Form10/00

UK ABWR

Document ID	:	GA91-9101-0101-32000
Document Number	:	FRE-GD-0008
Revision Number	:	B

UK ABWR Generic Design Assessment

Generic PCSR Chapter 32 : Spent Fuel Interim Storage

Hitachi-GE Nuclear Energy, Ltd.

DISCLAIMERS

Proprietary Information

This document contains proprietary information of Hitachi-GE Nuclear Energy, Ltd. (Hitachi-GE), its suppliers and subcontractors. This document and the information it contains shall not, in whole or in part, be used for any purpose other than for the Generic Design Assessment (GDA) of Hitachi-GE's UK ABWR. This notice shall be included on any complete or partial reproduction of this document or the information it contains.

Copyright

Table of Contents

32.1 **Introduction**

This PCSR chapter focuses on the generic design aspects for the Spent Fuel Interim Storage (SFIS) system for the UK ABWR. The SFIS system enables transfer of spent fuel from the Spent Fuel Storage Pool (SFP) to an on-site spent fuel storage facility where fuel will be stored until it is repackaged and sent off site for long term storage.

32.1.1 **Purpose**

The purpose of this PCSR chapter is to:

- Summarise the conceptual design for the SFIS system.
- Define the boundaries and key interfaces of SFIS operation.
- Present the safety case claims for SFIS.
- Describe the high level faults and hazards identified for SFIS.
- Define the safety claims of SFIS and describe how these claims have been integrated into the UK ABWR design.
- Outline how the concept SFIS system reduces risks As Low As Reasonably Practicable (ALARP).
- Outline the applicable legislation to which the SFIS facility must adhere.

More preliminary discussion of the SFIS system, operations, and analysis of the faults and hazards is presented in the SFIS Basis of Safety Case (BSC) [Ref-5] and associated supporting documents.

32.1.2 **Scope**

The scope of this PCSR chapter is limited to the SFIS concept design and SSCs specific to SFIS operations. This chapter will also outline key interfaces between the SFIS and other SSCs for other systems and buildings, referring to interfacing PCSR chapters and BSC for these systems and buildings as appropriate.

The SFIS lifecycle under consideration in this document spans from the point at which SFIS SSCs first arrive on site, and ends with the repackaging and removal of spent fuel and disposal of all SFIS SSCs from site. Transferring spent fuel from the SFP to the SFIS facility is intended to be carried out in batches, termed operations. Each operation is planned around refuelling outages to minimise disruption to station operation and allowing efficient use of resources. The starting point for a SFIS loading process is the movement of SFIS SSCs from their storage locations into the reactor building. The end point for a SFIS process is the placement of the spent fuel into the interim storage facility, outside the reactor building.

The interim storage period is currently proposed to last for 140 years after station decommissioning. Final limits and conditions for the interim storage period will be considered by the site licensee at the site licensing stage [Ref -7, Section 2.1].

32.1.3 **Generic Design Aspects**

The UK ABWR design has been developed based on the technology demonstrated from operating stations in Japan and around the world. The reactor design has undergone continuous improvement since the introduction of the Boiling Water Reactor (BWR) technology in the 1950s as described in PCSR Chapter 9. The handling, storage and removal of spent fuel from the reactor building has been included in the continual BWR design development.

During GDA Step 2 the generic SFIS approach was considered and an ALARP optioneering study was conducted on the storage solution for SFIS [Ref-1]. The result of this study was that a concrete cask storage system, consistent with international good practice was adopted as the most effective solution to take forward for GDA Step 3. This formed the basis for further design assessment and development during GDA Step 3 and provided a framework for further optioneering to provide a reference SFIS solution that reduces risk As Low As Reasonably Practicable (ALARP).

During GDA Step 3, and the following high level ALARP optioneering assessments have been presented [Ref-9]:

- The proposed method of removing spent fuel from the SFP reduces risk ALARP.
- The proposed route for moving spent fuel, and the associated transport equipment and ancillary systems within the reactor building reduces risk ALARP.

This included the development and assessment of different options, using agreed assessment criteria that have been developed in line with the ALARP methodology described in PCSR Chapter 20. The output of this process was a preferred option, upon which further risk optimisation can be conducted during GDA Step 4 and site specific phase.

Fault and hazard assessments have been conducted against the preferred option in order to understand the risks involved in preliminary.

These faults and hazards are assessed at high level during Step 3 to identify key risks. They will be assessed in greater detail during Step 4 to provide optimisation such that the risks are reduced ALARP.

Waste arisings and impact on radioactive waste systems resulting from SFIS processes will be documented in GDA Step 4. The final limits and conditions of waste arisings will be determined during site licensing. Other waste components (such as control rod blades) compatible with interim dry storage may be included into the SFIS system and these will be detailed further in GDA Step 4.

32.1.4 **Design Status for GDA**

SFIS operations will not be required until sufficient spent fuel has been generated by an operating station and cooled in the SFP for an appropriate time. Therefore detailed design of the SFIS SSCs will not be completed until after the GDA process is complete. This allows for the SFIS process to benefit from worldwide experience and developing good practice which can be incorporated into the design.

It is noted that the UK ABWR design (including the fuel assembly design to be placed in SFIS) is at a more advanced design stage relative to SFIS. Therefore evidence that the reference SFIS system can be incorporated around the station design, in a manner in which risks are reduced ALARP, has been provided as part of GDA Step 3 [Ref-9].

32.1.5 **Spent Fuel**

A number of assumptions regarding spent fuel are used to allow a reasonable assessment of the risks associated with the SFIS system. It is noted that these assumptions will require validation during site licensing. The working assumptions for spent fuel are: [Ref-7, Section 2.2]

- The SFIS system will hold up to 89 spent fuel assemblies in each cask.
- Fuel type: BWR fuel assembly (GE14).
- Burn up: 55 GWD/MTU (maximum bundle average).
- Enrichment: 4 wt. % of U235.
- Pool cooling period: 10 years (average).

Handling of damaged fuel must also be considered as part of the SFIS system and is discussed further in Section 32.2.1. This chapter assumes that the spent fuel for input into the SFIS system is in a condition and quality that meet defined SFIS acceptance criteria. Detailed fuel inspection processes and acceptance criteria prior to SFIS loading will be developed during the site specific design stage.

32.1.6 **Generic Site Envelope**

The SFIS system and SSCs will be designed to accommodate the relevant Generic Site Conditions and hazards, which are defined in the PCSR Chapter 2.

32.1.7 **Decommissioning**

It is important to consider decommissioning activities with regards to SFIS operations. Both in terms of decommissioning SFIS SSCs and also in terms of how the SFIS system will interact with and enable station decommissioning.

Decommissioning of the SFIS SSCs, including the storage facility will be required. This will include decommissioning considerations of SSCs, such as the concrete pad of the storage facility, which could become activated during interim storage. This will be considered in detail during site licensing.

The SFIS system will allow removal of all spent fuel and some specific activated non fuel components (such as control rod blades) from the reactor building during station decommissioning. As noted in Section 32.1.5, the working assumption in the SFIS BSC [Ref-5] is that fuel has been cooled in the SFP for 10 years (average) before being placed into interim storage. However, it is noted that the current station decommissioning strategy is likely to require the SFP to be emptied of spent fuel in less than 10 years after a station has been shut down. Therefore careful planning will be required to ensure that the decommissioning strategy can be implemented without exceeding SFIS operating limits and conditions. This should be determined by reactor core control of the last cycle and consideration of radiation protection for workers and public during decommissioning. This is consistent with the Decommissioning section of the PCSR Chapter 31, Section 31.4.2.4.

32.2 **System Description**

This section provides the SFIS operational process steps in normal conditions and describes the key systems and components of the SFIS system. This includes all processes from the start of SFIS operations through to storage of spent fuel within concrete storage overpacks and retrieval and repackaging operations.

