Office for Nuclear Regulation

New Reactors Division – Generic Design Assessment

Step 4 Assessment of Spent Fuel Interim Storage for the UK HPR1000 Reactor

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EXECUTIVE SUMMARY

This report presents the findings of my assessment of the Spent Fuel Interim Storage (SFIS) aspects of the generic UK HPR1000 design undertaken as part of the Office for Nuclear Regulation's (ONR) Generic Design Assessment (GDA). My assessment was carried out using the Pre-Construction Safety Report (PCSR) and supporting documentation submitted by the Requesting Party (RP).

The objective of my assessment was to make a judgement, from a SFIS perspective, on whether the generic UK HPR1000 design could be built and operated in Great Britain, in a way that is acceptably safe and secure (subject to site specific assessment and licensing), as an input into ONR's overall decision on whether to grant a Design Acceptance Confirmation (DAC).

The scope of my GDA assessment was to review the safety aspects of the generic UK HPR1000 design by examining the claims, arguments and supporting evidence in the safety case. My GDA Step 4 assessment built upon the work undertaken in GDA Steps 2 and 3 and enabled a judgement to be made on the adequacy of the spent fuel interim storage information contained within the PCSR and supporting documentation.

My assessment focussed on the following aspects of the generic UK HPR1000 safety case:

- Operating sequences in the Fuel Building and SFIS Facility.
- SFIS Facility design, including the construction strategy, storage capacity and layout.
- SFIS hazards and risks, targeting the adequacy of the RP's safety case on the safety functions of radioactive material confinement, heat removal and retrievability.
- Co-storage of Rod Cluster Control Assemblies (RCCAs) /Stationary Core Component Assemblies (SCCAs) with spent fuel in the SFIS Facility.
- Limits and conditions in the interests of safety and Examination, Inspection, Maintenance and Testing (EIMT).
- Failed fuel management strategy.
- Relevant aspects of disposability of spent fuel, RCCAs and SCCAs.
- Demonstration that relevant risks have been reduced to as low as reasonably practicable (ALARP), including whether the RP's safety case provides adequate evidence to support the claims made.
- Consolidated safety case.

The conclusions from my assessment are:

- The SFIS Facility conceptual design includes adequate facilities for the safe management of spent fuel, with due consideration of factors which may impact upon the storage capacity, which will need to be taken into consideration in the detailed design at the site-specific stages.
- Notwithstanding Assessment Finding AF-UKHPR1000-0021, the RP's safety case provides adequate evidence that the hazards and risks are understood, with engineered independent preventative and mitigative design features identified to demonstrate that the SFIS technology Systems, Structures and/or Components (SSCs) are consistent with Relevant Good Practice (RGP) and therefore capable of reducing the risks to ALARP.
- The RP's strategy to co-store RCCAs/SCCAs with Spent Fuel Assemblies (SFAs) in the spent fuel storage canister is consistent with the management strategy being proposed for similar radioactive waste items from Pressurised Water Reactors (PWRs) in operation and being constructed in the UK. The

RP's strategy also considers the regulatory expectations of Safety Assessment Principle (SAP) RW.3 on minimising the volume of radioactive waste accumulated on the site through inclusion of the neutron sources with the SCCAs in the spent fuel storage canister.

- The evidence that co-storage of RCCAs/SCCAs with SFAs meets the regulatory expectations of ONR SAPs ENM.5 (the characterisation and segregation of nuclear matter) and ENM.6 (storage in a condition of passive safety) is dependent on a number of aspects which will not be available until detailed design at the site-specific stages. I have therefore raised Assessment Finding AF-UKHPR1000-0022 on the safety analysis for co-storage, which needs to be developed with the detailed design of the SFIS SSCs. The safety analysis should underpin the safety case claims/argument that the presence of RCCAs/SCCAs (with neutron sources) does not have a significant impact on the drying operations, and that any potential swelling/deformation of the RCCAs/SCCAs does not have any significant impact on the passive safe storage of spent fuel.
- The RP's safety case adequately acknowledges the requirement to define limits and conditions in the interests of safety and the regime for EIMT as the detailed design of the SSCs of the SFIS technology progresses, with the information provided proportionate to the level of detail available at the GDA stage.
- The generic parameters required for the Operating Limits and Conditions (OLCs) identified by the RP align with the safety functions, are consistent with international good practice for fuel storage and meet the expectations in both Regulatory Observation RO-UKHPR1000-0050 and the scope of SFIS for the generic UK HPR1000 design.
- The RP's safety case presents a 'golden thread' from the need to define the details of OLCs to any restrictions or requirements which need to be taken into consideration when defining them, based upon the safety case at GDA and the links to EIMT, as expected by ONR SAP SC.6 on the content and implementation of safety cases.
- The assumption in the RP's safety case that failed fuel will be stored in the Spent Fuel Pool (SFP) is consistent with that for PWRs in the UK with similar dry storage facilities. It is my judgement that the generic UK HPR1000 design does not foreclose options for the future safe management of failed fuel in the SFIS Facility.
- The RP has sought advice from Radioactive Waste Management Limited (RWM) on the disposability of spent fuel with RCCAs/SCCAs. RWM's assessment concludes that the disposal package, containing 4 SFAs and a single RCCA/SCCA, is compatible with the future Geological Disposal Facility (GDF).
- The RP has provided adequate evidence on the versatility of the generic UK HPR1000 design to safely accommodate the SFIS technology through consideration of the systems/services required, the bounding size of the SFIS equipment, and the space available within the Fuel Building, without unduly foreclosing options for the detailed design.

These conclusions are based upon the following factors:

- A detailed and in-depth technical assessment, on a sampling basis, of the full scope of safety submissions at all levels of the hierarchy of the generic UK HPR1000 safety case documentation.
- Detailed technical interactions on many occasions with the RP, alongside the assessment of the responses to the substantial number of Regulatory Queries (RQs) and Regulatory Observations (ROs) raised during the GDA.

A number of matters remain, which I judge are appropriate for a licensee to consider and take forward in its site-specific safety submissions. These matters do not undermine the generic

UK HPR1000 design and safety submissions; but are primarily concerned with the provision of site-specific safety case evidence which will become available as the project progresses through the detailed design, construction and commissioning stages. These matters have been captured in two Assessment Findings.

Overall, based on my assessment undertaken in accordance with ONR's procedures, the claims, arguments and evidence laid down within the PCSR and supporting documentation submitted as part of the GDA process present an adequate safety case for the generic UK HPR1000 design. I recommend that from a SFIS perspective a DAC may be granted.

LIST OF ABBREVIATIONS

ALARP	As Low As Reasonably Practicable
BAT	Best Available Techniques
BMS	Business Management System
BFX	Fuel Building
BQF	Spent Fuel Interim Storage (SFIS) Facility
CAE	Claims, Arguments, Evidence
CGN	China General Nuclear Power Corporation Ltd
DAC	Design Acceptance Confirmation
DMK [FBHE]	Fuel Building Handling Equipment
EDF	Electricité de France
EIMT	Examination, Inspection, Maintenance and Testing
ERICP	Elimination, Reduction, Isolation, Control and Protect (hierarchy of hazard control)
FDP	Funded Decommissioning Programme
GDA	Generic Design Assessment
GDF	Geological Disposal Facility
GNI	General Nuclear International Ltd.
GNSL	General Nuclear System Ltd.
HAW	Higher Activity Waste
HLW	High-Level Waste
HOW2	(ONR) Business Management System
HPC	Hinkley Point C (nuclear power station)
HSWA	Health and Safety at Work Act 1974
IAEA	International Atomic Energy Agency
ICIA	In-Core Instrumentation Assembly
MW	Megawatts
NDA	Nuclear Decommissioning Authority
NEA	Nuclear Energy Agency (within OECD)
NFCC	Non-fuel Core Components
NNSA	National Nuclear Safety Administration
OECD	Organisation for Economic Cooperation and Development
OLCs	Operational Limits and Conditions
ONR	Office for Nuclear Regulation
OPEX	Operational Experience
PCSR	Pre-construction Safety Report
PIE(s)	Postulated Initiating Event(s)
PMC [FHSS]	Fuel Handling and Storage System

PSA	Probabilistic Safety Analysis
PTR [FPCTS]	Fuel Pool Cooling and Treatment System
PWR	Pressurised Water Reactor
RCCA	Rod Cluster Control Assembly
RCP(s)	Reactor Coolant Pump(s)
RGP	Relevant Good Practice
RO	Regulatory Observation
RP	Requesting Party
RPV	Reactor Pressure Vessel
RQ	Regulatory Query
RWM	Radioactive Waste Management Limited
SAP(s)	Safety Assessment Principle(s)
SCCA	Stationary Core Component Assembly
SFA	Spent Fuel Assembly
SFCC	Spent Fuel Cask Crane
SFIS	Spent Fuel Interim Storage
SFP	Spent Fuel Pool
SFPC	Spent Fuel Pool Crane
SG	Steam Generator
SoDA	(Environment Agency’s) Statement of Design Acceptability
SSCs	Structures, Systems and Components
SZB	Sizewell B (nuclear power station)
TAG(s)	Technical Assessment Guide(s)
TSC	Technical Support Contractor
WENRA	Western European Nuclear Regulators’ Association

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1 INTRODUCTION

1.1 Background

1. This report presents my assessment conducted as part of the Office for Nuclear Regulation (ONR) Generic Design Assessment (GDA) for the generic UK HPR1000 design within the topic of nuclear liabilities management, focusing on spent fuel interim storage (SFIS).

2. The UK HPR1000 is a Pressurised Water Reactor (PWR) design proposed for deployment in the UK. General Nuclear System Ltd (GNSL) is a UK-registered company that was established to implement the GDA on the generic UK HPR1000 design on behalf of three joint requesting parties (RP), i.e. China General Nuclear Power Corporation (CGN), EDF S.A. and General Nuclear International Ltd (GNI).

3. GDA is a process undertaken jointly by the ONR and the Environment Agency. Information on the GDA process is provided in a series of documents published on the joint regulators' website (www.onr.org.uk/new-reactors/index.htm). The outcome from the GDA process sought by the RP is a Design Acceptance Confirmation (DAC) from ONR and a Statement of Design Acceptability (SoDA) from the Environment Agency.

4. The GDA for the generic UK HPR1000 design followed a step-wise approach in a claims-argument-evidence hierarchy which commenced in 2017. Major technical interactions started in Step 2 of GDA which focussed on an examination of the main claims made by the RP for the UK HPR1000. In Step 3 of GDA, the arguments which underpin those claims were examined. The Step 2 reports for individual technical areas, and the summary reports for Steps 2 and 3 are published on the joint regulators' website. The objective of Step 4 of the GDA was to complete an in-depth assessment of the evidence presented by the RP to support and form the basis of the safety and security cases.

5. The full range of items that form part of my assessment is provided in ONR's GDA Guidance to Requesting Parties (Ref. 1). These include:

- Consideration of issues identified during the earlier Step 2 and 3 assessments.
- Judging the design against the Safety Assessment Principles (SAPs) (Ref. 2) and whether the proposed design ensures risks are As Low As Reasonably Practicable (ALARP).
- Reviewing details of the RP's design controls and quality control arrangements to secure compliance with the design intent.
- Establishing whether the system performance, safety classification, and reliability requirements are substantiated by a more detailed engineering design.
- Assessing arrangements for ensuring and assuring that safety claims and assumptions will be realised in the final as-built design.
- Resolution of identified nuclear safety and security issues or identifying paths for resolution.

6. The purpose of this report is therefore to summarise my assessment in the SFIS topic which provides an input to the ONR decision on whether to grant a DAC, or otherwise. This assessment was focused on the submissions made by the RP throughout GDA, including those provided in response to the Regulatory Queries (RQs) and Regulatory Observations (ROs) I raised. Any ROs issued to the RP are published on the GDA's joint regulators' website, together with the corresponding resolution plans.

1.2 Scope of this Report

7. This report presents the findings of my assessment of the SFIS topic of the generic UK HPR1000 design undertaken as part of GDA. I carried out my assessment using the Pre-Construction Safety Report (PCSR) (Ref. 3, Ref. 4, Ref. 5, Ref. 6) and supporting documentation submitted by the RP. My assessment was focussed on considering whether the generic safety case provides an adequate justification for the generic UK HPR1000 design, in line with the objectives for GDA.

1.3 Methodology

8. The methodology for my assessment follows ONR's guidance on the mechanics of assessment, NS-TAST-GD-096 (Ref. 7).

9. My assessment was undertaken in accordance with the requirements of ONR's How2 Business Management System (BMS). ONR's SAPs (Ref. 2) together with supporting Technical Assessment Guides (TAGs) (Ref. 8, Ref. 9, Ref. 10, Ref. 11, Ref. 12), were used as the basis for my assessment. Further details are provided in Section 2. The outputs from my assessment are consistent with ONR's GDA Guidance to RPs (Ref. 1).

2 ASSESSMENT STRATEGY

10. The strategy for my assessment of the SFIS topic aspects of the generic UK HPR1000 design and safety case is set out in this section. This identifies the scope of the assessment and the standards and criteria that have been applied.

2.1 Assessment Scope

11. A detailed description of my approach to this assessment can be found in assessment plan ONR-GDA-UKHPR1000-AP-19-007. Rev 0 (Ref. 13).

12. I considered all of the main submissions within the remit of my assessment scope, to various degrees of breadth and depth. I chose to concentrate my assessment on those aspects that I judged to have the greatest safety significance, or where the hazards appeared least well controlled. My assessment was also influenced by the claims made by the RP, my previous experience of similar systems for reactors and other nuclear facilities, and any identified gaps in the original submissions made by the RP. A particular focus of my assessment has been the RQs and ROs I raised as a result of my on-going assessment, and the resolution thereof.

2.2 Sampling Strategy

13. In line with ONR’s guidance (Ref. 7), I chose to focus a sample of the RP’s submissions to undertake my assessment on the highest hazard nuclear liabilities generated from the operation of the UK HPR1000. For the purpose of this assessment I considered the highest hazards to be the spent fuel and High Level Waste (HLW) Non-fuel Core Components (NFCCs). My assessment considers the adequacy of the RP’s safety case for the safe interim storage of spent fuel and the storage of HLW NFCCs.

14. In UK policy (Ref. 14) spent fuel from new nuclear power stations is kept in interim storage on the site of the power station until the point at which the Geological Disposal Facility (GDF) is available when spent fuel will be disposed of. During Step 3 of GDA the RP selected dry storage for the interim storage of spent fuel. The UK HPR1000 dry store for spent fuel, the SFIS Facility (BQF), has also been designed to store waste NFCCs categorised as HLW. Prior to Step 3 of GDA for the UK HPR1000 ONR and the Environment Agency provided clarity to the RP on their expectations for the scope of GDA for interim storage of spent fuel (Ref. 15). This has been used to inform the ONR sampling strategy. The main themes considered for SFIS were:

- Provision of information for the main steps in the operating sequence relevant to the SFIS within the Fuel Building (BFX) and SFIS Facility.
- SFIS Facility concept design. This includes the construction strategy, storage capacity, and layout.
- The safety case for operations supporting SFIS completed within the Fuel Building and for the storage of spent fuel in the SFIS Facility. This includes consideration of hazards and risks in both normal operations and faults, and safety functional requirements on key Systems, Structures and/or Components (SSCs).
- The safety case for the co-storage of Spent Fuel Assemblies (SFAs) with waste NFCCs identified as Rod Cluster Control Assemblies (RCCAs) and Stationary Core Component Assemblies (SCCAs) in the SFIS Facility.
- Limits and conditions in the interests of safety and Examination, Inspection, Maintenance and Testing (EIMT) considerations in the safety case.
- The demonstration that the safe management of failed fuel is considered within the generic UK HPR1000 design, and that the SFIS Facility design does not foreclose options for the management of failed fuel.

- The RP's consideration of the expectation to provide confidence that spent fuel, RCCAs and SCCAs are capable of being disposed of to a GDF.
- The RP's overall demonstration that the risks from radioactive waste management are ALARP. For the SFIS topic this includes demonstration of the versatility of the generic design of the Fuel Building to incorporate any future modifications which may be necessary to reduces the risks to ALARP during the detailed design.

2.3 Out of Scope Items

15. The following items were outside the scope of my assessment.

- The optioneering undertaken by the RP to underpin the selected technology of dry storage for the interim storage of spent fuel formed part of ONR's assessment during Step 3 of GDA (Ref. 16) and has not been reassessed during Step 4 of GDA.
- The reactor operations leading to the generation of SFAs, including periodicity of the refuelling cycle and storage in the Spent Fuel Pool (SFP) prior to safe transfer into dry storage.
- The effluent clean-up system for the SPF, the Fuel Pool Cooling and Treatment System (PTR[FPCTS]).
- Operations leading to the generation of waste of NFCCs including the operational safety case to support the use of the NFCCs, and the adequacy of the examination and inspection programme during operations.
- The management strategy and safety case for the storage of failed RCCAs within the SFP.
- The safety case for the retrieval, packaging, handling and storage of waste In-Core Instrument Assemblies (ICIAs), a sub-group of NFCCs.
- The identification of specific suppliers/vendors to deliver the selected SFIS technology. This includes the design of the spent fuel canister, transfer cask, concrete silo and failed fuel can. These aspects are all outside the scope of GDA.
- The identification, inspection and monitoring of any potential fuel failures or failed fuel both within the reactor core and during storage within the SFP.
- The adequacy of the RP's safety case in relation to lifting and handling operations for SFAs, RCCAs, SCCAs, the spent fuel canister, spent fuel transfer cask and spent fuel concrete silo. This includes cranes and handling tools in the Fuel Building, for example the Spent Fuel Cask Crane (SFCC) and in the SFIS Facility.
- The adequacy of the RP's safety case in relation to the principles of criticality control and shielding requirements in the SFIS Facility conceptual design.
- The detailed operational and decommissioning strategy for the management of failed fuel in the SFIS Facility is out of scope of GDA (Ref. 17).
- Security and safeguards requirements relevant to the SFIS Facility.
- The management steps, including facilities required, to enable the safe retrieval and re-packing of spent fuel to enable transport and disposal of spent fuel into a GDF. ONR does not regulate the disposal of spent fuel but maintains oversight of progress with disposability assessment, as this is relevant to minimising the risk that spent fuel is stored indefinitely on-site because it has no disposal route.

2.4 Standards and Criteria

16. The relevant standards and criteria adopted within this assessment are principally the SAPs (Ref. 2), TAGs (Ref. 8, Ref. 9, Ref. 10, Ref. 11, Ref. 12), relevant national and international standards, and relevant good practice informed from existing practices adopted on nuclear licensed sites in Great Britain. The key SAPs and any relevant TAGs, national and international standards and guidance are detailed within this

section. Relevant Good Practice (RGP), where applicable, is cited within the body of the assessment.

17. It is noted that spent fuel and radioactive waste are both examples of nuclear matter, and therefore where ONR guidance refers to nuclear matter this is relevant guidance to the topics in this assessment report. For further details on the definition nuclear matter see ONR TAG on the control of processes involving nuclear matter (Ref. 9).

2.4.1 Safety Assessment Principles

18. The SAPs (Ref. 2) constitute the regulatory principles against which ONR judge the adequacy of safety cases. The SAPs applicable to radioactive waste management and SFIS are included within Annex 1 of this report.

