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UK ABWR

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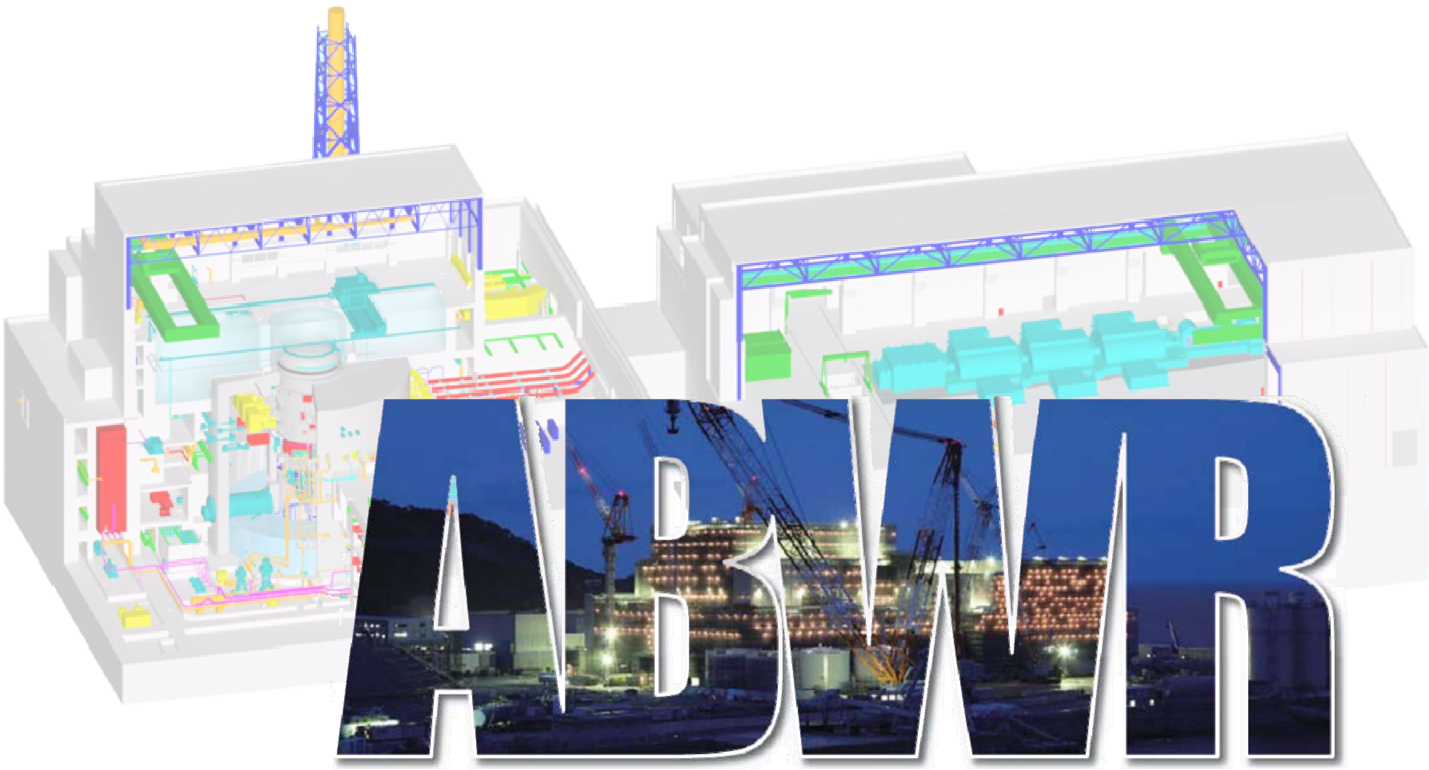
UK ABWR Generic Design Assessment

Internal Hazards Report



Hitachi-GE Nuclear Energy, Ltd.

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Abbreviations and Acronyms

ABWR	Advanced Boiling Water Reactor
ALARP	As Low As Reasonably Practicable
C/B	Control Building
ECCS	Emergency Core Cooling System
FHA	Fire Hazard Analysis
HAZOP	HAZard OPerability
HPCF	High Pressure Core Flooder system
I&C	Instrumentation & Control
PSA	Probabilistic Safety Assessment
R/B	Reactor Building
RW/B	Radwaste Building
SSCs	Systems, Structures and Components
T/B	Turbine Building

1 Introduction

1.1 Overview

This internal hazards topic report is Step2 GDA Submission which explains the assessment process for Internal Hazards for the generic UK ABWR. *This document will be developed during step 2 to become the Generic pre-construction safety Report (PCSR).

This document explains the identification process for internal hazards considered to be initiated in the generic UK ABWR design and will outline the methodology to assess and demonstrate the tolerance of the generic UK ABWR design to the hazards. During GDA, the assessment and demonstration of the tolerance to the hazards, the prevention and mitigation measures in the generic UK ABWR will be identified and evaluated.

Claims for internal hazards assessment will be discussed with separate documents during Step 2 of GDA and the outcome will be reflected in the Generic PCSR at the end of Step 2. The safety claims will be discussed with respect to each building, which are R/B, C/B, T/B, RW/B and other buildings.

This report includes the following information:

Section 1 Introduction; presents scope of this document (this subsection) and the general principles for the internal hazard assessment.