32.2.1 **Process Description**

Figure 1 describes the key steps involved in the transfer of spent fuel from the SFP to the interim storage facility and the eventual retrieval and repackaging for transfer of spent fuel off site after the interim storage period.

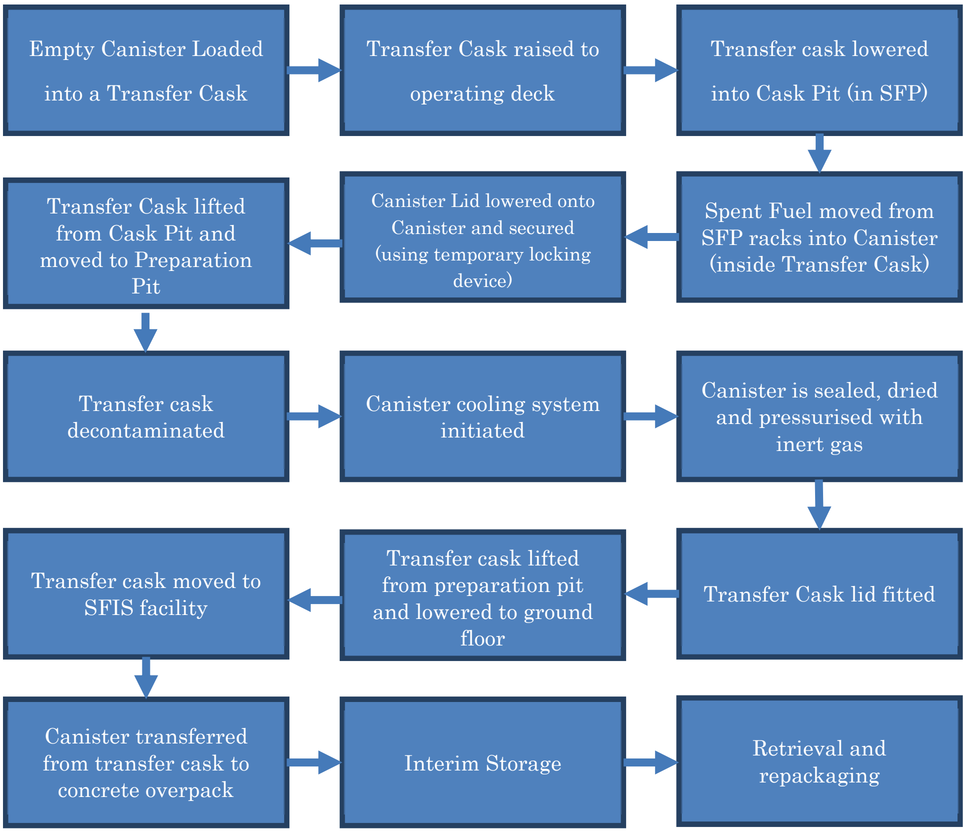

Figure 1: Sequence of key SFIS operations.

In addition to the steps shown in Figure 1, the following operations are also considered in more detail within [Ref-7] as part of the SFIS system:

- Non-fuel handling operations – the handling of any equipment on a nuclear site involves risk and has therefore been considered in the BSC for SFIS [Ref-7, Section 3.2]. These risks include the handling of empty casks, fuel containers and ancillary equipment. The assessment of risks includes nuclear safety risk (i.e. where heavy equipment is handled adjacent to nuclear safety related plant), and conventional safety where there may be a risk of injury or death to operators during handling.

- Reverse operations – it is a claim to be able to reverse SFIS operations (i.e. to return spent fuel to the SFP) either during handling (e.g. in the event of a handling error or fault in the process), or during interim storage (e.g. to allow inspection of fuel within the canister). This has been included within the BSC for SFIS [Ref-7, Section 3.3.6], and the risks associated with these reverse operations have been taken into account during ALARP optioneering for SFIS [Ref-9].
- Damaged fuel handling – A strategy for handling damaged fuel (including fuel which cannot be handled using normal handling equipment, as well as fuel with non-intact fuel clad) has been included within the BSC for SFIS [Ref-7, Section 3.1]. The strategy for SFIS during GDA is to demonstrate that there are a number of potential solutions to handle damaged fuel of different types, within the SFIS system, ranging from options that are commercially available currently to options that are conceptual and require research and development before they could be deployed. It is not considered appropriate to select a preferred option during GDA, as the optimum solution for handling damaged fuel will depend upon the type and quantity of damaged fuel generated during station operation. This approach also allows for the adoption of other options and the inclusion of developing worldwide good practice as SFIS experience develops. This strategy will be considered further during site licensing to ensure consistency with other sections of the safety case such as the Spent Fuel Storage Pool safety case [Ref-15].

The processes and associated risks with all SFIS operations as detailed above are described and considered within the SFIS BSC [Ref-5].

32.2.2 **Systems, Structures and Components (SSCs) Design**

This section provides a high level outline of SFIS equipment and their respective roles. Further description of the SFIS specific SSCs and buildings is provided by the SFIS BSC [Ref-5].

32.2.2.1 **Fuel Storage Equipment**

The following SSCs will be used to hold spent fuel for SFIS. All these items are at concept design status for GDA as they will not be required for several years into station operation and detailed design will be completed during site specific phase.

<u>Canister</u>

The canister will be used to store fuel assemblies during the lifetime of the SFIS process. The canister consists of two discrete components: the enclosure vessel and the fuel basket. The fuel basket maintains geometrical arrangement of fuel in the canister, while the enclosure vessel forms a containment barrier once sealed. The sealed canister will provide a pressurised and inert environment to maximise heat transfer from the spent fuel to the outer canister wall.

A number of different canister designs are available for handling spent fuel as well as non-fuel components, such as control rod blades. Canister designs are also available that can store damaged fuel. All these canisters can fit within the available transfer cask designs (described below) without modification to the transfer cask or any handling equipment.

Transfer cask

The transfer cask will be used to hold the canister (unloaded and loaded) while it is moved from the SFP to outside the reactor building and to transfer the canister into a concrete overpack via a cask interface. The transfer cask is a rugged and heavy-walled cylindrical vessel designed to contain a canister. The primary purpose of the transfer cask is to provide shielding when fuel is held in the canister and to provide physical protection to the canister while also maximising heat transfer from the fuel contained within the canister to the environment. Suitable lifting features will be included to facilitate the handling of the transfer cask.

Concrete overpack

The concrete overpack will be used to store the canister at the SFIS facility during the interim storage period. It will be a heavy-walled and multi-layered cylindrical vessel constructed of shielding material, with incorporated cooling vents. As with the transfer cask, the primary purpose of the concrete overpack is to reduce worker and public dose during interim storage ALARP, while providing physical protection to the canister and maximising heat transfer from fuel.

32.2.2.2 **Handling and Transfer Equipment**

The following SSCs will be used to move equipment that holds spent fuel:

- Interfacing SSCs that are not specific to SFIS:

  Fuel Handling Machine (FHM)

  The FHM will be used to load spent fuel from the SFP fuel racks into the canister. Detailed system description for the FHM is provided in the Fuel Storage and Handling PCSR Chapter 19, Section 19.5.

  Reactor Building Crane (RBC)

  The RBC will be used to move the canister/transfer cask assembly, canister lid, and other SFIS ancillary equipment inside the reactor building. The RBC will lift all equipment from the low profile transporter (described below) in the large component entrance onto the operating deck via the equipment hatch at the start of an SFIS operation. The RBC will then be used to move all equipment, including the transfer cask, containing a loaded and sealed canister from the operating deck back to the low profile transporter in the large component entrance via the equipment hatch. Detailed system description for the RBC is provided in the Fuel Storage and Handling PCSR Chapter 19, Section 19.6.

- SSCs that are specific to SFIS:

  Low Profile Transporter (LPT)

  The LPT will be used to move the transfer cask and other SFIS SSCs into and out of the reactor building via the large component entrance.

