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External Hazards			
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1. INTRODUCTION

1.1 ONR has established its Safety Assessment Principles (SAPs) which apply to the assessment by ONR specialist inspectors of safety cases for nuclear facilities that may be operated by potential licensees, existing licensees, or other duty-holders. The principles presented in the SAPs are supported by a suite of guides to further assist ONR's inspectors in their technical assessment work in support of making regulatory judgements and decisions. This technical assessment guide is one of these guides.

2. PURPOSE AND SCOPE

2.1 This guide explains the approach adopted by ONR in its assessment of duty holders' safety submissions that relate to external hazards (earthquake, extreme weather, flooding etc) that could have a detrimental effect on nuclear safety and are described in ONR Safety Assessment Principles (SAPs) (Ref. 1) EHA 1 to EHA 19 (paragraphs 228 to 274), although EHA.13 to 17 are primarily concerned with internal hazards. Table 1 provides a comprehensive, but not necessarily exhaustive list of hazards that should be considered.

2.2 The SAPs require that external hazards on nuclear facilities be identified and considered in the duty holder's safety assessments. External hazards are those hazards to plant and structures which either originate outside the site boundary or are external to the process (in the case of nuclear chemical plant) or the primary circuit (in the case of power reactors) i.e. the duty holder has limited, if any, control over the initiating event.

2.3 The assessment of external hazards requires detailed knowledge of natural processes, along with plant and site layout. In contrast with almost all internal hazards, external hazards can simultaneously affect the whole facility, including back up safety systems and non-safety systems alike. In addition, the potential for widespread failures and hindrances to human intervention can occur. For multi-facility sites this makes the generation of safety cases more complex, and requires appropriate interface arrangements to deal with the potential domino effects.

2.4 The SAPs also require that the risk from hazards be minimised by initial siting of the facility (ST.4) where possible and by attention to plant layout.

2.5 The safety assessment should demonstrate that threats from external hazards are either removed, minimised or tolerated. This may be done by showing that safety related plant and equipment are designed to meet appropriate performance criteria against the postulated external hazard, and by the provision of safety systems which respond to mitigate the effects of fault sequences.

2.6 This TAG contains guidance to advise and inform ONR inspectors in the exercise of their professional regulatory judgement. As for the SAPs, and to avoid repetition in this guide, the judgement is always subject to ALARP, not all the guidance applies to all assessments or all facilities, and consideration of proportionality applies throughout.

3. RELATIONSHIP TO LICENCE AND OTHER RELEVANT LEGISLATION

3.1 The majority of external hazards could have an impact on the matters addressed by most of the nuclear site licence conditions. However, the following are seen as being most relevant to the specific threats posed by external hazards on nuclear facilities:

a. **Licence condition 7: Incidents on the site -** records should be kept of the occurrence of relevant hazards.

b. **Licence condition 9: Instructions to persons on the site -** the instructions should provide explicit information on how to deal with external hazards and how site personnel are best protected. These instructions may require cross-referencing to specific operating instructions and limits for some hazards, e.g. flooding and temperature, where there may be a period before the event where it is possible to prepare for developing hazards. The actions following certain magnitudes of events i.e. the Operating Basis Earthquake (OBE) will also need to be defined.

c. **Licence condition 11: Emergency arrangements** – external hazards are one of the range of possible motives for the instigation of the emergency arrangement procedures.

d. **Licence condition 14: Safety documentation -** this condition requires documentation in which external hazards should be considered.

e. **Licence condition 15: Periodic review -** this condition requires external hazards to be considered as part of the periodic review. Typically, this will involve a review of events considered, including magnitude frequency values, data and methodological developments, and operational feedback. In addition, due consideration needs to be given to the effects of climate change over the remaining lifetime of the facility.

f. **Licence condition 16: Site Plans, Designs and Specifications** – The interaction between structures especially during construction and decommissioning changes the demands placed by external hazards.

g. **Licence condition 19: Construction or Installation of New Plant, and Licence Condition 20: Modification to design of plant under construction -** these conditions require that the design of plant under construction, or a modification to the design is assessed in the context of the external hazards safety case, where appropriate.

h. **Licence condition 22: Modification or experiment on an existing plant -** this condition requires that a modification or experiment on an existing plant is assessed in the context of the external hazards safety case, where appropriate.

i. **Licence condition 23: Operating Rules** – this condition requires that the duty holder shall, in respect of any operation that may affect safety, produce an adequate safety case to demonstrate the safety of that operation and to identify the conditions and limits necessary in the interests of safety. This may include limitations on activities during periods of extreme cold or high wind

j. **Licence condition 28: Examination, maintenance, inspection and testing (EMIT)** – this condition requires that the duty holder makes and implement adequate arrangements for the regular and systematic examination, inspection, maintenance and testing of all plant which may affect safety which would include a number of systems installed to protect and against external hazards e.g. temperature monitoring, seismic detectors/ alarms, and especially flood detection.

4. RELATIONSHIP TO SAPS, WENRA REFERENCE LEVELS AND IAEA SAFETY STANDARDS

4.1 The specific external hazard SAPs are: EHA 1 to EHA 19, which cover the wide range of external hazards identified that requires consideration.

4.2 There are a number of supporting and related SAPs. These are:

- EKP.1 – EKP.5 Key Engineering Principles.
- ECS.1 – ECS.5 Safety Classification and Standards.
- ECE.1 – ECE.24 Civil Engineering
- EDR.1 – EDR.4 Design for Reliability.
- ECV.1 – ECV.10 Containment and Ventilation
- FA.1 – FA.3, and FA. 5 Fault Analysis.
- AM.1 Accident Management
- ST.1, ST3 – ST.6 Siting

Due to the all-pervasive effects of external hazards, this list could include virtually all the SAPs. However, the shortened list above highlights those key SAPs which should be considered in the first instance. In addition, it is worth noting that the following paragraphs are also of relevance.

- 9-18 ALARP
- 33-34 Facilities Built to Earlier Standards
- 335 Ageing
- 42-43 Multi-facility sites

4.3 A duty holder's safety principles must define safety goals and the minimum essential plant and equipment and supporting services, together with performance requirements, needed to meet the goals. These requirements constitute the criteria against which the duty holder must judge the acceptability of its safety case, and should be commensurate with a level of safety acceptable to the Inspectorate, and so should be justified to the Inspectorate and, as a minimum, meet the intent of the SAPs unless appropriate mitigation and/ or ALARP arguments can be made.

4.4 A significant aspect is that the fault sequence (see SAPs EKP FA 1, 3, 5, and 8, together with their supporting text) should systematically identify the failure modes; identify safety functions and consequences. Safety systems and safety related plant should be qualified to withstand the effects of relevant external hazards or be protected against the hazards. External hazards may include earthquakes, meteorological extremes, flooding and industrial hazards. As there will be limitations on the accuracy with which the effects of hazards can be predicted and because random failures of equipment can occur, the duty holder's safety principles should recognise that diverse and segregated plant and equipment may be required to establish the level of reliability needed to meet their safety goals.

4.5 In order that safety systems and plant designed to perform essential safety functions will have the level of reliability required to meet safety criteria, the duty holder must consider the possibility of single random failures, common cause failures, and unavailability due to maintenance activities. Common causes include both plant and equipment failures and effects of external hazards. The appropriate level of reliability of essential safety functions may be achieved by engineering redundancy within single trains and/or segregation and diversity between trains.

4.6 The relationship between the frequency and consequences of hazards and the reliability of protection and plant required to perform essential functions should be defined in duty holder's methods and criteria. So there should be guidelines for translating high level goals into practical engineering requirements.

4.7 Redundancy, diversity and segregation should be incorporated as appropriate within the designs of structures, systems and components important to safety. For some civil structures, it may not be possible to achieve redundancy; however, it is allowable to use arguments of high margin and robustness in the design process (ECE.2).

4.8 Moreover it is expected that a safety case will demonstrate that support services and facilities such as access roads, water supplies, fire mains and site communications important to the safe operation of the nuclear plant should be designed and routed so that, in the event of any incident, sufficient capability to perform their emergency functions will remain.

4.9 As stated in para 1.5 and 1.6 benchmarking against the WENRA and IAEA standards has been undertaken at a high level, the results of which can be seen in Table 2. This has shown that the SAPS in the area of external hazards meet the requirements of both organisations.