Section 2 Identification of Internal Hazards; presents the way internal hazards of relevance to the generic UK ABWR design will be identified.

Section 3 Outline of internal hazards; presents safety requirements and evaluation of the generic UK ABWR design against each internal hazard identified in section 2.

Section 4 Consideration of internal hazards in the safety assessment; presents linkage between internal hazards and safety assessment such as PSA.

Section 5 Conclusion

Section 6 Reference

1.2 Scope of Internal Hazards

Internal hazards are events which are initiated within site boundary. Events initiated outside the site boundary are defined as external hazards. Internal hazards are events which we can implement some occurrence prevention in advance as the initiators of internal hazards are within controlled site boundary and, to some extent, within the control of the operating organisation.

1.3 General principles

The high level safety functions are identified below and the overall approach for internal hazards protection is presented in this sub-section.

The approach for demonstrating tolerance to internal hazards is composed of three steps, namely identification of internal hazards, identification of SSCs which are required to deliver safety functions, and evaluation of how these SSCs are protected against the internal hazards to ensure delivery of the safety functions for the generic UK ABWR design.

1.3.1 General safety requirements

Internal hazards are events initiated within site boundary, which have the potential to cause adverse conditions for the following safety functions of the generic UK ABWR,

- control of reactivity,
- removal of heat from the core, and
- containment of radioactive substance.

The design must ensure that these fundamental safety functions are maintained for all incidents in the design basis, which requires certain SSCs to be protected from internal hazards in the design basis. The list of SSCs which must be protected and the justification for how they are protected will be defined during the GDA process. This report will explain how the fundamental safety functions are maintained for internal hazards within the design basis. In addition, the PCSR and later evaluation in GDA will also demonstrate the design reduces risk from Internal Hazards to a level which is ALARP.

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1.3.2 Identification of internal hazards

Internal hazards to be considered in the generic UK ABWR are identified in two steps. In the first step, lists of all internal hazards are obtained from published documents about internal hazards assessment such as Safety Assessment Principles for nuclear facilities (SAP, Reference [1]), Technical Assessment Guide (TAG, Reference [2]) 014, Safety guides of IAEA (Reference [3] [4]). The lists are compared and a comprehensive internal hazard list is made.

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The UK ABWR is the result of design improvement and evolution from earlier BWR designs based on extensive operational experience. However, there is no operational experience in the UK to confirm that the identification of internal hazards is exhaustive there are no serious omissions from the list of internal hazards to be considered. Therefore, a limited HAZOP study was performed on an example safety system to confirm that the list of internal hazards presented in Section 2.1 is complete. .

1.3.3 Identification of SSCs to be protected against the internal hazard

Structures, Systems and Components (SSCs) to be protected against internal hazards will be identified. Basically SSCs to be protected are components required to maintain the safety functions identified in section 1.3.1. The safety categorization and classification process will be consistent with the internal hazards mitigation strategy in those SSCs important to nuclear safety. The identification of SSCs to deliver safety functions consist with the categorisation and classification process described in Step 1b document, “Categorisation and classification of systems, structures and components” (XE-GD-0104) within GDA.

1.3.4 Identification of internal hazards

Internal hazards which can affect the SSCs to be protected will be identified. Internal Hazards will be identified in a deterministic way as far as possible assuming a “worst case” initiating event and in many cases ignoring possible mitigatory defence in depth actions such as operator response. Where mitigatory response is relied upon for the safety case, this will be explicitly claimed. The PCSR will describe the approach to Internal Hazards mitigation within the design including defence-in-depth measures.

Combinations of the multiple internal hazards will be considered. There are two types of hazard combinations: consequential and coincident. The consequential combination of the hazard has cause-and-effect relationship between the hazards (e.g. dropped load causing a flood by breaking piping underneath the load), but coincident combination (e.g. independent hazards with no common cause initiator) does not have that relationship. Both types of combinations will be considered in the internal hazard assessment; however the coincident combinations of hazards will generally be bounded by other internal hazards or dismissed with appropriate justification. (e.g. due to probability of occurrence being extremely low)
*This is described in more detail in section 3.7.

1.3.5 Evaluation of the effect of the internal hazard on identified SSCs to be protected

It will be demonstrated that the SSCs to be protected (discussed in section 1.3.3) are tolerant of the initiators of internal hazards discussed in section 1.3.4. In the evaluation, propagation of the hazard (e.g. propagation of flooded water) will be considered. In many case, prevention and mitigation measure to the internal hazard will be identified and verified.

As generic UK ABWR has three divisions of safety systems, many of the hazards are mitigated by divisional segregation of safety components. If it is assumed that an internal hazard affects everything in a division, even with the assumption of a single failure in another division, all of the safety functions can still be delivered by the redundant SSCs to be protected in the third division provided the barriers between divisions are not breached. This leads to a series of safety claims on the barriers – walls and doors etc. – between divisions.

In addition, single failure of an active component such as a pump or a generator, which could render a second division of safety equipment inoperative, is basically considered during internal hazard assessment.

During normal plant operation, no safety division is unavailable if in test mode because the test mode is overridden by the initiating signal placing a demand on the safety system and switches the system's operation mode immediately after the signal. Time-consuming maintenance such as overhaul of components is not performed during normal plant operation. Having said this, it is assumed that the plant is in its most onerous normal plant operating condition during the evaluation of hazards.

