Revision	Approved by	Number of Pages
000		475
Approval Date	12/11/2018	

General Nuclear System Ltd.

UK HPR1000 GDA Project

Document Reference:	**HPR/GDA/PCSR/0010**

Title:

Pre-Construction Safety Report

Chapter 10

Auxiliary Systems

This document has been prepared on behalf of General Nuclear System Limited (GNS) with the support of China General Nuclear Power Corporation (CGN) and Électricité de France S.A. (EDF).

Although due care has been taken in compiling the content of this document, neither GNS, CGN, EDF nor any of their respective affiliates accept any liability in respect to any errors, omissions or inaccuracies contained or referred to in it.

DISTRIBUTION LIST

Recipients	Cross Box
GNS Executive	☐
GNS all staff	☐
GNS and BRB all staff	☒
CGN	☒
EDF	☒
Regulators	☒
Public	☒

MODIFICATION RECORD

Revision	Section	Page	Modification
000	ALL	ALL	First Issue

TABLE OF CONTENTS

10.1 List of Abbreviations and Acronyms 5

10.2 Introduction 11

10.2.1 Chapter Route Map 11

10.2.2 Chapter Structure 11

10.2.3 Interface with Other Chapters 12

10.2.4 General Design Requirements 16

10.3 Heavy Load Lifting System 27

10.3.1 Sub-chapter Structure 27

10.3.2 Applicable Codes and Standards 27

10.3.3 Reactor Building Handling Equipment (DMR [RBHE]) 28

10.3.4 Fuel Building Handling Equipment (DMK [FBHE]) 38

10.3.5 ALARP Assessment 46

10.3.6 Concluding Remarks 48

10.4 Nuclear Auxiliary Systems 48

10.4.1 Sub-chapter Structure 48

10.4.2 Applicable Codes and Standards 48

10.4.3 Chemical and Volume Control System (RCV [CVCS]) 49

10.4.4 Reactor Boron and Water Makeup System (REA [RBWMS]) 71

10.4.5 Coolant Storage and Treatment System (TEP [CSTS]) 88

10.4.6 Nuclear Sampling System (REN [NSS]) 100

10.4.7 Fuel Pool Cooling and Treatment System (PTR [FPCTS]) 116

10.4.8 Component Cooling Water System (RRI [CCWS]) 133

10.4.9 Essential Service Water System (SEC [ESWS]) 149

10.4.10 ALARP Assessment 161

10.4.11 Concluding Remarks 162

10.4.12 Simplified Diagrams 163

10.5 Process Auxiliary Systems 174

10.5.1 Sub-chapter Structure 174

10.5.2 Applicable Codes and Standards 174

10.5.3 NI Demineralised Water Distribution System (SED [DWDS (NI)]) 175

10.5.4 Nuclear Island Potable Water System (SEP [PWS (NI)]) 180

10.5.5 Nuclear Island Gas Distribution Systems (SGO [ODS], SGN [NDS], SGH [HDS]) 183

10.5.6 Compressed Air Distribution Systems (SAP [CAPS], SAR [ICADS] SAT [SCADS]) 185

10.5.7 ALARP Assessment 188

10.5.8 Concluding Remarks 189

10.6 Heating, Ventilation and Air Conditioning (HVAC) Systems 190

10.6.1 Sub-chapter Structure 190

10.6.2 Applicable Codes and Standards 191

10.6.3 Nuclear Auxiliary Building Ventilation System (DWN [NABVS]) 191

10.6.4 Fuel Building Ventilation System (DWK [FBVS]) 205

10.6.5 Containment Cooling and Ventilation System (EVR [CCVS]) 219

10.6.6 Containment Internal Filtration System (EVF [CIFS]) 228

10.6.7 Containment Sweeping and Blowdown Ventilation System (EBA [CSBVS]) ... 236

10.6.8 Annulus Ventilation System (EDE [AVS]) 249

10.6.9 Safeguard Building Controlled Area Ventilation System (DWL [SBCAVS]) 261

10.6.10 Electrical Division of Safeguard Building Ventilation System (DVL [EDSBVS]) 281

10.6.11 Main Control Room Air Conditioning System (DCL [MCRACS]) 292

10.6.12 Access Building Ventilation Systems (DVW [ABUAVS]-DWW [ABCAVS]) 302

10.6.13 Diesel Building Ventilation System (DVD [DBVS]) 310

10.6.14 Essential Service Water Pumping Station Ventilation System (DXS [ESWVS])

..... 321

10.6.15 Extra Cooling Water and NI Firefighting Building Ventilation System (DXE [ECW&FFB VS]) 328

10.6.16 Waste Treatment Building Ventilation System (DWQ [WTBVS]) 335

10.6.17 Safety Chilled Water System (DEL [SCWS]) 350

10.6.18 Operational Chilled Water System (DER [OCWS]) 360

10.6.19 ALARP Assessment 368

10.6.20 Concluding Remarks 369

10.6.21 Simplified Diagrams 369

10.6.22 Tables of Design Assumptions 386

10.7 Fire Protection Systems 397

10.7.1 Sub-chapter Structure 397

10.7.2 Applicable Codes and Standards 397

10.7.3 Fire Alarm System 398

10.7.4 Fire-fighting Systems 405

10.7.5 Smoke Control System (DFL [SCS]) 422

10.7.6 ALARP Assessment 430

10.7.7 Concluding Remarks 431

10.7.8 Simplified Diagrams 431

10.8 Diesel Generators 436

10.8.1 Sub-chapter Structure 436

10.8.2 Applicable Codes and Standards 436

10.8.3 Emergency Diesel Generator 437

10.8.4 SBO Diesel Generator 445

10.8.5 ALARP Assessment 452

10.8.6 Concluding Remarks 452

10.8.7 Simplified Diagrams 453

10.9 Concluding Remarks 456

10.10 References 457

Appendix 10A Route Map of Sub-Chapter 10.3 467

Appendix 10B Route Map of Sub-Chapter 10.4 469

Appendix 10C Route Map of Sub-Chapter 10.6 471

10.1 List of Abbreviations and Acronyms

AFFF	Aqueous Film-forming Foam
ALARP	As Low As Reasonably Practicable
APG	Steam Generator Blowdown System [SGBS]
ASP	Secondary Passive Heat Removal System [SPHRS]
ATWS	Anticipated Transient Without Scram
BPX	Personnel Access Building
BDX	Diesel Generator Buildings
BEJ	Extra Cooling System and Fire-fighting System Building
BFX	Fuel Building
BGA	Essential Service Water Supply Gallery A
BGB	Essential Service Water Supply Gallery B
BGC	Essential Service Water Supply Gallery C
BNX	Nuclear Auxiliary Building
BOP	Balance of Plant
BPA	Essential Service Water Pump Station A
BPB	Essential Service Water Pump Station B
BRX	Reactor Building
BSA	Safeguard Building A
BSB	Safeguard Building B
BSC	Safeguard Building C
BSX	Safeguard Buildings
BWX	Radioactive Waste Treatment Building
CGN	China General Nuclear Power Corporation
CRDM	Control Rod Drive Mechanism
CTE	Circulating Water Treatment System [CWTS]
DBC	Design Basis Condition
DCL	Main Control Room Air Conditioning System [MCRACS]

DCS	Digital Control System
DEC	Design Extension Condition
DEL	Safety Chilled Water System [SCWS]
DEQ	Waste Treatment Building Chilled water System [WBCWS]
DER	Operational Chilled Water System [OCWS]
DFL	Smoke Control System [SCS]
DG	Diesel Generator
DiD	Defence in Depth
DMK	Fuel Building Handling Equipment [FBHE]
DMR	Reactor Building Handling Equipment [RBHE]
DVD	Diesel Building Ventilation System [DBVS]
DVL	Electrical Division of Safeguard Building Ventilation System [EDSBVS]
DVW	Access Building Uncontrolled Area Ventilation System [ABUAVS]
DWK	Fuel Building Ventilation System [FBVS]
DWL	Safeguard Building Controlled Area Ventilation System [SBCAVS]
DWN	Nuclear Auxiliary Building Ventilation System [NABVS]
DWQ	Waste Treatment Building Ventilation System [WBVS]
DWW	Access Building Controlled Area Ventilation System [ABCAVS]
DXE	Extra Cooling Water and NI Firefighting Building Ventilation System [ECW&FFB VS]
DXS	Essential Service Water Pumping Station Ventilation System [ESWVS]
EBA	Containment Sweeping and Blowndown Ventilation System [CSBVS]
ECS	Extra Cooling System [ECS]
EDE	Annulus Ventilation System [AVS]

EDG	Emergency Diesel Generator
EHR	Containment Heat Removal System [CHRS]
EMIT	Examination, Maintenance, Inspection and Testing
EPP	Containment Leak Rate Testing and Monitoring System [CLRTMS]
EPW	Explosion Pressure Wave
EUF	Containment Filtration and Exhaust System [CFES]
EVF	Containment Internal Filtration System [CIFS]
EVR	Containment Cooling and Ventilation System [CCVS]
FHS	Fire Hose Stations
GDA	Generic Design Assessment
HEPA	High Efficiency Particulate Air
HPR1000 (FCG3)	Hua-long Pressurised Reactor under construction at Fangchenggang nuclear power plant unit 3
HVAC	Heating, Ventilation and Air Conditioning
I&C	Instrumentation and Control
IRWST	In-Containment Refuelling Water Storage Tank
IVR	In-Vessel Retention
JAC	Fire-fighting Water Production System [FWPS]
JDT	Fire Alarm System [FAS]
JPI	Fire-fighting Water System for Nuclear Island [NIFPS]
JPV	Fire Extinguishing System for Nuclear Island Diesel Generator Building [DBFS]
KRT	Plant Radiation Monitoring System [PRMS]
LHSI	Low Head Safety Injection
LOCA	Loss of Coolant Accident
LOOP	Loss of Offsite Power
LUHS	Loss of Ultimate Heat Sink
MCR	Main Control Room

ME	Mechanical Engineering
NDT	Non-Destructive Testing
NI	Nuclear Island
NPP	Nuclear Power Plant
ONR	Office for Nuclear Regulation (UK)
OPEX	Operating Experience
PCSR	Pre-Construction Safety Report
PLC	Programmable Logic Controller
PSA	Probabilistic Safety Assessment
PTR	Fuel Pool Cooling and Treatment System [FPCTS]
PWR	Pressurised Water Reactor
RBS	Emergency Boration System [EBS]
RCC-M	Design and Construction Rules for Mechanical Components of PWR Nuclear Islands
RCD	Reactor Complete Discharge
RCP	Reactor Coolant System [RCS]
RCPB	Reactor Coolant Pressure Boundary
RCV	Chemical and Volume Control System [CVCS]
REA	Reactor Boron and Water Makeup System [RBWMS]
REN	Nuclear Sampling System [NSS]
RGP	Relevant Good Practice
RHR	Residual Heat Removal
RIS	Safety Injection System [SIS]
RPE	Nuclear Island Vent and Drain System [VDS]
RPV	Reactor Pressure Vessel
RRI	Component Cooling Water System [CCWS]
RSS	Remote Shutdown Station
SA	Severe Accident

SAP	Compressed Air Production System [CAPS]
SAR	Instrument Compressed Air Distribution System [ICADS]
SAT	Service Compressed Air Distribution System [SCADS]
SBD	Radioactive Decontamination System [RDS]
SBE	Hot Laundry System [HLS]
SBO	Station Black Out
SDA	Demineralised Water Production System [DWPS]
SDM	System Design Manual
SEC	Essential Service Water System [ESWS]
SED	NI Demineralised Water Distribution System [DWDS (NI)]
SEO	Station Sewer System [SSS]
SEP	Potable Water System [PWS (NI)]
SES	Hot Water Production and Distribution System [HWPDS]
SFC	Single Failure Criterion
SFP	Spent Fuel Pool
SG	Steam Generator
SGH	Hydrogen Distribution System [HDS]
SGN	Nitrogen Distribution System [NDS]
SGO	Oxygen Distribution System [ODS]
SGTR	Steam Generator Tube Rupture
SI	Safety Injection
SSC	Structures, Systems and Components
SSE	Safe Shutdown Earthquake
TEG	Gaseous Waste Treatment System [GWTS]
TEP	Coolant Storage and Treatment System [CSTS]
TER	Nuclear Island Liquid Waste Discharge System [NLWDS]
TES	Solid Waste Treatment System [SWTS]
TEU	Liquid Waste Treatment System [LWTS]

TLOCC	Total Loss of Cooling Chain
UK HPR1000	UK version of the Hua-long Pressurised Reactor
VCT	Volume Control Tank
VDA	Atmospheric Steam Dump System [ASDS]
VVP	Main Steam System [MSS]
XCA	Auxiliary Steam Production System [ASPS]

System codes (XXX) and system abbreviations (YYY) are provided for completeness in the format (XXX [YYY]), e.g. Chemical and Volume Control System (RCV [CVCS]).

10.2 Introduction

10.2.1 Chapter Route Map

The ***Fundamental Objective*** of the UK HPR1000 (UK version of the Hua-long Pressurised Reactor) 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 objective**,** five high level claims and a number of level 2 claims are developed and presented in Chapter 1. Chapter 10 supports ***Claim 3.3*** and ***Claim 3.3.6*** derived from high level ***Claim 3***.

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

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

Claim 3.3.6: *The design of the Auxiliary Systems has been substantiated.*

To support ***Claim 3.3.6***, five sub-claims and a number of relevant arguments and evidences are developed in this chapter, detailed route maps of sub-chapters are presented in the appendices.

10.2.2 Chapter Structure

The structure of the Pre-Construction Safety Report (PCSR) Chapter 10 is outlined below; the detailed structure is presented in each sub-chapter:

a) Sub-chapter 10.1 (List of Abbreviations and Acronyms) lists all the abbreviations and acronyms presented in Chapter 10;

b) Sub-chapter 10.2 (Introduction) gives the objective, scope and overall structure of Chapter 10;

c) Sub-chapter 10.3 to Sub-chapter 10.8 are as follows:

   1) 10.3 Heavy Load Lifting System;

   2) 10.4 Nuclear Auxiliary Systems;

   3) 10.5 Process Auxiliary Systems;

   4) 10.6 Heating, Ventilation and Air Conditioning Systems;

   5) 10.7 Fire Protection Systems;

   6) 10.8 Diesel Generators;

These sub-chapters give the detailed design information of auxiliary systems.

d) Sub-chapter 10.9 (Concluding Remarks) gives the summary and the on-going work of Chapter 10;

e) Sub-chapter 10.10 (References) gives the references cited in Chapter 10.

