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UK ABWR

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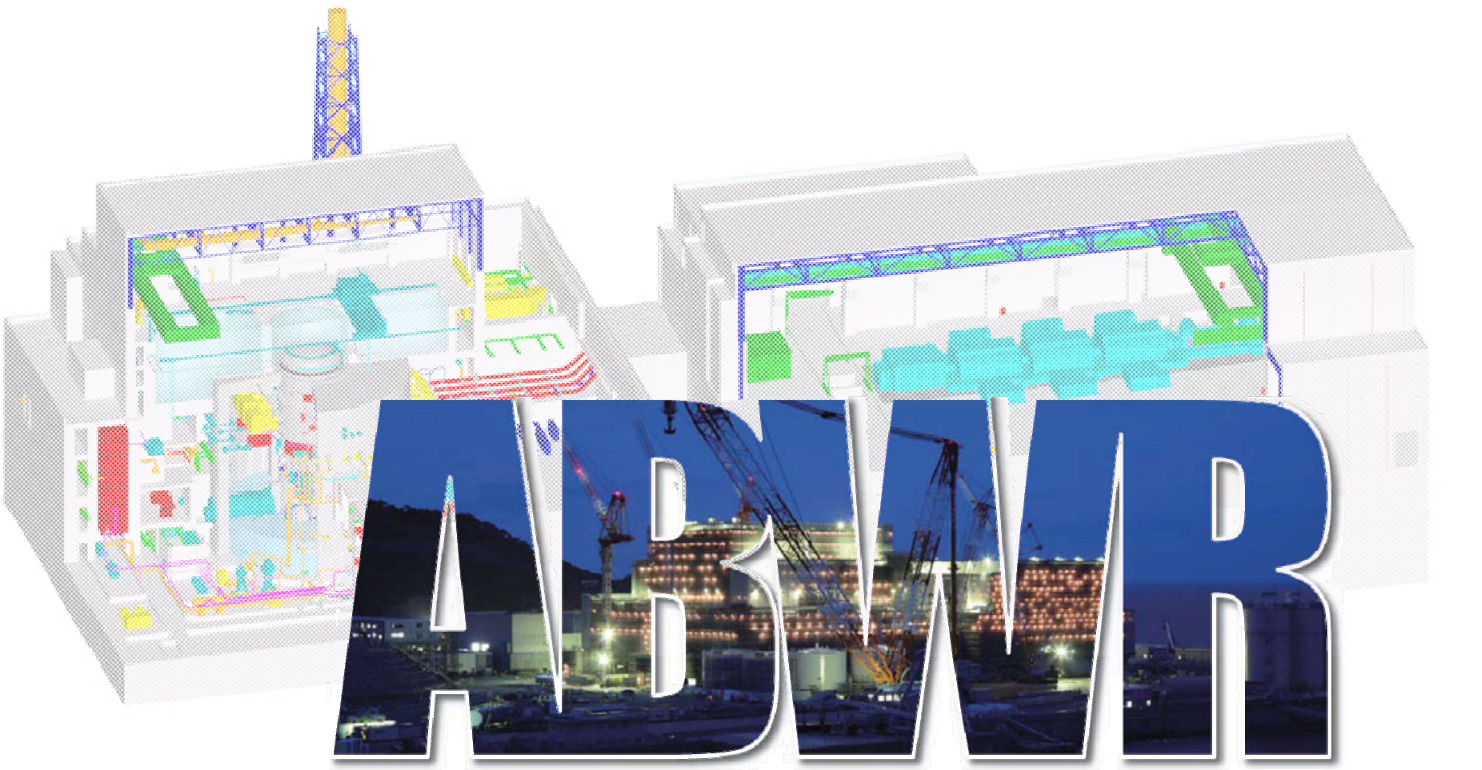
UK ABWR Generic Design Assessment

Generic PCSR Chapter 7 : Internal Hazards



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7.1 General Principles

7.1.1 Scope of PCSR in Internal Hazard Protection

This section presents the assessment of internal hazards and identifies the design principles which ensure the UK ABWR provides protection against the consequences of internal hazards to ensure delivery of all significant safety functions. Chapter 7 of the PCSR (this PCSR chapter) is the top document of the internal hazards document structure and provides an overview of the assessment. The next level of document will be an Internal Hazard Topic Report, which will include more detailed information about the assessment with claims, arguments and evidence explained. This Topic Report will reference out to “sub-topic” reports covering individual hazard categories, combinations and identification of hazards. Other supporting information (such as barrier justification reports, etc) will also be referenced including many individual Basis of Safety Case (BSC) for individual SSCs. The BSCs include design requirements derived from the results of the internal hazards assessment.

7.1.2 Overview of Contents of Sub-chapter

This section of the PCSR for the UK ABWR contains information about the internal hazards assessment.

Section 7.1 discusses the general principles of internal hazards assessment. It generally describes the Key Safety Functions and the method for assessing internal hazards.

Section 7.2 summarises internal hazards that have been identified but that have not been assessed in detail in this PCSR section.

Section 7.3 summarises the internal hazard assessment for internal fires.

Section 7.4 summarises the internal hazard assessment for internal flooding, including water spray and steam release.

Section 7.5 summarises the internal hazard assessment for pipe whip and jet impact.

Section 7.6 summarises the internal hazard assessment for dropped and collapsed loads.

Section 7.7 summarises the internal hazard assessment for internal missiles.

Section 7.8 summarises the internal hazard assessment for internal explosion.

7.1.3 Identification of Internal Hazard List

A comprehensive internal hazards list has been identified taking into account all internal hazards described in relevant documents, as described in Preliminary Safety Report “Internal Hazards Report” (GA91-9901-0002-00001, XE-GD-0108) [Ref-1]. The documents that were reviewed categorized hazards in different ways so HGNE has integrated the different lists to create categories that ensure the assessment systematically considers all possible hazards.

As a result of the document survey [Ref-6][Ref-14 to Ref-22] and integration, the following internal hazard categories have been identified for assessment;

- Internal fire,
- Internal flooding (including water spray and steam release),
- Pipe whip and jet impact
- Dropped and collapsesd loads,
- Internal missiles, and
- Internal explosion.

Additional internal hazards have been identified, but it is judged that no further assessment is required based on considerations related to probability, frequency, and deterministic arguments. These hazards and the preliminary arguments for their exclusion from further assessment are summarized below in Section 7.2.

In order to demonstrate that the list of internal hazards is complete for the UK ABWR, a limited HAZOP study was performed on a representative safety system, as discussed in [Ref-1]. This study did not find any additional internal hazards to consider and confirmed that the list above is complete.

7.1.4 General Principles for Protection against Internal Hazards

7.1.4.1 Safety Functions

The design of the UK ABWR is primarily based on providing redundant and diverse safety systems to protect against faults. The safety systems for the UK ABWR can be divided into two main groups: the systems that prevent faults and abnormal conditions in the facilities, and the systems that mitigate the consequences of a fault and abnormal events. The preventative or “defence-in-depth” systems and procedures which minimise the risk from internal hazards to the delivery of Key Safety Functions will be summarised later and more detail will be provided in the individual hazard topic reports. In defining the internal hazard safety case, we assume the prevention systems (which are often active systems) have failed for some reason, so significant importance is placed on the mitigative systems, which are largely passive in nature. These mitigative safety systems are required to perform the three Key Safety Functions when a fault occurs:

1. Control of reactivity, particularly the ability to invoke emergency reactor shutdown;
2. The provision of cooling to the core after shutdown and to the spent fuel pool; and
3. Maintaining radioactive material containment.

The overall objective is to ensure that at least one set of systems required to perform the three Key Safety Functions is available to safely shutdown the reactor, maintain it in a safe state and prevent the release of radioactive material in the event of a fault. These mitigative safety systems are generally positioned in three 'divisions' to provide redundancy in the Reactor Building. Each division also includes diverse equipment to perform the Key Safety Functions. Generally, only equipment within one division is necessary to maintain all three of the Key Safety Functions during and after a fault. The safety divisions are separated spatially, electrically, and by robust barriers, with the objective of ensuring that an internal hazard which occurs within a division is contained within the single affected division. Although a particular internal hazard would have the potential to damage safety equipment in a division, the UK ABWR design protects the safety systems in the other divisions so that they remain fully available to deliver the Key Safety Functions. Combinations of internal hazards that may affect more than one division are assessed and accounted for as well. Finally, the safety case will also explain how risks from internal hazards are prevented or mitigated for those SSCs which are not segregated into divisions (e.g. within the PCV).

In the UK, 'nuclear safety' relates not only to the safe operation or shutdown of the reactor but also to the containment of contamination and radiation such that the radiological risk to workers and the public is as low as reasonably practicable (ALARP). As a consequence of this UK definition of nuclear safety classification, there are likely to be classified safety systems that solely contain contaminated steam and water from the reactor that would lead to a significant dose to workers (and possibly the public) if released.

7.1.4.2 Prevention and Limitation of Severity of Internal Hazards

Prevention of internal hazards starts with the design processes and procedures. These processes lead to limiting the sources of potential hazards. Codes and standards, and design guides are used to appropriately design equipment and structures and develop a layout to prevent the occurrence of an internal hazard, and prevent the impacts of internal hazards whenever possible. The details of prevention measures are given in each internal hazard section below.

The specific internal hazard assessments will identify and assess the prevention measures included in the design. Based on the importance of the prevention measures to maintaining the Key Safety Functions and reducing risk ALARP, classification of these measures will be determined. As stated above, significant importance and higher classification is placed on mitigative measures so it is likely most of the preventative measures will be classified as defence in depth.

Some internal hazards have measures to limit severity of the hazards to reduce consequences or risk of the hazards (e.g. fire fighting). The details of the measures are also described in internal hazard section below.

7.1.4.3 Mitigation of Internal Hazards

If all the prevention measures were to fail, the general approach to ensuring protection of SSCs of the Key Safety Functions is to limit the impacts of an internal hazard to within the redundant division of the safety system. In some areas, it is necessary to consider secondary effects due to the proximity of the hazards. In these cases, other prevention and mitigation measures may be necessary. Internal hazards claims are achieved with the following design elements:

(1) SSCs of the Key Safety Functions that require redundancy are located in separate safety division areas fully-enclosed with appropriately designed barriers (floor, ceiling, wall, etc.), except equipment mounted in the Main Control Room, and Primary Containment Vessel, and the special cases that will be discussed in the Internal Hazard Assessment. Divisional barriers have been designed to withstand the potential fire, impact, and overpressure consequences of the various internal hazards that they may be exposed to.
(2) Penetrations of the barriers between redundant divisions are minimized. Any devices for closing penetrations such as doors, ductwork, hatches, and piping and cable entry seals which form part of a barrier are appropriately designed with the same ratings as the overall barrier.
(3) If a barrier cannot completely separate SSCs of the Key Safety Functions that require redundancy, the SSCs are protected by area separation. The area separation may not be completely surrounded by barriers designed to withstand the internal hazard in question, so the spread of internal hazard consequences between the areas is prevented by other protection measures. These measures include:
    - Administrative controls on the amount of materials that may cause an internal hazard;
    - Separation by individual room walls or equipment barriers which are not claimed as internal hazard divisional barriers;
    - Separation of equipment by distance, without intervening materials that may cause an internal hazard;
    - Local passive protection that may prevent internal hazards.

