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UK ABWR Generic Design Assessment

Generic PCSR Chapter 19 : Fuel Storage and Handling

Hitachi-GE Nuclear Energy, Ltd.

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Executive Summary

This mechanical systems chapter describes the safety case for the United Kingdom (UK) Advanced Boiling Water Reactor (ABWR) Fuel Storage and Handling systems. It lists the high level Safety Functional Claims (SFCs) that are made on the systems described in this chapter, together with the Safety Properties Claims (SPCs) that enable the process for demonstrating compliance with the Nuclear Safety and Environmental Design Principles (NSEDPs).

This chapter describes the Fuel Route Safety Case from the introduction of new fuel in transfer containers into the Reactor Building to the exit of spent fuel in Casks from the Reactor Building. It also describes the safety case for handling operations with either the Reactor Building Overhead Crane (RBC) or Fuel Handling Machine (FHM) that do not specifically involve handling of fuel, such as control rods, neutron monitors or Reactor Internal Pump components.

The information provided includes: system design; functionality in normal operation and during faults; safety categorisation and classification; important support systems; safety case Assumptions, Limits and Conditions for Operation (LCOs); resistance to hazards; and compliance with the principle that risks are as low as reasonably practicable (ALARP).

The overall Pre-Construction Safety Report (PCSR) justification that the UK ABWR is safe and satisfies the ALARP principle is underpinned by hazards assessments, design basis analysis, probabilistic safety analysis, beyond design basis analysis and human factors analysis (described in PCSR Chapters 6, 7 and 24 to 27), which demonstrate that the design of the systems covered by this chapter are fault tolerant. These hazards and analysis chapters specify the high level safety functional claims but do not specify requirements for design parameters on individual fuel route systems. Instead they apply analysis conditions and assumptions that are based on, and fully consistent with, the design information and safety claims for the fuel route systems that are presented in this chapter, in order to substantiate those claims.

The designs of all of the Safety Class 1 and 2 sub-systems and components within the fuel storage and handling systems are well advanced for GDA, being largely based on proven technology from the Japanese Advanced Boiling Water Reactor (J-ABWR) reference design. Additional risk reduction measures have been introduced (with reference to the J-ABWR design) in response to safety assessments undertaken in GDA. These include modifications to the FHM and RBC and their attachments to prevent heavy non-fuel items being lifted over spent fuel or to prevent fuel elements being dropped. In addition, the Cask Stand in the Cask Pit permits the welding of the canister lid and drying of the canister in the Cask Pit and therefore eliminates risks associated with unsealed canister handling to the Preparation Pit. Impact Limiters have been introduced to provide passive means of protection to the sealed canister in the event of a dropped load.

The ALARP assessment has specifically considered options to reduce the risks associated with lowering the Cask from the Operating Deck to the Truck Bay. The use of the RBC in conjunction with an Impact Limiter has been demonstrated to be reasonably practicable.

This chapter demonstrates that the risks associated with the design and operation of the fuel route systems for the UK ABWR are ALARP, or capable of being reduced ALARP. It is acknowledged that further work will be required post-GDA to develop the design and fully incorporate site specific aspects. This work will be the responsibility of any future licensee.

19.1 Introduction

This Chapter provides the description and justification of the plant and safety equipment used to store and handle Fuel Assemblies, non-Fuel Assemblies, and reactor components which need to be moved during refuelling outages. As such, this Chapter outlines the scope of the UK ABWR Fuel Storage and Handling, also termed Fuel Route.

19.1.1 Background

The fuel route includes four major operation processes:

- Outage Preparation,
- Outages,
- Spent Fuel Storage, and
- Spent Fuel Export (SFE).

The fuel route processes can be summarised as follows (these are further discussed in Section 19.3):

New fuel bundles are brought into the Reactor Building (R/B) in transfer containers. These are subsequently moved to the Operating Deck using the RBC.

The fuel bundles are unpacked and inspected at the New Fuel Inspection Stand (NFIS). The Fuel Assembly is subsequently constructed by placing a fuel channel on each fuel bundle in the NFIS. The Fuel Preparation Machine (FPM) lowers the Fuel Assemblies into the Spent Fuel Storage Pool (SFP). Prior to being loaded into the reactor core, these new Fuel Assemblies are transported and stored directly in a specific area of the SFP using the FHM.

During refuelling operations the FHM is used to remove spent fuel from the core and transport them to the SFP. It is also used to shuffle some partially used fuel to new positions and to move new fuel elements to predetermined positions in the core.

Spent Fuel Assemblies are removed from the core and stored in racks in the SFP. The Fuel Pool Cooling and Clean-up System (FPC) is used to remove decay heat from the SFP and maintain the water quality in the pool. Failed fuel, referred in the GE14 Fuel Mechanical Design Report [Ref-1] is handled and stored in the same manner as normal fuel. The fuel route is capable of handling and storing damaged fuel, although a specific risk assessment may identify additional measures , such as special handling equipment, containers and/or casks. It is assumed during GDA that any damaged fuel identified during reactor operation will be stored within the SFP until the end of generation. It should be noted that the strategy for identification, handling and storage of damaged fuel at a UK ABWR site will depend on the number and nature of damaged fuel assemblies generated during site operation. Therefore, it is not possible to determine the exact strategy that will be deployed at this stage of the GDA process. Potential solutions for handling and storage of damaged fuel assemblies are common in the industry and will be developed further by the future licensee, using industry-wide good practice.

The future licensee is responsible for developing their own management system based on their requirements, using fuel bundle ID and any target location.

After storage in the SFP for approximately 10 years, spent Fuel Assemblies are removed from the R/B to be stored in a Spent Fuel Interim Storage (SFIS) Facility.

The spent Fuel Assemblies are deposited with the FHM into an open Canister which sits inside a Transfer Cask. Once the Canister lid has been sealed, the Cask lid installed, and the Transfer Cask has been further decontaminated, the RBC is used to transport the Transfer Cask to the Truck Bay. The Transfer Cask is then ready for transfer to the SFIS.

The concept design of the SFIS is covered in Chapter 32: Spent Fuel Interim Storage.

The SFE process can be reversed, it should be required, in order to return spent fuel to the spent fuel storage racks. This would not be a normal operation, but would be required in the event of specific faults (such as in the event of handling faults, or canister degradation during storage). These reverse operations have been assessed to be both practically feasible and adequately safe.

The scope of the Fuel Route also covers the preparatory work for fuel handling performed during an outage. These include the SFP gate opening/closing, pool flooding, handling of reactor components, such as the Dryer and Separator, and the handling of other non-fuel items such as Control Rods (CRs) and Reactor Internal Pump (RIP) components.

19.1.2 Document Structure

The details of design for both new fuel and spent fuel storage and related fuel handling equipment are described in the following Sections. Sections 19.3 to 19.13 provide a description of the relevant safety claims, followed by a brief description of the relevant Systems, Structures and Components (SSCs) and their functions, and finally a description of the safety provisions.

- Section 19.3 provides a description of the 4 major processes associated with the UK ABWR's Fuel Route.
- Section 19.4 describes the NFIS and its functions, followed by a description of the relevant safety claims and provisions.
- Section 19.5 describes the FPM and its functions, followed by a description of the relevant safety claims and provisions.
- Section 19.6 describes the FHM and its functions, followed by a description of the relevant safety claims and provisions.
- Section 19.7 describes the RBC and its functions, followed by a description of the relevant safety claims and provisions.
- Section 19.8 describes the Spent Fuel Storage Facility (SFS) and its functions, followed by a description of the relevant safety claims and provisions.
- Section 19.9 describes the Fuel Pool Cooling, Clean-up and Makeup Systems (FPCMs) and its functions, followed by a description of the relevant safety claims and provisions.
- Section 19.10 describes the SFE and its functions, followed by a description of the relevant safety claims and provisions.
- Section 19.11 presents the safety functions and claims applicable to the Fuel Route.
- Section 19.12 summarises the Assumptions, Limits and Conditions for Operation that are specified in detail in the Basis of Safety Case (BSC) documents for the SSCs in the scope of this Chapter.
- Section 19.13 provides a summary of the ALARP justification.

Other relevant information is captured in Appendices as follows:

- Appendix A –SFCs Tables for the systems in Chapter 19.
  The claim tree for the SSCs in this chapter shown in Appendix A is a simplified version of the detailed claim tree contained in the BSC or Topic Report (TR) of the related SSC,
- Appendix B –SPCs Tables for Mechanical SSCs and the systems in Chapter 19.
  The nine generic SPCs for all Mechanical Engineering (ME) SSCs that define the design requirements applicable to the SSCs scope of this chapter are presented in Appendix B tables as ME SPCs. These tables of SPCs were derived for the ME SSCs based on the 'guide word' approach specified in Hitachi-GE's Safety Case Development Manual (SCDM) [Ref-21]. Having derived the SPCs, a mapping exercise was undertaken to ensure that the SPCs fully cover the relevant NSEDPs applicable to the ME area. More information on the development of SPCs, and the coverage, at the more detailed level in the safety case, to demonstrate full compliance with the relevant NSDEPs is presented in Chapter 5: General Design Aspects, Section 5.3 and the Topic Report on Safety Requirements for Mechanical SSCs [Ref-19]. Fulfilment of the requirements from the SPCs is justified in the BSC or Topic Report of the related SSC as well as the Topic Report on Mechanical SSCs Architecture [Ref-20], and

- Appendix C – Document map for Level 2 documents that support this Chapter.
  The document map showing Level 2 documents that support this chapter is provided in Appendix C.

This Chapter is supported by a set of reference documents, primarily BSCs and TRs. The BSCs describe the systems within the scope of Chapter 19, explaining where the arguments and evidence that substantiate the safety claims for those systems are presented.

This main links of this Chapter with other Generic Design Assessment (GDA) Pre-Construction Safety Report (PCSR) chapters are as follows:

- For generic links to GEP, and CSA documentation, please refer to Chapter 1: Introduction. For GEP, where specific references are required, e.g. in Radioactive Waste Management, Radiation Protection, Decommissioning, these are included in the specific sections within the relevant chapter,
- The general principles for the identification of Assumptions, LCOs are described in Generic PCSR Chapter 4: Safety Management throughout Plant Lifecycle. In addition, general requirements related to conventional safety aspects are also described in Chapter 4,
- The categorisation of safety functions and safety classification of SSCs in this chapter conforms to the methodology described in Chapter 5. Additionally, the general requirements for equipment qualification, Examination Maintenance Inspection and Testing (EMIT) and codes and standards that come from this safety categorisation and classification are also described in Chapter 5. Further details can be found in EMIT section of corresponding Basis of Safety Case document referred in this section,
- The ability of the systems described in this Chapter to withstand hazards (e.g. flooding, fires, rotating equipment related hazards) are described in Chapter 6: External Hazards and Chapter 7: Internal Hazards, which focus on External and Internal Hazards respectively. In terms of SFIS SSCs, consideration of External and Internal Hazards is summarized in [Ref-17] and [Ref-18],
- The assessment of the SFP civil structure to normal and fault loads is described in Chapter 10: Civil Works and Structures,
- The fuel design pre-requisites/requirements are described in Chapter 11: Reactor Core,
- The safety case for the Residual Heat Removal System (RHR), which provides supplemental cooling to the SFP, is summarised in Chapter 12: Reactor Coolant Systems, Reactor Control Systems and Assocaited Systems and Chapter 13: Engineered Safety Features,
- The safety case of the Standby Gas Treatment System (SGTS), which in the event of a fault concerning irradiated fuel filters and reduces the radioactivity to mitigate off-site doses, is described in Chapter 13,
- The safety case for Control and Instrumentation systems and for Electrical Power Supplies, which support the SSCs in this Chapter, is summarised in Chapter 14: Control and Instrumentation and Chapter 15: Electrical Power Supplies respectively,
- The safety case for Auxiliary Systems is described in Chapter 16: Auxiliary Systems, namely:
    - Makeup Water Condensate System (MUWC), which provides additional water to the SFP if required, is described in Section 16.3.

  - Fire Protection System (FP) and Suppression Pool Clean-up System (SPCU), which provide additional water to the SFP if required, are described in Section 16.6.
  - Heating Ventilating and Air Conditioning System (HVAC), which maintain the required atmosphere, is described in Section 16.5.
  - Flooding System of Specific Safety Facility (FLSS) and Flooding System of Reactor Building (FLSR), which can provide cooling and makeup water to the SFP in fault conditions, are described in Section 16.7.
- Radiation Protection is described in Chapter 20: Radiation Protection,
- The overall approach for development of Human Machine Interfaces for equipment control panels is part of the scope of Chapter 21: Human Machine Interface. In particular the Basic Design principles are described in Chapter 21, section 21.8. The design substantiation of the HMIs that fall within the scope of this chapter (as described in the Scope section) will be undertaken through this chapter during the post GDA phase,
- The safety case on the SFP water chemistry is described in Chapter 23: Reactor Chemistry,
- Fault analysis within the design basis is covered in Chapter 24: Design Basis Analysis. Beyond Design Basis and Severe Accident Analysis is covered in Chapter 26: Beyond Design Basis and Severe Accident Analysis,
- Probabilistic analysis that demonstrates adequate reliability of systems is in the scope of Chapter 25: Probabilistic Safety Assessment,
- Substantiation of Human Based Safety Claims related to human interactions with systems is described in Chapter 27: Human Factors,
- General requirements for decommissioning are described in Chapter 31: Decommissioning. The related claims are summarised in Chapter 31. Additionally, the detailed requirements for FHM and RBC functionality during the decommissioning phase are discussed in the BSC [Ref-4], and
- The handling and storage of spent fuel outside of reactor building and associated concept design of the SFIS is described in Chapter 32.

19.2 Purpose and Scope

19.2.1 Purpose

The purpose of this Chapter is to describe the Fuel Route Safety Case from the introduction of new fuel, in transfer containers, into the R/B to the exit of spent fuel, in Casks, from the R/B. Therefore, this Chapter describes the major processes associated with the UK ABWR's Fuel Route, and the SSCs used during these processes.

There are three main risks associated with the handling of fuel in the UK ABWR:

- Direct exposure of workers to radiation because of reduced or loss of shielding,
- Criticality accidents, and
- Loss of containment of fission products from damaged fuel or damaged containers leading to exposure of workers or the public to radiation.

The design of the fuel route for the UK ABWR is based on UK and international good practice. Spent fuel elements are transported and stored under water to provide adequate shielding at all stages of the process to prevent direct radiation exposure. The fuel storage racks are designed to ensure a subcritical configuration. Analyses investigating various improbable fuel assembly misloading and misoriented errors would not yield to fuel failure, and as such would not cause a release to the environment [Ref-2]. Therefore, these analyses concluded that the core would remain subcritical, and thus no evacuation would be necessary.

Cooling systems are provided to maintain adequate temperature of the fuel cladding and maintain a reasonably working atmosphere for workers. In addition, multiple makeup systems are available to maintain SFP water levels for cooling and shielding during normal operations and fault conditions.

The main potential causes of loss of containment are through the dropping of spent fuel either during transport of elements within the reactor and SFP or whilst in a transport container whilst being removed from the SFP, or due to the drop of heavy loads over spent Fuel Assemblies. The consequences of a dropped item can lead to severe on-site or off-site dose. Lifting devices are designed to nuclear standards with dual load paths and high reliability protection systems following UK and international good practice.

This Chapter provides a concise description of the following:

- Fuel route SSCs and operations, and associated safety cases. The information described in this chapter focuses on a mechanical engineering standpoint,
- The safety case hierarchy. This description extends from the Fundamental Safety Functions (FSFs) to the SFCs, and
- A summary of the ALARP case for the Fuel Route, with reference to the relevant safety analyses.

The information provided by this Chapter is a summary of the Safety Case presented in the references provided.

19.2.2 Scope

Chapter 19 covers the system safety case related to fuel route during normal operation including SFE. The scope of Chapter 19 is defined as follows:

- **From:** arrival of new fuel in transfer containers into the R/B.
- **To:** egress of spent fuel, in Casks, from the R/B.
- **Includes:**
    - All Fuel Assembly, non-Fuel Assembly, and reactor component handling operations, with either the RBC or FHM.
    - Storage of components, cooling, clean-up and water makeup in the SFP.
    - Non-Fuel Assembly and reactor component handling for maintenance activities.
    - All Cask handling activities within the R/B.

Related topics, SSCs and analysis covered in other PCSR Chapters are described in Section 19.1.2.

19.3 Description of Fuel Route Operations

The UK ABWR Fuel Route operations can be grouped into four major processes (See Figure 19.3-1.):

- Outage Preparation,
- Outages,
- Spent Fuel Storage, and
- Spent Fuel Export.

The following is a brief description of the fuel route processes. Additional information can be found in the TR on Safety Case of Fuel Route [Ref-3].

19.3.1 Outage Preparation

To enable continued operation of the reactor, new fuel bundles are brought onto the reactor site, inspected, prepared and stored under water in racks within the SFP. This operation is performed before an outage whilst the reactor is at power, and the Reactor Well (R/W) is covered with a Shield Plug.

A transporter carrying transport containers including inner containers of new fuel bundles enters the Truck Bay of the R/B. The RBC raises the transport containers to the Operating Deck, where they are stored in a temporary storage location. The RBC then removes the inner container and transfers it to the NFIS. Individually, the fuel bundles are removed from the inner containers, reoriented, inspected, and fitted with a fuel channel box to form a Fuel Assembly.

The RBC then transfers the new Fuel Assemblies to the FPM. The FPM lowers each Fuel Assembly into the SFP, after which the FHM transfers the Fuel Assembly into a storage rack.

Other preparatory work involving other components also take place, such as handling new components which will be introduced in the reactor (CRs, Fuel Supports (FSs), new RIP components, new neutron monitors, etc.), or handling of covers, gates and miscellaneous equipment.

19.3.2 Outages

The UK ABWR is expected to undergo an outage for refuelling approximately every 18 months. During this plant outage the reactor is disassembled, the Steam Dryer, Steam Separator Pit (DSP) is open and flooded, and the R/W is flooded and subsequently drained. The handling sub-processes performed during the outage are as follows:

To enable irradiated fuel handling to take place, the RBC is used to remove the following components:

- Reactor Well Shield Plug and Slot Plugs,
- Primary Containment Vessel Head,
- Reactor Pressure Vessel Insulator, and
- Reactor Pressure Vessel Head.

