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Pre-Construction Safety Report

Chapter 28

Fuel Route and Storage

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28.1 List of Abbreviations and Acronyms

ALARP	As Low As Reasonably Practicable
BFX	Fuel Building
BRX	Reactor Building
CGN	China General Nuclear Power Corporation
DMK	Fuel Building Handling Equipment [FBHE]
DMR	Reactor Building Handling Equipment [RBHE]
EMIT	Examination, Maintenance, Inspection, Test
EOMM	Equipment Operation and Maintenance Manual
EVR	Containment Cooling and Ventilation System [CCVS]
FA	Fuel Assembly
FCG3	Fangchenggang Nuclear Power Plant Unit 3
GDA	Generic Design Assessment
HVAC	Heating, Ventilation and Air Conditioning
IAEA	International Atomic Energy Agency
IFA	Irradiated Fuel Assembly
MSQA	Management System and Quality Assurance
NFA	New Fuel Assembly
OPEX	Operating Experience
PCSR	Pre-Construction Safety Report
PIE	Postulated Initiating Event
PMC	Fuel Handling and Storage System [FHSS]
PSA	Probabilistic Safety Assessment
PSR	Preliminary Safety Report
PTR	Fuel Pool Cooling and Treatment System [FPCTS]
RPV	Reactor Pressure Vessel
PWR	Pressurised Water Reactor
RCCA	Rod Cluster Control Assembly

RGP	Relevant Good Practice
SFA	Spent Fuel Assembly
SFIS	Spent Fuel Interim Storage [SFIS]
SFP	Spent Fuel Pool
SFPC	Spent Fuel Pool Crane
SSC	Structures, Systems and Components

System codes (XXX) and system abbreviations (YYY) are provided for completeness in the format (XXX [YYY]), e.g. Fuel Handling and Storage System (PMC [FHSS]).

28.2 Introduction

28.2.1 Objective

This chapter is related to Preliminary Safety Report (PSR) Chapter 10.7 and Chapter 23.7, which include the description of the PMC [FHSS].

The purpose of this chapter is to demonstrate the risk associated with the PMC [FHSS] for UK HPR1000 due to the failure of Structures, Systems and Components (SSCs) and human error is As Low As Reasonably Practicable (ALARP) throughout the PMC [FHSS] related operations.

28.2.2 Scope

The PMC [FHSS] related operations form part of the fuel route process. A general overview of fuel route process for the UK HPR1000 design is given below.

The fuel route process encompasses the entire life cycle of nuclear fuel within the nuclear plant site boundary. It includes all activities between the receipt of a New Fuel Assembly (NFA) on site and storage in the Spent Fuel Interim Storage (SFIS) facility.

The fuel route process for the UK HPR1000 can be divided into six operations, which are:

a) NFA receipt and storage operations (described in this chapter) - including NFA receipt, inspection and storage in air or underwater within the Fuel Building (BFX).

b) Core loading operations (described in this chapter) - including reactor core loading preparation and fuel loading operations during a reactor core outage.

c) Reactor power operations (described in Pre-Construction Safety Report (PCSR) Chapter 5) - including fuel located in the reactor core during reactor operation.

d) Core unloading and Spent Fuel Assembly (SFA) storage operations (described in this chapter) - including reactor core unloading preparation and fuel unloading

from the reactor core to Spent Fuel Pool (SFP) operations during reactor core outage, as well as SFA storage operations within the SFP before delivery.

e) SFA delivery Operations (described in this chapter) - including cask lifting, SFA loading preparation, fuel loading into cask and SFA delivery preparation operations within the BFX.

f) SFIS operations (described in PCSR Chapter 29) - including receipt and storage operations within the interim storage facility for casks containing SFAs. This operation starts when the SFAs leave the BFX boundary.

These operations are mainly supported by the following related systems:

a) The PMC [FHSS], which includes NFA receipt and storage operations, Core loading operations, Core unloading and SFA storage operations, and SFA delivery in the BFX operations. The PMC [FHSS] comprises all equipment used for fuel handling and storage within the Reactor Building (BRX) and BFX. Further detail on the PMC [FHSS] is given in this chapter.

b) Reactor Building Handling Equipment (DMR [RBHE]), which consists of all the handling equipment in the BRX. The most important DMR [RBHE] equipment which is related to fuel route is the polar crane. Further description of the DMR [RBHE] is given in PCSR Chapter 10.

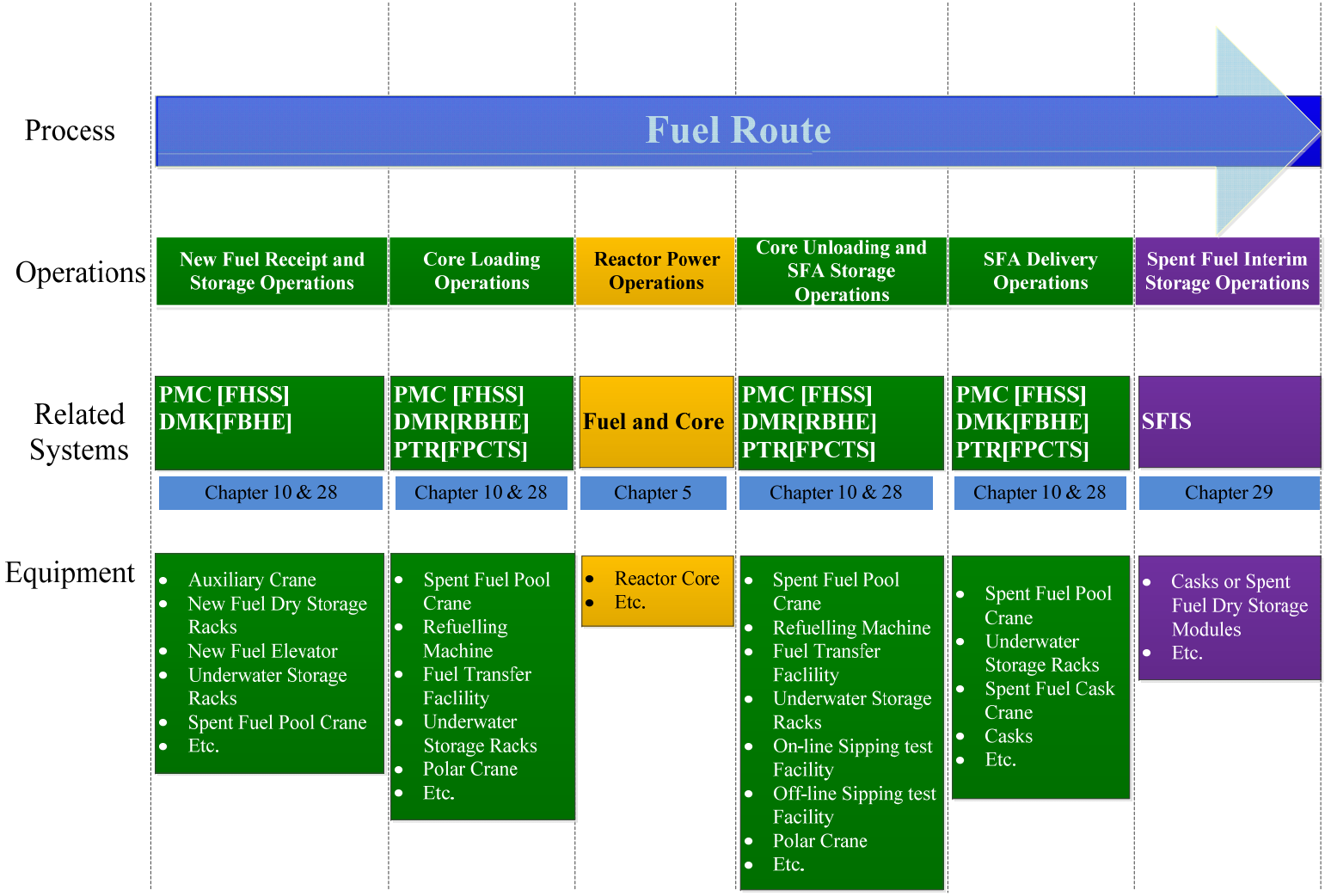
c) Fuel Building Handling Equipment (DMK [FBHE]), which consists of all the handling equipment in the BFX. The most important DMK [FBHE] equipment related to fuel route is the spent fuel cask crane. Further description of the DMK [FBHE] is given in PCSR Chapter 10.

d) Fuel Pool Cooling and Treatment System (PTR [FPCTS]), which is used to provide cooling and water make-up for the SFP, water purification, water transferring and skimming for the BRX pools (including reactor cavity and internal storage compartment) and BFX pools (including the SFP, fuel transfer compartment and cask loading pit). This system also provides shielding, cooling and criticality control for fuel handling and storage. Further description of the PTR [FPCTS] is given in PCSR Chapter 10.

e) SFIS, which includes structures, systems and components (SSCs) specific to SFIS, including spent fuel transport casks or spent fuel dry storage modules etc. Further description of SFIS is given in PCSR Chapter 29.

To summarise, this chapter only focuses on the description and demonstration of the PMC [FHSS], not the whole fuel route. For the remaining fuel route sections, refer to the PCSR Chapters highlighted in Table F-28.2-1 below, e.g. Chapters 5, 10, 29, etc.

The structure of fuel route process is shown in F-28.2-1.



F-28.2-1 General Structure of the Fuel Route

28.2.3 Chapter Route Map

The ***Fundamental Objective*** of the UK HPR1000 is that: *The Generic UK HPR1000 could be constructed, operated, and decommissioned in the UK on a site bounded by the generic site envelope in a way that is safe, secure and that protects people and the environment.*

To underpin this ***Fundamental Objective,*** five high level claims (Level 1 claims) and a number of Level 2 claims are developed and presented in Chapter 1. This chapter supports the ***Claim 3.3*** derived from the high level ***Claim 3***.

Claim 3*: Nuclear safety*

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

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

To support Claim 3.3, PCSR Chapter 28 develops a chapter claim, that is:

The Fuel Handling and Storage process, and design of the associated systems, have been substantiated.

Finally, the chapter claim can be split into five sub-claims as follows:

a) ***Sub-Claim 1:*** *The safety functional requirements have been derived for the system.*

b) ***Sub-Claim 2****: The design intent of the system can be met by the design of process and relevant SSCs.*

c) ***Sub-Claim 3****: All reasonably practicable measures have been adopted to improve the design of the system.*

d) ***Sub-Claim 4****: The system performance will be validated through commissioning and testing.*

e) ***Sub-Claim 5****: The effects of ageing on the system have been addressed in the design.*

The above sub-claims are developed further in sub-chapter 28.5.