  Cask Transporter (CT)

  The CT will be used to transfer canister/cask assemblies from the LPT once it is outside the reactor building to the interim storage position. The CT will be a multi-wheeled or tracked, multi-directional vehicle featuring a gantry crane and double wire hoist capable of handling a loaded transfer cask or concrete overpack.

  Lifting Devices

  Lifting devices for use during SFIS operations, such as a lifting yoke to allow lifting of the transfer cask by the RBC, will be required. These devices allow the RBC and FHM to interface with other SFIS SSCs. The design for these lifting devices will not be chosen until the final design for the SFIS system is developed.

32.2.2.3 **SFIS Ancillary Equipment**

The following SFIS ancillary equipment is required to carry out an SFIS process. All of the following systems are specific to SFIS.

Cask Interface

The cask interface (or mating device) will be used to connect the transfer cask to the concrete overpack to allow the canister to be moved from the transfer cask to the concrete overpack. The interface provides shielding to operators during this transfer. The device is likely to comprise two steel flanges and a sliding lid to allow the canister to be lowered from the transfer cask into the concrete overpack.

Canister Cooling System (CCS)

A CCS will be included as part of the SFIS design to provide cooling to the canister during canister preparation activities (including drainage, drying, pressurisation, and sealing). This is likely to be an active system to remove heat from the canister to prevent fuel clad failure during preparation activities.

Backup Canister Cooling System

A backup canister cooling system will be provided to reinstate cooling to the canister should the CCS fail, or should a delay be experienced before the CCS can be initiated. The backup system is likely to comprise of a multi-purpose pump and flexible hoses which will allow pool water to be circulated through the canister. The backup cooling system is likely to be skid-mounted on a separate skid to the CCS.

Canister Welding System

A canister welding system will be provided to weld the canister lid to the canister shell. The welding system is likely to be a skid mounted automated system comprising a rotary arm, a video camera and an automated welding rod or gun and spool.

Drying and Pressurisation System

A canister drying system will be provided to remove water from inside the canister following lid welding. A pressurisation system will also be provided to backfill the canister with an inert gas which optimises heat transfer from the spent fuel to the canister walls and provides an inert environment within the canister for the interim storage period [Ref-11].

32.2.2.4 **Buildings and Facilities**

The following buildings and facilities are required for SFIS operations.

- Interfacing facilities that are not specific to SFIS:

  Spent Fuel Storage Pool (SFP), including cask pit

  The key features of the SFP used during the SFIS process are the spent fuel racks and the cask pit. Fuel is moved from the spent fuel racks using the FHM and transferred to a canister which is inside a transfer cask in the cask pit. Further details of the SFP, including its design, construction, control and protection systems are provided in the Fuel Storage and Handling PCSR Chapter 19, Section 19.3 and its associated references.

  Preparation Pit

  The preparation pit (also referred to as the decontamination pit) is separate to the SFP and will be used for canister preparation activities. The transfer cask, containing the canister and the spent fuel, is lowered into the preparation pit using the RBC. The preparation pit is used for a range of operations including: decontamination of the cask, canister draining, lid welding, canister drying and backfilling with inert gas. Drains are provided at the bottom of the cask pit to remove contaminated waste water. An additional function of the preparation pit is to provide shielding to operators during cask preparation activities.

Standby Gas Treatment System (SGTS)

The reactor building will be supplied with an SGTS. During fault conditions the SGTS maintains a negative pressure within the secondary containment, relative to the outdoor atmosphere and filters radiological effluent from the secondary containment before it enters the environment, effectively forming the secondary containment barrier. Further details of the SGTS are provided by the SGTS BSC [Ref-6] and its associated references.

- Facilities that are specific to SFIS:

SFIS Facility and Storage Pads

The concrete overpacks will be stored on a seismically qualified pad within a lightweight building. The design for the SFIS facility and storage pads is site specific and will be developed during site licensing for SFIS and is therefore out of scope for GDA. The key functions of the interim storage location are:

- Limit off-site doses to within acceptable levels and to a level that is ALARP.
- Provide a stable facility for storage of the concrete overpacks.
- Protect the concrete overpacks and canisters from harsh environmental conditions SFAIRP.
- Preventing, or minimising potential activation of the concrete pad or surrounding systems during interim storage.

Repackaging Facility

A repackaging facility will be provided to allow removal of spent fuel from canisters after interim storage, and to allow inspection of fuel in the canisters during interim storage. An outline description of the repackaging facility is provided in the SFIS BSC [Ref-7, Section 4.4.5]. Development of a repackaging facility concept design will not be completed during GDA as it will not be required for a number of years into SFIS operations. This will allow incorporation of modern design and developing good practice as repackaging facilities are developed around the world.

32.2.2.5 **Examination, Maintenance, Inspection, and Testing Requirements for SFIS SSCs**

In order to ensure that the SFIS system provides the required safety functions throughout its design life, examination, maintenance, inspection, and testing (EMIT) requirements will be specified for each SSC during the detailed design stage. For GDA Step 3 the methodology for identifying EMIT requirements, along with examples of current EMIT options, is provided by [Ref-10].

32.3 **Safety Claims**

The fundamental safety principle for the SFIS system is that risk to workers and the public during normal operation and during fault and hazard conditions should be kept to a level that is acceptably low and ALARP.

The following sections present the claims that form the basis of this safety case, and the outline arguments which support those claims. The arguments are based upon the concrete cask concept for SFIS, which has been adopted for GDA. During site licensing specific phase the SFIS system will undergo detailed design and more detailed arguments the evidence will be presented.

32.3.1 **Safety Case Claims**

A set of Safety Functional Claims (SFCs) have been derived based on the following five High level Safety Functions (HLSFs) for SFIS, a complete list of the SFCs can be found in Table 1, Section 32.9.

SFIS SFC 1-10.1 (Criticality) – Spent fuel assemblies will be maintained in a sub-critical state during normal operation as well as during and following frequent and infrequent faults and hazards.

SFIS SFC 2-6.1 (Cooling) – Temperature of spent fuel will be maintained within specified limits such that fuel clad does not fail due to overheating during normal operation as well as during and following frequent and infrequent faults and hazards.

- During normal operation and following frequent faults or hazards, there shall be either two or more active lines of cooling, or at least a single passive means of cooling the spent fuel.
- Following infrequent faults and hazards, as a minimum there shall be a single line of active or passive cooling for the spent fuel.

SFIS SFC 4-14.1 (Containment) – Containment of spent fuel will be maintained during normal operations and following frequent and infrequent faults and hazards.

- Multiple containment barriers for spent fuel will be maintained during normal operation and following frequent faults and hazards.
- Following infrequent faults and hazards, there shall be at least a single containment barrier for spent fuel.

SFIS SFC 5-15.1 (Radiological Protection / Shielding) – Shielding and contamination control will be maintained to reduce radiological dose ALARP to operators and the public during normal operation, as well as during and following frequent and infrequent faults and hazards.

SFIS SFC 5-16.1 (Handling & Retrieval) – Handling and retrieval of spent fuel will be maintained during normal operation, and faults and hazards will be shown to be of acceptably low frequency.

- During normal operation and following frequent faults and hazards, the spent fuel and casks shall remain retrievable using the normal handling equipment.
- Handling during normal operation, faults and hazards shall not compromise the claims specified for Containment, Cooling, Criticality and Radiological Protection / Shielding.
- Handling during normal operation, faults and hazards shall not compromise the safety of the existing station.
- Following infrequent faults and hazards there is no claim to use normal handling equipment.[1]

More detailed safety case arguments for the process, systems, faults and hazards are presented in the SFIS BSC [Ref-5].