Examples of claimed barriers for R/B and C/B of the previous ABWR design are shown in the separate documents “Example of Internal Hazard Claims for R/B based on previous ABWR” [Ref-2] and “Example of Internal Hazard Claims for C/B based on previous ABWR” [Ref-3]. Those documents show general barrier claims applied to R/B and C/B, and show actual examples to cover the following process:
(1) Identifying the actual examples of internal hazards sources in each representative room in R/B and C/B.
(2) Confirming whether the room is adjacent to different safety division or not.
(3) Ensuring the actual examples of claimed barrier will meet the above-mentioned general barrier claims.

7.1.4.4 Divisional Separation Exceptions

As mentioned above, there are three redundant and independent divisions of equipment to maintain the Key Safety Functions. In general, systems are grouped together with respect to each safety division, with exceptions of the primary containment, the main control room and main steam tunnel, which contain all divisions. Consequences of each internal hazard will be assessed in the room in which the hazard source exists and the consequences will be used to design the structures to ensure that internal hazard in one safety division will not compromise the Key Safety Functions of other safety divisions.

The separation exception in the primary containment and main steam tunnel is made because it is not practical to completely divide these areas with barriers. The justification for this lack of separation is specific to each internal hazard and will be discussed in the sections below.

All divisions are also present in the main control room and this cannot be avoided. The remote shutdown panel provides redundant control of the safe shutdown functions from outside of the control room and C/B. The controls on the remote shutdown panels are hard-wired to the field devices and power supplies, and the signals between the remote shutdown panels and the control room are multiplexed over fibre optic cables so that there are no power supply interactions between the control room and the remote shutdown panels. The remote shutdown room is divided into two rooms and separated by a divisional barrier.

There are areas where there is equipment from more than one safety division in one safety divisional area. Inside primary containment, main steam tunnel room and main control room are the examples. Each of these cases is examined on an individual basis in the Internal Hazard Assessments to determine any additional design features that may be claimed to mitigate internal hazards, and to determine that the design is acceptable with respect to internal hazards.

7.1.4.5 Safety Systems

Table 7.1-1 below shows the redundancy and diversity of safety systems that are available to maintain the Key Safety Functions. The system descriptions can be found in their respective PCSR sections.

Two diverse systems, Control Rod Drive System (CRD) [Section 12.2.3.1 in PCSR] and Standby Liquid Control System (SLC) [Section 12.2.3.2] deliver reactivity control and reactor shutdown function. To protect the function against consequence of internal hazards, UK ABWR is designed to provide physical separation between those systems so as to defend at least one system from the hazard.

There are two types of fuel which need to be cooled, fuel in the core and spent fuel in the spent fuel storage pool. For the core cooling, there are three redundant safety divisions of the cooling systems. Each of them is composed of 1) a high-pressure cooling system, 2) multiple depressurization systems and 3) a low-pressure cooling system. As shown in “Cooling” – “Core” column of table 7.1-1, division I consists of 1) Reactor Core Isolation Cooling System (RCIC) [Section 13.3] for high pressure cooling, 2) a set of Automatic Depressurization Systems (ADS) [Section 13.3] and 3) Low Pressure Core Flooder (LPFL) [Section 13.3] for low pressure cooling. Similarly, both division II and III consist of 1) High Pressure Core Flooder System (HPCF) [Section 13.3], 2) ADS and 3) LPFL.

The UK ABWR design ensures delivery of the core cooling function by installing robust barriers between the divisions so as not to let internal hazards spread beyond a single division.

The spent fuel cooling function is delivered by back-up SFP cooling mode of three redundant Residual Heat Removal Systems (RHR), and each of them is also physically separated by distance and robust barriers

Containment function is delivered by Primary Containment Vessel (PCV) supported by 2 PCV Spray Cooling systems from RHR, two Flammable Gas Control Systems (FCS) and pairs of isolation valves for each of the penetrations on the PCV. PCV itself does not have redundancy. Additional containment function is delivered by secondary containment (Reactor Building) which is supported by two divisions of Standby Gas Treatment System (SGTS).

As described in later sections, basic mitigating measures against internal hazards consists of physical separation among the redundant safety systems briefly shown in table 7.1-1.

Table 7.1-1: Summary of Safety Systems

<table>
<tr><th colspan="2">Function</th><th>System</th><th>Redundancy / Segregation</th></tr>
<tr><td colspan="2" rowspan="2">Reactivity control and reactor shutdown</td><td>Control Rod Drive (CRD)
[Section 12.2.3.1 in PCSR]</td><td>Hydraulic Control Rod Drive Rooms
[Section 12.2.3.1.3.2 in PCSR]</td></tr>
<tr><td>Standby Liquid Control System (SLC)
[Section 12.2.3.2 in PCSR]</td><td>High Pressure Positive Displacement Pumps
[Section 12.2.3.2.3.2 in PCSR]</td></tr>
<tr><td rowspan="4">Cooling</td><td rowspan="3">Core</td><td rowspan="3">Division I:
RCIC+(ADS+LPFL(A))

Division II:
HPCF(B)+ (ADS+LPFL(B))

Division III:
HPCF(C)+ (ADS+LPFL(C))

[Section 13.3.1.4 in PCSR]</td><td>2 Segregated High Pressure Core Flooder (HPCF) Systems [Electric driven]
[Section 13.3.3.2.1 in PCSR]</td></tr>
<tr><td>1 Segregated Reactor Core Isolation Cooling (RCIC) System [Steam driven]
[Section 13.3.3.2.2 in PCSR]</td></tr>
<tr><td>3 Segregated Low Pressure Flooder (LPFL)
[Section 13.3.3.1.4 in PCSR]</td></tr>
<tr><td>Spent fuel</td><td>Spent Fuel Pool Makeup Spray
[Section 19.4.2.1.3 in PCSR]</td><td>3 Segregated RHR-SFP Make Up Spray System (pumps and heat exchangers)
[Section 19.4.2.1.3 in PCSR]</td></tr>
<tr><td colspan="2" rowspan="2">Containment</td><td>Primary Containment Vessel (PCV),
[Section 13.2.3.1 in PCSR]</td><td>Supported by:
• PCV Spray Cooling (from RHR system)
[Section 13.2.3.1.4 in PCSR]
• Flammable Gas Control System (FCS)
[Section 13.2.3.1.3.1 in PCSR]
• Containment isolation (by Valves located Internal and External to PCV)
[Section 13.2.3.1.2 in PCSR]</td></tr>
<tr><td>Secondary Containment (Reactor Building)
[Section 13.2.3.2 in PCSR]</td><td>Supported by:
• Standby Gas Treatment System (SGTS)
[Section 13.2.3.2.2 in PCSR]</td></tr>
</table>

The safety systems summarized in Table 7.1-1 are supplemented by an independent set of nuclear safety mitigation equipment that can be mainly used to maintain core cooling and decay heat removal, and maintain primary containment, located in a seismically qualified, Backup Building.

7.1.5 Types of Building

The UK ABWR design includes many different types of buildings. The main Power Block buildings are:

(1) Reactor Building (R/B), which houses the nuclear reactor and its associated operational and safety systems, and the fuel pond;
(2) Turbine Building (T/B); which houses three low pressure and one high pressure turbines, main generator and related systems, along with the Main Condenser;
(3) Heat Exchanger Building (Hx/B), which houses cooling system, heat exchangers and pumps to support safety and non-safety systems;
(4) Control Building (C/B), which houses the main control room and switchgear, as well as the emergency batteries;
(5) Radwaste Building (Rw/B), which is used to store and process contaminated equipment and medium and low level radioactive wastes;
(6) Services Building (S/B), which is the main entrance and security checkpoint to the Power Block and houses maintenance equipment; and
(7) Back-up Building (B/B), which houses a separate set of redundant and completely independent systems to maintain the Key Safety Functions during beyond design basis events.

Almost all of the systems identified in Table 7.1-1 are housed in the R/B. Other safety systems are contained in C/B Hx/B. As mentioned above, the safety systems located within those buildings are basically located in three different divisional areas, providing significant spatial and barrier separation. As the major safety systems are located in these buildings, the main nuclear safety claims are associated with systems and barriers in these buildings. As such, the approaches for internal hazards in the other buildings such as T/B, Rw/B and S/B are mitigation. The buildings (T/B, Rw/B and S/B) may have claims associated with Containment of Radioactive Material, but they do not contain safety systems which contribute to achieving the other Key Safety Functions. If the safety systems in R/B, C/B and Hx/B are unaffected by independent failures in other buildings, then containment isolation functions in the R/B, C/B and Hx/B mitigate the release of radioactive material from other areas and buildings.

7.1.6 General Principles for Internal Hazards

7.1.6.1 Internal Hazards Assessment Method

The approach for demonstrating tolerance to internal hazards is composed of four steps:

1. identifying what internal hazards are important,
2. identifying the sources of internal hazards in the design and elements of prevention and reduction of the hazard,
3. identifying the mitigative systems that are required to deliver safety functions,
4. evaluating the effects of internal hazards on the safety functions.

Each individual internal hazard assessment may include additional steps for assessing the specific hazards. This report summarises the results of these basic steps in order to demonstrate that the UK ABWR design is safe from internal hazards. Each of the internal hazards sections in this report references the detailed assessments that will be conducted to support the claims made as the design develops.

7.1.6.2 Internal and External Hazards

Internal hazards are events which are initiated within the site boundary. Events initiated outside the site boundary that may affect the site are defined as external hazards. Internal hazards are events that can be accounted for in the design and are to some extent, within the control of the operating organisation. It is important to ensure that internal hazards have been considered in the design and preventative measures and safety systems have been designed in and operationally accounted for as part of the facility. These preventative measures should be included in the assessment of internal hazards, as well as the mitigative systems and procedures.

7.1.6.3 Combinations of Internal Hazards

The ALARP principle requires consideration of probability of a hazard event, or a combination of hazard events occurring, when determining what measures are required to reduce or mitigate the risk. Generally, only a single internal event is postulated to occur at any given time as the events are usually independent and the probability of two independent events occurring simultaneously is extremely low. Similarly, some hazards may lead to consequential hazard events but on a very infrequent basis. Where it is evident from a high level survey using engineering judgement that combinations are highly improbable, they can be excluded from further consideration. However, there may be combinations of internal hazards that need to be analysed in more detail as they are more frequent.