28.2.4 Chapter Structure

The structure of PCSR Chapter 28 is as follows:

a) Sub-chapter 28.1 List of Abbreviations and Acronyms:

This section lists the abbreviations and acronyms that are used in PCSR Chapter 28.

b) Sub-chapter 28.2 Introduction:

This section introduces the chapter objective, scope, route map, structure and interfaces with other PCSR chapters.

c) Sub-chapter 28.3 Applicable Codes and Standards:

This section identifies the applied codes and standards for the PMC [FHSS].

d) Sub-chapter 28.4 Overview of the PMC [FHSS]:

This section describes the operation function, general layout, process, interfaces and main equipment for the PMC [FHSS].

e) Sub-chapter 28.5 Safety Case Strategy for the PMC [FHSS]:

This section introduces the safety case strategy for the PMC [FHSS].

f) Sub-chapter 28.6 Safety Assessment for the PMC [FHSS]:

This section introduces the safety assessment for the PMC [FHSS].

g) Sub-chapter 28.7 Concluding Remarks:

This section summarises the concluding remarks of this chapter.

h) Sub-chapter 28.8 References:

This section lists the supporting references of this chapter.

i) Appendix 28.A Route Map for the PMC [FHSS]:

This section describes route map for the PMC [FHSS].

j) Appendix 28.B General Layout and Process of the PMC [FHSS]

This section describes general layout and process of the PMC [FHSS].

k) Appendix 28.C Classification of the Main PMC [FHSS] Equipment:

This section describes classification of the main PMC [FHSS] equipment.

28.2.5 Interfaces with Other Chapters

The interfaces between this chapter and other chapters are listed in T-28.2-11.

T-28.2-1 Interfaces between Chapter 28 and Other Chapters

PCSR Chapters	Interface
Chapter 1 Introduction	Chapter 1 provides the Fundamental Objective, Level 1

PCSR Chapters	Interface
	Claims and Level 2 Claims, and Chapter 28 provides chapter claims, arguments to support relevant claims that are addressed in Chapter 1.
Chapter 4 General Safety and Design Principles	Chapter 4 provides the selection principles of codes and standards and general engineering substantiation principles relevant to the PMC [FHSS] substantiation in Chapter 28.
Chapter 5 Reactor Core	Chapter 5 covers the design of Fuel Assembly (FA), which is a key input to the design of the PMC [FHSS] SSCs.
Chapter 10 Auxiliary System	Chapter 10 covers the design of several supporting systems to the PMC [FHSS], such as DMK, DMR, PTR, etc.
Chapter 12 Design Basis Condition Analysis	Chapter 12 covers the potential design basis accident during the PMC [FHSS] related operations and relevant safety assessment.
Chapter 13 Design Extension Conditions and Severe Accident Analysis	Chapter 13 covers design extension conditions and severe accident analysis related to the PMC [FHSS].
Chapter 14 Probabilistic Safety Assessment	Chapter 14 provides the main results of the Probabilistic Safety Assessment (PSA) and risk insights for the PMC [FHSS]. Chapter 28 provides the layout and process of the PMC [FHSS], which is a design input for the SFP PSA.
Chapter 15 Human Factors	Chapter 15 provides the principles and methodology of human factor integration that are considered in the design of the PMC [FHSS].
Chapter 16 Civil Work and Structures	Chapter 16 provides the substantiation for the PMC [FHSS] related civil structures. Chapter 28 presents the design of the PMC [FHSS] which is housed in the BRX and BFX described in Chapter16.
Chapter 18 External Hazards	Chapter 18 provides the relevant external hazards that have to be considered in the design of the PMC [FHSS].
Chapter 19 Internal Hazards	Chapter 19 provides the principles that underpin the internal hazard assessment on the PMC [FHSS].
Chapter 20 MSQA and Safety Case Management	Chapter 20 covers the organisational management and quality assurance arrangements, which are implemented during the design of the PMC [FHSS] and during the production of this chapter.

PCSR Chapters	Interface
Chapter 21 Reactor Chemistry	Chapter 21 covers the water quality control of coolant in reactor pool and spent fuel pool, which provides support to fuel cooling and control of criticality during the PMC [FHSS] related operations described in Chapter 28.
Chapter 22 Radiological Protection	Chapter 22 provides the dose assessment for workers and the general radiation protection measures against direct radiation and radioactive contamination during the normal PMC [FHSS] related operation.
Chapter 23 Radioactive Waste Management	Chapter 23 provides the demonstration of safe management of potential radioactive waste generated during the PMC [FHSS] related operations.
Chapter 24 Decommissioning	Chapter 24 provides the decommissioning strategy for the SSCs related to the PMC [FHSS], including any potential requirements on the SSCs' functionality during the decommissioning period.
Chapter 25 Conventional Safety and Fire Safety	Chapter 25 provides the conventional health and safety risk management techniques and the general prevention principles in the PMC [FHSS] related operations.
Chapter 29 Interim Storage of Spent Fuel	Chapter 29 provides the interim storage of SFA which is part of the overall fuel route described in Chapter 28.
Chapter 30 Commissioning	Chapter 30 provides the arrangements and requirements for commissioning, which shall be considered for the PMC [FHSS] SSCs.
Chapter 31 Operational Management	Chapter 31 provides the general principles and requirements for operational management of the PMC [FHSS].
Chapter 33 ALARP Evaluation	Chapter 33 provides the ALARP approach adopted for the UK HPR1000, which is applicable to the ALARP analysis for the PMC [FHSS].

28.3 Applicable Codes and Standards

For the UK HPR1000, the applicable codes and standards for the PMC [FHSS] are selected and determined according to the existing Fangchenggang Nuclear Power Plant Unit 3 (FCG3) practices, *General Principles for Application of Laws, Regulations, Codes and Standards,* Reference [1] and the principles presented in PCSR Chapter 4, aiming to ensure the applied codes and standards comply with UK current requirements of applicable Acts, regulations and other statutory instruments, and it also takes account of international Relevant Good Practice (RGP).

For the design of the PMC [FHSS] in FCG3, Chinese codes and standards are applied as a priority, and international codes and standards are applied as supplement.

For the UK HPR1000, international codes and standards such as the International Atomic Energy Agency (IAEA) guidance are considered RGP, as well as British and American standards. Since some applied Chinese guidance is developed from IAEA guidance, the IAEA guidance is applied as a priority for the design of the PMC [FHSS] in the UK HPR1000. Meanwhile, some British and American standards are referenced additionally as a supplement, especially for the design of the lifting equipment.

The current identified main applicable regulations, codes and standards for the PMC [FHSS] in the UK HPR1000 are listed as follows:

a) Supply of Machinery (Safety) Regulations, 2008 edition;

b) The Lifting Operations and Lifting Equipment Regulations (LOLER), 1998 edition;

c) The Provision and Use of Work Equipment Regulations (PUWER), 1998 edition;

d) Management of Health and Safety at Work Regulations, 1999 edition;

e) The Construction (Design and Management) Regulations, 2007 edition;

f) The Electromagnetic Compatibility Regulations, 2006 edition;

g) The Low Voltage Electrical Equipment (Safety) Regulations, 1989 edition;

h) The Work at Height Regulations, 2005 edition;

i) No. NS-G-1.4, Design of Fuel Handling and Storage Systems in Nuclear Power Plants, 2003 edition;

j) No. NS-G-2.5, Core Management and Fuel Handling for Nuclear Power Plants, 2002 edition;

k) No. SSG-15, Storage of Spent Nuclear Fuel, 2012 edition;

l) No. SSG-27, Criticality Safety in the Handling of Fissile Material, 2014 edition.

m) RCC-M, Design and Construction Rules for Mechanical components of PWR Nuclear Islands, 2007 edition;

n) BS EN 13001, Cranes - General design Part 1: General principles and requirements, 2015 edition;

o) BS EN 15011, Cranes - Bridge and gantry cranes, 2011 edition;

p) ANS 57.1, Design Requirements for Light Water Reactor Fuel Handling Systems, 1992 edition;

q) ANSI/ANS 57.2, Design Requirements for Light Water Reactor Spent Fuel Storage Facilities at Nuclear Power Plants, 1983 edition;

r) ANSI/ANS 57.3, Design Requirements for New Fuel Storage Facilities at Light

Water Reactor Plants, 1983 edition;

s) ASME NOG-1, Rules for Construction of Overhead and Gantry Cranes, 2004 edition.

The application areas of the main standards in the PMC [FHSS] are listed in T-28.3-1.

T-28.3-1 Application Area of the Main Standards in the PMC [FHSS]

Standards Number	Application in the PMC [FHSS]
RCC-M 2007 edition	Design, manufacture, and inspection of fuel transfer tube and fuel storage rack
BS EN13001-1 2015 edition	Design, manufacture, and inspection of cranes, such as refuelling machine, Spent Fuel Pool Crane (SFPC) and auxiliary crane
BS EN15011 2011 edition	Design, manufacture, and inspection of cranes, such as refuelling machine, SFPC and auxiliary crane
ANS 57.1 1992 edition	Design of the PMC [FHSS] system and components
ANSI/ANS 57.2 1983 edition	Design of underwater fuel storage rack and associated components
ANSI/ANS 57.3 1983 edition	Design of new fuel storage rack and associated components
ASME NOG-1 2004 edition	Seismic analysis of cranes, such as refuelling machine, SFPC and auxiliary crane

28.4 Overview of the PMC [FHSS]

28.4.1 Role of the PMC [FHSS]

The role of the PMC [FHSS] is identified in PSR Chapter 10.7. The major operating functions of the PMC [FHSS] are described hereafter:

a) Receipt, inspection and storage of NFAs;

b) Core loading and unloading in the reactor core;

c) Inspection and storage of the Irradiated Fuel Assemblies (IFAs);

d) Storage of failed FAs and Rod Cluster Control Assembly (RCCA);

e) Rearrangement of relevant components, namely RCCAs, thimble plug assemblies and neutron source assemblies;

f) Loading SFAs into spent fuel casks for delivery;

g) Lighting for underwater fuel handling;

h) Handling control rod drive shafts, the irradiation surveillance capsule and specimen access plug with the help of unique tools.