The RBC is also used to remove the Dryer and Separator from within the Reactor Pressure Vessel (RPV) in order to provide access to the core, and to fit the Main Steam Line Plugs (MSLP).

Finally, the gates of the SFP are opened so that the FHM can transport the new and spent Fuel Assemblies between the spent fuel storage racks and the reactor core, and shuffle individual assemblies within the reactor core or SFP. For the event of Fuel Assembly movement causing dose increase of workers in drywell, some mitigation options are feasible to mitigate risks sufficiently.[Ref-14]

The FHM is used to transport and handle non- Fuel Assemblies such as:

- CRs,
- Double Blade Guides (DBGs),
- Neutron monitors and sources, and
- RIP components.

When these operations are finalised, the reactor is reassembled, gates are re-installed and Slot Plugs are moved back to their original position, and the DSP is drained.

19.3.3 Spent Fuel Pool Storage

Irradiated fuel is stored in racks within the SFP whilst the decay heat reduces. The FPC is used to remove the decay heat and maintain the water quality. Water makeup systems are available to maintain the water level in the pool.

19.3.4 Spent Fuel Export

The operations required to transfer irradiated fuel out of the R/B, following a typical dwell of 10 years in the SFP, are referred to as SFE and are as follows:

Auxiliary equipment, such as the Canister Cooling System (CCS), Welding System and Drying and Pressurisation System, are placed in the R/B Operating Deck prior to SFE operation.

A Transfer Cask, containing an internal Canister, is transferred to the SFP Cask Pit by the RBC Main Hoist.

Once the RBC opens the Cask Pit gate, irradiated fuel is transferred from the spent fuel storage racks to the Canister with the FHM. Once the Canister is loaded and the gate is re-installed, the Canister lid is placed and secured. The RBC then raises the Cask within the Cask Pit to the Cask stand, following decontamination as necessary, so it can be drained, dried and pressurised with inert gas to enable passive cooling for interim storage.

While on the Cask Stand, the Canister lid is welded to the Canister shell and the Canister is drained, dried and backfilled with inert gas so that the Transfer Cask can be moved to the Truck Bay for transfer to the SFIS facility.

Future licensees have the option to undertake decontamination or inspection activities of the Transfer Cask and Canister within the Preparation Pit if deemed appropriate.

The SFE scope for this Chapter includes all processes (handling and cooling) until the Cask reaches the exit of the R/B prior to being transferred to the SFIS facility. All operations within the SFIS, including transport to the facility (outside the R/B), are excluded from this Chapter. Chapter 32 provides a summary of the SFIS concept design, and describes how it integrates with other systems. The SFIS design is only conceptual during GDA and the detailed design will be developed at an appropriate stage for SFIS.

19.3.5 Fuel Route Operator Actions

The main human based safety claims for the Fuel Route Operations are made regarding the following key actions in relation to the:

- The assembly and checking of load paths (confirm correct engagement, perform lifting tests, etc.).
- The manual control of RBC operations.
- The manual control of some FHM operations.
- The monitoring of automatic and semi-automatic FHM operations.
- The use of emergency stop buttons in the instance of failure of mechanical safety functions where a dropped load or over raise fault is realised.
- The fitting of both the canister and cask lids once the canister is full, followed by visual inspections prior to commencing the lifting operation.
- The drying and cooling of the canister, e.g. connecting the coolant inlet/outlet tubes to the cooling system.

Where required, design provisions are provided to ensure that any human based actions required to support a Category A safety function are either eliminated, inherently safe by design, minimised, or of suitable reliability. Whilst feasible operator solutions for the SFE have been demonstrated in the SFE safety case, as summarised within Table 5-1 of [Ref-7], there will be options available for the operator to reduce or remove operator interaction.

The human based claims are further described in the BSC on Fuel Handling Systems and Overhead Crane Systems [Ref-4]. Human Factors are covered in Chapter 27.

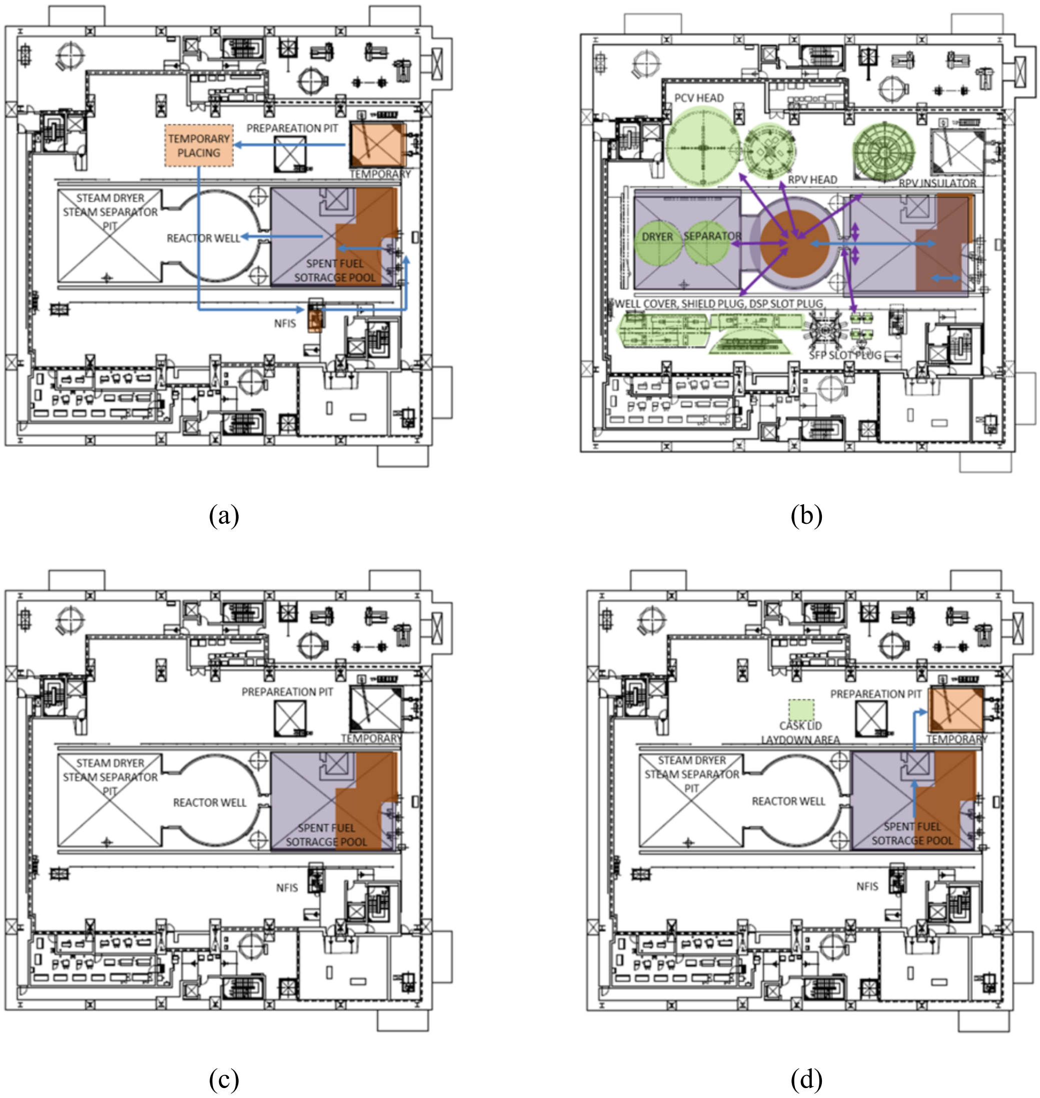

Figure 19.3-1: Fuel Route Process Overview, (a) Outage Preparation, (b) Outages, (c) Spent Fuel Storage, (d) Spent Fuel Export

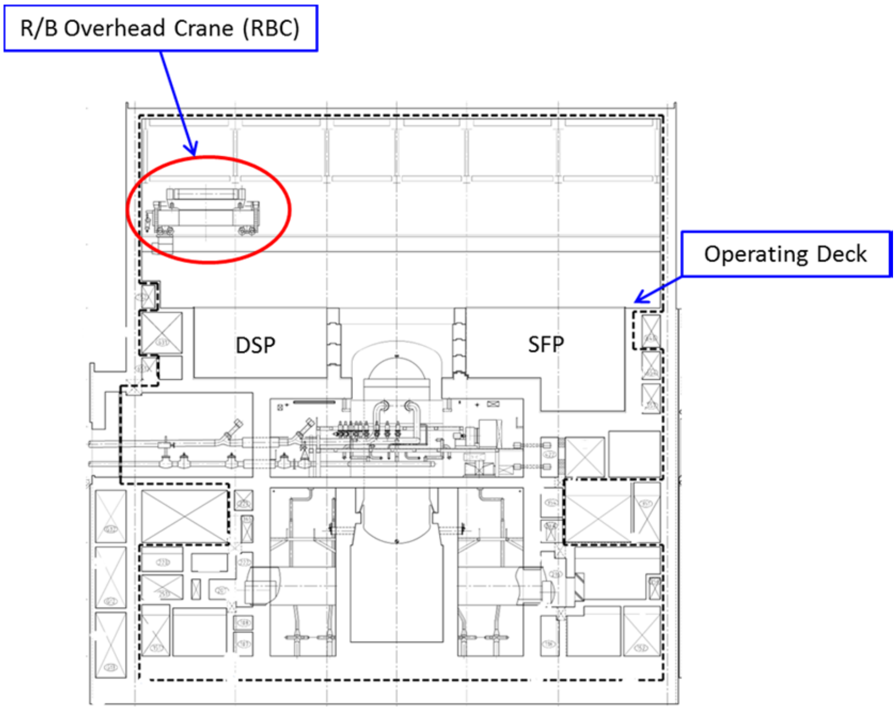

Figure 19.3-2: Side View of Fuel Building

19.4 New Fuel Inspection Stand

This Section describes the design basis for the NFIS and provides a description of the system and how the design meets the safety requirements.

19.4.1 Design Basis

The SFC related to the NFIS is:

- **NFIS SFC 5-6.1:** The NFIS handles loads safely such that load path integrity is maintained during normal conditions and frequent and infrequent faults within the design basis.

This function is categorised as Safety Category C and the SSCs which deliver it are designed to meet Safety Class 3 requirements.

19.4.2 System Design Description

19.4.2.1 Basic Configuration

The NFIS is located on the R/B Operating Deck and allows visual inspections of new Fuel Assemblies following import into the R/B and prior to loading into the SFP, using the RBC auxiliary hoist. The NFIS re-orientates new Fuel Assemblies, raises them up and down during inspections, and allows a fuel channel box to be fitted to the new Fuel Assembly.

A schematic of the NFIS is presented in Figure 19.4-1.

The NFIS consists of a container stand, a vertical guide column, two fuel carts, a work platform, a channel box handling boom, and other components. The channel box handling boom (also referred to as the jib crane) is used for the channelling process.

19.4.2.2 Operating Modes

The NFIS has only one operating mode termed the new fuel handling mode (manual). As such, it is operated using either a pendant or foot switch.

19.4.2.3 Safety Provisions

As previously stated this function is categorised as Safety Category C and the SSCs which deliver it are designed to meet Safety Class 3 requirements. As such this claim is not discussed further within this Chapter.

Further information regarding the NFIS is presented in the BSC on Fuel Handling Systems and Overhead Crane Systems [Ref-4].

19.4.3 Assumptions, Limits and Conditions for Operation

Since the safety function is Safety Category C and the NFIS is designed to meet Safety Class 3 requirements, Assumptions, LCO requirements will be developed during post GDA phase.

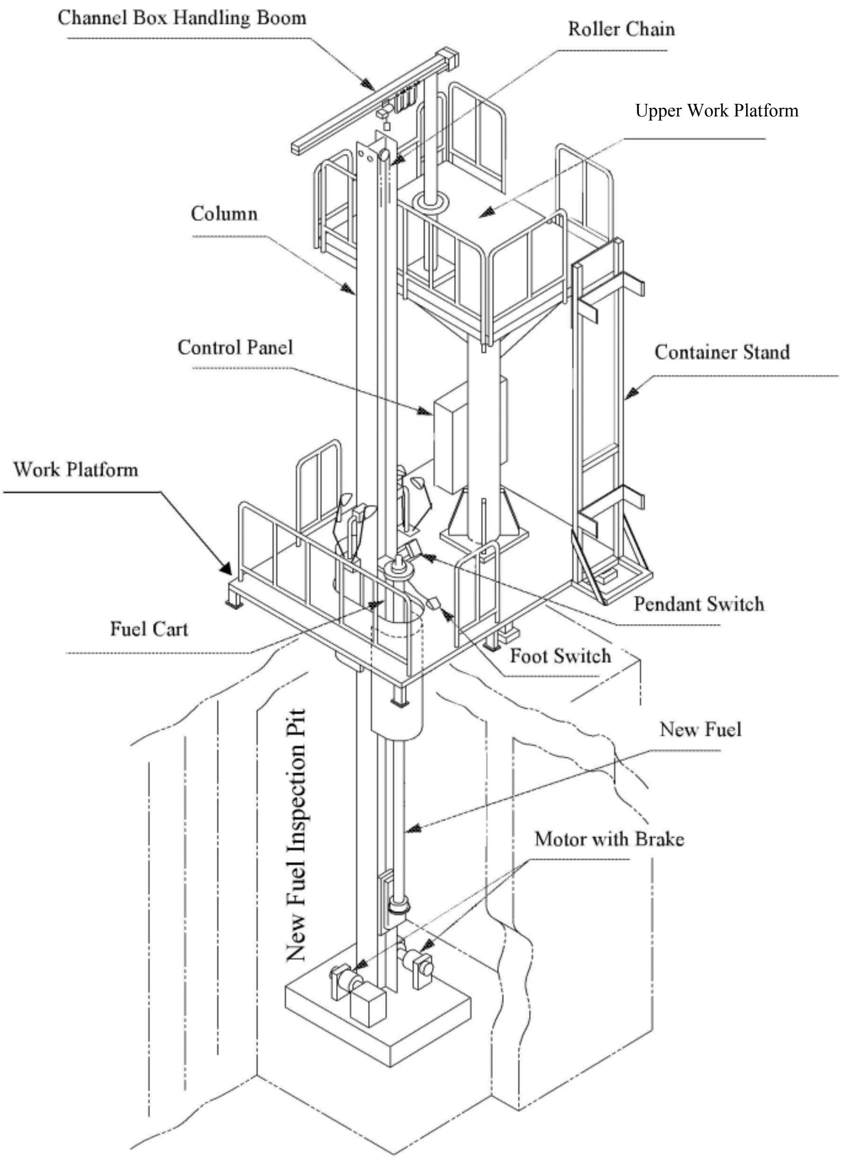

Figure 19.4-1: NFIS Schematic

19.5 Fuel Preparation Machine

This Section describes the design basis for the FPM and provides a description of the system and how the design meets the safety requirements. Design substantiation of local HMIs will be developed post GDA.

19.5.1 Design Basis

The SFCs related to the FPM are:

- **FPM SFC 5-6.1:** The FPM ensures fuel integrity in the event of a dropped load during normal conditions and frequent and infrequent faults within the design basis.

  This claim concerns the FPM's Main Hoist, and the Jib Arm and Channel Box handling tool. It also includes the lifted items (Fuel Assembly, Channel Box, and Visual Inspection Equipment).

  The associated faults are: fuel drop, fuel collision and drop of heavy equipment into the SFP over the stored fuel.

  The bounding function is categorised as Safety Category A and the SSCs which deliver it are designed to meet Safety Class 1 requirements.

- **FPM SFC 5-6.2:** The FPM handles irradiated loads suitably submerged so that adequate radiation shielding is provided.

  The claim concerns the FPM's Main Hoist, and Channel Box lifting attachment. It is applicable during both normal conditions and fault conditions (frequent and infrequent). The associated faults are: over-raise of irradiated fuel and over-raise of irradiated equipment.

  The bounding function is categorised as Safety Category A and the SSCs which deliver it are designed to meet Safety Class 1 and Class 2 requirements.

- **NSC SFC 5-6.1:** The Nuclear Special Cranes (NSCs) defined as cranes and machinery which can be used to handle fissile material - are designed to prevent a collision between the NSCs or other cranes, resulting from frequent and infrequent faults within the design basis.

  This claim applies to protection measures implemented to prevent collisions between the FPM and other cranes which could result in dropped loads and damage to irradiated fuel.

  The bounding function is categorised as Safety Category A and the SSCs which deliver it are designed to meet Safety Class 1 and 2 requirements.

  The NSC SFC 5-6.1 claim is discussed further in Sections 19.6.2.3 and 19.7.2.3 since it affects the FPM, FHM and RBC.

19.5.2 System Design Description

19.5.2.1 Basic Configuration

There are two FPMs located at the edge of the SFP, and installed on the SFP's wall. Only one is used at a time. The FPM's function is to load new fuel into the SFP. New Fuel Assemblies are loaded into the FPM using the RBC auxiliary hoist. The FPM subsequently lowers the new fuel into the SFP.

The FPM also allows the safe inspection of irradiated Fuel Assemblies in the SFP with use of cameras. The FHM transports irradiated fuel into the FPM. Subsequently, the fuel channel box surrounding the Fuel Assembly is detached and removed by the FPM jib crane to enable inspection of the fuel bundle. After inspection, the fuel channel box is reattached prior to the fuel being returned to the spent fuel storage racks. A jib crane is used to install and remove fuel channels from the Fuel Assemblies.

The FPM consists of guiderails, a fuel cart, a work platform and other smaller components. The jib crane and the storage rack for the irradiated fuel channels are located between the two FPMs.

A schematic of the FPM is shown in Figure 19.5-1.

19.5.2.2 Operating Modes

The FPM has two manual operating modes:

- New fuel handling, and
- Irradiated fuel handling.

19.5.2.3 Safety Provisions

Further information regarding the FPM is presented in the BSC on Fuel Handling Systems and Overhead Crane Systems [Ref-4]. This sub-Section presents the safety provisions used to meet the requirements set by the SFCs presented above.