1.3.6 Countermeasures to the effect of the internal hazard

Where the evaluation indicates that additional measures to mitigate the internal hazards are required, these measures will be identified.

2 Identification of Internal Hazards

2.1 Document survey

This section presents the approach to identify internal hazards to be assessed for the generic UK ABWR design.
To comply with the general practice of internal hazards assessment, the following documents regarding internal hazards assessment were surveyed.

- Safety Assessment Principles for nuclear facilities (SAP) (Reference [1])
- Technical Assessment Guide (TAG) 014 (Reference [2])
- IAEA safety standards No. SSR-2/1 (Reference [5])
- IAEA safety guide NS-G-1.7 & 1.11 (Reference [3] [4])
- ONR GDA Guidance Rev.0(Reference [7])
- NRC 10CFR Appendix A to Part50 GDC (Reference [6])
- WENRA Reactor safety reference levels Jan. 2008 (Reference [8])
- PCSRs of previous GDAs (Reference [9][10])

A comprehensive internal hazards list is derived taking into account all internal hazards described in those documents. The referenced documents categorize hazards in different ways meaning some overlap and duplication in the list. A rationalisation process was completed to create a definitive list with some identified categories "bounded" by other hazard categories. Definitions of the hazard categories are developed to ensure the assessment process fully consider all possible hazards.

Table 2-1 shows the document survey and rationalisation process in detail. Almost all surveyed documents identify "flood", "fire", "explosion" and "missile" therefore they are identified as internal hazards also for the generic UK ABWR.

"Pipe whip" and "Jet impact" and "Internal flooding" (includes water spray, steam release) hazard categories include "Breaks" and "Pipe work leaks and breaks" since they are consequences of failures of pipe work systems.

"Failure of tanks, pumps and valves" and "Pressure part failure" include failure of 1: pipe work system and 2: tanks, pumps and valves.
Failure of 1: pipe work system is covered by "Pipe whip", "Jet impact" and "Internal flooding" (includes water spray, steam release) as they are consequences of failure of pipe work system.
Failure of 2: tanks, pumps and valves are covered by "Internal missile" as those failures result in missile hazard.

"Dropped loads" category will also consider any potential "Collapsing/falling loads" which is argued in almost all surveyed documents therefore "Dropped Loads" is identified as an internal hazard category for the generic UK ABWR.

"Toxic and corrosive materials and gases" includes "Toxic gas release" which will also consider asphyxiation risk. "Discharge fluids" is bounded by the "Toxic and corrosive materials and gases" category as steam release is covered above, "internal flooding" category will consider fluid discharge hazards which are non-toxic or corrosive, and "Fire" hazard assessment will consider combustible fluid release hazards The "toxic and corrosive materials and gases category will be screened out of assessment as it cannot compromise nuclear safety functions but it will be considered within conventional safety topic area.

"Biological agents" are initiated by fish, birds, insects, etc., and their assessments are made in external hazard assessment.

"Impact from Vehicular Transport" is considered in this document. Since vehicular transport is restricted from entering the buildings which contain SSCs to be protected during normal plant operation, and transport during fuelling outage are limited to the area around the Large Component Entrance, this hazard is thought to be screened out in early stage of the assessment. The justification will be confirmed by the end of step2 of GDA process.

"Impact from Vehicular Transport" will be screened out on the flowing basis. The only vehicular access routes into buildings which contain SSCs to be protected are on the ground floor level at the following locations:

-Reactor Building Large Component Entrance - this access way is into a compartment bounded by thick concrete walls forming the Emergency Diesel Generator Compartment and the PCV and other compartments not containing SSCs. There are no SSCs within the Large Component Entrance compartment except the walls (barriers) mentioned. A hatch opens out to lower floors but multiple hatch covers on the levels below protect SSCs. Hatch covers would only be removed when equipment maintenance requires removal, in which case the SSC concerned would be out of service.

-R/B Emergency Diesel Generator access Panels – doors to allow removed of EDG components are blocked by concrete panels except when the EDG concerned requires removed so no vehicular impact to an in service SSC is possible.

-Heat Exchanger Building –Vehicular access into maintenance bay but this bay contains no SSCs. Only access to SSCs is via removable concrete covers which are removed only for maintenance of the relevant component, therefore there is no possibility of vehicular impact to an in-service SSC.

-Turbine Building – 3 vehicular entrances exist but all entrances lead only to areas where no safety related SSCs are directly accessible. Therefore, no possibility of vehicular impact to in-service SSCs is possible.

-Exterior components - Electrical transformers, Storage tanks and other external components are protected from vehicular impact by designated road ways with kerbs, spacing, blast walls and fences or bund-walls as appropriate. Safety critical SSCs such as EDG fuel oil tanks are located underground to avoid vehicular impact and other hazards.

-All SSCs requiring protection will be located within a security fenced area with vehicular access restricted to only essential vehicles. Administrative controls will be applied to ensure drivers are appropriately trained and qualified, to limit speeds and routes taken and to control high risk vehicle manoeuvres such as building entry or reversing using banks men. This will act as defence-in-depth to mitigate risk.

