the topography of the zone, the facility would only be flooded for a maximum of a few hours. The speed of the water in the ATI zone would be low and would not cause the instability of the casks.

In the more extreme case of flooding as a result of the rupturing of all the dams upstream from the site, the cask venting ducts could be sealed off with sludge. The loss of venting would affect the cooling capacity and this situation is analysed by the licensee in another section of his report and will be examined later in the following sections.

The licensee also analyses the consequences of the rupturing of the two fresh water storage tanks at the facility, which have a total capacity of 1280 m^3. It concludes that the possible effects are much lower than the design basis parameters of the storage system: which are as follows: maximum water column that can be withstood by the casks: 38.1 m; and maximum water speed: 4.57 m/s.

The drainage of the facility zone has been reviewed and its capacity for draining water has been evaluated. No consideration is given to the possible obstruction of the drains by materials entrained by the flooding.

The improvements mentioned by the licensee, which have already been made, are the same as those indicated in the previous section.

- *CSN evaluation*

The source of flooding with the highest impact on the site would be the joint rupturing of the dams. It has already been commented in the previous section that the extreme consideration submitted by the licensee with regard to the simultaneous rupturing of all the dams and the simultaneous nature of flood wave peaks generated by each one would appear to be a very pessimistic and not easily imagined scenario. The CSN will require additional information about the hypotheses and models applied in order to value the details of the support studies that have been performed by the licensee and it will make the corresponding checks.

- **Other extreme natural events**

- *Licensee's position*

The casks are designed for exterior storage on a concrete slab without a protection building and to maintain safe storage conditions in the event of natural phenomena and accidents during their design life (50 years).

The licensee indicates that the facility has been designed to withstand small or large projectiles caused by hypothetical tornadoes, even though they are not expected in the area.

In relation to the occurrence of a forest fire in the facility zone, the licensee has estimated the maximum temperature and temperature increases on the module surfaces for each meteorological scenario that has been considered. The results show temperature increases that are below the differences between the temperatures allowed for normal conditions and for short-duration accidents, whereby there would be no loss of any of the facility safety functions, since all the components of the cask and their contents comply with the applicable limits.

In the case of tornadoes, the licensee concludes that even though the analyses have shown that the tornado winds and/or projectiles would not turn the loaded storage module over or damage the protection materials or the confinement barrier, it is appropriate to perform a visual and radiological inspection of the module should any of these events occur, repairing any possible damage caused to the external ring of the module, the concrete or the venting duct screens.

No requirements for additional improvements are identified, although those that have already been mentioned have been adopted.

- *CSN evaluation*

In the assessment performed by the CSN, no weaknesses have been identified with regard to these extreme natural events.

4.2.7.b Loss of safety functions

- **Loss of off-site power**

All the ATI safety functions are guaranteed on a passive basis, whereby the total loss of off-site power does not affect said safety functions.

4.2.7.c Accident management

- **Planning of accident management**

- *Licensee's position*

The licensee analyses the consequences of the cask turning over and being buried under rubble, submitting information about the alternative, off-site resources that may be available to recover the passive cooling capacity of the system, remove the obstructions from the air inlet and outlet pipes and place it in a vertical position using the corresponding procedure, which involves two mobile cranes.

– In the event of tipping, the times estimated for hoisting would vary between 2 days, if a single cask were considered, and from 3 to 5 days for the 12 casks existing at the site.
– If the cask is buried under rubble, caused by an earthquake, the licensee proposes the corrective action whereby, after such an event, it would be necessary to remove the rubble with mechanical and manual resources and then perform a visual and radiological inspection to find damage after the rubble has been removed.

In relation to possible flooding caused by problems at the dams, the licensee has established a communication protocol between the facility and the Bolarque dam, whereby the latter would contact the plant immediately in the event of a rupturing of the dam or a large flood. The licensee also indicates that the equipment available for unblocking the cask venting pipes is located in the ATI facility warehouse at a level that is safe from potential flooding, including those caused by the hypothetical simultaneous rupturing of the Entrepeñas and Buendía dams, and that it will review the correct operation of said equipment on a regular basis, coinciding with the autonomy in place for the other facility equipment.

In the case of forest fires, the licensee indicates that there are agreements for the quick supply of tanker trucks and that it is to study the possibility of a nearby connection from the freshwater supply with a greater capacity than the current pipes, as well as clearing away the surrounding scrubland.