10.2.3 Interface with Other Chapters

The interfaces of Chapter 10 with other PCSR chapters are listed in the following table.

T-10.2-1 Interfaces between Chapter 10 and Other PCSR Chapters

PCSR Chapter	Interface
Chapter 1 Introduction	Chapter 1 provides the fundamental objective, level 1 claims and level 2 claims. Chapter 10 provides chapter claims, arguments to support relevant claims that are addressed in Chapter 1.
Chapter 2 General Plant Description	Chapter 2 gives an overall description of the plant and links the brief introduction of the main auxiliary systems to Chapter 10. Chapter 10 provides a further description of the auxiliary systems mentioned in Sub-chapter 2.8.
Chapter 3 Generic Site Characteristics	Chapter 3 provides generic site envelope to auxiliary systems and gives a preliminary description of heat sink, which is detailed in Chapter 10. Chapter 10 gives the detailed auxiliary system design (HVAC and heat sink sytems) using the site parameters.
Chapter 4 General Safety and Design Principles	Chapter 4 provides general engineering principles relevant to the auxiliary systems substantiation in Chapter 10. Chapter 10 demonstrates that the principles have been implemented in the auxiliary system design.
Chapter 5 Reactor Core	Chapter 5 describes the purification function of the RCV [CVCS] for primary loop source term control. Chapter 10 provides detailed design information of the RCV [CVCS].

PCSR Chapter	Interface
Chapter 6 Reactor Coolant System	Chapter 6 provides supporting functional requirements relevant to safety and operation for interfacing auxiliary systems. Chapter 10 provides the design substantiation relevant to these functions.
Chapter 7 Safety Systems	Chapter 7 provides supporting functional requirements relevant to safety and operation for the interfacing auxiliary systems. Chapter 10 provides the design substantiation relevant to these functions.
Chapter 8 Instrumentation and Control	Chapter 8 provides design substantiation relevant to the system control functions. Chapter 10 provides control functional requirement that shall be fulfilled by instrumentation and control systems.
Chapter 9 Electric Power	Chapter 9 provides the design information relevant to the electrical power systems supporting the function of auxiliary systems. Ventilation systems in Chapter 10.6 support the function of electrical power system in Chapter 9. Diesel generator engine and the auxiliaries in Chapter 9 are detailed in Chapter 10.8. Electrical parts of diesel generator in Chapter 10.8 are detailed in Chapter 9.
Chapter 12 Design Basis Condition Analysis	Chapter 12 provides the justification of current auxiliary system design in terms of the Design Basis Condition (DBC) analysis. Chapter 10 provides the system design considered in the fault analysis.
Chapter 13 Design Extension Conditions and Severe Accident Analysis	Chapter 13 provides the justification of current auxiliary systems design in terms of the Design Extension Condition (DEC) analysis. Chapter 10 provides the system design considered in the DEC analysis.
Chapter 14 Probabilistic	Chapter 14 provides the estimated feedback on auxiliary system

PCSR Chapter	Interface
Safety Assessment	design showing whether potential enhancement needs to be made on the design. Chapter 10 provides the design of auxiliary systems for the PSA analysis.
Chapter 15 Human Factors	Chapter 15 provides the principles and methodology of human factor integrity that shall be considered in the system and component design. Chapter 10 provides the substantiation of the principles in auxiliary systems design, which is further estimated in the human factor area.
Chapter 16 Civil Works & Structures	The design output of civil structures is considered in the system and component design of auxiliary systems presented in Chapter 10.
Chapter 17 Structure Integrity	Chapter 17 provides the structural integrity demonstration of auxiliary system components. Chapter 10 provides detailed design information of the auxiliary systems and equipment.
Chapter 18 External Hazards	Chapter 18 provides external hazards relevant to the UK HPR1000 as well as the design principles. Chapter 10 provides the auxiliary system design substantiation of applied hazard protection design principles, which is further estimated in the external hazards area.
Chapter 19 Internal Hazards	Chapter 19 provides internal hazards relevant to the UK HPR1000 as well as the design principles. Chapter 10 provides the auxiliary system design substantiation of applied hazard protection design principles, which is further estimated in the internal hazards area.
Chapter 20 MSQA and Safety Case Management	Chapter 20 provides the organisational arrangements and quality assurance arrangements in the production of Chapter 10. Chapter 10 implements the relevant requirements in the system design process and the safety case production process.

PCSR Chapter	Interface
Chapter 21 Reactor Chemistry	Chapter 21 provides the information of the chemistry control and sampling requirements (such as water quality control by chemical addition, and purities control by clean-up) to systems. Chapter 10 provides the system substantiation of the supporting chemistry related functions in Chapter 21.
Chapter 22 Radiological Protection	Chapter 22 provides radiological protection design considerations relevant to the auxiliary systems substantiation in Chapter 10. Chapter 10 provides design information used in radiological protection design in Chapter 22.
Chapter 24 Decommissioning	Chapter 24 provides decommissioning design considerations relevant to the SSC (Structures, Systems and Components) of UK HPR1000. Chapter 10 provides the system design substantiation of the principles in Chapter 24.
Chapter 25 Conventional Safety and Fire Safety	Chapter 25 provides the fire risk identification and prevention principles in auxiliary system design. Sub-chapter 10.7 of Chapter 10 provides information of fire protection systems related to fire safety strategy in Chapter 25.
Chapter 28 Fuel Route and Storage	Chapter 28 covers the design of fuel handling and storage system, which is related to some auxiliary systems presented in Chapter 10. Chapter 10 provides the design of supporting systems to the fuel handling and storage system, such as the DMK, the DMR, the PTR, etc.
Chapter 29 Interim Storage of Spent Fuel	Chapter 29 covers the spent fuel interim storage design related to some auxiliary systems presented in Chapter 10. Chapter 10 provides the design of supporting systems to the spent fuel interim storage design such as the DMK, the PTR, etc.
Chapter 30 Commissioning	Chapter 30 provides arrangement and scope relevant to commissioning.

PCSR Chapter	Interface
	Chapter 10 takes into account the information relevant to commissioning in Chapter 30.
Chapter 31 Operational Management	Chapter 31 provides relevant principle, requirements, and methodology for the periodic tests, inspection, maintenance and ageing and degradation. Chapter 10 provides the auxiliary system design substantiation of applied principles and requirements.
Chapter 33 ALARP Evaluation	Chapter 33 provides relevant principle, methodology and approach for the ALARP (As Low As Reasonably Practicable) demonstration. Chapter 10 applies the ALARP approach in the ALARP demonstration of auxiliary systems and supports the overall ALARP demonstration addressed in Chapter 33.

10.2.4 General Design Requirements

The design requirements derived from Chapters 4, 15, 18, 19, 30, 31 (general safety and design principles, human factors and hazard protection etc.) and relevant documents of general requirements, as well as the requirements of system design shall be considered in the system design process and are listed below. The detailed description of requirements and principles is presented in supplementary submissions, References [1][2][3].

a) Safety Classification

The aim of the classification is to help ensure that the item is designed, manufactured, constructed, commissioned and operated according to appropriate requirements so as to achieve good quality under all expected operating conditions and realise the safety functions. The safety classification principles (including seismic categorisation principle) in the document "*Methodology of Safety Categorisation and Classification*", Reference [2], shall be considered in the design of auxiliary systems.

b) Engineering Design Requirements

1) The Reliability Design of SSCs

- Single Failure Criterion (SFC)

The SFC is considered to ensure that more than the minimum of components are provided to carry out safety functions. The criterion is

applicable to a mechanical system that performs a safety function, such that it must be capable of performing its intended safety function in the presence of any single failure. It is beneficial to ensuring the high reliability of safety systems and to maintain the plant within its deterministic design basis. The redundancy design helps satisfy this criterion.

The single failure includes active and passive failures:

- An active single failure is defined as a failure which is sufficient to invalidate the relevant safety function of a component, including the malfunction of a mechanical or electrical component which relies on mechanical movement to complete its intended function upon demand, and the malfunction of an I&C (Instrumentation and Control) component;
- A passive single failure is defined as a failure which could occur in a component that does not change its state while realizing its function. The passive single failure at the start of a transient should be assessed in an appropriate means.

The SFC is applied to F-SC1 systems in the system level and F-SC2 systems in the function level, thus redundancy is needed in the design of these systems. Consideration of single failure criteria at the system level of F-SC1 indicates that these systems must be redundant. Consideration of single failure criteria at the function level for systems fulfilling F-SC2 functions indicates that these systems may not need redundancy.

Details about general principles for the SFC are provided in Reference [1].

– Independence

In addition to the high level principle of independence between levels of DiD (Defence in Depth), the following principles for independence should be applied in the design to achieve system reliability and tolerance to faults:

- Independence between the trains of redundant system should be maintained as far as reasonably practicable (avoidance of common cause failure);
- Independence between components of different safety categories should be maintained as far as reasonably practicable (avoidance of impact on the component of higher safety category from an item of lower safety category);

- The components designed to mitigate a potential initiating event should be independent from the effects of this potential initiating event as far as reasonably practicable.

Independence is accomplished in the design of systems by using functional isolation and/or physical separation. Functional isolation is used to reduce adverse effects between elements of connected systems or systems redundantly designed. These adverse effects may be caused by the normal operation, abnormal operation or failure of any part of these systems.

Physical separation should be applied in the layout of systems as far as reasonably practicable, to reduce the potential of common cause failure due to a localised initiating event. The choice of isolation measures (compartmentalisation, distance, orientation etc.) should take into account the nature of the initiating events.

Details about general principles for independence are provided in Reference [1].

– Diversity

To reduce the potential for common cause failure, diversity should be realised by incorporating different attributes into the design of systems or components, as appropriate, in the redundant systems or components that perform the same safety function. The auxiliary systems shall consider the requirement of diversity.

In order to achieve the reliability targets and to fulfil the DiD concept, diversity should be realised by incorporating different attributes into the design of systems or components, as appropriate, in the redundant systems or components that perform the same safety function. Such attributes can be different operating principles, different physical variables, different operating conditions, different manufacturers, etc.

Common cause failure of safety measures should be assumed in the analysis for frequent faults. Therefore, a main protection line and a diverse protection line should be established to achieve the fundamental safety objective for frequent faults.

What should be paid special attention is that the diversity should be taken into account in the design of systems performing FC1 or FC2 functions based on software to avoid common cause failure.

Details about general principles for diversity are provided in Reference [1].

- Fail-safe

  To ensure the performance of the intended safety function, failure or the failure of a support feature will not invalidate the performance of the intended safety function. The auxiliary systems shall consider the fail-safe design.

- Ageing and Degradation

  Considerations:

  The design life of items important to safety at a nuclear power plant shall be determined. Appropriate margins shall be provided in the design to take due account of relevant mechanisms of ageing, neutron embrittlement and wear out and of the potential for age related degradation, to ensure the capability of items important to safety to perform their necessary safety functions throughout their design life, including testing, maintenance, maintenance outages, plant states during a postulated initiating event and plant states following a postulated initiating event.

  Provision shall be made for monitoring, testing, sampling and inspection to assess ageing mechanisms predicted at the design stage and to help to identify unanticipated behaviour of the plant or degradation that might occur in service.

  Details about the general principles and requirements for management of ageing and degradation are addressed by asset management, including equipment qualification, state monitoring, pre-service inspection, commissioning tests, operating and Examination, Inspection, Maintenance and Testing (EMIT) and decommissioning, etc.

  Common Design Measures to Fulfil the Considerations:

  The ageing effects concerning individual components have been taken into consideration in the system design:

  - Sufficient margin has been taken in the component design to prevent failures caused by ageing effects;
  - Practical examining measures are planned during plant operation (EMIT) to address the ageing effects to the components;
  - For replaceable parts of components, replacement plans and layout designs are properly considered.

2) Human Factors

   Considerations:

According to Reference [1], the design shall allocate functions properly, and support personnel in the fulfilment of their responsibilities and in the performance of tasks. The design also needs to identify human actions that may affect safety and proportionately analyse all tasks important to safety, and limit the likelihood of operational errors and their impact on safety. The principle relevant to the human factors shall be considered in the system design.

Moreover, the design of the system, component, layout, HMI and operator working environment shall meet the human factors requirements which are presented in the safety case of human factors (starts in Chapter 15). The design will be further assessed in the human factors engineering task analysis.

Common Design Measures to Fulfil the Considerations:

In the system design, short term operator intervention is avoided and the dependence on human action is reduced to prevent human error. Detailed information about automatic control design of the system is presented in the Chapter 6 of the System Design Manual (SDM).

Operator actions during plant normal operation will also be assessed to estimate the possible harmful effects to the safety. Relevant human actions important to plant safety will be further identified, and substantiation of related system design will be evaluated in the human factors area (see Chapter 15).

3) Autonomy

- Autonomy in respect of operators;

  If the plant selected parameters exceed set points, the protection system shall come into action, providing automatic scram and initiation of post-trip cooling. The plant shall be designed in such a way that it meets the following autonomy objectives:

  - The numerical targets of DBC-2, DBC-3, DBC-4 and DEC-A can be met without operator action from the Main Control Room (MCR) in less than 30 minutes from the first significant signal;
  - The numerical targets of DBC-2, DBC-3, DBC-4 and DEC-A can be met without action outside the MCR in less than 1 hour from the first significant signal;
  - No site based mobile light equipment shall be required in less than 6 hours from accident initiation, for core damage prevention actions in DEC;

- No site based mobile light equipment shall be required in less than 12 hours from accident initiation, for containment performance assurance in DEC;
- No offsite or onsite mobile heavy equipment is required in less than 72 hours in both DBCs and DECs;
- In addition, the containment system shall be designed in such a way that it can withstand any of the severe accidents considered in DEC, without operator action during the first 12 hours from the beginning of the severe accident conditions.

– Autonomy in respect of the heat sink;

Design provisions shall ensure adequate decay heat removal under DBC and DEC, for 72 hours without external support. The initial means ensuring decay heat removal shall last at least 24 hours.

The design shall include provisions allowing additional means to ensure decay heat removal after 72 hours.

– Autonomy in respect of power supply systems.

- Electrical Power Supply

  √ The period of independence of the installation in relation to external electrical power supplies shall be at least 72 hours; this applies to DBC and DEC;

  √ The plant shall have an available power supply unit which is independent of the electrical power supply units designed for operational conditions and postulated accidents. It shall have sufficient capacity to support at the same time all these functions: remove decay heat, ensure primary circuit integrity, maintain reactor sub-criticality and monitor the unit state;

  √ The batteries which perform FC1 and FC2 functions shall be sized so that their expected autonomy is at least 2 hours following any DBC, without recharging;

  √ The batteries which perform significant safety functions shall be sized so that their expected autonomy could be 12 hours in severe accident without recharging.