Damage to Fuel Assemblies during cask movements will be considered within "Dropped Loads" category. Spent fuel casks are designed to extremely rigorous standards to withstand impacts. In addition, it is currently expected that spent fuel casks will be moved under controlled conditions a short distance from R/B to interim spent fuel storage facility (which is outside of scope of GDA) and administrative controls will prevent any possibility of vehicle accidents during these movements.

Considering the above, impact from vehicular transport is screened out of assessment.

"Electromagnetic Interference" is to be discussed within electrical supply and I&C documents.

"Vibration" as a hazard cannot impact operation of SSCs except where it causes failure of a component, and therefore is bounded by "Pipe whip/ jet impact" or "internal missile" hazard categories.

As a result of document survey and the rationalisation process, the following internal hazards are eventually identified for the generic UK ABWR design;

- Internal flooding,
- Internal fire,
- Pipe whip/ jet impact
- Dropped loads,
- Internal missiles, and
- Internal explosion.

2.2 HAZOP study

As noted in Section 1.3.2, a limited HAZOP study (Reference [12]) was performed on a representative safety system to confirm that the list of internal hazards presented in Section 2.1 is suitably complete.

2.2.1 HAZOP Methodology

HAZOP (**HAZ**ard and **OP**erability) is a structured and systematic procedure for identification of plant hazards and operability issues, and is based on the following methodology:

· A list of hazard-based keywords (prompts) relevant to the considered system is compiled from a 'standard' list.
· Each keyword is systematically applied to a series of sub-systems (Nodes) identified from the flow sheets, flow diagrams, plant layouts, or operating instructions.
· Nodes are normally chosen to represent single functional intent (and can consist of single or multiple plant items).
· The HAZOP is completed by personnel with appropriate knowledge of the system being assessed the HAZOP process

HPCF (High Pressure Core Flooder System) of ABWR was chosen as a node to apply the limited HAZOP since HPCF is one elemental system of the ECCS (Emergency Core Cooling System), which is a series of key safety systems, and HPCF has multiple divisions, which is an essential feature to mitigate internal hazards by using segregation.

The individuals attending the limited HAZOP study should provide experience to cover all disciplines relevant to the considered system. The study was carried out with participants who have sufficient professions from respective technical fields, which are internal hazard analysis, ECCS design, system design, piping analysis, piping design, plant layout design and electrical/instrumentation design.

The HAZOP study identified a number of recommendations but these all related to further assessment of the system and did not identify any new Internal Hazards. The recommendations will therefore all be considered within the proposed assessment of Internal Hazards based on the categories already identified above.

Table 2.1: Comparison of Internal Hazards to be Considered (1/2)

Table2-1: Comparison of Internal Hazards to be Considered

ID	Category	SAP (209)/TAG014	EPR PCSR	AP1000 PCSR	IAEA Safety Standards No.SSR-2/1	ONR GDA Guidance Rev.4	IAEA Safety Guide NS-G-1.11 & 1.7	NRC 10CFR Appendix A to Part50 GDC	WENRA Reactor Safety Reference Levels Jan. 2008	Justification	Further Action?	Proposal for UK ABWR
1	Flood	X	X	X	X	X	X	X	X	–	Identified as a Internal Hazard	Internal flooding
2	Fire	X	X	X	X	X	X	X	X	–	Identified as a Internal Hazard	Internal fire
3	Explosion	X	X	X	X	X	X	X	X	–	Identified as a Internal Hazard	Internal explosion
4	Dropped loads	X	X			X				–	Identified as a Internal Hazard	Dropped loads
5	Collapsing/Falling Loads	X		X	X		X			Collapsing/Falling Loads intiated by earthquake	Included in Dropped loads	-
6	Toxic and corrosive materials and gases	X		X					X	–	Identified as a Internal Hazard	Toxic and corrosive materials and gases
7	Toxic gas release	X			X					Toxic gas release to personnel and safety systems. Positional relation such as between gas storage area and MCR may be assessed.	Included in Toxic and corrosive materials and gases	-
8	Missiles	X	X	X	X		X	X	X	–	Identified as a Internal Hazard	Internal Missiles
9	Breaks		X							Failures of components which include high energy flow such as pipes. They lead Pipe whip, Jet impact, water spray, flooding etc.	Included in some other Internal Hazards. Pipe whip and Jet impact are identified on their own (see ID 13, 14). Water spray is bounded by Internal flooding.	-
10	Pipework leaks and breaks						X	X		Failures of components which include high energy fluid such as pipes. They lead Pipe whip, Jet impact, water spray, flooding etc. Failure of components containing high energy fluid.	Included in some other Internal Hazards. Pipe whip and Jet impact are identified on their own (see ID 13, 14). Water spray is bounded by Internal flooding.	-
11	Failures of tanks, pumps, and valves							X		Failure of components containing high energy fluid.	Included in some other Internal Hazards. Pipe break is bounded by pipe whip/jet and failure of other high pressure components such as tanks and valves are bounded by Internal missile.	-
12	Pressure part failure			X		X				See ID 11.	See ID 11.	-
13	Pipe whip				X		X	X	X	-	Identified as an internal hazard	Pipe whip/ jet impact
14	Jet impact				X		X		X	-	Identified as an internal hazard	Pipe whip/ jet impact
15	Water spray	X								-	Included in internal flooding. This hazard is initiated by failure of components containing high energy fluid.	-
16	discharging fluids				X			X		-	Included in Toxic gas release, Pipe whip, Jet impact, Water spray.	-
17	steam release					X				-	Included in internal flooding.	-
18	Biological agents			X						Initiated by fish, birds, insects, etc. Assessmet will be made in external hazard.	Treated in external hazard assessment.	-
		X: identified										

