Severe Accident Management Hierarchy and Resilience Architecture Post Fukushima – 14510

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ABSTRACT

This paper explains the approach developed and used by **DBD Limited** to assess the "key radiological" plants and the "emergency preparedness" on a complex nuclear "chemical processing" site. The approach ensured that the assessments were carried out in a consistent manner fully aligned to the European Nuclear Safety Regulator Group (ENSREG) "stress test" specifications which, while mandatory within the UK, was focused on Nuclear Power Plants (NPPs). It explains how this work is being expanded to develop the Severe Accident Management Strategies (SAMS) for the site, including managing the consequence of "man-made" initiators.

Whilst not wanting to be drawn into the many discussions on the frequency and magnitude of earthquakes; it is fair to say that Fukushima and the "stress test" work which followed have highlighted that the low frequency, low probability, high consequence events CAN occur. Coincident, multi-unit events are not improbable; hence deterministic and probabilistic risk assessment (PRA) MUST work together in the future to ensure that a holistic approach to develop a suitable level of "emergency preparedness". A cohesive Severe Accident Management Hierarchy (SAMH) that demonstrates adequate arrangements are in place to actively manage a "severe event" at each stage is proving to be successful. The approach is proving to be successful for various reasons; not least due to the workshop nature of the process which prompts engagement with key personnel and not only quickly highlights limitations with current arrangements but also facilitates the identification of solutions and practical improvements.

In doing so we must be realistic about the limitations and vulnerabilities of our aging nuclear facilities. That is those that were designed and constructed prior to the evolution of the modern nuclear safety case and prior to our enhanced understanding and appreciation of the impact of both natural and man-made initiators.

INTRODUCTION

In 2011, following the tragic events at Fukushima the nuclear industry committed to maximize learning and strive to ensure that the consequence of any similar events in the future would be minimized. With this is mind the Western European Nuclear Regulators Association (WENRA) and the European Nuclear Safety Regulator Group (ENSREG), among others, published a set of "stress test" specifications [1]. These were defined as targeted assessment of the safety margins of nuclear plant in light of extreme natural events challenging the plant safety functions and leading to a severe accident. It was a mandatory requirement that ALL Nuclear Power Plants (NPPs) in Europe carried out these "stress tests" and submitted their findings. The United Kingdom's nuclear regulatory (the Office for Nuclear Regulation (ONR)) extended this requirement to ALL nuclear facilities within the UK, including the Sellafield Reprocessing site; home to multiple waste management processes. Sellafield is one, if not the most congested nuclear site in the world, home to multiple diverse nuclear facilities.

While the “stress tests” was prescriptive about certain criteria; for example stating that heavy machinery/plant is unable to access the site for the first 72 hours following such an event. It was less prescriptive about other criteria; for example no duration was provided for a “prolonged” station/site black out (SBO) or definition for beyond “design basis earthquake or flood” (DBE or DBF). Therefore it was left to some extent to each “operator” to scope and bound their assessments.

As a result **DBD Limited** was approached by the Sellafield Site Licence Company (Sellafield Limited (SL)) to develop and implement a process to provide information to support their response to the ENSREG “stress test”. The process that DBD developed and implemented tested the robustness of the individual facilities, their back-up systems, the effect of interconnectivity of the facilities, the site safety cases as well as the site-wide and facility specific local emergency arrangements and their link into the national arrangements.

What follows in this paper is an explanation of the approach used to develop the process, a high-level overview of the findings, as well as how the process is continuing to develop. The paper doesn’t include details of any specific facilities but hopefully it will prompt discussion on the process which identifies and assesses “emergency arrangement” requirements for individual facilities and ultimately a site and the findings.