- Compressed Air

  Where required to support essential systems, the availability of compressed air reserves should be sufficient to be consistent with the timescale for the availability of the equipment.

4) Other Design Requirements

- Prevention of Harmful Interactions of Systems Important to Safety

  The potential for harmful interactions of systems important to safety at the nuclear power plant that might be required to operate simultaneously shall be evaluated, and effects of any harmful interactions shall be prevented.

  In the analysis of the potential for harmful interactions of systems important to safety, due account shall be taken of physical interconnections and of the possible effects of one system's operation, maloperation or malfunction on local environmental conditions of other essential systems, to ensure that changes in environmental conditions do not affect the reliability of systems or components in functioning as intended.

  If two fluid systems important to safety are interconnected and are operating at different pressures, either the systems shall both be designed to withstand the higher pressure, or provision shall be made to prevent the design pressure of the system operating at the lower pressure from being exceeded.

- Considerations Related to the Electrical Power Grid

  The functionality of items important to safety at the nuclear power plant shall not be compromised by disturbances in the electrical power grid, including anticipated variations in the voltage and frequency of the grid supply.

c) Equipment Qualification

Equipment qualification includes environmental and seismic qualification. Considering the results of fault analysis and the safety classifications, the specific equipment to be qualified is listed as follows:

1) Equipment required for environmental qualification:

All normal operational, fault and accident conditions should be considered in the equipment qualification process. Normal operational conditions should consider the lifetime of the equipment and the environment of the normal condition in the plant where the equipment is placed. The variation of environmental condition arising from the fault and accident conditions should be considered in the environmental qualification.

- Mechanical equipment and electrical equipment that perform FC1 or FC2 functions;

- Mechanical equipment and electrical equipment that perform FC3 functions are required:
  - to maintain a safe state;
  - to protect against DEC-A and mitigate DEC-B.

2) Equipment required for seismic qualification:

   The equipment that performs the following functions should be seismically qualified: operability (O), functionality (F), integrity (I) or stability (S).

d) Protection against Internal and External Hazards

Considerations:

According to Chapter 4 and further information which is presented in Reference [3], fulfilment of the fundamental safety functions for a nuclear power plant shall be ensured in hazard protection design, as well as limitation of accidental radioactive releases.

The principles of hazard protection design are as follows:

1) The concept of DiD should be applied in the design of hazard protection;
2) Hazards should not result in the failure of any fundamental safety function of nuclear power plants;
3) Priority should be given to passive barriers, and the integrity of the barrier against individual and combined hazards should be substantiated. The acceptability of any partial loss of integrity should be evaluated;
4) The habitability of the MCR should be ensured. The availability and the accessibility of the remote shutdown station should be ensured in case the MCR is unavailable;
5) The protection design measures should ensure that there is no cliff-edge effect;
6) The hazards safety evaluation should demonstrate that the risk is reduced to be ALARP.

For detailed information about protection requirements and measures refer to Reference [3].

Common Design Measures to Fulfil the Considerations:

The necessary capability, reliability and functionality of items important to safety shall be ensured in the conditions arising from internal and external hazards to deliver relevant safety functions.

Measures to protect the system against internal hazards are presented in Chapter 19.6. Detailed safety evaluation and analysis of protection measures will be made in the submissions of Chapter 19.

Measures to protect the system against external hazards are presented in Chapter 18.6. Detailed safety evaluation and analysis of protection measures will be made in the submissions of Chapter 18.

e) Commissioning

The safety related functions shall be effectively demonstrated via commissioning and testing before service. The system commissioning programme shall be established to guide the commission test onsite. The commission content, phased approach and scope are shown in Chapter 30.

f) Examination, Inspection, Maintenance and Testing

The design should be such that activities for EMIT are facilitated for the purpose of maintaining the capability of SSCs important to safety to perform essential safety functions, so as to satisfy the reliability requirement.

The types of inspections, maintenances, periodic tests, relevant requirements and the methodology of completeness analysis are presented in Chapter 31. The above activities are specified taking into account the design code requirements, reliability analysis and potential degradation mechanisms, commensurate with the safety class of the system. These requirements/principles shall be considered in the system design.

g) Decommissioning

Decommissioning shall be considered during the design stage for the UK HPR1000. At the current stage, the general considerations of decommissioning are mentioned in Chapter 24 and mainly include:

1) The consideration of facilitating decommissioning;

2) The consideration of decommissioning strategy; and,

3) The consideration of the preliminary decommissioning plan for the UK HPR1000.

h) Material Selection

Material selection of systems and equipment is one of the most significant factors for the safety and economy of the nuclear power plant, and therefore special attention shall be paid to the material selection at the design stage for SSCs to carry out their duties with high reliability throughout the design life of the plant.

The principles and the approach of material selection are presented in Reference

[4]. According to the reference, the general principles relevant to the material selection are summarised as shown below:

1) Material selection shall be consistent with the functional objectives of the system and equipment;

2) Material selection shall be performed in a manner in which the classification shall be reflected; the requirements shall be commensurate with the classification;

3) Materials selected for use shall be compatible with the full range of environmental conditions which may be encountered over the plant design life;

4) Materials selected for use shall present high functional reliability and good resistance to aging and degradation throughout the design life to mitigate against the risk of performance degradation and failure of SSCs;

5) Materials selected for use shall possess excellent manufacturability, and shall be convenient for performing processing sequences such as forging or casting, machining, heat treatment, welding and inspection;

6) Operating Experience (OPEX) and feedback shall be taken into account for material selection of the system;

7) Generation and transportation of source terms shall be specially considered when selecting the material to be used to minimise the radiological dose of workers and the public when performing in-service inspection, maintenance, replacement and decommissioning;

8) Compatibility with the chemistry regime shall be considered when selecting the material to ensure that the components can function well under the selected chemical conditions.

i) Special Thermal-hydraulic Phenomena

Thermal-hydraulic phenomena occur during fluid system operation, induced by normal or transient operation. Based on the feedback from the operating plant, several kinds of hydraulic phenomena may induce potential risk for the safe operation of the facility.

The thermal-hydraulic phenomena identified which shall be considered in the system design are presented as follows (including but not limited to):

1) Phenomenon regarding the dead leg;

2) Phenomenon regarding the hot water and cold water mixing;

3) Phenomenon regarding thermal stratification;

4) Phenomenon regarding the water hammer effect;

5) Phenomenon regarding the boiler effect.

Specific system design addressing these phenomena will be presented in the design substantiation section of each system.

j) Insulation

In the equipment and piping system insulation design, the following issues must be paid attention to:

1) During plant normal operation without any maintenance work to be carried out, the insulation design shall reduce the heat loss as much as possible to save energy;

2) During plant maintenance or refuelling, the insulation design shall protect the workers from being scalded;

3) During plant maintenance or refuelling, the insulation design shall ensure the convenience of installation or replacement, especially for the equipment or piping systems containing radioactive material;

4) The principles of material selection shall be considered in insulation design. Moreover, flammable material is prohibited to prevent potential internal hazards.

10.3 Heavy Load Lifting System

10.3.1 Sub-chapter Structure

The purpose of this sub-chapter is to present the design information of the heavy load lifting system in the UK HPR1000, including:

a) Reactor Building Handling Equipment (DMR [RBHE])

b) Fuel Building Handling Equipment (DMK [FBHE])

The structure of Sub-chapter 10.3 is as follows:

a) Sub-chapter 10.3.1-presents the sub-chapter structure.

b) Sub-chapter 10.3.2-presents the applicable codes and standards.

c) Sub-chapter 10.3.3-presents the design information of the DMR [RBHE].

d) Sub-chapter 10.3.4-presents the design information of the DMK [FBHE].

e) Sub-chapter 10.3.5-presents the ALARP assessment of the heavy load lifting system.

f) Sub-chapter 10.3.6-presents the concluding remarks of the heavy load lifting system.

10.3.2 Applicable Codes and Standards

The identification of applicable codes and standards in Sub-chapter 10.3 is compliant with the selection principles and the selection process stated in Chapter 4 and Reference [5].

Wherever possible, the selected codes and standards applied for the engineering substantiation are:

a) Commensurate with the categorisation of safety functions and classification of the SSCs;

b) Internationally good practice recognised by UK regulator in nuclear industry;

c) The latest version. Where to select an older version, gap analysis will be carried out.

Based on the selection principles and selection process, the applicable codes and standards which are applied in Mechanical Engineering (ME) design are identified in Reference [6]. Main applicable codes and standards for the heavy load lifting system and components design are presented in Table T-10.3-1; Currently, the work of conformity analysis and gap analysis of the codes and standards is continuing.

T-10.3-1 Applicable Codes and Standards in Sub-chapter 10.3

Codes and Standards Number	Title
BS EN 13001-1, 2015	Cranes-General Deign-General Principles and Requirements
BS EN 13001-2, 2014	Crane safety-General Design-Load actions
BS EN 15011, 2011	Cranes-Bridge and Gantry Cranes
BS EN 13135, 2013	Cranes-Safety-Design-Requirements for Equipment
BS EN 12644-1, 2001	Cranes-Information for Use and Testing-Instructions
BS EN 12644-2, 2001	Cranes-Information for Use and Testing-Marking
ASME-NOG-1, 2004	Rules for Construction of Overhead and Gantry Cranes

Load path analysis and utilisation is in accordance with BS EN 13001. Seismic analysis is in accordance with ASME-NOG-1. Essential health and safety requirements are in accordance with BS EN 15011 and BS EN 13135. Use and testing of cranes are in accordance with BS EN 12644.

For safety related cranes, the additional requirements will be provided in the future.

10.3.3 Reactor Building Handling Equipment (DMR [RBHE])

The DMR [RBHE] system belongs to the category of auxiliary systems, and performs the function of handling the equipment in the reactor building. The DMR [RBHE] system consists of a polar crane and miscellaneous handling devices, Reference [7]. The polar crane is used to handle a number of heavy loads and the failure of the polar crane may result in a serious accident. The miscellaneous handling devices are used to supply handling services for equipment such as the valves, pumps, etc. In Sub-chapter 10.3.3, the polar crane is specified.

10.3.3.1 Safety Functional Requirements

10.3.3.1.1 Control of Reactivity

Not applicable. The polar crane does not perform its function in plant normal operation. It does not perform the function of control of reactivity.

10.3.3.1.2 Removal of Heat

Not applicable. The polar crane does not perform its function in plant normal operation. It does not perform the function of removal of heat.

10.3.3.1.3 Confinement

Not applicable. The polar crane does not perform its function in plant normal operation. It does not perform the function of confinement.

10.3.3.1.4 Extra Safety Functions

During plant normal operation, the polar crane is located in the parking position. It is not required to perform its function.

During the refuelling stage, the polar crane can supply handling services for the loads in the reactor building. The Reactor Pressure Vessel (RPV) head assembly is the bounding load which is required to be handled by the polar crane in the refuelling stage. The dropped load from the polar crane may result in the release of the radioactive substances. In order to avoid the risk of release of radioactive substances, the design of the polar crane must avoid the risk of dropping the load and damaging the other safety related SSCs

10.3.3.2 Design Requirements

The general design requirements of the auxiliary systems which need to be considered are shown in Sub-chapter 10.2.4, among which the following requirements are not applicable for the polar crane.

a) Autonomy in Respect of the Heat Sink

   Not applicable, because the polar crane doesn’t provide a heat sink to the power plant.

b) Prevention of Harmful Interactions of Systems Important to Safety

   Not applicable, because the polar crane doesn’t have harmful interactions of systems important to safety.

c) Special Thermal-hydraulic Phenomena

   Not applicable, because the polar crane doesn’t have thermal-hydraulic phenomena.

d) Insulation

   Not applicable, because the polar crane doesn’t have insulation design.

The substantiation analysis of the polar crane to other design requirements is shown in Sub-chapter 10.3.3.5.2.

10.3.3.3 Design Bases

This Sub-chapter aims to provide the main design assumptions which are considered in the system design.

10.3.3.3.1 General Assumptions

a) Safety Classification

The DMR [RBHE] system consists of the polar crane and miscellaneous handling devices. Safety classification of the system and components complies with Sub-chapter 10.2.4.

In the GDA (Generic Design Assessment) process, the classification of the polar crane is related to the category of the lifting schedule of the loads. The failure of the lifting schedule impacts the classification of the polar crane.

b) Ageing and Degradation

The lifetime and degradation are taken into consideration during the system and components design. Some components of the crane can be replaced in the plant lifetime.

c) Autonomy

The polar crane is not required to perform its function during accident conditions, but it can perform its function after maintenance.

d) Equipment Qualification

The polar crane can operate in the plant normal condition and it is not required to perform its function without maintenance after an accident condition. All the seismically classified components shall maintain their integrity during and after the Safe Shutdown Earthquake (SSE). The components are designed to withstand the seismic load.

e) Considerations Related to the Electrical Power Grid

The design of the crane can satisfy the variation in volt and frequency of the electrical power grid.

f) Protection against Internal and External Hazards

The design of the polar crane is required to endure the impact of the internal and external hazards and avoid damaging the related safety SSCs.

10.3.3.3.2 Design Assumptions

a) Control of Reactivity

Not applicable. The polar crane does not perform its function in plant normal

operation. It does not perform the function of control of reactivity.

b) Removal of Heat

Not applicable. The polar crane does not perform its function in plant normal operation. It does not perform the function of removal of heat.

c) Confinement

Not applicable. The polar crane does not perform its function in plant normal operation. It does not perform the function of confinement.

d) Extra Safety Functions

The polar crane is not required to perform safety functions directly. The dropped load from the cranes may result in a serious accident.

The RPV head assembly is the bounding load which is required to be handled by the polar crane in the plant refuelling stage. The capacity of the polar crane can meet the requirements of the load.

The design of the polar crane meets the requirements:

1) The lifting schedule of the load and the load path are designed and the load path is designed to avoid passing above the SSCs.

2) The polar crane has been designed to avoid the risk of dropping the load.

3) The polar crane has been designed to avoid the risk of parts dropping from the polar crane.

10.3.3.4 System Description and Operation

The DMR [RBHE] system consists of the polar crane and miscellaneous handling devices.

10.3.3.4.1 System Description

a) General System Description

The detailed information is presented in the SDM, Reference [8].

b) Description of Main Equipment

The lifting capacity, service area and lifting height of the cranes should satisfy the handling requirements of the load.

The detailed information is presented in the SDM, Reference [9].

c) Description of Main Layout

The layout of the DMR [RBHE] system should meet the following requirements:

1) The layout of the crane meets the requirements for the handling of the load.