(1) Safety Provision for FPM SFC 5-6.1

The key arguments regarding ensuring fuel integrity can be summarised as follows:

The FPM structure is designed to prevent it from collapsing on the SFP.

The FPM Main Hoist and Jib Arm and Channel Box handling tool load paths are designed to withstand normal operational and fault loadings. It includes an over speed protection system and emergency brakes which fail safe on loss of power. A Shock Absorber is provided at the bottom of the rails to ensure fuel integrity is maintained in the event of a fault where the fuel cart drops.

An interlock prevents the raising of the FPM cart until the FHM Main Hoist is in parked position to prevent the Fuel Assemblies from dropping outside the fuel cart.

The FPM control panel interface with the operator is in the scope of Chapter 21.

(2) Safety Provision for FPM SFC 5-6.2

The key arguments regarding preventing over-raise of radioactive elements can be summarised as follows:

The FPM includes a redundant and diverse protection system to prevent an over-raise fault from occurring.

The channel box attachment is designed so that it cannot engage with the channel boxes when attached to the fuel bundle. The irradiated channel box lift height is limited by the fixed length of the attachment such that the channel box is always maintained sufficiently submerged.

(3) Safety Provision for NSC SFC 5-6.1

The key arguments regarding preventing the collision of the FPM with other NSCs can be summarised as the following:

An interlock prevents the operation of the FHM unless the FPM is in a parking position with the fuel cart fully lowered and the Jib Arm parked. Also the interlock prevents the operation of the RBC unless the FPM is in another position with the fuel cart fully lifted and the Jib Arm parked. Additionally, the FPM includes an interlock so that it cannot operate unless the FHM and the RBC are fully parked.

Operational procedures shall describe the use of only one NSC at any one time and the operator will stop the lifting operation in the event of a fault.

19.5.3 Assumptions, Limits and Conditions for Operation

To ensure that the FPM is operated within safety limits and the design requirements from the safety case are met during operation, appropriate LCOs have been defined. Additional measures are also in place in case the LCOs cannot be met. The information shown below is described in the BSC on Fuel Handling Systems and Overhead Crane Systems [Ref-4], and reflected in the generic technical specifications [Ref-15] transferred to the future licensee to operate the plant as designed in the safety case.

- Limit switches shall be operable when FPM is used for the delivery of the SFCs.

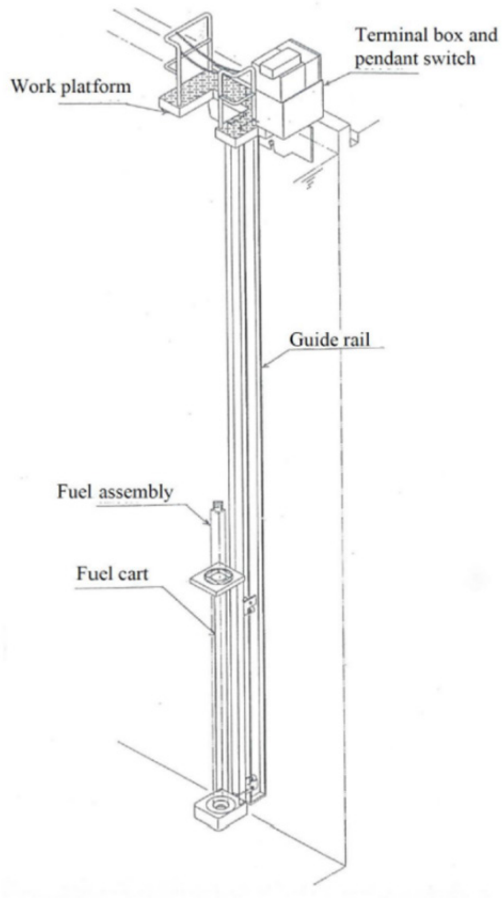

Figure 19.5-1: FPM Schematic

19.6 Fuel Handling Machine

This Section describes the design basis for the FHM and provides a description of the system and its safety provisions. Design substantiation of local HMIs will be developed post GDA. The FHM is key item planned for use in decommissioning activities for the removal of spent fuel, RPV and Reactor Internal sections. The design life, operational profile and functional requirements of this component includes the requirements for decommissioning which negates the need to introduce new lifting equipment during decommissioning and ensure that waste volumes are minimised. It may be necessary to update or modify the control systems for decommissioning but no major physical changes to the core lifting components themselves would be required.

19.6.1 Design Basis

The SFCs related to the FHM are:

- **FHM SFC 5-6.1:** The FHM, including lifting attachment and lifted items, handles loads safely such that load path integrity is maintained during normal conditions and frequent and infrequent faults within the design basis.

  This claim concerns the FHM's Bridge, Trolley, Main Hoist and Grapple, RIP Inspection Hoist, lifting attachments and zoning. It also concerns the Fuel Assemblies, in core insertion guide, DBG, CRs, FSs, RIP Components, MSLP and other lifted items.

  The associated faults are: fuel drop, fuel collision, drop of heavy equipment into the core, and drop of heavy equipment into the SFP.

  The bounding function is categorised as Safety Category A and the SSCs which deliver it are designed to meet Safety Class 1 requirements.

- **FHM SFC 5-6.2:** The FHM, associated lifting attachments and safety systems handle irradiated loads suitably submerged so that radiation shielding is provided.

  This claim concerns the FHM's Main Hoist, and RIP Inspection Hoist lifting attachments. It also concerns the Local Power Range Monitor (LPRM) and Start-up Range Neutron Monitor (SRNM) Basket. The associated faults are: over-raise of irradiated fuel and over-raise of irradiated equipment.

  The bounding function is categorised as Safety Category A and the SSCs which deliver it are designed to meet Safety Class 1 and 2 requirements.

- **FHM SFC 5-6.3:** The FHM handles fuel within the pools system in a subcritical configuration.

  This claim concerns the FHM's Main Hoist only, and is only applicable during normal conditions.

  The bounding function is categorised as Safety Category A and the SSCs which deliver it are designed to meet Safety Class 1 requirements.

- **NSC SFC 5-6.1:** The NSCs are designed to prevent a collision between the NSCs or other cranes, resulting from frequent and infrequent faults within the design basis.

  This claim applies to protection measures implemented to prevent collisions between the FHM and other cranes.

  The bounding function is categorised as Safety Category A and the SSCs which deliver it are designed to meet Safety Class 1 and 2 requirements. However, the categorisation and classification for the FHM is Category A and Safety Class 1.

  NSC SFC 5-6.1 claim is discussed further in Sections 19.5.2.3 and 19.7.2.3 since it affects the FPM, FHM and RBC.

19.6.2 System Design Description

19.6.2.1 Basic Configuration

The FHM is designed to transfer both new and irradiated Fuel Assemblies, and non-Fuel Assemblies between the reactor core and SFP. The FHM is a gantry crane which is comprised of a Bridge and a Trolley, a Telescopic Mast with a Grapple, and a RIP Inspection Hoist, as shown in Figure 19.6-1. It spans the width of the reactor core, DSP and SFP.

The FHM operations include:

- Transport of Fuel Assemblies (new and irradiated) between reactor core and spent fuel storage racks.
- Transport/Shuffling of Fuel Assemblies within reactor core and within spent fuel storage racks.
- Transport of Fuel Assemblies (new and irradiated) between FPM and spent fuel storage racks.
- Transport of non-Fuel Assemblies between RPV and SFP (control rods, fuel supports, LPRM, SNRM, RIP components).
- Transport of irradiated Fuel Assemblies from spent fuel storage racks to Cask Pit during SFE.

19.6.2.2 Operating Modes

The FHM has a number of operational modes which are selected based on the handling operations being performed:

For the FHM Main Hoist:

- Automatic,
- Half step,
- Local Semi-Automatic,
- Remote Manual, and
- Local Manual.

For the RIP Inspection Hoist:

- RIP handling automatic mode, and
- RIP handling local manual mode.

19.6.2.3 Safety Provisions

Further information regarding the FHM is presented in the BSC on Fuel Handling Systems and Overhead Crane Systems [Ref-4]. Handling procedures and optioneering studies are presented in the TR on Operating Deck Mechanical Handling Equipment [Ref-5] and lifting attachments are discussed in the TR of Lifting Attachments [Ref-6]. This sub-Section presents the FHM safety provisions used to meet the requirements set by the SFCs presented above.

The FHM is categorised as a gantry crane which handles nuclear material, and has therefore been designed against the relevant British Standards (BS EN 15011 and BS EN 13001) and the appropriate requirements from nuclear related codes (e.g. ASME NOG-1). The safety category and class of the FHM is Category A and Class 1.

Further information on the categorisation and classification can be found in the BSC on Fuel Handling Systems and Overhead Crane Systems [Ref-4].

(1) Safety Provision for FHM SFC 5-6.1

The key arguments regarding preventing fuel damage by ensuring the load path integrity is maintained can be summarised as the following:

The arguments supporting this claim are categorised according to which sub-SSC is concerned (e.g. Bridge, Trolley, Main Hoist, etc.).

The FHM Trolley and Bridge structures and rails, Main Hoist load and RIP Inspection Hoist load paths are designed to withstand normal operational and fault loadings. The Fuel Assembly, in core insertion guide and DBG are designed to withstand self-weight, snag loads and seismic loads.

The FHM Main Hoist and RIP Inspection Hoist load paths include redundant components (e.g. lifting wire ropes, sheaves, etc.). However, for the components where redundancy is not practicable, highly conservative margins are applied to their design (e.g. rails, Bridge beams and Trolley beams, etc.).

Each of the FHM's load paths are physically and functionally independent, and the failure of one redundant component does not affect the other. Each load path has a separate, independent, protection system, this ensures functional independence. There are two independent brakes which automatically engage in the event of a loss of power.

The FHM Main Hoist control system includes 5 different operating modes. Only one operating mode can be selected at any one time. The zoning system prevents a collision between the FHM hoists and FPM, surrounding furniture and structures, and with the Cask Pit. There are various direction and speed detections systems in place to prevent crabbing or over speed faults.

The FHM control and protection logic systems are functionally diverse.

The FHM can be controlled either from an operator on the FHM, or from a station located elsewhere within the R/B. The FHM control system is described in Generic PCSR Chapter 14, Section 14.6.9, and the control panel interface with the operator is within the scope of Chapter 21.

Dropped loads from the FHM have been assessed in both the fault assessment described in Generic PCSR Chapter 24, Section 24.11.1.2, and the internal hazard and dropped load hazard assessment described in Generic PCSR Chapter 7, Section 7.7.

(2) Safety Provision for FHM SFC 5-6.2

The key arguments regarding preventing over-raise of radioactive elements can be summarised as follows:

A significant on-site dose is expected if the spent Fuel Assembly is raised above the water. The Main Hoist protection system prevents an over raise fault from occurring.

The RIP Inspection Hoist handles irradiated components. To prevent over-raise faults from occurring, dedicated attachments with a fixed length are employed, so that over-raise faults are prevented passively by design.

The bending operation of in-core monitors (LPRM and SRNM) ensures the high dose end of the monitors can be kept submerged at a suitable depth during all subsequent handling operations.

Radiation Protection to workers is considered in Generic PCSR Chapter 20, Section 20.5.3.

(3) Safety Provision for FHM SFC 5-6.3

The key argument regarding maintaining sub-criticality of the Fuel Assemblies while handling is that the FHM can only handle one Fuel Assembly at a time so that K_{eff} remains less than 0.95.

(4) Safety Provision for NSC SFC 5-6.1

The key arguments regarding the prevention of the FHM colliding with other NSCs can be summarised as the following:

An interlock prevents the operation of the FPM and RBC unless the FHM is in a parked position. Additionally, the FHM includes an interlock so that it cannot operate unless the FPM and the RBC are fully parked.

Operational procedures shall describe the use of only one NSC at any one time and the operator will stop the lifting operation in the event of a fault.

19.6.3 Assumptions, Limits and Conditions for Operation

To ensure that the FHM is operated within safety limits and the design requirements from the safety case are met during operation, appropriate LCO have been defined. Additional measures are also in place in case the LCOs cannot be met. The information shown below is described in the BSC on Fuel Handling Systems and Overhead Crane Systems [Ref-4], and reflected in the generic technical specifications [Ref-15] transferred to the future licensee to operate the plant as designed in the safety case.

- Interlocks shall be operable during handling of irradiated loads for the delivery of the SFCs.

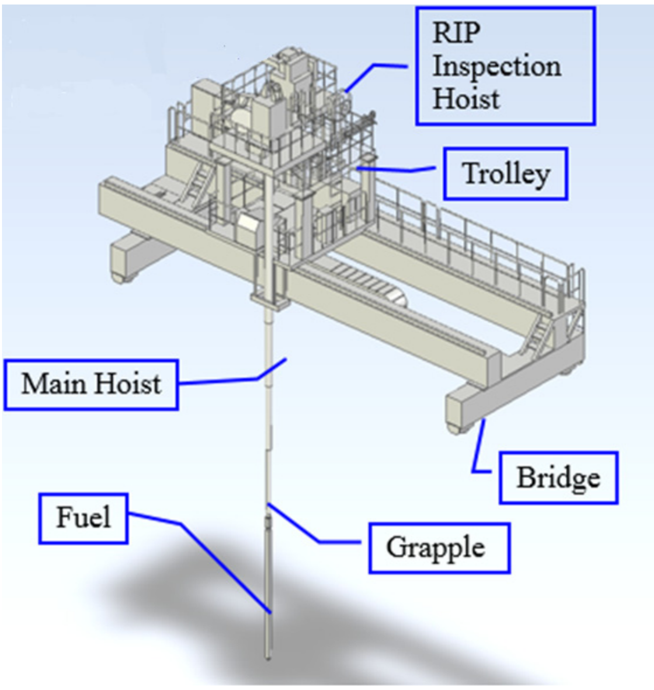

Figure 19.6-1: FHM Overview

19.7 Reactor Building Overhead Crane

This Section describes the design basis for the RBC and provides a description of the system and how the design meets the safety requirements. Design substantiation of local HMIs will be developed post GDA. The RBC is key item planned for use in decommissioning activities for the removal of spent fuel, RPV and Reactor Internal sections. The design life, operational profile and functional requirements of this component includes the requirements for decommissioning which negates the need to introduce new lifting equipment during decommissioning and ensure that waste volumes are minimised. It may be necessary to update or modify the control systems for decommissioning but no major physical changes to the core lifting components themselves would be required.

19.7.1 Design Basis

The SFCs related to the RBC are:

- **RBC SFC 5-6.1**: The RBC, including lifting attachments and lifted items, handles loads safely such that load path integrity is maintained during normal conditions and frequent and infrequent faults within the design basis.

  This claim includes the RBC's Bridge, Main Hoist, Auxiliary and Additional Hoists, lifting attachments and zoning. It also concerns the lifted items.

  The faults are: drop of heavy equipment into the core and SFP, and cask drops.

  The bounding function is categorised as Safety Category A and the SSCs which deliver it are designed to meet Safety Class 1 requirements.

- **RBC SFC 5-6.2:** The RBC, associated lifting attachments and safety systems handle irradiated loads suitably submerged so that radiation shielding is provided.

  This claim includes the RBC's Main Hoist and Dryer/Separator (D/S) Strongback. The fault concerned is the over-raise of irradiated equipment.

  The bounding function is categorised as Safety Category A and the SSCs which deliver it are designed to meet Safety Class 2 requirements based on the unmitigated consequences and initiating frequency.

- **NSC SFC 5-6.1:** The NSCs are designed to prevent a collision between the NSCs or other cranes, resulting from frequent and infrequent faults within the design basis.

  This claim concerns the RBC and its interface with the FHM and FPM Jib Arm. The relevant faults are: fuel drop, fuel collision, drop of heavy equipment into the core and into the SFP.

  The bounding function is categorised as Safety Category A and the SSCs which deliver it are designed to meet Safety Class 1 and 2 requirements.

19.7.2 System Design Description

19.7.2.1 Basic Configuration

The RBC consists of a gantry crane composed of Bridge Beams, a Trolley, a Main Hoist, an Auxiliary Hoist and an Additional Hoist, as shown in Figure 19.7-1. The RBC can thereby travel and traverse above the entire UK ABWR Operating Deck. Handling operations performed using the RBC include:

- Transport of new fuel from the Truck Bay to the NFIS and subsequently to the FPM.
- Transport of spent fuel (stored in the Cask) from the SFP Cask Pit to the Truck Bay.

- Reactor opening/closing series of works to enable an outage to be undertaken.

The Main Hoist is used for lifting heavy-loads such as the Well Shield Plug and RPV Head. The Auxiliary Hoist is used for lifting the lighter-loads such as the new Fuel Assemblies. The Additional Hoist is a suspension-type hoist used so that the RBC can access areas the Main and Auxiliary Hoist cannot reach.

The RBC is involved throughout the Fuel Route. Shown below is the RBC's global list of operations.

- **Outage Preparation:** Transport of new fuel from Truck Bay to FPM.
- **Refuelling Outages:** Reactor opening/closing series of work.
- **Spent Fuel Export:** Transport of cask to Truck Bay (from the Cask Pit).

Further information on the RBC is discussed in the BSC on Fuel Handling Systems and Overhead Crane Systems [Ref-4] and Preliminary BSC on SFE System [Ref-7]. Additional information regarding equipment associated with the SFE handling and cooling is presented in the Preliminary BSC on SFE System [Ref-7].

19.7.2.2 Operating Modes

The RBC includes several modes which restrict the access of the hoists to vulnerable areas depending on the handling operation.

(1) General Lifting Operations Mode:

This mode allows use of all RBC hoists and is used for general conventional lifting operations both during outages and when the reactor is on load. This mode prevents the RBC from handling loads above the SFP, including the Cask Pit, and permits lifting over the R/W only during reactor configurations where nuclear fuel is not exposed to potential dropped load faults.

(2) Dryer and Separator Handling Mode:

This mode allows use of the Main Hoist only. It is used for lifting operations required during Dryer and Separator handling.