WENRA

4.10 The current Western European Nuclear Regulators Association (WENRA) Reference Levels (RLs) were published in in 2014 Refs. 2. Issue T of the reference levels deals specifically with natural hazards and is included, in full, as section 8 of this TAG. Theese reference levels are considered to be consistent with the external hazard SAPs and should be used directly by inspectors where they add to or enhance the assessment process. The Waste and Spent Fuel Reference Levels do not have specific external hazard levels and there are no relevant decommissioning reference levels.

IAEA

4.11 The 2014

4.12 SAPs were benchmarked against the IAEA Safety Standards (requirements and guidance) and their main principles are encompassed within the SAPs. Guidance on how to assess them is included within the general guidance on the assessment of external hazards and in the various annexes to this TAG. References 11-28 provide international relevant good practice. Ref 11 in particular sets out the external hazards that should be considered when defining the design basis.

5. ADVICE TO INSPECTORS

Identification

5.1 The fundamental step in addressing the threats from external hazards is to identify those that are of relevance to the facility under consideration. EHA.1 provides an overview of this. Paras 228 and 229 provides an overview of the distinction between internal and external hazards, the key difference being that internal hazards are to some degree under the control of the duty holder. This definition may require some interpretation on multi-facility sites, where there may be multiple licensees or duty holders. For example, explosion from gaseous release from two separate facilities on a site with different licensees may be treated as an internal hazard to some plants and an external hazard to others depending on relationship between the plant under threat and the plant which is causing the hazard. Duty holders may choose to adopt a different definition which suits their facilities or safety case production. This is of little concern provided all hazards have been considered.

5.2 Hazards can be screened out (SAP EHA 19) from further consideration on two criteria, either because they are incapable of posing a significant threat to nuclear safety or because the frequency of occurrence is extremely low. As an exception, malicious actions are generally not expected to be treated in this manner. A figure of 1 in 10 million years is quoted as a cut off frequency (10-7 pa). In performing this cut off, the overall risk contribution from the hazard should also be borne in mind. Risk matrices may be useful in aiding judgements of this nature.

5.3 Table 1 contains a typical range of hazards that should be considered in the first instance. However, this should not be seen as exhaustive as local site conditions, and the plant design may invite further hazards. Annexes 1-10 provide further details on individual hazards. The duty holder should demonstrate that an effective process has been applied to identify all types of external hazard relevant to a particular site (paragraph 208).

Design basis events

5.4 The glossary in the SAPs provides the following definitions:

Design basis: - The range of conditions and events that should be explicitly taken into account in the design of the facility, according to established criteria, such that the facility can withstand them without exceeding authorised limits by the planned operation of safety systems.
Design basis fault: - A fault (sequence) which the plant is designed to take or can be shown to withstand without unacceptable consequence, by virtue of the facility's inherent characteristics or the safety systems.

5.5 FA.2 (and supporting text) state that external hazards should be considered. EHA.1 further amplifies this. EHA.4 points to FA.5 to define the frequency of exceedance that should be associated with a design basis event. FA.5 paragraphs 514a,c) state that the following can be excluded from the design basis;

- faults in the facility that have an initiating frequency lower than about 10-5 pa;
- natural hazards that conservatively have a predicted frequency of being exceeded of less than 1 in 10 000 years;
- those faults leading to unmitigated consequences which do not exceed the BSL for the respective initiating fault frequency in Target 4.

5.6 The above criteria do not explicitly specify man-made external hazards. For both natural and man-made external hazards an important distinguishing feature is that the duty holder has no control over their likelihood of occurrence or severity. This is of fundamental importance since the first line of defence to secure nuclear safety is the elimination of the hazard at source (SAP EKP.3 defence-in-depth refers). Thus for external hazards, natural and man-made, level 1 defence-in-depth is not available to the duty holder. Therefore whilst the 10-5 design basis criterion should be applicable to man-made external hazards, this may not always be practicable and in such cases a suitable ALARP justification should be provided.

5.7 Para 240 does allow for consideration of a relaxation of these criteria where the risk of high unmitigated doses is low. FA.5 (Target 4) defines the frequency of exceedance that should be associated with design basis events in terms of a relationship between frequency and consequences. This is shown on Figure 1. Whilst the IEF for plant initiated faults are generally evaluated on a best estimate basis, occurrence frequencies for external hazards should be evaluated on a conservative basis to allow for data uncertainty or unavailability. It is suggested that the following guidelines provide the basis for definition of the design basis providing consistency between plant initiated faults and faults initiated by external hazards. These guidelines are illustrated in Figure 1.

a. Facilities that could potentially give rise to unmitigated consequences (evaluated on a conservative basis) greater than 100 mSv to any person off-site or 500 mSv to a worker may have a design basis event that conservatively has a predicted frequency of being exceeded no more than once in 10 000 years.

b. Facilities which could give rise to doses (evaluated on a conservative basis) between 10 mSv and 100 mSv to any person off-site or 200 mSv to 500 mSv to a worker may be designed against a design basis event, defined on a sliding scale, that conservatively has a predicted frequency of being exceeded from no more than once in 1000 to no more than once in 10 000 years (See Figure 1).

c. Facilities which could give rise to doses between 1 mSv and 10 mSv (evaluated on a conservative basis) to any person off-site or 20 mSv to 200 mSv to a worker may be designed against a design basis event, defined on a sliding scale, that conservatively has a predicted frequency of being exceeded no more than once in 100 to no more than once in 1000 years (See Figure 1). For some facilities the external hazard loads arising from application of normal industrial standards may provide an appropriate design basis and compliance with Building Regulations may be sufficient.

d. Facilities that cannot give rise to doses (evaluated on a conservative basis) as high as 1 mSv to any person off-site or 20 mSv to a worker need not be subject to formal design basis analysis. There should not be a disproportionate increase in risk due to low consequence frequent hazards just outside the design basis. The licensee should therefore demonstrate that these risks are ALARP.

5.8 Whilst the approach detailed above is valid, care should be taken when reviewing duty holder submissions, as for the case of external hazards the levels of uncertainty around the hazard levels can be large (and difficult to quantify). Efforts at extreme precision should therefore be treated with caution, and the requirements of EHA 7 regarding cliff edge effects should also be borne in mind. Alternative approaches based round the targets laid out in SAPs Target 4 could also be considered provided they can be justified and the risks shown to be ALARP (see also SAP paragraph 727).

5.9 For many external hazards the available data are sparse and require specialist interpretation to allow a probabilistic treatment. Although the SAPs intend both a deterministic and probabilistic approach to be taken for external hazards, even the deterministic approach depends on a probabilistic definition of loading, i.e. 10-4 annual probability of exceedance for most external hazards. For some hazards, particularly seismic, a range of sophisticated approaches may be available to estimate the hazard load. In such cases the inspector should ensure that the methods adopted are reasonable and also that the results are not sensitive to specific assumptions. A specific range of sensitivity studies should be considered; SAP ERL.1 provides further guidance.

Figure 1 – Design Basis Criterion for External Hazards

Combination of hazards

5.10 It is possible for more than one external hazard to apply simultaneously (correlated hazards), and that even a single hazard will apply with other loadings (see below). However the simultaneous application of two independent low probability hazards is generally unreasonable, and is effectively ruled out by EHA.1. Exceptions occur where the external hazards are not truly independent (non-correlated hazards), for example where extreme wind may be associated with extreme flooding.

5.11 For example it would be appropriate to assume best estimate live loadings to apply with a 10-4 annual probability of exceedance wind or seismic hazard. Judgment may be required as to whether a "normal" snow load should apply with an extreme wind loading etc, or whether extreme wind is likely to remove all but the hardest snow crust. There may be a wide range of "normal" loadings which might apply at any single time, such as crane position or load etc., and in these the assumed combination should be such that all "normal" cases are shown to be enveloped. Sometimes a "time at risk"(SAP Para 759 et seq inc NT2) argument is proposed to limit the scope of combined load cases. Discretion may be applied to the application of normal wind load with design basis seismic load. The effects are likely to be additive over at least part of a structure, so consideration as to an appropriate wind load may be required. However, inclusion of multiple wind directions considerably increases the number of seismic load cases, and the combined results make comprehension of the seismic behaviour more obscure. It should be recognised that the 10-7 BSO target for a single class of event would require the time at risk to be roughly equal to 10-1 per annum, when combined with a 10-4 annual probability of exceedance hazard loading, and a10-2 reliability per demand to rule out any particular combination. This amounts to less than about 3 days per year. Care should be taken for example to ensure that short duration, but high risk operations are not automatically accepted on a time at risk basis, without a thorough investigation into the options for reducing the risk in some way. T/AST/005 - ONR Guidance on the Demonstration of ALARP (As Low As Reasonably Practicable)[1] provides further guidance.