2) Systematic consideration of human factors, including the human machine interface, shall be considered at an early stage of the design process for a nuclear power plant and shall be continued throughout the entire design process.

3) The design of workplaces and the working environment of the operating personnel shall be in accordance with ergonomic concepts.

4) From the design onwards, the supplier justifies the choices made in the design, in order to facilitate the maintenance of the crane during various phases.

d) Description of System Interfaces

Some electrical systems supply power for the cranes.

e) Description of Instrumentation and Control

The instrumentation and control of the cranes should satisfy the requirements of the related codes and standards.

10.3.3.4.2 System Operation

a) Plant Normal Condition

The polar crane performs its function during the refuelling stage of the plant.

b) Plant Accident Condition

The polar crane is not required to perform functions in a plant accident condition. But it is required to perform its function after maintenance.

10.3.3.5 Preliminary Design Substantiation

In this section, the system design is demonstrated to satisfy the safety functional requirements presented in Sub-chapter 10.3.3.1 and the design requirements stated in Sub-chapter 10.3.3.2.

Since the general principles are recently developed and have not been fixed at this stage, the system design is still based on the design of the Hua-long Pressurised Reactor under construction at Fangchenggang nuclear power plant unit 3 (HPR1000 (FCG3)). Review of the consistency of the system design against the newly developed principles is currently being undertaken. Detailed design of the system is presented in the SDM, Reference [7].

10.3.3.5.1 Compliance with Safety Functional Requirements

The system configuration and the capability of the components comply with the safety functional requirements. Detailed information of the system design is presented in the

SDM, Reference [7], [8] and [9].

a) Control of Reactivity

Not applicable. The polar crane does not perform its function in plant normal operation. It does not perform the function of control of reactivity.

b) Removal of Heat

Not applicable. The polar crane does not perform its function in plant normal operation. It does not perform the function of removal of heat.

c) Confinement

Not applicable. The polar crane does not perform its function in plant normal operation. It does not perform the function of confinement.

d) Extra Safety Functions

The dropped loads from the polar crane may result in a serious accident. The design of the crane should avoid the risk of the load dropping.

Avoiding load dropping should be considered for the design of the polar crane.

1) The lifting schedule of the RPV head assembly for the polar crane will be submitted.

2) The redundancy design of the polar crane brake and double reeving system, as well as the anti-falling mechanism, can meet the requirement of holding the load in the case of failure of critical parts and components.

3) The polar crane can maintain its structural integrity under all accident conditions, including earthquakes, airplane crashes and loss of coolant accidents.

4) The polar crane can prevent any improper movement due to the loss of the power supply. The brake can still function properly in the case of loss of electric power. The brake can immediately function once a failure is detected on the lifting chain.

5) The polar crane is designed to avoid any interference with the containment and the pipes on the dome of the containment.

6) The double Programmable Logic Controller (PLC) is designed, one is used to control the movement of the equipment and the other one is used to monitor the operation of the equipment.

10.3.3.5.2 Compliance with Design Requirement

a) Safety Classification

The polar crane design complies with the requirements described in the Sub-chapter 10.2.4.

The safety classification of the polar crane in the reference design is B-SC3. In accordance with the UK context, considering the consequence of the load dropping from the polar crane, the safety classification of the polar crane is preliminarily defined as B-SC1 for the UK HPR1000.

b) Engineering Design Requirements

1) The Reliability Design of SSCs

- Single Failure Criterion

  The hoisting mechanism of the main trolley, the second trolley and the auxiliary hoist should be designed with the criterions of single-failure-proof, which features a double-wire rope reeving system and three separated braking systems.

- Independence

  - The double wire is used and it can support the load when one of the wires fails for each trolley of the polar crane.
  - The service brake, emergency brake and the safety brake can perform each of their functions independently.

- Diversity

  In order to reduce the risk of the load dropping from the polar crane, the design of the polar crane meets the following requirements.

  - The polar crane can be operated in the cab by the operator and also can be operated by a mobile console.
  - To prevent the polar crane from hoisting and traversing out of the service area, the electrical limiter and mechanical stopper are used.
  - The hoisting unit can be controlled manually. When the malfunction of the hoisting system is detected, the operators can lower the load by manual control.
  - Each trolley is equipped with a drive chain detection system. The rotating speed of the motor and the drum is monitored. The moment of the motor and the drum are also monitored. If the divergence of the speed and moment between the motor and the drum is out of scope, the protective system is actuated.
  - Three braking systems on the hoist mechanism are used and the type of the safety braking system is different from the service and

emergency brake system.

- Fail-safe

  The fault analysis of crane is to be determined. The design of the polar crane adopts some measures to avoid the load dropping. E.g. the double-wire rope reeving system and three separated braking systems are used for the polar crane. When faults are detected, the polar crane can automatically stop the load safely and maintain the load at a safe position.

- Ageing and Degradation

  The design of the crane considers the ageing and the degradation of the crane. The structure of the polar crane is designed to satisfy the requirements of load handling in the plant construction, operation and decommission phase and the electrical components are replaceable.

2) Human Factors

- Human Action Optimisation

  - The polar crane is designed to make it easier for installation, dismantling and maintenance. E.g. the maintenance hoist is designed for the polar crane, it can be used to help the workers to replace the heavy components on the polar crane.
  - The polar crane is designed to protect the operators from being hurt. Such as the protection device designed for the rotation equipment.
  - The design of workplaces and the working environment of the operating personnel shall be in accordance with ergonomic concepts. E.g. the operator works in the cab, so the design of the cab should be suitable for the size of Europeans.
  - The distribution of the consoles is fitted with the operational habit of the operator in mind.

- Human Error Prevention

  The design shall support operating personnel in the fulfilment of their responsibilities and in the performance of their tasks, and shall limit the effects of operating errors on safety.

  - The polar crane is not allowed to move except when the operator uses the key to start.
  - On the screen of the control panel, the operator only selects one trolley to operate. It is not allowed to select two or more trolleys

simultaneously.

- The camera system is designed to help the operator to observe the environmental conditions.
- The emergency stop is designed and incorporated.

3) Autonomy

- Autonomy in Respect of Operators

  During the operation of the crane, when a fault is detected, the protection system is actuated and stops the movement of the crane automatically. E.g. the overload, overspeed, or power off and so on.

- Autonomy in Respect of Power Supply Systems

  During the refuelling stage, the electrical system supplies power for the polar crane.

4) Other Design Requirements

- Prevention of Harmful Interactions of Systems Important to Safety

  Not applicable.

- Considerations Related to the Electrical Power Grid

  The design of the polar crane can satisfy the variation in the voltage and frequency of the electrical power grid.

c) Equipment Qualification

The requirement concerning the equipment qualification is presented in PCSR Chapter 4. The design of the polar crane complies with these requirements. Equipment performing safety functions in the DMR [RBHE] should be qualified, such as the polar crane.

1) Equipment required for environmental qualification

The polar crane performs its function during the refuelling stage of the plant. It is not required to perform its function during the accident condition. But it can perform its function with maintenance after the accident condition.

2) Equipment required for seismic qualification

The equipment which performs the safety function should be seismically qualified. All the seismically classified components shall maintain their integrity during and after the SSE. The components are designed to withstand the seismic load.

d) Protection against Internal and External Hazards

Hazard protection should be considered for the design of polar carne. The specification is described in the SDM, Reference [8]. The design of the polar crane can withstand the internal and external hazards such as fire, earthquakes, aircraft crashes and loss of power and so on.

e) Commissioning

The polar crane is subject to commissioning and tests. Checking work should be carried out to fulfil its functions.

f) Examination, Inspection, Maintenance and Testing

Measures should be taken to enable access for inspection and testing of the components.

1) Examination and Inspection

The DMR [RBHE] system and equipment must be examined and inspected before using.

2) Maintenance

Maintenance of the crane is carried out during the refuelling stage. The main components of the crane can be repaired and replaced.

3) Periodic Tests

The DMR [RBHE] system must undergo periodic tests to ensure its ability to fulfil its function.

g) Decommissioning

The design of the DMR [RBHE] system considers the requirements of the decommissioning. It can supply handling service for the equipment in the reactor building. E.g. the polar crane can be used for handling equipment in the decommissioning phase.

h) Material selection

The material selected should satisfy the requirements of the load effects. The parts exposed to the air are not allowed to be manufactured with aluminium, zinc and other materials which release hydrogen while making contact with boric acid in accident conditions.

The detailed information is presented in SDM, Reference [8].

i) Special Thermal-hydraulic Phenomena

Not applicable.

j) Insulation

Not applicable.

10.3.4 Fuel Building Handling Equipment (DMK [FBHE])

The DMK [FBHE] system belongs to the category of auxiliary systems, and performs the function of handling the equipment in the fuel building. The DMK [FBHE] system consists of the spent fuel cask crane and miscellaneous handling devices, Reference [10]. The spent fuel cask crane is used to handle the cask and the failure of the crane may result in a serious accident. The miscellaneous handling devices are used to supply handling services for the equipment such as valves, pumps etc. In Sub-chapter 10.3.4, the spent fuel cask crane is specified.

10.3.4.1 Safety Functional Requirements

10.3.4.1.1 Control of Reactivity

Not applicable. The spent fuel cask crane performs its function in the process of the spent fuel cask delivery in the fuel building. It does not perform the function of control of reactivity.

10.3.4.1.2 Removal of Heat

Not applicable. The spent fuel cask crane performs its function in the process of the spent fuel cask delivery in the fuel building. It does not perform the function of removal of heat.

10.3.4.1.3 Confinement

Not applicable. The spent fuel cask crane performs its function in the process of the spent fuel cask delivery in the fuel building. It does not perform the function of confinement.

10.3.4.1.4 Extra Safety Functions

During normal conditions, the spent fuel cask crane is located at its parking position. It is not required to perform its function.

During the transfer process of spent fuel, the spent fuel cask crane supplies handling services for the loads in the fuel building.

Dropped loads from the spent fuel cask crane may result in a serious accident. The spent fuel cask is used to transfer the spent fuel and failure of the spent fuel cask may result in the release of radioactive substances. In order to mitigate the risk, the design of the spent fuel cask crane must avoid the risk of dropping the load and damaging the other safety related SSCs.

10.3.4.2 Design Requirements

The general design requirements of the auxiliary systems which need to be considered are shown in Sub-chapter 10.2.4, among which the following requirements are not

applicable for the spent fuel cask crane.

a) Autonomy in Respect of the Heat Sink

Not applicable, the spent fuel cask crane doesn't provide a heat sink to the power plant.

b) Prevention of Harmful Interactions of Systems Important to Safety

Not applicable, the spent fuel cask crane doesn't have harmful interactions with systems important to safety.

c) Special Thermal-hydraulic Phenomena

Not applicable, the spent fuel cask crane doesn't have thermal-hydraulic phenomena.

d) Insulation

Not applicable, the spent fuel cask crane doesn't have insulation design.

The substantiation analysis of the spent fuel cask crane to other design requirements is shown in the Sub-chapter 10.3.4.5.2.

10.3.4.3 Design Bases

This Sub-chapter aims to provide the main design assumptions considered in the system design.

10.3.4.3.1 General Assumptions

a) Safety Classification

The DMK [FBHE] system consists of the spent fuel cask crane and miscellaneous handling devices. Safety classification of the system and components complies with Sub-chapter 10.2.4.

In the GDA process, the classification of the spent fuel cask crane is related to the category of the lifting schedule of the loads. The classification of the spent fuel cask crane should comply with the category of the lifting schedule of the loads.

b) Ageing and Degradation

Lifetime and the degradation are taken into consideration during the system and components design. Some of the crane components can be replaced in the plant lifetime.

c) Autonomy

The spent fuel cask crane is not required to perform its function during accident conditions, but it can perform its function after maintenance.

d) Equipment Qualification

The spent fuel cask crane can operate in the plant normal condition and it can be functional following maintenance after an accident condition. All the seismically classified components shall maintain their integrity during and after the SSE. The components are designed to withstand the seismic load.

e) Considerations Related to the Electrical Power Grid

The design of the crane can satisfy the variation in volt and frequency of the electrical power grid.

f) Protection against Internal and External Hazards

The design of the spent fuel cask crane is required to endure the impact of the internal and external hazards and avoid damaging the SSCs related safety.

10.3.4.3.2 Design Assumptions

a) Control of Reactivity

Not applicable. The spent fuel cask crane performs its function in the process of the spent fuel cask delivery in the fuel building. It does not perform the function of control of reactivity

b) Removal of Heat

Not applicable. The spent fuel cask crane performs its function in the process of the spent fuel cask delivery in the fuel building. It does not perform the function of removal of heat.

c) Confinement

Not applicable. The spent fuel cask crane performs its function in the process of the spent fuel cask delivery in the fuel building. It does not perform the function of confinement.

d) Extra Safety Functions

The spent fuel cask crane is not required to perform safety functions directly. The dropped loads from the crane may result in a serious accident.

The spent fuel cask crane is required to handle the cask in the process of the spent fuel cask delivery. The lifting capacity of the spent fuel cask crane can meet the requirements of the load.

The design of the spent fuel cask crane meets the following requirements:

1) The transfer process of the spent fuel cask is presented in Sub-chapter 28.4.3.

2) The spent fuel cask crane has been designed to avoid the risk of dropping the

load.

3) The spent fuel cask crane has been designed to avoid the risk of parts dropping from the crane.

10.3.4.4 System Description and Operation

The DMK [FBHE] system consists of the spent fuel cask crane and miscellaneous handling devices.

10.3.4.4.1 System Description

a) General System Description

The detailed information is presented in the SDM, Reference [11].

b) Description of Main Equipment

The lifting capacity, service area and lifting height of the cranes should satisfy the handling requirements of the load.

The detailed information is presented in the SDM, Reference [12].

c) Description of Main Layout

The layout of the DMK [FBHE] system meets the following requirements:

1) The layout of the crane meets the requirements for the handling of the spent fuel cask.

2) Systematic consideration of human factors, including the human machine interface, shall be included at an early stage of the design process for a nuclear power plant and shall be continued throughout the entire design process.

3) The design of workplaces and the working environment of the operating personnel shall be in accordance with ergonomic concepts.

4) From the design onwards, the supplier justifies the choices made in the design, in order to facilitate the maintenance of the crane during various phases.

d) Description of System Interfaces

The electrical system supply power for the cranes.

e) Description of Instrumentation and Control

The instrumentation and control of the cranes should satisfy the requirements of the related codes and standards.