(3) RBC Auxiliary Hoist Access to NFIS, FPM and SFP Gates Mode:

This mode allows use of the Auxiliary Hoist only. The purpose of this mode is to enable the RBC to be used for the loading of items into the SFP (e.g. new Fuel Assemblies) and the handling of items within the SFP (e.g. SFP gates) whilst reducing the risks associated with a dropped load onto fuel stored in the spent fuel racks to ALARP.

(4) Cask Handling Mode:

This mode allows use of the Main Hoist only. It is used for lifting operations required during SFE. The primary purpose of this mode is to provide protection measures to limit the likelihood and radiological consequences of a dropped load fault during spent fuel Cask handling.

19.7.2.3 Safety Provisions

Further information regarding the RBC is presented in the BSC on Fuel Handling Systems and Overhead Crane Systems [Ref-4]. Handling procedures and optioneering studies are presented in the TR on Operating Deck Mechanical Handling Equipment [Ref-5] and lifting attachments are discussed in the TR of Lifting Attachments [Ref-6]. This sub-Section presents the RBC safety provisions used to meet the requirements set by the SFCs presented above.

(1) Safety Provision for RBC SFC 5-6.1

The key arguments regarding preventing fuel damage by ensuring the load path integrity is maintained can be summarised as the following:

The arguments supporting this claim are categorised according to which sub-SSC is concerned (e.g. Bridge, Trolley, Main Hoist, etc.).

The RBC Trolley and Bridge structures and rails, Main Hoist and Auxiliary Hoist load paths are designed to withstand normal operational and fault loadings. There are various direction and speed detections systems in place to prevent crabbing or over speed faults.

The RBC Main Hoist load path includes redundant components (e.g. lifting wire ropes, gearboxes, etc.). However, for the components where redundancy is not practicable, highly conservative margins are applied to their design (e.g. rails, Bridge beams and Trolley beams, etc.).

Each of the RBC Main Hoist load paths are physically and functionally independent, and the failure of one redundant component does not affect the other. Each load has a separate, independent, protection system, this ensures functional independence.

The RBC long travel drive includes duty brakes and independent emergency brakes. The RBC cross travel also includes independent duty and emergency brakes. The RBC Main hoist includes a primary brake, an independent backup brake, and two independent emergency brakes. The RBC Auxiliary Hoist includes service and backup brakes, and an emergency brake. All of which automatically activate when the power is removed from the brakes or when a seismic event is detected.

The lifting attachments are designed to withstand permissible normal operational and fault loads. The actuation system for both the D/S Strongback and Spent Fuel Cask Handling Grapple (SFCHG) cannot release the Dryer or Separator, and cask during handling.

The zoning systems prevent the RBC Main Hoist access to the SFP or flooded R/W (excluding the Dryer and Separator Handling mode), and the ledging of a Cask on the edge of the Hoist Well. The RBC hoist interlocks (via load cells and hoist upper height limit switches) prevent operation of multiple hoists simultaneously. The RBC control system can operate only one hoist at any given time.

The RBC has a high reliability mode selection system in order to ensure the correct operation is performed in the correct mode. For the D/S Strongback and the SFCHG, trapped keys are required to permit the lifting attachment to engage with the load.

The RBC control and protection logic systems are functionally diverse. The RBC control panel interface with the operator is in the scope of PCSR Chapter 21.

Dropped loads from the RBC have been assessed in both the fault assessment described in Generic PCSR Chapter 24, Section 24.11.1.3, and the internal hazard and dropped load hazard assessment is described in Generic PCSR Chapter 7, Section 7.7.

Sealed Canister/Cask drop faults during SFE activities are discussed in Section 19.10.

(2) Safety Provision for RBC SFC 5-6.2

The key arguments regarding preventing over-raise of radioactive elements can be summarised as follows:

The RBC Main Hoist includes an over-raise protection system so that both the Dryer and Separator are suitably submerged within water when handled. In addition, the D/S Strongback cannot be connected to the Dryer or Separator unless the RBC is in the correct operating mode.

(3) Safety Provision for NSC SFC 5-6.1

The key arguments regarding preventing the collision of the RBC with other NSCs can be summarised as the following:

An interlock prevents the operation of the FPM Jib Arm and FHM unless the RBC is in a parked position. Additionally, the RBC includes an interlock so that it cannot operate unless the FPM jib arm and the FHM are fully parked. Although not part of the NSCs, an interlock also prevents the collision of the RBC hooks and the lifted load with the Hoist Well Cranes.

Operational procedures shall describe the use of only one NSC at any one time and the operator will stop the lifting operation in the event of a fault.

19.7.3 Assumptions, Limits and Conditions for Operation

To ensure that the RBC is operated within safety limits and the design requirements from the safety case are met during operation, appropriate LCOs have been defined. Additional measures are also in place in case the LCOs cannot be met. The information shown below is described in the BSC on Fuel Handling Systems and Overhead Crane Systems [Ref-4], and reflected in the generic technical specifications [Ref-15] transferred to the future licensee to operate the plant as designed in the safety case.

- Zoning interlock for the RBC shall be operable when RBC is used for the delivery of the SFCs.

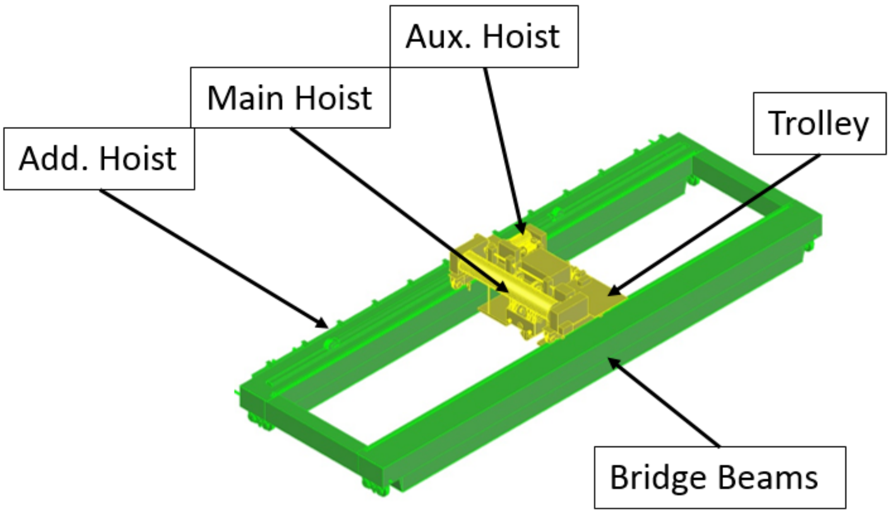

Figure 19.7-1: RBC Schematic

19.8 Spent Fuel Storage Facility

The SFS is comprised of the SFP, the Cask Pit, the spent fuel storage racks and the SFP gates. This Section describes the design basis for the facility and provides a description of the facility and its safety provisions.

19.8.1 Design Basis

The SFCs related to the SFS are:

- **SFS SFC 1-9.1**: The spent fuel storage racks maintain the Fuel Assemblies in a subcritical state.
- **SFS SFC 2-4.1:** The SFS keeps the Fuel Assemblies submerged in water, and provides cooling to the Fuel Assemblies.
- **SFS SFC 4-7.1:** The SFP, the Cask Pit, and associated SFP gates are designed to prevent loss of SFP water.
- **SFS SFC 4-7.2:** The SFP has sufficient water depth to provide radiation protection to operators working on the Operating Deck.

The SFS structures are designed with the appropriate reliability commensurate with Category A Class 1 equipment. The details are provided in the BSC on SFP and FPCMs [Ref-8].

19.8.2 System Design Description

19.8.2.1 Basic Configuration

The SFP is located adjacent to the R/W, and provides submerged storage for new Fuel Assemblies, irradiated and spent Fuel Assemblies, and non-Fuel Assemblies, which are removed from the reactor for maintenance or replacement during an outage or for disposal, whilst maintaining sub-criticality, shielding and cooling. A schematic of the SFS is shown in Figure 19.8-1.

The SFS is filled with demineralised water that is maintained at the desired temperature and quality by the FPC. The water provides both shielding and cooling, and is isolated from the R/W by two SFP gates which are handled by the RBC. The gates are removed during refuelling operations to allow submerged transfer of Fuel Assemblies between the SFP and RPV. In the Cask Pit, spent fuel can be loaded into Transfer Casks for export from the R/B.

The SFP contains storage racks for fuel and non-Fuel Assemblies. The spent fuel storage racks are arranged in a square grid and bolted to the floor of the SFP. The racks used for irradiated fuel storage prevent criticality by containing neutron absorbing boron, and ensuring fuel remains in a non-critical geometry.

The SFS is located within the R/B on the Operating Deck level. The Operating Deck atmosphere is maintained by the HVAC. The HVAC ensures the air is within a specified range of humidity and temperature of the R/B (For further details on the HVAC, see Generic PCSR Chapter 16, Section 16.5).

19.8.2.2 Safety Provisions

Further information regarding the SFS is presented in the BSC on SFP and FPCMs [Ref-8]. This sub-Section presents the SFS safety provisions used to meet the requirements set by the SFCs presented above.

(1) Safety Provision for SFS SFC 1-9.1

The key arguments regarding maintaining sub-criticality of the Fuel Assemblies while in the spent fuel storage racks can be summarised as follows:

The spent fuel storage rack prevents criticality by using materials such as boronated stainless steel with neutron-absorbing capability and a geometrically safe arrangement, with an appropriate physical fuel-to-fuel distance to ensure that the effective neutron multiplication factor (k_{eff}) remains ≤ 0.95 in all conditions. The criticality analysis is described in the BSC on SFP and FPCMs [Ref-8].

The spent fuel storage racks are designed to avoid any risk of criticality in the most conservative foreseeable conditions. The assessments assume that the maximum possible quantities of Fuel Assemblies are stored within the racks.

The spent fuel storage racks provide storage capability for more than 300% of a full reactor core load, and provides enough space to store the spent fuel generated during 10 years of operation. They are designed to be able to withstand all foreseeable fault loads presented by, for example, seismic events or dropped loads.

(2) Safety Provision for SFS SFC 2-4.1

The key arguments regarding keeping Fuel Assemblies submerged and cooled can be summarised as follows:

The SFP and the Cask Pit are filled with demineralised water to maintain the Fuel Assemblies (and other irradiated components) submerged, and it includes cooling and water makeup systems to maintain appropriate temperature, quality and water level.

The SFP also provides sufficient cooling to a submerged unsealed canister during spent fuel export and its reverse operations.

The description and safety case for the cooling and water makeup systems is provided in Section 19.9 and associated PCSR Chapters as referenced.

(3) Safety Provision for SFS SFC 4-7.1

The key arguments regarding the prevention of water leakage can be summarised as follows:

The SFP and the Cask Pit are made of reinforced concrete lined with stainless steel plate. The SFP, the Cask Pit and the SFP gate are fitted with a leak detection system, and SFP water level switches are present in order to identify loss of water faults. Both of these systems are alarmed in order to alert operators to a leak and thus allow prevention of uncovering of the spent fuel.

The civil structure of the SFP, the Cask Pit and the R/B are required to withstand fault loads, such as those resulting from seismic events. The assessment of the SFP civil structure to normal and fault loads is reported in Generic PCSR Chapter 10.

The SFP pipework and the SFP gate are designed to prevent potential uncovering of fuel elements by eliminating pipework or penetrations in the liner below the top of the active fuel level. The FPC pipework is designed to prevent syphoning of the SFP water.

(4) Safety Provision for SFS SFC 4-7.2

The key arguments regarding maintaining an appropriate water level to provide adequate shielding to workers can be summarised as follows:

The SFP is designed to have sufficient water depth over the stored spent Fuel Assemblies to provide radiation protection to operators working on the Operating Deck. The thickness of the concrete structure and steel lined floor and walls, which conform to the SFP and the Cask Pit, are designed such that operators and the public are afforded appropriate radiation protection. Radiation protection design provisions are described in Generic PCSR Chapter 20, Section 20.5.

19.8.3 Assumptions, Limits and Conditions for Operation

To ensure that the SFS is operated within safety limits and the design requirements from the safety case are met during operation, appropriate LCOs have been defined. Additional measures are also in place in case the LCOs cannot be met. The information shown below is described in the BSC on SFP and FPCMs [Ref-8], and reflected in the generic technical specifications [Ref-15] transferred to the future licensee to operate the plant as designed in the safety case.

- The SFP water level and temperature shall be within operation limits when irradiated fuel assemblies are seated in the SFP.

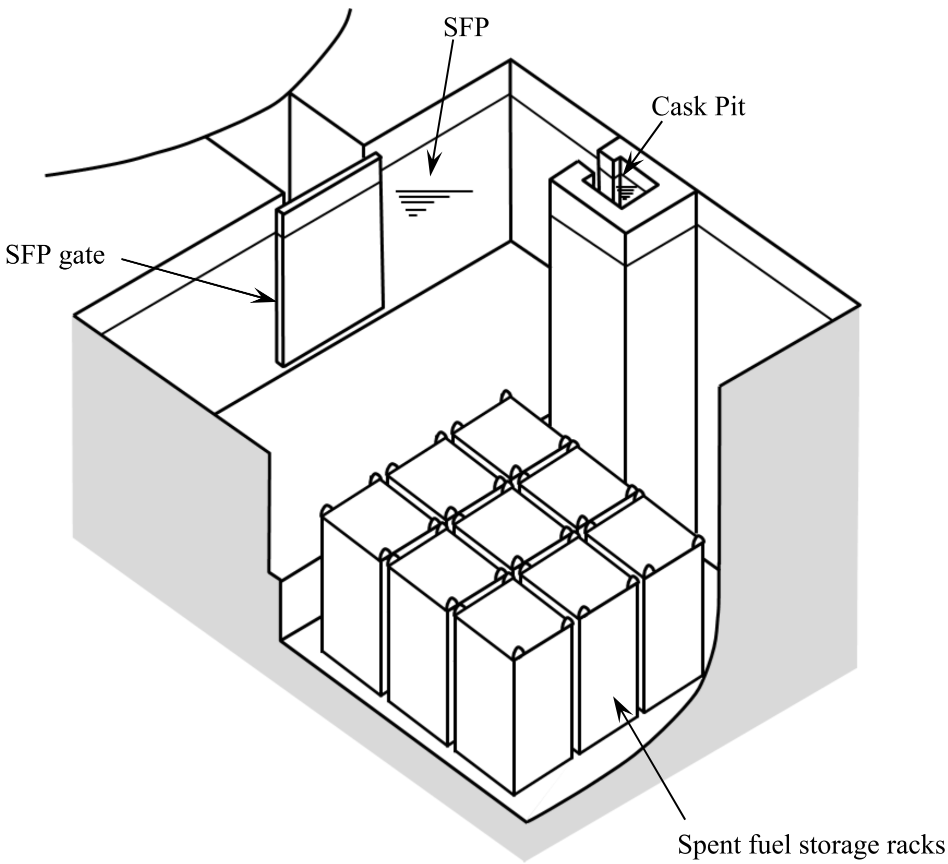

Figure 19.8-1: SFS Schematic

19.9 Fuel Pool Cooling, Clean-up and Makeup Systems

The FPCMs consist of several systems which provide cooling, clean-up or makeup water for the SFP. These systems include the FPC, RHR, MUWC, SPCU, FP, FLSS and the FLSR.

This Section describes the design basis for the FPCMs and provides a description of the system and how the system design meets the requirements of the design basis.

Further information regarding management of the SFP water chemistry is available in the Generic PCSR Chapter 23, Section 23.5.

19.9.1 Design Basis

This Section describes the design bases for the FPCMs. The claims put on the system come from the BSC on SFP and FPCMs [Ref-8]. Design basis faults considered in this chapter are provided by Design Basis Analysis specified in Generic PCSR Chapter 24 and the associated TR on Fault Assessment for SFP and Fuel Route [Ref-9].

19.9.1.1 Normal Conditions:

- **FPC SFC 2-4.1:** The FPC removes heat from the SFP and maintains the SFP water temperature within the designed values by removing decay heat.

  This function is classified as Safety Category A and the components which deliver it are designed to meet Safety Class 1 requirements.

- **RHR SFC 2-4.1:** The RHR provides the FPC with supplemental cooling to maintain the SFP water temperature within the design values by removing decay heat in the event of a full core offload where the heat load to the pool exceeds the FPC cooling capacity. This function can also be used for recovery from potential upper pools cooling failure and subsequent boiling event.

  This function is classified as Safety Category A and the components which deliver it are designed to meet Safety Class 1 requirements.

- **FPC SFC 5-9.1:** The FPC maintains the quality of the water in the pool to conform the quality requirements by removing the following impurities:

  - Impurities mixed into the pool from air.
  - Impurities brought into the pool with the fuel or components on which the impurities adhere to.
  - Corrosion and fission products from the core during refuelling.
  - Mixing material during refuelling and other operations.
  - Residual chemicals used for cleaning or flushing water after pool cleaning.

  This function is classified as Safety Category C and the components which deliver it are designed to meet Safety Class 3 requirements.

- **FPC SFC 4-4.1:** The FPC pipework contains radioactive liquid. A loss of containment of this piping could lead to a release of radioactive material; however, due to the predicted source term the operator dose is likely to be relatively low.

  This function is categorised as Safety Category C and the components which deliver it are designed to meet Safety Class 3 requirements.

19.9.1.2 Normal and Fault Conditions:

- **FPC SFC 4-7.1:** The check valves and syphon break system prevents potential syphon from the SFP and subsequent spent fuel exposure in the SFP.

  This function is categorised as Safety Category A and the components which deliver it are designed to meet Safety Class 1 requirements.

19.9.1.3 Fault Conditions:

- **FLSS SFC 2-5.1:** In the eventuality that the cooling function for the SFP is unavailable or small leakage from the SFP occurs, the FLSS supplies sufficient water to maintain the water level of the SFP as a secondary means of cooling the spent fuel stored in the SFP.

  This function is categorised as Safety Category A and the components which deliver it are designed to meet Safety Class 2 requirements.

- **FPC SFC 2-5.1:** The SPCU, MUWC or FP, which systems are for normal operating function, will be utilised to supply water to the SFP, if available.

  This function is classified as Safety Category C and the components which deliver it are designed to meet Safety Class 3 requirements.