The licensee has analysed the possibilities of accessing the facility in the case of extreme situations and concludes that, although the various roads that are currently available would be lost, a provisional access could be made without too much difficulty in a short period by opening the double fencing.

- *CSN evaluation*

The licensee's proposals are considered acceptable, with the following comments: in the case of forest fires, it is considered that the measures must be implemented in the short term and, with regard to the turning-over of the cask, the licensee must include the measures in the corresponding emergency procedures.

- **Relevant accident situations**

- *Licensee's position*

The licensee's report has considered three situations, regardless of their causes, which could affect one or more casks:

- Blocking of the ducts pipes
- Turning over
- Burial

The licensee indicates that none of these three situations is considered credible at the site, although the total blocking of the ducts could be caused by the sludge entrained by extreme flooding and the cask might turn over as a result of an earthquake beyond the design basis. The licensee considers the burial under rubble is less credible as there is no structure on or near the modules and no landslides are expected in view of the local topography.

The licensee has re-evaluated the behaviour of the HI-STORM 100Z system taking into account the thermal load generated by the fuel as of June 30th 2011, in order to estimate a maximum thermal load with regard to the stress tests of June 30th and has estimated the times required to reach limit situations in which the maximum pressure and temperature levels allowed in the case of an accident are exceeded. The minimum time available estimated by the licensee is 5.5 days owing to an increase in internal pressure, associated with accidental burial under rubble with rupturing of 100% of the fuel rods.

With regard to the blocking of the venting ducts of one of the storage modules, the licensee suggests the cleaning of the ducts with manual tools as a solution and has reinforced the personnel training programme for said operations. The programme will be implemented at least annually.

In relation to the turning-over of casks, the licensee provides the solution of returning the module to vertical position using self-propelled heavy cranes, for which it has developed a general procedure and checked the availability of the necessary equipment.

The procedures that have been developed also include visual and radiological inspections to evaluate the structural and radiological status of the casks and the inspection of the anti-particle vents.

The licensee indicates that, alternatively and in both cases, the cask could be cooled by sprinkling water on the air inlet or outlet ducts.

- *CSN evaluation*

The CSN evaluation estimates that none of the three situations considered by the licensee can be really expected (blocking of pipes, turning-over and burial of the cask) as caused by the events under consideration: earthquake, flooding, extreme thermal conditions and strong winds.

In the initial licensing process of the HI-STORM 100Z system, the behaviour of the group was checked with regard to a potential tipping in accordance with that given by the licensee, whereby the assessment considers that the licensee's conclusions are appropriate.

The estimation of the thermal load generated by the fuel as of June 30th 2011 and the thermal analyses performed by the licensee are considered appropriate, whereby the time margins for reaching cliff-edge situations improve with regard to that calculated in the license studies.

The CSN evaluation supports the development of procedures for returning the affected casks to the vertical position if they are turned over and for removing any obstructions from the air inlet and outlet ducts, as proposed by the licensee. However, the resources proposed by the licensee are being reviewed by the CSN to check that the quick action under the proposed terms, perhaps not strictly necessary in view of the low thermal load of the casks, does not lead to situations that have not been considered previously in the design.

- **Radiological protection issues**

- *Licensee's position*

The licensee indicates that the mobile units are permanently equipped with radiological protection instruments and material, available for the radiological control of contamination of individuals, the evaluation of individual doses and the monitoring of the local environmental conditions. In the event of maximum flooding, the facility would be flooded and the water would exceed the level of the facility by one metre. The licensee has procedures involving the instructions that are to be followed for visual and radiological inspections in order to evaluate the structural and radiological status of the storage module.

- *CSN evaluation*

For the power plant to strengthen its capacity for dealing with an emergency situation, facility's aplicable procedures must identify the resources that would be available to it in the mobile units to deal with an emergency (portable radiological protection instruments, protection resources, dosimetry, etc.) and it must guarantee that said mobile units are located in a safe place that is not affected by the maximum flooding scenario that has been analysed.

5. CONCLUSIONS

The CSN has evaluated the final reports sent by the licensees of Spanish nuclear power plants as part of the stress test programme that has been carried out at the European level; as part of this process the CSN has performed 24 inspections on the plants to verify certain aspects of the reviewed subject matters. The following conclusions have been drawn from the assessment made by this body:

A. Global aspects:

1. The CSN has verified that the reports submitted by licensees have been written following the stress test specifications drawn up by WENRA/ENSREG and that they adequately respond to the corresponding Complementary Technical Instructions (ITCs) issued by this body.