ACRONYM

CSF Critical Safety Function
DBE Design Basis Earthquake
DBF Design Basis Flood
ONR Office for Nuclear Regulation
ENSREG European Nuclear Safety Regulator Group
RESEP Resilience Evaluation Process
SAMH Severe Accident Management Hierarchy
SAMS Severe Accident Management Strategies
SBO Station/Site Black Out
SL Sellafield Limited
WENRA Western European Nuclear Regulators Association

THE INITIAL RESILIENCE EVALUATION PROCESS (RESEP)

As stated earlier the focus of the original task was to “stress” the existing arrangements for managing a “severe accident” on the site against the new, more challenging, ENSREG “stress test” criteria, to provide SL with the appropriate detail to produce their ENSREG stress test response. To do this a set of assumptions were agreed with the client such as:

- **The** fundamental assumption for the whole process was that the event HAS happened. Probability didn’t factor into the analysis stage as Fukushima had demonstrated that low frequency, high consequence, coincident events CAN happen.
- A “prolonged” SBO as defined as being up to 7 days.

- The definition of a “severe accident” was a given from the client based on the potential to give a public consequence of > 10mSv within 7 days.
- The DBE and DBF data was provided by the client and was taken 1 in 10,000 years, in line with current UK safety case methodology.

Due to the complex, multi-facility nature of the site the work was split into the following stages (shown pictorially in the power point presentation):

- Identify the “key radiological” facilities, identify any “Critical Safety Functions (CSFs)” that rely on a utility/service (e.g. power, water, steam, air) to prevent a radiological release during a “prolonged” SBO.
- “Stress” the existing declared arrangements/back-ups to prevent such a release under SBO conditions.
- Develop timelines for **each facility.** Two timelines were produced; a single facility event affecting just that facility and secondly for a site wide event which could impact the availability of the declared arrangements/back-ups. This allowed the overall “demand” for the “key radiological” facilities to be identified.
- In a similar way the buildings and services required to manage the event (e.g. communications, command and control, medical facilities) were also “stressed” against the same backdrop to allow the overall “demand” for these arrangements to be identified.
- The ability to provide the utilities (water, steam, air and power) via the existing infrastructure was also “stressed“.
- The final stage was to overlay the impact of concurrent “physical damage” due to beyond DBE and DBF (e.g. would the declared back-up systems still be available or not, the scale of any radiological release). This allowed a picture to be constructed which showed the potential limitations of the declared arrangements during a severe event such as availability, usability and accessibility.

The process was a direct development of DBD’s D_2O process and was workshop orientated which allowed any limitations and issues to be quickly identified. As well as identifying additional analysis required to fully understand the extent of some of the issues.

To minimize the impact on plant resources DBD scheduled a preparation phase for each area to allow the nominated DBD Lead and Scribe to become conversant with the safety systems and procedures for an area of the facility. This was in order to not only pre-populate the templates but to become knowledgeable facilitators and challengers. This ensured that the maximum benefit was gained from the plant personnel during the workshop. This approach is continuing to be used on subsequent stages of the work.

IMPROVING THE “RESILIENCE” OF A FACILITY/SITE

The next stage was to enhance the robustness of the arrangements. To do this enhanced expectations had to be set to define the level of “preparedness” that the client would work towards achieving. To support the development of the “resilience” improvement programme DBD proposed three (3) “resilience goals” which were accepted by the client as “aspirational” goals:

- “Key radiological” facilities and the Emergency Designated Buildings to be self-reliant during the first 24 hours of a SBO,
- “Site” to be self-reliant for 7 days during a Loss Of Offsite Power (LOOP),
- “Site” to be self-reliant for 3 days during a radiological challenge.

Following on from this and using their “optioneering and down selection (D_2O)” process DBD are leading the work to identify the improvement work for the first two “resilience goals”.

The third goal while linked to the ENSREG “stress tests” goes further than the “stress tests”, it is incorporating the findings from a suite of “Severe Accident Analysis (SAA)” documents provided by the client which also include “man- made” initiators. The Resilience Evaluation Process (RESEP) looked at “physical damage” and radiological releases but not in the same level of detail due to the ENSREG “stress test” time constraints. The inclusion of the additional initiator has also expanded the number of facilities to be considered and the challenges to be managed.

In a similar manner to RESEP; DBD has developed a complementary workshop process utilizing a standard risk reduction hierarchy approach to establish a Severe Accident Management Hierarchy (SAMH) for each facility which enables the overall site emergency preparedness strategy to be developed. This process provides the technical basis for both the facilities and the site’s emergence arrangements associated with the consequences identified in the SAA and via RESEP. As stated earlier these workshops are being prepared for and run in the same way as the RESEP workshops.