5.12 In addition, secondary hazards, arising from the effects of a primary hazard on plant and structures which have not been designed against the primary hazard should be examined. For example, damage to non-safety related structures from wind loading creating missiles, or seismically induced flooding/ collapse. Identification and initial screening of these secondary hazards is often best undertaken through use of a walkdown technique, as desktop exercises can often miss the physical proximity and interaction combinations.

5.13 An event may occur which causes some degree of damage to a facility, but which does not render the plant outside of its current safety case for that particular hazard. The plant however has a reduced capability to accommodate the effects of other hazards until such times as repairs have been undertaken. Duty holders should have in place systems which rapidly assess any damage caused by external events, assess any potential undermining of any safety case claims, and undertake repairs in a timescale commensurate with the risk posed. If repairs cannot be made readily, then mitigation strategies should be developed to reduce the residual risk to ALARP. It is not suggested that duty holders undertake detailed assessments of a wide range of potential succession scenarios.

Operating conditions

5.14 The inspector should ensure that a reasonable combination of other relevant loads (including fault loads where appropriate) is assumed to apply simultaneously with the hazard of interest, see EHA.5. For plant operating loads, temperature, pressure, availability etc, these should be taken as the extremes of the operating envelope, which should be reflected in the limits placed in the Operating Rules or Tech-Specs. Sensitivity studies may also be necessary to ensure that the chosen values and combinations are conservative.

Disproportionate consequences

5.15 EHA.7 introduces the need to demonstrate that there will not be a disproportionate increase in radiological consequences from an appropriate range of events which are more severe than the design basis event. The way in which this principle is satisfied may depend on the nature of the hazard being addressed. For some hazards a point will be reached where there is a step change in the effect on the installation. In the case of external flooding, for example, the site defences become overtopped. In such cases, it needs to be shown that there is a reasonable margin between the design basis and the point at which this step change would occur. For other hazards, such as seismicity, the forces acting on the installation will continue to increase progressively with increasing size or proximity of the event. A demonstration is needed that there will not be a step change in the response of the installation to the hazard, in terms of the likelihood of a release of radioactivity, for an appropriate range of events more severe than the design basis event. When addressing many extreme hazards the response of a structure beyond the design basis can be enhanced considerably by adopting a ductile structural form and incorporating ductile detailing. This is a preferred method of demonstrating no disproportionate consequences for structures unless structural collapse can be argued as being of little consequence. The accurate identification of critical failure modes and their nature (ductile or non-ductile) is helpful since this can aid the identification of the actual threshold of failure.

5.16 It should be re-iterated that a 40% increase on the design basis event to cover for a disproportionate increase in risk is not a regulatory expectation, despite this being the choice made by some duty holders, and that this approach does not automatically mean that a disproportionate increase in risk does not exist.

5.17 It has previously been accepted that one satisfactory approach to the demonstration of absence of a disproportionate increase in consequences is via the PSA. This has the merit, usually, of exploring the response of the plant to a wide range of hazard levels and is accepted internationally as a reasonable approach for external hazards. However, if this approach is adopted, the inspector should ensure that the hazard definition is reasonable for the more remote levels and that relevant equipment responses are reasonable, i.e. important structures are not omitted from consideration by virtue of alternative success paths. As noted in para 5.8 and variously in the Annexes to this document, the data for natural hazards requires careful interpretation.

5.18 If a PSA is not used to demonstrate the absence of a disproportionate increase in risk, either an approximate PSA approach may be undertaken or a margins evaluation may be undertaken. As noted above, however, the detail of the approach needs to be appropriate to the nature of the hazard being addressed. Care must be taken where the definition of the hazard levels is imprecise, and claims are made based on the accuracy of calculations which have an accumulation of assumptions and conservatisms (or lack of). A clear methodology is important, along with an understanding of the associated uncertainties, both epistemic and aleatory. This is particularly important where the work also supports numerical ALARP studies. The use of generic fragilities is something that should be treated with care, as failure mechanisms may not be similar for similar types of plant, despite appearances. There are many pitfalls with this approach, especially when extended into ALARP cases, including

- Over confidence in the absolute values of risk calculated. The numbers should be tested via sensitivity studies
- Over pessimism in the capacity of structures may result in false arguments over the economy of retrofitting being made.
- Failure to identify expedient retrofitting methods thus unbalancing the risk benefit of repair.

5.19 As stated in paragraphs 33 and 34 of the SAPs, the safety standards used in the design and construction of older plants may differ from those used in more recently built facilities. This may mean that for some older facilities it may be difficult to accommodate the loading associated with a 10-4 annual probability of exceedance event for some hazards. In these cases it is necessary, firstly, to ensure that the risk arising from the hazard is tolerable, and secondly to determine whether sufficient is being done by the duty holder to demonstrate that the risk is ALARP. In reaching this judgment the inspector should take into account the projected future life of the facility. In general, the longer the period for which the plant is required, the stronger is the case for it to be required to comply fully with modern standards. Further guidance on the demonstration of ALARP can be found in T/AST/005 - ONR Guidance on the Demonstration of ALARP (As Low As Reasonably Practicable)[2].

Multi-facility sites

5.20 The SAPs are not specific concerning external hazards with respect to multi-facility sites. However it is apparent that many external hazards such as extreme wind, temperature, flooding and earthquake, have the potential to challenge all facilities on a single site simultaneously. For reactor sites this potential has been assumed to be covered by other conservatisms in the overall assessment process, although this approach would have to be considered questionable if more than a small number of reactors were to be developed on a single site. For chemical plants and some MoD-related facilities the total risk targets from SAP Target 3 are often divided among the facilities on the site in an approximate way. Caution should be exercised if the SAP Para 215 approach for a less severe hazard definition (as suggested in paragraph 4.7 above) is adopted for a multi-facility site. In such cases, a cross site summary of risk should be undertaken in addition to the individual facility safety cases, (T/AST/051 - Guidance on the Purpose, Scope and Content of Nuclear Safety Cases[3]). Paras 42 and 43 of the SAPs should also be taken into account.

Single failure criterion

5.21 Safety systems required in response to any 10-4 annual probability of exceedance external hazard should comply with the single failure criterion of EDR.4. Consideration of the consequential effects of a failure on other safety systems should also be undertaken. Where this is not feasible in the case of existing facilities, the risk must be shown to be tolerable and ALARP.

Reliability, redundancy, diversity and segregation

5.22 In assessing safety systems claimed to mitigate the effects of external hazards, the inspector should have due regard to SAPs EDR1, 2 and 3. External hazards may particularly give rise to common mode or common cause failures.

Emergency preparedness

5.23 SAP AM.1 provides an overview of the requirements for emergency preparedness. There are often specific requirements for external hazards, which the inspector should be aware of. Typically, these include

- Availability of long term weather forecasting and storm forecasts, and a process for obtaining this data
- Availability of equipment to prevent flood water access into buildings, use of sandbags, stop logs
- Availability of access routes onto/ off site for essential equipment if local flood/ wind damage excludes normal routes.

- Availability of emergency equipment to repair damaged systems following a severe external hazard
- Availability of staff and workers that can be called upon in response to bad weather warnings to complete any necessary hazard mitigation actions, before the weather deteriorates to a level where worker safety becomes an issue
- Protection of emergency control centres and access points and associated equipment against external hazards.
- Requirement of a facility to maintain a degree of self reliance during and following external hazards that affect the surrounding regions as well as the site. Typically, we would expect a site to remain self sufficient for a period of 72 hours.
- On Site instrumentation to provide input to Operating Rules relating to use of facilities in given circumstances, i.e. anemometers.