19.9.1.4 Beyond Design Basis Fault Conditions:

- **FLSS SFC 2-5.2:** The FLSS is the principal means to provide SFP with makeup water to mitigate significant damage to the spent fuel due to potential long term SBO and subsequent loss of SFP cooling function in the event of beyond design basis faults or severe accidents.

  This function is categorised as Safety Category B and the components which deliver it are designed to meet Safety Class 2 requirements.

- **FLSS SFC 2-5.3:** The FLSS is the principal means to provide SFP with spray water to mitigate significant damage to the spent fuel due to loss of the fuel pool water resulting from loss of makeup water or a large leakage from the SFP in the event of beyond design basis faults or severe accidents.

  This function is categorised as Safety Category B and the components which deliver it are designed to meet Safety Class 3 requirements.

- **FLSR SFC 2-5.1:** The FLSR is a secondary means to provide SFP with makeup water as a backup of the FLSS in the event of design basis faults and beyond design basis faults or severe accidents.

  This function is categorised as Safety Category B and the components which deliver it are designed to meet Safety Class 3 requirements.

- **FLSR SFC 2-5.2:** The FLSR is a secondary means to provide SFP with spray water to mitigate significant damage to the spent fuel due to loss of the fuel pool water resulting from loss of makeup water or a large leakage from the SFP as a backup of the FLSS in the event of beyond design basis faults or severe accidents.

  This function is categorised as Safety Category B and the components which deliver it are designed to meet Safety Class 3 requirements.

Further information on the SFP water chemistry is presented in Generic PCSR Chapter 23, Section 23.5.

Further information for the FLSS and FLSR system design is shown in Generic PCSR Chapter 16, Section 16.7.

19.9.2 System Design Description

This Section describes the design of the systems that deliver the SFP cooling, clean-up and makeup to support and justify the delivery of the FPC SFC 2-4.1, RHR SFC 2-4.1 and FPC SFC 5-9.1 [Ref-8].

19.9.2.1 Basic Configuration

The FPC consists of two divisions, A and B. Each division has a Skimmer Surge Tank, FPC pump and FPC Heat Exchanger, and hence both divisions have a cooling function. For division B, two FPC Filter Demineralisers (F/D) and a standby pump are also installed. Therefore division B has a water clean-up function. Both cooling circuits are independently connected to a different division of the RHR (FPC (A) is connected to RHR (A), and FPC (B) is to RHR(B)) for the required supplemental cooling required during a full core offload event as shown in Section 19.9.2.2. A schematic of the FPC is shown in Figure 19.9-1.

19.9.2.2 Operating Modes

(1) Normal Heat Load Operation Mode

The purpose of this mode is to cool and clean up the SFP water under the normal heat load. The SFP water overflows out of the SFP through the skimmer weirs and into the Skimmer Surge Tanks, before being transferred by the FPC Pumps. It is filtered, demineralised and cooled through the FPC F/Ds and the FPC Heat Exchangers. The Reactor Building Cooling Water System (RCW) supplies cooling water to the FPC Heat Exchangers. The pool water is finally returned to the SFP.

One FPC Pump and one F/D unit is operated during this mode where the decay heat is relatively small and so the system is capable of maintaining the SFP water temperature sufficiently low (below 52°C) at the design flow rate (250m^3/h) given in Section 19.9.2.3(1).

This mode can bypass the F/Ds in case the clean-up line is unavailable due to any accident (e.g. a seismic event).

(2) Maximum Heat Load Operation Mode

In the event of a full core offload (Maximum Heat Load condition), the SFP Maximum Heat Load Operating Mode is required to remove the additional decay heat. The FPC operates in conjunction with the RHR to cool the SFP under the maximum heat load condition.

(3) Makeup Function

The MUWC supplies water to the SFP from the Condensate Storage Tank (CST) to compensate for evaporation during normal conditions. It is also designed to have sufficient makeup volume to compensate for leakage from liner cracks or overflow due to any event (e.g. seismic event).

The following systems can also supply sufficient water to the SFP as a backup of the makeup function if necessary:

- The SPCU can supply water to the SFP and can select the water source from the CST or Suppression Pool (S/P).
- The FLSS can supply water to the SFP from a water source in the Backup Building.
- The FLSR can supply water to the SFP from a water source in the plant site.
- The FP can supply water to the SFP from a water source in the plant site.

19.9.2.3 Equipment Design and Operation

(1) FPC Pump

(a) Purpose:

The purpose of the FPC pump is to circulate a coolant of the SFP for cooling and clean-up. [FPC SFC 2-4.1] and [FPC SFC 5-9.1].

(b) Configuration and Operation:

One FPC pump with 100% capacity is provided to division A and two FPC Pumps with 100% capacity each are provided in parallel to division B. They are capable of simultaneous operations.

(c) Performance:

The design flow rate of the FPC Pumps is determined considering the highest of the following cases to conduct sufficient water clean-up [FPC SFC 5-9.1]:

- The flow rate necessary to circulate the whole SFP water capacity twice a day.
- The flow rate necessary to circulate the whole capacity of combined pools water once a day (the water contained in the SFP to the R/W to the D/S Pit).

(2) FPC Filter Demineraliser

(a) Purpose:

The purpose of the FPC F/Ds is to remove impurities from the SFP coolant [FPC SFC 5-9.1].

(b) Configuration and Operation:

Two F/Ds with 100% capacity each are provided to the division B in parallel and be capable of simultaneous operation.

(c) Performance:

The FPC F/Ds are designed as follows:

- Type: Pressure pre-coating type with elements to preserve the pre-coating material is incorporated inside.
- Pre-coating material: The pre-coating material is a mixture of cation and anion resin powder.
- Replacement of pre-coating material: The pre-coating material is replaced when the differential pressure across the F/D unit exceeds a determined value or the conductivity rate at the outlet exceeds the determined rate.

(3) FPC Heat Exchanger

(a) Purpose:

The FPC Heat Exchangers intend to cool the Pool water below a specified temperature [FPC SFC 2-4.1].

(b) Configuration and Operation:

Two Heat Exchangers (50% capacity/unit x 2 units) are provided to each division in parallel. In division B, Heat Exchangers are installed on the downstream side of the F/D units in order to reduce contamination.

(c) Performance:

A set of FPC Heat Exchangers on each division is designed to satisfy following requirements:

- To remove the normal heat load from pool water at 52°C with two divisions with the design flow rate determined for the FPC pumps.
- To remove normal heat load from pool water at 65 °C with one division with the design flow rate determined for the FPC pumps.

(4) Skimmer Surge Tank

(a) Purpose:

The Skimmer Surge Tank receives the pool water that flows over the skimmer weirs and scuppers, and returns it to the FPC for circulating, cooling and cleaning up the SFP water [FPC SFC 2-4.1, RHR SFC 2-4.1 and FPC SFC 5-9.1].

(b) Configuration:

Two Skimmer Surge Tanks are located so that the pool water over the skimmer weirs and scuppers flows into the Skimmer Surge Tank.

(c) Performance:

Pipework downstream of the Skimmer Surge Tanks is connected with a pipe in order to equalise their water levels.

The weir on the SFP skimmer can let the flow of the system at the design flow rate, and distribute it equally to each Skimmer Surge Tank.

19.9.2.4 Main Support Systems

(1) Instrumentation and Control Systems

(a) Instrumentation

The Skimmer Surge Tanks are provided with water level detection switches that control the opening and closing of valves on the feed-water line, from the MUWC, upon high and low water levels in the Skimmer Surge Tanks. Additionally, water level signals are sent to the Main Control Room (MCR) [FPC SFC 2-4.1 and FPC SFC 5-9.1].

The SFP is provided with a water level switch to give the MCR a warning against high and low water levels. The set water level is adjustable within the skimmer weir range [FPC SFC 2-4.1 and FPC SFC 5-9.1].

A pressure switch is provided on the suction piping of each FPC Pump to provide the pump protection interlock and a warning sent to the MCR against low suction pressure [FPC SFC 2-4.1 and FPC SFC 5-9.1].

A flow meter is provided on the discharge piping of each FPC Pump to measure the system flow rate [FPC SFC 2-4.1 and FPC SFC 5-9.1].

The SFP temperature, the FPC Pumps inlet temperatures and the FPC Heat Exchangers outlet temperatures are recorded. The temperature recorder may be shared with another system. High SFP temperature is detected in the SFP and the FPC Pump suction side and, alarmed in the MCR [FPC SFC 2-4.1].

Differential pressure and conductivity transmitters are provided to each F/D unit for backwashing and recoating [FPC SFC 2-4.1].

The pool water conductivity at the inlet and outlet of each F/D unit and the outlet of the FPC Heat Exchangers are continuously monitored and recorded. A warning signal is generated in the MCR if the water quality exceeds the criteria [FPC SFC 5-9.1].

Leakage from the Refuelling Bellows and the SFP Gate is detected and a warning signal is sent to the MCR against high leakage conditions [SFS SFC 2-4.1].

Leakage from the SFP liner is detected and a warning is sent to the MCR against high leakage. Leak detectors are provided for the R/W and the D/S Pit as well [SFS SFC 2-4.1].

Signs indicating the operating status and the position of the major remotely operated valves are displayed in the MCR [FPC SFC 2-4.1 and FPC SFC 5-9.1].

(b) Control Systems

The FPC Pumps automatically stop under low suction pressure by the pressure switch or under low discharge flow by the flow switch.

The division B flow is automatically controlled by the flow control valves mounted on the outlet piping of the F/Ds. To division A, it is controlled by manual valve mounted on the outlet piping of the FPC pump.

(2) Power Supply System

FPC Pump motors, motor-operated valves, instrumentation and controllers related to the delivery of the cooling function are powered from the normal power source and the emergency power sources (EDG).

(3) Makeup Water Condensate System

The MUWC is designed to be capable of supplying water to the SFP to compensate evaporation, leakage from liner cracks or overflow due to a seismic event, etc. Related active components are powered from the normal power source and the emergency power source (EDG).

(4) Residual Heat Removal System

The RHR can work as a supplemental cooling for the SFP under the maximum heat load conditions. This function can also be used for recovery from potential upper pools cooling failure and subsequent boiling event.

(5) Suppression Pool Clean-up System

The SPCU provides sufficient makeup water to the SFP from the CST or the S/P as a backup in the event that water supply from the MUWC is lost.

(6) Flooding System of Specific Facility and Flooding System of Reactor Building

The FLSS and FLSR are capable of supplying sufficient water to the SFP from outside of the Reactor Building as backup systems of the MUWC. Details of the systems are shown in Generic PCSR Chapter 16, Section 16.7.

(7) Reactor Building Cooling Water System

The RCW supplies cooling water to the FPC Heat Exchangers. Each set of FPC Heat Exchangers is connected to independent and separated RCW divisions.

19.9.3 Assumptions, Limits and Conditions for Operation

To ensure that the FPCMs are operated within safety limits and that the design requirements from the safety case are met during operation, appropriate LCOs and surveillance requirements to ensure the LCOs are met as well as corrective actions (measures) to follow when the LCOs are not met are defined. The information shown below is described in the BSC on SFP and FPCMs [Ref-8] in detail.

- The SFP water level and temperature shall be within operation limits when irradiated fuel assemblies are seated in the SFP.
- At least one division is in operation for the delivery of the FPC SFC 2-4.1 or RHR SFC 2-4.1.
- RPV water level shall be within operation limits during refuelling for the delivery of the FHM SFC 5-6.2 and RBC SFC 5-6.2.

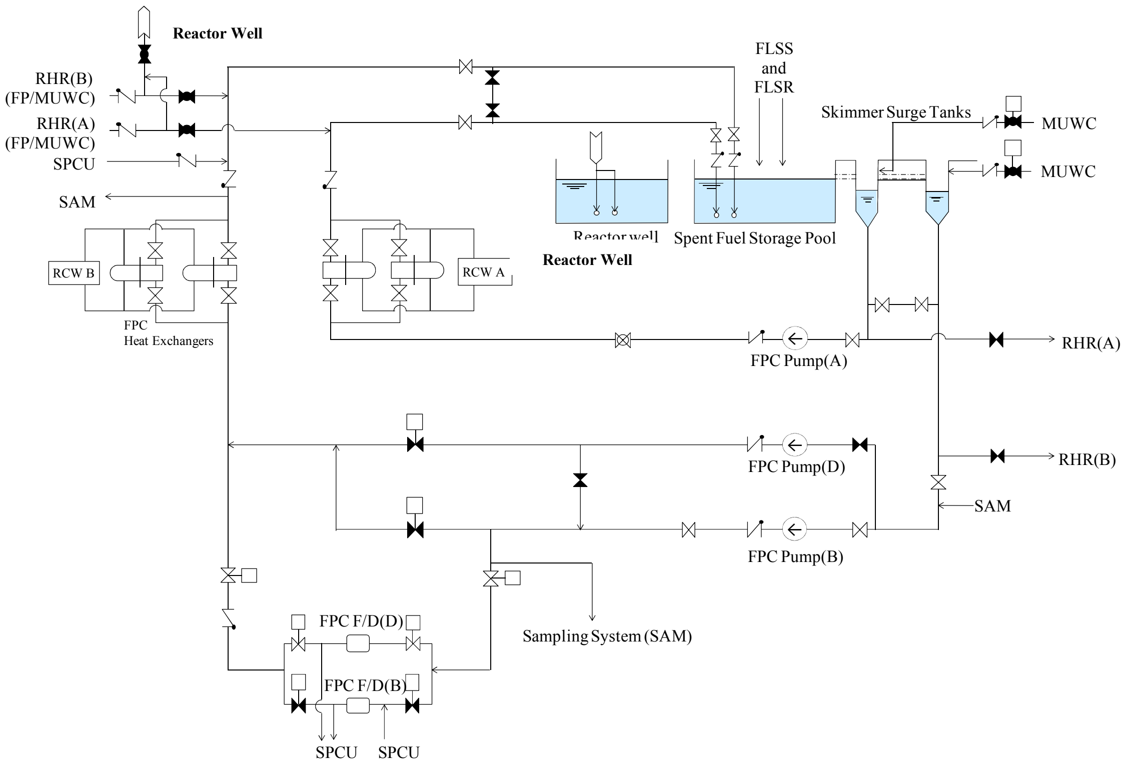

Figure 19.9-1: Outline of FPCMs

19.10 Spent Fuel Export Systems

The SFE route comprises a number of SSCs. Note, this does not take account of the RBC or FHM, which are used for numerous processes across the fuel route, and hence not specific to SFE. The specific SFE SSCs are:

- Transfer Cask,
- Canister,
- Canister Basket,
- Cask Stand,
- Impact Limiters,
- Canister Cooling System (CCS),
- Back-up Canister Cooling System (BCCS),
- Canister Welding System,
- Canister Drying and Pressurisation System,
- Over Temperature Protection System (OTPS) for Canister Drying, and
- Low Profile Transporter (LPT).

19.10.1 Design Basis

The SFCs related to the SFE are detailed in the Preliminary BSC on SFE System [Ref-7], with the relevant arguments and evidence. The TR on Consideration of Fault for SFE and SFIS [Ref-10] identifies all credible faults associated with SFE.

- **SFE SFC 1-10.1**: Fuel remains in a subcritical condition during operations under normal and fault conditions.

  This claim focusses on preventing criticality from occurring and concerns the Canister basket.

  The bounding function is categorised as Safety Category A and the SSC which delivers it is designed to meet Safety Class 1 requirements.

- **SFE 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 unsealed canister SFE operations and associated fault conditions.

  This claim involves the cooling of spent fuel during processes of spent fuel removal in the Cask Pit during unsealed SFE operations.

  During normal conditions and frequent faults or hazards, there are either two active lines of cooling or a single passive means of cooling the spent fuel. Whereas, following infrequent faults or hazards, there is a single line of active or passive cooling. These faults include delays during unsealed loaded Cask handling and failure of the CCS during preparation.

  This claim concerns the following SSCs: SFP, FPC, EDG (Emergency Diesel Generator), BBG (Backup Building Generator), CCS, BCCS, Canister Drying and Pressurisation System, OTPS for Canister Drying, Canister Basket, and Transfer Cask.

  The bounding function is categorised as Safety Category A and the SSCs which deliver it are designed to meet Safety Class 1 requirements.

- **SFE SFC 2-6.2**: Temperature of spent fuel will be maintained within specified limits such that the fuel clad does not fail due to overheating during sealed canister SFE operations and associated fault conditions.

  This claim involves the cooling of spent fuel during processes of spent fuel removal from the Cask Pit to outside the R/B during sealed SFE operations.

During normal conditions and frequent faults or hazards, there are either two active lines of cooling or a single passive means of cooling the spent fuel. Whereas, following infrequent faults or hazards, there is a single line of active or passive cooling.

This claim concerns the following SSCs: Canister, Canister Basket and Transfer Cask. The faults include impact load to sealed Canister/Cask faults (e.g. dropped sealed Canister, etc.).

The bounding function is categorised as Safety Category A and the SSCs which deliver it are designed to meet Safety Class 1 requirements.

- **SFE SFC 4-14.1**: Containment function will be maintained during SFE unsealed Canister operations and associated fault conditions.

  During normal unsealed Canister operations, multiple containment barriers for spent fuel will be maintained. Multiple containment is also maintained during frequent SFE faults and hazards, whereas for infrequent faults and hazards there is a single containment barrier for spent fuel [Ref-7].

  This claim concerns the Fuel Cladding and SGTS. It applies to both normal and fault conditions (e.g. Loss of Offsite Power (LOOP) during loaded Canister preparation, dropped Fuel Assembly onto fuel Canister, etc.).

  The categorisation and classification for the SGTS is Category B and Safety Class 2, and the safety case is discussed in PCSR Chapter 13. The Fuel Cladding delivers a Category C function and is designed to meet Safety Class 3 requirements.

- **SFE SFC 4-14.2:** Containment function will be maintained during SFE sealed Canister operations and associated fault conditions.

  During normal sealed Canister operations, multiple containment barriers for spent fuel will be maintained. Multiple containment is also maintained during all frequent SFE faults and hazards, whereas for infrequent faults and hazards there is a single containment barrier for spent fuel [Ref-7].