There are two types of combinations of internal hazards: coincidental and consequential. Coincidental combinations are random independent events that happen simultaneously. If coincidental, a more thorough assessment of the probability of occurrence of the two independent events occurring simultaneously may be required to demonstrate that the probability is so low that no further action is required to assess or reduce the risk. The assessment should consider defence-in-depth and redundancy and diversity, and often, coincidental hazards would be considered very low probability, and usually are not included in detailed internal hazard assessment.

Consequential combinations of internal hazards are hazards that occur as a result of another hazard having occurred. Six internal hazards have been identified, and therefore 36 consequential combinations can be simply considered. However, some combinations do not have cause–effect relationships and can be screened out. For instance internal flooding does not induce a dropped load. Applicable internal hazards consequential combinations are shown in Table 7.1-2. 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.

Table 7.1-2: Combination of Internal Hazards

		Induced hazards					
		Fire	flood	pipe whip/jet	dropped loads	missile	explosion
initiating hazard	fire	x	x	x	x	x	x
	flood	x	-	-	-	-	-
	pipe whip/jet	x	x	x	x	x	x
	dropped loads	x	x	x	-	x	x
	missile	x	x	x	x	x	x
	explosion	x	x	x	x	x	x

x :considered

Any internal hazard can induce another internal hazard; however this would only happen within the same division due to the design of divisional separation provided in the UK-ABWR design. In case of internal flooding, the detailed Internal Flooding Assessment will make claims in order to reduce the quantity of flooding as a result of a failure or another internal hazard.

Combinations of events when external hazards lead to internal hazards are also considered. External hazards are identified in PCSR Chapter 6. The external hazards which may induce internal hazards are identified there. The assessment of these combinations of external and internal hazards will be done in Steps 3 and 4.

7.1.6.4 Consideration of Single Failure

A single failure is a failure that results in the loss of capability of a component to perform its intended safety function(s), and any consequential failure(s) which result from it. Single failure is basically considered in a safety division different from that affected by internal hazards. In general, single failures do not prevent performance of Key Safety Fuctions because of the redundancy and diversity of the SSCs. As described in IAEA Safety Standards [Ref-23][Ref-24], the probability of single failure is also considered. This is due to the design, inspection and maintenance of the SSCs that maintain the Key Safety Functions, which reduce the likelihood of random failure in those components. The low probability of failure in those components combined with the probability of internal hazards results in a very low probability of a simultaneous single failure that will generally be outside of the design basis. The design, inspection, and maintenance of these SSCs are described in more detail in other sections of the PCSR.

In addition, a single failure in the protection system and instrumentation is accounted for in the design of the electrical segregation.

7.1.6.5 Rules for Operators Action

In general, the responses to internal hazards do not include operator intervention at all, and at the very least, no operator action within 30 minutes of the event is considered. Any claims which are required to be made on operator actions as a result of the Internal Hazards safety case will be assessed during Steps 3 and 4 within the Human Factors topic area and presented in Chapter 27.

7.1.6.6 Internal Hazards During Shutdown Period

Internal hazards that can occur during shutdown are assessed in the same way as internal hazards during operation. The list of important internal hazards may be slightly different, and the available safety systems to mitigate the hazards will also be different as some systems will not be operating or cannot be counted on due to maintenance activities. However, during shutdown, the risk is significantly reduced because the reactor will already be shutdown meaning cooling load is reduced and the need to control criticality is reduced as the reactor has been brought to cold shutdown. It is however recognised that maintenance activities can increase the risk of loss of containment of radioactive material as systems are maintained. Internal hazards during shutdown will be assessed in more detail later during the GDA process.

7.1.6.7 Scope of Internal Hazards Assessment

Internal hazards can either be or be caused by foreseeable or expected events, frequent or infrequent design basis faults, or beyond design basis faults. The internal hazards that will be assessed include foreseeable and expected events, and frequent and infrequent design basis faults. Internal hazards that are beyond design basis are not assessed. Practically, this means that any fault or event with a frequency more than 10^{-5}/year have been assessed. If a fault that results in an internal hazard occurs less than 10^{-5}/year, or if an internal hazard that leads to a fault occurs less than 10^{-5}/year, they are not considered in this assessment. These events and faults are described in "*Categorisation and Classification of Systems, Structures and Components revision B*" (XE-GD-0104) [Ref-4], and assessment of these faults is described in "*Fault Studies to Discuss Deterministic Analysis, PSA and Fault Schedule Development revision C*" (XE-GD-0105) [Ref-5]. The assessment of internal hazards within design basis will consider requirements that risks are reduced as low as reasonably practicable (ALARP) and ensure that no internal hazard events with slightly lower probability than that considered as design basis result in a disproportionately increased radiological consequence (i.e. no "cliff edges" exist.). This approach also applies to combinations of hazard events as discussed above.

7.1.7 Consideration of Internal Hazards in the Safety Assessment

A safety analysis of the design in the form of a fault study for the nuclear power plant will be conducted in which methods of both deterministic analysis and probabilistic analysis will be used to evaluate and assess the robustness of the plant. The deterministic safety assessment in the fault study will assess whether the plant safety criteria are challenged as a result of a fault, making assumptions about availability of safety systems. 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. The internal hazards assessment will largely take the form of a compartment-by-compartment analysis to identify fault sequence and consider important SSCs and how those SSCs are protected so the equipment and protection elements can be appropriately claimed to prevent and mitigate the fault sequences. The fault sequences of internal hazards described in this assessment will generally refer to the results of initiating event fault studies. The effects of internal hazards have already been considered in the initiating event fault studies and consequences are bounded and the mitigation for maintaining the Key Safety Functions will be the same. The progress of internal hazards assessment will be reflected in the fault studies area to maintain consistency between the areas.

The fault study will also describe 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 via engineering judgement to determine whether they are within the design basis.

7.2 Summary of Internal Hazards Not Considered in More Detail

The following hazards have been identified in other documents that consider internal hazards. However, for the UK-ABWR, it is intended that they will not be assessed further in the internal hazards sections. Justification for this is provided in the sections below.

7.2.1 Toxic and Corrosive Gases and Materials

This hazard, which includes discharge fluids that are not water based, is not assessed in this internal hazard PCSR since it does not compromise the Key Safety Functions described in Section 7.1.4.1. It will be considered as part of the assessment of conventional safety requirements because of the potential for harm to operations staff from the realization of any hazards of this type.

7.2.2 Biological Agents

Biological agents are initiated by fish, birds, insects, etc., and their assessments are made in the external hazard assessment in PCSR Chapter 6. Biological agents that occur within the power plant do not affect the Key Safety Functions.

7.2.3 Vehicle Impact

Vehicular access is restricted within buildings which contain SSCs that are protected during normal plant operation, and vehicle access during outage is limited to the area around the Large Component Entrance (LCE) of the Reactor Building. This access restriction, as well as site security and maintenance procedures, significantly reduces the risk of vehicle impact. It is not assessed as an internal hazard except for this section.

The only vehicle access routes into buildings that contain SSCs to be protected are on the ground floor level at the following locations:

(1) Reactor Building Large Component Entrance **-** this access way is into a compartment bounded by thick concrete walls forming the Division 3 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. Hatches provide access to lower and upper floors from the LCE, but would normally have robust covers. Hatch covers would only be removed when equipment maintenance requires removal, in which case the SSC concerned would be out of service.

(2) R/B Emergency Diesel Generator Access Panels – doors to allow removal of EDG components are blocked by concrete panels except when the EDG concerned requires removal. If the concrete panel is removed, the EDG is out of service, so there would be no additional impact.

(3) Heat Exchanger Building –Vehicle access is allowed into the maintenance bay but this bay contains no SSCs. The only access to SSCs is via removable concrete covers that are only removed for maintenance of the relevant component; therefore there will be no additional impact on available SSCs.

(4) Turbine Building – There are three vehicle entrances to the T/B, 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.

Electrical transformers, storage tanks and other components on the site but outside of buildings are protected from vehicle 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 vehicle impact and other hazards.

All SSCs requiring protection will be located within a security fenced area with vehicle 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 the "Dropped Loads" internal hazard assessment. 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 and administrative controls will reduce any possibility of vehicle accidents during these movements to extremely low (ALARP) levels.

Considering the above, impact from vehicular transport will not be assessed further, but additional justification will be provided in later GDA steps.

7.2.4 Electromagnetic Interference

Electromagnetic interference is discussed in the electrical supply Chapter 15, and Instrumentation and Control in Chapter 14 of the PCSR. The effects of electromagnetic interference as an external hazard are discussed in Chapter 6 of this PCSR. A future revision of the Internal Hazards chapter will summarise the approach to preventing and mitigating this risk.

7.2.5 Vibration

Vibration may be a consequence of an internal hazard. As such, vibration is addressed as a consequence in the internal hazards assessments for pipe whip, internal missile, dropped loads, and internal explosions. These consequences are used by civil designers to ensure appropriate design of barriers to protect the SSCs providing the Key Safety Functions.

7.3 Protection Against Internal Fire

Internal fires happen inside buildings in the UK ABWR as a result of combustible material in contact with an ignition source. Internal fires are a potential source of failures of safety systems.

7.3.1 Internal Fire Claim

UK ABWR is designed so that any internal fire event within the design basis will not compromise the Key Safety Functions.

7.3.2 Design Basis

7.3.2.1 Design Requirement

The internal fire claim in Section 7.3.1 will be achieved in the UK ABWR by:
(1) limiting the number of fire sources,
(2) preventing fires from starting,
(3) limiting the severity of fires that do start, and
(4) mitigating the consequences of severe fires.

The number of fire sources is limited as much as possible by minimizing quantities and storing potentially combustible materials in areas with limited or protected ignition sources. The sections below describe the design elements that prevent fires and mitigate the consequences.

7.3.2.2 Sources of Internal Fire Hazards

There are a number of potential sources of fire hazards in the UK ABWR design:
(1) Flammable liquids (e.g. diesel fuel, lubrication oils)
(2) Electrical equipment (e.g. control panels, motor control centres)
(3) Cables
(4) Flammable gases (e.g. hydrogen)
(5) Transient combustible materials (e.g. packaging materials, acetylene)

7.3.2.3 Assessment Assumptions

The following assumptions provide the basis for assessing postulated fire hazards:
(1) A fire can occur anywhere on the site where permanent or transient combustible material is stored;
(2) Only a single fire event takes place at any given time, except where secondary fires take place as a direct result of an initial fire (i.e. the second fire is not independent of the first)
(3) Fires may occur during any normal operation or during shutdown;
(4) A fire may occur as a result of another internal/external event;
(5) Multiple fires caused by a single event, such as an earthquake, may occur. Appropriate provisions will be developed.

