INTERNATIONAL NUCLEAR SAFETY JOURNAL

ISSN 2285 – 8717

ISSN–L 2248 – 8717

http://www.insj.info

vol. 5 issue 1, 2016, pages 88 - 99

Enhancements to Emergency Preparedness and Response in Spain

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Abstract

This paper summarizes some of the major improvements and features of the Emergency Preparedness and Response developed to face scenarios with Extensive Damage, aspect that has taken particular emphasis after the events happened at the Japanese Fukushima-Daiichi Nuclear Power Plant. After the so called “stress test" and taken as one of the main references the work developed by the United States, important enhancements are being applied in the nuclear industry both in Spain and internationally.

The aim is to review both the historical origin and evolution suffered after the accident at the Japanese nuclear power plant, and the fundamental aspects of Emergency Management that, taken into account its extended nature, have to be addressed by specific strategies that can prevent damage to the fuel and / or mitigate their potential consequences, when the plant response, considered normal, is severely affected.

Improvements initially proposed as part of the response to hostile acts, both in terms of improving the Emergency Command and Control as well as the generic Mitigation Strategies, are summarized in the paper. After that, the paper briefly describes the evolution based on the improvements already made. In this way, the paper summarizes the proposal from the international reference (USA) stating, among other measures, the definition of new Flexible and Diverse Response Strategies, called FLEX, supported by new mobile equipment to provide an enhancement on the safety of nuclear installations, providing an additional layer of defense in depth. These improvements include the definition of new emergency centers designed to face these “beyond design basis” scenarios.

The application carried out by the Spanish nuclear industry of some of the major improvements related to the Emergency Preparedness and Response, conducted as part of a wider process of enhancing nuclear safety developed in Spain based on the lessons learned from the accident to the nuclear power Fukushima-Daiichi, is summarized in this paper.

Keywords
nuclear safety, Fukushima accident, emergency preparedness and response, FLEX

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1.0 Background

After the events on March 11, 2011 at the Fukushima-Daiichi nuclear power plant following the earthquake and subsequent tsunami, the Council of the European Union, asked the European Commission and ENSREG[1] for the development of the so-called "stress test”. The European Council mandate to the Commission included the definition of both the scope and methodology for the safety assessments of nuclear power plants. The Commission and ENSREG agreed to work on two parallel tracks:

[1] ENSREG - European Nuclear Safety Regulators Group

- A Safety Track, to assess how nuclear installations can withstand the consequences of various types of unforeseen events, from natural disasters to human error or technical failure and other accidental impacts;
- A Security Track, to assess prevention and response capabilities against hostile acts.

In the Safety Track, WENRA[2] published on April 21, 2011, the specifications of the "Stress Test" with the proposed technical definition and implementation methodology. Stress tests were defined as a reassessment of the safety margins of NPPs in the light of the events in Fukushima; extreme natural events that can affect the safety functions and that could lead to Severe Accidents. In these cases a deterministic methodology is assumed and the event likelihood is not analysed, it is considered that will happen for sure and the robustness of the defence in depth is analysed, including the identification of potential cliff effects; when a small change in the assumptions could cause significant increases in the consequences. The technical scope included:

- Initiating Events: extreme natural phenomena such as earthquakes or floods.
- Loss of Safety Functions: Loss of Ultimate Heat Sink (UHS) with prolonged loss of electrical power (SBO).
- Severe Accident Management.

According to this, two Complementary Technical Instructions (ITC) were issued by the Spanish Nuclear Regulatory Body, the Nuclear Safety Council (CSN), in 2011;

- ITC-1 in the frame of the "stress tests" provided at European level, it is the adaptation performed by the CSN of the WENRA specification to each Spanish nuclear power plant.
- ITC-2 in relation to the development of mitigation measures to face events of external origin and beyond design basis related to the potential loss of large areas of nuclear power plants.