For a brief introduction to the PMC [FHSS], refer to *Fuel Handling and Storage System Design Manual Chapter 2 Brief Introduction to the System,* reference [3]. This document includes the scope, responsibility, and some other basic information of the PMC [FHSS].

28.4.2 General Layout of the PMC [FHSS]

The PMC [FHSS] is located in the BRX and BFX.

The equipment inside the BRX includes: refuelling machine, fuel transfer facility (BRX part), fuel transfer tube (BRX part), blind flange, on-line sipping test facility, temporary storage rack, spent fuel assembly emergency handling tool holder, BRX refuelling platform and underwater lighting.

The equipment inside the BFX includes: fuel transfer facility (BFX part), fuel transfer tube (BFX part), gate valve, SFPC, auxiliary crane, new fuel elevator, new fuel dry storage rack, underwater fuel storage racks, failed FA storage cells, failed RCCA storage cells, off-line sipping test facility, handling tools for FAs and relevant components and their respective holders, and underwater lighting.

More detailed descriptions for the PMC [FHSS] equipment are presented in *Fuel Handling and Storage System Design Manual Chapter 4 System and Component Design,* Reference [5].

Structures associated with the PMC [FHSS] include: the reactor cavity, core internal pool, fuel transfer compartment, SFP, loading pit, cleaning pit, fuel hoisting pit, PMC transport room, new fuel receipt room and new fuel storage room.

More detailed descriptions of the PMC [FHSS] equipment are presented in *Fuel Handling and Storage System Design Manual Chapter 5 Layout Requirements and Environment Condition,* Reference [6].

The general layout drawings of the PMC [FHSS] are shown in Appendices 28B F-28B-1 and F-28B-2.

28.4.3 Process of the PMC [FHSS]

Based on the role of the system and the general layout of the PMC [FHSS], the

process can be divided into three typical sub-processes:

a) NFA receipt, inspection and storage;

b) Core Loading/Unloading;

c) SFA delivery in the BFX.

The diagrams of these sub-processes are shown in *Fuel Handling and Storage System Design Manual Chapter 9 Flow Diagrams*, reference [8].

28.4.3.1 NFA Receipt, Inspection and Storage

a) Receipt of new fuel transport container

The NFAs are transported to the BFX in a new fuel transport container by a transportation truck.

The new fuel transport container is transferred into the new fuel receipt room using the auxiliary crane.

b) NFA inspection

The NFAs are taken out of the transport container for inspection using the auxiliary crane and new fuel handling tool.

c) NFA storage and new RCCA inspection

NFAs are lifted to the new fuel dry storage rack and undergo RCCA inspection if necessary.

Spare NFAs are transferred to the new fuel dry storage rack using the auxiliary crane.

The NFAs prepared for the next refuelling cycle are initially stored in the SFP. Firstly they are transferred into a fuel basket on the new fuel elevator using the auxiliary crane, then the basket is lowered to the bottom of the SFP, then the NFAs can be retrieved and placed into the underwater fuel storage racks using the SFPC.

The process diagram for new fuel receipt and storage is shown in Appendix 28B F-28B-3.

More detail on the sub-process covering receipt, inspection and storage of NFAs is presented in *Fuel Handling and Storage System Design Manual Chapter 6 System Operations and Maintenance*, Reference [7]

28.4.3.2 Core Loading/Unloading

a) First core loading

NFAs, along with the necessary relevant components for the first core loading, are stored in the underwater fuel storage racks. The first core loading operation can be carried out if the preparation work is finished. The main operating steps are as

follows:

1) The NFAs are transferred vertically and one at a time from the SFP into a fuel carrier located in the fuel transfer facility using the SFPC;

2) The fuel carrier is rotated to the horizontal position and moved from the BFX side to the BRX side;

3) The fuel carrier is rotated back to the vertical position;

4) The NFAs are transferred from the fuel carrier of the fuel transfer facility into the core using the refuelling machine.

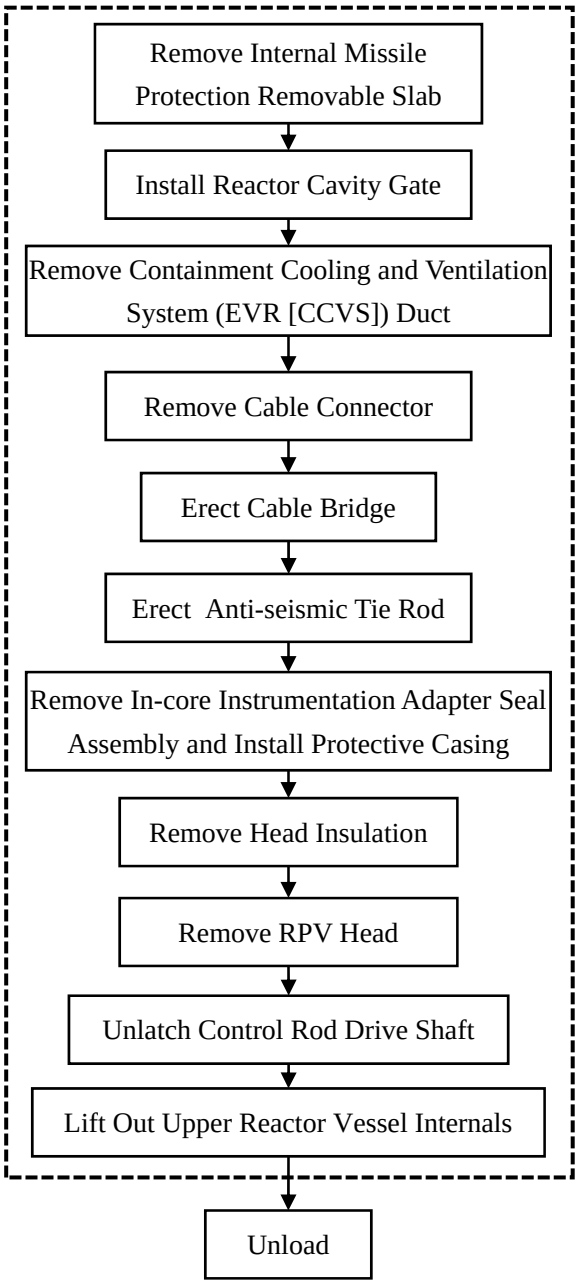
The above steps are repeated to load the reactor core for the first time.

b) Refuelling preparation and reactor disassembly

Before refuelling, it is necessary to remove the Reactor Pressure Vessel (RPV) head from the core using polar crane. Once completed, this opportunity is taken to inspect reactor structural components according to the manual of preventive maintenance.

The general steps of RPV head removal are shown in F-28.4-1. The majority of these operations are on the critical path for the total refuelling outage.

The gate valve and blind flange on the fuel transfer facility should be opened in advance, therefore the fuel building and reactor building can be connected by the fuel transfer tube.



F-28.4-1 RPV Head Removal for Refuelling

c) Core refuelling

During the refuelling shutdown stage, when the refuelling preparation is complete and the NFAs and relevant components necessary for refuelling are ready for retrieval in the underwater fuel storage racks, the core refuelling operation can be carried out. Refuelling operation can be divided into three stages as follows:

1) Stage 1: Unloading FAs from the reactor core and transferring to the SFP

The main steps for unloading FAs from the reactor core to the SFP are as follows:

- IFAs are transferred vertically, one at a time, from the core and placed

into a fuel transfer facility fuel carrier using refuelling machine;

- The IFA is inspected to identify whether it is failed or not using the on-line sipping test facility installed on the refuelling machine during the transfer from the core to the fuel transfer facility;
- The fuel carrier is rotated to the horizontal position and transferred from the BRX side to the BFX side;
- The fuel carrier is rotated to the vertical position, and the IFA is transferred from the fuel transfer facility and placed into the underwater fuel storage racks located in the SFP using the SFPC. The final storage position and subsequent operations are based on the results of on-line sipping test (as summarised below);
  - If it is confirmed that the FA is not damaged, it will be transferred to the underwater fuel storage racks for storage;
  - If it is confirmed that the FA is damaged, it will be transferred to the failed FA storage cell for storage;
  - If any FA is suspected to have been damage, but this has not been confirmed, it will be transferred to the off-line sipping test facility for quantitative damage detection. Subsequent storage location will then be as above depending on the results.

2) Stage 2: Rearrangement of relevant components in the SFP

This stage is used to rearrange components associated with the FAs in the SFP using the SFPC and relevant handling tools according to reactor core loading plan.

During the first core refuelling, the discharged neutron source assemblies are not reused, and NFAs with the thimble plug assembly are loaded in their place.

3) Stage 3: Reloading FAs to the reactor core

When the rearrangement of the relevant components in the SFP is complete and the reloading is ready to commence, the reactor core reloading operation can begin. The reloading operation is in the opposite order to the unloading operation. The FAs in the SFP are reloaded into the reactor core sequentially in series with their relevant components. The main operations include:

- The NFAs and IFAs are transferred vertically from the SFP into fuel carrier using the SFPC, one FA at a time;
- The fuel carrier is rotated to the horizontal position and transferred from the BFX side to the BRX side;
- The fuel carrier is rotated to the vertical position;

- The NFAs and IFAs are transferred from the fuel carrier to the core using the refuelling machine;
- The RPV head is lifted back in place with the polar crane.

The route of fuel loading and unloading is shown in Appendix 28B F-28B-4.

The operation of reactor reassembly is the opposite process of reactor disassembly, and so is not repeated here.

More details on the process of fuel loading/unloading are presented in *Fuel Handling and Storage System Design Manual Chapter 6 System Operations and Maintenance*, Reference [7].

28.4.3.3 SFA Delivery in the BFX

a) Receipt of spent fuel transport cask

An empty spent fuel transport cask is transported into the BFX by a dedicated transporter.

The spent fuel transport cask is transferred to the cleaning pit using the spent fuel cask crane.

b) Empty cask operations within the cleaning pit

The empty cask is inspected and cleaned in the cleaning pit.

c) Operations within the loading pit

The cask is lifted to the loading pit using the spent fuel cask crane. The loading pit is then filled with borated water until its surface level is equal to the SFP. The gate between the SFP and loading pit is subsequently opened. After that, the SFAs are loaded into the cask using the SFPC. Finally, the cask shielding cover is reinstalled.

d) Fully loaded cask operations within cleaning pit

The fully loaded cask is lifted to the cleaning pit, and the surface of cask is flushed, cleaned and dried. Then cask seal is reinstalled. Finally the cask is ready for delivery.