5.24 The claims made against operator actions during and following severe external hazards should be reviewed carefully from a practical standpoint and, wherever possible, limited to a small number through the use of automatic systems and fail safe devices.

Probabilistic Safety Analysis

5.25 For new facilities, it is anticipated that a PSA would include specific consideration of external hazards as initiating events (SAP FA.14). Fragility data tends to be expressed as median (best estimate) withstands rather than conservatively as for deterministic purposes. However any withstand data should be developed from the same base information, subject to relevant scale factors and uncertainties.

5.26 Development of fragilities against external hazards is a potentially complex and time consuming process, with large levels of uncertainty associated with it. Following completion of the PSA, it is suggested that the results are interrogated and the relative importance of plant, structures and equipment extracted. This will give a steer on those areas where the inspector should focus his attention. Care should be taken in the use of generic fragility data, especially when applied to bespoke plant or items of high importance to safety.

Climate change

5.27 It should also be borne in mind that forecast climate change is likely to have an impact on many of the external hazards addressed in this guide. This is likely to include extreme ambient temperatures, wind and flooding. The frequency and cyclical nature of the loading may also change, leading to differing detailed requirements, especially for wind and rainfall loadings. Duty holders should be expected to take the latest available predictions for the specific site over the projected life, which may need to include the decommissioning phase, of the installation, in their submissions.

5.28 The question of which emissions scenario (from the UK Climate Projections, UKCP-09) to use is one which arises. Para 259 of the SAPs expects “reasonably foreseeable” effects to be considered. The following is offered as guidance

- For periodic safety reviews, where the time horizon is relatively small, the use of the best estimate or medium scenario is seen as reasonable.
- For the design of new facilities, the design would be expected to be able to accommodate a wider range of emissions scenarios. The use of the most pessimistic scenario would be seen as too conservative from a current perspective.

However the approach that is considered most appropriate is that of EHA.5 and EHA.7, where a conservative choice is adopted, although not necessarily the most conservative, and an appreciation of the sensitivity of the design to changes is gained. In addition, it is prudent to ensure that there are not features of the design which are completely undermined by more radical changes to the climate. In any event, the predictions used should not be inconsistent with those outlined in Planning Policy Statement 25 [4] for essential infrastructure.

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7. TABLE 1 - SUMMARY OF EXTERNAL HAZARD TYPES

Seismotectonic

- Earthquakes
  - Ground motion
  - Long period ground motion
  - Earthquake effects
  - Liquefaction
  - Dynamic compaction
- Meteorite

Flooding

- Extreme Rainfall (note links to other meteorological phenomena)
- Tidal Effects
- Storm Surge
- Seiche
- Tsunami
- Dam Failure
- Watercourse containment failure

Meteorological

- Weather Effects
  - High Wind (Tornado, Hurricane, Cyclone) and wind blown debris
  - Extreme Drought
  - Extremes of Air Temperature

- Extremes of Ground Temperature
- Extremes of Sea (or river) Temperature
- Lightning
- Extreme Hail, Sleet or Snow and Icing
- Humidity
- Climate Change (Affects many of the above)

Man Made

- Accidental Aircraft Impact
- Impacts from Adjacent sites
- Gas Clouds (toxic, asphyxiates, flammables)
- Liquid Releases (flammables, toxic, radioactive)
- Fires
- Explosions (blast waves, missiles)
- Missiles (turbines, bottles BLEVE)
- Structural Failure
- Transport (road, sea, rail)
- Electromagnetic Interference
- Pipelines (Gas, Oil, Water)
- Vibrations
- Malicious activity

Biological

- Biological Fouling
- Seaweed
- Fish
- Jellyfish
- Marine growth
- Infestation
- Airborne swarms

Geological

- Settlement
- Ground heave
- Mining (inactive or active)
- Caverns
- Groundwater
- Leeching
- Contaminated land
- Landslides
- Radon
- Fissures
- Faults

8. ISSUE T : WENRA REFERENCE LEVELS FOR NATURAL HAZARDS

T1. Objective

T1.1 Natural hazards shall be considered an integral part of the safety demonstration of the plant (including spent fuel storage). Threats from natural hazards shall be re-moved or minimised as far as reasonably practicable for all operational plant states. The safety demonstration in relation to natural hazards shall include assessments of the design basis and design extension conditions[77] with the aim to identify needs and opportunities for improvement.

77 Design extension conditions could result from natural events exceeding the design basis events or from events leading to conditions not included in the design basis accidents.

78 This could include other natural hazards, internal hazards or human induced hazards. Consequential hazards and causally linked hazards shall be considered, as well as random combinations of relatively frequent hazards.

T2. Identification of natural hazards

T2.1 All natural hazards that might affect the site shall be identified, including any related hazards (e.g. earthquake and tsunami). Justification shall be provided that the com-piled list of natural hazards is complete and relevant to the site.

T2.2 Natural hazards shall include:

- Geological hazards;
- Seismotectonic hazards;
- Meteorological hazards;
- Hydrological hazards;
- Biological phenomena;
- Forest fire.

T3. Site specific natural hazard screening and assessment

T3.1 Natural hazards identified as potentially affecting the site can be screened out on the basis of being incapable of posing a physical threat or being extremely unlikely with a high degree of confidence. Care shall be taken not to exclude hazards which in combi-nation with other hazards[78] have the potential to pose a threat to the facility. The screening process shall be based on conservative assumptions. The arguments in sup-port of the screening process shall be justified.

T3.2 For all natural hazards that have not been screened out, hazard assessments shall be performed using deterministic and, as far as practicable, probabilistic methods taking into account the current state of science and technology. This shall take into account all relevant available data, and produce a relationship between the hazards severity (e.g. magnitude and duration) and exceedance frequency, where practicable. The maximum credible hazard severity shall be determined where this is practicable. **WENRA Safety Reference Level for Existing Reactors_September 2014.docx** 24th September 2014 / **Page 51**

T3.3 The following shall apply to hazard assessments:

 The hazard assessment shall be based on all relevant site and regional data. Par-ticular attention shall be given to extending the data available to include events beyond recorded and historical data.

 Special consideration shall be given to hazards whose severity changes during the expected lifetime of the plant.

 The methods and assumptions used shall be justified. Uncertainties affecting the results of the hazard assessments shall be evaluated.

T4. Definition of the design basis events

T4.1 Design basis events[79] shall be defined based on the site specific hazard assessment.

79 These design basis events are individual natural hazards or combinations of hazards (causally or non-causally linked). The design basis may either be the original design basis of the plant (when it was commissioned) or a reviewed design basis for example following a PSR.

80 If the hazard levels of RL T4.2 for seismic hazards were not used for the initial design basis of the plant and if it is not reasonably practicable to ensure a level of protection equivalent to a reviewed design basis, methods such as those mentioned in IAEA NS-G-2.13 may be used. This shall quantify the seismic capacity of the plant, according to its actual condition, and demonstrate the plant is protected against the seismic hazard estab-lished in RL T4.2.

81 A protection concept, as meant here, describes the overall strategy followed to cope with natural hazards. It shall encompass the protection against design basis events, events exceeding the design basis and the links in-to EOPs and SAMGs.

T4.2 The exceedance frequencies of design basis events shall be low enough to ensure a high degree of protection with respect to natural hazards. A common target value of frequency, not higher than 10^{-4} per annum, shall be used for each design basis event. Where it is not possible to calculate these probabilities with an acceptable degree of certainty, an event shall be chosen and justified to reach an equivalent level of safety. For the specific case of seismic loading, as a minimum, a horizontal peak ground ac-celeration value of 0.1g (where 'g' is the acceleration due to gravity) shall be applied, even if its exceedance frequency would be below the common target value.

T4.3 The design basis events shall be compared to relevant historical data to verify that historical extreme events are enveloped by the design basis with a sufficient margin.

T4.4 Design basis parameters shall be defined for each design basis event taking due con-sideration of the results of the hazard assessments. The design basis parameter values shall be developed on a conservative basis.

T5. Protection against design basis events

T5.1 Protection shall be provided for design basis events.[80] A protection concept[81] shall be established to provide a basis for the design of suitable protection measures.