19. The key SAPs applied within my assessment were SAPs RW.1-5, ENM.2, 5-7, ECV.3-4 and ELO.1 and 3.

2.4.2 Technical Assessment Guides

20. The following TAGs were used as part of this assessment:

- NS-TAST-GD-005 ‘ONR Guidance on the Demonstration of ALARP’ (Ref. 8).
- NS-TAST-GD-023 ‘Control of Processes Involving Nuclear Matter (SAP – ENM.1 to 8)’ (Ref. 9).
- NS-TAST-GD-024 ‘Management of Radioactive Material and Radioactive Waste on Nuclear Licensed Sites’ (Ref. 10).
- NS-TAST-GD-051 ‘The Purpose, Scope and Content of Nuclear Safety Cases’ (Ref. 11).
- NS-TAST-GD-081 ‘Safety Aspects Specific to Storage of Spent Nuclear Fuel’ (Ref. 12).

2.4.3 National and International Standards and Guidance

21. The following standards and guidance were used as part of this assessment:

- ‘General Safety Requirements Part 5: Predisposal management of radioactive waste’, International Atomic Energy Agency (IAEA) (Ref. 18).
- ‘Storage of Radioactive Waste Safety Guide’, IAEA (Ref. 19).
- ‘Storage of Spent Nuclear Fuel’, IAEA (Ref. 20).
- ‘Waste and Spent Fuel Storage Safety Reference Levels’, Western European Nuclear Regulator’s Association (WENRA) (Ref. 21).
- ‘The management of higher activity radioactive waste on nuclear licensed sites’, ONR, Natural Resources Wales, Scottish Environment Protection Agency and Environment Agency (Ref. 22).
- ‘New Nuclear Power Plants: Generic Design Assessment Technical Guidance’, ONR (Ref. 23).
- ‘Funded Decommissioning Programme Guidance for New Nuclear Power Stations’, Department of Energy and Climate Change (Ref. 14).

22. It is noted that the ONR SAPs and TAGs are benchmarked against the IAEA and WENRA guidance available at the time of publication.

2.4.4 Use of Technical Support Contractors

23. I did not utilise any Technical Support Contractors (TSC) to assist with my assessment.

2.5 Integration with Other Assessment Topics

24. GDA requires the submission of an adequate, coherent and holistic generic safety case. Regulatory assessment cannot be carried out in isolation as there are often issues that span multiple disciplines. I have therefore worked closely with a number of other ONR inspectors and the Environment Agency to inform my assessment. The key interactions for the SFIS topic were:

- ONR Fuel and Core specialist inspectors lead on ONR's assessment of the design of the reactor core and fuel management this includes aspects such as fuel criteria relevant to the safety of SFIS operations (processing and storage). Fuel criteria include, but are not limited to, fuel burn up, temperature limits, and the physical/chemical characteristics of the spent fuel cladding (Ref. 24).
- Fault Studies, including the Probabilistic Safety Analysis (PSA) specialist inspectors lead on ONR's assessment of the adequacy of the RP's identification of initiating events, fault analysis relevant to the SFIS operations (loading and storage) and the integration of SFIS-related faults within the relevant fault schedule(s) (Ref. 25) (Ref. 26).
- ONR Mechanical Engineering specialist inspectors consider the adequacy of the SSCs relevant to lifting and handling operations. This includes cranes and handling tools for SFAs, RCCAs, SCCAs, the spent fuel canister, spent fuel transfer cask and spent fuel concrete silo (Ref. 27). These aspects have also been the subject of RO-UKHPR1000-0014 'Spent Fuel Building – Design of Nuclear Lifting Operations to Demonstrate Relevant Risks are Reduced to ALARP' and RO-UKHPR1000-0056 'Fuel Route Safety Case' (Ref. 28).
- ONR Radiological Protection specialist inspectors consider the adequacy of the RP's safety case on topics relevant to radiation doses to workers and the public from SFIS related operations, including storage (Ref. 29).
- The adequacy of the RP's safety case for the management of radioactive waste, excluding RCCAs and SCCAs, is considered in the 'Step 4 Assessment of Radioactive Waste Management for the UK HPR1000 Reactor' (Ref. 30).
- The adequacy of the RP's safety case for the decommissioning of the facilities identified within this assessment, for example the SFP, are considered in the 'Step 4 Assessment of Decommissioning for the UK HPR1000 Reactor' (Ref. 31).
- Environment Agency inspectors consider the demonstration of Best Available Techniques (BAT) across the lifecycle of the management of spent fuel to ensure that future options for disposability are not foreclosed by the on-site management strategy.

2.6 Overseas Regulatory Interface

25. ONR has formal information exchange agreements with a number of international nuclear safety regulators and collaborates through the work of the IAEA and the Organisation for Economic Co-operation and Development Nuclear Energy Agency (OECD-NEA). This enables us to utilise overseas regulatory assessments of reactor technologies, where they are relevant to the UK. It also enables the sharing of regulatory assessments, which can expedite assessment and helps promote consistency.

2.6.1 Bilateral Collaboration

26. As part of this assessment ONR took part in a bilateral workshop on radioactive waste management (and environmental assessment), which included aspects on the storage of spent fuel, with the Chinese nuclear safety regulator, the National Nuclear Safety Administration (NNSA), and the Environment Agency in November 2019 (Ref. 32). This provided valuable background knowledge of practices and national infrastructure for radioactive waste management in China and the regulatory framework.

3 REQUESTING PARTY'S SAFETY CASE

3.1 Introduction to the Generic UK HPR1000 Design

27. The generic UK HPR1000 design is described in detail in the PCSR (Ref. 3). It is a three-loop PWR designed by CGN using the Chinese Hualong technology. The generic UK HPR1000 design has evolved from reactors which have been constructed and operated in China since the late 1980s, including the M310 design used at Daya Bay and Ling'ao (Units 1 and 2), the CPR1000, the CPR1000$^+$ and the more recent ACPR1000. The first two units of CGN's HPR1000, Fangchenggang Nuclear Power Plant Units 3 and 4, are under construction in China and Unit 3 is the reference plant for the generic UK HPR1000 design. The generic UK HPR1000 design is claimed to have a lifetime of at least 60 years and has a nominal electric output of 1,180 MW.

28. The reactor core contains zirconium clad uranium dioxide (UO_2) fuel assemblies and reactivity is controlled by a combination of control rods, soluble boron in the coolant and burnable poisons within the fuel. The core is contained within a steel Reactor Pressure Vessel (RPV) which is connected to the key primary circuit components, including the Reactor Coolant Pumps (RCPs), Steam Generators (SG), pressuriser and associated piping, in the three-loop configuration. The design also includes a number of auxiliary systems that allow normal operation of the plant, as well as active and passive safety systems to provide protection in the case of faults, all contained within a number of dedicated buildings.

29. The reactor building houses the reactor and primary circuit and is based on a double-walled containment with a large free volume. Three separate safeguard buildings surround the reactor building and house key safety systems and the main control room. The Fuel Building is also adjacent to the reactor and contains the fuel handling and short-term storage facilities as part of the SFP. Finally, the nuclear auxiliary building contains a number of systems that support operation of the reactor. In combination with the diesel, personnel access and equipment access buildings, these constitute the nuclear island for the generic UK HPR1000 design.

3.2 The Generic UK HPR1000 Safety Case

30. In this sub-section I provide an overview of the SFIS aspect of the generic UK HPR1000 safety case as provided by the RP during GDA. Details of the technical content of the documentation and my assessment of its adequacy are reported in the subsequent sections of my report.

3.2.1 Safety Case for Spent Fuel Interim Storage

31. Under the Energy Act 2008, operators of new nuclear power stations are required to have a Funded Decommissioning Programme (FDP) before construction of a new nuclear power station. Consistent with guidance on the FDP for new nuclear power stations (Ref. 14) a Base Case is described. The Base Case includes assumptions for management of spent fuel which a new nuclear power station must meet in the UK. This includes the assumption that there will be no reprocessing of spent fuel in the UK, and that spent fuel will be disposed of to the future GDF. The Base Case assumes that spent fuel from new nuclear power stations is kept in interim storage on the site of the power station until the point at which a GDF is available for spent fuel from new nuclear power stations. Radioactive Waste Management Limited (RWM), a subsidiary of the Nuclear Decommissioning Authority (NDA), is responsible for the delivery of a GDF. RWM's 2016 update to the generic design of the disposal facility (Ref. 33) estimates emplacement times for various waste streams in a GDF, spent fuel from new build power stations is estimated to be disposed of to a GDF between 2145 and 2190.

32. The HPR1000 in China is designed according to the domestic policy of China, where there are currently no requirement for long term on-site storage of spent fuel. ONR concluded within the Step 3 assessment of the UK HPR1000 GDA (Ref. 16) that the RP has selected a technology for the management of spent fuel on site for the UK HPR1000 that is consistent with international practice, UK practice on nuclear new build power stations and meets the expectations within the UK Base Case (Ref. 14). The technology option selected is dry storage of spent fuel within sealed canisters for long term interim storage on-site within a purpose-built storage facility. An initial cooling period within the SFP is required prior to loading into spent fuel storage canisters. The UK HPR1000 fuel route process within the nuclear site boundary up to storage in the SFIS Facility, including storage of spent fuel in the SFP, is described in PCSR Chapter 28 (Ref. 4). The SFIS Facility and associated operations, such as SFA loading into canisters in the Fuel Building, are described in PCSR Chapter 29 (Ref. 5).

33. There are three key buildings/facilities in the generic UK HPR1000 design to support implementation of dry storage of spent fuel:

- Fuel Building - The UK HPR1000 spent fuel strategy requires the SFA to be removed from the reactor and temporarily stored in the SFP in the Fuel Building for initial cooling. After the initial cooling period (at least 5 years, in most cases 10 years), SFAs will be loaded and weld sealed into spent fuel storage canisters, dried and the canister filled with an inert gas. These processing operations take place in the Fuel Building in purpose-built facilities connected to the SFP. Once complete the spent fuel canister within the transfer cask is moved to the on-site storage facility, identified as the SFIS Facility. The spent fuel canister/transfer cask are lifted by the dedicated SFCC as part of the Fuel Building Handling Equipment (DMK[FBHE]).
- SFIS Facility - The SFIS Facility is designed to receive the canister in its transfer cask and facilitate the safe transfer of the canister into a concrete silo for long term interim storage on site in the SFIS Facility. A single container is placed into a single concrete silo. The design life of the SFIS Facility for the UK HPR1000 is defined as 100 years. This facility is currently a conceptual design.
- Retrieval and Repackaging Facility - The generic UK HPR1000 design includes a facility to retrieve spent fuel from the canisters and repack/encapsulate immediately prior to transport off-site for disposal in a GDF, circa 100 years after the start of operations. The design and operations within the retrieval and repacking facility are outside the scope of GDA (see sub-section 2.3). The RP's assumptions for the retrieval and repacking facility are consistent with the UK Base Case for new nuclear power stations (Ref. 14).

34. A summary of the UK HPR1000 SFIS process can be found in Figure 1 taken from (Ref. 5). The RP's 'Spent Fuel Interim Storage Facility Design' document (Ref. 34) includes indicative structures of the spent fuel storage canister, transfer cask and concrete silo, these are repeated in Figure 2.

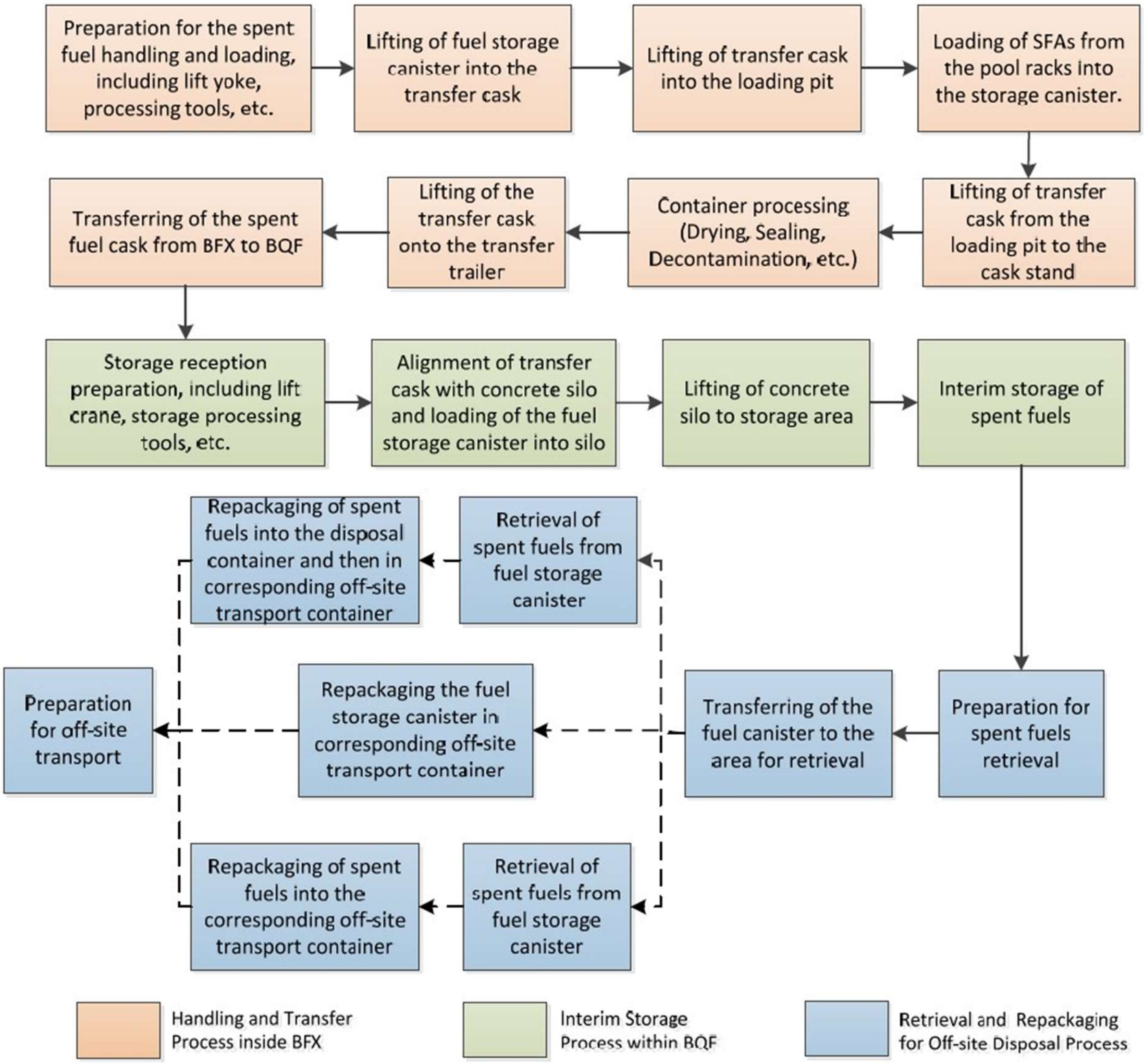

Figure 1: Spent Fuel Interim Storage Process Summary *(Ref. 5)*

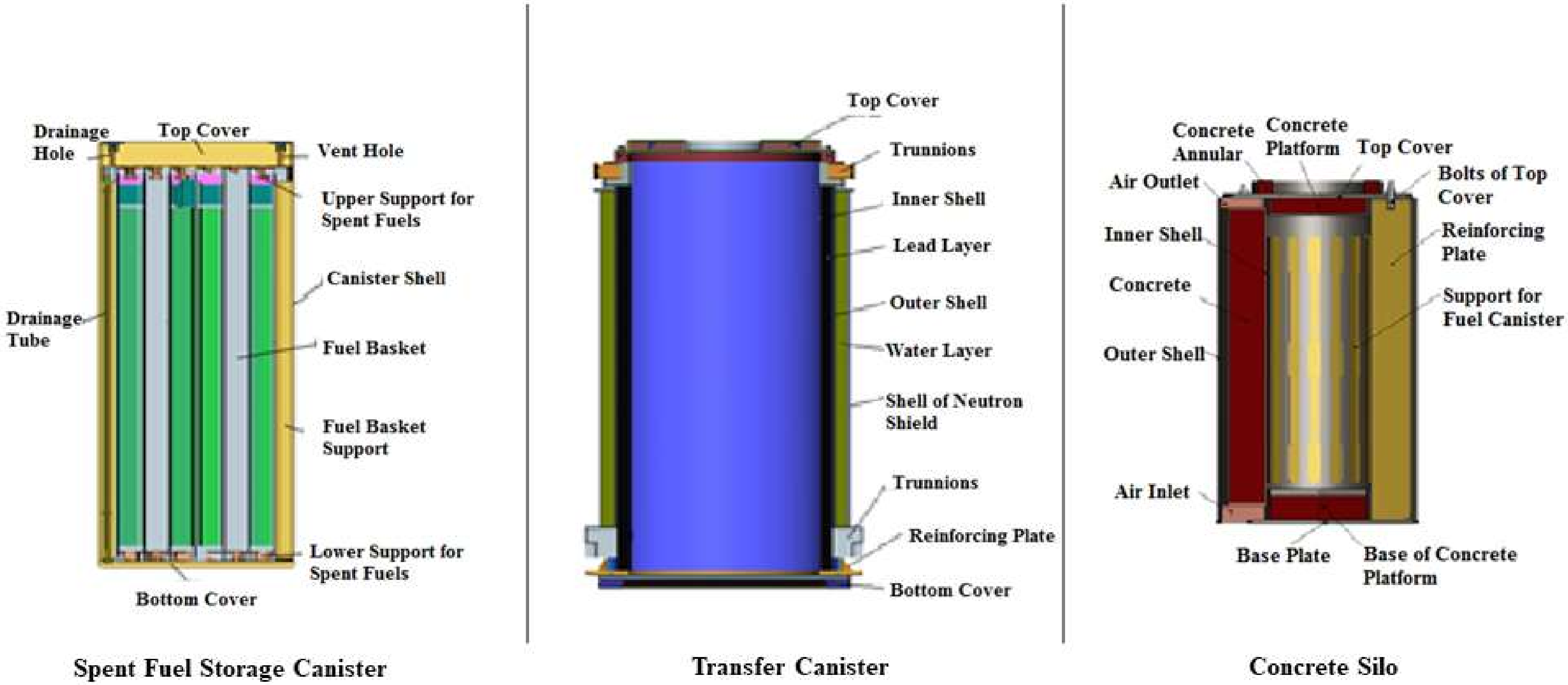

Figure 2: Indicative Structures of the Spent Fuel Storage Canister, Transfer Cask and Concrete Silo *(Ref. 34)*

35. The safety case for the on-site storage of spent fuel in the SFIS Facility is described in PCSR Chapter 29 (Ref. 5).The SFIS Facility safety case is not limited to the operations within the SFIS Facility itself, but includes all operations required to enable long-term interim storage within the SFIS Facility, including the implementation of the SFIS technology SSCs in the Fuel Building. The safety case assumes SFAs will need to be retrieved and repackaged into new containers suitable for disposal. The containers for the disposal of spent fuel are dependent upon the geology of a GDF and are not defined at the GDA stage.

36. The key claim and sub-claims within the RP's safety case (Ref. 5) as relevant to the SFIS topic are:

- "Claim 3.3.13: The SFIS process, and design of the associated systems, is substantiated."
    - "Sub-claim 3.3.13.SC29.1: All reasonable measures are adopted to ensure the technology selected satisfies the requirements in the UK."
    - "Sub-claim 3.3.13.SC29.2: The Spent Fuel Interim Storage is capable to achieve safe storage of spent fuel."

37. These claims link to the top-level Claim 3, which states that the generic UK HPR1000 design reduces the risks to ALARP, as shown (Ref. 5):

- "Claim 3: The design and intended construction and operation of 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."

38. The arguments and evidence to support these claims are summarised within the PCSR Chapter 29 Route Map, Appendix 29A of PCSR Chapter 29 (Ref. 5).