The process diagram for SFA delivery in the BFX is shown in Appendix 28B F-28B-5.

More details on the process of SFAs delivery in the BFX are presented in *Fuel Handling and Storage System Design Manual Chapter 6 System Operations and Maintenance,* Reference [7].

The process of SFA delivery for interim storage outside the BFX is described in PCSR chapter 29.

28.4.4 Interfaces with Other SSCs

The key interfaces between the PMC [FHSS] and other SSCs are:

a) The DMR[RBHE], which supports the refuelling preparation, including reactor disassembly and reassembly, is described in PCSR Chapter 10;

b) The DMK[FBHE], which supports SFA delivery in the BFX, including spent fuel transport cask lifting, is described in PCSR Chapter 10;

c) The PTR[FPCTS], which supplies borated water for fuel cooling, shielding and sub-criticality, is described in PCSR Chapter 10 as a typical auxiliary system;

d) Electrical power supply systems, which support the fuel handling and storage related operations, are described in PCSR Chapter 9;

e) Civil design of the BRX and BFX, which are related to the PMC [FHSS], is described in PCSR Chapter 16;

f) Heating, Ventilation and Air Conditioning (HVAC), which play a clear role in reducing offsite dose during fuel handling accidents, is described in PCSR Chapter 10.

The above SSCs will be considered while developing the safety case for the PMC [FHSS], particularly with regards to fault analysis and hazard assessment, such that performance demands placed on these SSCs are derived and ultimately achieved.

28.4.5 Main Equipment of the PMC [FHSS]

The PMC [FHSS] for the UK HPR1000 design includes the following sub-processes and main equipment, as listed in T-28.4-1.

T-28.4-1 Main Equipment of the PMC [FHSS]

Sub-Process	Main Equipment	Operational Function
NFA receipt, Inspection and Storage	Auxiliary Crane	Handling new fuel transport container and NFAs in air; Handling new RCCA during its inspection test.
	New Fuel Dry Storage Rack	Storing NFAs in dry conditions; Support to inspection and testing activities for the new RCCA.
	New Fuel Elevator	Lowering NFAs to the bottom of the SFP.
Core Loading	Refuelling	Transferring FAs between reactor cavity pool and the

Sub-Process	Main Equipment	Operational Function
/Unloading	Machine	fuel transfer facility in the BRX.
	Fuel Transfer Facility	Transferring FAs between the BRX and BFX.
	SFPC	Transferring FAs between the SFP and fuel transfer compartment in the BFX; Rearranging relevant components in the SFP.
	Underwater Fuel Storage Racks	Storing FAs underwater in the SFP.
	On-line Sipping Test Facility	Sampling FA to check for failure using qualitative testing.
	Off-line Sipping Test Facility	Sampling FA to check for failure using quantitative testing.
SFA Delivery in the BFX	SFPC	Transferring FAs between the SFP and cask loading pit in the BFX.
	Spent Fuel Cask Crane	Lifting the spent fuel transport cask between the loading pit and fuel hoisting pit.

28.5 Safety Case Strategy

28.5.1 Safety Function

The PMC [FHSS] safety functions are as follows:

a) Maintaining sub-criticality of FAs

The PMC [FHSS] does not directly participate in the fulfilment of core reactivity control, but it shall maintain the FAs in a sub-critical condition during handling and storage related operations.

b) Removal of residual heat from IFAs

The PMC [FHSS] shall provide sufficient cooling of the IFAs during handling and storage related operations.

c) Containment of radioactive substances

The PMC [FHSS] shall maintain the integrity of fuel cladding during handling and

storage related operations. During reactor operation, the fuel transfer facility forms part of the reactor containment boundary.

28.5.2 Safety Case Structure

As illustrated in sub-chapter 28.2.3 Chapter Route Map, the chapter claim can be split into five sub-claims, and each sub-claim will be substantiated with associated arguments and outline evidence in the following sub-chapters of this PCSR. Further evidence, and some of those listed below, will be given in the appropriate GDA steps in the form of references and supporting documents. The system design manual is a series of basic references to present the design of the PMC [FHSS] SSCs. The scope and content of system design manual can refer to *Fuel Handling and Storage System Design Manual Chapter 1 System Design Manual Content and State*, reference [2].

a) **Sub-Claim 1**: The safety functional requirements have been derived for the system.

   1) **Argument 1.1**: A thorough process has been followed to identify all faults related to the PMC [FHSS].

      - **Evidence 1.1.1**: Fault analysis in the safety assessment report for the PMC [FHSS].
      - **Evidence 1.1.2**: System design manual.

   2) **Argument 1.2**: The protection requirements have been identified for the PMC [FHSS] in all Sub-operations.

      - **Evidence 1.2.1**: System design manual.

   3) **Argument 1.3**: All practicable mitigation measures have been considered in response to failures of the PMC [FHSS] equipment and human errors.

      - **Evidence 1.3.1**: System design manual.

b) **Sub-Claim 2**: The design intent of the system can be met by the design of process and relevant SSCs.

   1) **Argument 2.1**: Safety related requirements for NFA receipt are met through appropriate design of sub-process and relevant SSCs.

      - **Evidence 2.1.1**: NFA receipt safety case and safety assessment in sub-chapter 28.6.3.

   2) **Argument 2.2**: Safety related requirements for NFAs dry storage are met through appropriate design of sub-process and relevant SSCs.

      - **Evidence 2.2.1**: NFA dry storage safety case and safety assessment in sub-chapter 28.6.3.

3) **Argument 2.3**: Safety related requirements for refuelling preparations are met through appropriate design of sub-process and relevant SSCs.

   - **Evidence 2.3.1**: Refuelling preparations safety case and safety assessment in sub-chapter 28.6.3.

4) **Argument 2.4**: Safety related requirements for refuelling operations are met through appropriate design of sub-process and relevant SSCs.

   - **Evidence 2.4.1**: Refuelling safety case and safety assessment in sub-chapter 28.6.3.

5) **Argument 2.5**: Safety related requirements for SFA storage are met through appropriate design of sub-process and relevant SSCs.

   - **Evidence 2.5.1**: SFA storage safety case and safety assessment in sub-chapter 28.6.3.

6) **Argument 2.6**: Safety related requirements for SFA delivery in BFX are met through appropriate design of sub-process and relevant SSCs.

   - **Evidence 2.6.1**: SFA delivery in BFX safety case and safety assessment in sub-chapter 28.6.3.

For further detail on the aforementioned sub-process safety cases, refer to sub-chapter 28.6.2.

c) **Sub-Claim 3**: All reasonably practicable measures have been adopted to improve the design of the system.

1) **Argument 3.1**: The system design meets appropriate standards, based on RGP and Operating Experience (OPEX), suitable for a UK context.

   - **Evidence 3.1.1**: ALARP assessment report for the PMC [FHSS].

2) **Argument 3.2**: The risk from failure of the system is acceptably low, and options for design improvement have been considered and will be adopted where practicable.

   - **Evidence 3.2.1**: ALARP assessment report for the PMC [FHSS].

d) **Sub-Claim 4**: The system performance will be validated through commissioning and testing.

1) **Argument 4.1**: Safety Functional Requirements for the PMC [FHSS] will be met through the appropriate factory acceptance testing.

   - **Evidence 4.1.1**: The requirements for factory acceptance testing.

2) **Argument 4.2**: Safety Functional Requirements for the PMC [FHSS] will be met through the appropriate site acceptance testing.

- **Evidence 4.2.1**: The requirements for commissioning procedures.

e) **Sub-Claim 5**: The effects of ageing on the system have been addressed in the design.

1) **Argument 5.1**: Appropriate obsolescence management and Examination, Maintenance, Inspection, Test (EMIT) arrangements will be put in place to ensure the design intent of the PMC [FHSS] is maintained.

- **Evidence 5.1.1**: Equipment Operation and Maintenance Manual (EOMM).

28.6 Safety Assessment of the PMC [FHSS]

The key aim of the safety assessment for the PMC [FHSS] is to demonstrate that the aforementioned five sub-claims will be supported by the necessary arguments and evidence.

28.6.1 Fault Analysis

To identify potential faults associated with fuel handling and storage related operations, assess the consequences and demonstrate that suitable and sufficient protection has been provided against these faults, the following will be carried out:

a) Postulated Initiating Event (PIE) identification

The identification of faults associated with the PMC [FHSS] related operations is underway through the process of PIE identification. PIEs which have the potential to lead to any person receiving a significant dose of radiation or to a significant radioactive material release due to the PMC [FHSS] related operations will be identified.

For PIE identification relevant to the PMC [FHSS], the PIEs will be identified by systematically following the fuel handling and storage related operations step by step, to ensure that the potential faults will be identified in a comprehensive manner. The faults considered for the UK HPR1000 PMC [FHSS] may include:

1) Loss of cooling;

2) Loss of water inventory;

3) Loss of power;

4) Criticality accident;

5) Over-raising of IFA;

6) Internal and external hazards, including dropped loads and collisions.

b) Protection Measures

Based on the results of PIE identification, the appropriate PIEs will be considered as part of the design basis analysis, severe accident analysis and probabilistic safety analysis with the proposed safety functions. If the analysis results show that the risk requires further reduction, potential design changes will be carried out to provide suitable and sufficient protection.

The fault analysis will be included in the safety assessment report for the PMC [FHSS], which will be submitted during the next step of GDA.

28.6.2 Safety Assessment of Sub-processes

Based on the stage of operation, the PMC [FHSS] related operations can be divided into three typical sub-processes as described in sub-chapter 28.4.3.
For each sub-process, several respective safety cases will be produced to demonstrate the level of safety achieved. A generic approach can be taken for this assessment. Firstly, the top events which can lead to the failure of a safety function during the sub-process will be identified, and then a thorough assessment step by step will be carried out to find out the potential initiating events. After that, relevant necessary protection measures are considered to prevent these events.

The safety cases of the aforementioned sub-processes will be presented in the safety assessment report for the PMC [FHSS].

28.6.3 Safety Assessment of Main Equipment

The contribution of specific components or equipment to the achievement of the fundamental safety functions is difficult to assess, as this cannot be achieved by any single piece of equipment alone. Some devices contribute to the achievement of fundamental safety functions directly, while others may do it indirectly. All the PMC [FHSS] SSCs contribute to personnel and fuel handling safety.

The relationship between the PMC [FHSS] equipment and the fundamental safety functions is shown in T-28.6-1.