T5.2 The protection concept shall be of sufficient reliability that the fundamental safety functions are conservatively ensured for any direct and credible indirect effects of the design basis event.

T5.3 The protection concept shall:

(a) apply reasonable conservatism providing safety margins in the design;

(b) rely primarily on passive measures as far as reasonable practicable;

(c) ensure that measures to cope with a design basis accident remain effective dur-ing and following a design basis event; **WENRA Safety Reference Level for Existing Reactors_September 2014.docx** 24th September 2014 / **Page 52**

(d) take into account the predictability and development of the event over time;
(e) ensure that procedures and means are available to verify the plant condition dur-ing and following design basis events;
(f) consider that events could simultaneously challenge several redundant or diverse trains of a safety system, multiple SSCs or several units at multi-unit sites, site and regional infrastructure, external supplies and other countermeasures;
(g) ensure that sufficient resources remain available at multi-unit sites considering the use of common equipment or services;
(h) not adversely affect the protection against other design basis events (not origi-nating from natural hazards).
T5.4 For design basis events, SSCs identified as part of the protection concept with respect to natural hazards shall be considered as important to safety.
T5.5 Monitoring and alert processes shall be available to support the protection concept. Where appropriate, thresholds (intervention values) shall be defined to facilitate the timely initiation of protection measures. In addition, thresholds shall be identified to allow the execution of pre-planned post-event actions (e.g. inspections).
T5.6 During long-lasting natural events, arrangements for the replacement of personnel and supplies shall be available.

T6. Considerations for events more severe than the design basis events

T6.1 Events that are more severe than the design basis events shall be identified as part of DEC analysis. Their selection shall be justified.[82] Further detailed analysis of an event will not be necessary, if it is shown that its occurrence can be considered with a high degree of confidence to be extremely unlikely.

82 See issue F section 2.

T6.2 To support identification of events and assessment of their effects, the hazards severi-ty as a function of exceedance frequency or other parameters related to the event shall be developed, when practicable.
T6.3 When assessing the effects of natural hazards included in the DEC analysis, and identi-fying reasonably practicable improvements related to such events, analysis shall, as far as practicable, include:
(a) demonstration of sufficient margins to avoid “cliff-edge effects” that would result in loss of a fundamental safety function;
(b) identification and assessment of the most resilient means for ensuring the fun-damental safety functions;
(c) consideration that events could simultaneously challenge several redundant or diverse trains of a safety system, multiple SSCs or several units at multi-unit sites, site and regional infrastructure, external supplies and other countermeasures;
(d) demonstration that sufficient resources remain available at multi-unit sites con-sidering the use of common equipment or services;
(e) on-site verification (typically by walk-down methods).

9. ANNEX 1 - CLIMATE CHANGE

In 2007, the Intergovernmental Panel on Climate Change (IPCC), the world’s most authoritative body on climate change, concluded that most of the observed increase in global average temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic (man-made) greenhouse gas concentrations.

The effects of climate change are seen as changes in the long term magnitudes, and consequential effects on the following:

- Air Temperature
- Sea Water Temperature
- Rainfall Intensity
- Wind Speed
- Storm Frequency and storminess patterns
- Drought
- Sea Level

The most recent UK data has been published by the UK Climate Impact Programme (UKCIP) [5], and dates from 2002. A major revision as UK Climate Projections (UKCP09) is to be released in 2009.

We would have expected duty holders to use such data as a first pass to estimate the impacts of climate change on their sites.

This annexe deals with the effects of climate change alone, rather than the effects of landscape change which is a related but entirely different area for consideration and is considered in a separate annexe.

The question over what emissions scenario to use is difficult to ensure retaining a level of proportionality. This is due primarily to the inherent uncertainty over the emissions scenario which will actually emerge, and also in the results from the complex mathematical climatic models with their myriad uncertainties, assumptions and limitations. The climate data from the current UKCIP-08 will be capable of statistical interrogation. However, it only extends out to 2080 as a time frame, and statistically includes up to the 99.9 percentile values.

For the purposes of periodic safety reviews which have a relatively short currency in terms of climate change effects, these limitations are of little practical consequence. For the consideration of new build however with a lifespan of 100-150 years the position is rather different however. Discussions with UKCIP indicate that there is a great instability in models extended out to this timeframe.

For new build, we would expect the designs to incorporate due consideration of the effects of climate change over the lifetime of the facility. To this end, we would expect the designs to be capable of accommodating the medium emissions scenario with an 84th percentile confidence. This is in the context of a 1 in 10,000 year design hazard. In addition, the requirements of EHA.7 Disproportionate increase in consequences should be borne in mind.

Precise mathematical derivation of the levels of the individual hazards is seen as difficult and open to challenge. An approach which considers the values in a more rounded manner, examining the physical limitations which may constrain the occurrence of such hazards is likely to give added confidence to the design basis parameters derived.

The frequency and intensities of individual climate effect may change, leading to differing detail requirements, e.g. cyclical loading may become significant for winds and higher intensity short duration rainfall may lead to higher drainage demands.

As a consequence of climate change, area parameters such as ground water and run off are likely to be altered and appropriate step changes should be considered.

Other considerations of a more practical nature include the following

- Avoid designs which cannot be upgraded should there be a need to account for longer demands than anticipated
- Provide provision for later upgrades at an early stage in construction
- Consider simple ALARP measures, such as provision of stop logs at door thresholds, availability of evacuation pumps/low point sumps.

For new facilities, site selection procedures should ensure that the facility is not vulnerable to flooding hazards.

10. ANNEX 2 - AIRCRAFT IMPACT (ACCIDENTAL ONLY)

SAP EHA.8 and Para 218, 219 are directly applicable to this hazard

Unlike many external hazards, it is not possible to calculate a hazard frequency curve for aircraft crash. This has led to the following approaches

- the development of a design basis impact and justification that it constitutes a demand commensurate with that expected of SAP EHA.3.
- the estimation of the frequency of impact and a review of the need to develop design assessments/ undertake protective measures.

This Annexe is split into three parts, the first which examines the derivation of the hazard, the second which examines assessment of consequences and effects, and the third which looks at mitigation strategies. It should be borne in mind that for most sites, the risk will be very low, and that a detailed review of the hazard may not be warranted. Instead, the inspector should satisfy himself that due process has been followed and that the consequences have also been considered in an ALARP manner.

Annex 2.1 - Hazard Derivation

Basic data required are as follows.

- The crash frequency statistics for different aircraft types, which are typically given as frequencies per km^2 per year.
- Details of any local aerodrome including flight paths, operating regime and volumes of flights
- Details of any military flight activity in the area of the facility
- Details of any local areas of intense aerial activity
- Details of any local flight restrictions including those in place for the facility itself.
- Details of any air corridors local to the site
- Details of the basic building layout, dimensions etc.

Methodologies have been developed by the UKAEA (Ref A2.1) and the National Air Traffic Control (NATS) for the estimation of aircraft crash risk. Inspectors should satisfy themselves that the methods used are at least comparable in approach with these techniques. There are a number of limitations associated with these methods, principal amongst which is the small volume of background data on which the models have been developed. This is especially true when considering data for crash locations adjacent to runways, where the location is at the tail of the experience data.

Another major limitation is the assumption that the flight paths in and out are linear tracks, i.e. they are essentially an extension of the runway centreline. Where the actual paths are non-linear, close to runways, care should be taken in interpreting risk figures calculated.

Air Navigation Maps are available via the CAA.

The inspector should also take into consideration the following.

- Type and nature of Instrument landing system employed at the aerodrome
- Local use of the facility as a navigational aid by “hobby fliers”
- Local navigational turn points
- Potential changes in flight paths and patterns
- Operational feedback of aircraft approaches to the facility.
- Possible expansion of the airport and runways

Annex 2.2 - Consequence evaluation

For aircraft crash structural demand depends on the mass, rigidity, velocity and engine location of any aircraft assumed to impact directly or skid onto the structure, and also the angle of incidence of the impact (direct or skidding). For these reasons, aircraft are often grouped into a small number of types - e.g. large commercial aircraft, light aircraft and military aircraft - to facilitate the analysis. In addition to structural effects, fuel fire is highly probable. This will be more significant for the heavier classes of aircraft because of the quantity of fuel carried. It may, however, be possible to exclude some (or all) classes of aircraft on the grounds of low probability (e.g. well below 10-7 per annum) of impact, thus obviating the need for structural design against impact or fuel fire. In order to assess the probability of impact, the safety case will normally derive an effective "target area" for the site, taking account of the plan area and height of safety related buildings, a representative range of angles of impact and so on, which can then be compared with the aircraft crash frequency per unit area. Further details of a particular method are published by the IAEA (Ref 13).