39. PCSR Chapter 29 provides a summary of the RP's SFIS safety case, the evidence is referenced from PCSR Chapter 29 and embedded in several supporting submissions. The four key supporting submissions, and a summary of their content, are:

- 'SFIS Facility Design' (Ref. 34). This provides details on the conceptual design for the SFIS Facility and how this meets UK regulatory expectations, including requirements which will need to be addressed in the future detailed design. The conceptual design includes SSCs required in the Fuel Building to support SFIS operations. The scope of operations in the SFIS Facility is not limited to the storage of spent fuels, the design also includes storage facilities for equipment (contaminated and non-contaminated) and HLW, specifically the storage of waste ICIAs in 500 litre robust shielded drums. ICIAs are identified as radioactive waste, therefore the storage facilities for ICIAs form part of the radioactive waste safety case (Ref. 30).
- 'Matching Analysis of Selected SFIS Technology with Current UK HPR1000 Design' (Ref. 35). This submission considers the SFIS process (Figure 1) and has two aims:
    - The first is to provide evidence that the existing SSCs within the Fuel Building are able to support the implementation of the selected SFIS technology or, where they cannot, identify SSCs that have been added to the Fuel Building design to enable implementation. Relevant SSCs include handling/lifting equipment, ventilation systems, power systems, demineralised water distribution system/decontamination equipment and the SFP cooling and treatment system.

- The second is to provide evidence that the newly added SFIS SSCs can be safely implemented within the existing generic design of the Fuel Building. Examples of newly added SSCs which need to be accommodated within the Fuel Building design are the spent fuel storage canister, transfer cask and trailer and the welding and gas filling equipment. The matching analysis (Ref. 35) also contributes to the arguments/evidence that the Fuel Building does not unduly constrain the implementation of the selected SFIS technology such that options to reduce the risks to ALARP during the detailed design are foreclosed.

- ‘Preliminary Safety Evaluation of SFIS’ (Ref. 36). This submission primarily aims to provide evidence of the risk/hazard identification process undertaken by the RP, as relevant to SFIS operations in both the Fuel Building and SFIS Facility. As the detailed design develops at the site-specific phase a licensee should take into consideration the information within the preliminary safety evaluation and develop it further. The submission identifies relevant safety functions which the detailed design of the SFIS Facility and associated SSCs should fulfil. The document also identifies explicit requirements which the detailed design should take into consideration and provides preliminary limits and conditions in the interests of safety which require refinement as the detailed analysis progresses beyond the GDA stage.
- ‘ALARP Demonstration of SFIS’ (Ref. 37). This submission draws upon the information presented within the SFIS Facility design (Ref. 34), the matching analysis (Ref. 35) and the preliminary safety evaluation (Ref. 36) to provide evidence by means of a risk assessment that the risks associated with the SFIS Facility are reduced to ALARP so far as can be demonstrated for the conceptual design. The RP’s ALARP demonstration acknowledges this is an iterative process which will be reviewed during the detailed design by a licensee at the site-specific stages.

3.2.1.1 Failed Fuel Management Strategy

40. The generic UK HPR1000 safety case identifies the potential that up to five failed fuel assemblies could be generated as a result of 60 years of operation of one UK HPR1000 reactor unit (Ref. 4). A fuel assembly is considered as failed when the fuel cladding is damaged (Ref. 4). The fuel cladding could be damaged during reactor operations and handling operations in the SFP. PCSR Chapter 28 makes an explicit claim (sub-claim 3.3.12.SC28.1) that the safety functional requirements have been derived for the Fuel Handling and Storage System (PMC [FHSS]), with maintenance of the fuel cladding as an explicit safety function for the confinement of radioactive substances. Assessment of the adequacy of the arguments and evidence to meet this claim are linked to the fuel criteria and are therefore in the scope of the Fuel and Core assessment (Ref. 24).

41. The RP’s UK HPR1000 safety case (Ref. 4) indicates failed fuel generated during the operation of the UK HPR1000 will be stored in the SFP within a dedicated failed fuel storage cell while the SFP is available (until at least the end of 60 years of reactor operations). The safety case for the storage of failed fuel within the SFP forms part of PCSR Chapter 28 (Ref. 4) and assessment of the fuel failure mechanisms which could lead to fuel clad failure is considered in the scope of the Fuel and Core assessment (Ref. 24).

42. In the event that there is inadequate space within the SFP, or at the point where the SFP is to be decommissioned, the safety case assumes failed fuel will be transferred to the SFIS Facility for dry storage. The detailed operational and decommissioning strategy for the management of failed fuel in the SFIS Facility is out of scope of GDA (Ref. 17). However, the RP’s safety case for the management of failed fuel within the

SFIS Facility at GDA aims to provide evidence that the generic UK HPR1000 design does not foreclose options for the management of failed fuel in the SFIS Facility.

3.2.1.2 Non-Fuel Core Components

43. The overall spent fuel safety case (Ref. 4, Ref. 5) includes aspects relevant to the management of waste NFCCs. NFCCs are typically metal components used inside the nuclear reactor core and are therefore subjected to an intense neutron flux during their operational life, becoming activated. Once the NFCCs reach the end of their operational life they need to be replaced. NFCC is a collective term for three types of components: RCCA, SCCA and ICIAs.

44. The UK HPR1000 strategy for the management of NFCCs (Ref. 38) provides details on the management of waste NFCCs once they have reached the end of their operational life.

Management of Waste RCCAs and SCCAs

45. There are two types of RCCAs (identified as black and grey RCCAs) and three types of SCCAs (thimble plug assemblies, primary source assemblies and secondary source assemblies, of which the latter two contain a neutron source). Each has a different function during operation of the reactor, but the waste management strategy is consistent for all RCCA/SCCA types.

46. During operation of the reactor RCCAs and SCCAs are inserted into a SFA. In the generic UK HPR1000 design the RCCA and/or SCCA are managed as part of the SFA during transfer from the reactor to the SFP. Once in the SFP, RCCAs/SCCAs can be moved independently from the SFA. This functionality is required because the operational life of RCCAs/SCCAs (15 and 20 years, respectively) is longer than the lifecycle of a fuel assembly (up to 3 cycles) see ‘Table T-6-2 General Information on the Objects Store within SFIS Facility’ (Ref. 34).

47. The management strategy for waste RCCAs and SCCAs, which are both categorised as HLW, is for them to remain an integral part of the SFA for long term interim storage. This includes during co-storage in both the SFP and dry storage in the SFIS Facility. The disposability strategy for RCCAs/SCCAs also assumes that they will be retained with the SFA (Ref. 39). For storage and disposal, it is assumed that every fourth SFA includes a RCCA or SCCA.

Management of Waste ICIAs

48. Waste ICIAs are managed separately to spent fuel, and therefore the management strategy and safety case for the retrieval, packaging and handling of waste ICIAs is considered in the Step 4 Assessment for Radioactive Waste Management for the UK HPR1000 Reactor (Ref. 30). I have considered the adequacy of the RP’s consideration for the storage of these within the SFIS Facility conceptual design.

4 ONR ASSESSMENT

4.1 Structure of Assessment Undertaken

49. Consistent with the sampling strategy (sub-section 2.2) the focus of my assessment is on the safety case associated with the transfer of spent fuel to the SFIS Facility.

50. The structure of my assessment is as follows:

- Operating sequences (Fuel Building and SFIS Facility).
- SFIS Facility design (construction strategy, storage capacity and layout).
- SFIS hazards and risks (radioactive material confinement, heat removal and retrievability).
- Co-storage of RCCAs/SCCAs.
- Limits and conditions in the interests of safety and EIMT
- Failed fuel management strategy.
- Relevant aspects of disposability of spent fuel, RCCAs and SCCAs
- Demonstration that relevant risks have been reduced to ALARP, including whether the RP's safety case provides evidence to support the claims made.
- Consolidated safety case.

4.1.1 Regulatory Observations and Queries

51. At the start of Step 4 of the GDA for the UK HPR1000 I assessed the safety case for SFIS and identified shortfalls with respect to meeting the regulatory expectations for the scope for SFIS (Ref. 15). As a result, I raised RO-UKHPR1000-0050 'Selected Spent Fuel Interim Storage Technology ALARP Demonstration' (Ref. 28). The expectations captured in the RO aimed to address the shortfalls identified, key expectations included:

- Identification of the principal hazards/risks associated with the implementation of the SFIS technology in both the existing Fuel Building and conceptual SFIS Facility.
- Identification of the safety functions that need to be provided, and the SSCs that will deliver them within the generic UK HPR1000 design.
- Identification of key limits and conditions necessary in the interests of safety required to provide assurance of the fuel cladding integrity during normal operations.
- The identification of prevention, protection and mitigation measures which could be implemented in the future detailed design to reduce the risks from the implementation of the SFIS technology to ALARP.
- The generic design of the SFIS Facility is sufficiently versatile to incorporate design changes as the detailed design of the technology is developed at the site-specific stage.

52. My assessment for the closure of RO-UKHPR1000-0050 can be found in the relevant closure note (Ref. 40). My assessment here considers how the RP has addressed the expectations in RO-UKHPR1000-0050, the sampling strategy outlined in sub-section 2.2, and the purpose of GDA. I have based my assessment on the latest versions of the RP's safety case submissions, which incorporate improvements to meet the expectations of RO-UKHPR1000-0050.

53. My assessment also considers clarification provided by the RP in response to several RQs raised during Step 4 of the UK HPR1000 GDA. Table 1 provides a summary of the RQs raised by ONR in Step 4 of the UK HPR1000 GDA relevant to the SFIS topic (Ref. 41).

Table 1: Spent Fuel Interim Storage Topic Relevant RQ Summary

Regulatory Query Number	Title	Summary of RQ response
RQ-UKHPR1000-0664	Justification of the safety of Rod Cluster Control Assemblies (RCCAs) and Stationary Core Component Assemblies (SCCAs)	Provided clarification on how the generic UK HPR1000 design enables the safe movement of RCCAs/SCCAs from the reactor to the SFP and provides for adequate safe co-storage with SFAs in the SFP and the SFIS Facility. Provides reference to evidence to underpin the physical/chemical/material properties of RCCAs/SCCAs during SFIS processing operations and dry storage.
RQ-UKHPR1000-0744	SFIS Availability for ICIA Storage	Provided clarity on the availability of the SFIS Facility for the safe storage of HLW ICIAs in 500 litre robust shielded drums.
RQ-UKHPR1000-0926	Spent Fuel Canister, Transfer Cask and Silo Queries	Provided clarity on the safety functional requirement and management of the water layer in the transfer cask and decontamination operations on the external surface of the spent fuel storage canister and transfer cask.
RQ-UKHPR1000-0998	Selected SFIS Technology Equipment Storage	Provided clarity of the storage locations of SSCs relevant to SFIS. This included the equipment storage room of the SFIS Facility, contaminated equipment storage room of the SFIS Facility and the nuclear power plant garage.
RQ-UKHPR1000-1086	Failed Fuel Special Storage Cell	Provided clarity on the failed fuel storage cell within the SFP and the use of filters on the cells to reduce the spread of contamination in the SFP.
RQ-UKHPR100-1206	Nuclear Power Plant Garage	Provided clarity on the requirements of the nuclear power plant garage identified in RQ-UKHPR1000-0998. The garage is considered to be an auxiliary building and therefore outside the scope of GDA (Ref. 17) and it does not exclusively support SFIS operations.
RQ-UKHPR1000-1593	Clarification of aspects in RO-0050	Provided clarity on aspects relevant to forced ventilation and the integration with the fault schedule and PSA topic area.
RQ-UKHPR1000-1759	Clarification of Assumptions in Disposability Assessment	Provided clarity on the basis for the assumptions used in the RWM disposability assessment.
RQ-UKHPR1000-1762	Fuel handling and storage system layout drawings	In response the RP provided copies of the layout drawings for facilities in the Fuel Building, see Figure 3.

4.2 SFIS Operating Sequences

4.2.1 The RP's Submissions on SFIS Operating Sequence

54. Consistent with the expected scope for the SFIS topic for the UK HPR1000 GDA (Ref. 15) a key expectation of the safety case for GDA was:

- Provision of information of the main steps in the operating sequence. Suitable and sufficient information should be provided which enables the future operator to adequately understand the nature of operations that need to be conducted.

55. I have considered whether the RP's safety case provides adequate evidence to enable the future operator to understand the nature of the SFIS operations which need to be conducted within the Fuel Building and SFIS Facility.

4.2.1.1 Fuel Building

56. The RP's submissions identified several facilities within the Fuel Building which are required for the safe packaging of SFAs into the spent fuel storage canister. Operations within the scope of the SFIS Facility, as summarised in Figure 1 include:

- Preparation of the empty spent fuel storage canister and transfer cask.
- SFA loading operations in the loading pit.
- Canister/transfer cask processing operations (welding, drying, gas filling and decontamination)
- Lifting the canister/transfer cask onto the transfer trailer for export to the SFIS Facility.

57. Further details of the SFA and canister/transfer cask handling operations are captured within Section 7.3 of the RP's 'Fuel Handling Process Operations' (Ref. 42) titled 'Spent Fuel Delivery in BFX', where BFX is the Fuel Building. This provides the future operator with a description of the operations to be carried out, together with information on starting conditions, handling equipment and relevant areas with figures showing the operating sequence. The following paragraphs describe the main elements of the sequence and the main equipment used.

58. Preparation of the empty spent fuel storage canister and transfer cask – the transfer cask enters the Fuel Building on the transfer vehicle and is lifted using the SFCC onto the Cask Stand, see Figure 3. The transfer cask is then prepared for receipt of the empty spent fuel storage canister. Preparations include, but not limited to, removal of the transfer cask lid and external/ internal surface cleaning with deionised water. Once the transfer cask is ready, the empty spent fuel storage canister is brought into the Fuel Building on the transfer vehicle. This is then lifted and loaded into the transfer cask on the Cask Stand using the SFCC. The transfer cask/spent fuel storage canister are then lowered to the bottom of the loading pit. The water level in the loading pit is increased so that it is consistent with the water level in the SFP. Once flooded, a sluice gate, which connects the Loading Pit to the SFP, is opened. The sluice gate is required to enable the SFA to pass from the SFP to the Loading Pit. The sluice gate also enables the water level in the Loading Pit to be managed independently of the SFP, with the capability to drain all water from the Loading Pit with the sluice gate closed.

59. SFA loading operations – after an initial cooling period in the SFP, SFAs are loaded into the spent fuel storage canister in the Loading Pit via the sluice gate. SFAs with (or without) an RCCA/SCCA are transferred to the spent fuel storage canister by the Spent Fuel Pool Crane (SFPC)/ fuel handling machine. Once the spent fuel storage canister is fully loaded with SFAs the sluice gate is closed and the water level in the Loading Pit lowered without uncovering the canister/transfer cask. The canister inner cover is then installed underwater using the SFCC. The transfer cask, with the loaded

spent fuel storage canister, is then lifted out of the water in the Loading Pit and positioned onto the Cask Stand, see Figure 3 (Ref. 43).

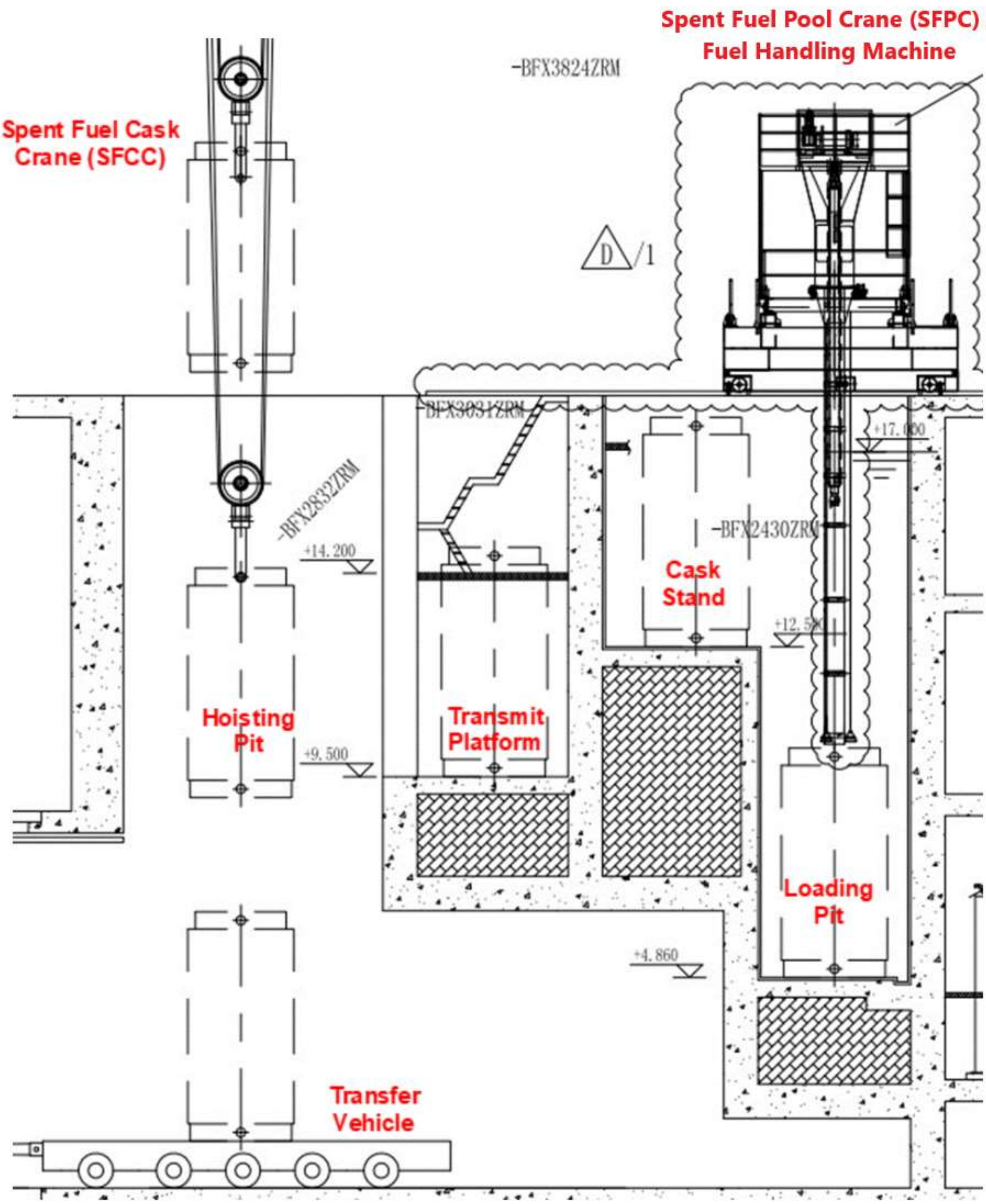

Figure 3: UK HPR1000 Fuel Building SFIS Processing Areas: Cross Sectional View

60. Canister/ transfer cask processing operations - When positioned in the Cask Stand, the transfer cask is decontaminated the canister inner cover is welded to the canister. The canister is then drained, vacuum dried and filled with inert gas using the drainage and vent holes on the canister, see Figure 2 for information on the generic canister design. The canister outer cover is then installed using the SFCC and welded in position. Once the spent fuel storage canister is sealed the transfer cask lid is installed and bolted into position. After drainage of the water in the annulus between the transfer cask and canister, the transfer cask is then prepared for lifting on to the transfer trailer. To

support operations, the Cask Stand and Loading Pit include both fixed and removable operator access platforms. The access platforms support operations on the top of the storage canister/transfer cask, for example welding operations.

