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UK HPR1000 GDA Project

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Pre-Construction Safety Report

Chapter 29

Interim Storage of Spent Fuel

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10.1 List of Abbreviations and Acronyms

ALARP	As Low As Reasonably Practicable
BFX	Fuel Building
CGN	China General Nuclear Power Cooperation
DMK	Fuel Building Handling Equipment [FBHE]
EMIT	Examination, Maintenance, Inspection and Testing
EDG	Emergency Diesel Generator
GDA	Generic Design Assessment
GDF	Geological Disposal Facility
GNS	General Nuclear System Limited
HPR1000	Hua-long Pressurised Reactor
LLW	Low Level Waste
NPP	Nuclear Power Plant
ONR	Office for Nuclear Regulation (UK)
PMC	Fuel Handling and Storage System [FHSS]
PTR	Fuel Pool Cooling and Treatment System [FPCTS]
RGP	Relevant Good Practice
RPV	Reactor Pressure Vessel
RWM	Radioactive Waste Management Ltd (UK)
SAP	Safety Assessment Principle (UK)
SFA	Spent Fuel Assembly
SFIS	Spent Fuel Interim Storage
SFP	Spent Fuel Pool
SFRR	Spent Fuel Retrieval and Repackaging
SSC	Systems, Structures and Components
SSER	Safety, Security, Environment Report
TAG	Technical Assessment Guide (UK)
UK HPR1000	The UK version of the Hua-long Pressurised Reactor

VLLW Very Low Level Waste

System codes (XXX) and system abbreviations (YYY) are provided for completeness in the format (XXX [YYY]), e.g. Fuel Building Handling Equipment (DMK [FBHE]).

10.2 Introduction

10.2.1 Overview

The Hua-long Pressurised Reactor (HPR1000) operating in China is designed according to the domestic policy of China. There are currently no Chinese regulations or codes relevant to new pressurised water reactors for on-site Spent Fuel Interim Storage (SFIS) Systems and Buildings. According to the HPR1000 spent fuel storage strategy, the Spent Fuel Assembly (SFA) is removed from the reactor and temporarily stored in the Spent Fuel Pool (SFP) of the Fuel Building (BFX). The total storage capacity of the underwater spent fuel storage racks in the SFP is enough for roughly 11 refuelling cycles, plus a full core for emergency unloading.

The UK Government has concluded that any new nuclear power station that might be built in the UK should be proceed on the basis that SFAs will not be reprocessed and that plans for, and financing of, waste management should be developed, Reference [1]. In the UK version of the Hua-long Pressurised Reactor (UK HPR1000), management arrangements for the SFAs arising from the full projected life of the nuclear power plant are required to be identified by the Requesting Parties taking into account existing and planned off-site facilities for ultimate spent fuel storage.

A Geological Disposal Facility (GDF), coupled with safe and secure interim storage was recommended by the Radioactive Waste Management Ltd (RWM) as the best available approach for the long-term management of SFAs. No GDF is currently available in the UK and it is estimated that the SFAs have to be stored on-site until the GDF is available for disposal of SFAs, Reference [2].

The UK HPR1000 is expected to be operated for 60 years and, therefore, a solution for spent fuel storage management (i.e. on-site spent fuel interim storage) is required prior to the GDF being available for the UK HPR1000 reactor. This chapter represents the current position of spent fuel interim storage for the UK HPR1000.

F-10.2-1 provides an overview of the UK HPR1000 spent fuel storage strategy.

The spent fuel storage strategy for the UK HPR1000 is divided to three phases:

a) Short Term Storage in the SFP

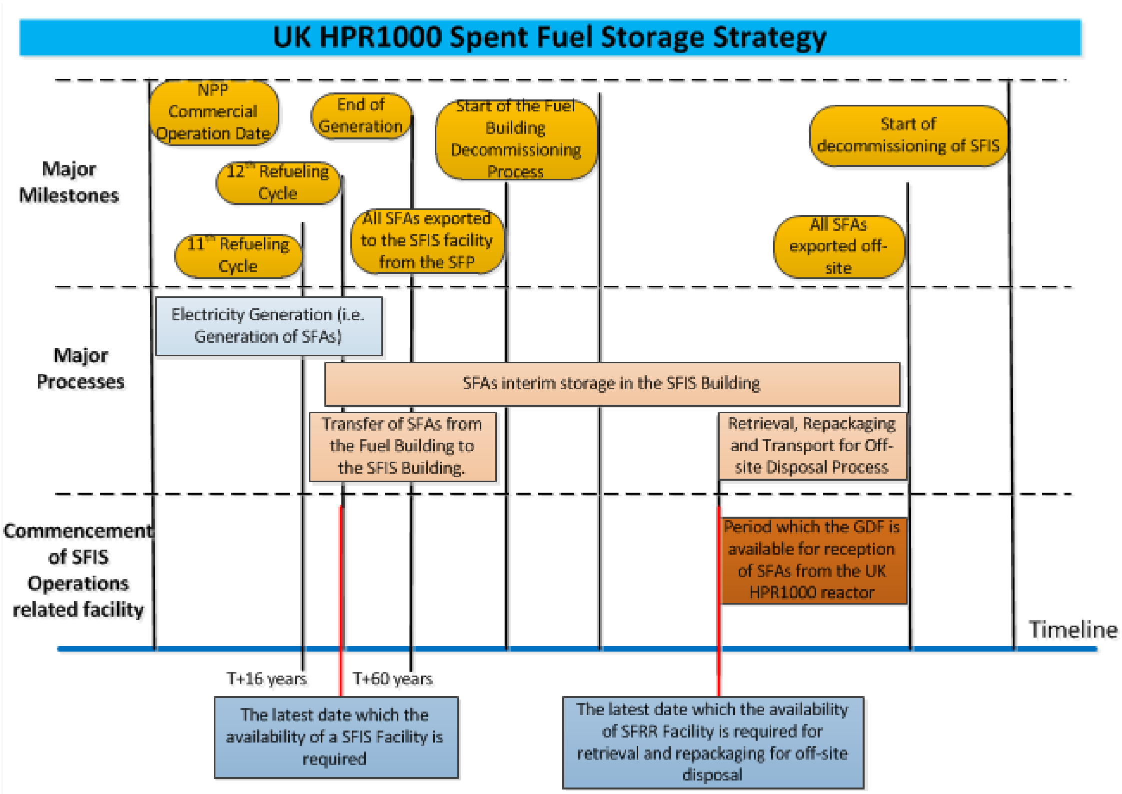
The spent fuels removed directly from the core are first stored in the spent fuel pool for several years. PCSR Chapter 28 describes the storage of SFAs in the SFP following refuelling operations, as part of fuel handling and storage operations.

However, the SFA cooling period in the SFP has knock-on effects on the design criteria of the SFIS Systems and Building. For example, the minimum storage period of the SFAs may affect the potential spent fuel cask cooling system, and the maximum number of SFAs to be stored in the spent fuel cask may affect the dose received by operators and the public during normal operations, as well as the design basis fault and hazard events.

The SFP has the capability to store a maximum of 1020 SFAs. The design of the SFP is required to accommodate a full core emergency unload, which accounts to 177 fuel assemblies, this leads to availability of 843 fuel assembly spaces. A SFIS facility will be required by the 12th refuelling cycle with an average number of 72 SFAs generated from a refuelling cycle.

b) Interim Storage On-site

The SFAs will be transferred into a transportation cask/canister and moved into a SFIS facility for storage prior to retrieval and repackaging for off-site disposal.



F-10.2-1 UK HPR1000 Spent Fuel Storage Strategy

c) Off-site Disposal in the GDF

Currently, there is no final disposal facility in the UK. In order to ensure that the SFAs can be safely disposed of in all potential scenarios, the UK HPR1000 storage facility shall consider the retrieval of SFAs from the spent fuel casks. When the GDF is available to receive SFAs from the UK HPR1000, the SFAs will be repackaged into an appropriate disposal canister depending on the final disposal facility and transportation requirements.

For spent fuel relevant non-fuel wastes and other higher activity waste, the waste characterisation and management strategy will be presented in PCER Chapter 4, in Reference [3].

10.2.2 Chapter Route Map

The objectives of this chapter are consistent with the GDA scope, in Reference [4], as follows:

a) Present a suitable approach to demonstrate that the potential spent fuel storage technology is capable of reducing the risk to a level that is As Low As Reasonably Practicable (ALARP).

b) Demonstrate that SFIS technology can be selected properly, and potential suitable SFIS options have been considered adequately for the UK HPR1000.