7.3.2.4 Prevent Fires From Starting

UK ABWR includes a number of design elements that prevent fires:

(1) non-combustible materials or fire retardant materials are used for interior materials where possible;
(2) piping containing flammable liquids is welded and sealed, and double walled where necessary;
(3) equipment containing flammable liquids is pressure tested;
(4) any leakage is detected by liquid level monitoring and captured;
(5) the area around equipment containing large quantities of flammable liquids includes bunds that prevent spread of the spill including consideration for any fire fighting water/foam;
(6) low combustible fluids are used if practicable;
(7) electrical systems use breakers and fuses to prevent overloading;
(8) dry type transformers are used for any transformers located within the building;
(9) electrical equipment in the areas around systems containing flammable liquids and gases, and the hydrogen supply systems will be appropriately rated per the Hazardous Area Classification guidelines;
(10) cables specified for the UK-ABWR meet stringent standards for flame spread and smoke generation;
(11) cables are installed in steel cable trays, conduits or other non-flammable cable supports and are appropriately spaced;
(12) piping with hot surfaces is insulated;
(13) piping for systems containing hydrogen is designed to prevent leakage and failure;
(14) piping systems that may contain hydrogen due to the decomposition of water will be in accordance with ASME Section III and/or B31.1 standards, in addition to meeting the Japanese design guide JANTI-NCG-01 for this specific hazard. The areas that contain batteries used in the UK ABWR will include a ventilation system designed to reduce the concentration of hydrogen gas from the batteries to acceptable levels.

7.3.2.5 Limit Severity of Fires That Do Start

If the preventative measures described above fail to prevent a fire, fire detectors and fire fighting systems are placed at adequate locations and designed to be capable of limiting the severity of fire effects on SSCs of Key Safety Functions. Operators will be trained and equipped to fight fires if necessary. The fire detection and fire fighting system features are addressed in PCSR Chapter 16 “Auxiliary Systems”, Section 16.4.1.

7.3.2.5.1 Fire Detection and Alarm Systems

Fire detection and alarm systems serve to detect a fire and provide warning to occupants in the vicinity of a fire and to the main control room. Detection and notification of a fire in an area containing SSCs of Key Safety Functions allows operators to take actions to mitigate the effects of fire.

7.3.2.5.2 Fire Fighting Systems

Fixed fire suppression systems limit the size and effect of a fire. There is no requirement to provide fixed fire suppression systems for nuclear safety for fire areas completely enclosed by fire barriers. However, fixed fire suppression systems typically are provided either to mitigate the effects of rapid fire growth or in areas of high fire load to limit the potential for fire spread. The fixed fire suppression systems may operate either automatically or manually. Automatic or manual operation is determined by the fire hazards the system protects, or operational requirements of the systems.

7.3.2.5.3 Fire Fighter Intervention

In addition to designing buildings with fixed fire suppression, consideration is given to allow fire fighters to safely enter and attack a fire where necessary. The UK-ABWR is designed to provide the following elements to enable fire fighter intervention:

(1) The provision of vehicular access for fire appliances to the perimeter of the building or site.
(2) The provision of quick and easy entry to the interior of the building for fire brigade members and their equipment.
(3) The provision of access to sufficient supplies of fire fighting materials.
(4) The means of enabling fire fighters access to all areas of a building, including the provision of fire fighting lifts if appropriate.
(5) The means of ensuring protected areas for fire fighters to carry out their operations.
(6) The provision for fire and rescue service communications.
(7) The provision of facilities to release, or extract, smoke and heat from the building or site.
(8) The provision for removing fire fighting extinguishing materials.

7.3.2.6 Mitigate Consequences of Severe Fires

If all the fire prevention measures fail, the general approach to ensuring protection of SSCs of Key Safety Functions from internal fires is through the “Fire Containment Approach” as described in IAEA Guide NS-G-1.7 [Ref-6], where each redundant division of a safety system is separated by appropriately rated fire barriers. The fire containment system is the structural system and appurtenances that work together to confine the direct effect of a fire to the fire area in which the fire originates. The fire containment system is required to contain the maximum expected fire.

In some areas, it is necessary to use a “Fire Influence Approach”, also described in IAEA Guide NS-G-1.7 [Ref-6], between fire cells, using other protection and mitigation measures like fixed fire suppression systems.

The internal fire hazard claim is achieved by mitigating the consequences of severe fires as described in Section 7.1.4.

7.3.2.7 Divisional Separation Exceptions

The separation exception in the primary containment and the main steam tunnel is made because it is not practical to divide these areas with fire barriers. The design is deemed acceptable because:

(1) Primary containment is inerted with nitrogen during plant operation, therefore a fire is not possible.
(2) Sprinkler coverage is provided in primary containment by the Containment Spray System.
(3) Maximum separation is maintained between the divisional equipment within primary containment.
(4) The main steam tunnel does not contain combustible materials except for such as a small amount of cabling that is contained in conduit.

All divisions are present in the control room and this cannot be avoided. The remote shutdown panels provide redundant control of the safe shutdown functions in case of a fire in the main control room. The remote shutdown room is divided into two rooms by a fire barrier. A fire in one divisional section will not affect the other divisional sections.

There are areas where there is equipment from more than one safety division in a fire area. Each of these cases is examined and justified on an individual basis in the fire hazard analysis to determine that the design is acceptable with respect to internal fire.

7.3.2.8 Door Monitoring System

The fire doors are designed to be closed during normal operation. The door monitoring system serves to monitor the fire door position, and alarm to operators when the doors are left open. The door monitoring system will be appropriately classified based on the importance of the system to maintaining the Key Safety Functions.

7.3.2.9 Fire Consequence

The fire hazard analysis assumes that a fire will result in the loss of all equipment in a fire area where the fire takes place. The fire hazard analysis will also include estimates of the fire rating requirements that will be used to determine appropriate civil and structural design.

7.3.3 Safety Evaluation

The UK ABWR is designed to prevent an internal fire from occurring. However, if, in the worst case, a fire does occur, the overall plant design with respect to the effects of fire is to assume that all Key Safety Functions are lost for equipment, including electrical cables, located within the entire safety divisional area experiencing a fire. Redundant equipment to maintain the Key Safety Functions is provided in other safety divisional areas, and generally protected from the effects of the fire by appropriately designed barriers. The fire hazard analysis evaluates the compliance of the design to this requirement for redundancy.

The fire hazard analysis also assumes that the functions of the fire detection, alarm, and fixed suppression equipment may be lost in the area with the fire, and confirms that redundant equipment is available to maintain the Key Safety Functions. The basis of the design provides redundant, protected equipment rather than evaluate a damage limit.

The main safety functional claims will be made for the redundant equipment used to maintain the Key Safety Functions as described above, as well as for the barriers that separate each division from fire impacts in other divisions. The specific barriers and their specific nuclear safety classification will be justified by the fire hazard analysis.

7.3.4 Combined Fire Hazards

As shown in Section 7.1.6.3, a fire can be a cause of other internal hazards. The table below shows that fire can cause other internal hazards considered in this report. However, these combined events would generally only happen within the same division due to the divisional separation provided in the UK ABWR design. Any exceptions will be assessed on a case-by-case basis.

Table 7.3-1: Combination of Internal Hazards (Initiating Hazard: Fire)

initiating hazard	Induced hazards					
	fire	flood	pipe whip/jet	dropped loads	missile	explosion
fire	x	x	x	x	x	x
x: considered						

7.3.5 Fire Hazard Analysis Methodology

The FHA will be performed based on the following approach, as documented in [Ref-7]:

(1) The sources of fire hazards will be identified.
(2) The prevention and mitigating features of the design will be identified.
(3) The SSCs that provide Key Safety Functions will be identified.
(4) An assessment of the impact of fire on the SSCs will be performed. This will include an assessment of the fire loadings, the equipment and barrier response.
(5) Justify the safety classification of the elements to protect against internal fire.

7.3.6 Conclusion

The UK ABWR design includes many elements and operational controls to limit the sources of fire hazards, prevent fires from occurring, and limit the severity of fires and their impacts on equipment. The design also provides for redundant and diverse equipment to maintain the Key Safety Functions in the case of an internal hazard. This redundant and diverse equipment is protected by robust barriers and separation able to withstand the fire hazards. The fire hazard analysis completed during GDA Step 4 will demonstrate that the UK ABWR is designed so that any internal fire event within the design basis will not compromise the Key Safety Functions.

7.4 Protection Against Internal Flooding

7.4.1 Definition of Internal Flooding

Internal Flooding is composed of submerging, water spray and steam release. Internal flooding can occur due to leakage from any pipe work or tanks containing any fluid, including general cooling water services, fire suppression services, boiler feedwater and condenser cooling water supplies, oil and chemical reservoirs, etc. Internal flooding may be the result of another internal hazard, as well.

7.4.2 Internal Flooding Claim

UK ABWR is designed so that any internal flooding event within the design basis will not compromise the Key Safety Functions.

7.4.3 Design Basis

7.4.3.1 Design Requirement

“Defence in Depth” is a fundamental principle in the design of UK ABWR. The approach with relation to flooding is to
(1) limit flooding sources,
(2) prevent failure of pipes and tanks that could be flooding sources
(3) reduce the amount of flooding water, or reduce flood levels through drainage, and
(4) mitigate consequences of severe flooding.

The number of flooding sources is limited as much as possible by routing piping in areas that are not susceptible to flooding and reducing the number of tanks.