2. The CSN's evaluation has not identified any aspect that involves a safety-relevant weakness of these facilities and could require the urgent adoption of measures therein.

3. The reports from the licensees conclude that the design bases and the licensing bases set for each facility are currently fulfilled. The CSN verifies these aspects by means of its continuous supervision and control programme and the periodic safety reviews that are conducted every ten years prior to the renewal of the operating licences.

4. The verifications and studies that have been conducted reveal the existence of margins that ensure that the safety conditions of the plants are maintained beyond the cases contemplated in their design. Additionally, in order to increase the capabilities to respond when faced with extreme situations even more, the licensees have proposed to introduce relevant improvements and strengthen the resources to face up to emergencies.

5. The identified improvements shall be made in several stages according to their technical characteristics and the time needed to implement them. The planned time scheme is the following:

   - Short term: those measures whose adoption is feasible within this period of time will be implemented and most of the complementary studies will be completed. Expected completion: between June and December 2012.
   - Medium term: the period of time where a second block of design modifications will be added. Expected completion: between 2013 and 2014.
   - Long term: the period of time needed to complete the entire improvement programme, including new developments and design modifications entailing new constructions or changes to existing systems. Expected completion: between 2015 and 2016.

6. The CSN's evaluation has identified additional actions and studies needed to ensure that all aspects are properly dealt with and that the proposed actions are effective. The CSN will issue Complementary Technical Instructions for each licensee at the beginning of 2012 where the implementation of the submitted proposals for improvement and the performance of additional studies or other modifications that the CSN deems necessary shall be required.

B. Aspects related to extreme off-site events:

7. The design basis earthquake for each facility has been revised with the data obtained from those earthquakes that have occurred since the cut-off date contemplated in the original design until the first half of 2011 by using the methodology applied in the initial studies for the licensing of

the facilities. As a result of this revision it has been concluded that the adopted value for the safe shutdown earthquake is still valid in all cases.

8. The CSN shall introduce a programme to update seismic site characterisation studies, following the IAEA's most recent regulations.

9. In relation to the analyses of seismic margins above the design basis:

   - Licensees have taken as a starting point the preliminary studies of seismic margins that were already conducted at the CSN's request – which include a "reference earthquake" corresponding to a maximum horizontal acceleration of the ground equal to 0.3 g, which has been considered a suitable revision margin for all Spanish nuclear power plants irrespective of their seismic design basis (which, in the case of Spanish plants, ranges from 0.1 g to 0.2 g). The scope of these studies focused on the carrying capacity of the structures, systems and components (SSCs) needed to achieve safe shutdown and maintain the integrity of the Containment Building; in these studies, the strength of these SSCs was compared to the 0.3g reference earthquake, although not all were required to reach said value.
   - In the current revision of these studies, which has been conducted within the context of the stress tests, the licensees propose to implement the actions for improvement needed to attain said objective, and have expanded the scope of the analyses of seismic margins to those SSCs which have been provided for to face up to a station blackout, to mitigate the consequences of severe accidents and to maintain the "confinement" function inside both the Containment Building and the spent fuel pool as well as the cooling thereof. These actions shall contribute to significantly strengthen the plants' response to seismic risks.

10. Other earthquake-induced effects, such as on-site fires and explosions that could take place at the plants, as well as those caused by nearby industrial facilities, have been analysed. The main sources of internal flooding have also been analysed, and additional studies will be carried out. The protection barriers and actions identified in licensee reports are deemed appropriate by the CSN.

11. The appropriateness of the design basis against external flooding – including the hydrological and meteorological data recorded at every site throughout the corresponding facility's operating life – has been checked, it being concluded that the flooding levels that were adopted as design-basis levels are still valid today.

    The safety margins against events that could give rise to flooding levels above the design bases have also been analysed. The most critical events correspond to the potential failure of upstream dams. In all cases it has been verified that said dams are capable of withstanding earthquakes greater than those adopted as the seismic design basis at every site; their seismic margins have been quantified. Additionally, licensees have analysed the consequences derived from dam failure, concluding that the flooding levels that would be reached at the plants affected by these events would be below the site grading elevation.