[1] The strategy for handling with respect to infrequent handling events is to demonstrate that there is no fault escalation (by demonstrating that the canister survives the event, maintaining an effective containment boundary). Therefore there is no claim to recover from such an event using normal handling equipment, noting that the best method of recovering from the event will depend upon the orientation of the dropped item and any damage to lifting attachments that may have occurred. The different options for recovering from such a scenario in required timescales will be discussed and presented during GDA Step 4.

32.4 System Performance Criteria during Normal Operations

The following section describes the key performance criteria for the SFIS system during normal operations.

32.4.1 Criticality

- The fuel basket design within the canister maintains fuel geometry and separates fuel assemblies to maintain criticality claims. The construction of the basket, including material selection will be optimised to minimise criticality through the use of neutron absorbing materials as described in [Ref-12].

32.4.2 Decay Heat Removal

- Whilst in the SFP, the SFP cooling systems provide cooling to the spent fuel to maintain fuel temperatures and to ensure that the fuel clad remains intact [PCSR Chapter 19, Section 19.4].
- SFAIRP the SFIS system will implement passive cooling to maintain fuel clad temperatures below acceptable limits, as defined by [Ref-11].
- Active cooling systems (as described in Section 32.2.2.3) will be provided to prevent boiling during periods where passive cooling cannot be claimed as well as during fault conditions [Ref-7, Section 4.3.1].
- During transfer of the transfer cask to the preparation pit (when the canister lid has not been welded), SFP water contained within the canister will provide a heat sink for the fuel, providing time to carry out operations before the onset of boiling. Active cooling measures will be available to provide cooling to the fuel during this period. Time-to-boil calculations based upon the initial water temperature and decay heat load will be available to show that required operations can be completed before boiling occurs.[2] [Ref-7, Section 5.5.1]
- During canister preparation in the preparation pit, cooling is primarily provided by the CCS [Ref-7, Section 3.3.3]. During drying, the CCS may be turned off such that it does not conflict with the heating function of the drying system. The drying system incorporates temperature controls that will prevent temperature limits of the fuel clad being threatened. The CCS can be reinstated during drying if required. The backup cooling system (described in Section 32.2.2.3) is provided in case the primary CCS fails.
- Passive cooling to the spent fuel clad is claimed once the canister has been sealed and pressurised with an inert gas [Ref-11].

---

[2] Time to boil clocks, which are conservative calculations for the time available before boiling initiates within the canister, are provided to operators during operations. These allow operators to initiate active cooling should operations take longer than anticipated, noting that due to the water inventory within a canister there will still be significant margin between the onset of boiling and fuel clad failure.

- During retrieval and repackaging, claims will be placed upon appropriate cooling systems (which are to be determined during development of the repackaging facility design).

32.4.3 **Containment**

- The spent fuel clad is claimed as the first containment barrier for all normal SFIS operations.[3] No gaseous discharges are envisaged during normal SFIS operations.
- The SGTS filters gaseous effluent from within the secondary containment in fault conditions, effectively acting as a secondary containment barrier while the canister is unsealed within the reactor building (i.e. before the lid is welded). Further detail of the SGTS is provided by [Ref-6].
- Once the canister lid is welded then the canister itself is claimed as the second containment barrier for all further operations.
- Containment features provided by the retrieval and repackaging facility may be claimed as containment barriers during this step (as discussed in 32.3.2.4).

32.4.4 **Radiological Protection / Shielding**

- The SFIS system will be designed such that the Basic Safety Objectives (BSOs) for dose to public and workers are met for all operations and that the design is optimised to reduce dose ALARP [Ref-13].
- Radioactive Substances Regulation – Environmental Principles (REP) have been taken into consideration in order to apply the Best Available Techniques (BAT) for the protection of people and the environment [Ref-18].

---

[3] Handling of damaged fuel (non-intact fuel clad) is not classed as ‘normal’ handling. The strategy for handling such fuel is discussed in Section 32.2.1.

32.4.5 **Handling**

- The RBC and FHM will provide adequate safety features to ensure handling integrity (e.g. interlocks, using high factors of safety in the design of structural components, and the use of double-wire hoists). Further details on these are provided by the BSC for these devices [Ref-7].
- The SFIS specific handling equipment (e.g. lifting yokes) will provide adequate safety features to ensure handling integrity. Further detail on these is provided by the SFIS BSC [Ref-7, Section 4.2.5].
- For non-intact fuel, the handling strategy will be to use specialist equipment to place non-retrievable fuel into a container which reinstates handling capability, for example, a sealed damaged fuel container [Ref-7, Section 3.1.3].

32.5 **Fault Conditions**

This section provides a high-level discussion of the credible SFIS faults, including fault identification processes and the approach to prevent, protect and mitigate against these faults.

The identified faults are based upon the concept level SFIS system. Further faults may be identified and accounted for during later GDA steps and during site licensing as the SFIS design develops.

It is important to consider the interaction between SFIS faults and the generic design for the reactor building. Therefore the fault assessment identifies where risk prevention, protection or mitigation measures are provided by reactor building SSCs to reduce risks ALARP. This ensures design changes are incorporated into the reactor building design and that options are not foreclosed without adequate ALARP optioneering.

32.5.1 **Fault Identification and Definition**

The fault consideration document [Ref-4] describes how SFIS faults were identified and defined. Faults are either derived from existing nuclear power plant operational experience (OPEX), or identified by the hazards which initiate them as shown by Figure 2 below. Examples of OPEX are referenced in [Ref-16][Ref-17].

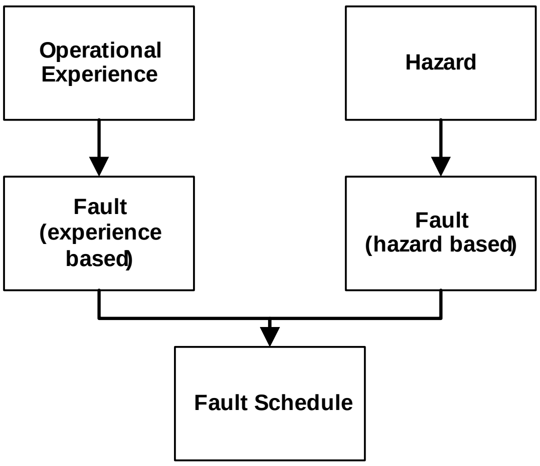

Figure 2 - Fault Identification Sequence

The process outlined in Figure 2 was used to determine a list of credible faults which could occur during each SFIS operational step. These were then categorised into groups from the viewpoint of their effect on the SFIS HLSFs. The identified fault groups were:

- Single Fuel Assembly Handling Faults
- Undetected Fuel Misloading
- Impact Load to Unsealed Canister/Cask
- Impact Load to Sealed Canister/Cask
- SFIS Cooling Faults

- Non-Cask Drop Handling Faults
- Long Term Degradation

Each fault group identified above is discussed in more detail below, including a discussion of the key fault or faults in each group and the approach taken with regards to ensuring HLSFs are maintained in fault conditions.

32.5.2 **Single Fuel Assembly Handling Faults**

Single fuel assembly handling faults are covered within the fuel handling and storage chapter of the PCSR Chapter 19, however a discussion is included here to show the key considerations specific to SFIS operations. The key faults associated with single fuel assembly handling for SFIS are the potential to drop a single element onto spent fuel in the canister, or the potential to damage spent fuel during handling (e.g. through collision with an obstacle).

The approach for these faults is to demonstrate that the FHM design and operating procedures minimise the likelihood of the fault occurring and to demonstrate that the consequences would be minimal noting that the fuel remains in the SFP at all times [Ref-7]. Detailed assessment for these faults is outside the scope of SFIS, and will be described in more detail by the BSC for the SFP [Ref-15] and the Fuel handling Systems and Overhead Crane Systems BSC [Ref-7] and their associated supporting references.