The safety route map of PCSR Chapter 29 is developed to support Claim 3.3.13 *The Spent Fuel Interim Storage process, and design of the associated systems, will be substantiated*, considering the current GDA scope, in Reference [4]. The safety route map of PCSR Chapter 29 is a part of the overall route map to support UK HPR1000 design and is in accordance with the safety case considerations of the UK HPR1000 presented in PCSR Chapter 1. Therefore, the claims development will be consistent with the overall route map arrangement of the project.

The analysis of Safety Assessment Principle (SAP) and Technical Assessment Guide (TAG), the GDA scope for SFIS and the experience of spent fuel interim storage facility design are also considered in the Claims, Arguments and Evidence (C-A-E) structure.

Claim 3: The design and intended construction and operation of the UK HPR1000 will protect the workers and the public by providing multiple levels of defence to fulfil the fundamental safety functions, reducing the nuclear safety risks to a level that is as low as reasonably practicable.

Claim 3.3: The design of the processes and systems has been substantiated and the safety aspects of operation and management have been substantiated.

Claim 3.3.13: The Spent Fuel Interim Storage process, and design of the associated systems, will be substantiated.

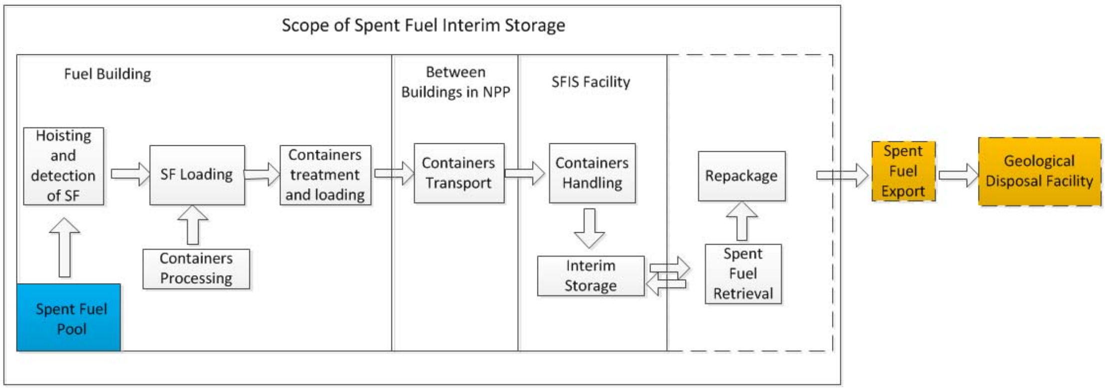
According to reference [5] (Section 5.1, page 4), the trail from safety claims through arguments to evidence should be clearly set out in the safety case. A route map for Chapter 29 is identified in this sub-chapter and is presented in Appendix A. This route map is intending to set out a "direction of moving forward" in Chapter 29.

The mapping of the PCSR chapter 29 content and corresponding C-A-E structures against the SFIS relevant SAPs will be presented in the relevant support documents, in Reference [6].

10.2.3 Scope of Spent Fuel Interim Storage

On-site fuel cycle is a process containing the entire life cycle of nuclear fuel within the nuclear licensed site boundary, that is, from the receipt of new fuel to retrieval and repackaging of SFAs for off-site disposal.

The scope of this chapter is limited to SFIS operations as a part of the on-site fuel cycle presented in F-10.2-2. The storage in the spent fuel pond (in blue) is presented in PCSR Chapter 28. And the design for spent fuel export and final disposal (in yellow) is not included within GDA.



F-10.2-2 Scope of Spent Fuel Interim Storage

Therefore, SFIS operations are defined as:

Starting point: Movement of the SFIS SSCs (e.g. empty spent fuel cask, processing equipment, and transporter) from their storage locations to the designated location in the BFX and SFIS facilities.

End point: Retrieval and repackaging of SFAs for off-site disposal. The spent fuel export from the station and transportation to the final geological disposal facility is not included in this scope.

For spent fuel retrieval and repackaging, the fuel building, the SFIS facility or a specific retrieval and repackaging facility can be the potential location for the operations, which is determined by the SFIS technology adopted. And the repackaging of the spent fuel within the site is considered to meet with the requirements of exporting from the site or final disposal, which will be determined according to the acceptance criteria of the final disposal facility and the following interaction with regulators and relevant organisations.

The SFIS technology has not been decided for the UK HPR1000. A proposal for safe and secure management of SFAs over the plant life cycle of the UK HPR1000 is considered necessary, acknowledging that the level of the information detail required may vary according to the significance of each aspect of the GDA, in Reference [7].

According to the current understanding of UK context, the GDA scope for SFIS is limited and high level, and only seeks to demonstrate that a future site-specific solution is able to be demonstrated as BAT and ALARP in the future, but this is not to be demonstrated during GDA. Any information remains independent of vendor specific details. Transport of Spent Fuel from the site to a long term UK storage facility is outside the scope of GDA. Design information for the facility itself will not be provided. The GDA scope for SFIS is detailed in Reference [4].

Fuel Handling & Storage operations are presented in PCSR Chapter 28 covering the refuelling process, new fuel receipt and the entire length of storage in the SFP. The failed fuel will be firstly stored in the SFP and relevant design considerations have also been presented in PCSR Chapter 28.

The Spent Fuel Retrieval and Repackaging (SFRR) facility provides SFA retrieval capability following the decommissioning of the BFX Building and repackaging of SFAs prior to off-site disposal. However, depending on the preferred SFIS technology chosen, the retrieval capability could be incorporated into the SFIS facility, which avoids the need for a separate SFRR facility. This decision will be made by the future site licensee at an appropriate stage and the requirements for SFRR may have little impact on rest of the plant design.

The GDA scope of SFIS to include and exclude the information of SFIS provided during the GDA phase is presented in Reference [4].

10.2.4 Chapter Structure

The structure of this chapter is as follows:

Sub-chapter 1: provide a list of abbreviations and acronyms.

Sub-chapter 2: present the introduction to this chapter including the scope of SFIS, chapter route map, interfaces with other chapters, and key assumptions.

Sub-chapter 3: present the spent fuel storage strategy for the UK HPR1000.

Sub-chapter 4: present an overview of SFIS operations and the relevant Systems, Structure and Components (SSC).

Sub-chapter 5: present the preliminary ALARP assessment on the SFIS operations with the focus on identification of gaps on the basis of RGP.

Sub-chapter 6: present the requirements to be considered in selecting the preferred SFIS technology.

Sub-chapter 7: present the current SFIS technology options and preliminary assessments against the requirements.

Sub-chapter 8: present the principles that underpin the optioneering process to select a preferred SFIS technology.

Sub-chapter 9: present the conclusions.

Sub-chapter 10: present the references.

10.2.5 Interfaces with other Chapters

The interfaces with other Chapters are listed in the following table.

T-10.2-1 Interfaces between Chapter 29 and Other Chapters

Chapter	Interfaces
PCSR Chapter 1 Introduction	PCSR Chapter 1 defines the claims that PCSR Chapter 29 should consider and support. PCSR Chapter 29 identifies the high level safety functions that must be maintained by the SFIS facility.
PCSR Chapter 2 General Plant Description	PCSR Chapter 2 gives a brief introduction to the spent fuel interim storage.
PCSR Chapter 3 Generic Site Characteristics	PCSR Chapter 3 provides generic site characteristics for Spent Fuel Interim Storage presented in Chapter 29.
PCSR Chapter 4 General Safety and Design Principles	PCSR Chapter 4 covers the UK HPR1000 safety and design principles to be applied to the design of SFIS operations.
PCSR Chapter 5 Reactor Core	PCSR Chapter 5 covers the fuel assembly design parameters and operation information, including size, weight, quantity, etc., which serves as a key input to spent fuel disposability assessment and SFIS facility capacity evaluation.
PCSR Chapter 10 Auxiliary System	PCSR Chapter 10 covers the safety case for supporting systems involved in the SFIS operations in the BFX Building.
PCSR Chapter 16 Civil Engineering	PCSR Chapter 16 covers the general description of the BFX building, which is one of the buildings included in the SFIS operation.
PCSR Chapter 20 MSQA and Safety Case Management	PCSR Chapter 20 presents the organisational arrangements and quality assurance arrangements implemented in the production of PCSR Chapter 29.
PCSR Chapter 22	PCSR Chapter 22 covers the general radiation

Chapter	Interfaces
Radiological Protection	protection measures against direct radiation and radioactive contamination which is considered in SFIS operation.
PCSR Chapter 24 Decommissioning	PCSR Chapter 24 covers decommissioning for SFIS operations, considering the SFIS design lifetime.
PCSR Chapter 28 Fuel Handling and Storage	PCSR Chapter 28 covers the Fuel Handling and Storage System (PMC [FHSS]), including the transfer of SFAs in the BFX from the SFP to a transfer cask for delivery, which is the foregoing work for SFIS.
PCSR Chapter 33 ALARP Evaluation	The ALARP approach presented in Chapter 33 covers the ALARP approach adopted for the work included in PCSR Chapter 29, which supports the overall ALARP demonstration addressed in Chapter 33.