61. Lifting the canister/transfer cask onto the transfer trailer for export to the SFIS Facility - The SFCC is used to lift the fully loaded and sealed transfer cask onto the Transmit Platform. The Transmit Platform is used as an interim step for lowering to the transfer vehicle at the bottom of the Hoisting Pit. The operations conducted here are primarily associated with lifting and handling operations which are outside of the scope of my assessment.

4.2.1.2 SFIS Facility

62. Operations within the scope of the SFIS Facility, as summarised in Figure 1 include:

- Receipt of the spent fuel storage canister and transfer cask.
- Transfer of the spent fuel storage canister from the transfer cask to the concrete silo.
- Lifting of the spent fuel canister in the concrete silo to the storage area.
- Interim storage of spent fuel, including monitoring inspection activities.

63. Considering the above operational requirements, Figure 4 is a schematic of the RP’s conceptual layout of the SFIS Facility, modified from the SFIS design (Ref. 34) to ensure labels are visible. Further details on the SFIS Facility processes, and relevant SSCs are included below.

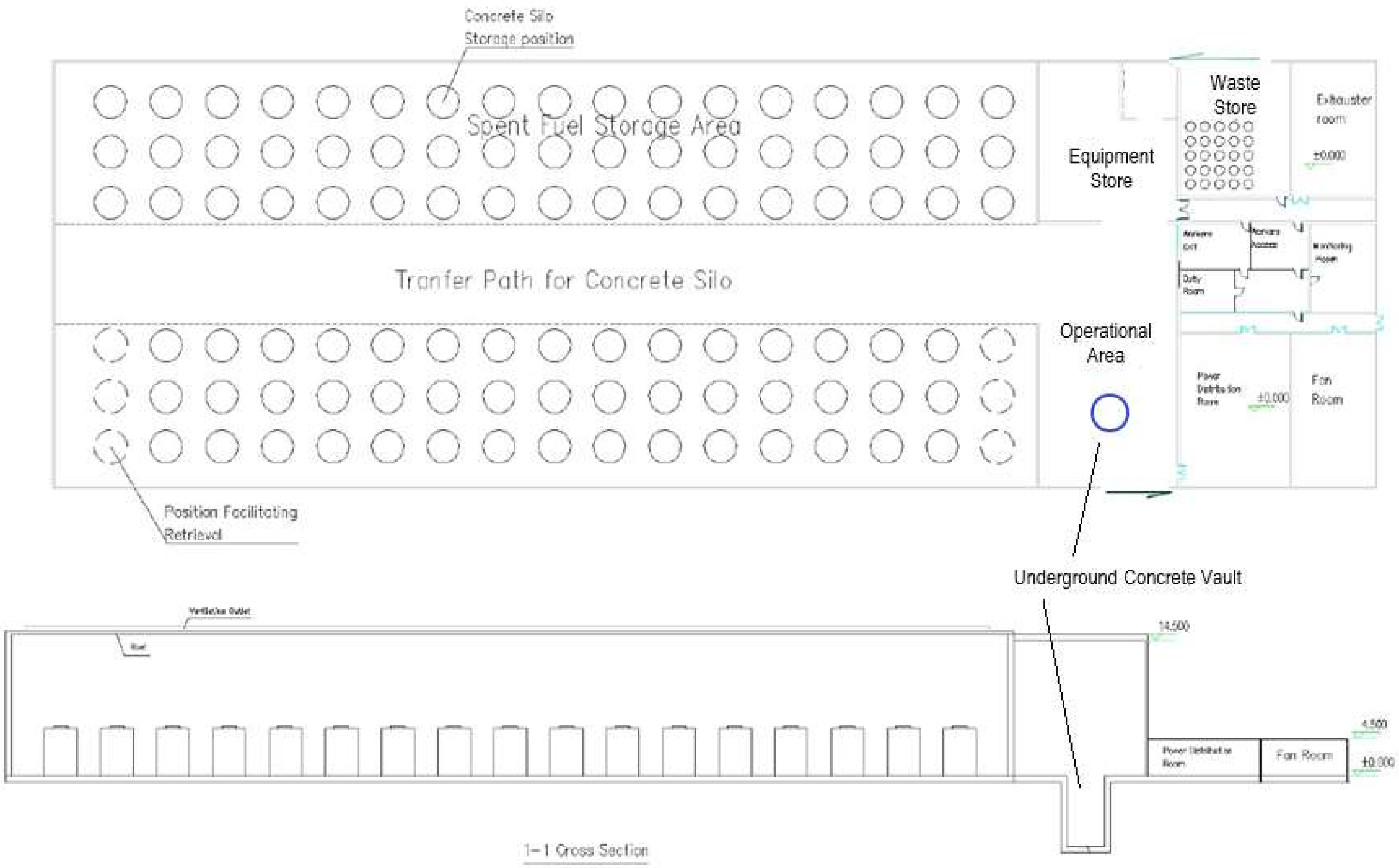

Figure 4: Preliminary SFIS Facility Layout for the First Phase

64. Preparation for Cask Receipt – The RP's safety case requires all necessary equipment and components are prepared within the SFIS Facility prior to receipt of the transfer cask in the operational area. This includes integrity checks of the concrete silo, loading of the empty concrete silo into the underground vault, and removal of the concrete silo cover. An adapter is required to enable the bottom of the transfer cask to be opened (the transfer cask is loaded from the top within the Fuel Building), this needs to be fitted to the concrete silo in the underground vault.

65. Transfer Cask Receipt – After the cask receipt preparations are complete the transfer trailer (with canister/cask) enters the operational area close to the underground vault. A lifting machine, which is vendor specific and therefore out of scope of GDA, is used to lift the transfer cask from the trailer onto the adapter on the concrete silo. The adapter on the concrete silo is used to confirm the transfer cask and concrete silo are aligned. The adapter is used to open the bottom of the transfer cask and the lifting machine lowers the spent fuel storage canister out of the transfer cask into the concrete silo.

66. Concrete Silo Lifting – The transfer cask lower cover is closed. The transfer cask and adaptor are removed and stored in the equipment storage area. The concrete silo cover is then installed. A lifting machine is required to enable the concrete silo to be lifted from the underground vault and moved to its designated storage position.

67. Interim Storage – The spent fuel storage canister in the concrete silo is stored within the SFIS Facility for up to 100 years, until retrieval for repacking/disposal. The RP's safety case identifies the requirement to undertake a programme of monitoring and inspection during storage including:

- Temperature monitoring of the concrete silo during storage.
- Humidity and chloride concentration monitoring. The RP's safety case recognises that humidity and chloride may affect the long-term performance of the concrete silo. The RP's safety case recognises the need to monitor for humidity and chloride concentration within the spent fuel store is dependent upon the requirements of the SFIS technology vendor, which will be determined beyond the GDA stage.
- Radiation monitoring of the concrete silo and in the facility. This should be conducted to provided confirmation that both adequate shielding is being maintained by the concrete silo, and that there is no leakage or escape of radioactive material from the spent fuel storage canister.
- Inspections of the concrete silo should be conducted to ensure any changes in the physical structure (for example cracks in the concrete) are identified and repaired.

4.2.2 Assessment of the Operating Sequences in the Fuel Building and SFIS Facility

68. In my opinion the RP's safety case provides suitable and sufficient information to enable the future operator to adequately understand the nature of the operations that need to be conducted in relation to SFIS in both the Fuel Building and SFIS Facility itself. This is consistent with regulatory expectations for the scope of SFIS (Ref. 15).The operations described by the RP are consistent with UK experience for similar facilities and supported by references to vendor technologies and relevant Operational Experience (OPEX).

69. Once a vendor for the SFIS technology is selected at the site-specific stage, the licensee will be required to undertake a detailed analysis of the operating sequences to determine the operating and maintenance instructions. This is a regulatory expectation of ONR SAP SC.6. The RP has identified post-GDA commitments to provide transparency on where the generic UK HPR1000 design at the GDA stage has defined a requirement that needs to be addressed by the licensee (Ref. 44). Several

commitments related to the detailed design of the SFIS SSCs and the SFIS Facility itself are included in the post-GDA commitment list.

70. Management of spent fuel, including on-site storage, forms part of the FDP requirements in UK policy (Ref. 14). ONR's guidance on licensing nuclear installations (Ref. 45) provides information on how ONR requires the FDP to be in place for the nuclear site prior to commencement of nuclear safety related construction.

71. Although the RP's process does not negate any regulatory requirements to maintain oversight of safety significant aspects, I consider the RP's definition of post-GDA commitments in the safety case, in addition to ONR's application of the licensing process, as appropriate in maintaining regulatory oversight of the development of the detailed design of the SFIS Facility and associated documentation (safety case and operating instructions) at the site licensing phase. I have thus not raised any Assessment Findings or minor shortfalls in relation to the operating sequence.

4.2.3 Operating Sequence Conclusions

72. Overall, in my opinion the RP's safety case provides suitable and sufficient information on the main steps in the operating sequence to enable the future operator to adequately understand the nature and sequence of operations that need to be conducted for the interim storage of spent fuel.

4.3 SFIS Facility Design

73. In line with the regulatory expectations in ONR SAP ENM.2, the RP should have suitable arrangements in place for the safe management of spent fuel generated on the site, including designated storage facilities with appropriate capacity. Therefore, I have targeted my assessment of the SFIS Facility design on the construction strategy, storage capacity and layout of the conceptual design primarily against the expectations in ONR SAP ENM.2.

4.3.1 The RP's Submission on the SFIS Facility Design

74. The SFIS Facility design is based upon a number of assumptions, as set out in Table T-5-1 of the RP's submission on the SFIS design (Ref. 34):

- The SFIS Facility should be designed to receive spent fuel and relevant HLW produced from two UK HPR1000 reactor units operated for 60 years.
- The design life of the SFIS Facility is defined as 100 years.
- Each spent fuel storage canister holds up to 32 SFAs.

75. The RP's safety case identifies the dependency between the spent fuel inventory and the refuelling cycles for the safe operation of the UK HPR1000 reactor (Ref. 46). The inventory presented within the RP's SFIS safety case (Ref. 34), is consistent with refuelling cycle assumptions at GDA (Ref. 46).

4.3.1.1 Construction Strategy

76. The design of the SFIS Facility is based upon the optioneering undertaken by the RP. For the construction strategy of the SFIS Facility the RP considered two options (Ref. 34):

- Option 1, a two-phase approach. Two independent facilities will be designed each with the capacity to accommodate 30 years of spent fuel and HLW packages from the operation of two UK HPR1000 reactor units. The first phase will be constructed to align with the start of generation, to recognise the need to store HLW packages approximately 54 months (4.5 years) after the start of operations. A second facility will be designed 15-20 years after the start of operations to be available 30 years after the start of operations. The second facility design can be updated to consider up-to-date inventory information and allow lessons learnt from the first facility and/or wider OPEX from similar facilities to be applied.

- Option 2, a one-off construction. For a single facility the capacity is required to accommodate all spent fuel and HLW packages generated during the full operational period of two UK HPR1000 units (60 years).

77. The RP's optioneering process (Ref. 34) took into consideration the following criteria:

- Nuclear safety (including safety functions for the SFIS Facility and relevant SSCs).
- Conventional safety.
- Environmental impact (including generation of secondary waste arisings).
- Technical feasibility (maturity of the option, flexibility of the option to support storage of spent fuel /HLW waste, EIMT requirements and decommissioning).
- Economy (start-up investment and operational costs).
- Security requirements.

78. The evidence of the RP's optioneering process for the construction of the SFIS Facility is captured in 'Table T-6-1 Options Assessment for Construction Plant' in the RP's submission on the SFIS design (Ref. 34). The RP concluded that in terms of nuclear safety, conventional safety, security and environment impact there is a small difference between the two options, however Option 1, a two-phase construction plan, is selected on the basis that:

- the storage capacity can be optimised;
- improvements to the design of the facility can be made for the second phase;
- the risk of material degradation due to the age of the facility is reduced as the second facility is built at least 20 years after the first facility;
- reduced upfront/one-time investment costs;
- two phases offer the flexibility to take into consideration technology development and policy or strategy changes; and
- OPEX considered by the RP provides supporting evidence that the strategy is consistent with on-site storage facility for new nuclear build sites within the UK.

4.3.1.2 Storage Capacity

79. In line with the regulatory expectations in ONR SAP ENM.2, the RP should have in place designated storage facilities with appropriate capacity, including spare and buffer capacity where necessary.

80. On the basis of a two phase construction strategy, the RP's safety case (Ref. 34) provides information on the refuelling requirements of the generic UK HPR1000 design (Ref. 46) to determine the number of SFAs generated from the operation of two UK HPR1000 over 30 years. This is used to define the total number of spent fuel storage canisters required to be stored within the SFIS Facility, with information provided in Table 2 (Ref. 34).

81. The safety case recognises that the number of PWR SFAs which can be safely stored within a single canister is dependent upon the performance of the selected vendor's SFIS technology and the fuel characteristics (for example burn-up and cooling time in the SFP) and is typically 24, 32 or 37. The RP's safety case (Ref. 36) refers to UK OPEX for similar dry spent fuel storage systems where 24 SFAs are loaded per spent fuel storage canister. The safety case, and design of the SFIS Facility for GDA, is based upon 32 SFAs per spent fuel storage canister.

Table 2: General Information on Objects Stored within the SFIS Facility from 30 Years of Operations of Two UK HPR1000 Units.

Parameter	Values
SFAs, RCCAs, SCCAs	
Average SFAs generated from one refuelling operations	72 SFAs (equilibrium cycle) 177 SFAs (last cycle)
1st refuelling cycle	1 year
Subsequent refuelling cycle	1.5 years (18 months)
Average SFAs generated from one refuelling operations (equilibrium cycle)	72 SFAs
Total number of fuel assemblies discharged over 60 years in operation (considering equilibrium cycles, single nuclear power units and 18-months refuelling pattern)	2985 SFAs
Average RCCAs generated from each change cycle	68 RCCAs
Change cycle frequency for RCCAs	15 years
Total number discharged over 60 years	272 RCCAs
Average SCCAs generated from each change cycle	112 SCCAs
Total number discharged over 60 years	333 SCCA
Number of assemblies/RCCAs/SCCAs in one fuel storage canister	32 SFAs, 8 RCCAs/SCCAs
Total number of canisters required	94
ICIAs	
Total number discharged over 60 years ICIA (i&ii)	560 sets
Total number of containers required	70
Required storage capacity in the SFIS Facility (number of containers including margin)	50
Stacking Type	Two layers

4.3.1.3 Layout

82. The layout of the SFIS Facility should take into consideration the regulatory expectation of ONR SAPs ELO.1, the design and layout should facilitate access for necessary activities and ELO.3, to minimise the need for movement of the spent fuel. In addition, ONR SAP ENM.2 includes regulatory expectations to have suitable arrangements for the safe management of spent fuel generated on the site, which the layout should be consistent with.

83. The RP's design for SFIS is conceptual at the GDA stage, and the RP's safety case is clear that demonstration of ALARP is an iterative process as the design develops through the site-specific stages (Ref. 37). I have thus assessed the layout of the SFIS Facility based upon the RP's use of OPEX in defining the design features of two key areas:

- Operational Areas (receipt/export area, underground concrete vault and transfer path)
- Storage Areas (concrete silo storage area, equipment storage area and consideration of other radioactive waste storage areas (waste ICIAs) within the SFIS Facility).

84. Operational Areas – the operational area is designed to enable the movement of the loaded spent fuel canister from the transfer cask to the concrete silo, which includes receipt of the transfer cask. The design includes an underground vault to enable the transfer of the spent fuel canister from the transfer cask to the concrete silo. This is typical for dry storage facilities as it enables the height of the SFIS Facility to be minimised. The operational areas are segregated from the storage areas.

85. Storage Areas - the conceptual design of the SFIS Facility includes three storage areas; the concrete silo storage area, the equipment storage area and the radioactive waste store. The conceptual layout includes:

- A transfer path to access the concrete silo storage area from the operational area.
- The requirement to position concrete silos to facilitate access for routine operations (such as EIMT, see paragraph 67).
- Direct access to the equipment store from the operational area. This is required for use/movement of SSCs to enable the transfer operations (for example access to lifting equipment and the transfer cask/concrete silo adapter).
- A segregated storage area for potentially contaminated equipment. The safety case recognises the risk that some equipment used within the SFIS canister processing operations are in direct contact with the spent fuel (for example vacuum drying equipment) and therefore there is a risk of contamination.
- Separate access arrangements to the radioactive waste storage area used for the decay storage of HLW ICIA wastes within 500 shielded drums. The assessment of the safety case for the radioactive waste storage area is out of scope of this assessment and is considered in the Step 4 assessment report for Radioactive Waste Management (Ref. 30).

4.3.2 Assessment of SFIS Design

86. There are no explicit regulatory expectations for the construction strategy for spent fuel storage facilities. However, the construction strategy should be consistent with the expectations in ONR SAP ENM.2, namely, to ensure appropriate designated storage facilities are available on site prior to generation of nuclear matter. In my opinion the RP has presented adequate evidence to underpin the decision to adopt a two-phase construction plan, supported by evidence that the facilities will be available prior to the generation of the spent fuel, consistent with ONR SAP ENM.2.

87. In my opinion, in defining 32 SFAs per canister at the GDA stage, the RP has not foreclosed the option to change this number and can either reduce or increase the size of the SFIS Facility during detailed design. In the conceptual design of the SFIS Facility, Figure 4, and the associated safety case submission (Ref. 34) it is clear that the detailed design depends on a number of factors, including the selected supplier and site specific information. The licensee will need to determine the actual number of SFAs per canister, and therefore the size of the SFIS Facility. The RP recognises the use of canister/concrete silos is a modular design which will facilitate changes to the detailed design to increase/decrease the storage capacity (Ref. 34).

88. In my opinion the evidence relevant to storage capacity in the SFIS Facility is proportionate to the level of detail available at GDA. This is consistent with the expectations of ONR SAP ENM.2 to ensure appropriate capacity. In my opinion, the modular nature of the dry storage technology has not foreclosed options to the

licensee to consider the requirement for spare or buffer storage capacity during the detailed design.

89. In my opinion there are several design features which facilitate access for necessary activities, and minimising adverse interactions between the different areas in the SFIS Facility conceptual design, which are consistent with the regulatory expectations of ONR SAP ELO.1. For example, creating a segregated operational area away from the concrete silo storage areas minimises the likelihood of a fault in one area from impacting upon the other. Inclusion of separate access arrangements for the radioactive waste store facilitates access to load/unload ICIA packages, without interacting with the SFIS storage facilities.

90. In my opinion, through enabling access to each individual concrete silo with minimum movement of further concrete silos the RP's safety case is consistent with regulatory expectations in ONR SAP ELO.3.

4.3.3 SFIS Design Conclusions

91. Overall, in my opinion the SFIS Facility conceptual design includes adequate facilities for the safe management of spent fuel, with due consideration of factors which may impact upon the storage capacity, which will need to be taken into consideration in the detailed design. Consistent with my conclusions in sub-section 4.2.2, I consider the development of the detailed design of the SFIS Facility to be normal business at the site licensing phase and have not raised any Assessment Findings or minor shortfalls.

4.4 SFIS Hazards and Risks (Normal Operations and Faults)

92. As captured in RO-UKHPR1000-0050 'Selected Spent Fuel Interim Storage Technology ALARP Demonstration' (Ref. 28), I identified shortfalls in the RP's safety case relevant to the identification of the hazards and risks associated with the SFIS SSCs operated within the Fuel Building and the SFIS Facility. In this sub-section I consider the adequacy of the evidence provided by the RP to address the following regulatory expectations from the scope of SFIS for GDA (Ref. 15) and RO-UKHPR1000-0050:

- A demonstration that the principal hazards/risks associated with the selected SFIS technology (dry storage) during normal operations are identified and understood.
- Identification of the initiating events which could give rise to the faults associated with the SSCs required for the packaging, movement and storage of spent fuel into canisters for dry storage.
- Identification of key safety functions that need to be provided and delivery of these functions by the SSCs within the generic UK HPR1000 design (or otherwise).