  The claim concerns the Fuel Cladding and Canister. It also applies to both normal and fault conditions (e.g. inert gas leakage, dropped sealed Canister, etc.).

  The categorisation and classification for the Canister is Category A and Safety Class 1. The Fuel Cladding delivers a Category C function and is designed to meet Safety Class 3 requirements.

- **SFE SFC 4-16.1:** Shielding from spent fuel will reduce dose to operators and public ALARP during normal SFE operations and associated fault conditions.

  This claim focusses on providing radiation shielding when the cask is inside the reactor building.

  This claim concerns the canister, Transfer Cask, SFP and FPC System.

  This function is categorised as Safety Category A and the SSC which delivers it is designed to meet Safety Class 1 requirements.

- **SFE SFC 5-16.1:** Handling of spent fuel within Canister shall not compromise other SFCs and the spent fuel and Casks shall remain retrievable during normal operation and following frequent faults.

- This claim focusses on providing handling and retrievability during spent fuel removal processes in the reactor building. It applies to both normal and fault conditions. These include Canister lid dropped onto Canister, dropped sealed Canister, etc.

- The SSCs concerned are: the Cask Stand, Low Profile Transporter, Transfer Cask, Canister, RBC, FHM, lifting attachments and Fuel Assembly.
- This function is categorised as Safety Category A and the SSCs which deliver it are designed to meet Safety Class 1 requirements, except the Cask Stand, Low Profile Transporter and Fuel Assembly. Cask stand provides a Category A function and is designed to meet Safety Class 2 requirements. Low Profile Transporter provides a Category B function and is designed to meet Safety Class 2 requirements. The Fuel Assembly delivers a Category C function and is designed to meet Safety Class 3 requirements.
- **SFE SFC 5-22.1**: Canister deceleration during design basis drop faults shall remain below allowable limits.

  This claim focusses on limiting the deceleration loading to the Canister containment boundary.

  It applies to impact load to sealed Canister/Cask faults. This claim only concerns the Impact Limiter.

  This function is categorised as Safety Category A and the SSC which delivers it is designed to meet Safety Class 1 requirements.

19.10.2 System Design Description

19.10.2.1 Basic Configuration

The Transfer Cask is made from steel and shielding material and is used to house the Canister during transferring operations of spent fuel. It provides shielding during spent fuel export operations and enables cooling and handling of the Canister. It also contains an Impact Limiter for Canister protection. The Canister itself is a large, steel cylindrical component with a thick lid, for shielding, and containing a basket which holds the fuel in place and maintains sub-criticality.

The Canister (already situated in the Transfer Cask) is loaded with the spent fuel stored in the SFP using the FHM. There are multiple safety measures to prevent and detect misloading of spent fuel as detailed in Section 3.3.6 of SFE and SFIS Fault TR [Ref-10]. Potential safety measures listed in this report are not foreclosed by station design, and therefore, these will be further considered at the appropriate stage by the future licensee. Following spent fuel loading, the Canister lid is secured in place and the Cask is raised by the RBC in a single axis lift and seated on the Cask Stand. The Cask Stand is a passive structure within the Cask Pit which is employed to facilitate preparation activities of the Cask (lid welding, decontamination, drying and pressurisation with inert gas) whilst utilising the water present in the Cask Pit to further improve shielding. At this concept design stage, the Cask Stand will be used for the majority of Canister preparation activities. However, no options have been foreclosed to operators. The Cask Stand will remain in the Cask Pit between SFE campaigns but can be removed for maintenance or if a fault is discovered.

It is anticipated that the CCS will be connected to the Cask before it is raised from the bottom of the Cask Pit. The CCS is a simple pumping system, supplying a cooling medium from the makeup water supply, which comprises a pump, pipework (or flexible hosing), choke valves, anti-syphoning equipment and flow gauges. The BCCS, which is a similar system fed directly from the SFP, will be available should the CCS fail, and provides diverse and redundant Canister cooling. Alternative options to the active cooling systems outlined are open to operators and will be investigated further at the appropriate stage.

The Canister is drained partially before the Welding System is placed onto the Canister lid. This welds the lid to the shell. The rest of the water is then drained from the Canister and heated helium is forced through the sealed Canister until required dryness levels are met. The OTPS is automatically initiated and shuts down the Drying and Pressurisation System if thermocouple readings indicate that the temperature reaches the limit which has the margin against the spent fuel is being subjected to excessive temperatures. Multiple lines of temperature sensing protection will be used and can be located in areas such as the heating system and the blowing system, to provide diversity and redundancy to the OTPS. Finally, helium is pressurised within the Canister to maintain passive fuel cooling during transportation and interim storage.

Once the Canister has been sealed, dried and pressurised, the Transfer Cask lid is secured to the body. The RBC subsequently lifts it over the Operating Deck and lowers it through the hoist well. An Impact Limiter is incorporated into the bottom of the hoist well and the Cask Pit in order to protect the Canister and the civil structure against potential Cask dropped load.

After being lowered down the hoist well, the Cask is placed onto the Low Profile Transporter which removes the Transfer Cask from the R/B for transportation to the SFIS facility. The same Transporter also brings new and empty Casks into the R/B at the beginning of the process. It is proposed in concept design that the Transporter will run on rails however other options are not foreclosed to operators. Operational processes during SFE and the relevant SSCs' functions are further detailed in the Preliminary BSC on SFE System [Ref-7].

Operations beyond this point are discussed in further detail in PCSR Chapter 32 which provides a summary of the SFIS concept design, and describes how it integrates with other systems.

19.10.2.2 Operating Modes

The operating modes for fuel handling with the FHM and Cask handling with the RBC are described in Sections 19.6.2.2 and 19.7.2.2(4), respectively.

19.10.2.3 Safety Provisions

(1) Safety Provision for SFE SFC 1-10.1

The key argument regarding maintaining sub-criticality of the Fuel Assemblies while in the Canister is that the Canister basket has been conservatively designed so as to ensure sub-criticality following the loading of new Fuel Assemblies, and this configuration will be maintained even in an accident such as dropped Cask.

(2) Safety Provision for SFE SFC 2-6.1

The key arguments regarding maintaining the temperature of the fuel cladding while in the unsealed canister can be summarised as follows:

Heat generated by the spent Fuel Assemblies is removed by the SFP cooling system prior to the lid placement, whilst localised boiling is prevented by the CCS. Should the CCS fail during unsealed canister preparations, the BCCS is used for heat removal.

During Canister preparation activities, the Canister Drying and Pressurisation System is used for water removal. The separate OTPS for canister drying provides protection to ensure the inert gas being circulated is maintained within the temperature limit.

(3) Safety Provision for SFE SFC 2-6.2

The key arguments regarding maintaining the temperature of the fuel cladding while in the sealed canister can be summarised as follows:

The Canister basket design enables cooling of spent Fuel Assemblies through passive circulation of the pressurised inert gas.

A cooling claim is also placed on the Transfer Cask as, when the Canister is sealed and contained within the Transfer Cask, it ensures the heat generated by spent Fuel Assemblies is removed sufficiently.

(4) Safety Provision for SFE SFC 4-14.1

The key arguments regarding containment during unsealed SFE operations can be summarised as follows:

During unsealed Canister operations, the spent fuel clad and reactor building with SGTS provide two containment barriers.

In the event of fuel cladding breach during unsealed operations, the reactor building with SGTS provides the secondary containment.

(5) Safety Provision for SFE SFC 4-14.2

The key arguments regarding containment during sealed SFE operations can be summarised as follows:

For sealed SFE operations, the sealed Canister provides the next containment boundary. This has been designed to provide containment in the event of 100% fuel rod failure resulting from infrequent faults. Rigorous quality control and testing is performed to ensure the welding is performed to Class 1 requirements.

This includes all design basis Cask drop faults onto the Impact Limiter.

(6) Safety Provision for SFE SFC 4-16.1

The key arguments regarding shielding to operators and public can be summarised as follows:

During SFE unsealed Canister operations, the SFP provides adequate shielding to operators. This remains valid until the Canister lid is placed and lifted onto the Cask Stand. Once the Cask is removed from the Cask Pit, both the Transfer Cask and Canister lid provide the shielding functions to ensure dose to operators and public is kept ALARP.

(7) Safety Provision for SFE SFC 5-16.1

The key arguments regarding handling and retrievability can be summarised as follows:

The Canister and Transfer Cask are designed to enable safe handling by the RBC and associated lifting attachment to ensure this SFC can be fulfilled.

The Cask Stand is designed to withstand the weight of a fully loaded Canister and Cask under normal and fault conditions.

The Low Profile Transporter is designed to withstand the weight of a fully loaded Canister and Cask under normal and fault conditions once the Cask is in place and engaged.

Related safety provisions of FHM, RBC and lifting attachment are described in Section 19.6, Section 19.7, BSC [Ref-4] and TR [Ref-6].

(8) Safety Provision for SFE SFC 5-22.1

The key arguments regarding the deceleration during a canister drop fault can be summarised as follows:

For sealed Canister/Cask drop faults, Canister deceleration is maintained below allowable limits through the provision of Impact Limiters at locations where drop faults could conceivably occur, and within the Transfer Cask itself.

19.10.3 Assumptions, Limits and Conditions for Operation

As stated in Preliminary BSC on SFE System [Ref-7], the key LCOs associated with SFE (related to criticality, containment, fuel cooling) are described in the relevant supporting documents. The SFE process is at an early stage of concept design and the export of spent fuel will not happen until 10 years after the start of reactor generation, therefore the limits and conditions for operation have not yet been defined. While the requirements to develop the LCOs and surveillance systems have been recognised, defining them is beyond the scope of the GDA because the detailed information of the selected spent fuel storage technology is required. Therefore these will be further detailed in the appropriate stage.

A number of working assumptions are made to demonstrate that the SFE system will achieve all safety claims and that nuclear safety aspects have been adequately considered in the GDA process. These assumptions are not final design decisions, but have been made in order to allow development of an adequate case during GDA. The key working assumptions for the SFE system include:

- The fuel storage canister will be similar in design to the canister design supplied by Holtec International,
- The canister will hold up to 89 spent fuel assemblies,
- The transfer cask and concrete overpack designs will be similar to the available HI-TRAC and HI-STORM designs provided by Holtec International,
- Transfer of the canister between the transfer cask and the concrete overpack will take place outside the R/B – and so canisters are exported in a transfer cask,
- A loaded cask can be returned to the SFP for unloading (e.g. following fuel assembly or canister failure),
- Fuel type: Boiling Water Reactor (BWR) fuel assembly (GE14),
- Pool cooling period: 10 years, and
- The damaged fuel identified during reactor operation will be stored within the SFP until the end of generation following packaging, transport and storage in the SFIS.

19.11 Claims and Links to High Level Safety Functions

The lists of claims in this Chapter/sub-Chapter and the linkage to corresponding HLSFs are shown in Appendix A. A short description on the application of HLSFs in the development of the claims, arguments and evidence is provided in Generic PCSR Chapter 1.

19.12 Assumptions, Limits and Conditions for Operation

19.12.1 Purpose

One purpose of this generic PCSR is to identify constraints that should be considered by an operator of a UK ABWR plant to ensure safety during normal operation, fault and accident conditions. Some of these constraints are maximum or minimum limits on the values of system parameters, such as pressure or temperature, whilst others are conditional, such as prohibiting certain operational states or requiring a minimum level of availability of specified equipment. They are collectively described in this GDA PCSR as Assumptions, LCOs.

This section considers the LCOs that apply specifically to Fuel Storage and Handling systems/facilities of the generic UK ABWR reference design. These LCOs have been identified following the standard procedure for GDA that is specified in [Ref-16], and are collated in the Generic Technical Specifications [Ref-15]. Note that [Ref-15] is only applied to safety Class 1 and 2 systems, which are within the scope of GDA.

19.12.2 LCOs Specified for Fuel Handling and Storage Systems and Associated Systems

The LCOs that apply to the Fuel Handling and Storage Systems are identified under each individual system within the chapter. (Section 19.4 through 19.9)

19.12.3 Assumptions for Fuel Handling and Storage Systems and Associated Systems

The Assumptions that apply to the Fuel Handling and Storage Systems are identified under each individual system within the chapter. (Section 19.10)

19.13 Summary of ALARP Justification

An iterative process has been undertaken to ensure the Fuel Route of the UK ABWR is designed so that risks are ALARP, and in line with Hitachi-GE's GDA ALARP Methodology [Ref-11]. The method can be summarised as follows:

(1) The starting point of the ALARP process for GDA was the J-ABWR reference design, based on the Kashiwazaki-Kariwa Nuclear Power Station Units 6 and 7 (KK6/7). A risk assessment was undertaken to identify any UK and international good practice that differs from the reference design and operation procedures.

(2) An enhanced design was then defined by implementing risk reduction measures where the identified good practices were not applied to the reference design. This enhanced design is termed the UK ABWR baseline.

(3) In addition to designing all fuel route operations according to international good practice, a large number of options were proposed that might further reduce risk [Ref-11], [Ref-12], particularly with respect to preventing loss of containment. The following options were considered:

- Options to prevent heavy non-fuel items being lifted over spent fuel.
- Options to prevent lifting a spent fuel Transfer Cask before the lid is fully attached.
- Options to prevent lowering a spent fuel Transfer Cask from the Operating Deck to the ground floor.
- Options to prevent a spent Fuel Assembly or spent fuel Transfer Cask being dropped.
- Options to mitigate the consequences of a dropped load including options to mitigate dose of workers in drywell during spent Fuel Assembly movement.

(4) The defined options were evaluated and, if reasonably practicable, considered for implementation. If they were deemed grossly disproportionate, they were discarded and the reasons recorded. Additional risk reduction measures were then considered until the ALARP option was identified.

As a result of evaluating these options, a number of modifications to the FHM and RBC and their attachments were made, as well as adopting procedural changes to the handling operations or changing Cask Pit opening location in order to prevent heavy non-fuel items being lifted over spent fuel or to prevent fuel elements being dropped [Ref-5], [Ref-6].

The spent fuel storage racks are designed to avoid any risk of criticality in the most conservative conditions, and are designed to withstand all foreseeable fault loads (e.g. seismic events or dropped loads). These use boronated stainless steel with neutron-absorbing capabilities, and a geometrically safe arrangement to maintain an appropriate fuel-to-fuel distance [Ref-8]. Similarly, sub-criticality is maintained in the canister basket during all SFE process and credible fault scenarios. Its design also includes a specific geometrical arrangement and ensures sufficient neutron absorption is achieved [Ref-7].

All options to reduce the spent fuel Transfer Cask lowering from the Operating Deck to the ground floor were deemed not reasonably practicable, either because the changes compromised the integrity of the R/B or because the costs were grossly disproportionate to the risk reduction, particularly in regard to its seismic withstand [Ref-13].

Following the risk assessment, Impact Limiters were introduced as part of the UK ABWR baseline design to provide passive means of protection to the sealed canister in the event of a dropped load. The frequency of a potential Cask drop is very low and, with the implementation of an Impact Limiter, the frequency of a release due to a Cask drop event through the hoist well is within the broadly acceptable ALARP region.

The option of introducing the Cask Stand into the Cask Pit was also deemed reasonably practicable and will be adopted [Ref-13]. This Cask Stand permits the welding of the canister lid and drying of the canister in the Cask Pit and therefore eliminates risks associated with unsealed canister handling on the operating deck and around the Preparation Pit.

For the systems covered by Chapter 19, specific areas where ALARP assessments have been used to inform the design and propose changes on the reference design include the following relevant examples:

- The reference design of all ME SSCs was subjected to a thorough assessment in order to demonstrate that their design life and replacement frequency are in line with RGP and reduce the risk as low as reasonably practicable. According to the design review process established, depending on the operational period and profile under which the SSCs are required to work for UK ABWR (construction and/or commercial operation and/or decommissioning) it is judged whether the SSC is provided with a design life of 60 years or longer, or periodically replaced whichever the most reasonably practicable approach is to ensure continued availability of the SSC for the required conditions. This assessment is still ongoing and the design life and replacement frequency of several SSCs have already been modified. For further details refer to section 5 the "Hitachi-GE Strategy on the Design Life of ME SSCs" [Ref-22]. See the chapter 31, section 31.5.2.4 for the systems supporting decommissioning.
  Specifically, for those SSCs that their availability is expected for operation during decommissioning, this safety demonstration must cover both commercial operation and decommissioning operational profiles showing that safety and environmental performance can be maintained based on a component/subsystem replacement policy. Where it is not reasonably practicable to replace a major structure or component then the future safety case and specification of requirements for an SSC must cover a full design life longer than 60 years and the differing operational profiles required for different phases of the overall lifecycle of the structure or component. See Chapter 31, Section 31.5.2.4 for a list of the systems supporting decommissioning.

The design of the fuel route follows UK and international good practice, and following a systematic and comprehensive options study, all reasonably practicable risk reduction measures have been adopted. The risks from the fuel route are therefore ALARP.

19.14 Conclusions

The fuel route of the UK ABWR operations employs a number of systems which facilitate the replenishment of fuel within the reactor to enable continued power generation.

The fuel route includes handling and storage systems from the receipt of new fuel, in transport containers into the R/B, to egress of spent fuel in Casks from the R/B. Between these operations it includes the handling of Fuel Assemblies and reactor components, with the NFIS, FPM, FHM, and RBC, storage and cooling in the SFP, and transfer to Casks.

This Chapter provides a high level description of all systems, processes and components comprising the UK ABWR fuel route, and summarised the safety case, safety claims, and faults associated with the systems and operations.

It also summarised how the risks associated with the fuel route have been demonstrated to be reduced ALARP.

19.15 References

[Ref-1] Hitachi-GE Nuclear Energy, Ltd., "GE14 Fuel Mechanical Design Report", GA21-3809-0012-00001 (UE-GD-0090) Rev. 2, October 2016.

[Ref-2] Hitachi-GE Nuclear Energy, Ltd., "Topic Report on Design Basis Analysis", GA91-9201-0001-00023 (UE-GD-0219) Rev. 14, August 2017.

[Ref-3] Hitachi-GE Nuclear Energy, Ltd., "Topic Report on Safety Case of Fuel Route", GA91-9201-0001-00246 (AE-GD-0861) Rev. 1, June 2017.