10.2.6 Key Assumptions

In order to develop an adequate case during GDA, the following assumptions for SFIS have been made, which are not final design decisions. The assumptions could be modified as the GDA phase progresses. The key assumptions for SFIS include:

a) The SFIS facility receives the spent fuel, including the failed fuel, produced from 2 units of the UK HPR1000 and the siting consideration of the facility will be based on this;

b) The lifetime of the SFIS facility is now assumed to be 100 years;

c) The spent fuel, after interim storage, is planned for transport out of the plant for geological disposal, instead of reprocessing;

d) The funded decommissioning programme, in Reference [8], defines a set of generic lifecycle assumptions for new nuclear power stations, known as the “Base Case”. The consistency of the UK HPR1000 situation with the “Base Case” has already been analysed in the response to RQ-UKHPR1000-0045. The “Base Case” will also be considered during the GDA.

10.3 Applicable Codes and Standards

For spent fuel interim storage, the following policies and regulations concerning the nuclear power plant, radiation protection and radioactive waste management in the UK serve as the reference for relevant work:

a) The Health and Safety at Work Act, 1974;

b) The Nuclear Installations Act 1965;

c) The Ionising Radiations Regulations 2017;

d) Hazardous Waste Regulations 2005;

e) The Environmental Permitting (England and Wales) Regulations 2016;

f) The Environment Act 1995;

g) UK Strategy for Radioactive Discharges 2011-2020;

h) Review of radioactive waste management policy: Final Conclusions;

i) Policy for the Long Term Management of Solid Low Level Radioactive Waste in the United Kingdom.

When considering the applicable codes and standards for SFIS, the standards applied for the engineering substantiation include:

a) Internationally recognised in nuclear industry;

b) The latest or currently applicable approved standards; and

c) Consistent with the plant reliability goals necessary for safety.

Where codes and standards are used as design rules, they must be identified and evaluated to determine their applicability, adequacy and sufficiency. UK context specific expectations and RGP have been taken into account in the Standards selection process. The methodology and principles are presented in the PCSR Chapter 4.

According to the principles in the project, the analysis of codes and standards is conducted, in Reference [9], on the basis of UK, WENRA and IAEA relevant documents. As a result of the analysis, the following codes and standards relevant to SFIS are applied in Chapter 29.

a) IAEA Safety Standards – Storage of Spent Nuclear Fuel (SSG-15), in Reference [10];

b) Industry Guidance. Interim Storage of Higher Activity Waste Packages – Integrated Approach, in Reference[11];

c) The Management of Higher Activity Radioactive Waste on Nuclear Licensed Sites, in Reference [12];

d) Waste and Spent Fuel Storage Safety Reference Levels Report, in Reference [13];

e) Funded Decommissioning Programme Guidance for New Nuclear Power Stations, in Reference [8];

f) Design of Fuel Handling and Storage Systems in Nuclear Power Plants (NS-G-1.4), in Reference [14];

g) Core Management and Fuel Handling for Nuclear Power Plants Safety Guide

(NS-G-2.5), in Reference [15];

h) Safety of Nuclear Fuel Cycle Facilities (SSR-4), in Reference [16].

Regulatory expectation, such as SAPs in Reference [17], and TAGs in Reference [18], will also be considered to guide the safety case in the UK HP1000 GDA phase.

10.4 Spent Fuel Interim Storage Operations Overview

10.4.1 Overview of Spent Fuel Interim Storage Operations

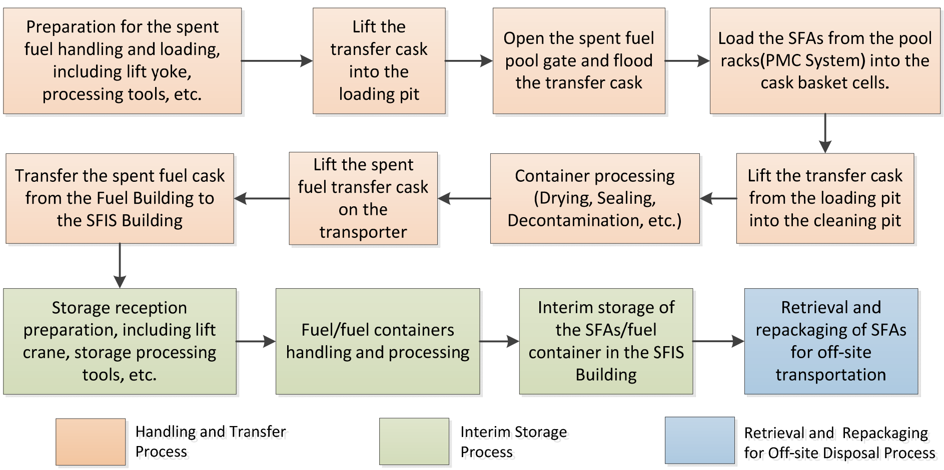
This Sub-chapter describes high level key steps of the SFIS operations. The objective of the SFIS operations is to provide safe handling and on-site interim storage of the SFAs prior to off-site disposal, including handling and transfer of the SFAs from the SFP to the SFIS facility, interim storage of the SFAs in the SFIS facility, and repackaging of the SFAs prior to off-site disposal. The SFIS operations are separated into the following processes:

a) Handling and Transfer Process;

b) Interim Storage Process;

c) Retrieval, Repackaging, and Transport for Off-site Disposal Process.

Since the types of SFIS facility have not been decided for the UK HPR1000, this Sub-chapter will focus on key steps of the SFIS operations in the BFX Building. It shall be noted that the key steps presented are subject to future changes depending on the SFIS technology selected. The high-level key steps of the SFIS operations are presented in F-29.4-1.



F-10.4-1 High Level Key Steps of the SFIS Operations

10.4.2 SFIS Operations Related SSC

This Sub-chapter presents a high level description of the SSC that are involved in the SFIS operations directly (supporting systems such as electrical are not presented here). Further information and associated PCSR chapters are presented in T-10.4-1.

T-10.4-1 List of SSC Involved in the SFIS Operations

<table>
<tr><th colspan="2">SSC</th><th>Roles in the SFIS Operations</th><th>Presentation in PCSR</th></tr>
<tr><td colspan="2">Fuel assemblies</td><td>• The primary confinement barrier (i.e. the fuel clad).
• Facilitate the lifting and handling of the spent fuel.</td><td>Chapter 5</td></tr>
<tr><td colspan="2">Fuel Pool Cooling and Treatment System (PTR [FPCTS])</td><td>• Provide the decay heat removal function for SFAs in the SFP.
• Provide capability to flood and drain the Loading and Preparation Bays.</td><td>Chapter 10</td></tr>
<tr><td colspan="2">Spent Fuel Pool</td><td>• House the Underwater Storage Fuel Rack containing the SFAs, including the failed fuels.</td><td>Chapter 28</td></tr>
<tr><td colspan="2">SFIS facility</td><td>• House all SSC for the entire duration of the Interim Storage Process.
• Potentially serve as an additional confinement barrier for the SFAs.</td><td>Chapter 29</td></tr>
<tr><td colspan="2">BFX Building</td><td>• House the SFP, Loading Bay, and Preparation Bay.
• House the majority of the Handling and Lifting Processes.
• Provide external hazard protection for the SFIS SSC
• Provide an additional confinement barrier for the SFAs.
• Provide SFAs retrieval capability.</td><td>Chapter 16</td></tr>
<tr><td colspan="2">SFIS Systems</td><td>• Provide decay heat removal, confinement (including shielding), lifting and handling, and criticality control function to the SFAs during handling and transfer from the SFP to the SFIS facility including the entire interim storage duration in the SFIS facility.</td><td>Chapter 29</td></tr>
<tr><td>Fuel Handling</td><td>Spent Fuel Pool Crane</td><td>• Lifting and handling system for the SFAs between the SFP and the spent fuel cask.</td><td>Chapter 28</td></tr>
</table>

SSC		Roles in the SFIS Operations	Presentation in PCSR
and Storage System	Underwater Storage Fuel Rack	• Storage location for the SFAs in the SFP.	
DMK	Spent Fuel Cask Crane	• Lifting and handling system for the spent fuel cask.	Chapter 10
SFRR Systems		• Provide decay heat removal, confinement (including shielding), lifting and handling, and criticality control for the SFAs during transfer in the process of Retrieval, Repackaging, and Off-site Disposal.	Chapter 29

10.5 ALARP Assessment

10.5.1 Introduction

As a part of the ALARP strategy presented in PCSR Chapter 33, a high level holistic review of the UK HPR1000 SFIS against applicable RGP is required to identify the relevant potential improvement, or areas for improvement for the technology optioneering.