T-28.6-1 Fundamental Safety Functions of the PMC [FHSS] Equipment

Equipment	Fundamental Safety Functions			Contribution
	Maintaining Sub-criticality of the Fuel	Removal of Residual Heat From Irradiated Fuel	Confinement of Radioactive Substances	
Refuelling Machine	N/A	N/A	Indirect	Prevent fuel dropping and collision.
Fuel Transfer Facility	N/A	Indirect	Indirect	Prevent fuel jamming and collision; Form part of reactor containment boundary.
SFPC	N/A	N/A	Indirect	Prevent fuel dropping and collision.
New Fuel Elevator	N/A	N/A	Indirect	Prevent fuel dropping and jamming.
Auxiliary Crane	N/A	N/A	Indirect	Prevent fuel dropping and collision.
New Fuel Dry Storage Rack	Direct	N/A	Indirect	Maintain sub-criticality of FAs.
Underwater Fuel Storage Rack	Direct	Direct	Indirect	Maintain sub-criticality and cooling of FAs.
Fuel Handling Tools	N/A	N/A	Indirect	Prevent fuel dropping.
Off-line Sipping Test Facility	N/A	N/A	Indirect	Identify the fuel cladding leakage or break.

Notes:

a) “N/A” means the equipment does not contribute to the achievement of fundamental safety functions.

b) “Direct” means the equipment participates in the achievement of fundamental safety functions directly.

c) “Indirect” means the equipment participates in the achievement of fundamental safety functions indirectly.

The classification of the main PMC [FHSS] equipment is provided in Appendix 28C T-28C-1. More detailed information about classification is presented in *Handling and Storage System Design Manual Chapter 3 System Functions and Design Bases*, Reference [4].

The following sub-chapters only give a preliminary safety assessment of the main PMC [FHSS] equipment, in order to show how the safety related requirements allocated by the system can be adhered to. The detailed design information for the PMC [FHSS] equipment will be provided in the technical specifications as references submitted in the next step.

28.6.3.1 Refuelling Machine

The safety related requirements allocated to refuelling machine are met and supported by the following design features (this list is not exhaustive):

a) The refuelling machine has been designed to prevent the FAs from dropping during the handling operation.

    1) The hoisting mechanism is equipped with redundant load paths.

    2) The hoisting mechanism is equipped with dual brakes.

    3) The hoisting mechanism is equipped with dual load cell.

    4) Logical interlocks prohibit the incorrect release of carried loads.

    5) The support structure is designed to withstand the maximum loads due to all normal and fault conditions.

b) The refuelling machine has been designed to prevent the FAs from experiencing collision during the handling operation.

    1) The route of refuelling machine is planned and verified in advance and the absence of obstacles during handling operations will be ensured.

    2) The FAs are protected by the stationary sleeve installed on the refuelling machine during transfer.

c) The refuelling machine has been designed to prevent the FAs from being lifted too high.

1) The lifting height will be limited by travel limit switches.

2) Position encoders will measure the real-time height of the FA continuously.

d) The refuelling machine has been designed to prevent the FAs from misloading.

1) The core loading is executed according to a pre-determined approved plan.

2) Each loading step is verified to assure its compliance with the plan.

28.6.3.2 Fuel Transfer Facility

The safety related requirements allocated to fuel transfer facility are met and supported by the following design features:

a) The fuel transfer facility has been designed to prevent the FAs from dropping during the handling operation.

1) The lifting winch of fuel transfer facility is equipped with dual cables.

2) The lifting winch of fuel transfer facility is equipped with dual brakes.

3) Logical interlocks prohibit the incorrect release of carried loads.

4) The support structure is designed to withstand the maximum loads due to all normal and fault conditions.

b) The fuel transfer facility has been designed to prevent the FAs from jamming during the handling operation.

1) Continuous rails are provided to guide the movement of fuel carrier.

2) Manual emergency drive mechanism is provided.

c) The fuel transfer facility has been designed to maintain the containment during the plant operation phase.

1) The reactor building end of the fuel transfer tube is sealed by a blind flange fitted with a twin gasket leak tightness control device.

2) The fuel building end of the transfer tube is sealed by a gate valve fitted with a twin gasket leak tightness control device.

28.6.3.3 SFPC

The safety related requirements allocated to SFPC are met and supported by the following design features:

a) The SFPC has been designed to prevent the FAs from dropping during the handling operation.

1) The hoisting mechanism is equipped with redundant load paths.

2) The hoisting mechanism is equipped with dual brakes.

3) The hoisting mechanism is equipped with dual load cell.

4) Logical interlocks prohibit the incorrect release of carried loads.

5) The support structure is designed to withstand the maximum loads due to all normal and fault conditions.

b) The SFPC has been designed to prevent the FAs from experiencing a collision during the handling operation.

1) The travel route of SFPC is planned in advance and the absence of obstacles during handling operations is ensured.

2) Boundary protection is provided using interlock control.

3) Limit switches are provided on the ends of travel.

c) The SFPC has been designed to prevent the FAs from being lifted too high.

1) The lifting height is limited by travel limit switches switch.

2) Position encoders will measure the real-time height of the FA continuously.

d) The SFPC has been designed to prevent the misloading of fuel.

1) The core loading is executed according to a pre-determined and approved plan.

2) Each loading step is verified to ensure its compliance with the plan.

28.6.3.4 New Fuel Elevator

The safety related requirements allocated to new fuel elevator are met and supported by the following design features:

a) The new fuel elevator has been designed to prevent the FAs from dropping during the handling operation.

1) The hoisting mechanism is equipped with redundant load paths.

2) The hoisting mechanism is equipped with dual brakes.

3) The hoisting mechanism is equipped with dual load cell.

4) A guidance structure is equipped to keep the fuel basket running on the rail.

5) The support structure is designed to withstand the maximum loads due to all normal and fault conditions.

b) The new fuel elevator has been designed to prevent the FAs from jamming during the handling operation.

1) The FAs are transferred in the fuel basket to protect it.

2) Continuous rails ensure the correct orientation of the fuel carrier is maintained.

28.6.3.5 Auxiliary Crane

The safety related requirements allocated to the auxiliary crane are met and supported by the following design features:

a) The auxiliary crane has been designed to prevent the FAs from dropping during the handling operation.

1) The hoisting mechanism is equipped with redundant load paths.

2) The hoisting mechanism is equipped with dual brakes.

3) The hoisting mechanism is equipped with dual load cell.

4) Logical interlocks prohibit the incorrect release of carried loads.

5) The support structure is designed to withstand the maximum loads due to all normal and fault conditions.

b) The auxiliary crane has been designed to prevent the FAs from collision during the handling operation.

1) The running route of auxiliary crane is planned in advance and the absence of obstacles is ensured prior to handling operations.

2) Limit switches are provided at the extremes of travel.

28.6.3.6 New Fuel Dry Storage Rack

The safety related requirements allocated to new fuel dry storage rack are met and supported by the following design features:

a) The new fuel dry storage rack has been designed to maintain the NFAs in a sub-critical state at all times.

1) The new fuel storage rack prevents criticality by ensuring proper geometrical structure and appropriate fuel-to-fuel distance.

2) To prevent water ingress or flooding, there are no water pipes within the new fuel storage area.

b) The new fuel dry storage rack has been designed to prevent the fuel from becoming damaged.

1) Each storage cell is composed of a stainless steel sleeve with a lead-in chamfer to facilitate the fuel handling.

2) The inner surface of the cell is a flat, smooth surface, which can provide physical protection for the stored fuel assembly against outside impact.

3) The strength of the new fuel storage rack is designed to withstand seismic loads and other impacts resulting from postulated events.

4) The top of each storage cell is equipped with a protective plug to protect the stored fuel from contamination.

5) The storage area is covered with a metal plate to protect the fuel assembly against damage or impact.

The criticality analysis report for the new fuel dry storage rack will be provided in step 3.

28.6.3.7 Underwater Fuel Storage Racks

The safety related requirements allocated to underwater fuel storage racks are met and supported by the following design features:

a) The underwater fuel storage racks has been designed to maintain the stored fuel in a sub-critical state at all times.

1) The racks are flooded with borated water.

2) Solid neutron absorbers are fixed to the racks.

b) The underwater fuel storage racks has been designed to provide adequate cooling to SFAs.

1) The underwater fuel storage racks are immerged in the spent fuel pool.

2) The structure of the racks permits natural circulation of coolant through the storage cell to cool the fuel assemblies.

c) The underwater fuel storage racks has been designed to maintain containment of radioactive substances.

1) Five failed fuel assembly storage filters are provided to store the fuel assemblies which are known to be damaged in order to prevent radioactive material from diffusing into the coolant.

The criticality analysis report for underwater fuel storage racks will be provided in step 3.

28.6.3.8 Fuel Handling Tools

The safety related requirements allocated to fuel handling tools are met and supported by the following design features:

a) The fuel handling tools has been designed to prevent the FAs and relevant

components from dropping during the handling operations.

1) All the fuel handling tools are equipped with a positioning device, which will provide positive indication of a good connection between the tools and the assemblies.

2) The gripper is designed to ensure that the fuel assembly can be smoothly grabbed and securely locked to avoid accidental loosening.

3) All the FHTs are equipped with a mechanical locking device, which can only be unlocked through the correct manual operation.

28.6.3.9 Off-line Sipping Test Facility

The off-line sipping test facility is installed in the spent fuel pool. It is used for detailed quantitative testing of suspected damaged FAs, based on results from the on-line sipping test facility. For the off-line sipping test facility, the damage assessment of the FA is based on the gamma activity concentration resulting from the release of fission nuclides and the analysis of water and gas samples extracted from off-line sipping test facility. The FA can be heated in the airtight sleeve of the off-line sipping test facility, and it will promote the release of the fission nuclides inside the cladding. By comparing the gamma activity concentration of the fission nuclides before and after heating up, the operator can qualitatively detect FA failure and quantify the size of the clad crack.

28.6.4 ALARP Approach

Demonstration that risks have been reduced to an ALARP level is an important part of developing the safety case for the PMC [FHSS]. PCSR Chapter 33 provides general ALARP methodology for the UK HPR1000. This chapter describes how the ALARP assessment will be applied to the PMC [FHSS].