Table 2.1: Comparison of Internal Hazards to be Considered (2/2)

Table2-1： Comparison of Internal Hazards to be Considered												
ID	Category	SAP (209)/TAG014	EPR PCSR	AP1000 PCSR	IAEA Safety Standards No.SSR-2/1	ONR GDA Guidance Rev.4	IAEA Safety Guide NS-G-1.11 & 1.7	NRC 10CFR Appendix A to Part50 GDC	WENRA Reactor Safety Reference Levels Jan. 2008	Justification	Further Action?	Proposal for UK ABWR
	(cont'd)											
19	Impacts from Vehicular Transport	X		X						-	No further action since limited hazard sources are not thought to compromize safety functions as descrived in section 2.1 in detail.	-
20	Electromagnetic Interference			X						-	Treated in other sections regarding electric power supply facilities.	-
21	vibration								X	-	Included in Pipe whip/jet and internal missile since vibration induces failure of high pressure components.	-
		X: identified										

3 Outline of internal hazards assessment

In this chapter, the methodology of evaluation is summarised for each internal hazard identified in the previous chapter, namely, internal flooding, internal fire, dropped loads, pipe whip/ jet impact, internal missiles, and internal explosion.

Claims for internal hazards assessment will be discussed in separate documents during Step 2 of GDA and the outcome will be reflected within the PCSR by the end of Step 2. The safety claims will be discussed with respect to each building, which are R/B, C/B, T/B, RW/B and other buildings.

3.1 Internal fire

3.1.1 Internal fire claim

During GDA, it will be confirmed that UK ABWR has been designed so that any internal fire event within the design basis will not compromise the control of core reactivity or the removal of heat from the core and spent fuel, and will not result in uncontrolled dispersion of radioactivity or the uncontrolled exposure of plant personnel or the public to radiation from any source within the plant. It will also be demonstrated that risks from internal fire are reduced ALARP by ABWR design.

3.1.2 Determination of Fire Compartments

"Defence in Depth" is a fundamental principle in the design of UK ABWR. The approach with relation to fire is to

- prevent fires starting,
- limit severity of fires that do start, and
- mitigate consequences of severe fires.

The UK ABWR is designed to utilise non-combustible materials and fire retardant materials wherever possible and attention is paid to removing ignition sources where possible. In addition, the primary containment vessel is maintained under an inert atmosphere of Nitrogen gas to prevent fires starting during operation. These measures help prevent fire start.
Limiting fire inventory through design and materials selection and through administrative control during operation and maintenance helps to limit fire severity. The ABWR includes fire detection fixed fire suppression and manual fire fighting provisions which also act to limit fire severity. These measures will all be claimed as "Defence-in-depth" against internal fire hazards.

The general approach to ensure protection of SSCs from internal fires is that UK ABWR is designed on a "Fire Containment Approach" where each redundant division of safety systems is separated by barriers. In some areas, it is necessary to use a "Fire Influence Approach" between fire cells, utilizing other protection measures such as individual room or equipment barriers which are not claimed as fire barriers, the limitation of combustible materials, the separation of equipment by distance without intervening combustible materials, the provision of local passive fire protection and mitigative measures such as the provision of fire fighting systems, already discussed.

This approach ensures mitigation of consequences of fires which do start and are severe.

Fire assessment proceeds on a compartment-by-compartment or a room-by-room basis as described below.

3.1.3 Initiators of fire hazards

The design basis is that a fire is assumed to occur at any place which contains permanent or transient combustible material and a single fire is assumed to occur at one time, given it is an independent event.

3.1.4 Design verification

Fire Hazard Analysis (FHA) will be carried out to demonstrate that UK ABWR does not lose the functions described in 3.1.1 in the event of internal fire. FHA is being conducted based on the approach outlined in 3.1.2. The adequacy of the fire barriers and any other measures will be demonstrated in the FHA, using a combination of demonstration of design standards, empirical data, calculation and modelling as necessary.

3.2 Internal flooding

3.2.1 Internal flooding claim

During GDA, it will be confirmed that the generic UK ABWR has been designed so that any internal flooding event within the design basis will not compromise the control of core reactivity or the removal of heat from the core and spent fuel, and will not result in uncontrolled dispersion of radioactivity or the uncontrolled exposure of plant personnel or the public to radiation from any source.
It will also be demonstrated that the risks from internal flooding are reduced to a level which is ALARP.

Flooding risk is minimised through design of pipe work systems (e.g. use of anti-siphon devices and check valves), appropriate codes and standards and materials selection, quality control of fabrication, building layout and drainage design. In addition, the provision of monitoring systems and administrative controls mitigate flooding consequences as defence-in-depth. The SSCs delivering safety functions are protected from internal flooding risks through the use of segregated redundant SSCs to provide each safety function and claims on barriers and doors/dampers penetrating barriers.

3.2.2 Determination of Flooding Compartments

All compartments which contain SSCs to be protected, the Main Control Room and essential access routes are considered in the flooding assessment.

