ENUSA-JUZBADO PLANT STRESS TEST APPROACH AND ACTIONS TAKEN

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ABSTRACT

The Fukushima Daiichi accident posed certain weaknesses and vulnerabilities in plant design, emergency preparedness & response arrangements, and in planning management of an accident beyond design basis. Lessons learned from this accident brought about a systematic review of the safety analysis by the international community, defining and establishing ways of preventing and minimizing the effects of these severe accidents. Thereby, during 2011 and 2012, ENUSA carried out a deep and systematic review of the design basis and safety analysis of the Juzbado Fuel Fabrication Facility. The analysis was developed in four steps: a) Initial situation; b) Robustness analysis; c) Beyond design basis situation; d) Emergency preparedness and response arrangements. All evaluations assume, under a deterministic approach, the sequential loss of the existing defensive lines and system's safety functions. After the analysis it was demonstrated that ENUSA Juzbado Plant meets all the requirements of its Design Basis, and that earthquake is the only credible risk which can produce a limit situation in combination with the fire caused by the earthquake itself.

1. Introduction

The Juzbado Plant was commissioned on 1985. Its main activity is focused on the first part of the fuel cycle fabrication. Thereby the production scope ranges from pelletizing uranium oxide and uranium oxide with gadolinium to rod loading and final assembling. The Plant has four manufacturing lines, three of which are devoted to PWR/BWR/VVER fuels and the other, to the fabrication of Gadolinia rods. The maximum authorized enrichment is 5%wt U-235 and the licensed capacity is five hundred metric tonnes of uranium per year.

As a result of the Fukushima Daiichi nuclear power plant accident, Stress Tests have been defined for the European Nuclear Power Plants, which have been focused on analysing a set of extreme situations. The objective of this analysis is to highlight the strength of the protective measures and to identify appropriate safety improvement plans. In July 2011, ENUSA received a Technical Instruction issued by the Spanish Regulatory Body (CSN) requiring ENUSA to submit a preliminary report by mid-august 2011, and a second report with the assessment by the end of October 2011. The review process took some time and, by the end of 2012, a final report was delivered with the commitment of implementing the identified actions following a schedule which ended in June 2015.

2. ENUSA methodology

The methodology that has been followed is based on the evaluation of the facility's response capacity in case of occurrence of extreme events, and on the verification of the preventive and mitigating measures, following the standards of the “defence in depth” philosophy. All evaluations assume, under a deterministic approach, the sequential loss of the existing defensive lines and system's safety functions, independently of the likelihood. Thus, the following steps are established in the analysis:

(a) Initial situation: Verification of the design basis, safety systems configuration, procedures associated to postulated accidents and license basis compliance, at the time of the assessment.
(b) Robustness analysis: Evaluation of the safety margins for each postulated accident sequence, identification of extreme situations or potential weaknesses, and definition of appropriate countermeasures, according to the defence in depth approach.
(c) Beyond design basis situation: Identification, analysis of the consequences and countermeasure definition of “extreme credible external hazards” that could damage structures, systems and important components for the safety (SSCs).
(d) Emergency preparedness and response arrangements: Evaluation of the structures, systems, components and human factors necessary to manage an emergency and to mitigate its consequences for each scenario.

The situations considered, which correspond to more and more degraded conditions, were earthquakes, floodings and extreme natural external hazards, such as hurricanes, snow or heavy rain. In addition, it was considered the sequential loss of the safety functions related with the initial event and in particular, the loss of offsite power including Station Black Out (SBO).

3. Results of the Stress Test

3.1 Earthquakes

The facility is located in Juzbado, province of Salamanca, which is situated in the west of Spain. The characterization of the region concludes that the maximum expected horizontal ground acceleration is equal to or less than 0.07g. In order to increase the safety margins, the design basis of the plant considers an earthquake with peak ground acceleration of 0.15g. The assessment methodology of the Design Basis Earthquake is based on the geological and seismic region characterization with a return period of 100,000 years and the historical data on the intensity of the earthquakes in the area.

After the Fukushima accident, ENUSA requested an independent evaluation of the Design Basis hypothesis. The new value of peak ground acceleration obtained was 0.10 g, so the value considered in the design of the Juzbado Plant is conservative and the current Design Basis Earthquake is correct.

In case of a severe earthquake, the manufacturing plant's structure and the fuel assemblies storage areas would remain stable. Although the rest of structures, systems and equipment do not have credibility to maintain their functions, the possible effects over them would be reduced by the manufacturing plant's structure.

However, although ENUSA has different procedures to respond to an earthquake and check the state of the Plant after the event, it was pointed out that some necessary equipment are located in buildings with no earthquake resistance, so there was no assurance that they would be available in case of earthquake.