32.5.3 **Undetected Fuel Misload**

The key faults associated with this group are:

- Inadvertently loading fuel with failed fuel clad into the canister, negating claims made on the fuel clad as a containment barrier.
- Inadvertently loading fuel assemblies with a higher than expected decay heat into the canister, potentially breaching heat load limits for the canister.
- Inadvertently loading a new fuel assembly into the canister, potentially breaching the critically limits for the canister.

The approach for these faults is to show that systems and operating procedures are provided to minimise the likelihood of such an event (including clear fuel labelling, the use of automatic handling systems the fuel handling machine and the removal of potential human performance issues SFAIRP) and to show that systems can be incorporated to detect misload before any radiological release is conceded.

32.5.4 **Impact Load to Unsealed Canister/Cask**

These faults consider impact loading to the canister, before the canister lid has been welded. This includes faults where:

- The unsealed canister is dropped or toppled during movement.

- The canister impacts obstacles during movement.

Key faults associated with this group include the potential to drop the unsealed canister onto the operating deck, causing fuel clad failure, or toppling of the unsealed canister resulting in fuel clad failure and loss of water from the canister. In all cases fuel clad failure is assumed resulting in a release into the reactor building.

The approach for these faults is to minimise the requirement to lift items SFAIRP through an ALARP process. Where lifting is required, impact limiters will be incorporated where possible to limit impact loads. The SFIS BSC [Ref-7, Section 5.4] provides claims and arguments that the SFIS SSCs design and operating procedures will minimise the likelihood of the fault occurring (including the removal of potential human performance issues as far as practicable), such that the risk of a release is ALARP [Ref-14]. Additionally the SGTS system will mitigate against any release as described by the SGTS BSC [Ref-6]. Criticality safety margins are maintained in fuel clad failure fault conditions by the canister basket geometry and neutron absorbing material that it is constructed from [Ref-7, Section 5.4.1].

32.5.5 **Impact Load to Sealed Canister/Cask**

These faults consider impact loading to the canister, after the canister lid has been welded. This includes faults where:

- The sealed canister is dropped or toppled during movement.
- The canister impacts obstacles during movement.

The key fault associated with this group is the potential to drop the sealed canister through the equipment hatch (approximately 20 m maximum drop height). In this scenario the fuel clad is expected to fail, but the canister will withstand the drop and will be claimed as a containment barrier [Ref-14].

The approach for these faults is to minimise the requirement to lift items SFAIRP through an ALARP process. Where lifting is required, impact limiters will be incorporated SFAIRP to limit impact loads. The reactor building secondary containment and negative pressure created by the SGTS would mitigate against any off-site release should the canister fail [Ref-6]. Criticality safety margins are maintained in fuel clad failure fault conditions by the canister fuel basket geometry and the neutron absorbing material that it is constructed from [Ref-7, Section 5.4]. The SFIS BSC [Ref-7, Section 5.4] explains that the SFIS SSCs design and operating procedures will minimise the likelihood of the fault occurring (including the removal of potential human performance issues SFAIRP), such that the risk of a release is ALARP.

32.5.6 **SFIS Cooling Faults**

These faults affect the cooling function of the SFIS system and thereby threaten the fuel clad temperature limits.

A key fault in this group relates to failure of the CCS during canister preparation as this is the main period where active cooling to the canister is required. Prolonged loss of cooling to the canister during preparation would in the worst case lead to fuel clad failure, which would lead to a breach of the primary containment barrier and a radiological release into the reactor building (should the canister not be sealed). The SGTS would provide mitigation in terms of the potential off-site release by maintaining a negative pressure differential within the reactor building and filtering out potential activity [Ref-6].

The key protection against this fault is the provision of a number of separate and diverse backup canister cooling systems which would be initiated in the event of the CCS failure, thereby restoring the cooling function, preventing fuel clad failure [Ref-7, Section 5.5].

32.5.7 **Non-cask Drop Handling Faults**

These faults include all other handling faults, including operator handling error which do not result in dropped or toppled casks. Key faults in this group are:

- Hangman's drop during handling.
- Damage to fuel during lid placement (misplacement or dropped lid).
- Dropping items onto the canister (sealed or unsealed).
- Exposure of operators to an unshielded canister (including inadvertent removal of the canister lid).

The key protection against these faults is the provision of suitable equipment to prevent mishandling (including the removal of potential human performance issues SFAIRP) or dropped items SFAIRP and design integrity to ensure that consequences are limited should the fault occur. Controls on handling operations will also be specified to reduce the likelihood of the fault occurring.

32.5.8 **Long Term Degradation**

These faults consider degradation of materials over time. Material degradation of the canister, concrete overpack and fuel clad could affect the radiation dose protection and radiological containment claims, while degradation of the canister basket could threaten sub-criticality claims.

The key faults associated with this group are:

- Degradation of the fuel clad during interim storage, potentially causing fuel clad failure causing a release into the canister.
- Degradation of the canister pressure boundary during interim storage which would allow the release of radioactivity from within the canister and reduce cooling to fuel in the canister, potentially causing fuel clad failure.
- Degradation of the concrete overpack, reducing the shielding provided by the overpack, or potentially degrading the cooling capacity of the overpack.

The approach for these faults is to demonstrate that material selection, equipment design, operating procedures, inspection requirements and environmental conditions are optimised such that the risk of significant degradation is acceptably low and ALARP.

32.6 Hazards

This section provides a high-level discussion of the key hazards related to the SFIS system. Hazards are grouped into two main categories: internal and external hazards.

This PCSR provides a high level identification and description of the main effects on the SFIS system, and an overview of how the nuclear safety claims are maintained is provided for each key hazard. The SFIS BSC provides the detailed arguments for each hazard [Ref-7, Section 6].

The hazard assessments shall ensure any hazards created by the SFIS systems and components do not adversely affect the performance of station safety critical equipment.

An assessment of the unmitigated consequences for the key hazards will be completed in GDA Step 4 following the production of further analysis.

32.6.1 Internal Hazards

Internal hazards are events which could affect nuclear safety that originate within the site boundary. Independent internal hazards are presented in this PCSR chapter, the effect of combined hazards has been considered and is presented by the internal hazards supporting document [Ref-3] and Attachment 1 to that document.

32.6.1.1 Internal Hazard Identification and Definition

Internal hazards for the UK ABWR generic design are specified in PCSR Chapter 7. The following additional internal hazards have been identified which are specific to the SFIS system:

- Impact and collision (defined in Section 32.6.1.8).
- Gas release (defined in Section 32.6.1.9).

The internal hazards supporting document [Ref-3] outlines how SFIS internal hazards are identified and defined. This reference considers the identification of the internal hazard source, its frequency and magnitude, and provides the internal hazards schedule.

It is noted that internal hazards related to the SFIS system may originate from three areas within the site boundary. Hazard sources for the following areas have been assessed:

- Reactor building large component entrance [Ref-8].
- Reactor building operating deck [Ref-8].
- Outside of the reactor building.

32.6.1.2 Fire

A fire has the potential to disable nuclear safety critical systems during an SFIS operation. The safety critical SFIS systems that are threatened by a fire are:

- Canister cooling system (threatening fuel clad temperature claims)

The key protection provided against the fire hazards to the CCS are:

- Fire prevention (e.g. limits on combustible materials and electrical isolation points) and mitigation (fire hydrants) such that CCS operability is maintained.
- A backup canister cooling system will be provided on a separate skid, in a segregated location away from the CCS, preventing damage to both systems caused by the same event.

32.6.1.3 **Internal Flooding**

Internal flooding has the potential to affect the following nuclear safety critical SFIS systems:

- The CCS may be disabled.
- Sub-criticality maintenance may be affected by moderation provided by the introduction of water.
- Cask drop or topple may be caused.

The key methods of protection provided against internal flooding to the above systems are:

- Minimising potential hazard sources, and liquid inventories within the operating deck area.
- A backup canister cooling system will be provided on a separate skid, in a separate location away from the CCS, preventing damage to both systems caused by the same event.
- Sub-criticality assessments and related design features assume that the canister will be filled with demineralised water, therefore flooding of fuel has been accounted for.