This ITC-2 is complementary to the previous one and aims to establish response measures to large explosions and fires of external origin that could affect the facility safety functions, leading to Severe Accident scenarios. This regulation proposes an acceptable reference to support the analysis; the NEI 06-12 [1], which main points are summarized below. The improvements in emergency response that the NRC (Nuclear Regulatory Commission, USA) had included as a result of the analysis of potential hostile acts [2], became therefore an important reference, which included alternative response centres and extensive damage mitigation strategies, and which propose extensive use of mobile equipment.

In the aftermath of Fukushima, NEI has deepened these improvements in the so called FLEX Strategy, as reflected in guidelines NEI 12-06 [3], NEI 12-01 [4] and others, collecting the recommendations made by the NTTF [5], and expanding scenarios to cover extensive damage caused by extreme natural events beyond the design basis (BDBe).

Based on the assessments made in relation to these two ITCs, the Spanish NPPs confirmed the robustness of the Spanish nuclear fleet and proposed a series of improvements aimed at reinforcing the response to events beyond design basis, thus increasing safety margins.

The most significant changes in the Emergency Preparedness and Response (EP&R) developed in Spain and its international references are summarized in this paper; they are

[2] WENRA - Western European Nuclear Regulators Association

related to the so-called mitigation strategies, procedures and guidelines to face external events beyond the design basis, which can cause extensive damage to nuclear facilities.

2.0 Extended Damage Mitigation Guidelines, EDMGs

After 9/11 Terrorist Attack at the USA a comprehensive review of the Emergency Planning (EP) basis was performed in order to analyse whether or not they remain still valid in the new threat environment. The main conclusions were:

1. The EP bases were still valid,
2. There were specific challenges associated with emergencies caused by Hostile Acts that warrant some improvements to properly face these specific scenarios.

The USA industry [6] and regulator [7] defined a set of enhancements in EP to face emergencies originated by hostile acts against NPP, causing Loss of Large Areas (LOLA) of plant due to big explosions and fires. Main enhancements were developed as modifications, adaptations or improvements related to the following issues:

1. Emergency Classification Scheme.
2. On-shift staffing.
3. Emergency Response Organization (ERO) Augmentation to Alternate Facilities.
4. Coordination and Integration between On-Site and Off-Site EROs.
5. Protective Actions.
6. Notifications and communications.
7. Training, Drills and Exercises.

In addition, the readiness of NPPs in USA to manage challenges to the containment and the core and spent fuel pool cooling (SFP) systems following large explosions or fires was enhanced through a series of new legal requirements included in:

a. 10 CFR 50.54(hh) [8]
b. ICM Order [9]

The ICM order in B.5.b section requires new procedures and guidelines and NEI 06-12 Rev.2 [1] provides acceptable guidance on mitigating strategies to fulfil those requirements; it was considered security classified until the Fukushima accident, when the USA Government released it, becoming a major reference in coping with Hostile Acts against NPPs.

Nuclear power plant licensees are responsible for overcoming design basis security threats and for using available resources to face beyond design basis threats. In these cases, it is not feasible to define a “bounding scenario" due to the wide range of beyond design basis terrorist threats, so it was determined that a critical feature of the response should be the flexibility to facilitate actions, over a wide range of potential scenarios. There are two critical elements of an improved response:

- Command and control enhancements, aimed at improving initial site operational response before the Emergency Response Organization (ERO) is fully activated, and
- A specific set of mitigation strategies for all BWRs and PWRs to be implemented if needed.

In this way, a set of flexible, deployable generic strategies that could be beneficial in responding to a broad spectrum of damage states was identified, including:

- Procedure/guidance enhancements,
- Minimal procurement, and/or
- Minor plant modifications to non-safety related systems and portable equipment.

3.0 Command and Control Enhancements

Command and Control is a key factor in mitigating the potential consequences of a NPP Emergency. Additionally, the magnitude and type of damage in the postulated threats beyond design basis may create specific challenges; the normal coordination structures would be severely affected, further complicating the response. Thus, it is essential to establish guidelines for the initial operational response at the site, allowing to analyze in advance the strategy to adopt if the normal coordination structure is disrupted.