The estimated aircraft crash frequency may seek to take into account any flying restrictions which may apply to the site. If so, the inspector should be satisfied that this is justified. Liaison concerning flying restrictions around nuclear licensed sites is handled by ONR Strategy Unit. The possible effects on safety related equipment from a nearby impact may need consideration.

In addition, consideration of skidding of aircraft should be undertaken. Although this is anecdotally not anticipated for approach angles much steeper than 15 degrees, as the aircraft tend to dig in/ buckle on impact with the ground. Shielding effects of non safety related structures can be taken into consideration

Where aircraft impact is not excluded in accordance with SAP Para 212 (see also Para 219) the type or types of aircraft and their associated load/time functions, or a bounding load/time function should be specified. The design basis analysis principles and the PSA principles should be satisfied, as appropriate, taking into account the direct impact of the aircraft on the structures, systems and components important to safety, secondary missiles, vibration effects and the effects of aircraft fuel burning externally to the buildings or other structures, or entering the buildings or structures

In 2012, the ONR Chief Inspector commissioned a Technical Advisory Panel (TAP) to consider this topic. The findings of this work can be seen at http://www.onr.org.uk/tap-accidental-aircraft-crash-hazard-assessment.htm. This provides a further source of background information on the estimation of crash risk.

Annex 2.3 - Mitigation

The low frequency of impact usually means that when combined with the high cost of structural upgrades, there is a clear ALARP case to be made. However, some simple measures which might prevent exacerbation should not be overlooked. For example, the explicit consideration of the scenario in emergency planning, consideration of how spread of fuel fires within buildings might be mitigated through use of fire barriers and the availability of fire fighting capability.

References and sources of further information

A2.1 Contract Research Paper 150/1997"The calculation of aircraft crash risk in the UK", UKAEA

A2.2 CAA Website [6]

A2.3 National Air Accident Investigation Board Website [7]

A2.4 USDOE Standard "Accident Analysis For Aircraft Crash Into Hazardous Facilities "DOE-STD-3014-96 1996

A2.5 US NRC NUREG-0800 Chapter 3.5.1.6 "Aircraft Hazards"

A2.6

A2.7 Review of Aircraft Crash Rates for the UK up to 2006 ESR/D1000646/001/Issue 1 A Report prepared for British Energy NRS Reference CE/GNSR/6016 30th May 2008

11. ANNEX 3 - EARTHQUAKES

Hazard derivation

The seismic hazard definition should include a reasonable frequency distribution of accelerations, i.e. the ground response spectrum, often called the free field response spectrum, must be appropriate. For design purposes it has often been the practice internationally, and in the UK, to use piecewise linear spectra based on a median-plus-standard deviation level of conservatism. Such spectra have been used for the design of new plant and for the design basis assessment of existing plant. These have typically been based on the Principia Mechanica Ltd (PML) spectra and have generally been accepted as a reasonable surrogate of the hazard.

More recently uniform hazard spectra (UHS) have also been derived. These spectra were developed for seismic PSA and aimed to have a risk of exceedance uniform for all frequencies (hence their name), unlike the varying conservatism implicit in piecewise linear spectra. UHS spectra have been derived for various confidence levels, including the expected level, which is appropriate for seismic PSA.

ONR(HMNII) has accepted the principle of UHS spectra. However, ONR(HMNII) has not accepted any UHS spectra for design purposes because of concern about the deliberate avoidance of conservatism. This can be particularly marked at specific frequencies, which may be dominant in the soil-structure interaction response, and the inspector should ensure that the overall approach is sufficiently robust. However the overriding intent of SAP EHA.4 should always be borne in mind, that for natural hazards the design basis event should be that which conservatively has a predicted frequency of not being exceeded of 10-4 per year (often, though not strictly accurately termed the once in 10,000 year event).

When examining the hazard derivation, the following key aspects should be understood

- Zonation model used and links to seismicity and underlying geology
- Attenuation Model(s) used
- Limits used in model
  - Minimum magnitude
  - Maximum magnitude
  - Magnitude frequency parameters (α and β)
  - Depth characterisation
- Sensitivity studies undertaken
- Magnitude corrections and cross scale conversions used
- Location of the “free field motion” (e.g. bedrock or ground surface)

The myriad of different relationships and methodologies mean that providing absolute guidance on the acceptability of particular approaches is difficult. Instead, it is considered that the following principles should be adhered to.

- Models should be explicit in their assumptions and inferences
- The limitations of the approach should be documented
- The sensitivity of key assumptions should be understood and documented
- The use of expert judgement should be supported in some way by a solicitation process
- Where weighting factors are used, the rationale behind the choice and the influence of changing them should be understood and documented

Unless specific relationships between vertical and horizontal ground motion have been developed the use of 2/3 of the horizontal ground motion in the vertical direction is generally accepted as reasonable, unless there is reason to believe that the site has particular characteristics which may amplify vertical motion.

Long period ground motion

For a small proportion of nuclear safety related structures - those with modal frequencies of around 1 Hz or less - it may be necessary to consider long period ground motion arising from a large magnitude distant event. The need arises because the foregoing design spectra are dominated by the contribution from small to medium earthquakes with epicentres close to the site and by intent do not significantly include the separate long period motion. This long period ground motion hazard may be considered separately from the design basis spectra, being a separate, infrequent hazard.

Local site effects

It should be clear in the hazard derivation where the seismic motion is being derived for, i.e. is it outcropping rock, or “free field”. The models used should reflect the claimed location of the ground motion. The use of deconvolution models to examine the decay in ground motion with depth or its modification in transmission from bedrock should be examined carefully. The models are generally simplified, and often use generic soil degradation data. For heavily layered sites, assumptions over the layer profiles can have a substantial impact on the results. In summary, inspectors should satisfy themselves over the sensitivity of the result to the base assumptions in the model.

Soil structure interaction

Like local site effects soil structure interaction and structure soil structure interaction are complex phenomena that require careful consideration.

If a lightweight flexible structure is built on a very stiff rock foundation, a valid assumption is that the input motion at the base of the structure is the same as the free-field earthquake motion. This assumption is valid for a large number of building systems since most building type structures are approximately 90 percent voids, and, it is not unusual that the weight of the structure is excavated before the structure is built. However, if the structure is very massive and stiff such as PCPVs heavily shielded stores etc, and the foundation is relatively soft, the motion at the base of the structure may be significantly different than the free-field surface motion. Even for this extreme case, however, it is apparent that the most significant interaction effects will be near the structure, and, at some finite distance from the base of the structure, the displacements will converge back to the free-field earthquake motion.

There are numerous calculation methods used to predict this behaviour, and the same guidance as for local site effects is valid.

Liquefaction and cyclic mobility

Soil liquefaction describes the behaviour of loose saturated cohesionless soils, i.e. loose sands, which go from a solid state to have the consistency of a heavy liquid, or reach a liquefied state as a consequence of increasing porewater pressures, and thus decreasing effective stress, induced by their tendency to decrease in volume when subjected to cyclic undrained loading (e.g. earthquake loading). Liquefaction is more likely to occur in loose to moderately dense granular soils with poor drainage, such as silty sands or sands and gravels capped or containing seams of impermeable sediments. Deposits most susceptible to liquefaction are either fill, especially hydraulically placed fill, or geologically young (Holocene-age, deposited within the last 10,000 years) sands and silts of similar grain size (well-sorted), in beds at least several feet thick, and saturated with water.