7.4.3.2 Sources of Submerging and Water Spray

There are a number of sources of potential flooding in the UK ABWR design:

Table 7.4-1: Sources of Potential Submerging and Water Spray

Feedwater System	Fuel Pool Cooling	RB Cooling Water	DG Fuel Oil
Control Rod Drive	Suppression Pool Cleanup	RB Service Water	Fire Protection
Standby Liquid Control	Radioactive Waste Drain	T/B Cooling Water	Suppression Pool Discharge
Reactor Recirculating Flow Control	Low Conductivity Waste	T/B Service Water	Miscellaneous Non-Radioactive Drain
Residual Heat Removal	Spent Sludge	HVAC Normal Cooling	Eye Wash
High Pressure Core Flooder	Circulating Water System	HVAC Emergency Cooling	SFP
Reactor Core Isolation Cooling	Makeup Water Purifier	Iron Injection	D/S pool
Reactor Water Clean Up	Makeup Water Condensate	DG Cooling Water	Reactor well

7.4.3.3 Sources of Steam Release

Steam release in this case is assessing the impact of humidity increases due to the steam release. There are several sources of steam release during normal operation or shutdown modes:

(1) House Steam system (HS)
(2) Main Steam (MS) (including extraction steam)
(3) Cleanup Water system (CUW)
(4) Reactor Core Isolation Cooling system (RCIC)
(5) Main Feedwater system (FDW)

7.4.3.4 Assessment Assumptions

The following assumptions provide the basis for assessing postulated flooding hazards:

(1) Flooding is initiated by failure of piping or tank.
(2) Piping or tank failure can occur in any piping or tank on the site except RPV and VHIC piping;
(3) Only a single piping failure takes place at any given time. Secondary piping failure is not considered due to flooding since consequences of flooding cannot induce piping failure.
(4) Pipe failure criteria for high energy piping for flooding assessment is consistent with the criteria for pipe whip assessment.
(5) Piping or tank failures on non-seismic classified systems are considered as a result of earthquake.
(6) Piping or tank failure may occur during normal operation or during shutdown;
(7) Piping or tank failure may occur as a result of another internal/external event.
(8) Multiple piping and tank failures caused by a single event such as earthquake or pipe whip may occur. Appropriate provisions will be developed. Note that pipe whip failure is dealt with as a separate hazard.
(9) Guillotine piping break is postulated no matter the piping classification.
(10) Assessment of radiation and contamination effects of failure of primary circuit systems is performed during the SSC categorization and classification assessment, as well as the deterministic safety assessment.
(11) Assessment of flooding in the main steam tunnel has been done separately [Ref-8] so is not included in this section.
(12) Buildings that do not contain SSCs to be protected are excluded from this assessment.

Assumptions specifically for steam release assessment:

(13) Sources of steam release are high energy piping.
(14) Steam release will spread throughout the room of the failure and through unsealed penetrations, including up, due to pressure release.
(15) Humidity will be assessed based on pressure increase in the room of the pipe break.
(16) All unprotected components will fail in contact with steam.
(17) Steam temperature is assumed to be 100°C.
(18) Duration of steam release is assumed until isolation.

Assumptions specifically for water spray assessment:

(19) Components that meet Japanese drip-proof specification (JIS C0920) are assumed not to fail.

7.4.3.5 Prevent Flooding

UK ABWR includes a number of design elements that minimize the probability of a flood from occurring inside the plant:

(1) Piping and tanks have mostly welded joints and are designed to ASME and ANSI standards (See Section 5.6 of this PCSR).

(2) Components are designed to be drip proof/waterproof.
(3) Most piping and tanks will be part of the EMIT schedule and will have periodic inspections according to ASME Section XI.
(4) Piping systems and tanks are pressure tested during commissioning to ensure integrity and piping systems are designed with suitable overpressure protection to comply with UK legislation as a minimum.
(5) Piping restraints and supports are provided where necessary to prevent or reduce pipe whip.
(6) The materials and chemical control specified for piping systems and components ensure corrosion or other failure mechanisms are minimized for the design life of the component or system.

7.4.3.6 Reduce the Amount of Flooding

In order to reduce the amount of flooding, isolation valves are used to isolate pipe and tank failures. This isolation can be initiated automatically using various instrumentations, or it can be manually actuated and implemented using instrumentation and manual action, either in the control room or locally. The reduction in flooding amount depends on the time required to close the isolation valves. This, the leak duration time, is conservatively assumed and depends on:
1) Interlocks to automatically close the isolation valves.
2) Leak detectors to alert operators and indicate the locations of leaks.
3) Remote or manual operation of the isolation valves (subject to Human Factors assessment).
4) Spray covers and lagging added to piping.

Leak detection and alarm systems in sumps and drains serve to detect the presence of fluid leakage and provide warning to occupants in the vicinity of flooding and the MCR in order for operators to take action to limit or isolate the leak. Leak detection may also actuate isolation automatically. Detection and notification of the existence of flooding in an area containing SSCs that perform a Key Safety Function allows operators to take actions to mitigate the effects of flooding.

7.4.3.7 Mitigate Consequences of Severe Flooding

If all the flood prevention approaches described above were to fail, the general approach to ensuring protection of SSCs of the Key Safety Functions is to limit the impacts of an internal flood to within the redundant division of the safety system. Internal flooding claim is achieved by mitigating the consequences as described in this section. The UK ABWR design uses pedestals to raise important equipment above the floor, which protects it against some flooding impacts. Additional mitigation is specified, including use of water-proof components. Flooding effects on temperature, humidity and radiation levels will be assessed to ensure the environmental conditions are maintained for operation of SSCs to maintain Key Safety Functions.

7.4.3.8 Divisional Separation Exceptions

The separation exception in the primary containment and main steam tunnel is made because it is not practical to divide the primary containment and main steam tunnel into three areas. The design is deemed acceptable because flooding water released inside primary containment is drained to the suppression pool without submerging or exposing SSCs to be protected for the Key Safety Functions. The effects of flooding in the main steam tunnel have been assessed separately [Ref-8] and the consequences have been found to be acceptable.

All divisions are present in the control room and this cannot be avoided. However, flooding sources in the control room are so limited that it does not provide significant influence to the control room. Furthermore, the remote shutdown panels are provided for redundant control of safe shutdown function from outside of the control room and control building. The controls on the remote shutdown panels are hard wired to the field devices and power supplies. The signal between the remote shutdown panels and the control room are multiplexed over fibre optic cables so that there are no power supply interactions between the control room and the remote shutdown panels. The remote shutdown room is divided into two rooms and separated by a divisional barrier.

There are areas where there is equipment from more than one safety division in one safety divisional area. Each of these cases is examined on an individual basis to determine that the encroachment is required and that failure in the worst conceivable fashion is acceptable.

7.4.3.9 Internal Flooding Consequence

The flooding assessment assumes that a flood will result in the loss of all equipment in the area where the flooding takes place. In addition, the internal flooding assessment will include estimates of the impacts created from the worst case flooding hazards. The estimated water volume will be used to determine appropriate civil and structural design, where necessary. Increases in temperature, humidity, and radiation release will also be assessed in detail to determine impacts on equipment and personnel. This information will be compared with the required environmental conditions to ensure the redundant equipment remains operational in other areas.

7.4.4 Safety Evaluation

The UK ABWR is designed to prevent an internal flood from occurring. However if, in the worst case, an internal flood does occur, the overall plant design with respect to the effects of flooding is to assume that all Key Safety Functions are lost for equipment, including electrical cables, located within the entire safety divisional area experiencing the flood. Redundant equipment to maintain the Key Safety Functions is provided in other safety divisional areas, and generally protected from the effects of the internal flooding by appropriately designed barriers. The Flooding Hazard Assessment evaluates the compliance of the design to this requirement for redundancy.

The Flooding Hazard Assessment assumes that the function of a piece of equipment may be lost if the equipment is involved in detection and alarm in case of existence of flooding, and confirms that redundant equipment in other safety division is available. The basis of the design provides redundant, protected equipment rather than evaluate a damage limit.

The main safety functional claims as a result of internal flooding will be made for the redundant equipment used to maintain the Key Safety Functions as described above, as well as for the barriers that separate each division from flooding impacts in other divisions. The specific barriers and their specific nuclear safety classification will be determined by the Internal Flooding Hazard Assessment. Additional safety functional claims may be required for detection and isolation of some systems.

HGNE has performed an assessment on the Japanese reference ABWR design to evaluate the impacts of the pressure effects of a steam release in certain R/B rooms. The high energy pipes assumed to be failed for evaluation were Main Steam piping, RCIC piping and CUW piping. The results confirmed that the wall designs throughout the R/B for the reference ABWR will withstand the pressure effects from these high energy line breaks.

7.4.5 Flooding Hazard Assessment Methodology

The Flooding Hazard Assessment regarding submerging assessment will be performed based on the following approach [Ref-9].

(1) Identification of SSCs and associated cabling within each room or area, which could provide Key Safety Functions.
(2) Identification of flooding barriers surrounding a room or area which separate safety divisional area.
(3) Evaluation of the amount of flooding water which presents the flooding sources identified for each room or area.
(4) Analysis of the means of containing or inhibiting the progress of flooding in each room or area. This is defined as the use of flood -resistant enclosure or barrier, with flooding-stopping at wall penetrations, dampers, and suitable doors.
(5) Listing of all the detection and alarm systems for existence of flooding water provided for each room or area.
(6) Analysis of the consequences of the flooding for each room or area. This is stated as loss of function and identifies the divisional backup capability available for Key Safety Functions.
(7) Analysis of the consequences of the flooding, if the flooding protection system functions as designed. The protection system is defined as having the capability to detect and alert the existence of a flood. The ability to restrict the flooding to a discrete area by means of the detection and alarm system are stated.

7.4.6 Conclusion

The UK ABWR design includes many design elements and operational controls to limit the sources of internal flooding hazards, and prevent floods from occurring. The design also provides for redundant and diverse equipment to maintain the Key Safety Functions in the case of an internal hazard. This redundant and diverse equipment is protected by robust barriers and separation able to withstand the flood conditions. The Internal Flooding Hazard Assessment completed during GDA Step 4 will demonstrate that the UK ABWR is designed so that any internal flood event within the design basis will not compromise the Key Safety Functions.

7.5 Protection Against Pipe Whip and Jet Impact

Pipe whip and jet impact occurs when a high energy piping system fails and the resulting energy release causes the pipe to whip and a jet of fluid to release. The whipping of the pipe or the fluid jet may impact other systems and equipment near the piping failure.

7.5.1 Pipe Whip and Jet Impact Claim

UK ABWR is designed so that any pipe whip and jet impact event within the design basis will not compromise the Key Safety Functions.

7.5.2 Design Basis

7.5.2.1 Design Requirement

"Defence in Depth" is a fundamental principle in the design of UK ABWR. The approach with relation to pipe whip and jet impact is to

(1) limit the sources of pipe whip and jet impact
(2) prevent pipe whip and jet impact hazard occurrence, and
(3) mitigate consequences of severe pipe whip and jet impacts.

The number of pipe whip and jet impact sources is limited as much as possible by reducing the amount of high energy piping and reducing the number of weld locations in the high energy piping.

7.5.2.2 Sources of Pipe Whip and Jet Impact

Pipe whip and jet impact is only assumed to occur in high energy piping. Medium energy piping is not assumed to cause pipe whip nor jet impact because of its low energy of internal fluid. High energy piping is defined in ANSI/ANS 58.2, 1988 as piping that contains a fluid operating at greater than 100C or greater than 2.0 MPa. The sources of high energy pipes in the UK ABWR are:

(1) Main Steam System (MS)
(2) Main Feedwater System (FDW)
(3) Residual Heat Removal system (RHR)
(4) High Pressure Core Flooder system (HPCF)
(5) Reactor Core Isolation Cooling system (RCIC)
(6) Reactor Water Cleanup system (CUW)
(7) Control Rod Drive system (CRD)
(8) Standby Liquid Control system (SLC)

Some of these system are not normally operating (RHR, HPCF, RCIC, SLC), and will operate only during transient or accident conditions. HGNE will apply the "2%" rule in cases where parts of some of the systems will be operating (including periods when the system is being tested) for less than 2% of the operational life of the plant. The parts of the systems that will operate for less than 2% of the time will be excluded from the pipe whip and jet impact assessment.