The analyses on the Plant's existing safety margins determined the seismic margin of the facility and identified load combinations and elements that have minor structural margin. Besides, new calculations were made for the critical elements, increasing the earthquake level to the design criteria and methodology of the initial licensing project. The results obtained are the following:

Element	**Safety Margin**	**Corresponding horizontal ground acceleration (g units)**
Manufacturing plant's structure	1.09	0.164g
PWR Fuel assemblies store	1.25	0.190g
BWR Fuel assemblies store	2.09	0.310g
Fire extinguishing pump room	< 1	< 0.150g
Control room	< 1	< 0.150g
Data process room	< 1	< 0.150g

Tab 1: Critical elements and safety margins

As Table 1 shows, the fire water pump room, the control room and the data process room do not resist the Design Basis Earthquake. In addition, the study identified the following “cliff edge” situations: Pendulum effect in the BWR fuel assemblies store, and the possibility of water leaks inside the manufacturing building, by failure of the supply pipes.

According to these results, several actions have been carried out:

- Implementation of a new water supply system for fire extinguishing, capable of operating after an earthquake.
- Emergency Room Extension with seismic resistance > 0.17g.
- Reinforcement of pillars in the data process centre.
- Design and implementation of handling clips to avoid the pendulum effect in the BWR Fuel assemblies store.
- Rearrangement of water supply pipes within the process areas.
- Installation of an accelerograph in the site.

To analyze the Beyond Design Basis situations, it is assumed an earthquake with acceleration higher than 0.164g, which involves the partial collapse of the Plant. It is also assumed a criticality accident or a fire at the same time of the earthquake. In both situations the dose to the public in the limit of the Security Area is lower than 5mSv, which is the established limit in the accident analysis of the Plant and therefore, these situations are covered by the current systems and procedures. Therefore, no limit situations and no potential weaknesses have been detected from a radiological point of view when the earthquake exceeds the Design Basis and there are other extreme situations at the same time.

From a non-radiological point of view, in case that the earthquake exceeds the Design Basis and a fire happens at the same time, the elements which must keep the safety of the plant are the water tanks, the water pumps and the water supply system for fire extinguishing. Therefore, a new water supply system and mobile equipment for fire extinguishing were implemented, able to operate after an earthquake of 0.195g.

In addition to the assumptions related to the stress tests, a particular study about the effects of a fire inside the manufacturing building was made with independence of the initial event. As a result of some weaknesses identified in this study, the following actions have been carried out:

- Rearrangement of H_2 supply pipelining outside the plant.
- Replacement of the H_2 supply pipelining with seismic resistance.
- Relocation of the non-nuclear components warehouse outside the plant.

3.2 Floodings

The Design Basis of the plant considers the following situations:

- Maximum water level river return.
- Maximum water level by the collapse of the nearby dam.

In the first situation, the maximum level of water for return periods of 500 and 1,000 years is calculated taking into account the minimal drainage section. Thus, the maximum level of water in the worst case is 760.10m, meaning that is 30m lower than the plant's level. The second case assumes that the dam is loaded to its maximum level and leaks the third of it. With these hypothesis, the water flow reached in the location of the plant after the leakage is lower than the flow required to reach the level of the facility (790m). The assessment methodology of the Design Basis is based on the historical information about events in the area. The License documents do not set up any structure, system or special component to achieve and maintain the safety conditions, providing that the water level does not reach the plant's level at any moment.

After the Fukushima accident, ENUSA performed an independent evaluation of the Design Basis hypothesis. The conclusions of these studies reflected the validity of the data and the hypothesis of the Design Basis for floodings. The studies also concluded that there is no need to set up any structure, system or special component to achieve and maintain the safety conditions, and that it is not necessary to implement any special measure to mitigate the effects of the maximum flooding in the manufacturing plant either.

The analyses on the Plant's existing safety margins considered a possible flooding resulting from the maximum water level return and the collapse of two nearby dams. Under these assumptions, the maximum water level reaches 765.30m, implying a safety margin of 24.70m.

No “cliff edge” or other Beyond Design Basis situations were identified regarding floodings, as they are covered by the aforementioned hypotheses.

3.3 Extreme natural external hazards: hurricanes, snow and heavy rain

The manufacturing building is designed to resist winds with a dynamic pressure equal to 87.5kg/m^2, as well as an overload by snow of 80kg/m^2. For both parameters, it was taken as reference the Spanish construction code applicable at the time the Plant was built. In case of overload by heavy rain, the regulation did not consider this parameter explicitly, so the value of maximum precipitation in the area (187l/h) was considered as a reference.