4.4.1 The RP's Submission on the SFIS Hazards and Risks

93. The 'Preliminary Safety Evaulation of Spent Fuel Interim Storage' (Ref. 36) provides evidence of the RP's risk identification and analysis process undertaken for normal operations, as documented in Table T-5-3 in the same reference (Ref. 36). The RP's preliminary safety evaluation (Ref. 36) identifies the SSCs required, and the safety functions the SSCs must provide, in order to restrict doses and reduce the risks from the implementation of the SFIS technology to ALARP during normal operations.

94. The safety functions identified within the RP's safety case (Ref. 36) include:

- Radioactive material confinement;
- Heat removal;

- Retrievability;
- Sub-criticality control (out of scope of my assessment, see sub-section 2.3);
- Radiation shielding (out of scope of my assessment, see sub-section 2.3).

95. The RP's safety case identifies the need to ensure the design of the SFIS SSCs are able to provide passive means of delivering against the safety functional requirements during normal operations. Passive safety within the ONR SAPs is defined as "providing and maintaining a safety function without the need for an external input such as actuation, mechanical movement, supply of power or operator intervention". The regulatory expectation in ONR SAP ENM.6 is to ensure nuclear matter, which is stored for a significant period of time, is stored in a passively safe condition. The RP's safety case recognises that the processing operations within the Fuel Building should be conducted to ensure that the passive safety during later storage of the spent fuel is not impacted.

96. The RP makes no claims on the SFIS Facility itself to provide any safety functions for the storage of spent fuel. Safety functional claims are placed on the SFIS Facility SSCs, including the spent fuel storage canister, the transfer cask and / or concrete silo.

97. The RP's safety case identifies the need to carry out a detailed and quantitative risk assessment of the detailed design of the SFIS SSCs, taking account of relevant site-specific information. The risk assessment presented at GDA is only qualitative. The RP's risk assessment uses two variable matrices of likelihood and consequence to evaluate the risk level and the RP describes application of the hierarchy of hazard control, ERICP (Elimination, Reduction, Isolation, Control and Protect) to reduce the likelihood and/or consequences associated with the risk to ALARP, as set out in 'Appendix D Hazards Record Sheet' of the ALARP demonstration for SFIS (Ref. 37).

98. Appendix D of the ALARP demonstration of SFIS (Ref. 37) includes information on relevant initiating events for faults and potential consequences linked to loss of one or more of the five safety functions. The RP has identified independent preventative and mitigative engineered features which are claimed to reduce the probability or consequences of a deviation from normal operations.

99. Several claims are made on the design of the spent fuel storage canister, transfer cask, and concrete silo that are consistent with the principle of passive safety. Consistent with the scope of my assessment, I have considered the adequacy of the RP's consideration of the following safety functions in the design of the SFIS SSCs and the faults which may challenge the ability of the SFIS SSCs to passively maintain them to achieve:

- Radioactive material confinement;
- Heat removal; and
- Retrievability.

4.4.1.1 Radioactive Material Confinement (Containment)

100. The RP has identified the fuel cladding as the primary means of confinement (also referred to as primary means of containment) of the radioactive material (for example fission products) in the SFA.

101. The RP's safety case makes claims on the spent fuel storage canister for maintaining the integrity of the spent fuel throughout the storage period. The integrity of the SFA is required to ensure retrievability of the spent fuel for repacking prior to disposal (Ref. 34). In addition, confinement of the radioactive material within the fuel cladding reduces the likelihood of the spent fuel storage canister itself from becoming radioactive waste due to internal contamination with radioactive material.

102. The RP's safety case indicates that the spent fuel canister, once sealed, acts as the secondary containment barrier (Ref. 34).

103. The RP's safety case (Section 5.1 of 'Preliminary Safety Evaluation of Spent Fuel Interim Storage' (Ref. 36)) considers the Postulated Initiating Events (PIEs) which could compromise the containment function of the fuel cladding and/or spent fuel storage canister, several of which are outside the scope of my assessment and / or are considered by the relevant ONR specialist, see Section 2.3 on out of scope items and Section 2.5 on integration with other assessment topics. However, I have included details on the RP's safety case here for completeness:

- Events which increase the temperature of the fuel cladding (i.e. reduce the effectiveness of the heat removal).
- External stresses:
    - external hazards (for example flooding, earthquake);
    - internal hazards (for example fire or explosion of the welding/gas systems);
    - over-pressurisation within the spent fuel storage canister which challenges the integrity of the welding (caused by fuel cladding failure and the release of fission gases from within the fuel cladding).
- Dropped load (out of scope of my assessment, see sub-section 2.3):
    - dropping the SFA during loading;
    - dropping the transfer cask during operations in the Fuel Building or transfer from the Fuel Building;
    - dropping the concrete silo during handling operations within the SFIS Facility.
- Criticality (out of scope of my assessment, see sub-section 2.3):
    - Misloading of spent fuel in the canister leading to a criticality;
    - Damage to the storage canister affecting the function of the canister, designed to eliminate the risk of a criticality occurring.

104. The RP's risk assessment (Ref. 37), provides evidence that the RP has applied the hierarchy of hazard control, ERICP, to each of the initiating events identified to reduce the likelihood of failure of the containment function of the storage canister. The RP has provided information in the preliminary safety evaluation of SFIS (Ref. 36) on the need for the licensee to consider aspects such as the structure and material of the spent fuel storage canister and the supporting SSC (transfer cask or concrete silo) during detailed design to minimise the likelihood of radiological consequences from the faults.

4.4.1.2 Heat Removal

105. ONR NS-TAST-GD-081 (Ref. 12) identifies regulatory expectations for the duty holder's safety case to provide a clear demonstration that the heat removal systems are capable of providing the necessary functions for all normal operations and fault scenarios. Management of the heat during the SFIS operations is also identified as a requirement to maintain fuel cladding integrity, and therefore confinement of radioactive material.

106. The RP's safety case (Ref. 36) identifies the need to implement passive means for removal of heat generated by the spent fuel so far as is reasonably practicable throughout all operations. This includes passive systems which rely on natural convection, conduction and radiant heat transfer. The heat load limit needs to be

defined for the spent fuel storage canister, which is dependent upon the fuel criteria and the canister vendor and is thus outside the scope of my assessment.

107. The RP's safety case identifies the need to quantify the level of the residual heat produced by the SFA to ensure consistency with the heat load limit of the SFIS SSCs. The RP's safety case identifies that the residual heat is dependent upon factors such as fuel burn-up and the period of cooling within the SFP. The ONR Fuel and Core specialist inspector has considered the availability of adequate space in the SFP to enable sufficient time for cooling of the SFAs prior to processing for transfer to the SFIS Facility (Ref. 24). The ONR assessment of the SFP capacity and the capability of the SSCs within the SFP to maintain cooling of the SFAs is outside of the scope of my assessment. For completeness only:

- The RP's generic design of the SFP includes a capacity which is able to accommodate 10 refuelling cycles of one unit, which equates to approximately 15 years after the start of operations (Ref. 47).
- The RP's safety case considers typical SFIS products, and details on the UK HPR1000 specific fuel, and concludes that after 5-10 years of cooling in the SFP (6-11 years after the start of generation), spent fuel could be safely transferred to the SFIS Facility (Ref. 34).

108. The safety case identifies that the spent fuel storage canister, once loaded, is either in one of the two following configurations during normal operations:

- the spent fuel storage canister is in the transfer cask, both in the Fuel Building and during movement from the Fuel Building to the SFIS Facility; or
- the spent fuel storage canister is inside the concrete silo during interim storage.

109. The RP considers initiating events which could challenge the passive means of heat removal from the spent fuel storage canister in these two configurations. The RP has also identified features to prevent or mitigate against the likelihood of the initiating event resulting in a loss of the capability of the SSCs to remove heat in these two configurations.

Spent Fuel Storage Canister and Transfer Cask Configuration

110. The RP's safety case (Ref. 36) identifies that the transfer cask should be designed to support the safety functions of heat removal, shielding and retrievability. An indicative structure of a transfer cask is presented in Figure 2 (see page 18).

111. The RP's safety case identifies the need to define a time limit for spent fuel in the spent fuel storage canister/transfer cask configuration as part of the detailed design. This is due to the limited capability for the transfer cask to passively remove heat (Ref. 34). Passive features of the spent fuel storage canister and transfer cask to assist in the management of heat include consideration of material selection and the physical structure/design of the canister/cask to facilitate heat transfer.

112. The RP's safety case (Ref. 36) provides evidence that the RP has considered initiating events from operator and mechanical errors which may lead to exceedance of the time limit for the spent fuel in the spent fuel storage canister/transfer cask configuration. In the event the time limit is exceeded for transfer of spent fuel from the Fuel Building to the SFIS Facility, the safety case identifies the need for the detailed design to include a means to provide forced ventilation to control the temperature through cooling. Forced ventilation is required to reduce the risk that the fuel cladding (primary containment) will fail due to overheating in the transfer cask.

113. While the need for active cooling during the transfer of spent fuel casks is common (Ref. 48), the RP has been unable to define the time limit before active cooling is

required during GDA. The time limit is dependent upon the integration between the UK HPR1000 fuel criteria and the detailed design of the SFIS technology. The requirements for the detailed design of SFIS as captured in Section 6.12 of the RP's submission on the same topic (Ref. 34), include the need for the future operator to understand the fuel cladding limits further and to determine a time limit. The adequacy of the RP's evidence relevant to the fuel criteria at GDA to underpin the RP's limits and conditions (for normal and off-normal conditions) is outside the scope of my assessment and has been assessed by the ONR Fuel and Core specialist inspector (Ref. 24).

Spent Fuel Storage Canister and Concrete Silo Combination

114. The RP's safety case (Ref. 34) identifies the requirement for the SFIS design to include a concrete silo as an overpack during the storage of spent fuel within the storage canister. An indicative structure of the concrete silo is provided in Figure 2. The primary safety functional requirements of the concrete silo are radiation shielding and physical protection of the storage canister against internal and external hazards, however the design also needs to ensure that heat can be removed by passive means.

115. The RP's SFIS concept design (Ref. 34) identifies OPEX for the concrete silo which indicates it should use natural circulation of air across the canister to maintain cooling by means of air inlets at the bottom of the silo and outlets at the top in the concrete silo design. The RP's safety case identifies the requirement to monitor the temperature on the ventilation outlet to identify any changes. Variations in the outlet temperature could be an indicator that the storage system is no longer passively safe. A temperature increase may not be a result of changes within the spent fuel storage canister but could be an indicator that the passive cooling is not functioning as designed. The RP's safety case identifies the following risks in their risk assessment (Ref. 37) which could result in higher temperatures being monitored:

- The concrete silo inlets and/or outlets could be blocked as a result of an external hazard.
- An internal fire (internal hazard) or extreme environmental temperature (external hazard) could result in extreme temperatures that could render the passive cooling design features inadequate.
- Misloading of the spent fuel in the canister due to operator error could result in an excessive heat loading in the canister.

116. Several design features have been identified to prevent and / or mitigate against the risk of overheating occurring in the concrete silo, including:

- Material selection to facilitate heat transfer;
- Structural design to facilitate heat transfer and reduce the possibility of air inlet blockage;
- Temperature monitoring of the concrete silo.
- Nuclear material record management and a pre-defined SFA loading strategy;
- Definition of a sufficient heat load margin in the canister design to address the risk of misloading.

117. The RP has not identified any additional SSCs to actively control the temperature when in the concrete silo. In the event that the outlet temperature remains high, and no fault is identified, the RP's safety case requires the licensee to retrieve the spent fuel from the storage canister to inspect the fuel cladding integrity and verify passive safety is being maintained, see sub-section 4.4.1.3 on retrievability.

4.4.1.3 Retrievability

118. The difference between disposal and storage is the intention to retrieve from storage facilities (Ref. 49). Therefore, to meet the safety function of retrievability the RP's safety case should define how the intention to retrieve will be safely implemented in the generic UK HPR1000 design. There are two scenarios where the spent fuel would require retrieval, in normal operations to enable repacking for a GDF, and in a fault scenario where the spent fuel is no longer stored passively safe within the spent fuel storage canister.

119. Consistent with the out-of-scope items identified in sub-section 2.3, the management steps, including the facilities required to enable the safe retrieval and re-packing of spent fuel to enable transport and disposal of spent fuel into a GDF are outside the scope of GDA. This sub-section considers the adequacy of the RP's consideration of the retrievability of SFAs from the spent fuel storage canister prior to the retrieval and repacking facility becoming available. The ability to inspect spent fuel (as nuclear matter) is a regulatory expectation in ONR SAP ENM.7.

120. Routine retrieval of spent fuel from the canisters during normal operations is not expected to be required. The reasons for retrieval of spent fuel identified within the RP's safety case (Ref. 34) are in response to identification of off-normal (fault) scenarios only, and include:

- A leak from the spent fuel storage canister is detected during storage, where the canister would be retrieved to the Fuel Building for repairs or repacking (as appropriate).
- Exceeding the limits and conditions identified in the interest of safety which are indicators that the fuel cladding (primary containment) has failed. For example, exceeding the time limit for spent fuel in the transfer cask or a high reading on the ventilation outlet temperature on the concrete silo during storage.

121. The RP's safety case assumes this activity will be completed through reverse engineering from the SFIS Facility into the Fuel Building Cask Stand/Loading Pit. The RP's safety case (Ref. 34) identifies the requirement for the Fuel Building decommissioning strategy to consider constructing a specific facility to maintain this capability in the time between the decommissioning of the Fuel Building and the construction of the repacking facility for disposal of the spent fuel. The RP has identified the function of retrievability in the conceptual design of key SSCs, including the spent fuel storage canister and transfer cask.

122. The RP provides evidence that it has considered the operational aspects of retrieval and repacking of spent fuel from the spent fuel storage canister in the matching analysis submission (Ref. 35). This includes aspects relevant to the use of boronated water to flood the spent fuel storage canister, the risk of radioactive aerosols and gases from any drilling or cutting processes (to open the spent fuel storage canister) and the management of radioactive wastes generated from the processes. In addition, the RP's safety case identifies the role of the commissioning stage in demonstrating the feasibility of spent fuel retrieval (drilling and cutting). Commissioning tests will be developed at the nuclear site licensing phase along with the detailed design (Ref. 34).

4.4.2 Assessment of SFIS Hazards and Risks

123. The safety functions identified by the RP are consistent with those identified in IAEA Specific Safety Guide 15 on the storage of spent fuel (Ref. 20), as embedded within ONR NS-TAST-GD-081 on the same topic (Ref. 12), both of which are sources of RGP for the storage of spent fuel.

124. In my opinion, the RP's identification of the need for detailed design information to undertake a quantitative risk assessment is consistent with IAEA guidance (Ref. 20). The RP's qualitative risk assessment undertaken at GDA identifies adequate independent preventative and mitigative engineered features to fault progression consistent with ONR's expectations in ONR SAP EKP.3.

4.4.2.1 Radioactive Material Confinement (Containment)

125. In my opinion the RP's identification of the fuel cladding as primary containment is consistent with the regulatory expectations of ONR SAP ECV.3 and ONR NS-TAST-GD-081 (Ref. 12). The ONR Fuel and Core specialist inspector is leading on ONR's assessment of the adequacy of the RP's safety case with respect to the parameters (fuel criteria) which need to be controlled to minimise the likelihood of a loss of fuel cladding integrity, and therefore the loss of primary containment (Ref. 24). As part of their assessment (Ref. 24), the ONR Fuel and Core specialist inspector has also considered the residual matter from RO-UKHPR1000-0050 on the adequacy of the evidence to support the fuel criteria as relevant to the implementation of the SFIS technology. This includes parameters which need to be controlled during SFIS loading operations in the Fuel Building and during storage in the SFIS Facility. Claiming the fuel cladding as the primary means of confining the radioactive material of the spent fuel limits the spread of contamination in the spent fuel storage canister. This is, in my opinion, consistent with the regulatory expectation of ONR SAP RW.2 to prevent, or where this is not reasonably practicable, to minimise the quantity of radioactive waste generated.

126. I have not assessed the fuel criteria, but I have considered the adequacy of the RP's application of the hierarchy of controls (ERICP) and the SFIS SSC design features. Using this information, I have made a judgement on whether the RP's safety case is consistent with RGP and similar technologies applied in the UK, and therefore whether the RP's safety case demonstrates that the risks are capable of being reduced to ALARP.

127. In my opinion identification of the spent fuel storage canister as a secondary confinement barrier is consistent with the regulatory expectations in ONR SAP ECV.4 on provision of further containment barriers where the radiological challenge dictates. In my opinion the RP has also identified the relevant internally and externally initiated events which may impact upon the integrity of the spent fuel cladding and/or spent fuel storage canister. These have then been used to inform the scope of the RP's qualitative risk assessment and define the design features required to ensure consistency with ERICP. In my opinion, the scope of the internally and externally initiating events, outlined in paragraph 103, are consistent with the RGP in ONR NS-TAST-GD-081 (Ref. 12) and IAEA guidance on the storage of spent fuel (Ref. 20).

128. Until the detailed design of the spent fuel storage canister is defined, I am unable to assess whether the canister is consistent with the design features identified in the RP's application of ERICP for normal operations. However, based upon ONR's knowledge of similar dry storage technologies in the UK, including information provided in the RP's safety case on OPEX (Ref. 36), the design features identified by the RP to prevent and mitigate against the failure of the confinement function of the spent fuel and/or storage canister are consistent with products available worldwide and are not unique to the UK HPR1000. ONR notes, in its experience with similar systems, it would be considered a good practice to use a dummy canister/concrete silo in the SFIS Facility as a means of monitoring for any changes to the storage SSCs, without the hazard/risk posed by a canister containing spent fuel. In my opinion the generic UK HPR1000 design does not foreclose this option for the licensee at the site-specific phase and a minor shortfall is identified for the licensee to consider this once a vendor is selected as part of the detailed design of the SFIS Facility.

129. Consistent with my conclusions on sub-section 4.2.2, I consider the development of the detailed design of the SFIS Facility and the SSCs for normal operations to be normal business at the site licensing phase, and thus raise no Assessment Findings or minor shortfalls.

4.4.2.2 Heat Removal

130. For the safety function of heat removal, in my opinion the RP's safety case places emphasis on ensuring passive means of heat removal are implemented so far as is reasonably practicable, which is consistent with the regulatory expectations in ONR SAP ENM.6. To support this, a number of design features to facilitate passive heat removal in normal operations have been identified in the RP's safety case for the spent fuel storage canister, in both the transfer cask and concrete silo (Ref. 36). In my opinion the design features are consistent with the expectations in ONR SAP ENM.6 and are consistent with ONR's knowledge of SSCs serving the same purpose used in the UK and worldwide (Ref. 20) (Ref. 50).

131. In my opinion the RP's safety case adequately identifies the risks which could challenge the ability of the systems to passively remove heat, which are consistent with international guidance on initiating events (Ref. 20).

132. For the spent fuel storage canister in the transfer cask, the RP's safety case identifies the need to consider forced ventilation, as an active means of providing cooling, to reduce the risk that the fuel cladding (primary containment) will fail due to overheating. The requirement for a forced ventilation system to control the temperature on the spent fuel storage canister when in the transfer cask is consistent with international guidance considered as RGP (Ref. 48), and ONR's knowledge of similar processes and international experience (Ref. 20) (Ref. 50).