The general process that will be adopted for the PMC [FHSS] SSCs ALARP assessment is shown as follows:

a) RGP - the PMC [FHSS] design will be reviewed against UK RGP. Where gaps are identified between the UK HPR1000 and UK RGP, consideration will be given to the implementation of design improvements.

b) Risk assessment - once the UK HPR1000 design is developed, it will undergo a risk assessment. This will review all parts of the process of the PMC [FHSS] and identify the associated risk levels.

c) Options - the PMC [FHSS] design will undergo an optioneering process, which will consider the rationale of the design improvements, while also considering “what more can be done?” in terms of safety improvements.

    1) Define and characterise the problem (potential area for improvement);

2) Generate the potential options to address the problem;

3) Assess the options and their merits/drawbacks;

4) Identify, develop and justify the best option or options;

5) Implement the reasonably practicable options.

d) Finally, a conclusion will be provided which demonstrates that there are no further reasonably practicable improvements that can be implemented into the design.

The ALARP assessment will not be done in isolation, but will consider holistic risk and potential risk transfer (i.e. where a safety improvement in one area could cause a safety disadvantage in another area).

For the operations of the PMC [FHSS], the main nuclear safety risks include:

a) Criticality accidents;

b) Loss of cooling to fuel;

c) Loss of confinement of fission products due to fuel cladding failure;

d) Exposure to workers.

The protection measures for these risks have been considered in the design of the PMC [FHSS], as described in Section 28.6.3 above. As part of the ALARP assessment, the areas identified as high risk in the analysis will be identified as potential areas for enhancement, to further reduce the nuclear safety risks.

At present, the identification and analysis of PMC [FHSS] related GAPs have been finished. And all the gaps will be eliminated in GDA step 3 and step 4.

In order to demonstrate that the risks from the PMC [FHSS] are ALARP, all reasonably practicable improvements will be adopted.

28.6.5 Human Factors

Many aspects of the PMC [FHSS] involve human actions. Therefore consideration of human factors is an important aspect of developing the PMC [FHSS] safety case. PCSR Chapter 15 provides the holistic approach to human factors for the UK HPR1000 design. This sub-chapter will describe the approach taken to assess human factors for the PMC [FHSS], and how this process aligns with the overall human factors assessment process for the UK HPR1000 design.

The process of considering human factors for the PMC [FHSS] is outlined as follows:

a) Process review and participation in fault analysis - during this stage, human factors specialists will review the PMC [FHSS] SSC design as well as fuel handling processes and procedures. This review will determine the operator

actions that are undertaken during normal operational conditions for the PMC [FHSS]. It will also review the required operator actions during fault and hazard conditions for the PMC [FHSS].

b) Identification of operator initiated faults, administrative controls, and post fault operator actions - this will identify how operators may lead to faults (i.e. how a human performance issue could initiate an event), while also considering operator actions to prevent fault, provide protection against the fault sequence, or mitigate fault consequences.

c) Task analysis and reporting - during this stage the required operator performance will be evaluated and detailed human based safety claims will be developed. This will identify areas where significant claims are placed on operators to support safe operation of the plant.

d) Detailed human factors assessment and analysis to support development of a design which reduces risks to levels that are ALARP – once the human based safety claims are developed then these will be assessed to determine where design or procedural improvements could be made to optimise the design, in terms of minimising human based performance issues as far as reasonably practicable.

The detailed human factors analysis for the PMC [FHSS] related operations will be covered under a dedicated report as a supporting document.

28.6.6 Protection against External and Internal Hazards

The PMC [FHSS] is designed to withstand internal and external hazards in accordance with the principles described in PCSR Chapter 18 and PCSR Chapter 19.

Hazard protection shall be considered during the design of the PMC [FHSS]. The specification is described in the document *Fuel Handling and Storage System Design Manual Chapter 3 System Functions and Design Bases*， Reference [4].

28.6.7 Commissioning

Initial testing of the PMC [FHSS] SSCs before delivery to site (for example factory acceptance tests) will be undertaken in accordance with procurement, manufacturing and commissioning quality arrangements. These technical documents shall be prepared by the equipment designer and reviewed by the installer and operator. All the operational and safety requirements and performances shall be confirmed before delivery to the site.

Following acceptance of the PMC [FHSS] SSCs by the commissioning organisation, a structured, systematic and progressive test programme, which includes all the activities required for confirmation and demonstration of the plant SSCs operational and safety functional performance requirements, will be implemented. The arrangements for the development of the commissioning, and the management of the

commissioning activities are discussed in PCSR Chapter 30. These activities include the requirements for system performance tests to establish and demonstrate the plant performance characteristics, which can be used subsequently in order to help demonstrate ongoing the PMC [FHSS] SSC performance and potentially detect the onset of unacceptable degradation.

The testing and commissioning arrangements will be based on those developed for the design reference plant. Further detailed site specific arrangements for the UK HPR1000 commissioning activities, in addition to those described in PCSR Chapter 30, will be presented during the nuclear site licensing phase.

28.6.8 Examination, Maintenance, Inspection and Testing (EMIT)

The design of the PMC [FHSS] equipment will take into account maintenance work, and all parts that may be damaged or worn will be positioned such that they are as accessible as possible, for ease of removal and replacement.

The PMC [FHSS] equipment will be inspected and tested regularly according to appropriately defined regimes to ensure performance and early detection of potential issues. For example, the fuel handling equipment and tools will be checked and tested before the reactor is shut down for refuelling.

Each device will be provided with an EOMM when supplied to the plant site, which includes all the EMIT requirements and related guidance. These procedures are out of GDA scope, and will be produced by the equipment supplier after detailed design and manufacture.

28.7 Concluding Remarks

This chapter provides the general design information for the UK HPR1000 PMC [FHSS], as well as the outline safety case strategy. Safety claims, arguments and preliminary evidence are also summarised.

According to the preliminary assessment, the fundamental safety requirements related to fuel handling and storage will be achieved through proper design of the system and equipment. Further demonstration or improvements will be implemented during the appropriate GDA Steps.

28.8 References

[1] CGN, General Principles for Application of Laws, Regulations, Codes and Standards, GHX00100018DOZJ03GN, Rev F, 2018.

[2] CGN, Fuel Handling and Storage System Design Manual Chapter 1 System Design Manual Content and State, GHX17PMC001DPFJ45GN, Rev A, 2018.

[3] CGN, Fuel Handling and Storage System Design Manual Chapter 2 Brief Introduction to the System, GHX17PMC002DPFJ45GN, Rev A, 2018.

[4] CGN, Fuel Handling and Storage System Design Manual Chapter 3 System Functions and Design Bases, GHX17PMC003DPFJ45GN, Rev A, 2018.

[5] CGN, Fuel Handling and Storage System Design Manual Chapter 4 System and Component Design, GHX17PMC004DPFJ45GN, Rev A, 2018.

[6] CGN, Fuel Handling and Storage System Design Manual Chapter 5 Layout Requirements and Environment Condition, GHX17PMC005DPFJ45GN, Rev A, 2018.

[7] CGN, Fuel Handling and Storage System Design Manual Chapter 6 System Operations and Maintenance, GHX17PMC006DPFJ45GN, Rev A, 2018.

[8] CGN, Fuel Handling and Storage System Design Manual Chapter 9 Flow Diagrams, GHX17PMC009DPFJ45GN, Rev A, 2018.

Appendix 28A Route Map for the PMC [FHSS]

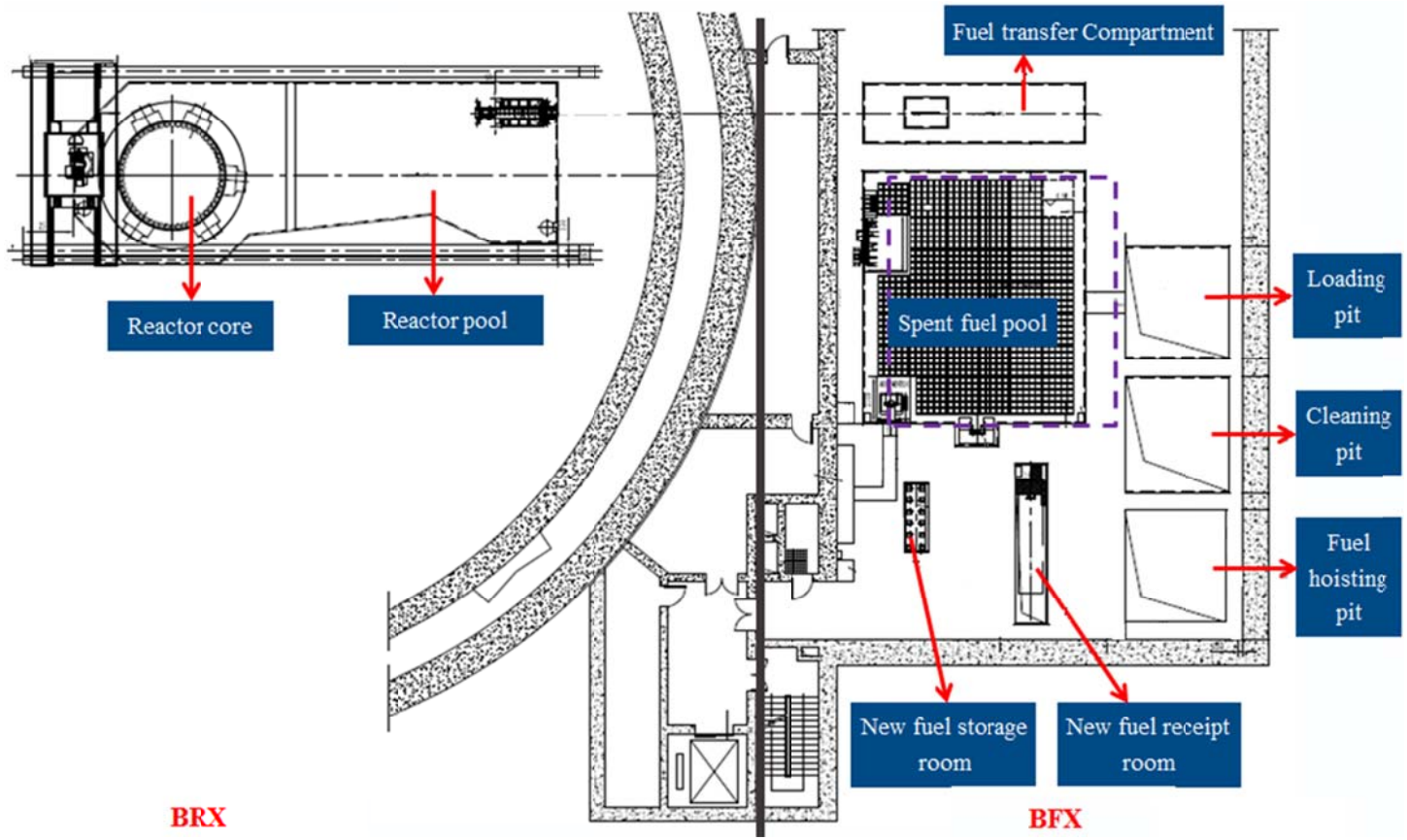
T-28A-1 Route Map of the PMC [FHSS]