In order to confirm that all SSCs requiring protection have been identified, verification will be carried out with the system drawings and the piping drawings of the facilities object of protection. In addition, plans, etc. will be used to verify that access routes are represented. Furthermore, in the case of separation of a room by barriers, etc. to protect against the effects of flooding, the separated compartments are considered to be protected against flooding.

3.2.3 Initiators of internal hazards

The assumed initiators of internal flooding are classified as follows according to the cause of initiation. Furthermore, the design basis assumes damage to a single component is considered when assuming internal hazard initiators (hereinafter, assumption of single internal flooding initiators).

(1) Flooding caused by the water leakage from a damaged component assumed for evaluation of the effects of flooding.
(2) Flooding caused by the water discharge from systems installed to prevent the expansion of abnormal states (including fire hazards) within the plant.
(3) Flooding caused by the water leakage from a damaged component due to earthquake effects.

The so-called assumption of single internal flooding initiators consists in the supposition that a single component of one system is damaged causing the flood. Other systems and components are assumed not to contribute to the initiating flooding event, except where an event could cause multiple failures.

With regard to components installed in buildings shared by several units and buildings formed by an integral structure, a single internal flooding initiator is assumed and the flooding route is considered for the entire building regardless of shared components. Flooding routes also consider water flowing under doors (unless waterproof) and down stairwells, conduits, etc to lower levels where this is possible.

3.2.3.1 Flooding caused by the water leakage from a damaged component

With regard to damage to piping, piping is classified into high energy piping and low energy piping according to the energy of the fluid contained. In both cases, a guillotine break is assumed when assessing flooding potential.

3.2.3.2 Flooding caused by the water discharge from systems installed to prevent the expansion of abnormal states within the plant

Water discharges in the event of fire are considered as internal flooding initiators. These are water discharges from the fire extinguishing water system and water discharges from the fire extinguishing hoses provided inside the buildings. With regard to flooding due to the water discharge from the fire extinguishing water system, the causes of flooding are further divided into flooding due to water discharge from the automatic operation of the sprinklers of the fire detections system, flooding due to the water discharge from the primary containment spray system and flooding due to manual fire fighting.

3.2.3.3 Flooding caused by the water leakage from a damaged component due to earthquake effects

Internal flooding initiators considered are water leakage from the damage of components installed within the plant and the sloshing of water from the spent fuel storage pool.

3.2.4 Design verification

The assessment considers all SSCs in all rooms within the flooded area from the assumed leakage point. The assessment will consider whether the safety functions are still delivered by redundant segregated SSCs. If this is not the case, assessment will consider the flood level within flooded compartments and whether the essential SSCs are above flood levels and continue to operate. If necessary, the ability of the SSC to continue operating when submerged will be evaluated and claimed.

3.3 Pipe whip/ jet impact

3.3.1 Pipe whip/ jet impact claim

During GDA, it will be confirmed that the generic UK ABWR has been designed so that any other event such as pipe whip, jet impact, etc caused by failures of pipes within the design basis will not compromise the control of core reactivity or the removal of heat from the core and spent fuel, and will not result in uncontrolled dispersion of radioactivity or the uncontrolled exposure of plant personnel or the public to radiation. It will also be demonstrated that risks from internal pipe whip/ jet impact are reduced ALARP by ABWR design.

3.3.2 Identification of components to be protected

SSCs to be protected against pipe whip/ jet impact hazards will be identified consistent with safety categorizations and safety classifications during GDA.

3.3.3 Initiators of pipe whip/ jet impact

Piping is classified into two types depending on design conditions and the parameters of the fluid conveyed, (1) high energy piping and (2) medium energy piping. Failures of both types of piping are considered.

Pipe whip and jet impact are considered as consequences of high energy piping failure. Steam and water Spray are also considered as consequences of piping failure but they will be assessed in internal flooding hazard category.

Identification of initiating events for failures of pipes will be carried out in co-ordination with other topics in GDA as necessary, particularly mechanical engineering and structural integrity.

Defence-in-depth is ensured through use of appropriate design codes and standards, specification of materials and equipment, testing and quality control inspection during manufacture and operation and maintenance provisions. To ensure delivery of safety functions, the ABWR design employs divisional segregation of redundant SSCs such that failure of pipe system in one division cannot affect another division because the barriers are robust to resist the failure consequences.

3.3.4 Design verification

The verification of the effects of piping failure consists in evaluating whether the functions described in 3.3.1 are ensured or not

This will require assessment of failure possibility of the system, examination of the area influenced by the failure consequences and whether other SSCs requiring protection are affected and finally qualification of any intervening barriers which are relied upon to protect SSCs.

3.4 Dropped loads

3.4.1 Dropped loads claim

During GDA, it will be confirmed that the generic UK ABWR has been designed so that any dropped or mishandled load event, including consequential equipment failure, fire, flood or other hazard will not compromise the control of core reactivity or the removal of heat from the core and spent fuel, and will not result in uncontrolled dispersion of radioactivity or the uncontrolled exposure of plant personnel or the public to radiation. It will also be demonstrated that risks from dropped loads are reduced ALARP by ABWR design.

3.4.2 Identification of components to be protected

SSCs to be protected against dropped loads will be identified consistent with safety categorizations and safety classifications, during GDA.