    The assessment made by the CSN – with the technical support of CEDEX (Centro de Estudios y Experimentación de Obras Públicas) – concludes that the provided analyses are valid and make a justified estimation of the margins beyond the design bases as regards the aspects related to the failure of dams for seismic reasons. The CSN deems it necessary to further analyse dam failure due to other reasons. As a result of these studies, and according to the results that are obtained, it might be necessary to revise the studies performed and adopt those measures which are derived therefrom.

12. With regard to other natural external events, a specific re-evaluation of this type of events has been carried out. To this end, a preliminary screening of the existing data with probabilistic methodology – where those events which are likely to occur less than once every one hundred thousand years have been discarded and those safety margins that exist beyond design bases have been determined – has been taken as the starting point. Likewise, the scope of contemplated events has been expanded so as to include those events which have been previously screened but whose occurrence is still considered credible at each site. The proposed reinforcement measures are considered appropriate.

    The CSN shall require licensees to properly complete the analyses of some possible combinations of extreme natural events and to propose, where appropriate, the appropriate measures.

C. Aspects related to the loss of safety functions:

13. The power supplies available at each of the plants and the existing interconnections to the off-site grid have been analysed, it being concluded that they are highly robust and reliable. The Spanish grid operator procedures give priority to supplying power to nuclear power plants and envisage the preferential supply of power thereto from nearby hydroelectric stations.

    In the event of a loss of off-site power, the plants are capable of feeding the safeguard systems by means of emergency diesel generators, which meet the redundancy and physical-separation requirements set by regulations. These diesel generators can run for at least 7 days straight.

    The preceding characteristics are part of the plants' design bases and have been the object of assessment and inspection by the CSN as part of its normal supervision processes.

14. For a prolonged station blackout (SBO) situation (on-site and off-site power), the sequence of events and the required safety functions have been analysed, those cliff-edge situations and times where the degradation of the core or the loss of integrity of the containment would take place having been studied; only the equipment already installed at the plants has been taken into consideration.

    Licensees propose several measures for improvement to face up to the aforementioned event, which would allow all plants to fulfil the criterion of being self-sufficient for the first 24 hours with the equipment available at the facility, which could be extended to 72 hours with some off-site support. The most relevant proposals are the following:

    - Measures to ensure there is a direct current power supply to those controls and instruments needed to maintain the plant's safety conditions in such a situation.
    - Several backup measures with autonomous equipment (diesel generators, motor pumps, and so on).
    - Periodic tests to check the recovery of the off-site power supply from those hydroelectric stations which are close to the site.

    In addition to these proposals, the feasibility of alternative measures to reinforce core and containment cooling capabilities shall be considered. The CSN considers that the proposed measures will contribute to strengthen the plants' response capabilities when faced with long-lasting SBO extreme events.

15. In addition to the above cases and beyond the scope established in the CSN's Complementary Technical Instructions and in WENRA/ENSREG specifications, which only required assessing

the time to depletion of the batteries, licensees have analysed the possible courses of action in the event of a total loss of direct current. To this end, they have taken into account the existing chances of keeping the plant in a stable condition by means of local, manual actions.

The CSN thinks the ambient temperature or radiation conditions inside the rooms where some equipment is located could hinder said manual actions, so individual justifications or the performance of actual tests, in those cases where they have not been conducted yet, shall be required to ensure the feasibility of the operations.

16. Licensees have analysed the characteristics of the ultimate heat sink and the situations which could hinder or prevent its proper operation. Those events involving the loss of the ultimate heat sink coinciding with a station blackout (SBO) have been analysed too, it being concluded that all of them are covered by station blackout events, so the proposed improvements would also be applicable in these cases. The CSN's assessment considers the analyses conducted by licensees to be adequate.

D. Aspects related to accident management:

17. All nuclear power plant licensees already have an accident management organisation and measures to deal with accidents beyond the design bases of each facility.