Likewise for the other events, ENUSA requested an independent evaluation of these design criteria. The conclusions of the evaluation reflected that the definition and values of the parameters had not changed over time.

Regarding extreme natural external hazards, the only structures, systems and necessary components necessary to achieve safety conditions are the structure and enclosure elements of the manufacturing building. Therefore, the only requirement of protection to extreme external conditions is maintaining the integrity of the structure and enclosure elements.

Although in case of hurricanes some indirect effects, such as damages in the chimneys of the ventilation system were identified, no special countermeasures were deemed necessary, providing that the ventilation system's shutdown causes the blackout of equipment, avoiding thus the occurrence of uranium powder emissions. Another risk of these events is the possible presence of water in areas where the uranium is not encapsulated, with the consequent criticality risk. However, the drain system, the cover sealing and the individual protection of the units with nuclear material minimize the likelihood of presence of water inside of them. In summary, it was concluded that these events do not produce leaks greater than the potential accidents that may occur during the manufacturing process or in the auxiliary systems of the Plant. Therefore, it is not necessary to implement special measures to mitigate the effects of these extreme events.

In order to ensure the safety margins, the design parameter was compared with the values of the reference values. The results obtained are the following:

Event	Design parameter	Reference parameter	Safety Margin
Hurricanes/winds	87.5kg/m^2	75kg/m^2	1.17
Snow	80kg/m^2	72kg/m^2	1.11
Heavy rains	200l/h	187l/h	1.07

Tab 2: Safety margins under extreme external events

As Table 2 shows, all the safety margins for these events are higher than one, which verifies the conservatism of the Design Basis. In addition, independent studies identified no “cliff edge” or other Beyond Design Basis situations, so it is not necessary to apply any special measure.

3.4 Loss of Electrical Power supply system

The power supply system of the Plant is composed of the following elements:

- Normal electrical power supply system, which comes from the external electricity grid and provides services to the manufacturing equipment, ventilation system, utilities and normal lighting system. It also provides support to the rest of safety systems and the emergency lighting system.
- Emergency electrical power supply system, composed by two diesel generators and batteries groups that supply energy to the most important detection and alarm systems

Therefore, power supply is a necessary system for the manufacturing operations and provides support to systems that control the safety of the facilities, but in case of failure, it does not imply an accident situation. The lack of electrical power supply would lead to a shutdown of the plant until achieving safety conditions, but the power supply system itself is not necessary to maintain the safety condition of the Plant. In any case, the impact of the loss of electrical power supply on the Plant was analysed, including station black-out. The conclusions are shown in the following paragraphs.

Loss of external electrical power supply (LOOP)
The lack of the electrical power supply does not pose any risk because this situation leads to the safe shutdown of the production equipment and the ventilation system at the same time. Therefore, the failure of the electrical power system does not lead to any accident situation. On the other hand, emergency electrical power supply guarantee the functions of the main safety systems of the Plant for not less than eight hours.

Station black out (SBO)
In addition to the diesel generators, there is an emergency electrical power supply system supported by batteries, which provides power to certain systems as Fire Protection System, Criticality Alarm System, etc. These batteries provide a minimal autonomy of two hours.

Although the loss of electrical power supply in the Plant does not suppose an accident situation, some measures were taken with the aim of increasing its robustness. These actions are the following:

- Connecting the tanks of both diesel generators to a third tank with 5,000 liters of capacity.
- Separating the filling lines of the diesel generators tanks.
- Auxiliary pump with flexible connections for filling the diesel tanks.
- Re-distribution of charges to maximize the capacity of the diesel generators.

4. Conclusions

The main conclusions of the Juzbado Plant's stress test are listed below:

1. The Plant meets all the Design Basis requirements. No findings were discovered by the stress test.

2. “Cliff edge” and beyond Design Basis situations were identified only in case of earthquakes.

3. Several improvements related with the different events have been implemented to increase the level of Defence in Depth:

- Implementation of a new water supply system for fire extinguishing, capable of operating after an earthquake.
- Emergency Room Extension with seismic resistance > 0.17g.
- Reinforcement of pillars in the data process centre.
- Design and implementation of handling clips to avoid the pendulum effect in the BWR Fuel assemblies store.

- Rearrangement of water supply pipes within the process areas.
- Installation of an accelerograph in the site.
- Rearrangement of H_2 supply pipelining outside the plant.
- Replacement of the H_2 supply pipelining with seismic resistance.
- Relocation of the non-nuclear components warehouse outside the plant.
- Connecting the tanks of both diesel generators to a third tank with 5,000 litres of capacity.
- Separating the filling lines of the diesel generators tanks.
- Auxiliary pump with flexible connections for filling the diesel tanks.
- Re-distribution of charges to maximize the capacity of the diesel generators.