The relevant holistic ALARP reviews of the SSC (e.g. PTR and PMC Systems) are presented in the corresponding SSC chapters. As the SFIS technology for the UK HPR1000 has not been decided yet, the holistic ALARP review presented in this chapter focuses on the Spent Fuel Storage Strategy (instead of individual SSC).

10.5.2 Applicable RGP and Gap Analysis

According to the principles of this project, the analysis of codes and standards is conducted, in Reference [9]. The following items are judged as the appropriate RGP for the SFIS operations at the current stage of the project:

a) The Management of Higher Activity Radioactive Waste on Nuclear Licensed Sites, in Reference [12];

b) Waste and Spent Fuel Storage Safety Reference Levels Report, in Reference [13];

c) IAEA Safety Standards – Storage of Spent Nuclear Fuel (SSG-15), in Reference [10];

d) Funded Decommissioning Programme Guidance for New Nuclear Power Stations, in Reference [8].

The main aspects of the above RGP that specifically apply to the spent fuel storage strategy are summarised in T-10.5-1 along with associated gap analysis reference to the HPR1000 (FCG3).

T-10.5-1 Gap Analysis of the Spent Fuel Storage Strategy

No	RGP	Design Reference Plant	Gap Analysis
1	The Base Case assumes that there will be no reprocessing of the uranium fuel, and spent fuel will ultimately be disposed of.	The spent fuel will be sent to the reprocessing plant instead of the disposal facility.	For spent fuel management, a gap is identified because of the different disposal policies between the UK and China. UK HPR1000 will be developed to comply with UK policies and regulation, spent fuel will be assumed to be disposed of in the geological disposal facility (GDF).
2	Spent fuel will be stored in cooling ponds for a period of time, followed by storage in safe and secure interim stores on the site of the power station until decommissioning has been completed and disposal facilities are available to accommodate it.	The spent fuel will also be stored in the spent fuel pool for a period and then be transported out of the station for reprocessing. No interim storage consideration of spent fuel exists for the HPR1000.	For spent fuel storage strategy, a gap is identified because of the different disposal policies between the UK and China. UK HPR1000 spent fuel will firstly be stored in the spent fuel pool for cooling, then in the interim storage facility, and finally be disposed of in the geological disposal facility. Relevant forward actions are developed according to the GDA scope and expectation of Office for Nuclear Regulation (UK) (ONR) for spent fuel interim storage.

According to the analysis, two main gaps on spent fuel management strategy exist. To eliminate the first gap, the fuel management strategy is determined according to the UK requirements, presented in Sub-chapter 29.2.1 and a key assumption, that the spent fuel assemblies are transported out of the plant for geological disposal after interim storage, is added in Sub-chapter 29.2.6. In response to the second gap, a forward action plan has been developed, which includes a disposability assessment, technology optioneering, and the matching analysis of selected technology with current UK HPR1000 design. The forward action plan will be conducted through the ALARP assessment methodology developed by CGN and will contribute to the substantiation that the work included in the GDA scope for SFIS is ALARP.

To eliminate the potential gaps produced during the design of SFIS in the future, the applicable codes and standards for UK HPR1000 SFIS design are analysed in Reference [9]. The codes and standards listed in Sub-chapter 29.3 will be considered in the design, which will be conducted in the site-specific phase, to ensure the risk related to SFIS is ALARP and satisfies the UK requirements.

10.6 Design Requirements

The design requirements are categorised into requirements related to the SFAs being stored, the BFX Building, the final disposal facility, the safety functions and security, optimisation as well as the general requirements.

Parameters for fuel design, the SFP and fuel cycle related to the design requirements of SFIS systems are presented in T-10.6-1. Further information on the fuel and SFP design parameters are presented respectively in PCSR Chapter 5 and Chapter 28.

T-10.6-1 Fuel Design, SFP and Fuel Cycle Parameters

Parameter	Values (One unit)
Average discharge fuel burn-up	47 GWd/tU
Refueling enrichment of U^{235}	4.45%
1^{st} refuelling cycle	1 year
Subsequent refuelling cycle	1.5 years (18 months)
Average SFAs generated from one refuelling operations(equilibrium cycle)	72 SFAs
Operation lifetime of the UK HPR1000	60 years
Total number of fuel assemblies discharged over 60 years in operation(considering equilibrium cycles, single nuclear power units and 18-months refuelling pattern)	2985 fuel assemblies

It is assumed that the SFIS facility has to store the SFAs until all SFAs meet the required heat load, radiation limits and any other requirements for disposal in the GDF. The value will be revised once the UK HPR1000 spent fuel disposability assessment has been undertaken and an estimated commercial operation date of the reactor has been provided. However, an option to mix longer and shorter cooled SFAs will be available if the requirements are not expected to be met near the date when the GDF is available for reception of spent fuel from the UK HPR1000.

10.6.1 Safety Functional Requirements

The following high level safety functional requirements will be considered as part of the nuclear safety elements in the technology optioneering to determine a preferred SFIS technology:

a) Reactivity Control

The SFAs are required to be maintained in a subcritical state during normal operations, off-normal operation and accident conditions, involving handling, packaging, transfer and storage. For the reactivity control evaluation, any bias and uncertainty should be considered.

b) Heat Removal

Temperature of the SFAs is required to be maintained within specified limits so that the fuel cladding is considered intact (when the fuel cladding remains as an effective confinement barrier) during normal operations, off-normal operation and accident conditions. The material temperature of other storage relevant SSC, including the cask, the structure and the building should also remain within the allowable values or criteria for each of the conditions above.

c) Confinement, shielding, and limitation of accidental radioactive release

Confinement of radioactive material is achieved and maintained through the use of multiple barriers where reasonably practicable. The shielding design of the SFIS facility or its SSCs should ensure that the radiological dose received by workers and the public shall be reduced to a level that is ALARP. The radiological release to the environment will be within the limits established by the regulations.

d) Retrievability

The SFAs are required to be retrievable during normal operations (including consideration of long term degradation effects), off-normal operation and accident conditions using standards equipment and if necessary, special equipment. This high level safety functional requirement is specific for SFIS operations to allow maintenance, inspection, repackaging, or off-site transport as discussed in Reference [10] and Reference [13].

10.6.2 General Requirements

One of the most important requirements for spent fuel interim storage is to ensure the safe management of spent fuel across the whole lifecycle on site and to minimise the risk that spent fuel cannot be ultimately disposed of. Therefore, the following general requirements will be considered in the technology optioneering to determine a preferred SFIS technology:

a) The overall spent fuel management strategy of UK HPR1000;

b) The required operation lifetime of the SFIS Facility;

c) SFIS facility and equipment requirements to ensure the general safety requirements, including passive safety, inherent safety and defence in depth and safety function requirements presented in Sub-chapter 29.6.1;

d) Inspection requirements within the SFIS facility during the operations (including long term interim storage) to ensure confinement of radioactive material;

e) The SFIS Facility compatibility with the Nuclear Power Plant(NPP) during construction, erection, commissioning and operating, and meeting the surrounding environmental conditions;

f) Location of the SFIS facility with respect to the BFX Building;

g) Location of the SFIS facility with respect to internal and external hazard sources;

h) Accessibility of other required site infrastructure such as off-site power supply, water supply, and the connection to Emergency Diesel Generators (EDG);

i) Retrievability of the SFAs prior to and after the Reactor Building and BFX Building has been decommissioned;

j) Operation and maintenance;

k) Records management;

l) Generic site conditions;

m) Decommissioning of the SFIS Facility;

n) The environmental impact concerning SFIS operations and decommissioning.

The exact location of the SFIS facility has not been decided yet. However, the SFIS facility will be located close to the BFX Building so that the duration of the on-site transfer route from the BFX Building to the SFIS facility is minimised to avoid other hazards as far as practicable. In addition, there will be sufficient space within the generic site boundary to accommodate the SFIS Building regardless the SFIS technology selected.

10.6.3 BFX Building Facility Requirements

The following BFX Building facility related requirements will be considered in the technology optioneering to determine a preferred technology:

a) Capacity of the SFP to accommodate the number of SFAs discharged from the reactor is enough for approximately 11 refuelling cycles plus a full core’s worth following emergency with additional safety margin;

b) Layout of the BFX Building to accommodate the required SFIS-related systems. For example, in the event the radio-protection requirements for spent fuel handing operations increases the weight of the transport containers, which must be accommodated by the fuel building structures and lifting equipment.

10.6.4 Final Disposal Requirements

The following final disposal related requirements will be considered in the technology optioneering to determine a preferred technology:

a) Compatibility of the SFAs to be repackaged into final disposal canisters after the interim storage period;

b) Suitability of the interim storage packages to be used for final disposal.