For high energy piping that is included in the pipe whip and jet impact assessment, the locations of the postulated breaks are the terminal ends and intermediate locations where stress exceeds the thresholds according to ANSI/ANS 58.2-1988, and in addition, failure locations that have the potential to impact more than one division of redundant safety equipment are considered.

7.5.2.3 Assessment Assumptions

The following assumptions provide a basis for assessing postulated pipe whip and jet impact hazards:

(1) A pipe whip and jet impact can occur on the welds or heat affected zones of high energy piping;
(2) Only a single pipe whip and jet impact event takes place at any given time, except where secondary pipe whip and jet impacts occurs as a direct result of an initial pipe whip and jet impact (i.e. the second pipe whip and jet impact is not independent of the first)
(3) Pipe whip and jet impacts may occur during normal operation, not during accident conditions, in terms of the probability;;
(4) A pipe whip and jet impact may occur as a result of another internal/external event.

7.5.2.4 Prevent Pipe Whip and Jet Impact

UK ABWR includes a number of design elements that prevent pipe whip and jet impact:

(1) High energy piping is designed according to ASME Section III standards, including welds.
(2) The number of welds in high energy piping is minimized.
(3) The materials specified for the high energy piping systems are in accordance with ASME Section II.
(4) Inspection and testing of the high energy piping systems are in accordance with ASME Section V.
(5) Maintenance of high energy piping is in accordance with ASME Section XI.
(6) High energy piping will include leak detection to notify operators of potential failure.

High energy large bore piping near Reactor Pressure Vessel (RPV) includes pipe whip restraints to reduce the range of pipe whip and jet impact consequence.

7.5.2.5 Pipe Whip and Jet Impact Consequence

The pipe whip and jet impact assessment will include estimates of the impact forces from the pipe whip and jet impact. If equipment will not withstand the impact forces, the equipment within the range of pipe whip and jet impact consequences will be destroyed, and the functions are assumed to be lost. These estimates will be used to determine appropriate civil and structural design, or equipment qualification, where necessary.

7.5.2.6 Mitigate Consequences of Severe Pipe Whip and Jet Impact

If all the pipe whip and jet impact prevention approaches described above were to fail, the general approach to ensuring protection of SSCs of the Key Safety Functions is to limit the impacts of a pipe whip and jet impact to within the redundant division of the safety system. In some areas, it may be necessary to consider influence among multiple high energy piping systems, using other protection and mitigation measures. The pipe whip and jet impact claim is achieved by mitigating the consequences as described in Section 7.1.4.3.

7.5.2.7 Divisional Separation Exception

The separation exception in the primary containment and main steam tunnel is made because it is not practical to divide the primary containment and main steam tunnel into three areas. The design is deemed acceptable because:

(1) Maximum separation by distance is maintained between the divisional equipment within primary containment.
(2) In addition, pipe whip restraints are used in primary containment to reduce the range of pipe whip/ jet impact consequence
(3) The consequences of pipe whip and jet impact in the main steam tunnel has been preliminarily assessed in [Ref-8] with the conclusion that separation within the room is not required, however further assessment such as worst case flooding scenario will be undertaken in the later GDA Steps.

All divisions are present in the control room and this cannot be avoided. But there is no high energy piping in the control room therefore pipe whip/ jet impact is not a concern.

There are areas where there is equipment from more than one safety division in one safety divisional area. Each of these cases is examined on an individual basis to determine that the design is acceptable with respect to internal hazards.

7.5.3 Safety Evaluation

The UK ABWR is designed to prevent a pipe whip and jet impact from occurring. However, if, in the worst case, a pipe whip and jet impact does occur the overall plant design with respect to the effects of pipe whip and jet impact is to assume that all Key Safety Functions are lost for equipment, including electrical cables, located within a safety divisional area experiencing a pipe whip and jet impact. Redundant equipment to maintain the Key Safety Functions are provided in other safety divisional areas, and are generally protected from the effects of pipe whip and jet impact by appropriately designed barriers. The Pipe whip and jet impact Hazard Assessment evaluates the compliance of the design to this requirement for redundancy.

The main safety functional claims will be made for the redundant equipment used to maintain the Key Safety Functions as described above, as well as for the barriers that separate each division from pipe whip and jet impacts in other divisions. The specific barriers and their specific nuclear safety classification will be determined by the Pipe Whip and Jet Impact Assessment. Additional safety functional claims may be required for the separation distance between safety systems in the PCV and for the pipe whip restraints within the PCV.

7.5.4 Pipe Whip and Jet Impact Hazard Assessment Methodology

The Pipe whip and jet impact Hazard Assessment will be performed based on the following approach [Ref-10].

(1) The sources of potential pipe whip and jet impacts will be identified.
(2) Identify the prevention and mitigation features of the design, including barriers.
(3) Identify rooms that contain both high energy piping and SSCs that provide Key Safety Functions.
(4) Determine pipe whip and jet impact effects in those rooms. This assessment includes analysis of pipe whip path and jet shape, as well as forces and pressures.
(5) Evaluate the consequences on SSCs that provide Key Safety Functions, including barriers.
(6) Determine additional protection measures, if needed, based on evaluation of impact on SSCs.
(7) Confirm the safety classification of the elements to protect against pipe whip and jet impacts in order to meet the safety claim.

7.5.5 Conclusion

The UK ABWR design includes many design elements and operational controls to limit the sources of pipe whip and jet impacts, and prevent them from occurring. The design also provides for redundant and diverse equipment to maintain the Key Safety Functions in the case of an internal hazard. This redundant and diverse equipment is protected by robust barriers and separation able to withstand the pipe whip and jet impacts. The Pipe Whip and Jet Impact Assessment completed during GDA Step 4 will demonstrate that the UK ABWR is designed so that any pipe whip and jet impact event within the design basis will not compromise the Key Safety Functions.

7.6 Protection Against Dropped and Collapsed Loads

Dropped loads may happen when a lifting device fails during a lifting activity and the load is dropped. A collapsed load may happen when a normally static system, building or support element fails and collapses or drops. Either dropped or collapsed loads can damage SSCs. Radioactivity exposure assessment in case of radioactive dropped loads is outside the scope of dropped and collapsed loads hazard assessment, and will be addressed during the safety categorization and classification process of lifting devices or the loads themselves.

7.6.1 Dropped Loads Claim

UK ABWR is designed so that any dropped or collapsed loads within the design basis will not compromise the Key Safety Functions.

7.6.2 Design Basis

7.6.2.1 Design Requirement

"Defence is Depth" is a fundamental principle in the design of UK ABWR. The approach with relation to dropped and collapsed loads is to:

(1) limit the sources of dropped and collapsed loads,
(2) prevent dropped and collapsed load hazards, and
(3) mitigate consequences of severe dropped loads hazard.

The number of dropped loads is limited by reducing the number of loads to be lifted, as well as the timing of the lifts. The number of collapsed loads is limited by restricting heavy elements from being installed at height during the design process.

7.6.2.2 Sources of Dropped and Collapsed Loads

The sources of potential dropped loads in the UK ABWR are limited to the number of lifting devices:

(1) R/B overhead crane
(2) Fuel Handling Machine
(3) RHR crane
(4) R/B maintenance area cranes
(5) Crane in the Large Component Entrance
(6) Jib crane in the Large Component Entrance
(7) T/B Operating Deck cranes
(8) Rw/B cranes

There are also a variety of monorails and chain blocks used to perform lifting operations.

These cranes and lifting devices could also be sources of collapsed loads if the cranes or monorails were to fail without a load. There are also a variety of support structures installed during construction that will be left in place after construction is complete.

Some large components installed at height, such as pipes and valves, may also collapse.

7.6.2.3 Assessment Assumptions

The following assumptions provide the basis for assessing dropped load hazards:

(1) A dropped load hazard can occur on any lifting device in service on the site, either permanent or temporary;
(2) Only a single dropped load event takes place at any given time. Secondary dropped load cannot be caused by initial dropped load. It will be confirmed that dropped loads cannot cause secondary collapsed loads.
(3) A dropped loads hazard may occur during normal operation or during shutdown;
(4) A dropped loads hazard may occur as a result of another internal/external event.
(5) Multiple dropped loads caused by a single event such as an earthquake may occur. Appropriate provisions will be developed.

It is assumed at this stage that large components like monorails, pipes and valves installed at height are designed and supported using appropriate standards. Temporary construction elements will be embedded in the structure and the potential for collapse is very low.

7.6.2.4 Prevent Dropped and Collaped Loads Hazard

UK ABWR includes a number of design elements that prevent dropped loads, as described below. Section 19 of the PCSR describes the fuel handling machine and R/B overhead crane in more detail, including the prevention devices.

(1) Lifting devices are designed using the appropriate design codes.
(2) The R/B crane and fuel handling machine have redundant load paths to prevent a single failure leading to a dropped load.
(3) The R/B crane and fuel handling machine have latched hooks to keep loads from slipping off.
(4) The R/B crane and fuel handling machine have an electromagnetic brake system to prevent hoist from falling down.
(5) The design of monorails requires installation separate from important equipment.
(6) Interlocks, operational procedures and operator training restrict operators lifting loads beyond the capability of the lifting device. Appropriate Human Factors assessment will be completed of any human factors claims.
(7) Interlocks are provided to restrict movement of cranes over certain areas in certain modes of operation. Details are provided in reference Document ID GA91-9201-0003-00069 in response to RQ-ABWR-0001 [Ref-11].

The hazards from a dropped load are reduced by only operating certain lifting devices during outage. Some lifting devices are operated only for maintenance of equipment and therefore, dropped loads would not affect any equipment other than that under maintenance. Lifting devices operating in areas with equipment important to safety (except R/B crane and fuel handling machine) will be lifting equipment that will make its entire division out of service. As the divisions are separated, the other equipment in that room will also be out of service so a dropped load impacting other equipment in that area will not affect the Key Safety Function equipment in other divisions.

R/B crane is designed to take into account the heaviest loads in the R/B (reactor well plug, reactor head, dryer, separator, spent fuel cask). A load cell in the R/B crane also prevents the crane from operating if the load is heavier than the crane rating. The R/B overhead crane will be prevented using an interlock from handling a spent fuel cask over the spent fuel.

The fuel handling machine vertical position interlocks ensure sufficient water shielding over the spent fuel being handled.

There is a process for the layout designers and the system designers to review the overall design to ensure dropped load do not impact important equipment, piping, ducts and cables.