The term "extensive damage" reflects the spatial extent of the damage, which may not only affect the equipment but also operating personnel and access to large areas of the plant including the target buildings. These are scenarios with a probability considered negligible in traditional accident analysis. Furthermore, the boundary conditions for EDMGs are very different from those associated to EOPs or SAMGs (to which EDMGs are not intended to replace):

- The loss of the building that holds the main control room (MCR) and all its contents, including access, equipment, material or personnel located in it.
- The loss of electric power (AC and DC).
- The measures can be taken by staff operating without a license.

The Initial Response (IR) EDMGs are described in NEI 06-12 [1]. The scope of the IR EDMGs include:

1. Assessment of communications and establishment of an Alternative Response Center.
2. Methods for activating the ERO, and the definition of management and control.
3. The basic initial response actions, including mitigation strategies:
   a. To confirm the Reactor Shutdown.
   b. To perform the initial damage assessment.
   c. To confirm the injection from an AFW pump to a Steam Generator (in PWRs) or confirm RCIC injection into the RPV, or the performance of the Isolation Condenser (in BWRs).

The IR EDMGs are intended to be used when the use of EOPs is not feasible, providing support between normal operation and emergency management by the ERO, summarized in Fig. 1.

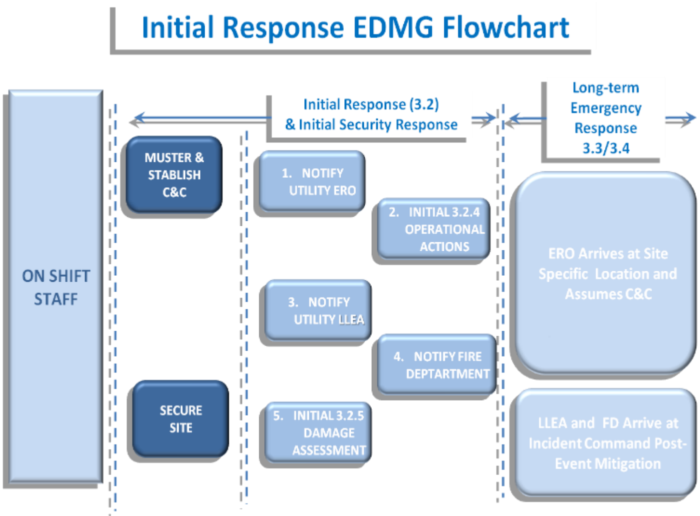

Fig. 1- IR EDMG Flowchart

4.0 Mitigation Strategies

Mitigation strategies or Technical Support Center (TSC) EDMGs would not be properly considered EDMGs and could be included in the EOPs, SAMGs, or other set of procedures or guidelines.

For the SFP a combined solution that recommended the use of sprays in case of difficult access was considered. If access is possible, the first option is the strategy of internal make up, otherwise the option is the strategy of external make up, for which mobile equipment is required.

For Reactor and Containment, candidates for safety functions (Fig. 2a) were first identified. To support them, a set of generic, flexible and deployable strategies, which provides a broad spectrum of response scenarios, were selected. Most of them involve improved procedures and/or minor modifications of the plant. A total of ten mitigation strategies for BWR and seven for PWR, applicable independently, were recommended (Fig. 2b).

Fig. 2 (a) Safety Functions (b) Mitigating Strategies

5.0 FLEX Strategy

A week after the start of the Fukushima accident, the NRC established the Near Term Task Force (NTTF), with the aim of developing a systematic and methodological analysis of the lessons learned in Japan. Based on the general philosophy of defence in depth, the analysis focused on three aspects (Fig. 4):

- **Protection** of external events that could lead to fuel damage.
- **Mitigation** of their consequences, paying special attention to the core and spent fuel damages and radioactivity releases.
- **Emergency preparedness**, to mitigate the effects of releases, if they occurred.