To ensure the spent fuel produced during UK HPR1000 operation can be safely disposed of after interim storage, the engagement with RMW to conduct the spent fuel disposability assessment is planned. Disposability assessment results will be provided in PCER Chapter 4, in Reference [3]. According to the result of the disposability assessment, the final disposal requirements will be modified accordingly.

10.7 Optioneering Approach

This Sub-chapter presents the optioneering methodology, in Reference [19] and selection principles to be adopted in the technology optioneering to determine the preferred SFIS technology for the UK HPR1000. The methodology of ALARP and BAT in PCSR Chapter 29 will be in accordance with the generic approach of the UK HPR1000 project, which is presented respectively in PCSR Chapter 33 and PCER Chapter 4.

The optioneering principles adopted in the SFIS technology optioneering are as follows:

a) Optionneering methodology

The optioneering methodology is developed based on the robust optioneering and decision making methodology for the UK HPR1000, in Reference [19].

b) Comprehensive optioneering team

An optioneering team will be established by the relevant suitably, qualified and experienced personnel, which ensures so far as is reasonably possible that each option is adequately assessed against the wide range of criteria and that the assessment criteria are considerably comprehensive.

c) Selection of Criteria

The assessment criteria will be selected on the basis of the following main aspects: nuclear safety, conventional safety, engineering, environment, financial and schedule, security, etc., which will be based on the codes and standards listed in Sub-chapter 29.3 and the requirements presented in Sub-chapter 29.6. The criteria, including implications for the relevant scoring system, will be clearly defined and agreed by the optioneering team.

The BAT elements will be included in the technology optioneering with consideration of assessment criteria such as environmental impact, dose to the public and generation of radioactive waste through the life cycle. The methodology for BAT demonstration in PCER Chapter 3, Reference [20], will also be considered in the optioneering.

d) Graded Approach

A graded approach to the technology optioneering will be adopted with the level of detail that corresponds to the significance of potential impacts. This technology optioneering will be undertaken with sufficient preparation, assembling of a multi-disciplinary optioneering team, a workshop to discuss and agree on the scoring against each assessment criterion, and a dedicated optioneering report to document the process and result of the technology optioneering. The level of detail on each SFIS technology will be appropriately high level as a further optioneering process will be undertaken as part of the ALARP assessment of the SFIS operations once a preferred SFIS technology has been chosen.

e) Weighting

If necessary, the weighting factor will be considered for evaluating different technologies. In this case, each assessment criterion will be assigned to a weighting factor based on the relative importance to each other. The weighting factors will be discussed and agreed by the optioneering team.

f) Justification

An appropriate justification will be discussed and agreed by the optioneering team for the scoring of each optioneering methodology against each assessment criterion. The justification will be documented in the optioneering report and subjected to further challenge via the review and acceptance process.

10.8 Technology Options

10.8.1 Introduction

This Sub-chapter presents the various SFIS technology options to be considered. The SFIS technology currently available falls broadly into two categories, wet and dry, distinguished according to the cooling medium used.

The wet SFIS technology has historically been used for temporary storage and cooling at reactor sites and in some interim off-site storage facilities generally associated with disposal or reprocessing sites (in anticipation of the next step in the cycle). The wet SFIS technology is considered to be a mature technology currently.

A variety of dry SFIS technology has been developed and applied recently in the international market. Dry SFIS technology with concrete overpacks and metal canisters is currently being developed at Sizewell B and Hinkley Point C in the UK. The UK ABWR design adopts a concept design of the dry SFIS technology with casks as well. Dry storage is also a mature technology, which has been developed over the past 30 years, especially in the US, and can be regarded as an established industrial technology.

When comparing options for technology, international RGP, especially UK RGP will be taken into consideration. It has been noted that most of the PWRs in the UK, which require a SFIS facility, have elected the dry storage technology.

Another option is to increase the size and storage capacity of the SFP to accommodate all SFAs discharged from the reactor during the operation lifetime. However, this option is eliminated from further assessment based on the following factors:

a) Relevant good practice

Most water-based reactors in the world consider or adopt SFIS technology in the absence of suitable fuel reprocessing plant and final disposal route, instead of increasing the size and storage capacity of the SFP.

b) Safety

SFAs freshly discharged from the reactor demand higher cooling, criticality and shielding requirements from the safety measures (e.g. PTR System) as the decay heat and reactivity are significantly higher compared to SFAs that have been stored in the SFP for more than 5 years. Therefore, utilising a combination of a dedicated SFIS Facility and the SFP provides better diversity and separation of high risk items compared to utilising the SFP to store all discharged SFAs from the reactor.

c) Cost

To enable the storage capacity improvement, the initial space for the SFP should be planned and frozen during the construction of NPP, which requires a larger space for the site. As the SFP shall be constructed along with the NPP, the initial capital cost will be high. In addition, the protection provisions against damage to the pool during an increase to capacity should be conducted, which brings additional costs.

d) Design modification

Significant design modification is required to enable the SFP to accommodate all SFAs discharged from the reactor. These changes are expected to affect the fundamental design of the NPP. According to lessons learned from storage capacity improvement, in Reference [21], there might be no further opportunity to increase storage capacity if the original design assumptions are insufficient.

e) Decommissioning

Decommissioning activities of the Reactor Building will potentially affect the SFAs stored in the SFP. A separate SFIS Building will allow the Reactor Building to be decommissioned without having significant impacts on the SFAs.

10.8.2 Wet SFIS Technology

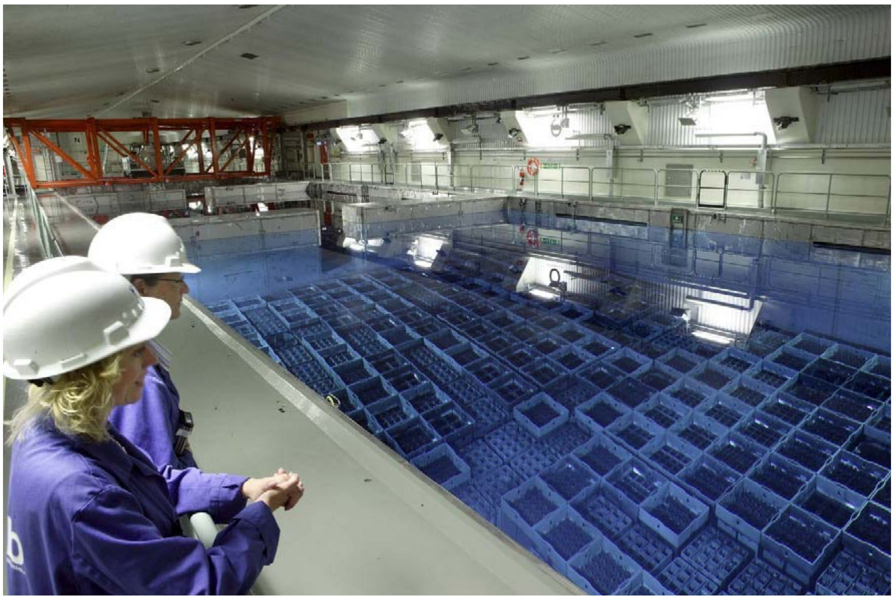
Wet SFIS technology is pool-based storage and the storage principle is thus similar to that of the SFP. Wet SFIS technology generally involves the following operations:

a) The SFAs are transferred from the SFP to a water-filled wet/dry transportation cask.

b) The transportation cask is then processed, sealed (welded/bolted), and transferred to the SFIS facility.

c) The transportation cask is stored in a water-filled pool or the SFAs are transferred from the transportation cask to underwater storage racks.

An example of wet SFIS is presented in F-10.8-1, in Reference [22]. It is a complex technology requiring equipment and systems including wet transfer casks, the fuel handling system, the cask handling system, the pool cooling and decontamination system, the forced circulation cooling system and the waste handling system.



F-10.8-1 Example of Consolidated Wet Storage Facility at Clab, Sweden

Most pools have a stainless steel inner pool lining, with permanent monitoring of the welded seams and x-ray inspection capability to locate and detect any leaks during pool operations. The wet storage facility is designed to:

a) Retain water and minimise leakage;

b) Be operable at all times during the facility design life;

c) Be operable in the event of extreme weather conditions or that pool water temperature increases following a prolonged loss of cooling system;

d) Maintain safe storage conditions even after a seismic event.

In order to ensure the safe storage of spent fuel in the pool, the continuous inspection of more than 10 parameters, including pH, concentration of chlorine in the water, water level, and radioactivity within the facility is required during the SFIS operations, in Reference [21].