10.3.4.4.2 System Operation

a) Plant Normal Condition

The spent fuel cask crane performs its function during the transfer process of the spent fuel cask.

b) Plant Accident Condition

The spent fuel cask crane is not required to perform its function in plant accident conditions. But it is required to perform its function after maintenance.

10.3.4.5 Preliminary Design Substantiation

In this section, the system design is demonstrated to satisfy the safety functional requirements presented in Sub-chapter 10.3.4.1 and the general design requirements stated in Sub-chapter 10.3.4.2.

Since the general principles are recently developed at this stage, the system design is still based on the reference design. A review of the consistency of the system design against the newly developed principles is currently being undertaken. The detailed design of the system is presented in the SDM, Reference [10].

10.3.4.5.1 Compliance with Safety Functional Requirement

The system configuration and the capability of the components comply with the safety functional requirements; detailed information of the system design is presented in the SDM, Reference [10], [11] and [12].

a) Control of Reactivity

Not applicable. The spent fuel cask crane performs its function in the process of the spent fuel cask delivery in the fuel building. It does not perform the function of control of reactivity.

b) Removal of Heat

Not applicable. The spent fuel cask crane performs its function in the process of the spent fuel cask delivery in fuel building. It does not perform the function of removal of heat.

c) Confinement

Not applicable. The spent fuel cask crane performs its function in the process of the spent fuel cask delivery in the fuel building. It does not perform the function of confinement.

d) Extra Safety Functions

The dropped loads from the spent fuel cask crane may result in a serious accident. The design of the spent fuel cask crane should avoid dropping the load.

1) The detailed information of the transfer process of the spent fuel cask is described in the PCSR Sub-chapter 28.4.3.

2) The redundancy design of the spent fuel cask crane brake and double reeving system, as well as the anti-falling mechanism, can meet the requirement of holding the load in the case of failure of critical parts and components.

3) The spent fuel cask crane can maintain its structural integrity under all accident conditions, including earthquakes, variations due to airplane crashes and loss of coolant accidents.

4) The spent fuel cask crane can prevent any improper movement due to the loss of the power supply. The brake can still function properly in the case of loss of electric power. The brake can immediately function once a failure is detected on the lifting chain.

5) The double PLC is designed, one is used to control the movement of the equipment and the other one is used to monitor the operation of the equipment.

10.3.4.5.2 Compliance with Design Requirements

a) Safety Classification

The DMK [FBHE] system design is compliant with the requirements described in Sub-chapter 10.2.4.

The safety classification of the spent fuel cask crane is preliminarily defined as B-SC2.

b) Reliability Design of SSCs

1) Single Failure Criterion

The hoisting mechanism of the spent fuel cask crane should be designed with the criterion of single-failure-proof, which features a double drum, double-wire rope reeving system and three separated braking systems. The reducers are designed with a closed gear drive mechanism.

2) Independence

- A double wire is used and it can support the load when one of the wires fails for each trolley of the spent fuel cask crane.
- The service brake, emergency brake and the safety brake can perform each of their functions independently.

3) Diversity

In order to reduce the risk of the load dropping from the spent fuel cask crane,

the design of the spent fuel cask crane meets the following requirements:

- To prevent the spent fuel cask crane from hoisting and traversing out of the service area, the electrical limiter and mechanical stopper are used.
- The hoisting unit can be controlled manually. When the malfunction of the hoisting system is detected, the operators can lower the load by manual control.
- The trolley is equipped with a drive chain detection system. The rotating speed of the motor and the drum is monitored. The moment of the motor and the drum are also monitored. If the divergence of the speed and moment between the motor and the drum is out of scope, the protective system is actuated.
- Three braking systems on the hoist mechanism are used and the type of the safety braking system is different from the service and emergency brake system.

4) Fail-safe

The fault analysis of crane is to be determined. The design of the spent fuel cask crane adopts measures to avoid the load dropping. E.g. the double-wire rope reeving system and three separated braking systems are used. When faults are detected, the spent fuel cask crane can automatically stop the load safely and maintain the load at a safe position.

5) Ageing and Degradation

The design of the crane considers the ageing and the degradation of the crane. The structure of the spent fuel cask crane is designed to satisfy the requirements of load handling in the plant construction, operation and decommission phase and the electrical components are replaceable.

c) Human Factors

1) Human Action Optimisation

- The spent fuel cask crane is designed to make it easier for installation, dismantling and maintenance.
- The equipment is designed to protect the operators from being hurt, such as the protection device designed for the rotation equipment.
- The design of workplaces and the working environment of the operating personnel shall be in accordance with ergonomic concepts. E.g. a protection device is designed on the platform of the spent fuel pool for operators.

- The distribution of the consoles is fitted for the operational habits of the operator.

2) Human Error Prevention

The design shall support operating personnel in the fulfilment of their responsibilities and in the performance of their tasks, and shall limit the effects of operating errors on safety.

- The spent fuel cask crane is not allowed to move except when the operator uses the key to start.
- On the screen of the control panel, the operator can only select one control mode to operate at.
- The emergency stop is designed and incorporated.

d) Autonomy

1) Autonomy in Respect of Operators

During the operation of the crane, when a fault is detected, the protect system is actuated and stops the movement of the crane automatically. E.g. overload, overspeed, or power off and so on.

2) Autonomy in Respect of Power Supply Systems

During the operation of the crane in the refuelling stage, the electrical systems supply power for the cranes.

e) Considerations Related to the Electrical Power Grid

The design of the crane can satisfy the variation in the voltage and frequency of the electrical power grid.

f) Equipment Qualification

The requirement concerning equipment qualification is presented in PCSR Chapter 4. The design of the spent fuel cask crane complies with these requirements. Equipment performing safety functions in the DMK [FBHE] shall be qualified, such as the spent fuel cask crane.

1) Equipment required for environmental qualification

The spent fuel cask crane performs its function during the refuelling stage of the plant. It is not required to perform its function during accident conditions. But it can perform its function following maintenance after the accident condition.

2) Equipment required for seismic qualification

The equipment which performs safety functions should be seismically qualified. All the seismically classified components shall maintain their integrity during and after the SSE. The components are designed to withstand the seismic load.

g) Protection against Internal and External Hazards

Hazard protection should be considered for the design of the spent fuel cask crane. The specification is described in the SDM, Reference [11]. The design of the spent fuel cask crane can withstand the internal and external hazards such as fire, earthquakes, aircraft crashes and loss of power and so on.

h) Commissioning

All the components of the DMK [FBHE] are subject to commissioning and tests. The equipment will be checked to ensure its ability to fulfil its function.

i) Examination, Inspection, Maintenance and Testing

Measures should be taken to enable access for the inspection and testing of the components.

1) Examination and Inspection

The DMK [FBHE] system and equipment must be examined and inspected before use.

2) Maintenance

Maintenance of the crane is carried out during the refuelling stage. The main components of the crane can be repaired and replaced.

3) Periodic Tests

The DMK [FBHE] system must undergo periodic tests to ensure its ability to fulfil its function.

j) Decommissioning

The design of the DMK [FBHE] system considers the requirements of the decommissioning. It can supply handling services for the equipment in the fuel building.

k) Material selection

The material selected should satisfy the load requirements.

The detailed information is presented in the SDM, Reference [11].

10.3.5 ALARP Assessment

Preliminary ALARP analysis has been performed on the heavy load lifting system, the

analysis is consistent with the arguments stated in Sub-claim 3.3.6C in the route map presented in Appendix A:

Argument 3.3.6C-1: The SSCs meet the requirements of the relevant design principles (generic and system specific) and therefore of relevant good practice:

The detailed codes and standards list is presented in Reference [6]. The consistency analysis is still under development to ensure that the design of the SSCs meets the requirements of the UK context.

A compliance analysis of the system design with the UK HPR1000 general safety engineering principles is made in the system section. The analysis shows that the design of the SSCs meets relevant requirements and no gaps are identified. Meanwhile, technical assessments such as the hazard schedule, fault schedule, probabilistic safety assessment, human factors and instrumentation and control are being developed simultaneously. The analysis of the design against the requirements of these technical disciplines needs to be reviewed periodically. A systematic review will be carried out on the system design to ensure that no new gaps are identified between the newly developed requirements and the design. Any potential enhancements identified during this review will be taken into account in the further development of the design;

Argument 3.3.2C-2: PSA indicates the SSCs are not a disproportionate contributor to risk:

Potential areas of improvement in the system design will be identified to reduce the risks during the process of fault analysis. Since the PSA and the fault analysis are still under development, further ALARP analysis will be performed once the fault schedule work is finished.

If any new gap is identified during the systematic technical review, analysis and optioneering will be undertaken to determine whether there are possible enhancements to the current system design, in order to reduce the risk as low as reasonably practicable.

Argument 3.3.2C-3: Design improvements have been considered in the SSCs and any reasonably practicable changes implemented:

Design improvements will be carried out once the potential areas of improvement in the design are identified. The ALARP assessment will be further developed to evaluate the design improvements.

In summary, the ALARP analysis and demonstration work is currently being carried out. A preliminary ALARP demonstration topic report to present the current analysis results as well as the arrangement for future ALARP analysis work is presented in Reference [13].

10.3.6 Concluding Remarks

This sub-chapter provides an introduction of the design information of the heavy load lifting system in the UK HPR1000 nuclear power plant.

According to the preliminary assessment, the fundamental safety targets related to the heavy load lifting system have been achieved by proper design of the system and equipment.

As the factors mentioned above may affect the current design result, a systematic review will be carried out after the preliminary work has been completed. Further demonstrations or improvements will be implemented during the GDA process until the risks have been reduced ALARP.

10.4 Nuclear Auxiliary Systems

10.4.1 Sub-chapter Structure

The structure of Sub-chapter 10.4 is as follows:

a) Sub-chapter 10.4.1 (Sub-chapter Structure) gives the overall structure of Sub-chapter 10.4;

b) Sub-chapter 10.4.2 (Applicable Codes and Standards) presents the relevant codes and standards adopted in this chapter;

c) Sub-chapters 10.4.3 to 10.4.9 present the following nuclear auxiliary systems:

   1) 10.4.3 Chemical and Volume Control System (RCV [CVCS]);

   2) 10.4.4 Reactor Boron and Water Makeup System (REA [RBWMS]);

   3) 10.4.5 Coolant Storage and Treatment System (TEP [CSTS]);

   4) 10.4.6 Nuclear Sampling System (REN [NSS]);

   5) 10.4.7 Fuel Pool Cooling and Treatment System (PTR [FPCTS]);

   6) 10.4.8 Component Cooling Water System (RRI [CCWS]);

   7) 10.4.9 Essential Service Water System (SEC [ESWS]).

These sub-chapters give the detailed description of the nuclear auxiliary systems;

d) Sub-chapter 10.4.10 (ALARP Assessment) gives the preliminary ALARP analysis of this chapter;

e) Sub-chapter 10.4.11 (Concluding Remarks) gives the summary and the on-going work of this chapter;

10.4.2 Applicable Codes and Standards

The identification of applicable codes and standards in Sub-chapter 10.4 is compliant

with the general principles of codes and standards selection stated in Chapter 4 and Reference [5].

Wherever possible, the standards applied for the engineering substantiation should be:

a) Internationally recognised in nuclear industry;

b) The latest or currently applicable approved standards; and

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

Based on the above principles, the applicable codes and standards which are selected and used in Mechanical Engineering (ME) design are identified in Reference [6]. Main applicable codes and standards for the nuclear auxiliary systems and components design are presented in Table T-10.4-1. Currently, the work of conformity analysis and gap analysis of the codes and standards is continuing.

T-10.4-1 Applicable Codes and Standards in Sub-chapter 10.4

Codes and Standards Number	Title
IAEA, SSR-2/1, 2016	Safety of Nuclear Power Plants: Design
IAEA, NS-G 1.9, 2004	Design of the Reactor Coolant System and Associated Systems in Nuclear Power Plants Safety Guide
RCC-M, 2007	Design and Construction Rules for Mechanical Components of PWR Nuclear Islands
RSE-M, 2010+2012 Addenda	In-service Inspection Rules for Mechanical Components of PWR Nuclear Islands

10.4.3 Chemical and Volume Control System (RCV [CVCS])

The Chemical and Volume Control System (RCV [CVCS]) falls into the category of auxiliary systems, and performs the functions of reactivity control, volume control and chemical control. The RCV [CVCS] consists of a letdown line, purification unit, hydrogenation station, charging line, chemical injection unit, seal injection line and seal leak-off line. The main components of the RCV [CVCS] (heat exchangers, pressure reducing valves, charging pumps, volume control tank, demineralisers and filters) are located in the reactor building, fuel building and nuclear auxiliary building of the Nuclear Island (NI). Information of the system is presented in the SDM, Reference [14].

10.4.3.1 Safety Functional Requirements

The requirements of the fundamental safety functions of the RCV [CVCS] system

design for the UK HPR1000 are identified as follows:

10.4.3.1.1 Control of Reactivity

The RCV [CVCS] shall contribute to the control of reactivity as follows:

a) The RCV [CVCS] shall adjust the Reactor Coolant System (RCP [RCS]) boron concentration together with the Reactor Boron and Water Makeup System (REA [RBWMS]) to compensate for operational leaks and slow variations of core reactivity in all plant operation conditions;

b) The RCV [CVCS] shall ensure the automatic isolation of the RCV [CVCS] charging pump suction when the anti-dilution protection signal is triggered so as to prevent homogeneous or heterogeneous boron dilution accidents.

10.4.3.1.2 Removal of Heat

The RCV [CVCS] shall contribute to the removal of heat as follows:

a) To ensure that the fuel shall be cooled during normal operation and in the event of a very small break in RCP [RCS], the RCV [CVCS] shall maintain the water inventory of the RCP [RCS] by regulation of letdown flow and charging flow;

b) In DBC-3/4 and DEC-A conditions, RCV [CVCS] shall ensure the automatic isolation of letdown line to maintain the water inventory of the RCP [RCS].

10.4.3.1.3 Confinement

The RCV [CVCS] shall contribute to the confinement as follows:

a) The RCV [CVCS] shall ensure the automatic isolation of the containment isolation valves in the DBC-3/4 and the DEC-A conditions;

b) The RCV [CVCS] shall ensure the automatic isolation of the Reactor Coolant Pressure Boundary (RCPB) valves in the DBC-3/4 and the DEC-A conditions;

c) The RCV [CVCS] shall supply cooled and purified seal water to the reactor coolant pumps to prevent leaking of the reactor coolant from leaking through the seal of the reactor coolant pumps;

d) In normal operating condition, the RCV [CVCS] shall provide auxiliary spray for the pressuriser to prevent the pressuriser from overpressure;

e) In Steam Generator Tube Rupture (SGTR) condition, the RCV [CVCS] shall ensure the automatic isolation of the charging line and auxiliary spray line to avoid overflowing of the affected Steam Generator (SG) and prevent leakage at break points.