TIER 1 - RECOMENDATIONS	NRC
Rec. 4.2 Mitigating strategies (BDBE[2] – B5b extension)	Order
Rec. 8.1 Strengthening and integration of EOPs, SAMGs & EDMGs.	Draft Order
Rec. 9.3 Emergency Preparedness (Staffing and Communications)	Request of Information
Rec. 5.1 Hardened vents (Mark I&II)	Order
Rec. 7.1 SPF[1] Instrumentation	Order
Rec. 2.1 Hazard reevaluations	Request of Information
Rec. 2.3 Seismic & Flood walkdowns.	Request of Information
Rec. 4.1 SBO Regulatory Actions.	Draft Order

FIG. 3 - NTTF Tier 1 Recommendations

Fig. 4 Application of Defence in Depth

This way a comprehensive set of recommendations [5] was developed, which were prioritized by NRC ([10], [11] SECY-11-0124/137) in three stages, depending on the potential improvements in safety and the necessary resources to implement them; Tier 1 to be implemented without unnecessary delay, Tier 2, not included in the short-term capacity constraints and Tier 3, which require further study.

Fig. 3 shows the recommendations of Tier 1, the light background directly related to the Emergency Preparedness and Response, described in this paper.

Based on the Recommendations and on previous experience with EDMGs, the US nuclear industry issued the guideline NEI 12-06 [3] – an extension of NEI 06-12 [1] - which sets out a flexible and diverse response strategy (FLEX) to address these scenarios. It supports most of the recommendations associated to Tier 1 and is based on the following elements:

1. Development of strategies, procedures and guidelines; FSG, FLEX Support Guidelines.
2. Two components of FLEX Equipment: On-Site (fixed and portable) - Off-Site (Portable).
3. Storage and reasonable protection of FLEX Equipment.
4. Controls to ensure the viability and reliability of the FLEX Strategies.
5. A response approach in three phases (Fig. 5).

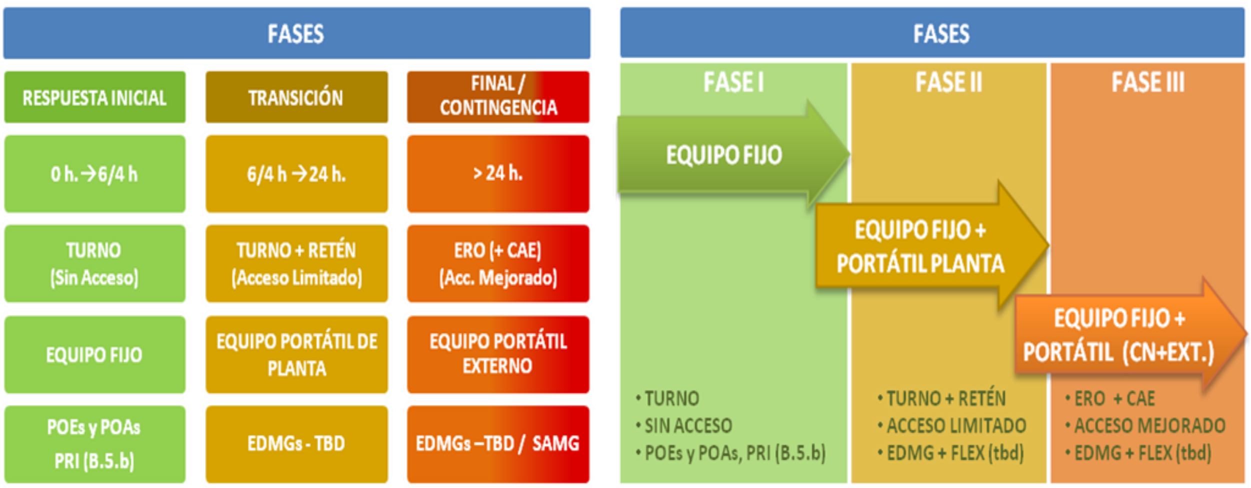

Fig. 5 Phases for the response to external events BDE

The guideline sets out the criteria, boundary conditions and the development process of the FSG. It also includes, in relation to external resources, fundamental aspects to be included, the equipment recommended and minimum capabilities of the centres that provide this function. (Fig. 6)