In order to increase the response capabilities and strengthen the emergency organisation, the following actions for improvement, among others, have been proposed by the licensees:

- Creating an Emergency Support Centre (ESC) – common for all plants – which shall be equipped with human and material means so as to capable of intervening at any of the plants within 24 hours at the most.
- Building on each site an Alternative Emergency Management Centre (AEMC) – designed to seismic standards and fitted with radiation protection means – so as to facilitate emergency operations in extreme situations.
- The joint performance of additional analyses by all plants, where the organisational needs thereof will be studied by taking the lessons learnt from the Fukushima accident into account so as to strengthen their emergency organisations; furthermore, the need to improve the available auxiliary means and, in particular, the on-site and off-site voice and data communication means shall also be analysed.

These actions are deemed appropriate by the CSN and will significantly reinforce the capabilities for managing an emergency at the plants. Given the importance of having the proper human resources to perform the actions required in an emergency – and, in particular, in the event of a severe accident, the CSN shall require every licensee to submit within one year at the most a report that includes the results of the proposed analyses and the specific plans for improving and reinforcing the emergency organisation, taking into account those resources required to carry out actions with portable equipment and each facility's specific circumstances.

Licensees have considered that the radiological conditions at the emergency support centres other than Control Room and Technical Support Centre would force to evacuate them in certain severe-accident scenarios. The CSN shall request licensees to come up with alternatives to deal with the need for evacuating said centres insofar as the AEMC is not up and running.

18. The possible difficulties both people and auxiliary equipment might experience in accessing

the site in the event of extreme situations caused by earthquakes or flooding – the existence of routes and means that are open and available in all cases has been identified – and the proposals for reinforcing structures or equipment in those cases where it is necessary have been analysed.

19. Licensees currently have strategies in place to face up to severe accidents in the reactor core. Said strategies are included in severe-accident management manuals or guides, which had been previously evaluated by the CSN.

    The main actions for improvement proposed in this area are the following:

    a. Installing diverse systems for injecting water into the reactor vessel, the steam generators or the containment building.

    b. Installing passive catalytic recombiners at those plants that do not have them yet.

    c. Installing a filtered venting system in the containment building, with the exception of one licensee, which requests analysing this instance more in depth.

    d. Applying additional measures to know, in the event of a total loss of direct current, the essential parameters that are required in severe-accident strategies.

    e. Applying measures to prevent core damage sequences with high pressure in the reactor.

    f. Applying measures to boost the ability to implement containment flooding strategies.

    The CSN's evaluation concludes that said improvements are appropriate and that they will strengthen the plants' ability to face up to severe accidents and to mitigate their consequences. Additionally, the CSN considers it necessary that all licensees have a filtered venting system for the containment building.

20. Licensees have analysed the cooling systems of the spent fuel pools (SFP) and the strategies in place to face up to a loss thereof, as well as those aspects relating to the loss of radiation shielding that a decrease in the water level of the pools would entail. In the submitted reports, licensees propose improvements so as to strengthen the response of the plants when faced with prolonged scenarios of loss of safety functions in combination with external events:

    a. Having alternative fixed and portable means to provide water to the SFP.

    b. Improving the instrumentation for measuring the level and temperature of the SFP.

    The CSN's assessment concludes that said improvements are positive to face up to accidents affecting the cooling of the spent fuel pools.

21. As for the radiological conditions in the event of a severe accident, licensees have estimated the doses in the control room in a scenario with a prolonged loss of power that requires the containment building to be vented, in order to identify the measures needed to guarantee the protection of the staff that are inside said room at that time. Within this context, the CSN views the proposal made by some licensees (to install a power supply system in emergency control room filtering units, or to study the advisability of fitting them therewith) in a positive light and shall require the other licensees to consider this course of action and to solve any uncertainty in relation to guaranteeing the habitability of the control room during an prolonged SBO.

    Likewise, the available means to monitor and control worker doses and radioactive releases have been analysed by the licensees, it having been concluded that the available procedures and human and material means are adequate in general, even though all plants shall be required to make, in a coordinated manner, improvements to boost the response in the event of severe-accident scenarios.

22. As for the radiological conditions that might affect on-site recovery actions, licensees have submitted analyses and propose reference dose levels for the staff belonging to the emergency response organisation, which, in some cases, match those set in ICRP-103 and, in others, those set in the IAEA's TECDOC-953 and the BSSs recently approved by the IAEA. The CSN shall issue specific requirements to harmonise said reference levels in order to reconcile the necessary individual protection of workers with the feasibility of performing critical mitigation actions, as well as the implications of local courses of actions from the point of view of individual radiation protection.

6. ACRONYMS LIST

This chapter contains the list of acronyms used in the report.