No disproportionate increase in risk

There may be more than one way in which this can be achieved, for which see also T/AST/017 – Structural Integrity Civil Engineering [9]. In the case of seismic engineering, one approach which has been adopted has been to show that the response of the plant remains fully elastic up to a significant margin beyond the design basis. Alternatively, the trend for new design is increasingly to show that the plant will accommodate the seismic forces through a ductile response beyond the DBE without any danger of a release of radioactivity occurring. The residual seismic risk from events less probable than the DBE can be a significant contributor to the total risk. It has also been demonstrated in numerous earthquakes that structural ductility is very desirable. Ductility provides a better assurance than elastic margins for the ability to withstand beyond design basis seismic events, and also gives confidence in the ability of structures to cope with the uncertainty in the actual hazard spectrum (peaks etc), uncertainties in the material data, uncertainty in the analyses, and uncertainty concerning other simultaneous loads. Ductility is increasingly being required by nuclear and non-nuclear structural seismic design standards, even where the structure is designed to remain elastic under the design earthquake loads. However, the difficulty with assuring that ductile response will be achieved must not be underestimated and requires careful attention to detailing.

References and sources of further information

A3.1 Seismic Analysis of Safety-Related Nuclear Structures, ASCE 4-17

A3.2 USNRC Reg Guide 1.12 “Nuclear Power Plant Instrumentation for Earthquakes

A3.3 Seismic Hazard Working Party Report on Seismic Hazard Assessment (all volumes especially Volume 3M) “A review of seismic hazard assessment methods and their application” June 1988

A3.4 Regulatory Guide 1.165, "Identification and Characterization of Seismic Sources and Determination of Safe Shutdown Earthquake Ground Motion, USNRC March 1997

A3.5 Regulatory Guide 1.208 A Performance-Based Approach To Define The Site-Specific Earthquake Ground Motion. USNRC March 2007

A3.6 ASCE 43-05 Seismic Design Criteria for Structures, Systems, and Components in Nuclear Facilities American Society of Civil Engineers Jan 2005

12. ANNEX 4 - ELECTRO MAGNETIC INTERFERENCE

Electromagnetic interference (or EMI, also called radio frequency interference or RFI) is a (usually undesirable) disturbance that affects an electrical circuit due to electromagnetic radiation emitted from an external source. The disturbance may interrupt, obstruct, or otherwise degrade or limit the effective performance of the circuit. The source may be any object, artificial or natural, that carries rapidly changing electrical currents, such as an electrical circuit, radar, communication systems, electrical storms, the Sun or the Northern Lights

The potential for electro-magnetic interference to instrumentation and control equipment should be considered. Guidance on the assessment of EMI is set out in T/AST/015 on Electro Magnetic Compatibility[10], which also includes references and sources of further information. Depending on whether the hazard can be adequately controlled, the Duty holder may need to provide screening to protect equipment from electro-magnetic interference or install instrumentation and control equipment of a proven electro-magnetic compatibility.

13. ANNEX 5 - EXTREME WEATHER

EHA.11 provides an overview along with paras 224-226

The typical Scope of Meteorological Phenomena is as follows:

- Wind incl blown debris
- Precipitation
  - Rain
  - Snow
  - Hail
  - Accumulated ice
- Lightning
- Temperatures (Air and Sea)
  - High
  - Low
- Humidity & Drought
- Sea Ice (Frazil)

Note: most of these are also affected by Climate Change.

Annex 5.1 - Extreme wind

Whilst duty holders may use whatever data they choose, the hazard should be at least as onerous as that in BS 6399 Part 2. However any particular application should be assessed to ensure that there are not plant specific, i.e. local aerodynamic, effects which could exacerbate the wind loadings. Typical problems could be wind tunnelling between tall structures, or vortex shedding from upwind facilities. In addition the presence of dominant openings should be considered. Any structure which is shown to be vulnerable to wind loading should be considered from this point of view. In addition the potential for damage from wind-borne missiles must be considered.

Care should be taken with comparisons between BS 6399 part 2 and the previous code CP3 ChV pt 2. The approaches are different, and trying to draw conclusions purely from a high level comparison can be misleading. This is primarily due to the changes in the local pressure coefficients, particularly at corners and roof edges. It is important that clear understanding is conveyed of both wind speeds and duration/basis of assessment.

Within the UK, there is a limited opportunity for Tornado generation, other than for local events. The most recent research study is. This document is now quite aged, and it is suggested that its conclusions should be considered in a pragmatic fashion.

Annex 5.2 - Precipitation, snow and hail

Whilst duty holders may use whatever data they choose, the snow hazard should be at least as onerous as that in BS 6399 Part 3 1998. The often complex roof geometries mean that the code may need to be interpreted to achieve a satisfactory result. If drifting of snow is possible this should be taken account of.

When considering precipitation, it is usual to define a frequency/ rate relationship. It may not be immediately obvious that the highest rate is the most onerous, as the duration is considerably shorter. Care should be taken to ensure that volume effects are considered as part of the design.

For the design of ground drainage, the effects of high water table and hard standing on the potential for soakaway should be considered.

Annex 5.3 - Lightning

Lightning cannot readily be defined in terms of a magnitude frequency relationship. Instead, a justification against the appropriate British Standard (BS EN 62305 Series. Protection against lightning) is considered a minimum requirement.

Annex 5.4 - Extreme ambient temperatures

The extreme ambient temperature hazard is ameliorated by the slow development of extreme conditions and the relatively long timescales for the plant to respond. It can be assumed that there will be at least several hours notice of extreme conditions developing, and often several days. High temperatures are a potential challenge to electrical equipment which may have essential safety functions. Low temperatures may through brittle fracture of safety related structures and/or the freezing of liquid filled systems pose a threat to safety functions. Low temperatures may also threaten cooling water supplies through freezing. High ambient temperatures may also be accompanied by solar gain. Methods for assessment of this can be found in BS 5400. The inspector should establish that the potential threats and consequences are recognised by the operators and appropriate prearranged responses are embodied in operating instructions.

It is possible that there is a need for operating rules/ instructions which limit activities, for example crane usage during periods of particularly low temperature.

If extended periods of sub zero temperatures occur, there is a possibility of the development of sea ice (or frazil). This is a slow developing process, and one which the plant operators should have contingency for recognising.

Annex 5.5 - Hazard combinations

Some of the extreme weather hazards act in concert with each other, for example, high wind and rain can often be seen to be semi-correlated, as can wind and snow. The development of complex arguments on a statistical basis for correlation should be treated with care. It is considered that a simplified and demonstrably conservative combination is more appropriate. For some floating structures such as jetties etc, this may well form the limiting load case.

References and sources of additional information

A5.1 BS 6399-2:1997 Loading for buildings. Code of practice for wind loads

A5.2 "A Study of Tornadoes in Britain with Assessments of the General Tornado Risk Potential and the Specific Risk Potential at Particular Regional Sites", George Terence Meaden, prepared for ONR, December 1985

A5.3 http://www.torro.org.uk/TORRO/index.php

A5.4 BS EN 62305 Series. Protection against lightning

14. ANNEX 6 - FLOODING

EHA.12 and para 227 and 228 apply.

Flooding from internal hazards is covered in T/AST/014 – Internal Hazards[12].

Flooding from external sources, the bulk of which is listed in para 227, should not be restricted to simply the immediate environs of the facility. A more considered view of the impacts of flooding on the wider geographical area, which may affect access routes, and support facilities should be made.

Coastal flooding is usually a result of a combination of different components, still water levels, storm surge, lunar tides etc. Care should be taken when examining the correlations used in arriving at the design basis flood level. This is due to the disparity between say monthly (known) variations, and storm surge effects which are much less frequent. When coupled with still water levels which have been influenced by climate change predictions, it can be seen that there is the potential for a less than rigorous/ conservative treatment.

When examining the effects of sea flooding, the behaviour of local currents, and the influence of local bathymetry should be considered. In addition, the levels of overtopping from wind waves should also be considered, especially if a collector arrangement is used rather than say a pumped drainage.

The dynamic effects of storms should be considered in the design of defences, and this is especially true where measures such as dunes or dolosse are used which can be depleted during storms.

When considering flooding for a particular site, the broader context of flood defences (ownership, maintenance, erosion etc) which may not bee the responsibility of the duty holder, but nevertheless contribute to the protection of the site should be understood. On coastal sites, this could be usefully achieved by participating local shoreline management groups, and contributing to the development of shoreline management plans.