[Ref-4] 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. 4, June 2017.

[Ref-5] Hitachi-GE Nuclear Energy, Ltd., "Topic Report on Operating Deck Mechanical Handling Equipment", GA91-9201-0001-00228 (M1E-UK-0088) Rev. 2, June 2017.

[Ref-6] Hitachi-GE Nuclear Energy, Ltd., "Topic Report of Lifting Attachment", GA91-9201-0001-00221 (M2E-UK-0033) Rev. 1, November 2016.

[Ref-7] Hitachi-GE Nuclear Energy, Ltd., "Preliminary Basis of Safety Case on Spent Fuel Export System", GA91-9201-0003-01562 (FRE-GD-0146) Rev. 1, June 2017.

[Ref-8] 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. 2, June 2017.

[Ref-9] Hitachi-GE Nuclear Energy, Ltd., "Topic Report on Fault Assessment for SFP and Fuel Route", GA91-9201-0001-00082 (AE-GD-0229) Rev. 3, July 2017.

[Ref-10] Hitachi-GE Nuclear Energy, Ltd., "Consideration of Fault for Spent Fuel Export and Spent Fuel Interim Storage," GA91-9201-0003-00526 (FRE-GD-0057) Rev. 4,June 2017.

[Ref-11] Hitachi-GE Nuclear Energy, Ltd., "GDA ALARP Methodology", GA10-0511-0004-00001 (XD-GD-0037) Rev.1, November 2015.

[Ref-12] Hitachi-GE Nuclear Energy, Ltd., "ALARP Report for Spent Fuel Export", GA91-9201-0003-01563 (FRE-GD-0144) Rev. 0, September 2016.

[Ref-13] Hitachi-GE Nuclear Energy, Ltd., "Spent Fuel Interim Storage Optioneering for Spent Fuel Removal from Spent Fuel Pool to Outside of Reactor Building", GA91-9201-0003-00689 (FRE-GD-0080) Rev. 3, September 2016.

[Ref-14] Hitachi-GE Nuclear Energy, Ltd., "Topic Report on Design Basis Analysis for SFP and Fuel Route", GA91-9201-0001-00137 (AE-GD-0441) Rev. 3, June 2017.

[Ref-15] Hitachi-GE Nuclear Energy, ltd., "Generic Technical Specifications", GA80-1502-0002-00001 (SE-GD-0378) Rev. 3, August 2017.

[Ref-16] Hitachi-GE Nuclear Energy, ltd., "Standard Control Procedure for Identification and Registration of Assumptions, Limits and Conditions for Operation", GA91-0512-0010-00001 (XD-GD-0042) Rev. 2, March 2017.

[Ref-17] Hitachi-GE Nuclear Energy, ltd., "Consideration of Internal Hazard for Spent Fuel Export and Spent Fuel Interim Storage", GA91-9201-0003-00528 (FRE-GD-0055) Rev. 1, May 2016.

[Ref-18] Hitachi-GE Nuclear Energy, ltd., "Consideration of External Hazard for Spent Fuel Export and Spent Fuel Interim Storage", GA91-9201-0003-00527 (FRE-GD-0056) Rev. 1, May 2016.

[Ref-19] Hitachi-GE Nuclear Energy, Ltd. "Topic Report on Safety Requirements for Mechanical SSCs", GA91-9201-0001-00117 (SE-GD-0308) Rev.2, May 2017.

[Ref-20] Hitachi-GE Nuclear Energy, Ltd. "Topic Report on Mechanical SSCs Architecture", GA91-9201-0001-00210 (SE-GD-0425) Rev.1, July 2017.

[Ref-21] Hitachi-GE Nuclear Energy, Ltd. "GDA Safety Case Development Manual", GA10-0511-0006-00001 (XD-GD-0036) Rev.3, June 2017.

[Ref-22] Hitachi-GE Nuclear Energy, Ltd. "Hitachi-GE Strategy on the Design Life of ME SSCs", GA91-9201-0003-00532 (SE-GD-0188) Rev.1, August 2016.

Appendix A. Safety Functional Claims Tables

The SFCs table for each system is provided in the following tables:

(1) SFC for NFIS (Section 19.4),

(2) SFC for FPM (Section 19.5),

(3) SFC for FHM (Section 19.6),

(4) SFC for RBC (Section 19.7),

(5) SFC for interaction between NSCs,

(6) SFC for SFS (Section 19.8),

(7) SFC for FPCMs (Section 19.9), and

(8) SFC for SFE (Section 19.10).

SFC Table for NFIS

	Top Claim for NFIS						Safety Functional Claims for Mechanical System and Components (SFC)		
	Fundamental Safety Function (FSF)		**High Level Safety Function (HLSF)**		**Fault Schedule (Bounding Fault)**				
	PCSR Ch.5 Section 6 Table 5.6-1: High Level Safety Functions in UK ABWR		PCSR Ch.5 Section 6 Table 5.6-1: High level Safety Functions in UK ABWR		Topic Report on Fault Assessment for SFP and Fuel Route [Ref-9]		**State**	**Claim ID**	**Claim Contents**
1	5	Other	5-6	Functions to handle fuel and heavy equipment safely	N/A	Drop of new Fuel Assembly	Normal and Fault conditions	NFIS SFC 5-6.1	The NFIS handles loads safely such that load path integrity is maintained during normal conditions and frequent and infrequent faults within the design basis.

SFC Table for FPM

	Top Claim for FPM						Safety Functional Claim for Mechanical System and Components (SFC)		
	Fundamental Safety Function (FSF)		**High Level Safety Function (HLSF)**		**Fault Schedule (Bounding Fault)**				
	PCSR Ch.5 Section 6 Table 5.6-1: High Level Safety Functions in UK ABWR		PCSR Ch.5 Section 6 Table 5.6-1: High level Safety Functions in UK ABWR		Topic Report on Fault Assessment for SFP and Fuel Route [Ref-9]		**State**	**Claim ID**	**Claim Contents**
1	5	Other	5-6	Functions to handle fuel and heavy equipment safely	14.5 14.6 14.8	Fuel drop Fuel collision Drop of heavy equipment into SFP	Normal and Fault conditions	FPM SFC 5-6.1	The FPM ensures fuel integrity in the event of a dropped load during normal conditions and frequent and infrequent faults within the design basis.
2	5	Other	5-6	Functions to handle fuel and heavy equipment safely	14.9 14.10	Over-raise of irradiated fuel Over-raise of irradiated equipment	Normal and Fault conditions	FPM SFC 5-6.2	The FPM handles irradiated loads suitably submerged so that adequate radiation shielding is provided.

SFC Table for FHM

	Top Claim for FHM						Safety Functional Claim for Mechanical System and Components (SFC)		
	Fundamental Safety Function (FSF)		**High Level Safety Function (HLSF)**		**Fault Schedule (Bounding Fault)**				
	PCSR Ch.5 Section 6 Table 5.6-1: High Level Safety Functions in UK ABWR		PCSR Ch.5 Section 6 Table 5.6-1: High level Safety Functions in UK ABWR		Topic Report on Fault Assessment for SFP and Fuel Route [Ref-9]		**State**	**Claim ID**	**Claim Contents**
1	5	Other	5-6	Functions to handle fuel and heavy equipment safely	14.5 14.6 14.7 14.8	Fuel drop Fuel collision Drop of heavy equipment into the core Drop of heavy equipment into SFP	Normal and Fault conditions	FHM SFC 5-6.1	The FHM, including lifting attachments and lifted items, handles loads safely such that load path integrity is maintained during normal conditions and frequent and infrequent faults within the design basis.
2	5	Other	5-6	Functions to handle fuel and heavy equipment safely	14.9 14.10	Over-raise of irradiated fuel Over-raise of irradiated equipment	Normal and Fault conditions	FHM SFC 5-6.2	The FHM, associated lifting attachments and safety systems handle irradiated loads suitably submerged so that radiation shielding is provided.
3	5	Other	5-6	Functions to handle fuel and heavy equipment safely	-	No Corresponding Fault	Normal Conditions	FHM SFC 5-6.3	FHM handles fuel within the pools system in a subcritical configuration.

SFC Table for RBC

	Top Claim for RBC						Safety Functional Claim for Mechanical System and Components (SFC)		
	Fundamental Safety Function (FSF)		High Level Safety Function (HLSF)		Fault Schedule (Bounding Fault)				
	PCSR Ch.5 Section 6 Table 5.6-1: High Level Safety Functions in UK ABWR		PCSR Ch.5 Section 6 Table 5.6-1: High level Safety Functions in UK ABWR		Topic Report on Fault Assessment for SFP and Fuel Route [Ref-9]		State	Claim ID	Claim Contents
1	5	Other	5-6	Functions to handle fuel and heavy equipment safely	14.7 14.8	Drop of heavy equipment into the core Drop of heavy equipment into SFP	Normal and Fault Conditions	RBC SFC 5-6.1	The RBC, including lifting attachments and lifted items, handles loads safely such that load path integrity is maintained during normal conditions and frequent and infrequent faults within the design basis.
2	5	Other	5-6	Functions to handle fuel and heavy equipment safely	14.10	Over-raise of irradiated equipment	Normal and Fault conditions	RBC SFC 5-6.2	The RBC, associated lifting attachments and safety systems handle irradiated loads suitably submerged so that radiation shielding is provided.

SFC for System Interaction between FPM, FHM and RBC (NSCs)

	Top Claim for FPM, FHM and RBC (NSCs)						Safety Functional Claim for Mechanical System and Components (SFC)		
	Fundamental Safety Function (FSF)		**High Level Safety Function (HLSF)**		**Fault Schedule (Bounding Fault)**				
	PCSR Ch.5 Section 6 Table 5.6-1: High Level Safety Functions in UK ABWR		PCSR Ch.5 Section 6 Table 5.6-1: High level Safety Functions in UK ABWR		Topic Report on Fault Assessment for SFP and Fuel Route [Ref-9]		**State**	**Claim ID**	**Claim Contents**
1	5	Other	5-6	Functions to handle fuel and heavy equipment safely	14.5 14.6 14.7 14.8	Fuel drop Fuel collision Drop of heavy equipment into the core Drop of heavy equipment into the SFP	Normal and Fault Conditions	NSC SFC 5-6.1	The NSCs are designed to prevent a collision between the NSCs or other cranes, resulting from frequent and infrequent faults within the design basis.

SFC for SFS

	Top Claim for SFS						Safety Functional Claim for Mechanical System and Components (SFC)		
	Fundamental Safety Function (FSF)		High Level Safety Function (HLSF)		Fault Schedule (Bounding Fault)				
	PCSR Ch.5 Section 6 Table 5.6-1: High Level Safety Functions in UK ABWR		PCSR Ch.5 Section 6 Table 5.6-1: High level Safety Functions in UK ABWR		Topic Report on Fault Assessment for SFP and Fuel Route [Ref-9]		State	Claim ID	Claim Contents
1	1	Control of Reactivity	1-9	Functions to maintain sub-criticality of spent fuel outside the reactor coolant system	-	No Corresponding Fault	Normal and Fault conditions	SFS SFC 1-9.1	The spent fuel storage racks maintain the Fuel Assemblies in a subcritical state.
2	2	Fuel Cooling	2-4	Function to cool spent fuel outside the reactor coolant system	14.4	Loss of Water inventory	Normal and Fault conditions	SFS SFC 2-4.1	The SFS keeps the Fuel Assemblies submerged in water, and provides cooling to the Fuel Assemblies.
3	4	Confinement/ Containment of radioactive materials	4-7	Functions to confine radioactive materials, shield radiation, and reduce radioactive release	14.4	Loss of Water inventory	Normal and Fault conditions	SFS SFC 4-7.1	The SFP, the Cask Pit, and associated SFP gates are designed to prevent loss of SFP water.
4								SFS SFC 4-7.2	The SFP has sufficient water depth to provide radiation protection to operators working on the Operating Deck.

SFC for FPCMs

	Top Claim for FPCMs						Safety Functional Claim for Mechanical System and Components (SFC)		
	Fundamental Safety Function (FSF)		**High Level Safety Function (HLSF)**		**Fault Schedule (Bounding Fault)**				
	PCSR Ch.5 Section 6 Table 5.6-1: High Level Safety Functions in UK ABWR		PCSR Ch.5 Section 6 Table 5.6-1: High level Safety Functions in UK ABWR		Topic Report on Fault Assessment for SFP and Fuel Route [Ref-9]		**State**	**Claim ID**	**Claim Contents**
1	2	Fuel Cooling	2-4	Function to cool spent fuel outside the reactor coolant system	-	No Corresponding Fault	Normal Conditions	FPC SFC 2-4.1	The FPC removes heat from the SFP and maintains the SFP water temperature within designed values by removing decay heat.
2	2	Fuel Cooling	2-4	Function to cool spent fuel outside the reactor coolant system	-	No Corresponding Fault	Normal Conditions	RHR SFC 2-4.1	The RHR provides the FPC with supplemental cooling to maintain the SFP water temperature within the design values by removing decay heat in the event of a full core offload where the heat load to the pool exceeds the FPC cooling capacity. This function can also be used for recovery from potential upper pools cooling failure and subsequent boiling event.

	Top Claim for FPCMs						Safety Functional Claim for Mechanical System and Components (SFC)		
	Fundamental Safety Function (FSF)		High Level Safety Function (HLSF)		Fault Schedule (Bounding Fault)				
3	2	Fuel Cooling	2-5	Functions to makeup water for spent fuel pool	14.1 14.2 14.3 14.4	Loss of Decay heat removal LOOP (loss of off-site power) Station Blackout (SBO): LOOP with failure of the Emergency Diesel Generators (EDGs) Loss of Water inventory	Fault Conditions	FPC SFC 2-5.1	The SPCU, MUWC or FP, which systems are for normal operating function, will be utilised to supply water to the SFP, if available.
4	2	Fuel Cooling	2-5	Functions to make-up water for spent fuel pool	1 2 3	Failure of two FPC pumps (loss of FPC cooling) Loss of off-site power Small leakage from SFP pool lining	Fault Conditions	FLSS SFC 2-5.1	In the eventuality that the cooling function for the SFP is unavailable or small leakage from the SFP occurs, the FLSS supplies sufficient water to maintain the water level of the SFP as a secondary means of cooling the spent fuel stored in the SFP.
5	2	Fuel Cooling	2-5	Functions to make-up water for spent fuel pool	-	Severe Accidents	Beyond Design Basis Conditions	FLSS SFC 2-5.2	The FLSS is the principal means to provide SFP with makeup water to mitigate significant damage to the spent fuel due to potential long term SBO and subsequent loss of SFP cooling function in the event of beyond design basis faults or severe accidents.
6	2	Fuel Cooling	2-5	Functions to make-up water for spent fuel pool	-	Severe Accidents	Beyond Design Basis Conditions	FLSS SFC 2-5.3	The FLSS is the principal means to provide SFP with spray water to mitigate significant damage to the spent fuel due to loss of the fuel pool water resulting from loss of makeup water or a large leakage from the SFP in the event of beyond design basis faults or severe accidents.

	Top Claim for FPCMs						Safety Functional Claim for Mechanical System and Components (SFC)		
	Fundamental Safety Function (FSF)		High Level Safety Function (HLSF)		Fault Schedule (Bounding Fault)				
7	2	Fuel Cooling	2-5	Functions to make-up water for spent fuel pool	-	Severe Accidents	Beyond Design Basis Conditions	FLSR SFC 2-5.1	The FLSR is a secondary means to provide SFP with makeup water as a backup of the FLSS in the event of design basis faults and beyond design basis faults or severe accidents.
8	2	Fuel Cooling	2-5	Functions to make-up water for spent fuel pool	-	Severe Accidents	Beyond Design Basis Conditions	FLSR SFC 2-5.2	The FLSR is a secondary means to provide SFP with spray water to mitigate significant damage to the spent fuel due to loss of the fuel pool water resulting from loss of makeup water or a large leakage from the SFP as a backup of the FLSS in the event of beyond design basis faults or severe accidents.
9	4	Confinement/Containment of radioactive materials	4-4	Functions to contain radioactive material	-	No Corresponding Fault	Normal Conditions	FPC SFC 4-4.1	The FPC pipework contains radioactive liquid. A loss of containment of this piping could lead to a release of radioactive material; however, due to the predicted source term the operator dose is likely to be relatively low.
10	4	Confinement/Containment of radioactive materials	4-7	Functions to confine radioactive materials, shield radiation, and reduce radioactive release	14.4	Loss of Water inventory	Normal and Fault Conditions	FPC SFC 4-7.1	The check valves and syphon break system prevent potential syphoning from the SFP and subsequent spent fuel exposure in the SFP.