The RESEP improvement work is primarily “prevention” focused, primarily stopping a radiological release occurring during a “prolonged” SBO/LOOP. The SAMH work builds on this and extends into “managing a release” once it has occurred for whatever reason. This enables Severe Accident Management Strategies (SAMS) to be developed for each facility/consequence.

Due to the experience of the DBD team, with respect to the knowledge of the site, its processes and their interpersonal skills, they are able to ensure that the atmosphere during all stages of the process is constructive, focused and is such that participants feel comfortable talking openly about potential shortfalls and issues. As a result direct engagement with plant personnel willing to attend and participate is ensured, delivering powerful new insights into operability and emergency response at the site. In addition valuable information identifying Critical Safety Functions and timelines to support effective decision making in severe crises was collated during the RESEP which is now being built on and incorporated as part of the SAMS work.

DISCUSSION & CONCLUSIONS

The initial insights gained during RESEP identified that robust utilities and services are essential to manage a severe event, primarily:

- power,
- water,
- communications,
- data,

- command and control.

The SAMH work is continuing to emphasize/underpin this. In addition the SAMH work has identified that irrespective of the initiator the consequences and issues from severe events can be grouped into common types (listed below);

- managing a liquid release,
- managing an aerial release,
- managing a solid release,
- preventing and fighting fire,
- managing an explosive atmosphere,
- understanding/monitoring the event including key plants parameter and wider/domino impact,
- enablers such as mobile shielding, access/lifting equipment.

This allows more “generic/flexible” responses to be defined for multiple facilities and hence common equipment can be identified rather than bespoke difficult to operate kit.

From this work two main differentiators are emerging:

- “accessibility”; due to both the initiator (some could cause more physical disruption than others) and the scale of the potential radiological release (large beta/gamma release would significantly hinder access and hence limit the use of some of the response options),
- available “response time”; again due to both the initiator (some could cause an almost immediate release outside the facility) and the type of the potential radiological release (airborne releases (especially alpha) generally require a faster response than liquid release).

From the RESEP and SAMH work, principles are emerging that could be used to inform the design of plants and projects and emergency arrangements for any high hazard facility not just nuclear, such as:

- back-ups should be “passive and dumb” where possible,
- design for the “likely” (e.g. SBO); plan for the more “unlikely” (e.g. >DBE, > DBF).

Key to having a site robust to severe events is to ensure that it is the arrangements are considered holistically rather than as separate entities (e.g. individual facilities, site utilities and infrastructure, site emergency arrangements separately), as each assumes a reliance on/availability of the others which must be clearly understood, communicated and exercised, including in safety cases. Modern safety cases assume an availability of utilities/services; Fukushima is now making us ask the question “what if they aren’t available?”. Low frequency, low probability yes, but impossible no. These processes have significantly improved industry understanding on how deterministic and probabilistic risk assessment (PRA) MUST work together in the future.

In June 2012 The American Society of Mechanical Engineers (ASME) issued “Forging A New Nuclear Safety Construct” [2]. While terminology may be different to that used in this paper the principle findings and messages associated with “managing severe events” are the same.

Arrangements should “dove tail/marry” together, there should be no glaring gaps between the different arrangements (e.g. facility specific, site wide, regional and national arrangements). Each stage of the hierarchy should build on the previous, “prevent” should build on “remove/reduce”, limit and mitigate should build on “prevent”. The aim of the SAMH is to demonstrate that there are adequate arrangements in place to actively manage a “severe event” at each stage.

In doing so we must be realistic about the limitations and vulnerabilities of our aging nuclear facilities. That is those that were designed and constructed prior to the evolution of the modern nuclear safety case and prior to our enhanced understanding and appreciation of the impact of both natural and man-made initiators.

REFERENCES

1 “Stress Tests” Specifications, May 2011, WENRA
2 “Forging A New Nuclear Safety Construct”, June 2012, ASME