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DESIGNING FOR THE CONSEQUENCES OF HAZARDS

EXTERNAL HAZARDS FOR NUCLEAR FACILITIES

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INTRODUCTION

Of the five fundamental principles embodied in the design and assessment of nuclear safety related facilities, two relate directly to accidents. These are:

- All reasonably practicable steps shall be taken to prevent accidents

- All reasonably practicable steps shall be taken to minimise the radiological consequences of any accident.

In the nuclear industry, accidental situations include consideration of the effects of external hazards and environmental influences. This contribution to the colloquium outlines how these issues are dealt with and comments on the possible lessons for other sectors.

In the context of the nuclear industry, accidental situations are concerned with safety, in particular radiological safety, and not economic loss. Costs are taken into account in consideration of ALARP (As Low As Reasonably Practicable), but this only applies once the design has been shown to meet Basic Safety Limits and that the risks are tolerable.

In all cases, safety is achieved through sound engineering design. The likelihood of accidents occurring should be minimised by conservative design, by operational controls and by adequate maintenance, inspection and testing.

The philosophy adopted towards accidents and hazards by all nuclear facility operators can be summarised as prevent, protect and mitigate:

- Avoid or eliminate potential hazards by design

- Provide protection by engineered safeguards within the design

- Provide mitigation of the consequences (radiological) of the hazard

DESIGN BASIS ACCIDENTS

Nuclear facilities are designed to cope with a wide range of potential accidents. These are referred to as Design Basis Accidents (DBAs). The approach to the analysis of Design basis

Accidents is deterministic. This is in line with international practice which also requires a robust demonstration of the tolerance of the facilities to the event and the effectiveness of the safety systems. Uncertainties in the analysis are covered by the use of appropriate conservatism in the treatment.

ACCIDENTS BEYOND THE DESIGN BASIS

A deterministic approach is also followed for those accidents which are beyond the design basis (severe accident) and hence are liable to have serious consequences. The analysis of these accidents differs from that for DBAs in that it is performed on a best estimate basis. This is because it is primarily required to give realistic guidance on performance and the actions to be taken in the unlikely event of such an accident occurring.

PROBABILISTIC SAFETY ANALYSIS

Since the Design Basis Accident analysis and the severe accident analysis are deterministic, they give no quantitative indication of the risk posed by the facility. Consequently these analyses are complemented by Probabilistic Safety Analysis (PSA), which addresses the full range of possible accidents. PSA is performed on a best estimate basis, except where this is not practicable and in which case any bias is in the pessimistic direction. The PSA searches out any weaknesses in the design, provides estimates of overall risks from the facility and enables checks to be made on defence in depth.

IDENTIFICATION OF EXTERNAL HAZARDS

External hazards are those that occur outside the facility (internal hazards occur within the facility and conveniently may be thought of as arising from operation of the plant, equipment and processes in the facility). A key requirement is to ensure that all potential hazards that could affect safe operation of the facility are identified.

The potential hazards include natural events, environmental influences and man made hazards. In a study in 1999, BNFL, now British Nuclear Group, identified 44 hazards. Of these, 20 required no further detailed consideration, leaving 24 hazards to be considered in all cases. These were classified as follows:

Natural hazards	8
Man-made hazards	7
Protected by engineering safeguards	9

Clearly, a number of those identified have the potential to affect only the plant and equipment and not the buildings and structures. However, the buildings and structures may themselves be part of an engineered safeguard to the plant and equipment and thus have a safety function.

GENERAL PRINCIPLES

For all hazards the design basis principles and the PSA principles should be satisfied unless it can be demonstrated

- that the frequency of an event being exceeded is < 1 in 10,000,000 years
- that the source of the hazard is sufficiently distant that it cannot reasonably be expected to affect the plant

For natural hazards, the uncertainty of the data may prevent reasonable prediction of events for frequencies of less than 1 in 10,000 years. The design basis event should be an event that conservatively has a predicted frequency of being exceeded no more than once in 10,000 years.

It must be shown that there will be no disproportionate increase in risk from an appropriate range of events which are more severe than the design basis event. This is a very misunderstood principle and can lead to excessive conservatism.

Hazards are assumed to occur with the most adverse normal operating conditions.

Either site specific or, if this is not appropriate, best available relevant data should be used to determine the size of the hazard.

PRINCIPLES FOR SPECIFIC HAZARDS

Aircraft Impact

Predicted frequency of aircraft crash should be determined for the site (note this is "accidental" aircraft crash). The calculation should take into account the most recent statistics, flight paths and forecast changes to these factors. Exclusion from approach to, or overflying of, the site should be considered.

Earthquakes

This hazard possibly represents the most thorough application of the principles on external hazards to date. Detailed seismological and geological studies of the area around the site are required together with analysis of the historical information of earthquakes. The hazard is defined at a frequency of 1 in 10,000 and a study is required of the margins in the design beyond that level.

Extreme Weather Conditions

The principles are similar to those for earthquakes, but generally these conditions have received comparatively less attention. Extreme winds at a frequency of 1 in 10,000 are used, but belatedly, the validity of other parameters, such as the effects of dominant openings, is only now receiving attention. Extreme temperatures may affect material properties as well as induce loadings.

Fire, Explosion, missiles, toxic gases etc.

The principles in this context are focused on minimising the risk by avoiding the sources of the hazards.

Flooding

Similar to extreme weather conditions, with the emphasis on ensuring that all potential sources of flooding are identified (rain, rivers, tides, failure of dams, seiches and tsunamis).

Analysis and Design

Design data and analytical models are subject to rigorous assessment of their relevance and validation. In particular, for analytical model it is required that they be validated against experimental results and that independent checks are made using different models and methods. Human factors (operator errors), layout, maintenance, inspection and testing and ageing are all require to be taken into account in the design process.

Increasing computer power has led to the ability to numerically model with increased sophistication many of the dynamic loadings associated with external hazards. Whilst computing power will continue to increase, there is perhaps now a reaction to this trend of increased analysis, with regulators now looking to ensure that safety is achieved through sound engineering design rather than by more analysis.

Research Needs

Recent views on the immediate needs for research in the area of external hazards are:

Extreme Weather Conditions

1. Wind loading in a closely spaced multi-plant environment – aerodynamic interaction and funnelling.

2. The effects of dominant openings in very large buildings

Earthquakes

1. Performance based seismic design

2. The use of Uniform Risk Spectra and real time histories in seismic design

3. Alternative damage measures for the seismic design of buildings

4. Beyond design basis assessment technique

5. The use of Eurocode 8 for the seismic design of structures

CONCLUSIONS

The need to ensure the safety of nuclear facilities has led to the development of a rational and highly structured approach to accidents and external hazards. The industry therefore has the potential to offer considerable experience to other sectors.