For failed fuel management considerations, the wet SFIS technology is similar to the spent fuel short-term storage in the fuel building. Specific failed fuel storage cells and relevant SSC considerations, including the inspection equipment and arrangements, filters for decontamination, etc., as presented in PCSR Chapter 28, are to be considered if wet SFIS technology is selected.

The high level safety functional requirements are met via the following general design features:

a) Decay heat removal

The pool water is cooled and purified with heat exchangers and ion exchange units, either in-pool systems or systems located outside the pool. The cooling capacity of the wet storage pool can be designed according to SFA decay heat rate. However, decay heat limit during the transfer of SFAs (inside a transportation cask) from the BFX Building to the SFIS facility may be a potential limiting factor.

b) Reactivity control

Reactivity control can be achieved through the use of spent fuel storage racks, ensuring suitable geometry and presence of a neutron absorber.

c) Confinement including shielding

Confinement barrier is provided by fuel cladding (for intact fuel), and the pool (including pool water and pool structure). Shielding is provided by the transport cask during the transfer from the BFX to the SFIS facility and by maintaining the SFAs at an appropriate depth under water during storage.

d) Retrievability

The structural integrity of the SFAs is maintained by an appropriate control of the pool water (e.g. chemistry, temperature, specific activity) as well as a suitable monitoring and inspection system to allow forewarning of potential degradation mechanisms. In addition, a suitable lifting and handling system would retrieve the SFAs for off-site disposal.

The key benefits (including safety features) of the wet SFIS technology are as follows:

a) A safety class 1 (or equivalent to other classification) building is usually provided to protect the SFAs from hazard effects (e.g. aircraft crash, turbine missile disintegration etc.);

b) Short pre-cooling duration in the SFP. The spent fuel assemblies can be stored in the wet interim storage facility once removed from the core. However, the pre-cooling requirements for fuel handling, processing and transferring should be considered during the design of SFIS;

c) Potential for redundant decay heat removal capability.

The key disadvantages of the wet SFIS technology are as follows:

a) Requirement of an active system (cooling and recirculation of pool water) for secondary confinement and decay heat removal;

b) Generation of secondary radioactive waste (e.g. liquid radioactive waste);

c) Higher initial capital investment for the nuclear power plant as the SFIS pool is normally constructed along with the NPP.

A preliminary assessment of the wet SFIS technology is presented in T-10.8-1.

T-10.8-1 Preliminary Assessment of the Wet SFIS Technology

Requirements	Preliminary assessment
Potential for the use of the SFIS facility for multiple reactor units.	A wet SFIS facility can be easily designed for storage of SFAs from multiple reactor units.
The operation lifetime of the SFIS Facility.	Significant technical input to justify more than 60 years operation lifetime of a safety class 1 (or equivalent) building (which is based on the BFX Building SFP design lifetime) or significant undertaking is required to construct a new safety class 1 (or equivalent) building prior to end of the SFIS facility design life.
Structural integrity of the SFAs during long term interim storage lifetime (i.e. storage duration of the SFAs in the SFIS facility).	A wet SFIS technology requires active maintenance of pool water control.

Requirements	Preliminary assessment
Operation and maintenance.	A wet SFIS facility requires an active management operation (e.g. monitoring leakage of the pool, pool water quality) to ensure safety. Maintenance of the wet SFIS facility is expected to be significant resulting in potentially greater dose to the operators since most of the equipment requires maintenance and some equipment, such as lifting and handling system and inspection equipment, would become contaminated.
Capacity of the SFP to accommodate the SFAs discharged from the reactor for 11 refuelling cycles and plus full core emergency unloading with adequate margin to ensure safety.	A wet SFIS facility is judged to be able to be commenced prior to the SFP reaching full capacity and the design is capable of exporting the SFAs at a through put greater than the number of SFAs being stored in the SFP during normal operations of the reactor.
Location of the SFIS facility with respect to internal and external hazard sources.	A wet SFIS facility shall be located to avoid as many hazard effects as possible.
The SFIS Facility will be compatible with the Nuclear Power Plant (NPP) during construction, erection, commissioning and operating, and meet the surrounding environmental conditions.	Due to the significant undertaking for constructing a wet storage facility, it is a likely requirement for it to be constructed during construction of the NPP to minimise the risk. A wet SFIS Facility is required to be compatible with the NPP on various aspects such as normal and emergency electrical supply, water sources, and radioactive waste disposal route.
Accessibility of other required site infrastructure such as off-site power supply, water supply, and the connection to EDGs.	A wet SFIS facility is required to have access to site infrastructure such as the off-site power supply, water supply and the connection to EDGs.

Requirements	Preliminary assessment
Retrievability of the SFAs prior to and after the Reactor Building and BFX Building has been decommissioned.	Retrievability of the SFAs is maintained after the decommissioning of Reactor Building and BFX Building without any additional facility.
Location of the SFIS facility with respect to the BFX Building.	The distance between the SFIS facility and BFX Building is critical to safety because the means of decay heat removal (i.e. relies on heat transfer from SFAs to the environment through water and the cask) during transfer is considered as a time at risk situation.
Inspection requirements for the SFAs during the SFIS operations (including long term interim storage) to verify the integrity of the SFAs.	Direct inspection of the SFAs using standard equipment such as remote cameras.
Compatibility of the SFAs to be repackaged into final disposal canisters after the interim storage period.	The SFAs are expected to be repackaged into final disposal canisters with some additional ancillary equipment.
Layout of the BFX Building to accommodate the required SFIS related systems.	It is judged that the BFX Building is capable of accommodating the relevant wet SFIS systems.
Generic site conditions.	It is judged that a wet SFIS Facility can be designed according to the generic site conditions.
Suitability of the interim storage packages to be used for final disposal.	Dedicated disposal canister will be required for final disposal.

10.8.3 Dry SFIS Technology

The dry SFIS technology can be generally divided into two categories: dry storage in either storage or dual purpose casks (dry cask SFIS technology) and dry storage in vault type storage facilities (dry vault SFIS technology), in Reference [10].

10.8.3.1 Dry Cask SFIS Technology

The dry cask SFIS technology can be further classified according to the type of cask used. The most commonly used casks are metal casks with a concrete overpack. Dry cask storage generally has the advantage of being modular, which spreads capital investments over time, in the longer term. The simple passive cooling system used in the dry cask SFIS technology reduces the requirement and cost for operation and maintenance.

Examples of metal cask storage systems are Dresden in the U.S., Gundremmingen in Germany, and Tokai in Japan. An example of a concrete cask dry storage facility is presented in F-10.8-2, in Reference [22].

F-10.8-2 Concrete Casks Storage at the Connecticut Yankee Nuclear Power Plant Site

The metal cask storage process is widely used for spent fuel storage. Metal casks can be designed either for storage only or for dual-purpose, i.e. both storage and transportation. Shielding is provided primarily by the cask structural material, which can be forged steel, nodular cast iron, or composite materials. Generally, the casks are stored on a concrete pad in an upright vertical position with cooling provided by natural air recirculation.

A concrete cask (overpack) is similar in shape to a metal cask. The concrete cask provides shielding, and the steel liner on inner cavity of the canister provides the confinement function. The concrete cask SFIS technology is the most widely used dry SFIS technology in the world. Usually, the canister in the concrete cask consists of a double layered welded redundant seal to contain any potential releases of radioactive substances to the environment.

Unlike the wet SFIS technology, the dry cask SFIS technology achieves the safety functions through passive systems. Therefore, the continuous inspection requirements during the dry cask SFIS operations are much simpler than those for wet SFIS, and generally include temperature detection at the outlet opening and surface of the storage structure and radioactivity detection within the facility.

For failed fuel management, one of the options used in dry SFIS technology is to seal the failed fuel in a specific packaging, with a limited size. Then, the package containing the radioactive material will be loaded into the spent fuel casks, which may be the same as those for the intact spent fuel, or the loading arrangements inside the casks may be modified to meet with the requirements of criticality and heat removal. After loading into the spent fuel casks, the failed fuel interim storage will be similar to that of the intact spent fuel.

The dry cask SFIS technology normally involves the following operations:

a) The SFAs are transferred from the SFP to a metal cask, or a canister contained within a concrete overpack;

b) The metal or concrete cask is drained, dried, processed, sealed (welded for a canister within a concrete overpack and bolted for metal casks), and transferred to the SFIS facility;

c) The metal or concrete cask is stored within the SFIS facility in a vertical or horizontal position.

The safety functional requirements are maintained via the following general design features:

a) Decay heat removal

   Decay heat removal from the SFAs will be achieved through natural air circulation (i.e. passive cooling).

b) Reactivity control

   Reactivity control is provided through fuel arrangement and provision of a neutron absorber inside the fuel basket. Burn-up credit is one of the safety assessment methods for spent fuel reactivity. The credit for burn-up in SFIS will not be used until the decision is fully justified and reaches an agreement with the regulators.

c) Confinement, shielding, and limitation of accidental radioactive release

   The confinement barrier is provided by the fuel clad (for intact fuel), metal cask (usually bolted) or canister (usually welded).