133. I raised RQ-UKHPR1000-1593 (Ref. 41) to seek clarification on the point in the process at which the time limit for the transfer starts for the UK HPR1000, and therefore when forced ventilation would need to be available. In response, the RP provided clarity that the transfer time starts at the point where the water is drained from the annulus between the canister and the transfer cask on the Cask Stand in the Fuel Building.

134. The safe implementation of forced ventilation within the Fuel Building is dependent on the detailed design and therefore outside the scope of GDA. The ventilation system will be key to the RP's safety case that the risks for fuel cladding failures due to overheating in the transfer cask have been reduced to so far as is reasonably practicable for the UK HPR1000. How the future operator will ensure active cooling is available cannot be defined until the detailed design of the SSCs progresses and a vendor selected for the spent fuel canister/transfer cask, both of which are outside the scope of GDA. During my assessment of the closure for RO-UKHPR1000-0050 (Ref. 40) I also identified a residual matter related to the identification of all relevant initiating events which could exceed the transfer time limit for spent fuel in the canister/transfer cask to ensure it is consistent with the SFIS safety case and failed fuel management strategy.

135. Based upon my assessment here, which is consistent with the residual matter identified during my closure of RO-UKHPR1000-0050 (Ref. 40), I am raising an Assessment Finding. The Assessment Finding aims to maintain regulatory oversight at the site-specific phase of the licensee's detailed design and evidence that the SSCs associated with the active cooling can be safely implemented within the Fuel Building and reduce the risk of fuel cladding failure from overheating to ALARP. This is consistent with ONR guidance on the identification of Assessment Findings (Ref. 51) where in my judgement I consider this topic to be of sufficient significance to warrant maintaining regulatory oversight.

AF-UKHPR1000-0021 – The licensee shall provide evidence to demonstrate the detailed design of the structures, systems and components in the Fuel Building which actively cool spent fuel during export, are capable of preventing fuel overheating; and demonstrate that the risk of fuel cladding failure is reduced so far as is reasonably practicable.

136. In my opinion, the design features identified by the RP to prevent and mitigate against impairment of the heat removal function during storage in the concrete silo are consistent with the products for spent fuel storage available worldwide and are not unique to the UK HPR1000. Consistent with my conclusions in sub-section 4.2.2, I consider the development of the detailed design of the SFIS Facility and the SSCs for normal operations to be normal business at the site licensing phase, and thus raise no Assessment Findings or minor shortfalls in relation to storage in the concrete silo.

4.4.2.3 Retrievability

137. In my opinion, the RP has adequately identified the SSCs that would enable retrieval of the SFAs from the spent fuel storage canister in the event of a fault condition, including those in the Fuel Building, and has considered the need to demonstrate the feasibility of retrieval during commissioning. I consider this to be consistent with regulatory expectations in ONR SAP ENM.7, as appropriate to GDA. I expect the issue of retrievability to be considered further during the detailed design of the SSCs at the site-specific phase and do not consider it necessary to raise an Assessment Finding or minor shortfall.

4.4.3 SFIS Hazards and Risks Conclusions

138. In my opinion, and consistent with the regulatory expectations set out in the SFIS scope (Ref. 15) and RO-UKHPR1000-0050 (Ref. 28), the RP has adequately:

- Identified the hazards and risks associated with SFIS during normal operation within the Fuel Building and the SFIS Facility.
- Identified the initiating events which could give rise to faults associated with the SSCs required for the packaging, movement and storage of spent fuel in dry canisters.
- Identified the key safety functions that will need to be provided and the SSCs that will deliver them in the generic UK HPR1000 design.

139. I have identified a single Assessment Finding, AF-UKHPR1000-0021, which requires the licensee to provide evidence that the detailed design of SSCs for active cooling can be safely implemented within the Fuel Building and reduce the risk of the fuel cladding failure from overheating so far as is reasonably practicable. This is outside of the scope of GDA, but in my judgement the topic is of sufficient significance to warrant raising an Assessment Finding to maintain regulatory oversight at the site-specific phase. I have also identified a minor shortfall for the licensee to consider the use of a dummy canister/concrete silo in the SFIS Facility.

140. Overall, notwithstanding Assessment Finding AF-UKHPR1000-0021 and the minor shortfall, in my opinion the RP's safety case provides adequate evidence that the hazards and risks are understood, with engineered independent preventative and mitigative design features identified to demonstrate that the SFIS technology SSCs are consistent with RGP and therefore capable of reducing the risks to ALARP.

4.5 Co-Storage of RCCAs/SCCAs with Spent Fuel

4.5.1 The RP's Submissions on Co-Storage of RCCAs/SCCAs with Spent Fuel

141. The optioneering presented by the RP for the management of waste RCCAs/SCCAs (Ref. 38) concludes that co-storage with SFAs, using existing integral features of the SFA, does not result in a change to the number of spent fuel storage canisters required. In addition, the strategy to co-store means that no separate waste packages for RCCAs/SCCAs will be generated. The RP has provided evidence on OPEX to underpin the selection of the option which indicates co-storage is consistent with the management strategy being proposed at PWRs in operation or being constructed within the UK. A subtle difference between the RP's strategy and the OPEX available is that for the UK HPR1000 the SCCA neutron sources are not segregated and managed separately; but are retained with the SCCA.

142. The management proposal for NFCCs (Ref. 38) provides information on the development of the materials selected for RCCA and SCCA components, which has resulted in the extension of their operational life through improved understanding of material behaviour in the high radiation environment of the reactor core. Life-extending factors (Ref. 38) include:

- modifications to cladding material to minimise degradation;
- modifications to absorber materials to reduce the likelihood of swelling (which causes the cladding to deform or damage);
- increase in thermal efficiencies (i.e. heat transfer) through backfilling with Helium (an inert gas); and
- selection of materials with good irradiation performance.

143. For RCCAs, where there is the risk of the absorber swelling causing the damage/deformation to the RCCA cladding, the RP has included an inspection programme in the safety case (Ref. 38). The adequacy of the inspection programme is outside the scope of my assessment. However, this indicates that there is a risk of swelling/deformation of the RCCAs, which needs to be taken into consideration in the RP's safety case for co-storage with SFAs in the SFIS Facility.

144. The RP has provided evidence that the RCCAs and SCCAs do not have any adverse impact on spent fuel during co-storage, based upon evidence from OPEX that no degradation is observed during wet storage within the SFP. Any degradation would occur during use within the reactor and RCCAs/SCCAs are replaced prior to degradation to ensure they maintain their nuclear safety functions and thus will not be degraded prior to co-storage. The RP's argument that RCCAs/SCCAs can be co-stored safely in a dry storage canister in the SFIS Facility is based upon the following evidence:

- Humidity and oxygen levels within the spent fuel storage canister are controlled through vacuum drying and inert gas filling in order to protect the spent fuel, if uncontrolled this could lead to the degradation of metallic components, including spent fuel cladding and the stainless-steel cladding of the RCCA/SCCA.
- The RCCA/SCCA cladding material has a good performance in terms of heat resistance. The limits and conditions defined in the interests of safety placed on the storage canister to minimise the failure of the spent fuel cladding during processing and storage operations are also expected to protect the stainless steel from degradation.
- The RCCAs/SCCAs form an integral part of the SFA. The SFA is designed to ensure that there is no mechanical interaction between the spent fuel cladding and the RCCA/SCCA.

145. The RP's argument that the drying process in the spent fuel storage canister will not be negatively impacted by the presence of the RCCAs/SCCAs is based upon the evidence that:

- There is a low number of RCCAs/SCCAs per canister. In the SFIS design (Ref. 34) it is identified that for every 32 SFAs per canister, there will be eight RCCAs or SCCAs, as shown in Table 2.
- The drying process uses the pressure within the spent fuel storage canister to indicate the presence of air and water. The pressure is monitored in the vacuum drying system. The pressure is decreased to a design limit (to be determined during the detailed design) and maintained to indicate whether all the contents of the canister are dry.

146. The RP's safety case (Ref. 34) includes limits and conditions in the interests of safety and sets requirements and restrictions related to the spent fuel for the future design (see sub-section 4.6). The strategy to co-store RCCAs/SCCAs with SFAs is consistently referenced throughout the RP's SFIS Facility safety documentation. However, there is no explicit reference in the safety case to any consideration of the impact, if any, of the presence of the neutron sources in SCCAs during storage or drying operations during detailed design.

4.5.2 Assessment of Co-Storage of RCCA/SCCA

147. In my opinion the strategy of co-storage of RCCAs/SCCAs with the SFA is consistent with both my experience and knowledge of the strategy for RCCAs/SCCAs being proposed at PWRs in operation or being constructed within the UK. Co-storage is also consistent with the regulatory expectations in ONR SAP RW.3, for the safety case to demonstrate that the volume of radioactive waste accumulated on site has been minimised. In addition, the inclusion of the neutron sources with the SCCA, as opposed to separating the neutron source from the activated metal parts of the SCCA, provides an additional opportunity to eliminate the operation required to segregate the neutron source from the SCCA. In my opinion this minimises the volume of radioactive waste accumulated and is also consistent with ONR SAP RW.3. I will consider whether the inclusion of the neutron sources is consistent with the regulatory expectation of ONR SAP RW.1, to ensure radioactive waste is in a form which is compatible with the disposal route, in sub-section 4.8. Through extension of the operational life of RCCAs/SCCAs the RP is also providing evidence of minimising the rate of radioactive waste generation, which is a regulatory expectation of ONR SAP RW.2.

148. For my assessment I have considered whether the characteristics of the waste RCCAs and SCCAs are sufficiently well understood to underpin the selected storage strategy and associated safety case. Key expectations of ONR SAPs ENM.5 (and RW.4) and ENM.6 is that where different types of nuclear matter are mixed the safety case should adequately justify that it does not impact upon the passive safe storage of either element, in this case of the spent fuel, RCCA or SCCA (with neutron source).

149. To support my assessment, I sought clarification from the RP in RQ-UKHPR1000-0664 (Ref. 41) on the material properties (physical and chemical) of the RCCAs and SCCAs, and the RP's evidence for their compatibility with the SFA during drying and interim storage in the SFIS Facility. In response the RP referred to documents which provided information on the description and material properties of the RCCAs (Ref. 52) and SCCAs (Ref. 53), and has been used by the RP to justify that the RCCAs/SCCAs can be co-stored safely with the SFAs. The response to RQ-UKHPR1000-0664 acknowledges the requirement for the loading of RCCAs/SCCAs into the spent fuel canister to be considered during the detailed design once the performance of the canister is understood.

150. In my opinion the RP's arguments are consistent with ONR's understanding of similar safety cases in the UK. However, the RP will be unable to fully provide evidence to support arguments that the presence of the RCCAs/SCCAs (with neutron sources) will not impact on passive safety during storage in the spent fuel storage canister until the vendor is selected for the SFIS technology. This evidence will need to include a greater understanding of the conditions within the spent fuel storage canister, as expected by ONR SAP ENM.6.

151. On the basis of the conceptual design, I have insufficient evidence to reach a judgement whether the presence of RCCAs/SCCAs (with neutron source) will have an impact on the safe storage of spent fuel, as required by ONR SAP ENM.5. The impact on safety relates to both the potential degradation (swelling or deformation) of the RCCAs during storage, the impact of the presence of the RCCAs/SCCAs on the drying operations, and the inclusion of the neutron sources with the SCCAs. The immaturity of the safety analysis to underpin the co-storage of RCCAs/SCCAs with the SFAs is not unique to the UK HPR1000, with the exception of the inclusion of the neutron sources. Therefore, consistent with ONR's approach to this technical topic on other sites within the UK, I am raising an Assessment Finding concerning the licensee's safety analysis for co-storage. The UK HPR1000 safety analysis should ensure there is no impact on the passive safety storage of spent fuel (and the RCCAs/SCCAs) through consideration of:

- OPEX (if available);
- the impact, if any, of the presence of RCCAs/SCCAs during drying operations;
- the safety assessment of the inclusion of the neutron sources during processing and storage, and;
- the consequences, if any, of swelling or degradation of the RCCAs/SCCAs during storage.

AF-UKHPR1000-0022 – The licensee's safety case for the detailed design of the Spent Fuel Interim Storage Facility shall assess how the presence of Rod Cluster Control Assemblies and Stationary Core Component Assemblies, including neutron sources, may impact on spent fuel drying and storage operations. The analysis should demonstrate relevant risks arising from co-storage are reduced so far as is reasonably practicable.

4.5.3 Co-storage of RCCAs/SCCAs Conclusions

152. In my opinion, the RP's strategy to co-store RCCAs/SCCAs with SFAs in the spent fuel storage canister is consistent with the management strategy being proposed for similar radioactive waste items from PWRs in operation and being constructed in the UK. The RP's strategy also considers the regulatory expectations of ONR SAP RW.3 and minimising the volume of radioactive waste further through inclusion of the neutron sources with the SCCAs in the spent fuel storage canister.

153. The evidence to meet the regulatory expectations of ONR SAPs ENM.5 and ENM.6, namely that passively safe storage of spent fuel is not negatively impacted if different types of nuclear matter are present, depends on a number of aspects which will not be addressed until detailed design. It is my judgement that it is appropriate to raise Assessment Finding AF-UKHPR1000-0022 on the safety analysis for co-storage, which needs to be developed with the detailed design of the SFIS SSCs. The safety analysis should underpin the safety case claims/argument that the presence of RCCAs/SCCAs (with neutron sources) will not impact upon the drying operations, and that any potential swelling/deformation of the RCCAs/SCCAs does impact upon the passive safe storage of spent fuel.

4.6 Limits and Conditions in the Interests of Safety and EIMT

4.6.1 The RP's Submission on Limits and Conditions in the Interests of Safety and EIMT

154. One of the regulatory expectations for the SFIS scope (Ref. 15) was for the RP's safety case to identify limits and conditions in the interests of safety (proportionate to a GDA) for the UK HPR1000 relevant to the SFIS generic safety case. During Step 4 of the GDA I identified shortfalls on this topic, which I captured in RO-UKHPR1000-0050 'Selected Spent Fuel Interim Storage Technology ALARP Demonstration' (Ref. 28). These included the need to identify key limits and conditions in the interests of safety. This focused on the need for assurance of the fuel cladding integrity during normal operations in the Fuel Building and the SFIS Facility.

155. The RP's safety case (Ref. 34) identifies a set of parameters which should be monitored during operations to ensure the SSCs associated with the SFIS technology are operating safely, which are defined by the RP as operational limits and conditions (OLCs). The OLCs defined by the RP are generic parameters for which refinement or specific values will be determined as the design of the SFIS technology progresses beyond the GDA stage, see Table T-6-9 in the SFIS design (Ref. 34). OLCs relevant to providing assurance on the integrity of the fuel cladding include:

- Minimum cooling time for spent fuel in the SFP prior to transfer to SFIS.
- Prevention of a criticality from the SFIS operations.
- Ensuring sufficient heat removal and radiological protection.
- Prevention of fuel cladding failure during drying and backfilling operations.
- Prevention of fuel cladding failure during storage through drying and providing an inert atmosphere in the canister.
- A temperature and time at temperature limit to ensure the spent fuel cladding does not fail prior to storage.
- Temperature limits on the spent fuel storage canister in the concrete silo.

Other OLCs have been identified by the RP relevant to handling/lifting operations and shielding.

156. The RP has taken the approach of identifying requirements and restrictions for the subsequent design stages which may inform the OLCs, as set out Table T-6-14 in the SFIS design (Ref. 34). These are principally associated with the fuel criteria due to the claims on the fuel cladding as the primary means of confinement of the fission products.

157. Consistent with the RP's risk assessment (see sub-section 4.4) the RP's safety case (Ref. 34) includes the following requirements for the future design:

- To determine a spent fuel loading strategy for the storage canister. This should take into consideration the performance of the SFIS SSCs and the characteristics of the spent fuel (enrichment, burn up and cooling time).
- To reduce the risk of fire and explosion in the Fuel Building and SFIS Facility from the introduction of the transfer vehicle, required to move the spent fuel storage canister on site.
- To reduce the risk of the gas filling system for the spent fuel storage canister becoming an internal hazard in the Fuel Building.

158. The RP's safety case (Ref. 34) identifies the need to undertake EIMT for both security and safety reasons, including ensuring the integrity of the fuel storage canister, concrete silo and transfer cask are maintained. Further details on the RP's considerations for monitoring and inspection in the SFIS Facility are summarised in paragraph 67.

4.6.2 Assessment of the Limits and Conditions and EIMT

159. In my opinion, the RP's safety case (Ref. 34) adequately acknowledges the requirement to define limits and conditions in the interests of safety and the EIMT regime as the detailed design of the SFIS technology SSCs progresses, with the information provided proportionate to the level of detail available at GDA. This is consistent with the regulatory expectations in ONR SAP SC.6. In my opinion the generic parameters required for the OLCs identified by the RP align with the safety functions, are consistent with international good practice for fuel storage (Ref. 20), and meet the expectations set out in RO-UKHPR1000-0050 and the scope of SFIS for the UK HPR1000 GDA (Ref. 15).

160. Limits and conditions will need to be developed as the detailed design of the SFIS SSCs progresses, including the details of the fuel criteria (Ref. 24). In my opinion the safety case presents a golden thread from the need to define the details of OLCs to any restrictions or requirements which need to be taken into consideration when defining them, based upon the safety case at GDA and the links to EIMT, as expected by ONR SAP SC.6.

4.6.3 Limits and Conditions and EIMT Conclusions

161. In my opinion, and consistent with the expectations in the scope of SFIS for the UK HPR1000 (Ref. 15) the RP is only able to define general parameters, as opposed to limits and conditions in the interests of safety, for the SFIS operations until the detailed design of the SFIS Facility and the SSCs. The general parameters identified by the RP as OLCs are consistent with international guidance (Ref. 20).

162. Consistent with my conclusions in sub-section 4.2.2, I consider the development of the detailed design of the SFIS Facility to be normal business at the site licensing phase, and thus raise no Assessment Findings or minor shortfalls on the limits and conditions in the interests of safety or EIMT requirements within the scope of my assessment.

4.7 Failed Fuel Management Strategy

4.7.1 The RP's Submission on the Failed Fuel Management Strategy

163. The RP's failed fuel management strategy at GDA (Ref. 34) assumes storage within a failed fuel assembly storage cell within the SFP during operations. Once the SFP is decommissioned failed fuel will be managed within the SFIS Facility. The detailed operational and decommissioning strategy for the management of failed fuel in the SFIS Facility is out of scope of GDA (Ref. 17).

164. For GDA the RP's safety case for the management of failed fuel within the SFIS Facility aims to provide evidence that the generic UK HPR1000 design does not foreclose options for the management of failed fuel from being implemented. The RP identifies two options to support the storage of failed fuel in the SFIS Facility:

- Failed fuel is sealed within specific failed fuel cans prior to loading into the spent fuel storage canister: or
- Failed fuel is directly loaded into the spent fuel storage canister.