7.6.2.5 Mitigate Consequences of Dropped and Collapsed Loads Hazard

If all the dropped load prevention approaches described above were to fail, the general approach to ensuring protection of SSCs of the Key Safety Functions is to limit the impacts of a dropped load to within the redundant division of the safety system. The dropped load claim is achieved by mitigating the consequences as described in Section 7.1.4.3.

7.6.2.6 Divisional Separation Exceptions

The separation exception in the primary containment and main steam tunnel is made because it is not practical to divide the primary containment and main steam tunnel into three areas. The design is deemed acceptable because:

(1) Maximum separation by distance is maintained between the divisional equipment within primary containment.
(2) If lifts are performed in primary containment the reactor will be in cold shutdown mode.
(3) Lifts in main steam tunnel will only occur with main steam isolation valves closed.
(4) The consequences of internal hazards in the main steam tunnel have been assessed in [Ref-8] and the consequences are acceptable without separation.

All divisions are present in the control room and this cannot be avoided. But there are no lifting devices in the control room therefore dropped load hazards is not a concern.

There are areas where there is equipment from more than one safety division in one safety divisional area. Each of these cases is examined on an individual basis to determine that the design is acceptable with respect to internal hazards.

7.6.2.7 Dropped and Collapsed Loads Hazard Consequence

The dropped load hazard assessment assumes that equipment placed beneath the moving range of lifting devices is damaged and unavailable. In addition, the dropped load hazard assessment will include estimates of the impacts created from the dropped load. The impact estimates will be used to determine appropriate civil and structural design, where necessary.

The “worst-case” cask drop scenario will be assessed, inside the R/B during loading of a full cask onto the trailer. The assessment will determine the radiological release as a result of a dropped cask inside the R/B. This assessment will be described in PCSR Section 24.4.

A fuel drop accident in the reactor core and spent fuel pool will be assessed and described in PCSR Section 24.4.

7.6.3 Safety Evaluation

The UK ABWR is designed to prevent a dropped load from occurring. However, if, in the worst case, a dropped load does occur, the overall plant design with respect to the effects of dropped loads hazard is to assume that all Key Safety Functions are lost for equipment, including electrical cables, located within a safety divisional area experiencing a dropped load. Redundant equipment to maintain Key Safety Functions is provided in other safety divisional areas, and is generally protected from the effects of dropped loads by appropriately designed barriers. The Dropped Loads Hazard Assessment evaluates the compliance of the design to this requirement for redundancy.

The basis of the design provides redundant, protected equipment rather than evaluate a damage limit.

The main safety functional claims will be made for the redundant equipment used to maintain the Key Safety Functions as described above, as well as for the barriers that separate each division from dropped load impacts in other divisions. The specific barriers and their specific nuclear safety classification will be determined by the Dropped Loads Hazard Assessment. Additional safety functional claims may be required for certain elements of the prevention and protection measures, such as the double wire hook, and interlocks for the FHM and R/B crane.

7.6.4 Dropped and Collapsed Loads Hazard Assessment Methodology

The Dropped Loads Hazard Assessment will be performed based on the following approach [Ref-12]:

(1) Identify sources of dropped loads and collapse hazards.
(2) Identify heaviest loads of each lifting device.
(3) Identify the prevention features to limit the dropped and collapsed loads.
(4) Assess the impact of the heaviest dropped load. This will include the impact loadings and an assessment of potential impacts on important SSCs and barriers.
(5) Determine the safety classification of the elements to protect against dropped and collapsed loads.

7.6.5 Conclusion

The UK ABWR design includes many design elements and operational controls to limit the sources of dropped and collapsed loads, and prevent them from occurring. The design also provides for redundant and diverse equipment to maintain the Key Safety Functions in the case of an internal hazard. This redundant and diverse equipment is protected by robust barriers and separation able to withstand the dropped and collapsed loads. The Dropped Load Hazard Assessment completed during GDA Step 4 will demonstrate that the UK ABWR is designed so that any dropped or collapsed load event within the design basis will not compromise the Key Safety Functions.

7.7 Protection Against Internal Missile

Internal missiles are missiles generated inside the buildings of the UK ABWR from high pressure or rotating equipment or potentially explosive materials. Internal missiles are usually projectiles with significant kinetic energy, which can damage other equipment and structures.

7.7.1 Internal Missile Claim

UK ABWR is designed so that any internal missile event within the design basis will not compromise the Key Safety Functions.

7.7.2 Design Basis

7.7.2.1 Design Requirement

The internal missile claim in Section 7.7.1 will be achieved in the UK ABWR by the following approach:

(1) To limit missile sources,
(2) To prevent the generation of missiles, and
(3) To mitigate the consequences on SSCs of missiles.

The number of missile sources is limited as much as possible by minimizing the amount of high pressure and rotating equipment, and limiting the amount of potentially explosive materials.

7.7.2.2 Sources of Missiles

There are a number of sources of potential missiles in the UK ABWR design:

(1) Rotating machinery-pumps
(2) Turbine
(3) Generator
(4) Fans/blowers
(5) Compressors
(6) Pressure vessels and connecting equipment

7.7.2.3 Assessment Assumptions

The following assumptions provide the basis for assessing postulated missile hazards:

(1) A missile can occur anywhere on the site where permanent or transient missile sources are located;
(2) Only a single missile event takes place at any given time, except where secondary missiles are induced as a direct result of an initial missile (i.e. the second missile is not independent of the first)
(3) Missile hazards may occur during normal operation or during shutdown;
(4) A missile may be induced as a result of another internal/external event.
(5) Multiple missiles caused by single event such as earthquake may occur. Appropriate provisions will be developed.

7.7.2.4 Limit Missile Sources

UK ABWR is designed in consideration of following requirements so that the probability of missiles minimized.

(1) The sources of internal missile should be eliminated as far as reasonably practicable. Systems, structures and components containing explosive material are designed to prevent or limit potential missile sources.
(2) Rotating machines or tanks containing pressurized fluid are removed as far as reasonably practical to reduce internal missiles hazard sources. However, when the use of such machines or tanks is necessary to deliver nuclear safety or operational functions, the number of such machines and tanks is minimised.
(3) Administrative controls and procedures are used to control the locations of mobile or temporary missile sources.

7.7.2.5 Prevent Generations of Missiles

UK ABWR includes a number of design elements that prevent a missile:

(1) Equipment is designed and manufactured according to appropriate international design and operational health and safety standards (See Section 5.6 of this PCSR).
(2) Appropriate quality assurance programs are followed in design and fabrication
(3) Testing inspection and commissioning of equipment
(4) Detection system and force-trip system against over speed of rotating machines
(5) Detection and relief systems for over-pressure in tanks and vessels
(6) Pump, fan, and turbine casings have a robust design to retain internal components.
(7) Explosion prevention features as described in Section 7.8.2.4.

The potential missile paths and impact locations have been considered in the orientation and layout of the sources.

7.7.2.6 Mitigate Consequences of Internal Missiles

If all the missile prevention measures described above were to fail, the general approach to ensuring protection of SSCs of Key Safety Function is to limit the impacts of the missile to within the redundant division of the safety system. In some areas, it is necessary to consider secondary missiles due to the proximity of the hazards. In these cases, other protection and mitigation measures may be necessary. The internal missile claim is achieved by mitigating the consequences of missile impact as described in Section 7.7.2.6.

7.7.2.7 Divisional Separation Exception

The separation exception in the primary containment and main steam tunnel is made because it is not practical to divide the primary containment and main steam tunnel into three areas. The design is deemed acceptable because:

(1) Missile sources in the primary containment have structure to prevent missile generation such as an adequate integrity of pump casing.
(2) In addition, maximum separation is maintained between the divisional equipment within primary containment.

(3) The consequences of missile impact in the main steam tunnel have been assessed in [Ref-8] and the consequences are acceptable without separation.

All divisions are present in the control room and this cannot be avoided. However, there are no missile sources in the main control room.

There are areas where there is equipment from more than one safety division in one safety divisional area. Each of these cases is examined on an individual basis to determine that the design is acceptable with respect to internal hazards.

7.7.2.8 Internal Missile Consequence

The results of the missile generation include projectile impact on SSCs and barriers. Generation of missiles may also generate an overpressure. The impacts and overpressure can lead to failure of equipment and barriers that are not designed or protected to withstand these forces. The internal missile assessment assumes that a missile will result in the loss of all equipment in the area where the missile impacts. In addition, the missile assessment will include estimates of the impact load created by a missile. These estimates will be used to determine appropriate civil and structural design, where necessary.

7.7.3 Safety Evaluation

The UK ABWR is designed to prevent a missile impact from occurring. However if, in the worst case, a missile impact does occur the overall plant design with respect to the effects of an internal missile is to assume that all Key Safety Functions are lost for equipment, including electrical cables, located within a safety divisional area experiencing a missile hazard. Redundant equipment to maintain the Key Safety Functions is provided in other safety divisional areas, and is generally protected from the effects of missile impact by appropriately designed barriers. The Missile Hazard Assessment evaluates the compliance of the design to this requirement for redundancy.

The main safety functional claims will be made for the redundant equipment used to maintain the Key Safety Functions as described above, as well as for the barriers that separate each division from missile impacts in other divisions. The specific barriers and their specific nuclear safety classification will be determined by the Internal Missile Impact Assessment. Additional safety functional claims may be required for the turbine missile on the casing or over speed protection.

The Missile Hazard Assessment assumes that the function of a piece of equipment may be lost if the equipment is involved in detection and alarm in case of over-speed of rotating machines or over-pressure of fluid contained tanks, and confirms that redundant equipment out of the safety divisional area is available. The basis of the design is not to assume a questionable limit on damage within a given safety divisional area but to provide redundant equipment elsewhere.

7.7.4 Combined Missile Hazards

As shown in Section 7.1.6.3, a missile can be a cause for other internal hazards. The table below indicates that missiles can cause all other internal hazards considered in this report. However, these combined events would only happen within the same division due to the divisional separation provided in the UK ABWR design. In the case of a missile causing internal flooding, the internal flooding assessment will evaluate the impact of the internal flooding.

Table 7.7-1: Combination of Internal Hazards (Initiating Hazard: Missile)

initiating hazard	Induced hazards					
	fire	flood	pipe whip/jet	dropped loads	missile	explosion
missile	x	x	x	x	x	x
x: considered						

7.7.5 Missile Hazard Assessment Methodology

The Missile Hazard Assessment will be performed based on the following approach.

(1) Identification of SSCs and associated cabling within each room or area, which could provide Key Safety Functions.

(2) Identification of missile barriers surrounding a room or area which separate safety divisional area.

(3) Evaluation of missile loadings resulting from the missile sources identified for each room or area.