A.C. (a.c.):	Alternate Current
ADS:	Automatic Depressurization System (ECCS subsystem; GE)
AEMC:	Alternative Emergency Management Centre
AFW:	Auxiliary Feedwater System (Westinghouse design)
AFWTP:	Auxiliary Feedwater Turbine-driven Pump
ATI:	Individual Temporary Repository (*Almacenamiento Temporal Individualizado*)
ATWS	Anticipated Transient Without Scram
BWR:	Boiling Water Reactor
BWROG:	Boiling Water Reactor Owners Group
BWT:	Borated Water Tank (KWU design)
CEDEX:	*Centro de Estudios y Experimentación de Obras Públicas*
CHE:	*Confederación Hidrográfica del Ebro*
CR:	Control Room
CRDH:	Control Rod Drive Hydraulic System (GE)
CSN:	Nuclear Safety Council (*Consejo de Seguridad Nuclear*)
CST:	Condensate Water Storage Tank
DBE:	Design Bases Earthquake
DBF:	Design Bases Flooding
D.C. (d.c.):	Direct Current
EC:	European Commission
ECCS	Emergency Core Cooling System
EMC:	Emergency Management Centre (Centro de Apoyo en Emergencia)
ENRESA:	*Empresa Nacional de Residuos Radiactivos*
ENSREG:	European Nuclear Safety Regulator's Group
EOP:	Emergency Operating Procedures

EPRI:	Electric Power Research Institute (USA)
ERP	On-Site Emergency Response Plan
ESC	Emergency Support Centre
EU:	European Union
FPS:	Fire Protection System
GE:	General Electric
HCLPF:	High capacity Low probability of Failure (Seismic Margin)
HPCI:	High Pressure Core Injection System (ECCS subsystem; GE design)
HPCS:	High Pressure Core Spray System (ECCS subsystem; GE design)
IAEA:	International Atomic Energy Agency
IC:	Isolation Condenser System (GE design)
ICRP:	International Commission on Radiological Protection
IEEE:	Institute of Electrical and Electronic Engineers
IGN:	*Instituto Geográfico Nacional*
IPEEE:	Individual Plant Examination on External Events
IS:	CSN Instruction (Spanish Regulation)
ITC:	*Instrucción Técnica Complementaria* (issued by the CSN)
KTA:	*Kerntechnischer Ausschuss* (German Technical Standard for Nuclear Safety)
KWU:	*Kraftwerk Union Aktiengesellschaft*
LOCA:	Loss of Coolant Accident
LOOP:	Loss of Off-site Power
LPCI:	Low Pressure Core Injection System (ECCS subsystem; GE design)
LPCS:	Low Pressure Core Spray System (ECCS subsystem; GE design)
MSLB:	Main Steam Line Break
NRC:	Nuclear Regulatory Commission (USA)
NPP:	Nuclear Power Plant
OBE:	Operating Basis Earthquake
OSC:	Operative Support Centre
PAR:	Passive Autocatalytic Recombiners
PSA:	Probabilistic Safety Assessment

PVRE: *Plan de Vigilancia Radiológica en Emergencia (*Emergency Radiological Surveillance Plan)

PWR: Pressurized Water Reactor

RCIC: Reactor Core Isolation Cooling (GE design)

RCP: Reactor Coolant Pump

RCS: Reactor Coolant System

REE: *Red Eléctrica de España* (Spanish electric grid operator)

RG: Regulatory Guide (issued by the NRC)

RVRAC: *Red Vigilancia Radiológica Ambiental en continuo* (On-line Environmental radiological monitoring network)

RWST: Refueling Water Storage Tank (Westinghouse design)

SAMG: Severe Accident Management Guidelines

SBLC: Standby Liquid Control System (GE design)

SBO: Station Black-Out

SC: Seismic Category

SG: Steam Generator

SE: Safe Earthquake (German definition)

SFP: Spent Fuel Pool

SP: Suppression Pool

SSC: Systems, Structures and Components

SSE: Safe Shutdown Earthquake (American definition)

TSC: Technical Support Centre

UHS: Ultimate Heat Sink

UNESA: *Unidad Eléctrica* (Spanish utilities association)

UPS: Uninterrupted Power Supply

WANO: World Association of Nuclear Operators

WENRA: West Europe Nuclear Regulator's Association