165. The RP's safety case does not determine whether the failed fuel will be stored in a separate spent fuel storage canister to intact SFAs, or if failed fuel and intact SFA could be co-stored in a single canister. The safety case assumes up to five fuel assemblies will fail during the operation of the UK HPR1000 reactor, and that the handling and SFIS loading operations minimise the likelihood of fuel cladding failure, see sub-section 4.4.1.1 on fuel cladding integrity. Considering the inventory in Table 2, five failed fuel assemblies equate to less than 0.17% of the total SFA inventory,

therefore only small quantities of failed fuel are anticipated. The number of spent fuel canisters defined for the spent fuel inventory (Table 2) is 94, in the preliminary design of the first phase of the SFIS Facility (Figure 4) storage locations for 102 canisters are identified, six of which are intended to be left empty to facilitate retrieval of a canister/concrete silo, if required. The inventory defined for the conceptual design of the first phase the SFIS Facility assumes failed fuel assemblies remain stored within the SFP, and that all failed fuel assemblies are transferred to SFIS in the spent fuel storage canisters for the second phase of the SFIS Facility.

166. The RP's safety case at the GDA stage acknowledges the requirement to consider additional engineering methods for the safe storage of failed fuel, including the potential requirement for using additional containment for failed fuel, a failed fuel can, during long-term interim storage as the fuel cladding cannot be claimed as primary containment. The safety case concludes that neither of the two options for the management of failed fuel in the SFIS Facility are foreclosed by the generic UK HPR1000 design.

4.7.2 Assessment of the Failed Fuel Management Strategy

167. In my opinion, the assumption in the UK HPR1000 generic safety case that failed fuel will be stored in the SFP until the end of generation ensures the safe storage of failed fuel during the operational phase of the UK HPR1000 lifecycle. This allows time for the RP to underpin the strategy for the management of failed fuel within the SFIS Facility. This assumption is consistent with those adopted internationally, as described in ONR NS-TAST-GD-081 (Ref. 12). The UK HPR1000 reactor is a PWR, where there is evidence available through OPEX worldwide on the stability of failed PWR fuel during wet storage. ONR's assessment of the adequacy of the design and number of the failed fuel storage cells within the SFP is outside the scope of my assessment.

168. In my opinion the RP's consideration of the need to consider additional engineering methods for the safe storage of failed fuel in the SFIS Facility, such as the need to design a specific failed fuel can, is consistent with international guidance (Ref. 20).

169. In my opinion, the RP does not explicitly present the arguments in the safety case that neither of the two options for the management of failed fuel in the SFIS Facility are foreclosed by the generic UK HPR1000 design. However, it is my judgement that the generic UK HPR1000 design does not foreclose options for the management of failed fuel within the SFIS Facility as these are aspects which depend upon the detail design of the SFIS SSCs. My judgement is based upon ONR's knowledge and experience of similar dry storage facilities in the UK and how this applies to the generic UK HPR1000 design, including:

- The spent fuel storage canister size is dependent upon the length of the SFA. The canister lengths in the UK vary depending on the reactor core design and length of the fuel assemblies. The spent fuel canister also needs to be long enough to accommodate the RCCA/SCCA (sub-section 4.5). This additional length offers flexibility to accommodate a failed fuel container within the canister, if required, while maintaining compatibility with the transfer cask and concrete silo, which are designed to safely accommodate the spent fuel storage canister.
- The internal furniture (for example the fuel basket in Figure 2) within the spent fuel storage canister can be customised and the packing arrangements modified without impacting the external diameter of the storage canister. This would enable accommodation of failed fuel within a failed fuel can, if required, and again ensures the transfer cask and concrete silo remain compatible.
- The storage capacity of the SFIS Facility may need to vary to accommodate an additional canister (or canisters) with failed fuel, should a decision be made to store failed and intact fuel assemblies separately.

- The size of the first phase SFIS Facility will need to be defined during the detailed design of the SFIS SCCs, in particular the decision on the number of SFAs per canister. The conceptual design of the first phase of SFIS currently includes storage for 102 canisters, eight more than is needed to meet the inventory requirements. In my opinion this provides adequate buffer storage for spent fuel in the first phase SFIS Facility.
- The detailed analysis for the storage of failed fuel in the SFIS Facility will need to be determined for the design of the second phase of the SFIS Facility, at ~15-20 years after start of operations, to ensure adequate storage capacity for the storage of failed fuel. Transfer to SFIS is not anticipated until after 60 years of operations. The RP's safety case (Ref. 34) identifies the need to consider the latest OPEX when determining the strategy for the management of failed fuel in the second phase of the SFIS Facility. I have identified a minor shortfall for the licensee to ensure the capacity of the second phase of the SFIS Facility considers storage of canisters for failed fuel from the SFP alongside consideration of buffer storage. It is my judgement that given the timescale for the development of the second phase of the SFIS Facility, the low quantity of failed fuel expected in the generic UK HPR1000 design, and the modular nature of the spent fuel storage canister/concrete silo, this is not of sufficient significance to warrant ONR tracking to resolution from the GDA, and therefore does not align with the definition of an Assessment Finding (Ref. 51).

4.7.3 Failed Fuel Management Strategy Conclusions

170. The RP's safety case assumption that failed fuel will be stored in the SFP is consistent with that for PWR reactors in the UK with similar dry storage facilities. It is my judgement that the generic UK HPR1000 design does not foreclose options for the safe management of failed fuel in the SFIS Facility. There is an expectation for the licensee to develop an adequate safety case to enable the safe management of failed fuel in the SFIS Facility after the operational period of the UK HPR1000. I have identified a minor shortfall for the licensee to consider the dry storage of failed fuel alongside buffer storage when defining the storage capacity of the second phase of the SFIS Facility.

4.8 Disposability of SFAs, RCCAs and SCCAs

4.8.1 The RP's Submission on the Disposability of SFAs, RCCAs and SCCAs

171. There are regulatory expectations in the 'Joint Guidance' on the management of Higher Activity Waste (HAW) (Ref. 22) and scope of GDA (Ref. 23) relating to the need for evidence that the packaging and conditioning of spent fuel and HAW is compatible with the requirements of geological disposal. Ensuring compatibility with appropriate off-site disposal routes ensures the accumulation of radioactive waste on-site is minimised, an expectation in ONR SAP RW.3. Therefore, the RP sought advice from RWM on the disposability of the spent fuel and HAW arising from operation and decommissioning of the UK HPR1000. This advice is intended to provide confidence to the regulators that the wastes and spent fuel generated from the operation and decommissioning of the UK HPR1000 are likely to be capable of being disposed of to a GDF. RWM's generic design for a GDF includes wastes and spent fuel from the operation of up to 12 nuclear new build reactors in the UK, with only four currently planned. Although the UK HPR1000 wastes are not explicitly identified in the generic design of a GDF, RWM concludes that, as a PWR, the UK HPR1000 wastes may be interchangeable for wastes and spent fuels already assumed without major revision to a GDF design (Ref. 39).

172. The RP provided information to RWM to enable a preliminary assessment of the disposability of spent fuel and HAW, which includes the RCCAs/SCCAs that will be co-stored with spent fuel in the SFIS Facility. RWM's disposability assessment assumes co-disposal of the SFA with RCCAs/SCCAs for the UK HPR1000 (Ref. 39). Consistent with ONR's understanding, RWM indicates that they are currently considering a similar strategy for co-disposal of SFAs with RCCAs/SCCAs from PWR reactor designs in operation and being constructed in the UK. There are two key elements to RWM's assessment which may impact upon the disposability of the UK HPR1000 spent fuel with RCCA/SCCA:

- Disposal container heat limits;
- Co-disposal.

4.8.1.1 Disposal Container Heat Limits

173. The RP's safety case (Ref. 5) assumes a repacking facility will be required to load SFAs into disposable containers immediately prior to transfer to a GDF, which is consistent with UK policy (Ref. 14). As noted in sub-section 4.4.1.3 the retrieval facility for repacking spent fuel into disposal containers is outside the scope of GDA. The inventory used by RWM to assess disposability is based upon a maximum and average package inventory, where a disposal package is assumed to contain four SFAs and a single RCCA or SCCA:

- The maximum inventory is based on four SFAs of maximum burn up, assuming all are discharged at the end of generation with only 1 year of cooling.
- The average disposal package inventory is calculated assuming that 72 SFAs are discharged from the reactor approximately every 18 months and are not all generated at the end of operations. Each SFA is assumed to have an average burn up and 1 year of cooling and the total average inventory has been divided by the number of disposal packages to obtain a lifetime average inventory per package.

174. RWM's assumption of 1 year of cooling is conservative and does not align with the safety case for the SFIS operations, where the cooling period within the SFP is expected to be 5-10 years (Ref. 34). RWM concludes that a disposal container with four SFA and one RCCA/SCCA can be disposed of to a GDF after a storage period on site of between 15 and 64 years to allow the decay heat to reduce. This is due to thermal limits on a GDF and is based on:

- the generic geology for a GDF;
- the maximum and average inventory; and
- the generic design of a GDF (such as container/tunnel spacing).

175. RWM's assessment identifies opportunities to reduce the on-site storage period, but still maintaining the thermal limits of GDF through:

- use of a placement strategy for containers in a GDF tunnels, which distributes containers with higher heat loadings between cooler spent fuel containers. RWM indicates this could reduce the need for on-site storage from 64 years to 44 years for the maximum inventory container;
- increasing the container/tunnel spacing; and/or,
- reducing the number of SFAs per container.

176. In its response to RWM's assessment (Ref. 54) the RP identifies there is an opportunity during the repacking activities to select SFAs for each disposal package based on their heat output. This could reduce the overall heat output of a disposal package and reduce the storage period on site prior to repacking and transfer to a GDF. The strategy to select SFAs in the disposal packages to reduce the heat output

is consistent with ONR's understanding of repacking strategies identified by nuclear power plants in operation or being constructed in the UK.

177. The generic design of a GDF assumes nuclear new build fuel from 12 reactors will be transferred to a GDF between 2145 and 2190. Therefore, depending on the construction date of the UK HPR1000, the design life of the first phase SFIS Facility may not be adequate for the on-site storage of spent fuel. The SFIS Facility design life is assumed to be 100 years, so the design life of the first phase of the SFIS Facility extends 40 years beyond the 60 years of reactor operations. The design life of 100 years is consistent with industry guidance on new build surface stores (Ref. 55). Based on a two-phase approach the second SFIS Facility will be constructed 15-20 years after the start of operations, see sub-section 4.3. The second SFIS Facility will store the last fuel discharged from the reactor with an inventory closest to the maximum defined by RWM. The second SFIS Facility will therefore have a design life of at least 55-60 years after the end of reactor operations. At the site-specific phase, and as part of the FDP (Ref. 14) the operator will be provided with an assumed disposal date for wastes (including spent fuel). The licensee will need to take into consideration the assumed disposal date when defining the design life during detailed design of the SFIS Facility at the site-specific phase.

4.8.1.2 Co-Disposal

178. RWM's assessment (Ref. 39) has identified no issues which would result in a GDF being unable to accept the proposed SFA/RCCA/SCCA package for disposal. RWM has noted it has not previously considered a spent fuel disposal package with the intentional inclusion of neutron sources (associated with a fraction of the SCCAs) in the criticality safety case for a GDF. RWM's preliminary assessment does not consider the presence of neutron sources to be a risk to the future disposability assessments. In response to RWM's assessment (Ref. 54) the RP notes that the criticality assessment for the presence of the neutron sources will be considered throughout the lifecycle of the spent fuel, including for the on-site safety case. The topic is considered as normal business for the licensee to provide the safety analysis for co-storage/disposal. The RP has also identified a post-GDA commitment (Ref. 44) to work with the fuel designer to identify opportunities to reduce the number of secondary neutron sources required during the operation of the UK HPR1000 as they contribute to discharges of tritium to the environment.

4.8.2 Assessment of Disposability of SFAs, RCCAs and SCCAs

179. In my opinion the RP has met the regulatory expectations in the joint guidance on the management of HAW (Ref. 22) and scope of GDA (Ref. 23) by seeking advice from RWM on the disposability of spent fuel with RCCAs/SCCAs. The conclusion from RWM's assessment is that the disposal package, with 4 SFA and a single RCCA/SCCA, is compatible with a GDF for both the maximum and average inventory. Detailed analysis will be needed for the inclusion of the neutron sources in the packages as this has not previously been considered by RWM. However, RWM's preliminary assessment has not identified any issues with the intentional inclusion of the neutron sources with the SCCAs. In my opinion this provides confidence that the strategy selected by the RP for co-storage of SCCA with neutron sources is consistent with the regulatory expectation in ONR SAP RW.1 to ensure radioactive waste is in a form which is compatible with the disposal route.

180. I note that a number of the assumptions in RWM's assessment are conservative and, in some instances, inconsistent with the generic UK HPR1000 safety case for the management of spent fuel (for example the cooling time for the SFA). This results in the maximum inventory requiring an on-site storage period of 64 years prior to disposal. However, RWM identifies several opportunities to reduce the on-site storage period of spent fuel to ensure timely transfer to a GDF. These include aspects which

could be adopted by the RP or RWM and are consistent with strategies adopted on PWR reactor designs in operation and being constructed in the UK.

181. I raised RQ-UKHPR1000-1759 (Ref. 41) to understand how the RP would consider the conservative nature of RWM's assumptions in their safety case. In response the RP noted they consider the uncertainties between the construction schedule for both a GDF and the UK HPR1000 constrain what can be determined at GDA, with further details captured in the RP's response to RWM's disposability assessment (Ref. 54) and therefore incorporated into the safety case.

182. In my opinion the RP's decision to define a design life of 100 years in GDA is adequate given the information available at the GDA stage. There are several elements relevant to the SFIS Facility which will be site specific and time dependent, such as the construction dates for the first phase of the SFIS Facility. The transfer of spent fuel to the SFIS Facility is not expected to occur until after 5-10 years of cooling within the SFP (Ref. 34), which is 6 -11 years after the start of generation. PCSR Chapter 29 (Ref. 5) indicates the SFP capacity is such that SFAs are not required to be transferred from the Fuel Building to the SFIS Facility until approximately 15 years after the start of reactor operations. The construction date of the SFIS Facility aligns with the start of generation to ensure the availability of a facility for the safe storage of HLW ICIAs in 500 litre robust shielded drums, which arise approximately 4.5 years after the start of generation, as set out in sub-section 4.3 on the SFIS design, with further details in the Step 4 assessment report for Radioactive Waste Management (Ref. 30).

183. I have identified a minor shortfall for the licensee to consider the construction schedule of the SFIS Facility in the context of the assumed disposal date for spent fuel (once available) to determine if there are any opportunities to optimise the design life of the SFIS Facility. This may include review of the strategy to store HLW ICIAs within the SFIS Facility, which drives the construction dates, and consideration of the use of the SFP for initial storage of SFAs for longer than 5-10 years, but less than 15 years when the SFP reaches capacity, to maximise the SFIS Facility design life. It is my judgement that this does not warrant ONR tracking to resolution, and therefore does not meet the definition of an Assessment Finding, on the basis that this is an integral part of ONR's licensing process and the FDP, and therefore regulatory oversight and engagement is maintained through defined processes.

184. For completeness, it is noted that the licensee will be required to demonstrate continued safe storage of spent fuel through periodic safety reviews, this includes during the 100-year design life and, if applicable, beyond. This is a regulatory expectation of ONR SAPs ENM.6 and RW.5 for the licensee to justify the continued safe storage and is a requirement of Licence Condition 15 Periodic Review (Ref. 56).

4.8.3 Disposability of SFAs, RCCAs and SCCAs Conclusions

185. Taking into consideration the maximum inventory of a disposal package defined by RWM, and the timescales for transfers of new nuclear build spent fuel to a GDF, there is the risk that packages will need to be stored in the first SFIS Facility beyond the 100-year design life. Consistent with my conclusions on sub-section 4.2.2, I consider the development of the detailed design of the SFIS Facility to be normal business at the site licensing phase. I have not raised any Assessment Findings, but I have raised a single minor shortfall for the licensee to consider the construction schedule of the SFIS Facility against the assumed disposal date for spent fuel (once available) to determine if there are any opportunities to extend the design life of the SFIS Facility.

4.9 Demonstration that Relevant Risks have been Reduced to ALARP

186. The requirement for risks to be reduced to ALARP is fundamental and applies to all activities within the scope of the Health and Safety at Work Act 1974 (HSWA). For the

generic UK HPR1000 design, the RP is expected to demonstrate that all measures have been taken to reduce the risks so far as is reasonably practicable. In line with guidance on the demonstration of ALARP (NS-TAST-GD-005) (Ref. 8), I have considered whether the RP has applied RGP in the development of the SFIS safety case, rather than making an explicit judgement on whether the benefits of implementing the measures outweigh the sacrifice (cost and trouble), see sub-section 4.9.1.

187. A key regulatory expectation relevant to the RP's ALARP demonstration outlined in the SFIS scope (Ref. 15), is for the RP to undertake a proportionate evaluation of the impact on the existing generic UK HPR1000 design from the implementation of the selected SFIS technology, which was introduced for the UK HPR1000 to align with UK policy. This evaluation should include identifying any potential reasonably practicable modifications which may be necessary, and a demonstration of the versatility of the generic UK HPR1000 design to incorporate any future modifications, as a minimum, see sub-section 4.9.2. At the start of Step 4 of the GDA for the UK HPR1000 I identified shortfalls in the RP's safety case with respect to meeting this expectation and thus raised RO-UKHPR1000-0050 'Selected Spent Fuel Interim Storage Technology ALARP Demonstration' (Ref. 28).

188. The ONR Radiological Protection specialist inspector has assessed the RP's evidence that the public and occupational radiation doses are reduced to ALARP, which was an expectation outlined in the scope of SFIS for the UK HPR1000 (Ref. 15) (Ref. 29).

189. ONR NS-TAST-GD-051 on the purpose, scope and content of safety cases (Ref. 11) includes guidance on how the Claims, Arguments, Evidence (CAE) structure can provide advantages in effectively building and presenting an adequate safety case to demonstrate that risks have been reduced ALARP. Therefore the final aspects of this section, sub-section 4.9.3, is my assessment of whether the RP's safety case (Ref. 5) provides adequate evidence to substantiate the claims made relevant to the SFIS topic, see sub-section 3.2.1.

4.9.1 Relevant Good Practice

190. The ALARP demonstration of SFIS (Ref. 37) provides evidence of the evolution of the RP's safety case for the SFIS Facility. This is an iterative process which started with the RP's gap analysis process during Step 2, which identified a gap between Chinese and UK practices due to differences in Government policies. By the end of Step 4 of GDA, the RP concluded that the SFIS Facility and associated operations are based upon RGP and OPEX and has provided a risk assessment to demonstrate that the risks associated with SFIS are reduced to ALARP.

191. The RP has provided evidence supporting the position that the SFIS Facility and operations are consistent with RGP in the ALARP demonstration of SFIS (Ref. 37). Table T-7-1 in the ALARP demonstration of SFIS (Ref. 37) identifies the sources of international and UK RGP for SFIS used by the RP, which are consistent with those identified in ONR's NS-TAST-GD-081 on the storage of spent fuel (Ref. 12). The RP has also identified relevant OPEX for similar systems used or proposed in the UK. This included seeking information on the UK OPEX from Electricité de France (EDF) on the practices adopted at Sizewell B (SZB) and to be adopted at Hinkley Point C (HPC) (Ref. 37).

192. Based upon my detailed assessment in sub-section 4.2 on operating sequences, sub-section 4.3 on the SFIS design, and finally the RP's risk assessment, in sub-section 4.4, I consider the RP has provided adequate evidence that the conceptual design of the SFIS Facility and associated processes are consistent with RGP.

193. The RP's safety case, as summarised in PCSR Chapter 29 (Ref. 5), consistently recognises the need to review the risk assessment during the detailed design at the site-specific phase to ensure the risks remain ALARP.

4.9.2 Versatility of the Generic UK HPR1000 Design

194. I decided to focus my assessment of the versatility of the generic UK HPR1000 design on the facilities in the Fuel Building, which enable the delivery of the selected SFIS technology, and how these contribute to the overall ALARP demonstration, including any potential reasonably practicable modifications.