(4) Analysis of the means of containing the progress of a missile in each room or area. This is defined as the use of a missile-resisting enclosure or barrier (i.e. wall, wall penetrations, dampers, and suitable doors).

(5) Listing of all the detection and alarm system for over-speed of rotating machines and over-pressure of fluid contained tanks. Listing of all over-speed trip systems for the rotating machines is also implemented.

(6) Analysis of the consequences of the missile for each room or area. This is stated as loss of function and identifies the divisional backup capability available for Key Safety Functions.

(7) Analysis of the consequences of the missile, if the missile protection system functions as designed. The protection system is defined as 1: having the capability to detect and alert an existence of over-speed of rotating machines and over-pressure of fluid contained tanks and 2: having over-speed trip system on rotating machines. The ability to restrict the missile to a discrete area by means of the detection, alarm and trip system is stated.

(8) For turbine missile, favourable locations for related buildings are considered of hazard zone of low-trajectory (direct) impact. For high-trajectory impact, the probability of failure of an essential SSC because of turbine missiles is analysed.

7.7.6 Conclusion

The UK ABWR design includes many design elements and operational controls to limit the sources of internal missiles, and prevent them from occurring. The design also provides for redundant and diverse equipment to maintain the Key Safety Functions in the case of an internal hazard. This redundant and diverse equipment is protected by robust barriers and separation able to withstand the missile impacts. The Internal Missile Assessment completed during GDA Step 4 will demonstrate that the UK ABWR is designed so that any missile impact event within the design basis will not compromise the Key Safety Functions.

7.8 Protection Against Internal Explosion

Internal explosions could happen inside buildings in the UK ABWR as a result of flammable gases and liquids and combustible materials causing deflagrations and/or detonations. Explosions usually result in a pressure wave or a fire that can damage equipment in the vicinity of the explosion.

7.8.1 Internal Explosion Claim

UK ABWR is designed so that any internal explosion event within the design basis will not compromise the Key Safety Functions.

7.8.2 Design Basis

7.8.2.1 Design Requirement

The internal explosion claim in Section 7.8.1 will be achieved in the UK ABWR by:
(1) limiting the number of explosion sources,
(2) preventing the ignition of explosion sources, and
(3) mitigating the consequences on SSCs of severe explosions.

The number of explosion sources is limited as much as possible by minimizing quantities and storing potentially hazardous materials outside any buildings containing SSCs important to safety. Sections below describe the design elements that prevent explosions and mitigate the consequences.

7.8.2.2 Sources of Explosions

There are a number of sources of potential explosions in the UK ABWR design:
(1) Hydrogen
  - Used to cool the TG set
  - Created from the radioactive decomposition of water
  - Venting of batteries
  - Calibration of the Off gas System
(2) Acetylene used for welding during outages
(3) Oil mist released from a failure in a high pressure oil system
(4) High energy arcing fault
(5) Pyrophoric material in explosively actuated valves.

These different sources are contained in tanks and piping systems; occur as a result of a piping failure; occur as a result of an electrical failure; or can inherently cause an explosion.

7.8.2.3 Assessment Assumptions

The following assumptions provide the basis for assessing explosion hazards:
(1) An explosion can occur anywhere on the site where permanent or transient explosive material is stored;

(2) Only a single explosion event takes place at any given time, except where secondary explosions take place as a direct result of an initial explosion (i.e. the second explosion is not independent of the first)
(3) Explosions may occur during normal operation or during shutdown;
(4) An explosion may occur as a result of another internal/external event;
(5) Multiple explosions caused by single event such as an earthquake may occur. Appropriate provisions will be developed.

7.8.2.4 Prevent Explosions

UK ABWR includes a number of design elements that prevent an explosion:

(1) Piping for systems which contain hydrogen is designed to prevent leakage and failure. It will include welded joints, leak tight valves and will comply with ASME Section III and B31.1 standards, in addition to meeting the UK Pressure Equipment Directive (PED), Pressure Systems Safety Regulations (PSSR) and other appropriate UK regulation.
(2) Piping systems that may contain hydrogen due to the decomposition of water will be in accordance with ASME Section III and B31.1 standards, in addition to meeting the Japanese design guide JANTI-NCG-01 for this specific hazard.
(3) The batteries used in the UK ABWR will be the sealed type, which do not vent hydrogen. Moreover, a ventilating system is installed in the battery areas.
(4) Hydrogen tank for TG cooling is stored in a separate building.
(5) Storage tanks containing compressed flammable gases (acetylene for welding, hydrogen for calibration) have been designed and specified for the pressure and include relief valves, as per British Compressed Gases Association (BCGA) standards. The hydrogen concentration in small tanks inside of the R/B is below the explosive limit.
(6) High pressure oil system piping is designed to prevent leakage and failure and includes welded joints and complies with ASME Section III and B31.1 standards.
(7) High energy electrical systems are designed to include circuit breakers and other trip devices to prevent overpower.
(8) Areas containing hydrogen gas tanks and the battery rooms are actively ventilated to prevent accumulation of an explosive atmosphere.
(9) Storage tanks and cylinders of combustible gases are stored either inside a locked area, or are restrained to a robust structure.
(10) Piping systems are pressure tested during commissioning to ensure integrity.
(11) All systems are regularly inspected.
(12) Hydrogen concentration is monitored in the Off gas System. The Off gas (OG) system is designed with Steam Jet Air Ejector (SJAE) which ensures any hydrogen extracted from the condenser with other incondensable gases is diluted by driving steam to below flammable limits. The OG system uses catalytic recombiners to remove hydrogen before the driving steam is condensed to minimize the risk of hydrogen explosion.

7.8.2.5 Prevent Ignition of Explosion Sources

Based on the DSEAR assessment, the UK ABWR design will include specific equipment to address the ignition potential. In areas susceptible to explosive atmospheres, hot surfaces will be insulated and electrical equipment will be appropriately rated depending on the Hazardous Area Classification.

The explosively actuated valves are self-contained and the amount of explosive used in these valves is extremely small (size of the valves is about 150mml and contain less than 1 gram per valve and three valves). The valves are designed and specified for their casings to withstand the normal operation and so that their actuation would not result in a pressure wave in a normal volume in a typical room. These valves are located approximately 1 m away from the primary containment structure outside the PCV in the R/B.

7.8.2.6 Mitigate Consequences of Severe Explosions

If all the explosion prevention approaches described above were to fail, the general approach to ensuring protection of SSCs of the Key Safety Functions is to limit the impacts of an explosion to within the redundant division of the safety system. In some areas, it is necessary to consider secondary explosions due to the proximity of the hazards. In these cases, other protection and mitigation measures may be necessary. The internal explosion claim is achieved by mitigating the consequences of severe explosions as described in Section7.8.2.6.

7.8.2.6.1 Divisional Separation Exception

The separation exception in the primary containment and main steam tunnel is made because it is not practical to divide the primary containment and main steam tunnel into three areas. The design is deemed acceptable because:

(1) Primary containment is inerted during plant operation. Therefore, an explosion by flammable gas ignition is not possible.
(2) Sprinkler coverage is provided by the Containment Spray System.
(3) Maximum separation is maintained between the divisional equipment within primary containment.
(4) The main steam tunnel does not contain any explosive material. Steam may contain very small amount of hydrogen, however there are no vents or high points where it could accumulate in pipe work.

All divisions are also present in the control room and this cannot be avoided. The remote shutdown panels provide redundant control of the safe shutdown functions from outside of the control room.

There are areas where there is equipment from more than one safety division in one safety divisional area. Each of these cases is examined on an individual basis to determine that the design is acceptable with respect to internal hazards.

7.8.2.7 Explosion Consequence

The explosion assessment assumes that an explosion will result in the loss of all equipment in the area where the explosion takes place. In addition, explosion assessment will include estimates of overpressure created from certain hazards, or reference bounding overpressures created by other hazards. These estimates will be used to determine appropriate civil and structural design, where necessary, to demonstrate robustness of safety class barriers.

7.8.3 Safety Evaluation

The UK ABWR is designed to prevent an internal explosion from occurring. However, if, in the worst case, an explosion does occur, the overall plant design with respect to the effects of explosion is to assume that all Key Safety Functions are lost for equipment, including electrical cables, located within the entire safety divisional area experiencing an explosion. Redundant equipment to maintain the Key Safety Functions is provided in other safety divisional areas, and is generally protected from the effects of the explosion by appropriately designed barriers. The Explosion Hazard Assessment evaluates the compliance of the design to this requirement for redundancy.

The Explosion Hazard Assessment assumes that the function of a piece of equipment may be lost if the equipment is involved in detection and alarm in case of existence of explosive gas, and confirms that redundant equipment out of the safety divisional area is available. The basis of the design provides redundant, protected equipment rather than evaluate a damage limit.

The main safety functional claims will be made for the redundant equipment used to maintain the Key Safety Functions as described above, as well as for the barriers that separate each division from explosion impacts in other divisions. The specific barriers and their specific nuclear safety classification will be determined by the Explosion Hazard Assessment.

7.8.4 Combined Explosion Hazards

As shown in Section 7.1.6.3, an explosion can be a cause of other internal hazards. The table below indicates that explosions can cause all other internal hazards considered in this report. However, these combined events would only happen within the same division due to the divisional separation provided in the UK ABWR design. In the case of an explosion causing internal flooding, the internal flooding assessment will evaluate the impact of the internal flooding.

Table 7.8-1: Combination of Internal Hazards (Initiating Hazard: Explosion)

initiating hazard	Induced hazards					
	fire	flood	pipe whip/jet	dropped loads	missile	explosion
explosion	x	x	x	x	x	x
x: considered						

7.8.5 Explosion Hazard Assessment Methodology

The Explosion Hazard Assessment will be performed based on the following approach [Ref-13].

(1) The sources of explosion hazards will be identified.
(2) The elements of the designs of the systems susceptible to explosion will be identified.
(3) The prevention and mitigating features of the design will be identified.
(4) The SSCs that provide Key Safety Functions will be identified.

(5) An assessment of the impact of the explosion on the SSCs will be performed. This will include an assessment of the explosion loadings, the equipment and barrier response.
(6) Determination of the safety classification of the elements to protect against internal explosions.

The explosion hazard assessment will refer to a separate DSEAR assessment.

7.8.6 Conclusion

The UK ABWR design includes many design elements and operational controls to limit the sources of explosion hazards, and prevent explosions from occurring. The design also provides for redundant and diverse equipment to maintain the Key Safety Functions in the case of an internal hazard. This redundant and diverse equipment is protected by robust barriers and separation able to withstand the explosion hazards. The Explosion Hazard Assessment completed during GDA Step 4 will demonstrate that the UK ABWR is designed so that any internal explosion event within the design basis will not compromise the Key Safety Functions.

7.9 References

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