   The shielding is provided by the canister and overpack, or metal cask.

d) Retrievability

   The structural integrity of the SFAs is maintained through appropriate control of the dry inert environment within the canister or metal cask prior to sealing. The dry cask SFIS technology also relies on a suitable monitoring and inspection system to allow forewarning of potential degradation mechanisms for the SFAs. However, the metal cask with a bolted lid provides better access to the SFAs for retrieval than the canister with a welded lid.

The key benefits of the dry cask SFIS technology are as follows:

a) Relying on a passive system as the secondary confinement barrier (i.e. the canister/cask);

b) Relying on a passive cooling system (natural circulation of air);

c) Lower initial investment cost as the dry SFIS technology storage cask is based on modular design.

The key disadvantage of the dry cask SFIS technology is the longer pre-cooling duration in the SFP. As the spent fuel assemblies directly removed from the core are of high decay heat, it is necessary to cool the fuel in the spent fuel pool to sufficiently decrease the heat release rate before interim storage. The cooling time in the spent fuel pool normally lasts for 5 to 8 years. The spent fuel pool of UK HPR1000 can contain the spent fuel of more than 11 refueling cycles, which means that the cooling period for spent fuel can be satisfied. More information on the spent fuel pool is presented in PCSR Chapter 28.

A preliminary assessment of the dry cask SFIS technology is presented in T-10.8-2.

T-10.8-2 Preliminary Assessment of the Dry Cask SFIS Technology

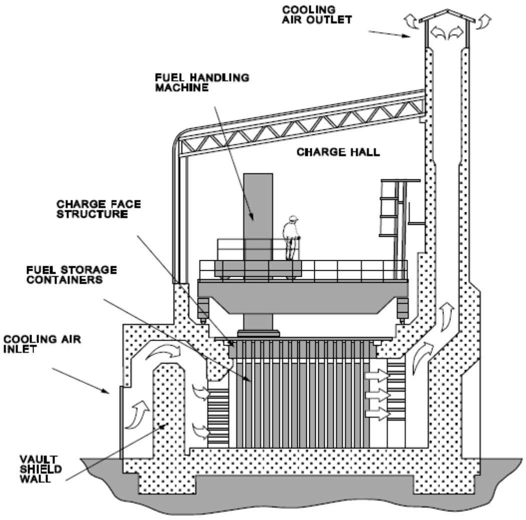
Requirements	Preliminary assessment
Inspection requirements for the SFAs during the SFIS operations (including long term interim storage) to verify the integrity of the SFAs.	No direct access for inspection of the SFAs. A hot cell facility is required to undertake inspection of the SFAs safely.
Potential for the use of the SFIS facility for multiple reactor units.	A dry cask SFIS facility can be easily designed to store SFAs from multiple reactor units with addition of modular casks or canisters and a bigger SFIS facility.

Requirements	Preliminary assessment
Structural integrity of the SFAs during long term interim storage lifetime (i.e. storage duration of the SFAs in the SFIS facility).	The dry cask SFIS technology relies on passive mechanisms (i.e. the dry inert internal environment of the metal cask/canister) to maintain the structural integrity of SFAs.
Location of the SFIS facility with respect to internal and external hazard sources.	A dry cask SFIS facility is required to be located to avoid hazard effects so far as is reasonably practicable.
The operation lifetime of the SFIS facility (building and system).	The design lifetime of a metal cask or canister is assumed to be 100 years and therefore, the SFAs will be transferred to a new metal cask or canister at the end of metal cask or canister design lifetime. In addition, it is assumed that the design life of a metal seal is approximately 50 years and therefore, replacement of the metal seal in the metal cask is needed. It is judged that the impact of cask or canister replacement is not a significant undertaking and can be carried out in batches.
The SFIS facility will be compatible with the Nuclear Power Plant (NPP) during construction, erection, commissioning and operating, and meet the surrounding environmental conditions.	A dry cask SFIS facility can be constructed during the operations of the NPP, depending on the location of the SFIS facility relative to other safety significant building, the cask and canister and ancillary system can be manufactured off-site so that SFIS facility is expected to be a simple civil structure. The dry cask SFIS facility has minimum interface with the rest of the NPP.
Location of the SFIS facility with respect to the BFX Building.	The distance between the SFIS facility and BFX Building is not critical to safety because the estimated travel duration is judged to be insignificant compared to the expected time of fuel clad breach.

Requirements	Preliminary assessment
Operation and maintenance.	A dry cask SFIS Facility requires minimum active management operation to ensure safety (e.g. temperature differential monitoring). Maintenance of a dry cask SFIS facility is expected to be insignificant with very few contaminated systems.
Layout of the BFX Building to accommodate the required SFIS related systems.	It is judged that the BFX Building can accommodate the relevant dry cask SFIS systems.
Capacity of the SFP to accommodate the SFAs discharged from the reactor is enough for about 11 refuelling cycles and plus a full core emergency unloading with adequate margin to ensure safety.	Commencement of a dry cask SFIS facility prior to the SFP reaching full capacity is judged to be feasible with detailed design development starting after NPP commercial operation date The design will be capable of exporting the SFAs at a throughput greater than the number of SFAs being stored in the SFP during normal operations of the reactor.
Suitability of the interim storage packages to be used for final disposal.	It is judged that the metal cask or canister can not meet the requirements of a disposal cask for the GDF.
Retrievability of the SFAs before and after the BFX Building has been decommissioned.	Depending on the preferred SFIS technology chosen, the retrieval capability could be incorporated into the SFIS Facility and avoid the need for a separate SFRR facility.
Decommissioning of the SFIS facility.	Solid radioactive waste is expected to be generated from the decommissioning of a dry cask SFIS facility (mainly from canisters or metal casks). However, the building and other ancillary systems are expected to be Low Level Waste (LLW) or Very Low Level Waste (VLLW).
Generic site conditions.	It is judged that a dry cask SFIS Facility shall be designed according to the generic site conditions.

10.8.3.2 Dry Vault SFIS Technology

In this context, a vault is a massive, radiation shielded facility for storing SFAs. The dry vault facility can either be located above or below ground level. The facility can be constructed of a reinforced concrete structure containing an array of storage cavities. The SFAs are stored in sealed small containers or metal storage cylinders.



F-10.8-3 Dry Vault SFIS Technology in Modular Vault Dry Store, in Reference [23]

The dry vault SFIS technology normally involves the following operations:

a) The SFAs are transferred from the SFP to a cask;

b) The cask is then drained, dried, processed, sealed (welded/bolted), and transferred to the vault;

c) The cask is stored within the vault either in a vertical or horizontal position.

The safety functional requirements are maintained via the following general design features:

a) Decay heat removal

Decay heat removal from the SFAs will be achieved by circulation of air or gas over the exterior of the containers/cylinders and exhausting the air directly to the outside atmosphere or dissipating the heat via a secondary heat removal system.

b) Reactivity control

Reactivity control is provided by appropriate arrangement of SFAs and the use of a neutron absorber inside the fuel basket.

c) Confinement including shielding

The confinement barrier is provided by the fuel clad (for intact fuel) and the containers/cylinders.

The shielding protection is provided by the container, facility, and notably the ground.

d) Retrievability

The structural integrity of the SFAs is maintained by ensuring appropriate control of the dry inert environment within the canister or metal cask prior to sealing. The dry SFIS technology also relies on a suitable monitoring and inspection system to allow forewarning of potential SFA degradation mechanisms on the SFAs. The metal cask with a bolted lid provides better access to the SFAs for retrieval than the canister with a welded lid.

The key benefits of the dry vault SFIS technology are as follows:

a) Relying on a passive system as the secondary confinement barrier (i.e. the canister/cask);

b) Relying on a passive cooling system (natural circulation of air).

The key disadvantages of the dry vault SFIS technology are as follows:

a) Longer pre-cooling duration in the SFP;

b) Higher initial investment cost as the vault facility is normally constructed along with the NPP.

For dry vault SFIS technology, the pre-cooling duration in the SFP can be easily achieved using the current design of SFP. The justification is similar to that used for dry cask SFIS technology, which can be found in Sub-chapter 29.7.3.2.

For failed spent fuel management, the considerations will be similar to those described in Sub-chapter 29.7.3.2.

A preliminary assessment of the dry vault SFIS technology is presented in T-10.8-3.

T-10.8-3 Preliminary Assessment of the Dry Vault SFIS Technology

Requirements	Preliminary assessment
Structural integrity of the SFAs during long term interim storage lifetime (i.e. storage duration of the SFAs in the SFIS facility).	Relies on passive mechanisms (i.e. the dry inert internal environment of the metal cask/canister) to maintain the structural integrity of SFAs.