3.4.3 Initiators of dropped loads

The assessment of dropped load hazards will involve considering all lifting devices within ABWR and assessing whether a dropped load may cause uncontrolled dispersion of radioactivity, or the uncontrolled exposure of plant personnel or the public to radiation, or damaging SSCs which require protection. Many lifting devices are dedicated to a single component and therefore will be screened out as they only have potential to damage the SSC they are being used to maintain, in which case, no in-service SSCs are affected. Defence-in-depth will be assessed in conjunction with Mechanical Engineering topic considering, equipment design and qualification, operating procedures and load routes.

3.4.4 Design verification

Each dropped load scenario will be evaluated in terms of effect on safety functions and uncontrolled exposure of plant personnel or the public to radiation

Cranes which carry fuel assembly, for example, are basically equipped with high-integrity safety measures such as redundant wire ropes of the fuel handling machine hoist and latch structure which keeps the hook of the fuel handling machine closed in case that driving source for the machine is lost.

As SSCs to be protected are not placed directly beneath the moving paths of the above cranes and also SSCs to be protected are physically segregated on a basis of safety divisions, the above dropped loads scenarios are not anticipated to compromise the safety functions.
This will be demonstrated in PCSR.

3.5 Internal Missiles

3.5.1 Internal Missiles claim

During GDA, it will be confirmed that the generic UK ABWR has been designed so that any internal missiles event caused by failures of pipes, tanks, pumps and valves within the design basis will not compromise the control of core reactivity or the removal of heat from the core and spent fuel, and will not result in uncontrolled dispersion of radioactivity or the uncontrolled exposure of plant personnel or the public to radiation from any source. It will also be demonstrated that risks from internal missile are reduced ALARP by ABWR design.

3.5.2 Identification of components to be protected

SSCs to be protected against internal hazards will be identified consistent with safety categorisations and safety classifications during GDA.

3.5.3 Initiators of Internal Missiles

The "internal missiles" are flying objects resulting from failure of valves, piping, and other equipment containing fluid with high internal energy, failure of high-speed rotating equipment, a gas explosion, a heavy equipment fall, failure of valve actuators, etc.

Defining the internal missiles hazard must also take into account the impacts of secondary missiles, fire, flood, chemical reaction, electrical damage, pipe rupture and equipment breakdown that are generated by above incidents.

Defence-in-depth against internal missiles is built into the design of ABWR through use of appropriate codes and standards, equipment and materials specification, quality control in fabrication and maintenance, operational procedures and control equipment to avoid plant being placed beyond safe operating limits, and effective maintenance regimes. To ensure protection of safety functions, the ABWR uses segregated redundant safety systems separated by physical barriers to ensure internal missile hazards do not prevent delivery of safety functions.

3.5.4 Design verification

As mentioned above, appropriate separation of safety systems by such as physical barrier etc. and elimination of common cause failure of safety systems are considered in design. The designs will be assessed by using deterministic approach or probabilistic approach which estimates no significant influence on safety systems. In particular, evaluation policy is described below,

- Evaluation to identify the objects which becomes internal missile
- Analysis of the effects of objects which becomes missile according to evaluation results on

SSCs to be protected.

- Estimation of missile occurrence frequency which is sufficiently low or verification and, where necessary, enhancement of barrier strength if missile has some effect on important safety systems.

3.6 Internal explosion

3.6.1 Internal explosion claim

During GDA, it will be confirmed that the generic UK ABWR has been designed so that any internal explosion event within the design basis will not compromise the control of core reactivity or the removal of heat from the core and spent fuel, and will not result in uncontrolled dispersion of radioactivity or the uncontrolled exposure of plant personnel or the public to radiation from any source. It will also be demonstrated that risks from internal explosion are reduced ALARP by ABWR design.

3.6.2 Identification of components to be protected

SSCs to be protected against internal hazards will be identified consistent with safety categorizations and safety classifications.

3.6.3 Initiators of internal explosion

Piping, valves and tanks containing high energy fluid, flammable gas, including from chemical reactions are considered as initiators of internal explosion.

Defence-in-depth against internal explosion is built into the design of ABWR through use of appropriate codes and standards, equipment and materials specification, quality control in fabrication and maintenance, operational procedures and control equipment to avoid plant being placed beyond safe operating limits, and effecting maintenance regimes. To ensure protection of safety functions, the ABWR uses segregated redundant safety systems separated by physical barriers to ensure internal explosion hazards do not prevent delivery of safety functions.

3.6.4 Design verification

The following additional effects are caused by internal explosion, such as compression wave, rarefaction wave, heat flux, toxicity of leaked gas, etc. Prevention and mitigation measures against those effects are considered.

Consequential combinations with internal explosion are also considered.

3.7 Combination of hazards

Combinations of internal hazards are considered in UK ABWR. There are two types of combination: consequential combination and coincidental combination. The internal hazard assessment, will consider consequential combinations within the design basis, however it is likely that many independent or coincidental combinations will conservatively have such a low probability, that once consideration of defence-in-depth is included, further design changes to reduce risk further will not be judged ALARP. Assessment of combination Internal Hazards will be consistent with the PSA and Fault Studies topic areas.