32.6.1.4 **Pipe whip and Jet Impact**

Pipe whip and jet impact may disable the following nuclear safety critical SFIS systems:

- The CCS may be disabled.

The key protection provided against pipe whip and jet impact to the CCS is:

- Minimising hazard sources in the vicinity of the operating deck.
- A backup canister cooling system will be provided on a separate skid, in a segregated location away from the CCS, preventing damage to both systems caused by the same event.

32.6.1.5 **Internal Missile and Blast**

Internal missile and blast may disable the following nuclear safety critical SFIS systems:

- The CCS may be disabled.
- Cask drop or topple may be caused.

The key methods of protection provided against internal missile and blast to the CCS are:

- Minimising hazard sources in the vicinity of the operating deck.

- A backup canister cooling system will be provided on a separate skid, in a segregated location away from the CCS, preventing damage to both systems caused by the same event.

32.6.1.6 **Dropped and Collapsed Loads**

For the SFIS system, dropped loads involving spent fuel, or loads dropped directly onto spent fuel are considered in Section 32.5, therefore this section does not consider these again.

The following scenarios, not involving spent fuel, have been identified in which a dropped or collapsed load could threaten nuclear safety:

1. Dropping SFIS SSCs onto non-SFIS plant or structures.
2. Dropping SFIS SSCs onto other SFIS SSCs.
3. Dropping non-SFIS loads onto SFIS SSCs.

For the above scenarios the corresponding strategies to protect against a threat to nuclear safety are:

1. Removing the requirement to lift equipment SFAIRP. Where lifts are required, strict controls (crane protection systems as well as administrative controls) will be implemented to prevent lifting of SFIS SSCs above nuclear significant plant. It will be demonstrated that dropped loads considered as internal hazards will not be more significant than those already considered as faults in Section 32.5, and are therefore taken into account.

2. The CCS and canister may be affected by dropped SFIS SSCs. It will be demonstrated that requirements to lift equipment have been removed SFAIRP. Where lifts are required it will be demonstrated that the canister safety functions will not be affected by a dropped load. A backup canister cooling system is provided to reinstate cooling should the CCS be disabled, this will be stored in a location where it will not be threatened by the same event as the CCS.

3. Removing the requirement to lift equipment SFAIRP. Where lifts are required, controls will be in place to prevent lifting of heavy objects in the vicinity of the SFIS SSCs during an SFIS operation.

32.6.1.7 **Electromagnetic Interference (EMI) / Radio Frequency Interference (RFI)**

Electrical equipment will be qualified to applicable modern standards. This will ensure that electrical equipment will not emit EMI/RFI that could interfere with adjacent equipment and that equipment has an acceptable immunity to wide band EMI/RFI.

32.6.1.8 **Impact and Collision**

Impact and collision of SFIS systems with other SFIS SSCs, and reactor plant or structures could affect the related nuclear safety functions.

The key protection against impact and collision event is removing the requirement to handle equipment SFAIRP. Where handling is still required it will be demonstrated that automatic protection systems and administrative controls will be implemented to prevent collisions occurring. A backup canister cooling system is provided to reinstate cooling in the event of CCS failure due to impact and collision hazards, this will be stored in a location where it will not be threatened by the same event as the CCS.

32.6.1.9 **Gas Release**

The SFIS BSC reviews credible sources of gas that could threaten claims placed on SFIS SSCs during operation. This has shown that there are no sources of gas that would threaten SFIS key safety functions within the generic station design [Ref-7, Section 6.2.8].

The SFIS system is likely to require supplies of pressurised gas to enable welding of the canister lid as well as backfilling the canister with an inert gas after sealing. The threat to adjacent systems and operators due to failure of the SFIS system and a release of this gas is judged to not constitute a significant hazard due to the limited gas inventory associated with these systems and the relatively large volume of the buildings that operations are carried out in.

32.6.2 **External Hazards**

External hazards are those events which could affect nuclear safety and originate from outside the site boundary.

32.6.2.1 **External Hazard Identification and Definition**

External hazards for the UK ABWR generic design are specified in PCSR Chapter 6. The following additional external hazards which have been identified which are specific to the SFIS system:

- Land and Air Based Biological fouling (defined in Section 32.6.2.16).

The external hazards supporting document outlines how external hazards were identified and defined [Ref-2]. This report considers the identification of the external hazard source and provides the external hazards schedule.

It is noted that external hazards may affect the SFIS system and SSCs at three stages of the SFIS process:

- Inside the reactor building.
- Transfer from the reactor building to the SFIS facility.
- During interim storage.

32.6.2.2 **Extreme Ambient Temperatures**

Extreme ambient temperatures may affect the following SFIS nuclear safety functions and equipment:

- Passive cooling during transfer to SFIS facility and interim storage.
- SFIS SSCs integrity and function.

The main protections against extremes of temperature are the following:

- The manufacturer for the SFIS components will rate their equipment against certain extreme (high and low) temperature conditions.
- SFIS systems will be protected by the reactor building and SFIS facility building whilst operating inside it.
- SFIS operations may be postponed during periods of extreme ambient temperatures.

32.6.2.3 **Extreme Wind**

The extreme wind event includes both wind loading and toppling due to wind generated missile.

The main protections against extreme wind are:

- The reactor building will be qualified against extreme wind and will protect SFIS systems within it.
- Administrative controls will prohibit SFIS transfer operations from the reactor building to SFIS facility if extreme wind is occurring or forecast.
- The concrete overpack will protect the canister during interim storage.

32.6.2.4 **Rainfall and Ice**

The main protections against rainfall and ice are:

- The reactor building and SFIS facility building will be designed against extreme rainfall or ice and therefore protect SFIS operations carried out within them.
- SFIS transport operations will not be conducted outside the reactor buildings during severe adverse weather conditions.

32.6.2.5 **Drought**

Significant changes in water table can affect the stability of the ground on site, either at the reactor building, the transport route or at the interim storage location.

The main protections provided against drought are:

- The reactor building will be designed against the drought hazard and will protect SFIS activities within the reactor building.
- A dropped or toppled cask event due to sudden collapse has been covered by the consideration of faults in Section 32.5.
- The SFIS building slab will be designed to consider credible drought hazards.

32.6.2.6 Snow

The main protections against the snow hazard are:

- The reactor building and SFIS facility building will be designed against the snow hazard and therefore protect SFIS operations carried out within them.
- SFIS transport operations will not be conducted outside the reactor buildings during severe adverse weather conditions (or if forecast).

32.6.2.7 Electromagnetic Interference (EMI) including Lightning

The main external hazard sources for EMI are:

- Electrical interference from electrical pylons or off site electrical equipment; and
- Lightning.

The main protections against the EMI hazard are:

- The reactor building and SFIS facility building will provide protection to SFIS SSCs operating within them.
- SFIS SSCs will meet required standards to protect against EMI/RFI.
- SFIS transfer operations outside the reactor building will not take place if there is a high threat of lightning.

32.6.2.8 Sea or River Water Temperature

Operation of the SFIS system will not be threatened by extreme sea or river water temperatures.

32.6.2.9 External Flooding

The main protections against external flooding are:

- The reactor building will be protected against credible external flooding events and will provide protection to SFIS operations within it.
- During transfer outside the reactor building drop and topple protection is provided and the consequences of such events are accounted for by assessments made for faults in Section 32.5.
- The external flooding hazard will be accounted for during detailed design of the concrete overpack.

32.6.2.10 Seismic

The main protections against the seismic hazard are:

- The reactor building and SFIS facility slab will be seismically qualified.
- SFIS and related lifting equipment will be seismically qualified to the required standard

- Should seismic activity cause SFIS facility collapse, the fuel will be protected by the substantial structure of the concrete overpack. The canister will remain intact and therefore the key safety functions will not be threatened. Some blockage of cooling vents may occur, however, both the fuel clad and the canister itself would need to be breached before a release occurs. There will be significant time available to operators to remove debris and cask vent blockages to reinstate passive cooling to concrete overpacks in the SFIS facility.