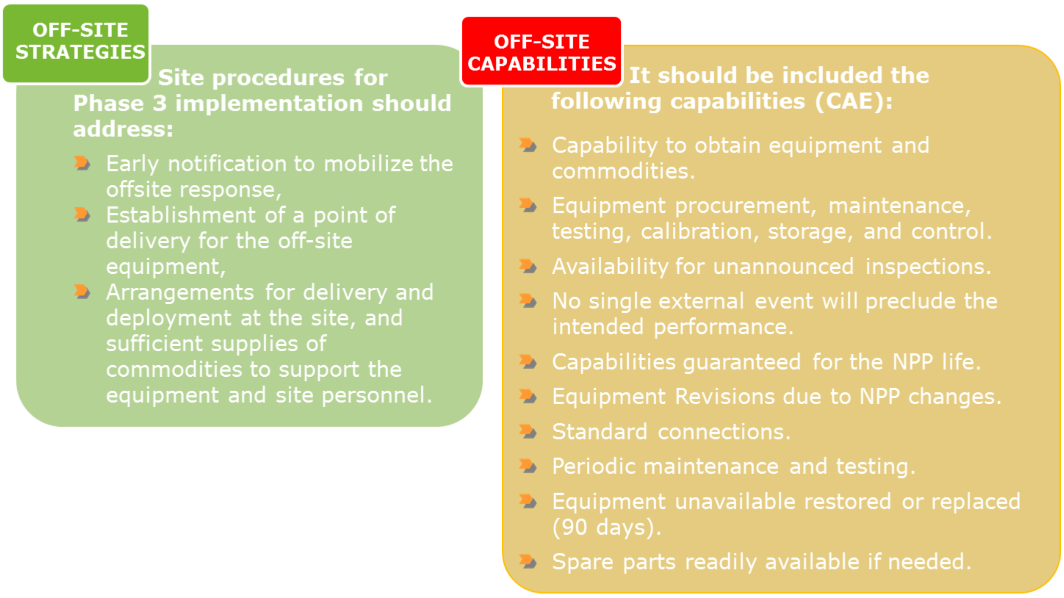

Fig. 6 Integration of external resources (ESC/CAE)

Recommendation 9.3 requires an assessment of the necessary staff and communications to deal with such scenarios, considering infrastructure loss; the guide [4] NEI 12-01 deals with these subjects, on the same bases as the NEI 12-06, summarized in Figure 5. It includes the following considerations for the assessment of the required personnel:

- All units are affected and working at full power at the beginning of the event.
- Limitation of the available staff to the minimum,
- Conditions of access to the plant in three phases: No Access, Limited Access, Enhanced Access.

For evaluation of communications are proposed, in summary, the following conditions:

- Neither the sources nor fixed AC equipment are available.
- The following equipment and materials will be available, only if they are reasonably protected against external phenomena considered: The fuel-oil, DC chargers, portable equipment associated with SAMG and /or EDMGs and communications at the site.
- External communications will not be available within a radius of 25 miles.

Recommendation 8 finally reflects the lack of integration in the Emergency Management and Control, due to the diversity of procedures and situations analysed and proposes reinforcement and integration, as shown in Fig. 7, extracted from NEI 12-01. The Recommendation proposes:

- To include EOP, SAMGs, EDMGs (and FSGs) in an integrated system,
- Clearly specify the management and control,
- Define the qualification and training of related personnel,
- Modify administrative control requirements, and include it in Technical Specifications.

NRC has conducted a regulatory reform that includes SAMGs and training associated with SAMGs, EDMGs and FSGs as licensing requirements.