Fundamental Objective	Claim 3 (Level 1)	Claim 3.3 (Level 2)	Chapter Claim	Sub-claims	Arguments	Evidence
The Generic UK HPR1000 could be constructed, operated and decommissioned in the UK, on a site bounded by the generic site envelope, in a way that is safe, secure and that protects the environment	The design and intended construction and operation of the UK HPR1000 will protect the workers and the public by providing multiple levels of defence to fulfil the fundamental safety functions, reducing the nuclear safety risks to a level that is as low as reasonably practicable;	The design of the processes and systems has been substantiated and the safety aspects of operation and management have been substantiated.	The fuel handling and storage process, and design of the associated systems, have been substantiated.	The safety functional requirements have been derived for the system.	A thorough process has been followed to identify all faults related to the PMC [FHSS].	Fault analysis in the safety assessment report for the PMC [FHSS].
					The protection requirements have been identified for the PMC [FHSS] in all Sub-operations.	System design manual
					All practicable mitigation measures have been considered in response to failures of the PMC [FHSS] equipment and human errors.	
				The design intent of the system can be met by the design of process and relevant SSCs.	Safety related requirements for NFA receipt are met through appropriate design of sub-process and relevant SSCs.	NFA receipt safety case and safety assessment in sub-chapter 28.6.3.
					Safety related requirements for NFAs dry storage are met through appropriate design of sub-process and relevant SSCs.	NFA dry storage safety case and safety assessment in sub-chapter 28.6.3.
					Safety related requirements for refuelling preparations are met through appropriate design of sub-process and relevant SSCs.	Refuelling preparations safety case and safety assessment in sub-chapter 28.6.3.
					Safety related requirements for refuelling operations are met through appropriate design of sub-process and relevant SSCs.	Refuelling safety case and safety assessment in sub-chapter 28.6.3.
					Safety related requirements for SFA storage are met through appropriate design of sub-process and relevant SSCs.	SFA storage safety case and safety assessment in sub-chapter 28.6.3.
					Safety related requirements for SFA delivery in BFX are met through appropriate design of sub-process and relevant SSCs.	SFA delivery in BFX safety case and safety assessment in sub-chapter 28.6.3.
				All reasonably practicable measures have been adopted to improve the design of the system.	The system design meets appropriate standards, based on RGP and Operating Experience (OPEX), suitable for a UK context.	ALARP assessment report for the PMC [FHSS].
					The risk from failure of the system is acceptably low, and options for design improvement have been considered and will be adopted where practicable.	

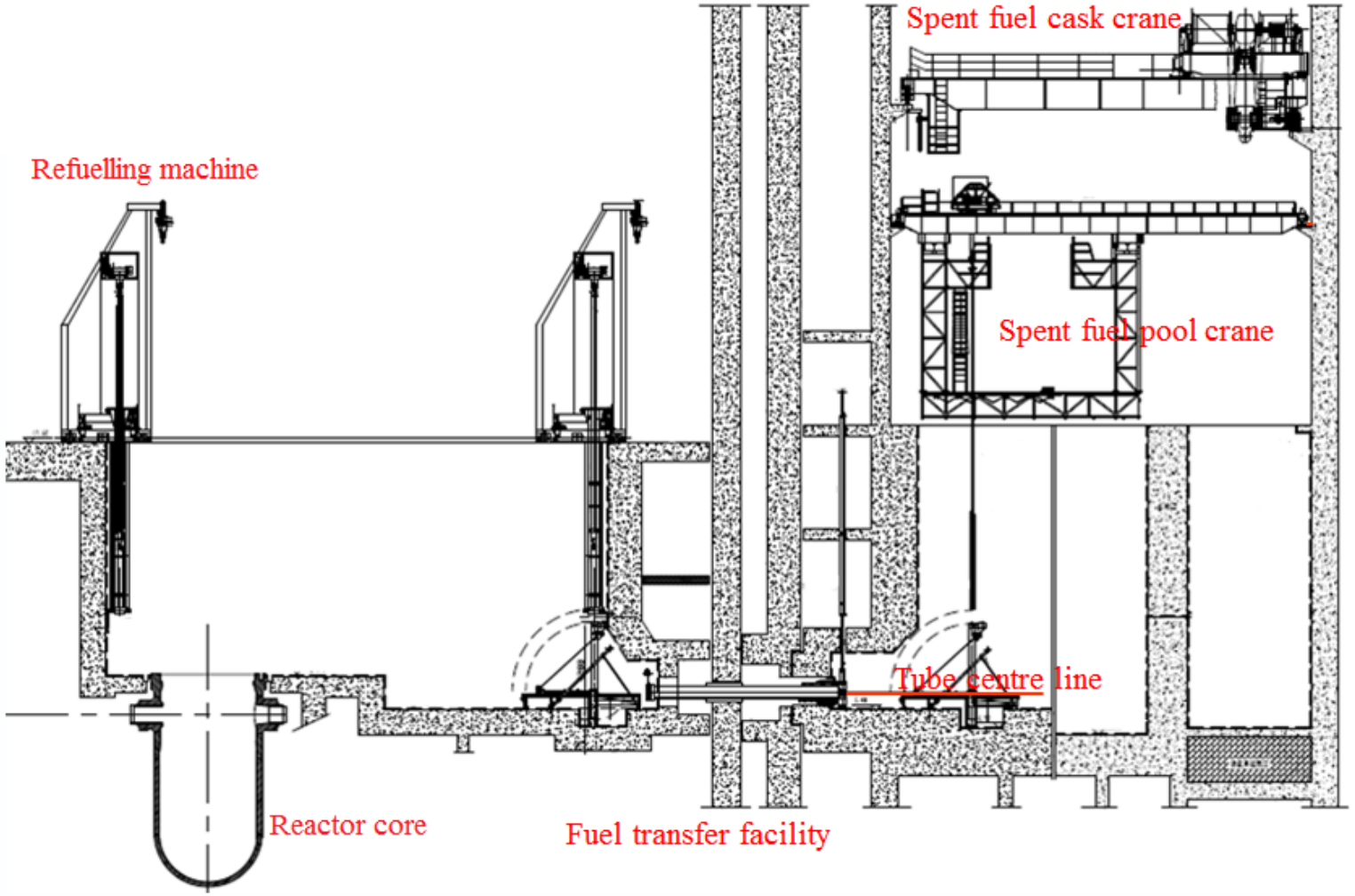
Fundamental Objective	Claim 3 (Level 1)	Claim 3.3 (Level 2)	Chapter Claim	Sub-claims	Arguments	Evidence
				The system performance will be validated through commissioning and testing.	Safety Functional Requirements for the PMC [FHSS] will be met through the appropriate factory acceptance testing.	The requirements for factory acceptance testing.
					Safety Functional Requirements for the PMC [FHSS] will be met through the appropriate site acceptance testing.	The requirement for commissioning procedure.
				The effects of ageing on the system have been addressed in the design.	Appropriate obsolescence management and Examination, Maintenance, Inspection, Test (EMIT) arrangements will be put in place to ensure the design intent of the PMC [FHSS] is maintained.	EOMM

Appendix 28B General Layout and Process of the PMC [FHSS]

28B.1 General Layout of the PMC [FHSS]

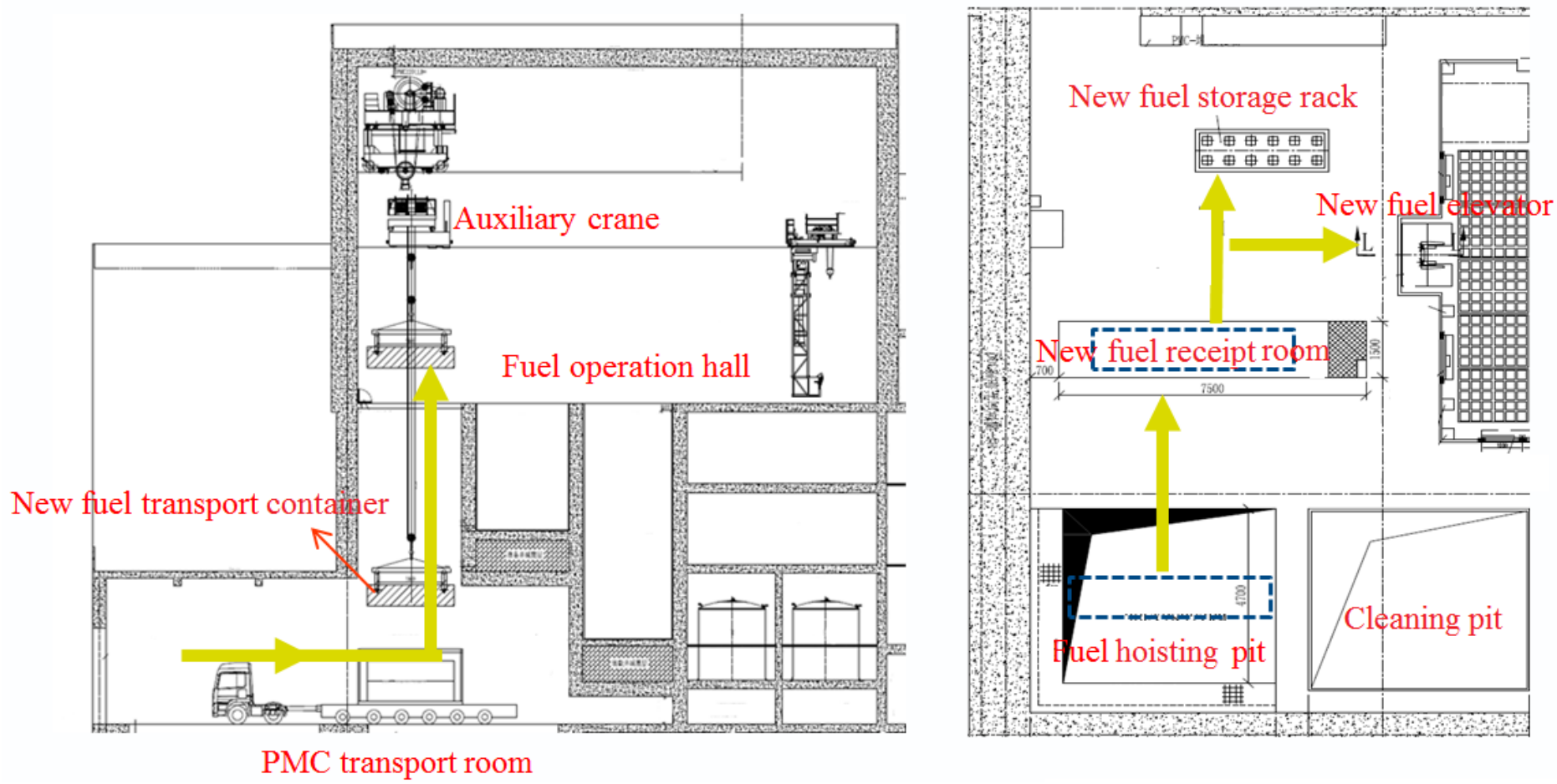


F-28B-1 General Layout of the PMC [FHSS] System and Equipment (Horizontal)