10.4.3.1.4 Extra Safety Functions

The extra safety functional requirements of the RCV [CVCS] are identified as

follows:

a) The hydrogen supply line to the gas separator should be isolated after receiving a protection signal so as to prevent the risk of hydrogen explosion hazards;

b) The integrity of components and lines that are associated with the RRI [CCWS] shall be ensured such that the cooling functions of these higher-classified users of the Component Cooling Water System (RRI [CCWS]) are not affected to support the removal of heat;

c) The RCV [CVCS] shall ensure the automatic isolation of the letdown line when the temperature downstream of the letdown heat exchanger exceeds the threshold to prevent the containment penetration from exceeding the temperature limit to support the confinement function.

d) The RCV [CVCS] shall ensure the automatic isolation of the charging line and auxiliary spray line when the safety injection signal is triggered to support the control of reactivity function of the Safety Injection System (RIS [SIS]).

10.4.3.2 Design Requirements

The general design requirements of the nuclear auxiliary systems which need to be considered are shown in Sub-chapter 10.2.4, among which the following requirements are not applicable for the RCV [CVCS] system:

a) Autonomy in Respect of the Heat Sink

Not applicable, because the RCV [CVCS] system doesn’t provide heat sink function to the power plant.

The substantiation analysis of the RCV [CVCS] system to other design requirements is shown in the Sub-chapter 10.4.3.5.

10.4.3.3 Design Bases

10.4.3.3.1 General Assumptions

a) Safety Classification

The RCPB isolation function is required to confine the radioactive substances in DBC-2/3/4 and DEC-A conditions, the function category is FC1.

The containment isolation function is required to confine the radioactive substances in DBC-2/3/4 and DEC-A conditions, the function category is FC1.

The anti-dilution protection function is required to prevent dilution accident in DBC-2 and DEC-A conditions, the function category is FC1.

b) Ageing and Degradation

According to Chapter 2, the operational design life of the UK HPR1000 is 60

years. The main components of the RCV [CVCS] are required to have a service life of 60 years, such as the regenerative heat exchanger, letdown heat exchangers, volume control tank, charging pumps, etc.

c) Considerations Related to the Electrical Power Grid

The functionality of items important to safety at the nuclear power plant shall not be compromised by disturbances in the electrical power grid, including anticipated variations in the voltage and frequency of the grid supply, which is considered as 49.5Hz-50.5Hz according to the design of the HPR1000 (FCG3). It will be adjusted in the future design phases based on the actual conditions of the UK.

10.4.3.3.2 Design Assumptions

This sub-chapter aims to provide the main design assumptions considered in the system design.

a) Control of Reactivity

1) There's no quantitative safety-related design assumption for the RCV [CVCS] system.

2) The RCV [CVCS] is required to contribute to the anti-inadvertent-dilution protection function by isolating the charging pumps' suction from potential dilution sources. The closing time of the anti-dilution isolation valves shall be less than 30s.

b) Removal of Heat

There's no quantitative safety-related design assumption for the RCV [CVCS].

c) Confinement

There's no quantitative safety-related design assumption for RCV [CVCS].

d) Extra Safety Functions

There's no quantitative safety-related design assumption for RCV [CVCS].

10.4.3.4 System Description and Operation

10.4.3.4.1 System Description

a) General System Description

The RCV [CVCS] is designed to provide to maintain and purify the reactor coolant by continuous letdown flow and charging flow. The RCV [CVCS] consists of one letdown line and one charging line. The redundant components of RCV [CVCS] are powered from different electrical zones to meet the SFC. And the components of RCV [CVCS] which perform FC1-classified are physical

separated.

The composition of RCV [CVCS] is described below:

1) Letdown Line

There is a regenerative heat exchanger, two parallel letdown heat exchangers and two parallel high-pressure reducing valves on the letdown line. The regenerative heat exchanger and the letdown heat exchanger together reduce the temperature of reactor coolant to a target value, and the high-pressure reducing valve depressurizes the pressure.

2) Purification Unit

Two parallel reactor coolant filters, two parallel mixed-bed demineralisers, one cation-bed demineraliser and two parallel resin trapping filters are placed in the purification unit. These devices provide the purification function for the reactor coolant. Downstream the purification unit, there is also a degassing unit of the Coolant Storage and Treatment System (TEP [CSTS]) which can remove the dissolved gas as needed.

3) Hydrogenation Station

The hydrogenation unit is consisted of a water jet pump, a mixing pipe and a gas separator. The hydrogenation station continuously adds hydrogen into the reactor coolant in order to keep the dissolved hydrogen concentration of the reactor coolant at the required value.

4) Volume Control Tank (VCT)

The VCT is located downstream the purification unit and provide water source for the charging pump as long as the level of VCT is high enough.

5) Chemical Injection Unit

The chemical injection unit is consisted of a chemical injection pump and a chemical injection tank. According to the need, ^{7}LiOH, hydrazine or hydrogen peroxide will be injected into the reactor coolant for water chemistry control through the chemical injection unit.

6) Charging Line

There are two parallel charging pumps on the charging line. The reactor coolant will be sent back to the Reactor Coolant System (RCP [RCS]) via the charging pump. In addition, there is also an auxiliary spray line which can provide auxiliary spray as needed.

7) Seal Injection Line and Seal Leak-off Line

There are two parallel seal injection filters on the seal injection line and one

seal leak-off filter on the seal leak-off line. RCV [CVCS] provide the seal injection water for the reactor coolant pumps through seal injection line and recycle the seal leak-off water via seal leak-off line.

8) Chemical Injection

In order to control the chemical characteristics of the RCP [RCS] coolant, the chemical injection unit can inject chemical additives to the inlet of the charging pumps and then can be injected to the RCP [RCS] via the charging line.

b) Description of Main Equipment

1) Charging Pumps

The charging pump is a vertical multistage centrifugal pump. It sends back the reactor coolant to RCP [RCS] and provides the seal injection water for the reactor coolant pumps.

T-10.4-2 Data sheet of charging pumps

Parameters	Value	Unit
Type	Multi-Stage Centrifugal Pump	
Design Lifetime	60	yr.
Nominal Flow rate	28	m^3/h
Discharge Head at Nominal Flow rate	1846	mWc
Material	Stainless Steel	

2) Regenerative Heat Exchanger

The regenerative heat exchanger is designed to recover heat from the letdown flow and to heat the charging flow. The regenerative heat exchanger is U-tube type. The letdown flow is at the tube side while the charging flow is at the shell side.

T-10.4-3 Data Sheet of Regenerative Heat Exchanger

Parameters	Value		Unit
Type	Shell & Tube		
	Hot Side	Cold Side	
Design Thermal Load	11.35		MW

Parameters	Value		Unit
Medium	Reactor Coolant	Reactor Coolant	
Design Pressure	21	21	MPa (g)
Design Temperature	343	343	°C
Design Flow rate	50	46.4	t/h
Material	Stainless Steel	Stainless Steel	

3) Letdown Heat Exchangers

The letdown heat exchanger is U-tube type. It is used to cool down the letdown flow from the regenerative heat exchanger. The letdown heat exchangers use the Component Cooling Water System (RRI [CCWS]) for cooling the letdown flow to a temperature acceptable for the resins of the downstream demineralisers and the coolant degasification subsystem of the TEP [CSTS]. The letdown flow is at the tube side of the heat exchanger and component cooling water from the RRI [CCWS] is at the shell side.

T-10.4-4 Data Sheet of Letdown Heat Exchangers

Parameters	Value		Unit
Type	Shell & Tube		
	Hot Side	Cold Side	
Design Thermal Load	3.76		MW
Medium	Reactor Coolant	RRI Cooling Water	
Design Pressure	21	1.35	MPa (g)
Design Temperature	343	170	°C
Design Flowrate	50	110	t/h
Material	Stainless Steel	Carbon Steel	

4) High-pressure Reducing Valve

The high-pressure reducing valves are angle globe control valves, located downstream of the letdown heat exchangers. They are used to reduce the pressure of the letdown flow and to control the pressuriser water level. During plant start-up and shutdown, it is possible to operate the two high-pressure reducing valves in parallel. In this case, the pressuriser level is automatically controlled by one high-pressure reducing valve and the other reducing valve is controlled manually. The downstream pressure is maintained by the high-pressure reducing valves to ensure that the letdown flow remains in the liquid phase.

5) Low-pressure Reducing Valve

The low-pressure reducing valve is a globe control valve, and it is required to reduce the pressure of the letdown flow when the low-pressure letdown line is open.

6) Volume Control Tank

The VCT is a vertical cylindrical vessel which is used to compensate for volume fluctuations of the reactor coolant in different operation conditions in conjunction with the REA [RBWMS] and TEP [CSTS]. The TEG [GWTS] purges the gaseous phase space in the upper part of the VCT continuously to prevent hydrogen accumulation. Detailed information is presented in Table T-10.4-5.

T-10.4-5 Data Sheet of Volume Control Tank

Parameters	**Value**	**Unit**
Type	Cylindrical Tank	
Medium	Reactor Coolant	
Design Pressure	1.2	MPa (g)
Design Temperature	100	°C
Usable Volume	15	m^3
Max. Volume	15	m^3
Material	Stainless Steel	

7) Hydrogenation Station

Hydrogen is dissolved in the coolant via a hydrogenation station. The hydrogenation station consists of a water jet pump, a mixing pipe and a gas separator. The hydrogenation station continuously adds hydrogen into the reactor coolant in order to keep the dissolved hydrogen concentration of the reactor coolant at the required value.

c) Description of Main Layout

The regenerative heat exchanger, letdown heat exchangers and high-pressure reducing valves and associated letdown and charging pipelines connected with RCP [RCS] are located in the Reactor Building (BRX). The coolant purification unit is located in the BNX. The other parts of the RCV [CVCS] are located in the BFX.

Detailed information can be found in Reference [15].

d) Description of System Interfaces

The main interface systems which support the RCV [CVCS] functions are:

1) REA [RBWMS]

The REA [RBWMS] is required to provide automatic makeup of boric acid of the same concentration as the primary coolant when the volume control tank level falls to a low-level set value and regulate the coolant boron concentration by makeup of boric acid or demineralised water according to the requirements of reactivity control.

2) RRI [CCWS]

The RRI [CCWS] is required to provide component cooling water for the letdown heat exchangers and the charging pumps motors.

3) TEP [CSTS]

The TEP [CSTS] is required to remove the dissolved gas in the reactor coolant and discharge the excess reactor coolant into the reactor coolant storages when needed.

4) TEG [GWTS]

The TEG [GWTS] is required to continuously purge the volume control tank by removing the fission gas.

5) RIS [SIS]

The RIS [SIS] guarantees the letdown function through the low-pressure letdown line connecting the RIS [SIS] in Residual Heat Removal (RHR) mode (RIS/RHR) to the RCV [CVCS] system, provide IRWST water intake for the RCV [CVCS] charging pumps when the level of the VCT is too low

or the anti-dilution protection signal is triggered, and guarantees the purification of the reactor coolant through the RIS/RHR-RCV connection line in case the primary pressure is low.

6) EHR [CHRS]

The EHR [CHRS] provides the suction pipe for the charging pumps to take suction from the IRWST and returns the small flow rate of the charging pumps and the seal leak-off through the EHR [CHRS] line back to the IRWST when the charging pumps take water from the IRWST.

7) KRT [PRMS]

The KRT [PRMS] detects activity at the inlet and outlet of each letdown heat exchanger on the RRI [CCWS] side to identify heat exchanger tube leaks.

Other interfacing systems are presented in the SDM, Reference [16].

e) Description of Instrumentation and Control

Instrumentation is designed to monitor and control the main parameters of the RCV [CVCS]. The main parameters include temperature, pressure, flow, water level, hydrogen concentration and radioactivity.

The RCV [CVCS] has the following main control functions:

1) PZR level control function by regulating the letdown flow;

2) The seal injection flow control function of the reactor coolant pumps of the RCP [RCS];

3) The seal leak-off pressure control function of the reactor coolant pumps of the RCP [RCS];

4) The pressure control function downstream the high-pressure reducing valves;

5) The temperature control function of the letdown flow;

6) The water level control of the volume control tank;

7) The pressure control of the volume control tank;

8) The water level control of the gas separator;

9) The charging flow control function.

Detailed system control functional requirements are presented in the SDM of RCV [CVCS], Reference [17]. The design of the UK HPR1000 I&C system is presented in PCSR Chapter 8.

10.4.3.4.2 System Operation

a) Plant Normal Conditions

1) Plant Start-up

During plant start-up, the high-pressure letdown line of the RCV [CVCS] is isolated, and the reactor coolant enters the purification unit through the low-pressure letdown line to remove corrosion products, and is also sent to the coolant degassing unit to remove oxygen from the reactor coolant.

Before the reactor coolant temperature reaches 120 °C, ^{7}LiOH and hydrazine can be added to the reactor coolant by the chemical injection pump as needed to control the pH value and deoxygenation.

When the chemical properties of the reactor coolant meet the chemical requirements, the hydrogenation station is started so as to reach and maintain the required dissolved hydrogen concentration in the reactor coolant which is used to control the dissolved oxygen content during power operation.

During the RCP [RCS] heating and pressurizing, when the reactor coolant pressure exceeds 2.6 MPa.a, the RCV [CVCS] will switch to the high-pressure letdown line and the low-pressure letdown line is isolated.

During plant start-up, two letdown heat exchangers, two high-pressure reducing valves and two charging pumps are all put into operation. In this operation mode, the volume fluctuations caused by expansion of the reactor coolant can be absorbed. The excess coolant resulting from the expansion of the heating will be discharged to the TEP [CSTS] coolant storage unit.

The boric acid and demineralized water makeup lines of the Reactor Boron and Water Makeup System (REA [RBWMS]) are put into operation according to the requirement of boron concentration regulation.

During plant start-up, the RCV [CVCS] maintains the pressurizer level by letdown and charging, and continuously provides seal injection water for the Reactor Coolant Pumps.

2) Normal Power Operation

During normal power operation, reactor coolant is discharged from the RCP [RCS] through the high pressure letdown line, while the low pressure letdown line is isolated. The regenerative heat exchanger, one letdown heat exchanger, one high-pressure reducing valve and one charging pump are in operation. After cooling by the regenerative heat exchanger and the letdown heat exchanger, the letdown flow passes through the high-pressure reducing valve for depressurizing. Then the letdown flow is routed out of the reactor building to the purification unit. One coolant filter, one mixed bed

demineraliser and one resin trap filter are in operation. If needed, a cation-bed demineraliser can be put into intermittent operation as necessary to remove excess lithium, caesium, molybdenum and ytterbium in the reactor coolant. According to the need, fission gas (such as krypton and xenon) in the reactor coolant can be removed by the coolant degassing unit of the Coolant Storage and Treatment System (TEP [CSTS]) system, and the hydrogen and nitrogen in the coolant will be removed together.