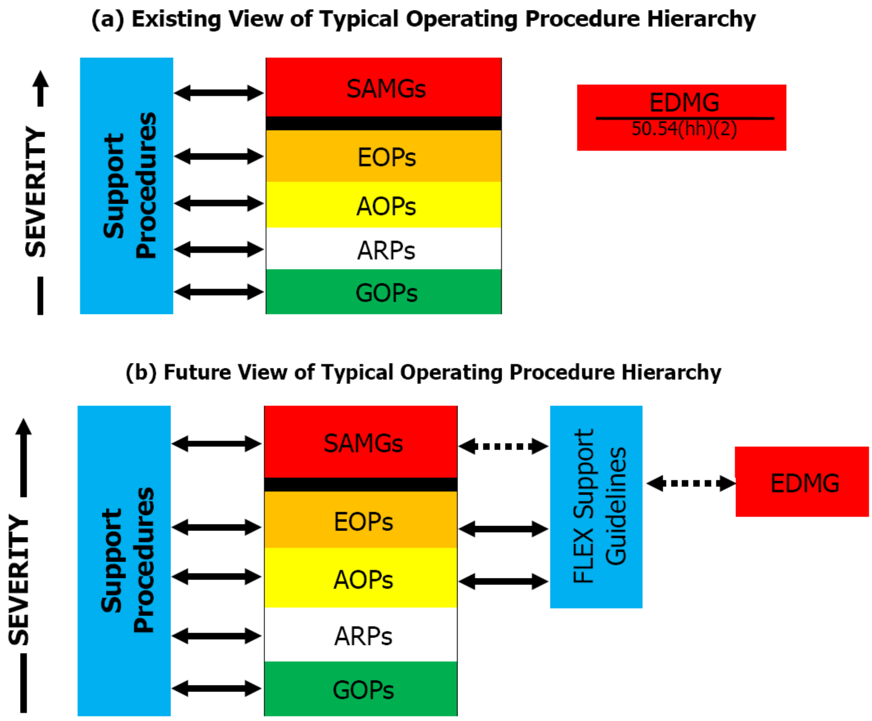

Fig. 7 Procedures and Guidelines integration

6.0 Developments in Spain

As referred before, two Complementary Technical Instructions (ITC) were issued by the Spanish CSN, in 2011; ITC-1 according to the European "stress tests", and ITC-2 in relation to the potential loss of large areas of nuclear power plants due to big explosions and fires.

The analysis required by ITC-1 included the following issues:

- Credible Initiating Events (earthquakes and floods)
- Consequent loss of safety functions (Total loss of electrical power (SBO), Loss of Ultimate Heat Sink (UHS), or both)
- Issues related to the management of severe accidents, including measures to protect and manage loss of core cooling function, of cooling pools spent fuel storage and of containment integrity.

The ITC-2 required analysis can be summarized in the following points:

- Emergency Command and Control
- Big fires fighting
- Fuel Damage Mitigation
- Radioactive releases Mitigation

This last regulation also required to perform cutting-cross studies, including aspects as procedures revision, staff training and needed equipment for each one of the aforementioned points.

As result of these analyses, and based on the international references reviewed, the main improvements developed on the area of Emergency Management can be summarized as follows:

1. Reassessment of the Emergency Response Organization and Emergency Plan review.
2. Enhancements on Emergency Communications.
3. Development of the new EDMGs.
4. Radiological protection and control improvements, including new equipment and guidelines for emergency response.
5. New Emergency Response Facilities, including;
    a. Alternate Center for Emergency Management (CAGE)
    b. Emergency Support Center (CAE)

The new Emergency Centers are among the most relevant aspects of the improvements in the Emergency Preparedness and Response. These facilities have been designed with the aim of establishing a flexible and robust response that will address a wide range of accident scenarios beyond the design basis.

6.1 CAGE

A new Alternative Emergency Management Centre (in Spanish, CAGE) has been built at each one of the Spanish NPPs (or is nearing completion, as the deadline is committed to the end of 2015). These new centers are designed to allow the management of the emergency in extensive damage scenarios, when the conventional Emergency Response Facilities are not operational or accessible.

These facilities have protection against all scenarios considered in the ITC including earthquakes, floods, etc. and also against expected radiological hazards. They are independent centers that have the resources to deal with the proposed scenarios autonomously for 72 hours, providing protection to the intended personnel.

6.2 CAE

At the request of the Spanish nuclear industry, Tecnatom has developed the CAE Project [12],[13] directed by the author, to define and establish a centralized service composed of intervention equipment and specialized personnel in the framework of an Emergency Support Center shared between all the Spanish NPPs, to strengthen the Nuclear Safety and Emergency Preparedness and Response. The emergency support service is designed to reinforce the NPP emergency capabilities, by integrating with the ERO of plants.