	Top Claim for FPCMs						Safety Functional Claim for Mechanical System and Components (SFC)		
	Fundamental Safety Function (FSF)		High Level Safety Function (HLSF)		Fault Schedule (Bounding Fault)				
11	5	Others	5-9	Functions to clean up water except for reactor coolant	-	No Corresponding Fault	Normal Conditions	FPC SFC 5-9.1	The FPC maintains the quality of the water in the pool to conform the quality requirements by removing the following impurities: • Impurities mixed into the pool from air • Impurities brought into the pool with the fuel or components on which the impurities adhere to • Corrosion and fission products from the core during refuelling • Mixing material during refuelling and other operations • Residual chemicals used for cleaning or flushing water after pool cleaning

SFC for SFE

	Top Claim for SFE						Safety Functional Claim for Mechanical System and Components (SFC)		
	Fundamental Safety Function (FSF)		**High Level Safety Function (HLSF)**		**Fault Schedule (Bounding Fault)**				
	PCSR Ch.5 Section 6 Table 5.6-1: High Level Safety Functions in UK ABWR		PCSR Ch.5 Section 6 Table 5.6-1: High level Safety Functions in UK ABWR		Consideration of Fault for SFE and SFIS [Ref-10]		**State**	**Claim ID**	**Claim Contents**
1	1	Control of Reactivity	1-10	Functions to maintain sub-criticality of spent fuel during processes of spent fuel removal from Cask Pit to storage area and during interim storage period	All	All SFE Faults	Normal and Fault conditions	SFE SFC 1-10.1	Fuel remains in a subcritical condition during operations under normal and fault conditions

							Top Claim for SFE			
	Fundamental Safety Function (FSF)		High Level Safety Function (HLSF)		Fault Schedule (Bounding Fault)		Safety Functional Claim for Mechanical System and Components (SFC)		
	PCSR Ch.5 Section 6 Table 5.6-1: High Level Safety Functions in UK ABWR		PCSR Ch.5 Section 6 Table 5.6-1: High level Safety Functions in UK ABWR		Consideration of Fault for SFE and SFIS [Ref-10]		State	Claim ID	Claim Contents
2	2	Fuel Cooling	2-6	Functions to maintain spent fuel temperature during processes of spent fuel removal from Cask Pit to storage area and during interim storage period	1.1 1.3 1.4 Group 6	LOOP during loaded Canister preparation Failure of Canister Cooling System during preparation / Mis-operation of Canister Cooling System Drying and Pressurisation System temperature control fault / mis-operation and malfunction of drying device or back filling device Misloading Fault	Normal and Fault conditions	SFE 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 unsealed canister SFE operations and associated fault conditions
3	2	Fuel Cooling	2-6	Functions to maintain spent fuel temperature during processes of spent fuel removal from Cask Pit to storage area and during interim	1.2 3.1 3.2	Inert gas leakage after sealing Dropped sealed Canister/Transfer Cask from the RBC onto the ground floor Dropped and toppled sealed Canister/Transfer Cask from RBC on the	Normal and Fault conditions	SFE SFC 2-6.2	Temperature of spent fuel will be maintained within specified limits such that fuel clad does not fail due to overheating during sealed SFE operations and associated fault conditions.

Top Claim for SFE			Safety Functional Claim for Mechanical System and Components (SFC)		
Fundamental Safety Function (FSF)	**High Level Safety Function (HLSF)**	**Fault Schedule (Bounding Fault)**			
PCSR Ch.5 Section 6 Table 5.6-1: High Level Safety Functions in UK ABWR	PCSR Ch.5 Section 6 Table 5.6-1: High level Safety Functions in UK ABWR	Consideration of Fault for SFE and SFIS [Ref-10]	**State**	**Claim ID**	**Claim Contents**
	storage period	Operating Deck 3.3 Sealed Canister/Transfer Cask collision into wall or SSCs/hangman's drop 3.4 Sealed Canister/Transfer Cask/concrete overpack collision by the Cask transporter 3.7 Dropped sealed Canister/Transfer Cask from reactor building crane into the Cask Pit/onto the Cask stand 6.3 Thermal misload			

	Top Claim for SFE						Safety Functional Claim for Mechanical System and Components (SFC)		
	Fundamental Safety Function (FSF)		High Level Safety Function (HLSF)		Fault Schedule (Bounding Fault)				
	PCSR Ch.5 Section 6 Table 5.6-1: High Level Safety Functions in UK ABWR		PCSR Ch.5 Section 6 Table 5.6-1: High level Safety Functions in UK ABWR		Consideration of Fault for SFE and SFIS [Ref-10]		State	Claim ID	Claim Contents
4	4	Confinement/ Containment of radioactive materials	4-14	Functions to provide containment barrier during processes of spent fuel removal from Cask Pit to storage area and during interim storage period	1.1 1.2 1.3 1.4 Group 2 5.1 Group 6	LOOP during loaded Canister preparation Inert gas leakage Failure of Canister Cooling System during preparation/Mis-operation of Canister Cooling System Drying a Pressurisation System temperature control fault/Mis-operation and malfunction of drying device or back filling device Impact load to unsealed Canister /Cask Dropped Fuel Assembly onto fuel basket/Canister Fuel Misload	Normal and Fault conditions	SFE SFC 4-14.1	Containment function will be maintained during SFE unsealed_Canister operations and associated fault conditions.

	Top Claim for SFE						Safety Functional Claim for Mechanical System and Components (SFC)		
	Fundamental Safety Function (FSF)		**High Level Safety Function (HLSF)**		**Fault Schedule (Bounding Fault)**				
	PCSR Ch.5 Section 6 Table 5.6-1: High Level Safety Functions in UK ABWR		PCSR Ch.5 Section 6 Table 5.6-1: High level Safety Functions in UK ABWR		Consideration of Fault for SFE and SFIS [Ref-10]		**State**	**Claim ID**	**Claim Contents**
5	4	Confinement/ Containment of radioactive materials	4-14	Functions to provide containment barrier during processes of spent fuel removal from Cask Pit to storage area and during interim storage period	1.2 3.1 3.2 3.3 3.4 3.7 Group 6	Inert gas leakage Dropped sealed Canister/Transfer Cask from the RBC onto the ground floor Dropped and toppled sealed Canister/Transfer Cask from RBC on the Operating Deck Sealed Canister/Transfer Cask collision into wall or SSCs/hangman's drop Sealed Canister/Transfer Cask/concrete overpack collision by the Cask transporter Dropped sealed Canister/Transfer Cask from reactor building crane into the Cask Pit/onto the Cask stand Fuel misload	Normal and Fault conditions	SFE SFC 4-14.2	Containment function will be maintained during SFE sealed canister operations and associated fault conditions.

	Top Claim for SFE						Safety Functional Claim for Mechanical System and Components (SFC)		
	Fundamental Safety Function (FSF)		High Level Safety Function (HLSF)		Fault Schedule (Bounding Fault)				
	PCSR Ch.5 Section 6 Table 5.6-1: High Level Safety Functions in UK ABWR		PCSR Ch.5 Section 6 Table 5.6-1: High level Safety Functions in UK ABWR		Consideration of Fault for SFE and SFIS [Ref-10]		State	Claim ID	Claim Contents
6	4	Confinement/ Containment of radioactive materials	4-16	Functions to provide radiation shielding during processes of spent fuel removal from Cask Pit to storage area and during interim storage period	All	All SFE Faults	Normal and Fault conditions	SFE SFC 4-16.1	Shielding from spent fuel will reduce dose to operators and public ALARP during normal SFE operations and associated fault conditions.

	Top Claim for SFE						Safety Functional Claim for Mechanical System and Components (SFC)		
	Fundamental Safety Function (FSF)		High Level Safety Function (HLSF)		Fault Schedule (Bounding Fault)				
	PCSR Ch.5 Section 6 Table 5.6-1: High Level Safety Functions in UK ABWR		PCSR Ch.5 Section 6 Table 5.6-1: High level Safety Functions in UK ABWR		Consideration of Fault for SFE and SFIS [Ref-10]		State	Claim ID	Claim Contents
7	5	Others	5-16	Functions to provide handling and retrievability during processes of spent fuel removal from Cask Pit to storage area and during interim storage period	2.1 2.3 2.4	Canister lid dropped onto Canister/Damage to fuel during lid placement Dropped and toppled unsealed Canister/Transfer Cask from overhead crane on the operating level/unsealed Canister/Transfer Cask collision to other structures/hangman's drop Dropped unsealed Canister/Transfer Cask from overhead crane into the Cask Pit	Normal and Fault conditions	SFE SFC 5-16.1	Handling of spent fuel within canister shall not compromise other safety functional claims and the spent fuel and casks shall remain retrievable during normal operation and following frequent faults.

Top Claim for SFE			Safety Functional Claim for Mechanical System and Components (SFC)		
Fundamental Safety Function (FSF)	**High Level Safety Function (HLSF)**	**Fault Schedule (Bounding Fault)**			
PCSR Ch.5 Section 6 Table 5.6-1: High Level Safety Functions in UK ABWR	PCSR Ch.5 Section 6 Table 5.6-1: High level Safety Functions in UK ABWR	Consideration of Fault for SFE and SFIS [Ref-10]	**State**	**Claim ID**	**Claim Contents**
		3.1 Dropped Sealed Canister/Transfer Cask from the overhead crane onto the ground floor (Bounds a dropped sealed Canister/transfer cask from the overhead crane into the preparation pit) 3.2 Dropped and toppled sealed Canister/Transfer Cask from overhead crane on the Operating Deck 3.3 Sealed Canister/transfer cask collision into preparation pit wall and hoist well/collision into SSCs/hangman's drop 3.4 Sealed Canister/concrete overpack/Transfer Cask collision by the Cask transporter crush or tilt			

	Top Claim for SFE						Safety Functional Claim for Mechanical System and Components (SFC)		
	Fundamental Safety Function (FSF)		High Level Safety Function (HLSF)		Fault Schedule (Bounding Fault)				
	PCSR Ch.5 Section 6 Table 5.6-1: High Level Safety Functions in UK ABWR		PCSR Ch.5 Section 6 Table 5.6-1: High level Safety Functions in UK ABWR		Consideration of Fault for SFE and SFIS [Ref-10]		State	Claim ID	Claim Contents
					3.5	Dropped sealed Canister/concrete overpack from the Cask transporter during Cask transfer/Dropped sealed Canister/Transfer Cask from the Cask transporter during Cask transport			
					3.7	Dropped sealed Canister/Transfer Cask from reactor building crane into the Cask Pit/onto the Cask stand			
					5.1	Dropped Fuel Assembly onto fuel basket/Canister			
					Group 6	Fuel misload			

	Top Claim for SFE						Safety Functional Claim for Mechanical System and Components (SFC)		
	Fundamental Safety Function (FSF)		High Level Safety Function (HLSF)		Fault Schedule (Bounding Fault)				
	PCSR Ch.5 Section 6 Table 5.6-1: High Level Safety Functions in UK ABWR		PCSR Ch.5 Section 6 Table 5.6-1: High level Safety Functions in UK ABWR		Consideration of Fault for SFE and SFIS [Ref-10]		State	Claim ID	Claim Contents
8			5-22	Function to limit deceleration loading to Canister containment boundary during credible Cask drop faults	Group 3	Impact load to sealed Canister /Cask	Fault conditions	SFE SFC 5-22.1	Canister deceleration during design basis drop faults shall remain below allowable limits.

Appendix B. Safety Properties Claims Tables

The safety properties claims defined for mechanical systems are shown in the following table.

SPCs for Mechanical Systems

	SPC	Safety Properties Claims (SPC) Contents	SCDM SPC Guide word
1	ME SPC1	Design provision against Single Failure Mechanical systems and their support systems are designed with redundancy against single failure of any dynamic component under the worst permissible system availability state so that single failure does not prevent the delivery of the corresponding safety functions.	• Fault Tolerance • Reliability
2	ME SPC2	Design provision against Common Cause Failure Mechanical systems are designed with independence between redundant components so that the failure of one dynamic redundant component does not lead to a common cause failure that could prevent the delivery of the corresponding safety functions.	• Defence in Depth • Reliability
3	ME SPC3	Design provision against System Interfaces The mechanical interfaces between SSCs of different safety classes inside a mechanical system or between several systems are designed such that failure in a lower class item will not propagate to higher safety class items and jeopardise the delivery of the corresponding safety functions.	• Defence in Depth • Reliability
4	ME SPC4	Internal Hazards Protection Mechanical SSCs are protected or designed to withstand the effects of the following internal hazards so that they do not affect the delivery of the corresponding safety functions: (1) Internal flooding (2)Internal fire and explosion (3) Internal missiles (4)Dropped and collapsed loads (5) Pipe whip and jet impact (6)Internal blast (7) Electromagnetic Interference (EMI) (8)Miscellaneous hazards	• Fault Tolerance • Reliability
5	ME SPC5	External Hazards protection Mechanical SSCs are protected or designed to withstand the effects of the external hazards (Earthquakes, Loss of Offsite Power (LOOP)) so that they do not affect the delivery of the corresponding safety functions.	• Fault Tolerance • Reliability
6	ME SPC6	Automation Mechanical systems are designed so that no human intervention is necessary for approximately 30 minutes following the start of the requirement for the safety function.	• Human Factors • Reliability
7	ME SPC7	Qualification Provision Mechanical SSCs are capable to deliver their safety functions under the associated operational and environmental conditions throughout their operational life.	• Qualification • Life Cycle • Reliability
8	ME SPC8	EMIT(Examination, Maintenance, Inspection and Test) Mechanical SSCs are designed with the capability for being tested, maintained, and monitored during power operation and/or refuelling outages in order to ensure the capability to deliver the safety functions claimed without compromising their availability throughout their operational life.	• Life Cycle • Reliability • Layout and Accessibility • Radiation Protection
9	ME SPC9	Codes and Standards Mechanical components are designed manufactured, constructed, installed, commissioned, quality assured, maintained, tested and inspected according to codes and standards commensurate to their Safety Class.	• Relevant Good Practice • Reliability

Note: the ME SPCs are derived based on the guide word approach as described in Generic PCSR Chapter 5, Section 5.3 'General Safety Design Bases'.

A specific SPC has been defined for the NSCs (NSC SPC 10) such that these can be safely recovered after the activation of a safety measure [Ref-4].

The safety properties claims table of each system described in this Chapter is provided in the following table.

SPC Table of Systems in Chapter 19

	Safety Cat. & Class	ME SPC1	ME SPC2	ME SPC3	ME SPC4	ME SPC5	ME SPC6	ME SPC7	ME SPC8	ME SPC9	NSC SPC10
		Design provision against Single Failure	Design provision against Common Cause Failure	Design provision against System Interfaces	Internal Hazards Protection	External Hazards protection	Automation	Qualification Provision	EMIT	Codes and Standards	Recovery
NFIS	C3					X	X	X	X	X	X
FPM	A1	X	X	X	X	X	X	X	X	X	X
FHM	A1	X	X	X	X	X	X	X	X	X	X
RBC	A1	X	X	X	X	X	X	X	X	X	X
SFS	A1			X	X	X		X	X	X	
FPC	A1	X	X	X	X	X	X	X	X	X	
Transfer Cask	A1			X		X		X	X	X	X
Impact Limiter	A1			X		X		X	X	X	
Canister Containment Boundary	A1	X	X	X		X		X	X	X	X
Canister Basket	A1			X		X		X	X	X	
Canister Drying and Pressurisation System	C3			X		X	X	X	X	X	
OTPS for Canister Dyring	A1			X		X	X	X	X	X	
CCS	A1	(*)	(*)X	X	X	X		X	X	X	
BCCS	A2	(*)X	(*)	X	X	X		X	X	X	
LPT	B2			X		X		X	X	X	
Cask Stand	A2			X		X		X	X	X	

(*: The BCCS provides redundancy and diversity to the CCS)

Appendix C. Document Map

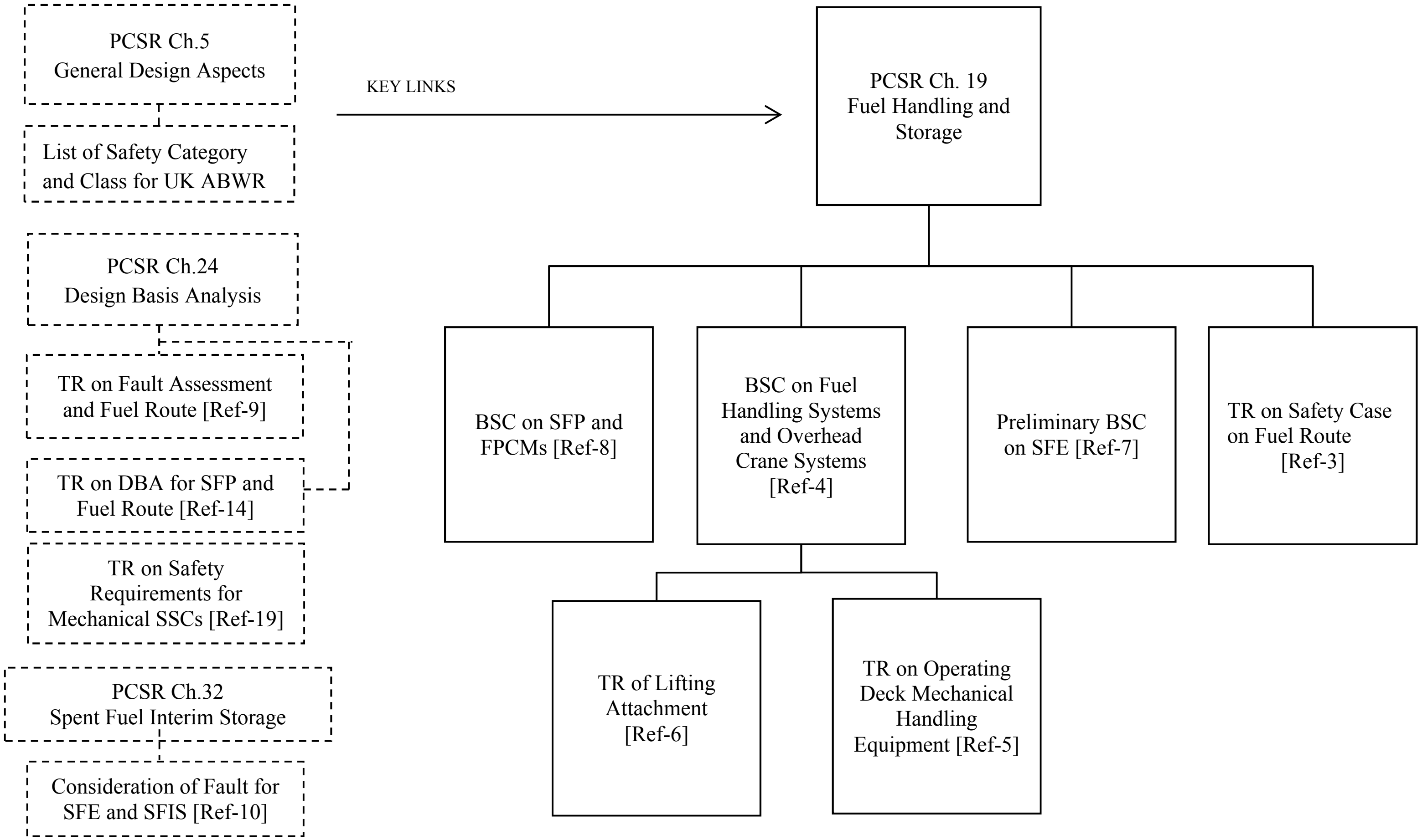

Figure C-1: Document Map of Supporting References