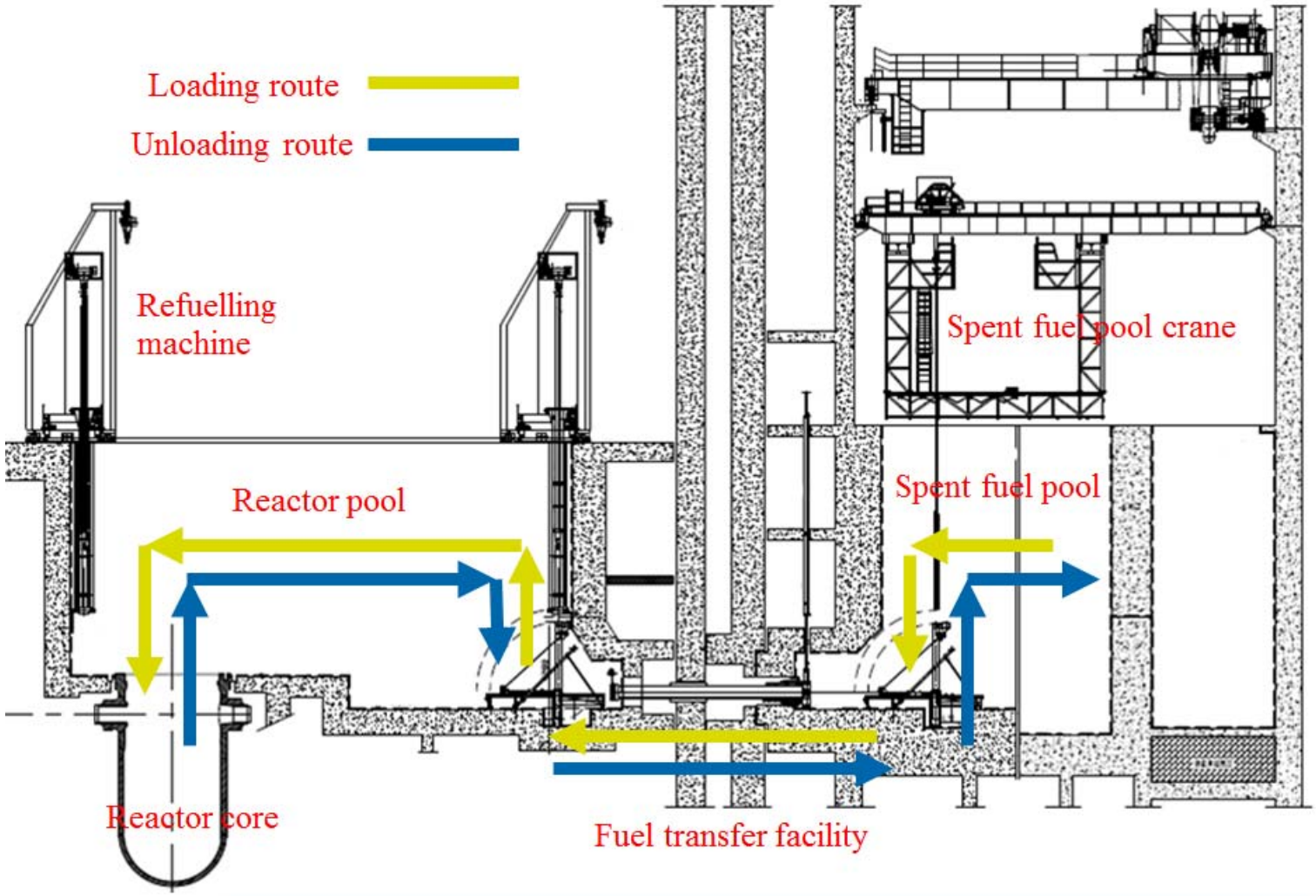


F-28B-2 General Layout of the PMC [FHSS] System and Equipment (Vertical)

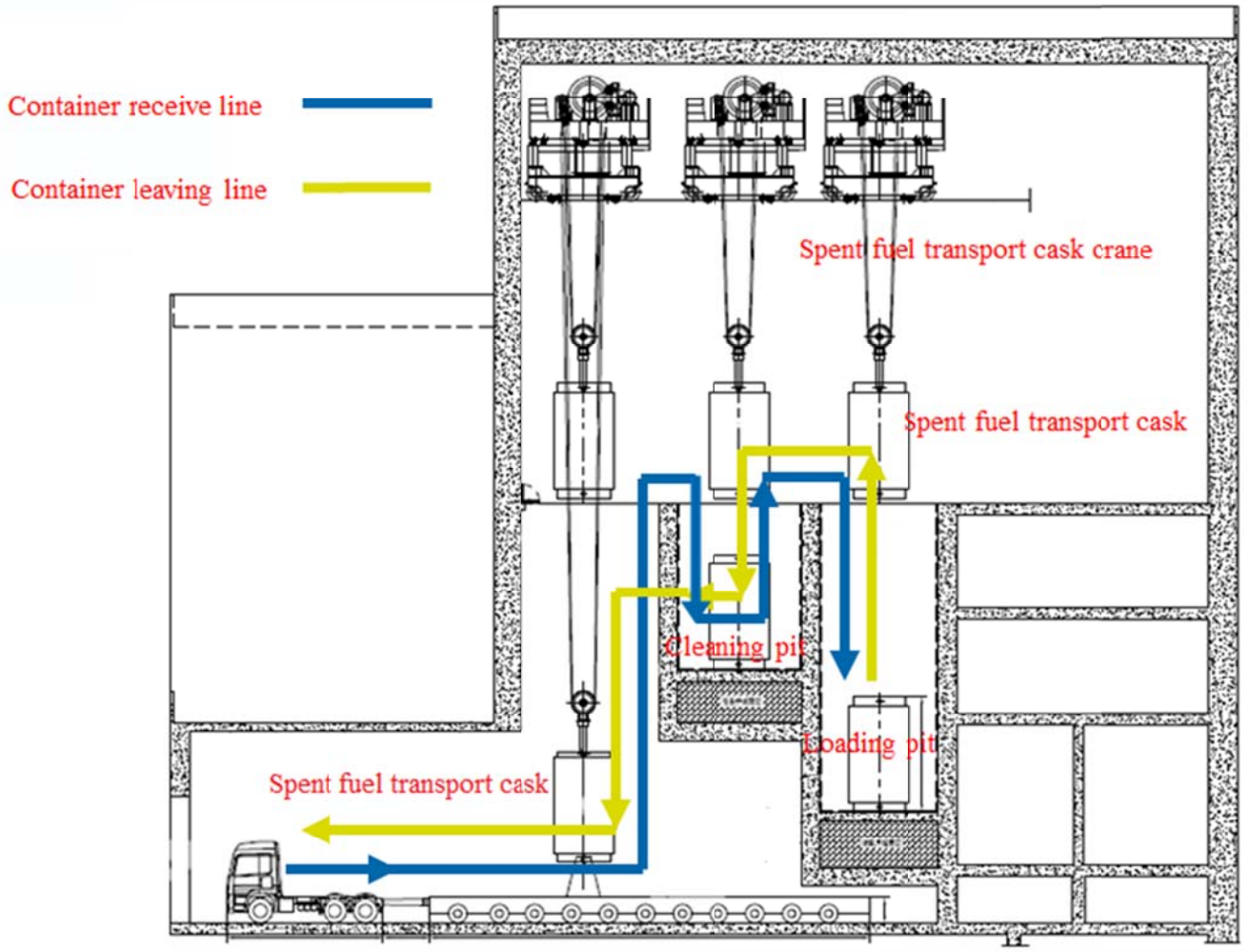
28B.2 Process of the PMC [FHSS]



F-28B-3 Receipt, Inspection and Storage of NFAs



F-28B-4 Core Loading/ Unloading, and Storage of SFAs



F-28B-5 SFAs Delivery in BFX

Appendix 28C Classification of the Main PMC [FHSS] Equipment

T-28C-1 Classification of the Main PMC [FHSS] Equipment

No.	Equipment	Function Classification	Provision Category	Seismic Classification	Quality Assurance Classification
1	Refuelling Machine	NC	B-SC2	SSE1	Q1
2	Fuel Transfer Facility	NC	B-SC2	SSE1	Q1
3	Spent Fuel Pool Crane	NC	B-SC2	SSE1	Q1
4	Spent Fuel Assembly Handling Tool	NC	B-SC2	SSE1	Q1
5	Blind Flange/ Transfer Tube/ Gate Valve	F-SC1	B-SC2	SSE1	Q1
6	Auxiliary Crane	NC	B-SC3	SSE2	Q2
7	New Fuel Elevator	NC	B-SC3	SSE2	Q3
8	New Fuel Assemble Handling Tool	NC	B-SC3	SSE2	Q3
9	Spent RCC/ Neutron Source/ Thimble Plug Assemble Handling Tool	NC	NC	NO	Q3
10	New Fuel Storage Racks	F-SC3	B-SC3	SSE1	Q3
11	Underwater Fuel Storage Racks	F-SC1	B-SC2	SSE1	Q1
12	Off-line Sipping Test Facility	NC	NC	SSE2	Q3
13	On-line Sipping Test Facility	NC	NC	NO	Q3