This service has successfully developed operational tests at each one of the Spanish NPPs on 2014. With these tests the performance of the Emergency Support Center service, at every Spanish NPP, was validated in four stages:

(1) CAE mobilization in less than 24h.
(2) Equipment Deployment to its final location in the plant.
(3) Checking the connections with NPP's interfaces, and
(4) Functionality of equipment.

The CAE proved in this way its capability to provide support to the Spanish NPPs, to strengthen their already strong characteristics in EP&R, to face these new Beyond Design Basis Scenarios.

The CAE main objective is to provide the NPPs an emergency support service, reinforcing their capacity of facing Extensive Damage Scenarios, by its integration in the emergency response of the NPPs. To do this, the center has been equipped with:

A. The Intervention Unit composed of specialized, available round the clock.
B. Intervention Equipment, as backup to provide additional cooling capacity and electric power.
C. A Centralized Storage Building, designed for holding, maintenance, and mobilizing the equipment.
D. Logistics to transport the Intervention Equipment to the NPPs.
E. The required procedures, for maintenance, operating, mobilizing, deployment and general managing.
F. The supporting organization for managing the service in normal situation.
G. Training capabilities to train CAE staff and other personnel required by the NPPs.
H. Emergency communications to face the specific scenarios considered.

All these features are shared between the Spanish NPPs, ensuring the efficient use of resources, with a structure that is consistent with other leading countries in Nuclear Safety, such as the United States, France and Switzerland [14], among others. Some of the main characteristics are summarized in the following points;

Fig. 8 CAE Team and Equipment at Preliminary Test

6.2.1 Personnel and Training

The intervention Team was selected by the performance of psychometric and physical tests, provided with reference to the CSN[3] Safety Guide 1.19 (2011), then they were trained for five months, including basic training, specific training and on the job training in all Spanish NPPs in operation. The staff working plan devotes 17% of working time in training, including an annual Exercise in an NPP with CAE equipment, two weeks of practice in two different NPPs, and one week of training at CAE headquarters, plus quarterly partial activations. The remaining 83% are devoted to synergistic tasks related to various aspects of the EP&R in the NPPs where they are intended.

[3] CSN, Consejo de Seguridad Nuclear, the Spanish Nuclear Regulatory Body

6.2.2 Equipment

CAE equipment has been defined to support the development of mitigation strategies for two units at the same site. The following are the characteristics associated to the main equipment of the CAE:

- Pumping groups: a submersible pump (63 l/s., 2 bar), two low pressure pumps (63 l/s., 15 bar), and two high pressure pumps (21 l/s., 10 bar), which when connected in series will discharge at over 25 bar.
- The Electric Power groups: four 150 kVA diesel generators, able to be connected in pairs.

The service also counts on other equipment to ensure lifting, mobilization, deployment and connection of these major components, and for performing the maintenance and to test them at the premises of CAE. Connecting components acting as interfaces with the different NPPs have been defined and tested, to ensure the ability to connect CAE equipment. The service includes equipment testing and maintenance, transport logistics and staff training.

6.2.3 Centralized Storage Building and Equipment

The facility provides accessibility of transport vehicles and means for loading and unloading intervention equipment, and capabilities for equipment testing and maintenance.

With easy access to terrestrial communications as well as to two military airports, it also counts on full coverage communications and industrial Security. It is located far enough from NPPs to reasonably ensure the absence of common cause events.

Fig. 8 Equipment in Centralized Storage Building

6.2.4 Transport

The Transport Logistics provides; the needed vehicles for the equipment transport, and the required staff, including drivers and support staff for load/unload tasks, personnel for control and managing the actuation, including communications systems required for tracking actuation, the necessary procedures associated with the service and the required infrastructure for the system activation, available round-the-clock.

7.0 Conclusions

After reviewing only some of the initiatives that Spanish NPPs have implemented, according to international best practices, it can be concluded that the Spanish NPPs not only count on solid safety margins in situations beyond the design basis, but that they are making a major effort to increase them, placing the Spanish nuclear industry among the international leaders on Nuclear Safety.

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