Since six internal hazards have been identified, 6x6 consequential combinations can be simply considered. However the combinations which do not have cause–effect relationship are screened out. For instance internal flooding does not induce pipe whip or internal missile; hence pipe whip caused by internal flooding is screened out. Furthermore, some consequential combinations may be screened out in early stage of the assessment for example pipe whip/jet caused by dropped loads is eliminated if it is confirmed that no high energy piping exists below any possible dropped loads.

Where an initiating internal hazard affects a redundant and segregated SSC, the deterministic safety case approach utilised for the majority of the ABWR Internal Hazard safety case means that the safety division affected by the initiating hazard is considered to be unavailable due to the initiating hazard, so generally any consequential hazards which will affect the same segregated decision do not matter because they are bounded by the initiating hazard.

During GDA Step 2, consequential combinations will be identified and assessed in accordance with statements in WENRA report (Reference [8]) and IAEA safety Guides (Reference [5]). Applicable internal hazards consequential combinations are shown in Table 3.1.

Table 3.1: Consequential combinations of Internal Hazards

		Induced hazards					
		fire	flood	pipe whip/jet	dropped loads	missile	explosion
initiating hazard	fire	✓	✓	✓	✓	✓	✓
	flood	✓	–	–	–	–	–
	pipe whip/jet	✓	✓	✓	✓	✓	✓
	dropped loads	✓	✓	✓	–	✓	✓
	missile	✓	✓	✓	✓	✓	✓
	explosion	✓	✓	✓	✓	✓	✓

✓ :considered

Combinations with external hazards are also considered. External hazards are identified in "Preliminary Safety Report on Civil Engineering and External Hazard" (Reference [11]). External hazards which may induce internal hazards will be considered in PCSR.

4 Consideration of internal hazards in the safety assessment

A safety analysis of the design for the nuclear power plant will be conducted in which methods of both deterministic analysis and probabilistic analysis will be applied to enable the challenges to safety in the various categories of plant states to be evaluated and assessed. As for deterministic analysis, characterisation of the postulated initiating fault that are appropriate for the site and the design of the plant have to be considered. A deterministic approach, as mentioned above, will be adopted for consideration of the majority of internal hazard initiating events.

On the other hand, the design takes due account of the probabilistic safety analysis of the plant for all modes of operation and for all plant states with particular reference to establishing that a balanced design has been achieved such that no particular feature or postulated initiating fault makes a disproportionately large or significantly uncertain contribution to the overall risks. Combination effects due to coincident initiating events will be considered in a probabilistic manner or in an engineering judgement to determine whether they are within the design basis.

The deterministic assessment will largely take the form of a compartment-by-compartment analysis considering the barriers between compartments that protect the SSCs to be protected in one compartment from internal hazards occurring in adjacent compartments. The claims on barriers identified in this way will be justified in the appropriate sections of the PCSR during later steps of GDA.

Contributions from internal hazards to initiating events through consequential failures of components or by spurious actuation will be identified as part of the development of the fault schedule in the fault studies area.

5 Conclusion

In this document, internal hazards are identified by document survey and limited HAZOP study. Identified potential internal hazards for the generic UK ABWR are as follows.

- Internal fire,
- Internal flooding,
- Pipe whip/ jet impact
- Dropped loads,
- Internal missiles, and
- Internal explosion.

For each internal hazard, identification of Structures, Systems and Components (SSCs) to be protected, identification of initiators of the internal hazard and design evaluation will be described as the internal hazards assessment progress through GDA.

The claim that internal hazards do not compromise the control of core reactivity or the removal of heat from the core and spent fuel, and will not result in uncontrolled dispersion of radioactivity or the uncontrolled exposure of plant personnel or the public to radiation from any source will be justified by deterministic and probabilistic assessments during GDA. It will also be demonstrated that risks from internal hazards are reduced ALARP by ABWR design.

6 Reference

1. *Safety Assessment Principles for Nuclear Facilities.* : Health and Safety Executive, 2006.

2. *Technical Assessment Guides.* : Health and Safety Executive, 2005.

3. *Protection against Internal Fires and Explosions in the Design of Nuclear Power Plants.* : IAEA, 2004. No. NS-G-1.7.

4. *Protection against Internal Hazards other than Fires and Explosions in the Design of Nuclear Power Plants.* : IAEA, 2004. NS-G-1.11.

5. *Safety of Nuclear Power Plants: Design.* : IAEA, 2012. No. SSR-2/1.

6. *General Design Criteria for Nuclear Power Plants.* : United States Nuclear Regulatory Commission. Appendix A to Part 50.

7. *New nuclear reactors: Generic Design Assessment Guidence to Requenting Parties.* : Health and Safety Executive, 2013. ONR-GDA-GD-001.

8. *WENRA Reactor Safety Reference Levels.* : Western European Nuclear Regulators' Association, 2008.

9. *The Pre-Construction Safety Report (PCSR).* : AREVA NP & EDF, 2012.

10. *AP1000 Pre-Construction Safety Report revision 2.* : 2009 WESTINGHOUSE ELECTRIC COMPANY LLC. UKP-GW-GL-732.

11. *Preliminary Safety Report on Civil Engineering and External Hazard revision A* : 2013 Hitachi GE Nuclear Energy, Ltd. XE-GD-0112.

12. *Preliminary HAZOP Study to Identify Internal Hazards issue No: 02* : 2013