32.6.2.11 **Loss of Off Site Power**

The only nuclear safety function that could be threatened by Loss Of Off-site Power (LOOP) is active cooling provided by the CCS, noting that lifting equipment would be designed to fail in a safe and recoverable manner following a LOOP.

The main protections provided against this hazard are:

- The CCS will be provided with an essential power supply (with adequate redundancy) that will remain available after any loss of grid connection event.
- Active cooling will be available during lifting operations that occur before sealing.

32.6.2.12 **Aircraft Impact**

The main protections against the aircraft impact hazard are:

- The reactor building is designed to withstand the effects of aircraft impact and will protect SFIS activities within it.
- The transfer cask and concrete overpack will be designed to withstand a design basis aircraft impact during detailed design.

32.6.2.13 **External Fire**

The main protections against the external fire hazard are:

- The reactor building will be protected against the off-site fire hazard, therefore SFIS operations within will also be protected.
- SFIS transport operations will not occur while fire threatens the site. The consequences of a fire during transport leading to a dropped cask are already considered as a dropped cask fault (Section 32.5.5).
- Strict controls and limitations on combustible materials in the SFIS building will prevent a sustained significant fire.

32.6.2.14 **External Missile**

The main protections against the external missile hazard are:

- The reactor building will be qualified against external missiles and will protect SFIS operations within it.
- The concrete overpack will be designed against external missile strike.

32.6.2.15 **External Explosion**

The main protections against the external explosion hazard are:

- The reactor building will be qualified against external explosion and will protect SFIS operations within it.
- The concrete overpack provides protection to the canister.

32.6.2.16 **Land and Air-based Biological Fouling**

It is possible for concrete overpack vents to become blocked due to biological fouling (such causes include nesting animals or accumulation of plant debris).

The main protections against this are:

- Vent screens on the concrete overpack to prevent blockages.
- Regular inspections will be conducted to ensure that vents are not blocked.
- Electronic temperature monitors may be used to identify blocked vents (to be considered during site licensing).

32.7 Demonstration of ALARP and Optioneering Process

A fundamental principle of the GDA process is to demonstrate that the generic station design reduces risk ALARP. This includes consideration of risks associated with SFIS and the incorporation of changes to the generic design to ensure risks are ALARP. This section therefore identifies the process adopted to ensure this principle is met.

32.7.1 Demonstration of Good Practice

The UK ABWR concept design incorporates good practice in terms of:

- Incorporation of design features that are consistent with UK legislation (e.g. nuclear lifting requirements).
- Incorporation of good practice identified by the Western European Nuclear Regulators Association (WENRA) and the International Atomic Energy Agency (IAEA).
- Good practice employed by operating nuclear power stations in the UK and elsewhere.

Further details regarding the incorporation of good practice are provided by the SFIS BSC [Ref-5]. Details regarding good practice incorporated into the FHM and RBC are provided by the BSC related to those systems [Ref-7] and its associated references.

32.7.2 UK ABWR Design ALARP Optioneering

A process of ALARP optioneering has been conducted to consider the potential different ways of managing nuclear safety risk associated with SFIS operations, as reported by [Ref-9]. For GDA Step 3 this has focused on the route taken by the transfer cask into, and out of the reactor building. The handling of the transfer cask is judged to contribute the greatest risk during SFIS operations.

Options were generated based on a range of considerations including, but not limited to:

- Minimising the requirement to handle SFIS equipment.
- Reducing required lift heights SFAIRP.
- Reducing operator interaction and operational complexity (Human Factors).
- Reducing conventional safety risk ALARP.

Consideration was also given to future dry storage technology advancements with a view to non-foreclosure of potential developments. The output ALARP option identified in [Ref-9], reduces overall station risks ALARP and has therefore been adopted. This preferred option, and its impact on risk, will be assessed in greater detail during GDA Step 4.

32.7.3 Conventional Safety

During the ALARP optioneering process conventional and industrial safety has been used as a factor in the scoring of options to reduce risks ALARP. This will ensure that the preferred option presents no significant conventional safety risks at odds with international SFIS OPEX and good practice. Further work is required to identify and reduce potential risks ALARP during GDA Step 4. Compliance with relevant UK safety regulations will be demonstrated during site licensing.

32.8 Compliance with Regulations

This section provides a provisional list of the regulations and legislation with which the SFIS for UK ABWR will comply. Confirmation of all regulations, and demonstrated compliance with regulations will not be available until detailed design for SFIS, during site specific design phase.

The SFIS system will be fully compliant with relevant UK and international legislation including (but not limited to):

- ONR, Nuclear Installations Act 1965 (as amended) (NIA) relating to the licensing and inspection of nuclear installations.
- HSE, Ionising Radiation Regulations 1999 (IRR).
- HSE, Management of Health and Safety at Work Regulations 1999.
- ONR, Management of Radioactive Materials And Radioactive Waste On Nuclear Licensed Sites (ONR Guide, May 2013).
- HSE, Provision and Use of Work Equipment Regulations 1998 (PUWER).
- HSE, Lifting Operations and Lifting Equipment Regulations 1998 (LOLER).
- HSE, Pressure Systems Safety Regulations 2000 (PSSR).
- PER, Pressure Equipment Directive 1999.
- HSE, Control of Major Accident Hazards Regulations 2015 (as amended) (COMAH).
- EA, Environment Agency Regulations.
- ONR, Civil Nuclear Security (CNS) Regulations.
- ASME, American Society of Mechanical Engineers BPVC Section III - Rules for Construction of Nuclear Facility Components.
- IAEA, International Atomic Energy Agency - Regulations for the Safe Transport of Radioactive Material, No. SSR-6, 2012.

32.9 **Claims and Link to High Level Safety Functions**

The list of claims in this chapter is shown in Table 1 below. A short description on the application of High Level Safety Functions in the development of the claims, arguments and evidence is provided in GDA PCSR Chapter 1 (GA91-9101-0101-01000 (XE-GD-0214)). For GDA Step 3 it is recognised that there are a number of Safety Properties Claims (SPC) relating to SFIS, these will be detailed during GDA step 4.

Table 1 - List of Safety Functional Claims

Claim	**Operational Condition**	**Number**	**Argument**
SFIS SFC 1-10.1 Spent fuel assemblies will be maintained in a sub-critical state during normal operation as well as during and following frequent and infrequent faults and hazards. (Criticality) During the cask drop accident, the basket configuration should be maintained to prevent from sub-criticality.	Normal	SFIS SFC 1-10.1.1	The fuel basket will maintain sub-criticality during normal operations
	Fault	SFIS SFC 1-10.1.2	Criticality margin will be maintained in all fault conditions
		SFIS SFC 1-10.1.3	The fuel basket will maintain sub-criticality during the following credible drop faults: 1. Drop and/or topple of an unsealed canister 2. Drop and/or topple of a sealed canister
		SFIS SFC 1-10.1.4	Moderator faults (i.e. the introduction of credible moderating sources, such as the CCS coolant) will not threaten criticality limits. (includes reverse process)
	Hazard	SFIS SFC 1-10.1.5	Criticality will be maintained in all hazard conditions