Flooding of inland areas from extreme rainfall generally occurs because water arrives at a point faster than it can escape, causing water levels to rise. Flooding can also occur as a result of failure of manmade structures such as pressure pipelines and dams. A duty holder will need to demonstrate an understanding of the hazard resistance of any barriers that control or prevent significant flood water from entering a licensed site when evaluating flooding sources. When considering the means of escape of water under extreme conditions normal underground drainage systems should generally be ignored, unless a case has been made that they could not become blocked by debris washed along with the water. The preference is a demonstration that flood water can escape naturally from important areas of the site on the surface, such as along channels and roads, with water not rising to a level where it could present a threat to nuclear facilities.

Duty holders should have arrangements in place for the monitoring during and post storms of the condition of their defences. Rain induced flooding should be viewed carefully in the context of broader run-off/catchment considerations, including the reliance on drainage paths, downstream discharge and reliance on other parties.

Tsunami risk, whilst of low probability, has been examined in considerable detail by a DEFRA lead team, and further details can be seen at 6.3. For the UK, the risk is relatively low of anything much greater than a 200mm high wave; however this should be confirmed for individual sites.

A systematic approach to the mitigation of the consequences of all assumed flooding events should be demonstrated. This should include detailed consideration of the plant layout, preferably including a specific walkdown. For each assumed flooding event mitigating features such as drainage, provision of raised thresholds, stoplogs or temporary sandbagging and raising of equipment above floor level should be employed to minimise the effect on safety-related plant including electrical control and protection equipment. The safety case should identify the ORs/ORIs/Emergency Instructor, TechSpecs and maintenance requirements related to these features.

The effects of any “allowed” flooding on structures and plant should be assessed to ensure any credible flood could not result in potential consequential effects. Care should be taken over claims on the ingress protection (IP) rating (Ref A6.4) assigned to essential plant and equipment. This should not generally be used as a primary claim, but as an ALARP measure.

References and sources of additional information

A6.1 BS 6349-1:2000 Maritime structures. Code of practice for general criteria

A6.2 Mouchel Report “Methodology for the Assessment of Flooding Hazard from Extreme Sea Levels. Jan 1995. An IMC Report.

A6.3

A6.4 NEMA IEC 60529 Degrees of Protection Provided by Enclosures - IP Code

15. ANNEX 7 - BIOLOGICAL HAZARDS

1 Biological hazards cover a wide range of potential issues. There is no specific SAP which refers, however they should be considered as part of the general need to cover all credible hazards (EHA.1)

2 Typical Hazards that need to be considered are as follows.

- Marine
  - Jellyfish
  - Seaweed
  - Fish
- Land
  - Infestation from mice, rats, rabbits etc
- Air
  - Swarms of insects/birds

Marine hazards generally pose a blockage or flow restriction on the intakes for sea or river cooling water systems. This had lead in the past to reactor trips and must therefore be considered as a frequent fault. In some cases, severe damage to drum screens has ensued, and material has passed into the seaward side of coolers within the plant itself. This has lead in a number of cases to reactor trips. Where there is a high reliance on cooling systems which have secondary cooling from river or sea, the sensitivity of the plant to interruptions of supply should be well understood.

There are some techniques such as sonar and bubble curtains which can limit/ deter the influx of marine creatures. However passive items such as seaweed rely on more physical means to prevent ingress.

Infestation is primarily prevented through the use of high quality doors and sealing arrangements to buildings and service trenches etc.

Insect swarms can pose a threat to intakes to HVAC or back up diesel plant by restricting air flow and essentially choking the plant. It is therefore useful to ensure that this hazard is considered as part of the design, and some measures are in place to allow a bypass or back up system to provide support.

It is common to find a high reliance on operator intervention either to prevent the hazard from developing unduly, or in recovery of the situation. It is therefore recommended that an inspection of operating instructions and training are undertaken as part of a review of this hazard.

16. ANNEX 8 - INDUSTRIAL HAZARDS

The hazard here will arise either due to the conveyance of hazardous materials on adjacent transport routes (pipeline, rail, road and sea) or adjacent permanent facilities, e.g. quarries. Typical hazards, which may arise from industrial plants, may be from stored gas, fuel, explosives, pressure vessels or turbine disintegration. Useful data and references are available on some of these aspects in the R3 procedure. The external hazards safety case should consider all potential sources of external missiles and explosion. Detailed advice on the methods of achieving this is given by the IAEA.

Explosion/missiles

- Sources of possible explosions/missiles should be identified, the possible magnitude of explosions, blast waves and the likely size, (pressure and impulse, including reflection effects), ground shock, frequency and trajectory of missiles estimated, and their effects on safety related plant and structures assessed. Note: stores of fuel/chemicals within the site boundary should be dealt with as internal hazards, but may be susceptible to external hazard initiators.
- The results of a hazard analysis in conjunction with the duty holder's acceptance criteria should be used to verify the adequacy of protection provided by spatial segregation, protective barriers, and redundancy in safety related plant and safety systems.
- Possible causes of explosions to be considered include the ignition of flammable gas, vapour or oil-mist clouds, exothermic reactions, pyrophoric materials, failure of pressure parts, and explosions associated with switchgear, high energy transformers, electrical batteries, terminal boxes and power cables.
- Consequential effects should also be considered, i.e. domino effects following fire/explosion and generation of secondary fragments.
- Where high reliance on containment is required, particular attention to the effects of missiles should be given.

Toxic and corrosive materials and gases

- Toxic and corrosive materials and gases have the potential to disable both personnel and safety related plant. Therefore the safety case should provide a demonstration that the range of materials that if released could either disable/impair or cause the asphyxiation of personnel, or may disable safety related plant and equipment.

Examples of industrial facilities examined for their potential threats to nuclear facilities include.

- Refineries
- LPG pipelines
- Wind Turbines
- Explosive handling facilities
- Dockyards

References and sources of additional information

A8.1 British Energy Impact Assessment Procedure R3. 1998.

A8.2 IAEA Safety Guide - Protection against internal hazards other than fires and explosions in the design of nuclear power plants. Safety Series No. 111-G1.11.

17. ANNEX 9 - MALICIOUS ACTIVITY

Malicious activity is considered in the SAPs as an external hazard, where it poses a physical threat to the facility. For Civil Nuclear Sites, aspects of vetting and site security are addressed by OCNS as part of its regulation under the Nuclear Industry Security Regulations (2003). This includes the need for ‘Vital Area’ identification and for a security plan. For defence sites, relevant advice should be sought.

The Hazard State and the malicious capabilities to be considered are made in another place. Note that conventionally, no probability is assigned to a malicious event, but that advice is received from the Security Services as to the current threat level.

References and sources of additional information

A9.1 IAEA Document,

A9.2 IAEA Technical Guidance Report "Engineering Safety Aspects of the Protection of Nuclear Power Plants against Sabotage. Nuclear security Series No. 6. 2007.

To assist Member States in this area, the IAEA is developing a Nuclear Security series of documents comprising a Fundamentals document, Recommendations for best practice, Implementation Guides and Technical Guides. These may potentially impact on external hazard assessment in this area. It is recommended that the assessor monitors the IAEA web site for the latest available relevant guidance material, which may be found webpage.

18. ANNEX 10 - LANDSCAPE CHANGE

Landscape change is not a particular external hazard itself. However the processes that drive it are clearly related to external hazards. The processes themselves may well be gradual in nature. However over time they may undermine the protection against the more extreme design basis and beyond design basis events.

The key processes involved are.

- Wind induced erosion
- Water induced erosion/ ground movement

Other effects such as glacial rebound are of minimal practical interest for the 100 year timeframe generally under consideration.

The more detailed effects that result from the above are listed below.

Wind induced

- Wind blown sand and dune movement

Water induced

- Coastal Erosion
- Longshore Drift
- Shingle mounding
- Sediment deposition
- Water course erosion
- Water course path change
- Water table movements resulting in settlement/ heave.

The gradual nature of these processes mean that in most case, a monitoring regime is appropriate to ensure that significant changes are identified in an appropriate timeframe. However it is seen as beneficial to have a proportionate monitoring system, such that after say a storm surge event, there is a requirement to inspect those areas of sea defence which may have been damaged, and to have arrangements in place to ensure that repairs can be undertaken in a suitable timeframe. Clearly, this should be linked to any weather warning arrangements which may be in place.