After purification and degassing, the letdown flow (about 90% of the flow) enters into the hydrogenation station. The hydrogenation station continuously adds hydrogen into the reactor coolant so as to keep the dissolved hydrogen concentration in the coolant at the required value. Part of the letdown flow (about 10% of the flow) and the Reactor Coolant Pump seal leak-off water will flow into the VCT to ensure the boron concentration in the VCT is the same as the primary coolant.

In order to maintain the weak alkalinity of the reactor coolant, during normal operation, ^{7}LiOH can be injected into the reactor coolant upstream of the charging pump by chemical injection pump as needed for pH control.

The reactor coolant is sent back to the RCP [RCS] by charging pump, and a bypass flow is used as reactor coolant pump seal injection, which will be injected into the reactor coolant pump seal after flowing through the seal injection filter. The seal injection water flow of each reactor coolant pump is the same, which is measured by the corresponding flow measurement devices and manually regulated by the control valve on the branch line.

During normal operation, the pressurizer auxiliary spray line is isolated.

In normal operation, if it is necessary to improve the reactor coolant purification and degassing efficiency, or adjust the reactor coolant boron concentration, the second charging pump can be put into operation as needed.

In order to compensate for fuel burn-up, the boron concentration is adjusted by the RCV [CVCS] in conjunction with the REA [RBWMS] which provides the make-up demineralised water to the VCT.

The charging flow is kept constant by regulating the charging flow adjusting valve. The letdown flow is regulated by a high-pressure reducing valve according to the pressuriser level to control the RCP [RCS] water inventory. The VCT level may change if the charging flow and letdown flow dis-match. In order to make sure that the VCT level is at the normal value, a part of or all of the letdown flow is discharged to the TEP [CSTS] when the VCT level reaches a high value, while the REA [RBWMS] provides the make-up boric acid solution of the same concentration as the reactor coolant to the VCT when the VCT level reaches a low value.

3) Plant shutdown

During plant shutdown, depending on the reactor coolant purification or degassing requirements, as well as compensating for volume fluctuation caused by reactor coolant shrinkage, the RCV [CVCS] high-pressure letdown line remains normally open until the pressurizer is relieved. The two letdown heat exchangers, two high-pressure reducing valves and two charging pumps are all put into operation. As long as the reactor coolant pressure exceeds 2.6 MPa.a, it is not allowed to switch to low-pressure letdown line.

When the reactor coolant temperature is below 140 °C, the Safety Injection System (RIS [SIS]) in Residual Heat Removal (RHR) mode is connected to the RCP [RCS], and the residual heat is removed by RIS/RHR. When the temperature and pressure of the RCP [RCS] is low enough, the high-pressure letdown line is isolated and the letdown function is switched to the low-pressure letdown line. The reactor coolant still returns to the RCP [RCS] through the normal charging line.

During cooling and depressurization, according to the requirement of boron concentration regulation, the boric acid and demineralized water makeup lines of the REA [RBWMS] will open and provide the boric acid for the RCV [CVCS], which will inject into the RCP [RCS] eventually. The excess coolant will be discharged to the TEP [CSTS] coolant storage unit.

After the complete depressurization of the primary loop, the charging pumps may be shut down and by-passed, and the Reactor Coolant Pump seal injection water is maintained by the RIS/RHR pumps.

b) Plant Accident Conditions

The RCV [CVCS] can be used in accident conditions if there is no safety-classified isolation signal (e.g. safety injection and containment isolation). The RCPB isolation valves on the RCV [CVCS] letdown line will close automatically at the safety injection signal. The RCPB isolation valves and containment isolation valves on the letdown line will close automatically at the first-stage containment isolation signal, while the charging line, seal water injection line and seal leak-off recovery line operate normally. The charging line, seal injection line and seal leak-off recovery line will be isolated when the second-stage containment isolation is activated, while the charging pumps will continue operating in mini flow mode.

The RCV [CVCS] can operate even in a Loss of Offsite Power (LOOP) condition as the electric components required are powered by EDG (Emergency Diesel Generator). When the reactor coolant pumps stop due to LOOP, the RCV [CVCS] can provide auxiliary spray for the pressuriser.

The VCT and hydrogenation station will be isolated automatically and the suction line of the charging pumps is switched to IRWST automatically at the dilution protection signal. Letdown flow is drained to the TEP [CSTS] if the VCT level reaches a high value. The mini flow line of the charging pumps and the seal leak-off flow line from the RCP [RCS] reactor coolant pumps are switched to the IRWST.

Detailed information of the operation of the RCV [CVCS] is presented in the SDM of RCV [CVCS], Reference [17].

10.4.3.5 Preliminary Design Substantiation

In this section, the system design is demonstrated to satisfy the safety functional requirements presented in Sub-chapter 10.4.3.1 and the general design requirements stated in Sub-chapter 10.2.4.

Since the general principles are newly developed at this stage, the system design is still based on the reference design and the information presented in this section is preliminary. A review of the consistency of the system design against the newly developed principles is currently being undertaken.

10.4.3.5.1 Compliance with Safety Functional Requirements

The system configuration and the capability of the components comply with the safety functional requirements and the detailed design of the system is presented in the SDM [18], [16] and [17]. Furthermore, design substantiation of the RCV [CVCS] has been estimated in the fault study in Chapters 12 and 13.

a) Control of Reactivity

1) The RCV [CVCS] regulates reactor activity by controlling the boron concentration of the RCP [RCS] in conjunction with the REA [RBWMS]. The letdown and charging flow rate can meet the requirements of reactor activity control. When the REA [RBWMS] fails, the charging pumps suction line can be switched to the IRWST.

2) Two safety classified isolation valves in series are provided on each charging pump suction line from either the VCT or hydrogenation station. The closing time of the anti-dilution isolation valves is designed to be less than or equal to 30s, this is evaluated in the fault analysis, presented in Chapter 12.

b) Removal of Heat

1) In plant normal operations, the RCV [CVCS] can adjust the balance between the charging flow rate and the letdown flow rate to control the water inventory of the RCP [RCS], thus the fuel can be cooled suitably.

2) In post accidental conditions, the RCV [CVCS] system can participate in

maintaining primary coolant inventory by automatic isolation of the letdown line.

c) Confinement

1) Redundant isolation valves are installed in series to ensure automatic containment isolation in accident conditions when receiving the containment isolation signals;

2) Redundant isolation valves are installed in series to ensure RCPB isolation in accident conditions when receiving the RCPB isolation signals;

3) The RCV [CVCS] can supply cooled and purified seal water to the reactor coolant pumps to prevent the reactor coolant from leaking through the seal of the reactor coolant pumps to reduce radioactivity release;

4) The RCV [CVCS] can provide auxiliary spray for the pressuriser automatically or manually to prevent the pressuriser from overpressure;

5) In SGTR accidents, the charging line and the auxiliary spray line will be isolated automatically to avoid overflowing of the affected SGs and prevent leakage at break points to reduce radioactivity release;

d) Extra Safety Functions

1) The hydrogen supply line to the gas separator is designed to be isolated automatically after receiving a protection signal from the KRH [HDS] when a leak is detected;

2) To ensure that the cooling functions of higher-classified users of the RRI [CCWS] are not affected by the failure of integrity of components and lines associated with the RRI [CCWS], radioactivity detecting instruments are designed on the shell side of the heat exchanger of the RCV [CVCS]. When a leak is detected, the heat exchanger can be isolated to prevent radioactivity release to the RRI [CCWS];

3) When the temperature downstream of the letdown heat exchanger has reached 90°C, the isolation valve downstream of the high-pressure reducing valve will be automatically closed to prevent the temperature of the containment penetration from exceeding its limits;

4) In case of the excessive rise in the secondary steam flow rate, especially steam line break accident, the RCV [CVCS] can automatically isolate the charging line and auxiliary spray line to guarantee that the safety injection system (RIS [SIS]) is able to provide sufficient boric acid to assure core sub-critical.

The detailed information is presented in Reference [18].

10.4.3.5.2 Compliance with Design Requirements

a) Safety Classification

The RCV [CVCS] design is compliant with the requirements described in the Sub-chapter 10.4.1. The safety classification of RCV [CVCS] functions and the safety classification of main components are as follows.

T-10.4-6 Function Categorisation of the RCV [CVCS]

System Function	Function Category
RCPB isolation	FC1
Containment isolation	FC1
Anti-dilution protection	FC1
Other parts of the RCV [CVCS]	FC3

T-10.4-7 Classification for Components

Component	Function Class	Design Provision Category	Design Provision Class	Seismic Category
Regenerative heat exchanger	F-SC3	DPL	B-SC3	SSE2
Letdown heat exchanger	F-SC2	DPL	B-SC3	SSE1
High-pressure reducing valve	F-SC3	DPL	B-SC3	SSE2
Low-pressure reducing valve	F-SC1	DPM	B-SC2	SSE1
Mixed-bed demineraliser	F-SC3	DPL	B-SC3	SSE1
Cation-bed demineraliser	F-SC3	DPL	B-SC3	SSE1
Mechanical filter	F-SC3	DPL	B-SC3	SSE1
Volume control tank	F-SC3	DPM	B-SC2	SSE1

Component	Function Class	Design Provision Category	Design Provision Class	Seismic Category
Charging pump	F-SC3	DPL	B-SC3	SSE2
Water jet pump	F-SC3	DPL	B-SC3	SSE2
Gas separator	F-SC3	DPL	B-SC3	SSE2
Chemical injection pump	NC	NC	NC	NO
Chemical injection tank	NC	NC	NC	NO

b) Engineering Design Requirements

1) Reliability Design of SSCs

- Single Failure Criterion (SFC)

  The components ensuring the FC1 and FC2 safety functions such as the containment isolation valves, anti-dilution protection isolation valves and RCPB isolation valves are designed to be redundant. The redundant components of the RCV [CVCS] are powered from different electrical zones to meet the SFC. Detailed information is presented in Reference [18].

- Independence

  The requirement of independence is taken into considerations with the layout design. The components of the RCV [CVCS] which perform FC1 classified functions are physically separated. The two containment isolation valves are physically separated by the installation location, one inside and the other outside the containment.

  Detailed information is presented in Reference [15].

- Diversity

  Two types of sensors are provided for the protection of charging pumps. One is a water level sensor in the volume control tank and gas separator, and the other one is a pressure sensor in the suction line of the pumps. When low water level or low pressure occurs, it can be detected by diverse means which can guarantee the alarm to be more reliable. The operating charging pump can thus be automatically stopped which protects the pump.

- Fail-safe

  The chemical injection line is controlled by a solenoid valve, which will be automatically closed when losing the power supply, therefore plant operation will not be disturbed if there is failure of the valves or power supply.

- Ageing and Degradation

  According to Chapter 2, the plant design life is 60 years. The service life of some main components is also 60 years. For example, the regenerative heat exchanger, the letdown heat exchangers, the volume control tank, the charging pumps, etc.

  The RCV [CVCS] system considers the requirements stated in Sub-chapter 10.2.4 and the design considerations and measures described in Sub-chapter 10.2.4 are applied in the design of the RCV [CVCS] system.

  Detailed design arrangement around Examination, Maintenance, Inspection and Testing (EMIT) and equipment monitoring is presented in the SDM, Reference [17].

2) Human Factors

The RCV [CVCS] system considers the requirements stated in Sub-chapter 10.2.4 and the design considerations and measures described in Sub-chapter 10.2.4 are applied in the design of the RCV [CVCS] system.

The RCV [CVCS] does not require short term operator intervention after a dilution accident. Detailed information about automatic control design of the system is presented in the SDM, Reference [17].

3) Autonomy

- Autonomy in Respect of Operators

  The design principles relevant to the autonomy in respect of operators are detailed in Reference [1]. The RCV [CVCS] does not require short term operator intervention after a dilution accident. The detailed information is presented in the SDM, Reference [17]. The design result is estimated in the safety analysis.

- Autonomy in Respect of the Heat Sink

  Not applicable.

- Autonomy in Respect of Power Supply Systems

  The redundancy valves of the RCV [CVCS] system performing FC1 and

FC2 classified isolation functions shall be powered by the emergency power supply and must meet the single failure criteria. Therefore, the redundancy valves should be powered by different electrical zones.

In addition, the containment isolation valves inside the containment of the RCV [CVCS] system are required to be powered by the Station Black Out (SBO) diesel generators and 2h batteries. The containment isolation valves outside the containment are required to be powered by the SBO diesel generators and 12h severe accident batteries.

Power supply requirements of the components performing safety functions are identified in Reference [17].

4) Other Design Requirements

- Prevention of Harmful Interactions of Systems Important to Safety

  - Provisions have been made to prevent the design pressure of the system operating at the lower pressure from being exceeded. Adequate isolation (e.g. using double isolating valves) and appropriate control functions between the RCV [CVCS] and interfacing systems are designed to protect the interfacing system from overpressure, Reference [16];

  - Provisions have been made to prevent radioactivity from being released to supporting systems, for example, to ensure that the cooling functions of higher-classified users of the RRI [CCWS] are not affected by the failure of integrity of components and lines associated with the RRI [CCWS]. Radioactivity detecting instruments are designed on the shell side of the heat exchanger of the RCV [CVCS]. When a leak is detected, the heat exchanger can be isolated to prevent radioactivity release to the RRI [CCWS], Reference [16];

- Considerations Related to the Electrical Power Grid

  The function of the charging pump of the RCV [CVCS] could be disturbed by the fluctuations of the electrical power grid. In this case, two charging pumps may be put into operation to compensate for the possible lack of flowrate when required. The functional reliability of the main valves shall be substantiated by the equipment vendor to take the electrical power grid fluctuation into account.

c) Equipment Qualification

The requirements concerning equipment qualification are presented in Chapter 4. The design of the RCV [CVCS] complies with these requirements.

Active components of the RCV [CVCS] such as the containment isolation valves, anti-dilution protection isolation valves, RCPB isolation valves that perform FC1 or FC2 safety functions shall be qualified. Active components of the RCV [CVCS] that perform FC3 safety functions required under DEC conditions shall be qualified. All the seismic classified components of the RCV [CVCS] shall be available during and after the SSE. The components are seismic designed and qualified for the SSE loads.