Requirements	Preliminary assessment
Inspection requirements for the SFAs during the SFIS operations (including long term interim storage) to verify the integrity of the SFAs.	No direct access for inspection of the SFAs. A hot cell facility is required to undertake the inspection of SFAs safely.
Operation and maintenance.	A dry vault SFIS facility requires minimum active management to ensure safety (e.g. temperature differential monitoring). Maintenance of a dry vault SFIS facility is expected to be insignificant as there will be insignificant contamination present.
Retrievability of the SFAs before and after the BFX Building has been decommissioned.	A new hot cell facility is required to provide retrieval capability following decommission of the BFX Building.
Accessibility of other required site infrastructure such as an off-site power supply, water supply, and the connection to EDGs.	A dry vault SFIS facility may require access to site infrastructure such as an off-site power supply, water supply and the connection to EDGs depending on the need for an active secondary heat exchanger system.
Location of the SFIS facility with respect to the BFX Building.	The distance between the dry vault SFIS facility and BFX Building is not critical to safety because the estimated travel duration is judged to be insignificant compared to the expected time to breach the fuel clad.

Requirements	Preliminary assessment
The operation lifetime of the SFIS facility (building and system).	The design lifetime of a metal cask or canister is assumed to be 100 years and therefore, the SFAs will be transferred to new metal cask or canister at the end of metal cask or canister design lifetime. It is assumed that the design life of a metal seal is 50 years approximately and therefore, replacement of the metal seal in the metal cask is needed prior to end of cask/canister life. In addition, the design lifetime of a vault facility is assumed to be 100 years and a second vault facility will be required to meet the required on-site storage duration.
The SFIS facility will be compatible with the NPP during construction, erection, commissioning and operation, and will meet the surrounding environmental conditions.	Due to the significant undertaking for constructing a dry vault storage facility, it is likely construction would be required during construction of the NPP to minimise the risk. Depending on SFA decay heat, an active secondary heat removal system and connection to an emergency electrical supply may be required.
Capacity of the SFP to accommodate the SFAs discharged from the reactor is enough for approximately 11 refuelling cycles plus a full core emergency unload with adequate margin to ensure safety.	Commencement of a dry vault SFIS facility prior to the SFP reaching full capacity is judged to be feasible. The design is capable of exporting the SFAs at a throughput greater than the rate of SFAs being stored in the SFP during normal operation of the reactor.
Location of the SFIS facility with respect to internal and external hazard sources.	The dry vault SFIS facility is required to be in a location to avoid hazard effects so far as is reasonably practicable.
Potential for the use of the SFIS facility for multiple reactor units.	A dry vault SFIS facility is normally a large facility and the use of dry cask/canister permits modular storage of SFAs from multiple reactors.

Requirements	Preliminary assessment
Generic site conditions.	It is judged that a dry vault SFIS Facility shall be designed according to the generic site conditions.
Layout of the BFX Building to accommodate the required SFIS related systems.	It is judged that the BFX Building is capable of accommodating the relevant dry SFIS systems.
Compatibility of the SFAs to be repackaged into final disposal canisters after the interim storage period.	The SFAs are expected to be repackaged into final disposal canisters with some additional ancillary equipment.
Suitability of the interim storage packages to be used for final disposal.	The metal cask or canister is not capable of meeting the requirements of disposal casks for GDF.
Decommissioning of the SFIS facility.	Significant solid radioactive waste is expected to be generated from decommissioning of a dry vault SFIS facility (mainly from the concrete structure, and canisters or metal casks).

10.9 Conclusion Remarks

This chapter presents the GDA approach and plans adopted for the SFIS safety case development, according to the current GDA scope, in Reference [4]. The GDA SFIS safety case will be made to demonstrate that a future site-specific solution will be able to be demonstrated as BAT and ALARP in the future, but will not be demonstrated during GDA, and will avoid foreclosure of potential options and improvements for the future site licensee.

Suitable SFIS options are considered and a preliminary assessment of each option against the requirements specified has been undertaken. But it is not necessary to reach the final decision during this phase of the GDA since there are 11 refuelling cycles plus the SFAs from a full core emergency unload before the SFP reaches the design capacity. Nevertheless, a preferred SFIS technology will be selected through the technology optioneering.

To ensure the selected technology of SFIS could satisfy the requirements of ALARP and will not result in significant design changes to the current UK HPR1000 design, a compatibility analysis of the selected SFIS technology with current UK HPR1000 design will be conducted in the appropriate subsequent GDA phase.

GDA scope will be developed according to the GDA progress and discussions with regulators. As such, the forward action plan will be developed correspondingly, whenever possible, in order to meet with regulator expectations and ensure a meaningful assessment.

10.10 References

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Appendix 29A Route Map

Sub-claim	Argument	Evidence	Supporting Documents
3.3.13A All reasonable measures are adopted to ensure the technology selected satisfies the requirements in the UK.	3.3.13A-1 The requirements of spent fuel management, especially for interim storage in the codes and standards are analysed.	•**Evidence 1:** Applicable acts, regulations, codes and standards for spent fuel management, including those for spent fuel interim storage have been identified in Sub-chapter 29.3.	CGN, Analysis report of applicable codes and standards. GHX00100024DNFF02GN, July 2018.
		•**Evidence 2**: The requirements in the codes and standards specific for spent fuel interim storage are identified in Sub-chapter 29.6.	CGN, Analysis report of applicable codes and standards. GHX00100024DNFF02GN, July 2018.
	3.3.13A-2 The scope, process and relevant SSC concerning spent fuel management strategy for the UK HPR1000 are clearly defined before the technology optioneering.	•**Evidence 1:** The overview of the spent fuel management strategy for the UK HPR1000 is presented in Sub-chapter 29.1.	/
		•**Evidence 2**: The scope of SFIS operation, the work within the GDA phase, and relevant information concerning SFIS in other chapters are clearly identified in Sub-chapter 29.2.3.	GNS, Requirements on Optioneering & Decision-Making. HPR-GDA-PROC-0012.
		•**Evidence 3**: The main process and related SSC of SFIS operations are identified in Sub-chapter 29.4.	/
	3.3.13A-3 The preliminary ALARP/BAT assessment is conducted for SFIS.	•**Evidence 1:** The RGP suitable for SFIS for the UK HPR1000 has been identified and presented in Sub-chapter 29.5.	CGN, Analysis report of applicable codes and standards. GHX00100024DNFF02GN, July 2018.
		•**Evidence 2:** Gaps between the spent fuel storage strategy for the HPR1000 and RGP in the UK is identified in Sub-chapter 29.5.2.	/
		•**Evidence 3**: The considerations for eliminating the gaps in SFIS are presented in Sub-chapter 29.5.2.	•Technology optioneering on Spent Fuel Interim Storage •Potential effects analysis of spent fuel interim storage on UK HPR1000 design •Disposability assessment of higher activity wastes
	3.3.13A-4 The technology optioneering will be conducted in an appropriate way.	•**Evidence 1:** The requirements in the codes and standards specific for spent fuel interim storage are identified in Sub-chapter 29.6, based on which the general criteria for technology optioneering is selected in Sub-chapter 29.7.	Technology optioneering on Spent Fuel Interim Storage
		•**Evidence 2**: The technology optioneering is conducted through a systematic methodology, presented in Sub-chapter 29.7.	•GNS, Requirements on Optioneering & Decision-Making. HPR-GDA-PROC-0012 •Technology optioneering on Spent Fuel Interim Storage
	3.3.13A-5 The matching of selected SFIS technology with current UK HPR1000 design is analysed.	•**Evidence 1**: The matching of selected SFIS technology with current UK HPR1000 design will be conducted in later phase of GDA, presented in Sub-chapters 29.9 and 29.10.	Potential effects analysis of spent fuel interim storage on UK HPR1000 design
3.3.13B The relevant design of SFIS will be able to achieve ALARP.	3.3.13B-1 The design of SFIS will consider the requirements under different conditions, including normal operation, off-normal operation and accident.	{ }	{ }
	3.3.13B-2 The design of SFIS will satisfy the safety requirements, including heat removal, criticality	{ }	{ }

Sub-claim	Argument	Evidence	Supporting Documents
	control, radiation protection, radioactive confinement and spent fuel retrievability under different conditions, i.e. normal operation, off-normal operation and accident conditions.		
	3.3.13B-3 The design of SFIS will satisfy other requirements in the nuclear power plant and will be proved to be compatible with UK HPR1000 design.	{ }	{ }
	3.3.13B-4 The design of SFIS concerning the construction and EMIT will be conducted in the basis of safety analysis results.	{ }	{ }