195. For the UK HPR1000 Fuel Building the assessment was focused on:

- The adequacy of the evidence presented by the RP that sufficient space is available in the Fuel Building SFP to allow the UK HPR1000 spent fuel to adequately cool prior to transfer to the SFIS Facility. This was assessed by the ONR Fuel and Core specialist inspector (Ref. 24).
- The RP's justification that the risks from dropped loads during lifting/handling operations within the Fuel Building, for both spent fuel assemblies and the spent fuel transfer cask/spent fuel storage canister, are reduced to ALARP. This was assessed by the ONR Mechanical Engineering specialist inspector (Ref. 27). This topic is also within the scope of two regulatory observations, RO-UKHPR1000-0014 'Spent Fuel Building – Design of Nuclear Lifting Operations to Demonstrate Relevant Risks are Reduced to ALARP' and RO-UKHPR1000-0056 'Fuel Route Safety Case' (Ref. 28).
- The scope of the operations in the Fuel Building presented by the RP, the purpose of which is to ensure they are complete, consistent with regulatory expectations in NS-TAST-GD-081 (Ref. 12) and international good practice (Ref. 20), as set out in sub-section 4.2. This is considered with the information in the RP's risk assessment, to make a judgement on whether any additional features are needed within the Fuel Building design at the GDA stage to reduce the relevant risks to ALARP, as discussed in sub-section 4.4. Given the SSCs for the SFIS technology are at concept design, I have focused my assessment on the availability of systems/services, space and the versatility to modify the design as the details are developed at the site-specific phase.

196. The 'Matching Analysis of Selected SFIS Technology with Current UK HPR1000 Design' (Ref. 35) provides evidence of the RP's consideration of the implementation of the selected SFIS technology into the Fuel Building. The RP's consideration of the existing systems for SFIS normal operations, Table T-3-2 in 'The Matching Analysis of Selected SFIS Technology with Current UK HPR1000 Design' (Ref. 35), includes consideration of design features such as:

- Fuel Building handling equipment / handling and storage system (lifting of SFIS equipment and loading SFAs into the spent fuel storage canister);
- Fuel Building ventilation system;
- Normal power distribution system (power supply for SFIS equipment);
- Demineralised water distribution system (demineralised water for decontamination activities on the transfer cask);
- Fuel pool cooling and treatment system (boronated water supply to fill the spent fuel storage canister).

197. The RP's SFIS operations includes the need to fill the spent fuel storage canister with an inert gas, typically helium, to ensure the storage environment in the canister is stable and promotes passive safe storage of the spent fuel. The supply of inert gas is a new requirement for the Fuel Building. The inert gas is only required for the filling of the spent fuel storage canister after loading of the SFAs. The RP's generic UK HPR1000 design assumes compressed gas cylinders (referred to by the RP as bottles) will be

used, rather than an installed gas supply line. The RP argues that this is the ALARP option as the use of gas cylinders limits the quantity of the gas stored within the Fuel Building at any one time, and therefore reduces the magnitude of the hazard posed by the presence of the gas (Ref. 35). The RP's ALARP demonstration (Ref. 37) and qualitative risk assessment include the requirement for the detailed design to consider the risk from introducing the gas cylinders, which represent a new internal hazard.

198. The RP's consideration of gas cylinders as an internal hazard is consistent with RGP in IAEA guidance on initiating events for consideration in the safety assessment of spent fuel storage technology (Ref. 20). The RP's ALARP demonstration (Ref. 37) makes claims on the transfer cask to protect the spent fuel from the internal hazard posed by the gas cylinders in the Fuel Building. The specific details of this new internal hazard are outside the scope of GDA, so it is not possible to undertake a meaningful assessment at the GDA stage.

199. With respect to the adequacy of the space available within the Fuel Building, the matching analysis (Ref. 35) provides evidence of the RP's consideration of:

- The adequacy of the space available for the handling of the transfer cask and transfer trailer, with the transfer cask in the vertical orientation (as the largest item). This is consistent with the processes highlighted in Figure 3 and has been assessed by the ONR Mechanical Engineering specialist inspector (Ref. 27).
- The adequacy of space for the storage and use of SFIS equipment. The RP refers to the fuel handling process and operations (Ref. 42), which includes details on bounding SFIS processing equipment dimensions, the space requirements in the Fuel Building for the laydown (identified as the canister processing zone) and requirements for operator access to the spent fuel storage canister/transfer cask during operation. For example, access platforms for operators on the Cask Stand and around the Loading Pit and stair access to the transfer cask on the Transmit Platform.

200. In my opinion the RP has adequately identified the operations and equipment relevant to SFIS which are required in the Fuel Building and provided evidence that the impacts of implementing the technology within the Fuel Building are understood. I consider the RP has demonstrated the versatility of the Fuel Building through consideration of the systems/services required, the bounding size of the SFIS equipment, and the space available within the Fuel Building to safely accommodate the technology, without unduly foreclosing options for the detailed design.

201. The RP's safety case, as summarised in PCSR Chapter 29 (Ref. 5), consistently recognises the need to review the risk assessment during the detailed design at the site-specific phase to ensure the risks remain ALARP from the implementation of the SFIS technology in the Fuel Building.

4.9.3 SFIS Claims, Arguments and Evidence

202. The claims relevant to the interim storage of spent fuel are linked to the RP's top-level claim on reducing the nuclear safety risks to ALARP (Claim 3) (Ref. 5). I have focused my assessment on the arguments and evidence to meet the SFIS specific sub-claims 3.3.13.SC29.1 and 3.3.13.SC29.2, which are:

- "Sub-claim 3.3.13.SC29.1: All reasonable measures are adopted to ensure the technology selected satisfies the requirements in the UK."
- "Sub-claim 3.3.13.SC29.2: The Spent Fuel Interim Storage is capable to achieve safe storage of spent fuel."

203. Appendix 29A of PCSR Chapter 29 (Ref. 5) provides a route map which shows how the claims are linked to relevant arguments and the evidence available at GDA. For sub-claim 3.3.13.SC29.1 the RP defined five arguments with supporting evidence available at GDA, and for sub-claim 3.3.13.SC29.2 three arguments with supporting evidence have been identified for GDA.

204. Sub-claim 3.3.13.SC29.1 – In my opinion this claim is focused on providing evidence that the RP understands and has adequately considered UK expectations relevant to SFIS. This includes consideration of differences between Chinese and UK Government policy, and the undertaking of optioneering and analysis to ensure the generic UK HPR1000 design enables the RP to demonstrate that the risks from implementation of dry storage in the UK HPR1000 are reduced to ALARP. I presented my assessment of the adequacy of the RP's safety case against UK requirements and expectations in sub-sections 4.2 - 4.8. I consider the RP has provided adequate evidence that the conceptual design of the SFIS Facility and associated processes are consistent with RGP. It is therefore my judgement that the RP's safety case provides adequate arguments and evidence that all reasonable measures have been adopted to satisfy the UK requirements (sub-claim 3.3.13.SC29.1).

205. Sub-claim 3.3.13.SC29.2 –I have identified two Assessment Findings in my assessment which are relevant this claim and the detailed design and/or safety analysis. AF-UKHPR1000-0021 focuses on the detailed design of the active cooling system for the transfer cask to ensure this can be safely implemented, and AF-UKHPR1000-0022 focuses on the detailed safety analysis for the co-storage of RCCAs/SCCAs with the SFAs in the spent fuel storage canister. The Fuel and Core assessment report (Ref. 24) has considered the adequacy of the RP's evidence on the fuel criteria, including the evidence that these can be met throughout the SFIS related operations (for example drying), to ensure the safe storage of spent fuel in the SFIS Facility.

4.9.4 Demonstration that Relevant Risks have been Reduced to ALARP Conclusions

206. Overall, it is my opinion that the RP has provided adequate evidence that the SFIS Facility conceptual design is consistent with RGP and that the Fuel Building is sufficiently versatile to safely accommodate the relevant equipment without foreclosing options for the detailed design. Therefore, in my opinion the RP's safety case provides adequate evidence, which is linked to the RP's claims, that the risks associated with the implementation of the SFIS technology in the generic UK HPR1000 design are reduced to ALARP.

207. The RP's safety case, as summarised in PCSR Chapter 29 (Ref. 5), consistently recognises the need to review the risk assessment during the detailed design at the site-specific phase to ensure the risks remain ALARP. Consistent with my conclusions in sub-section 4.2.2, I consider the development of the detailed design to be normal business at the site licensing phase, and no additional Assessment Findings are raised.

4.10 Consolidated Safety Case

208. My assessment in Section 4 is based upon the RP's revision of submissions as a result of RO-UKHPR1000-0050 and responses to several regulatory queries raised throughout Step 4 of the GDA. Table 1 provides a summary of the RQs raised by ONR in Step 4 of the UK HPR1000 GDA relevant to the SFIS topic (Ref. 41).

209. On the basis of the evidence I have assessed in sub-sections 4.2 - 4.9, I consider that the RP has adequately incorporated the RQ responses, has made adequate improvements to the safety case to address the shortfalls identified in RO-UKHPR1000-0050, and meets regulatory expectations on the scope of SFIS for GDA

(Ref. 15). This includes the update of PCSR Chapter 29 Interim Storage of Spent Fuel (Ref. 57).

4.11 Strengths

210. From my assessment of the SFIS topic in Section 4 the key strengths of the safety case are:

- The safety case provides suitable and sufficient information to enable the future operator to adequately understand the nature of the operations that need to be conducted in relation to SFIS within both the Fuel Building and the SFIS Facility.
- The RP has presented a conceptual design for the SFIS Facility which is consistent with RGP and OPEX and which includes clear assumptions and requirements, including aspects relevant to the SSCs, to aid the future site-specific detailed design.
- As evident from the references in this report to other ONR topic assessment reports, the RP's safety case for SFIS integrates well with the expectations of different technical topics, including Fuel and Core, Fault Studies (PSA), Mechanical Engineering and Radiological Protection.

4.12 Outcomes

211. Based upon my assessment of the SFIS technical topic presented in Section 4, I have identified the following Assessment Findings:

- AF-UKHPR1000-0021 – The licensee shall provide evidence to demonstrate the detailed design of the structures, systems and components in the Fuel Building which actively cool spent fuel during export, are capable of preventing fuel overheating; and demonstrate that the risk of fuel cladding failure is reduced so far as is reasonably practicable.
- AF-UKHPR1000-0022 – The licensee's safety case for the detailed design of the Spent Fuel Interim Storage Facility shall assess how the presence of Rod Cluster Control Assemblies and Stationary Core Component Assemblies, including neutron sources, may impact on spent fuel drying and storage operations. The analysis should demonstrate relevant risks arising from co-storage are reduced so far as is reasonably practicable.

212. Three minor shortfalls have been identified:

- For the licensee to consider the use a dummy canister/concrete silo in the SFIS Facility as a means of monitoring for any changes to the storage SSCs, without the hazard/risk posed by a canister containing spent fuel, as discussed in sub-section 4.4.2.1.
- For the licensee to consider the dry storage of failed fuel alongside buffer storage when defining the storage capacity of the second phase of the SFIS Facility, as discussed in sub-section 4.7.2.
- For the licensee to optimise the construction schedule/design life of the SFIS Facility to take into consideration the assumed disposal date, as discussed in sub-section 4.8.2.

4.13 Conclusion

213. Based on the outcome of my assessment of the interim storage of spent fuel technical topic, I have concluded that, notwithstanding the two assessment findings raised, the RP's safety case for SFIS is consistent with relevant regulatory expectations of the ONR SAPs (Ref. 2), ONR NS-TAST-GD-081 (Ref. 12) and international good practice (Ref. 20). Overall, in my opinion the RP has provided adequate evidence that the

hazards and risks are understood, with engineered, independent preventative and mitigative design features identified. This provides an adequate demonstration that the SFIS technology SSCs are consistent with RGP and therefore capable of reducing the risk to ALARP.

4.14 Comparison with Standards, Guidance and Relevant Good Practice

214. I have compared the information in the RP's safety case for SFIS against standards, guidance and relevant good practice throughout my assessment in Section 4. The full list used is provided in sub-section 2.4. I have mainly used the ONR SAPs for the control of nuclear matter and radioactive waste management, IAEA SSG-15 and the TAGs on safety aspects specific to the storage of spent nuclear fuel and ALARP, noting these take account of international guidance such as the WENRA SRLs. A list of the relevant ONR SAPs considered during my assessment are summarised in Annex 1.

5 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

215. This report presents the findings of my SFIS assessment of the generic UK HPR1000 design as part of the GDA process.

216. Based on my assessment, undertaken on a sampling basis, I have concluded the following:

- The SFIS Facility conceptual design includes adequate facilities for the safe management of spent fuel, with due consideration of factors which may impact upon the storage capacity, which will need to be taken into consideration in the detailed design.
- Notwithstanding Assessment Finding AF-UKHPR1000-0021, the RP's safety case provides adequate evidence that the hazards and risks are understood, with engineered independent preventative and mitigative design features identified to demonstrate that the SFIS technology SSCs are consistent with RGP and therefore capable of reducing the risks to ALARP.
- The RP's strategy to co-store RCCAs/SCCAs with SFAs in the spent fuel storage canister is consistent with the management strategy being proposed for similar radioactive waste items from PWRs in operation and being constructed in the UK. The RP's strategy also considers the regulatory expectations of ONR SAP RW.3 on minimising the volume of radioactive waste accumulated on the site through inclusion of the neutron sources with the SCCAs in the spent fuel storage canister.
- The evidence that co-storage of RCCAs/SCCAs with SFAs meets the regulatory expectations of ONR SAPs ENM.5 (the characterisation and segregation of nuclear matter) and ENM.6 (storage in a condition of passive safety) is dependent on a number of aspects which will not be available until detailed design outside of GDA. I have therefore raised Assessment Finding AF-UKHPR1000-0022 on the safety analysis for co-storage, which needs to be developed with the detailed design of the SFIS SSCs. The safety analysis should underpin the safety case claims/argument that the presence of RCCAs/SCCAs (with neutron sources) does not have a significant impact on the drying operations, and that any potential swelling/deformation of the RCCAs/SCCAs does not have any significant impact on the passive safe storage of spent fuel.
- The RP's safety case adequately acknowledges the requirement to define limits and conditions in the interests of safety and the regime for EIMT as the detailed design of the SSCs of the SFIS technology progresses, with the information provided proportionate to the level of detail available at the GDA stage.
- The generic parameters required for the OLCs identified by the RP align with the safety functions, are consistent with international good practice for fuel storage, and meet the expectations in both RO-UKHPR1000-0050 and the scope of SFIS for the UK HPR1000.
- The RP's safety case presents a golden thread from the need to define the details of OLCs to any restrictions or requirements which need to be taken into consideration when defining them, based upon the safety case at GDA and the links to EIMT, as expected by ONR SAP SC.6 on the content and implementation of safety cases.
- The assumption in the RP's safety case that failed fuel will be stored in the SFP is consistent with that for PWR reactors in the UK with similar dry storage facilities. It is my judgement that the generic UK HPR1000 design does not foreclose options for the future safe management of failed fuel in the SFIS Facility.

- The RP has sought advice from RWM on the disposability of spent fuel with RCCAs/SCCAs. RWM's assessment concludes that the disposal package, with 4 SFA and a single RCCA/SCCA, is compatible with a GDF.
- The RP has provided adequate evidence on the versatility of the generic UK HPR1000 design to safely accommodate the SFIS technology through consideration of the systems/services required, the bounding size of the SFIS equipment, and the space available within the Fuel Building, without unduly foreclosing options for the detailed design.

217. Overall, based on my sample assessment of the safety case for the generic UK HPR1000 design undertaken in accordance with ONR's procedures, I am satisfied that the case presented within the PCSR and supporting documentation is adequate. On this basis, I am content that a DAC should be granted for the UK generic HPR1000 design from a SFIS perspective.

5.2 Recommendations

218. Based upon my assessment detailed in this report, I recommend that:

- Recommendation 1: From a SFIS perspective, ONR should grant a DAC for the generic UK HPR1000 design.

- Recommendation 2: The two Assessment Findings identified in this report relevant to the SFIS topic should be resolved by the future licensee for a site-specific application of the generic UK HPR1000 design.

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Annex 1

Relevant Safety Assessment Principles Considered During the Assessment

SAP No	SAP Title	Description
EKP.3	Defence in depth	Nuclear facilities should be designed and operated so that defence in depth against potentially significant faults or failures is achieved by the provision of multiple independent barriers to fault progression.
ECV.3	Means of Confinement	The primary means of confining radioactive materials should be through the provision of passive sealed containment systems and intrinsic safety features, in preference to the use of active dynamic systems and components.
ECV.4	Provision of further containment barriers	Where the radiological challenge dictates, waste storage vessels, process vessels, piping, ducting and drains (including those that may serve as routes for escape or leakage from containment) and other plant items that act as containment for radioactive material, should be provided with further containment barrier(s) that have sufficient capacity to deal safely with the leakage resulting from any design basis fault.
ENM.2	Provisions for nuclear matter brought onto, or generated on, the site	Nuclear matter should not be generated on the site, or brought onto the site, unless sufficient and suitable arrangements are available for its safe management on the site.
ENM.5	Characterisation and segregation	Nuclear matter should be characterised and segregated whenever practicable to facilitate its safe management.
ENM.6	Storage in a condition of passive safety	When nuclear matter is to be stored on site for a significant period of time it should be stored in a condition of passive safety whenever practicable and in accordance with good engineering practice.
ENM.7	Retrieval and inspection of stored nuclear matter	Storage of nuclear matter should be in a form and manner that allows it to be retrieved and, where appropriate, inspected.

SAP No	SAP Title	Description
SC.6	Safety case content and implementation	The safety case for a facility or site should identify the important aspects of operation and management required for maintaining safety and how these will be implemented.
ELO.1	Access	The design and layout should facilitate access for necessary activities and minimise adverse interactions while not compromising security aspects.
ELO.3	Movement of nuclear matter	Site and facility layouts should minimise the need for movement of nuclear matter.
RW.1	Strategies for radioactive waste	A strategy should be produced and implemented for the management of radioactive waste on a site.
RW.2	Generation of radioactive waste	The generation of radioactive waste should be prevented or, where this is not reasonably practicable, minimised in terms of quantity and activity.
RW.3	Accumulation of radioactive waste	The total quantity of radioactive waste accumulated on site at any time should be minimised so far as is reasonably practicable.
RW.4	Characterisation and segregation	Radioactive waste should be characterised and segregated to facilitate its subsequent safe and effective management.
RW.5	Storage of radioactive waste and passive safety	Radioactive waste should be stored in accordance with good engineering practice and in a passively safe condition.

Annex 2

Assessment Findings

Note: These Assessment Findings must be read in the context of the sections of the report listed in this table, where further detail is provided regarding the matters that led to the findings being raised.

Number	Assessment Finding	Report Section
AF-UKHPR1000-0021	The licensee shall provide evidence to demonstrate the detailed design of the structures, systems and components in the Fuel Building which actively cool spent fuel during export, are capable of preventing fuel overheating; and demonstrate that the risk of fuel cladding failure is reduced so far as is reasonably practicable.	4.4.1
AF-UKHPR1000-0022	The licensee's safety case for the detailed design of the Spent Fuel Interim Storage Facility shall assess how the presence of Rod Cluster Control Assemblies and Stationary Core Component Assemblies, including neutron sources, may impact on spent fuel drying and storage operations. The analysis should demonstrate relevant risks arising from co-storage are reduced so far as is reasonably practicable.	4.5.1