SFIS SFC 2-6.1 Temperature of spent fuel will be maintained within specified limits such that fuel clad does not fail due to overheating during normal operation as well as during and following frequent and infrequent faults and hazards. (Cooling)	Normal	SFIS SFC 2-6.1.1	During normal operation and following frequent faults or hazards, there shall be either two active lines of cooling or a single passive means of cooling the spent fuel.
	Fault	SFIS SFC 2-6.1.2	Cooling will be maintained in all fault conditions
		SFIS SFC 2-6.1.3	Fuel clad temperatures will be maintained below acceptable limits during all credible fault scenarios at all stages of the SFIS process
	Hazard	SFIS SFC 2-6.1.4	Cooling will be maintained in all hazard conditions
SFIS SFC 4-14.1 Containment of spent fuel will be maintained during normal operations and following frequent and infrequent faults and hazards. (Containment)	Normal	SFIS SFC 4-14.1.1	During unsealed canister operations and canister preparation activities, the spent fuel clad and reactor building SGTS provide two containment barriers

		SFIS SFC 4-14.1.2	After canister sealing the spent fuel clad and canister provide two containment barriers
		SFIS SFC 4-14.1.3	The canister and spent fuel clad provide two containment barriers throughout the interim storage period
		SFIS SFC 4-14.1.4	Two containment barriers will be maintained when handling damaged fuel (failed fuel clad)
		SFIS SFC 4-14.1.5	During repackaging activities containment will be provided by the spent fuel clad and repackaging facility containment features (e.g. similar system to SGTS)
	Fault	SFIS SFC 4-14.1.6	Fuel clad integrity will be maintained (small drops and impacts, including canister toppling)

		SFIS SFC 4-14.1.7	Canister containment will be maintained in all fault conditions, including: Containment provided by the canister will be maintained in the following credible drop faults: 1. Dropped / toppled transfer cask 2. Dropped canister during transfer cast to concrete overpack transfer. 3. Dropped / toppled concrete overpack (Note: canister is only claimed as containment barrier once it has been sealed) Containment provided by the canister will be maintained in the following credible scenarios: 1. Canister over temperature 2. Canister over pressurisation
	Hazard	SFIS SFC 4-14.1.8	Containment will be maintained in all hazard conditions

SFIS SFC 5-15.1 Shielding and contamination control will be maintained to operators and the public during normal operation as well as during and following frequent and infrequent faults and hazards. (Radiological Protection / Shielding)	Normal	SFIS SFC 5-15.1.1	Doses to the public and to workers will be maintained below acceptable levels and ALARP during normal operations.
	Fault	SFIS SFC 5-15.1.2	Doses to workers and the public will be maintained below acceptable levels in all fault conditions
		SFIS SFC 5-15.1.3	Doses to the public and to workers will be maintained below acceptable levels and ALARP during fault conditions.
	Hazard	SFIS SFC 5-15.1.4	Radiation Protection will be maintained in all hazard conditions
SFIS SFC 5-16.1 Handling and retrieval of spent fuel will be maintained during normal operation, and faults and hazards will be shown to be of acceptably low frequency. (Handling & Retrieval)	Normal	SFIS SFC 5-16.1.1	During normal operation, the spent fuel and casks shall remain retrievable using the standard handling equipment
		SFIS SFC 5-16.1.2	Handling during normal operations shall not compromise claims specified for containment, criticality, radiological protection/shielding or cooling
		SFIS SFC 5-16.1.3	Handling of SFIS equipment shall not compromise the safety of the station

		SFIS SFC 5-16.1.4	The route through which fuel is moved reduces risks ALARP
		SFIS SFC 5-16.1.5	The canister and concrete overpack shall remain retrievable at all times during interim storage
	Fault	SFIS SFC 5-16.1.6	Canister containment will be maintained in all fault conditions (includes reverse process)
		SFIS SFC 5-16.1.7	SFIS equipment shall remain retrievable in frequent fault conditions
		SFIS SFC 5-16.1.8	In fault conditions, the SFIS SSCs shall not compromise claims specified for Containment, Criticality, Radiation Protection/Shielding or Cooling.
		SFIS SFC 5-16.1.9	Dropped SFIS SSCs will not threaten station structures
	Hazard	SFIS SFC 5-16.1.10	Handling and retrievability will be maintained in all hazard conditions

32.10 **References**

[Ref-1] Hitachi-GE Nuclear Energy, Ltd., “High Level Optioneering on Spent Fuel Interim Storage”, GA91-9201-0003-00458(FRE-GD-0019), Rev 0, March 2015.

[Ref-2] Hitachi-GE Nuclear Energy, Ltd., “Preliminary external hazard consideration for SFIS”, GA91-9201-0003-00527(FRE-GD-0056), Rev 0, March 2015.

[Ref-3] Hitachi-GE Nuclear Energy, Ltd., “Preliminary internal hazard consideration for SFIS”, GA91-9201-0003-00528(FRE-GD-0055), Rev 0, March 2015.

[Ref-4] Hitachi-GE Nuclear Energy, Ltd., “Preliminary fault consideration for SFIS”, GA91-9201-0003-00526(FRE-GD-0057), Rev 1, July 2015.

[Ref-5] Hitachi-GE Nuclear Energy, Ltd., “Preliminary Basis of Safety Case on Spent Fuel Interim Storage”, GA91-9201-0003-00540(FRE-GD-0042), Rev 1, July 2015.

[Ref-6] Hitachi-GE Nuclear Energy, Ltd., “Basis of Safety Case on Standby Gas Treatment System”, GA91-9201-0002-00019(SE-GD-0043), Rev 1, April 2015.

[Ref-7] Hitachi-GE Nuclear Energy, Ltd., “Basis of Safety Cases on Fuel Handling Systems and Overhead Crane Systems”, GA91-9201-0002-00056(M1D-UK-0006), Rev 0, January 2015.

[Ref-8] Hitachi-GE Nuclear Energy, Ltd., “Room Data Sheets for Internal Hazards Assessment”, GA91-9201-0003-00427(BKE-GD-0020), Rev.1, April 2015.

[Ref-9] Hitachi-GE Nuclear Energy, Ltd., “Spent Fuel Interim Storage Optioneering for Spent Fuel Route from Spent Fuel Pool to Outside of Reactor Building”, GA91-9201-0003-00689(FRE-GD-0080), Rev 0, July 2015,

[Ref-10] Hitachi-GE Nuclear Energy, Ltd., “Preliminary Evaluation for EMIT of SFIS”, GA91-9201-0003-00539(FRE-GD-0062), Rev 0, May 2015.

[Ref-11] Hitachi-GE Nuclear Energy, Ltd., “Preliminary Evaluation for Heat Removal of Loaded Cask in Normal Operation”, GA91-9201-0003-00525(FRE-GD-0054), Rev 0, March 2015.

[Ref-12] Hitachi-GE Nuclear Energy, Ltd., “Preliminary Evaluation for Subcriticality Safety”, GA91-9201-0003-00501(FRE-GD-0053), Rev 1, March 2015.

[Ref-13] Hitachi-GE Nuclear Energy, Ltd., “Public and Worker Dose Evaluation, Zoning and Radiation Shielding of SFIS System during Normal Operation (Methodology and Example) ”, GA91-9201-0003-00632(HE-GD-5105), Rev 0, March 2015

[Ref-14] Hitachi-GE Nuclear Energy, Ltd., “Canister Integrity Evaluation for Cask Drop”, GA91-9201-0003-00436(FRE-GD-0041), Rev 1, Jun 2015.

[Ref-15] Hitachi-GE Nuclear Energy, Ltd., “Basis of Safety Cases on Spent Fuel Storage Pool and Fuel Pool Cooling, Clean-up and Makeup Systems”, GA91-9201-0002-00055(SE-GD-0194), Rev 0, February 2015.

[Ref-16] US NRC, Information Notice No. 97-51: “Problems Experienced with Loading and Unloading Spent Nuclear Fuel Storage and Transportation Casks”, 1997.

[Ref-17] IAEA, TECDOC 1725 “Spent Fuel Storage Operation - Lessons Learned”, 2013

[Ref-18] Hitachi-GE Nuclear Energy, Ltd., "Generic Environmental Permit Chapter 5: Demonstration of BAT", GA91-9901-0023-00001(XE-GD-0097), Rev.D, November 2014