The documents relevant to equipment qualification will be delivered before the step 4 of GDA.

d) Protection against Internal and External Hazards

The RCV [CVCS] system considers the requirements stated in Sub-chapter 10.2.4 and the design considerations and measures described in Sub-chapter 10.2.4 are applied in the design of the RCV [CVCS] system.

e) Commissioning

Commissioning and tests will be carried out for the RCV [CVCS] to validate its functionality. Documents related to the commissioning will be delivered before the step 4 of GDA. Further detailed site specific arrangements for the UK HPR1000 commissioning activities will be presented during the Nuclear Site Licencing phase in conjunction with the site licensee.

f) Examination, Inspection, Maintenance and Testing

1) Inspections and Surveillances

In-service inspection is required for a number of components and pipelines of the RCV [CVCS] in order to maintain a satisfactory safety level for components enduring sustained pressure.

According to the RSE-M code, equipment and lines belonging to the main primary loop require in-service inspection, i.e. the equipment and pipelines within the RCPB isolation boundary.

The RCV [CVCS] is designed with a range of surveillance methods to monitor system configuration status in real time, so as to help the operators to keep abreast of the system operating status and intervene at the first instance when an abnormal event occurs to ensure the safety operation of the system.

The main monitoring methods of the RCV [CVCS] are described below:

- The surveillance of the high-pressure letdown line operation status;
- The surveillance of the low-pressure letdown line operation status;
- The surveillance of the charging line operation status;

- The surveillance of the seal injection line operation status;
- The surveillance of the seal leak-off line operation status;
- The surveillance of the auxiliary spray line operation status.

Equipment of RCV [CVCS] requiring periodic maintenance must be provided with enough maintenance space, especially the heat exchangers, charging pumps, safety valves and control valves.

2) Maintenances

The system layout should consider the convenience of maintenance operations and reducing the irradiation dose to workers to a reasonable level. When the main equipment is being repaired, it is necessary to facilitate the draining and venting after isolation.

Maintenance of the main equipment of the RCV [CVCS] is carried out during the refuelling cold shutdown. The maintenance and replacement of the RCV [CVCS] mainly includes the following:

- The maintenance of the heat exchangers;
- The maintenance of the pumps and valves;
- The maintenance of the VCT;
- The maintenance and replacement of the demineralisers;
- The maintenance and replacement of the filters.

3) Periodic Tests

The system design must ensure the feasibility of the testing and in-service inspection, especially for the equipment which needs to be put into operation after an earthquake.

The equipment performing FC1-classified and FC2-classified safety functions and those that perform FC3-classified safety functions but are not required to operate continuously must be tested.

The parts of the RCV [CVCS] which are not safety related also need to be tested, such as the safety valves.

The safety functions required for periodic testing of the RCV [CVCS] are as follows:

- The isolation downstream of the VCT and hydrogenation station;
- The isolation of the charging line and the auxiliary spray line;
- The isolation of the high-pressure letdown line;

- The isolation of the seal injection line;
- The isolation of the containment;
- The isolation of the RCPB.

For equipment operating during the full fuel cycle, it is not required to carry out periodic testing, as their availability has been checked during normal operation.

For the equipment not operating during the fuel cycle, its availability must be checked by periodic testing.

For the UK HPR1000, the periodic test design will also be adapted from those developed for the HPR1000 (FCG3). Documents relevant to periodic tests for the UK HPR1000 will be delivered before the step 4 of GDA.

g) Decommissioning

The design of the RCV [CVCS] considers the decommissioning. A certain gradient is set in the pipeline layout to prevent liquid accumulation and all equipment and pipes can be drained by the draining lines.

h) Material Selection

The metal parts of the RCV [CVCS] system that convey borated water during operation must be made of austenitic stainless steel in order to limit corrosion.

i) Special Thermal-hydraulic Phenomena

In order to ensure the functional reliability of the system and to prevent challenges in performing the safety functions, the hydraulic phenomena listed below shall be carefully considered in RCV [CVCS] design:

1) Phenomenon regarding the dead leg;
2) Phenomenon regarding the hot water and cold water mixing;
3) Phenomenon regarding the thermal stratification;
4) Phenomenon regarding the water hammer.

j) Insulation

The pipes and components containing fluid with a temperature more than 60°C in normal operating conditions need insulation design to protect the workers. This includes the charging line, seal injection line, seal leak-off line and the letdown heat exchanger upstream line.

10.4.3.6 Simplified Diagrams

The simplified system functional diagram is presented in Figure F-10.4-1, the detailed system functional diagram is in Reference [19].

10.4.4 Reactor Boron and Water Makeup System (REA [RBWMS])

The Reactor Boron and Water Makeup System (REA [RBWMS]) falls into the category of auxiliary systems. The REA [RBWMS] controls the reactivity of the core by adjusting the boron concentration in the reactor coolant system (RCP [RCS]) via the chemical and volume control system (RCV [CVCS]) under normal conditions, and compensates for the reactivity change of the core along with the control rods in case of unit start-up and shutdown and burn-up change. Information of the system is presented in the SDM, Reference [20].

10.4.4.1 Safety Functional Requirements

10.4.4.1.1 Control of Reactivity

The REA [RBWMS] contributes to the control of reactivity by performing the following functions:

a) The REA [RBWMS] shall protect the reactor from the risk of unexpected dilution caused by the REA [RBWMS] in plant normal operating conditions;

b) The REA [RBWMS] shall provide borated makeup water to the RCP [RCS] via the RCV [CVCS] to control the boron concentration in the RCP [RCS] and compensate for the slow reactivity change in plant normal operating conditions;

c) The REA [RBWMS] shall ensure adjustment of the boron concentration in the RCP [RCS] and VCT level by providing borated water makeup in the event of short term loss of offsite power conditions (DBC-2).

10.4.4.1.2 Removal of Heat

The REA [RBWMS] does not directly contribute to the removal of heat function.

10.4.4.1.3 Confinement

The part of the REA [RBWMS] containing radioactive substances shall ensure the confinement of radioactive substances and prevent radioactivity release.

10.4.4.1.4 Extra Safety Functions

The REA [RBWMS] does not indirectly contribute to the three safety functions.

10.4.4.2 Design Requirements

The general design requirements of the nuclear auxiliary systems which need to be considered are shown in Sub-chapter 10.2.4, among which the following requirements are not applicable for the REA [RBWMS] system:

a) Single Failure Criterion (SFC)

Not applicable, because the REA [RBWMS] system doesn't perform safety functions of category FC1.

b) Diversity

Not applicable. There's no diversity design in the REA [RBWMS].

c) Fail-safe

Not applicable. There's no fail-safe designed equipment in the REA [RBWMS].

d) Autonomy in Respect of Heat Sink

Not applicable, because the REA [RBWMS] doesn't provide a heat sink to the power plant.

The substantiation analysis of the REA [RBWMS] to other design requirements is shown in Sub-chapter 10.4.4.5.

10.4.4.3 Design Bases

This sub-chapter aims to provide the main design assumptions considered in the system design.

10.4.4.3.1 General Assumptions

a) Safety Classification

The boric acid storage and injection, and the demineralised water injection function are required to control the boron concentration in the primary loop within a suitable range during normal operating conditions and DBC-2 conditions (in case of short term loss of offsite power (< 2 hours)), the function category is FC3.

The demineralised water restriction function is required to restrict the flowrate of demineralised water injecting into the primary loop when unexpected dilution happens, the function category is FC3.

The confinement of radioactive substances function is required to prevent radioactivity release in all conditions, the function category is FC3.

b) Ageing and Degradation

According to Chapter 2, the operational design life of the UK HPR1000 is 60 years. The main components of the REA [RBWMS] are required to have a service life of 60 years.

c) Considerations Related to the Electrical Power Grid

The functionality of items important to safety at the nuclear power plant shall not

be compromised by disturbances in the electrical power grid, including anticipated variations in the voltage and frequency of the grid supply, which is considered as 49.5Hz-50.5Hz according to the design of the HPR1000 (FCG3). It will be adjusted in the future design phases based on the actual conditions of the UK.

10.4.4.3.2 Design Assumptions

a) Control of Reactivity

The REA [RBWMS] is required to fulfil the safety functional requirements with the following design assumptions:

1) To avoid unexpected dilution accidents in normal operation, the flowrate of demineralised water injection shall be restricted, to give enough time for the operator to take appropriate corrective actions (at least 30 minutes).

2) The boric acid storage tank capacity is sufficient to bring the reactor to cold shutdown from power operation at the beginning of life and after a shutdown for refuelling at end of life, without recovering of boric acid from the TEP [CSTS];

3) To ensure the adjustment of the boron concentration in the RCP [RCS] and VCT level in DBC-2 condition of short term loss of offsite power (less than 2 hours), the REA [RBWMS] shall provide borated makeup water.

b) Removal of Heat

Not applicable. The REA [RBWMS] system does not directly contribute to the safety function of removal of heat.

c) Confinement

Not applicable. There’s no quantitative safety-related design assumption for the REA [RBWMS] system.

d) Extra Safety Functions

The REA [RBWMS] does not indirectly contribute to the three safety functions.

10.4.4.4 System Description and Operation

10.4.4.4.1 System Description

a) General System Description

1) Boron Acid Mixing and Distribution

The boric acid mixing and distribution subsystem prepares and distributes 4% boric acid solution to the boric acid storage tanks and emergency boric acid tanks of the Emergency Boration System (RBS [EBS]). Boric acid solution

with a concentration for the refuelling shutdown is made up for the PTR [FPCTS]/IRWST by mixing the 4% boric acid solution with demineralised water.

2) Boric Acid Storage and Injection

The boric acid storage and injection subsystem consists of two trains, each train is equipped with a boric acid injection pump. In normal conditions, one of the two trains is connected to the boric acid storage tank to provide make-up boric acid solution to the RCV [CVCS] system, while the other train can be used to circulate the boric acid solution in the boric acid storage tank to ensure the uniformity of its concentration.

3) Demineralised Water Injection

The demineralised water injection subsystem consists of two trains. Each train is equipped with a demineralised water injection pump. One of the trains makes up demineralised water to the RCV [CVCS] system. A flow restricting orifice is installed on the demineralised water makeup line to restrict the maximum dilution flow.

The detailed information is presented in the SDM, Reference [21].

b) Description of Main Equipment

1) Boric Acid Mixing Tank

The boric acid mixing tank is a vertical cylindrical vessel. An agitator is fixed at the head of the tank to provide for the mixing of the demineralised water and boric acid powder.

T-10.4-8 Main Design Characteristics of the Boric Acid Mixing Tank

Parameters	Value	Unit
Type	Cylindrical Tank	
Medium	Boric Acid	7000-7700mg/kg, B-10 enrichment 35%at
Design Pressure	0	MPa (g)
Design Temperature	100	°C
Usable Volume	10	m^3

Parameters	Value	Unit
Max. Volume	12	m^3
Material	Stainless Steel	

2) Boric Acid Feed Pump

The boric acid feed pump is a horizontal centrifugal pump providing boric acid solution from the boric acid mixing tanks to different users.

T-10.4-9 Main Design Characteristics of the Boric Acid Feed Pump

Parameters	Value	Unit
Type	Centrifugal Pump	
Design Lifetime	60	yr.
Nominal Flowrate	25	m^3/h
Discharge Head at Nominal Flowrate	60	mWc
Material	Stainless Steel	

3) Boric Acid Storage Tank

The boric acid storage tanks are vertical cylindrical vessels. During normal operation, the boric acid storage tanks collect 4% boric acid solution recycled from the TEP [CSTS] and provide it to the RCP [RCS] via the RCV [CVCS] according to the requirements of volume and reactivity control.

T-10.4-10 Main Design Characteristics of the Boric Acid Storage Tank

Parameters	Value	Unit
Type	Cylindrical Tank	
Medium	Boric Acid	7000-7700mg/kg, ^{10}B, B-10 enrichment 35%at
Design Pressure	0.3	MPa (g)

Parameters	Value	Unit
Design Temperature	150	°C
Usable Volume	70	m^3
Max. Volume	76.4	m^3
Material	Stainless Steel	

4) Boric Acid Injection Pump

The boric acid injection pumps are of horizontal centrifugal type, which can supply the necessary flow of boric acid solution to the RCV [CVCS]. The designed flow range can be reached by adjusting the control valves downstream of the pump

T-10.4-11 Main Design Characteristics of the Boric Acid Injection Pump

Parameters	Value	Unit
Type	Centrifugal Pump	
Design Lifetime	60	yr.
Nominal Flowrate	25	m^3/h
Discharge Head at Nominal Flowrate	85	mWc
Material	Stainless Steel	

5) Demineralised Water Injection Pump

The demineralised water injection pumps are of a horizontal centrifugal type, which can deliver the required amount of demineralised water to the RCV [CVCS]. In normal operation, the flowrate of demineralised water can be adjusted by the control valve downstream of the pump.

T-10.4-12 Main Design Characteristics of the Demineralised Water Injection Orifice

Parameters	Value	Unit
Type	Centrifugal Pump	

Parameters	Value	Unit
Design Lifetime	60	yr.
Nominal Flowrate	50	m^3/h
Discharge Head at Nominal Flowrate	61.4	mWc
Material	Stainless Steel	

6) Demineralised Water Injection Orifice

The demineralised water injection orifice is of the single plate type, which shall restrict the maximum flow of demineralised water in case of mechanism malfunction or instrumentation and control failure.

T-10.4-13 Main Design Characteristics of the Demineralised Water Injection Orifice

Parameters	Value	Unit
Type	Single Plate	
Design Lifetime	60	yr.
Material	Stainless Steel	

The detailed information is presented in the SDM, Reference [21].

c) Description of Main Layout

The main components of the REA [RBWMS] are arranged in the Nuclear Auxiliary Building (BNX) except for the pipes connecting with the VCT which are arranged in the Fuel Building (BFX).

The detailed information is presented in the SDM, Reference [22].

d) Description of System Interfaces

The REA [RBWMS] system interfaces with the following systems:

1) Coolant Storage and Treatment System (TEP [CSTS])

During normal operation, the TEP [CSTS] provides 4% boric acid solution, retrieved by the evaporator, to the boric acid storage tanks.

The demineralised water injected to the RCV [CVCS] is suctioned from the TEP [CSTS] reactor coolant storage tanks.

2) Nuclear Sampling System (REN [NSS])

The REN [NSS] analyses the chemical parameters of the boric acid storage tanks inventory before it is injected to the RCV [CVCS].

The detailed information is presented in the SDM, Reference [21].

e) Description of Instrumentation and Control

Operators may select different operating modes according to the requirements of volume control and reactivity control:

1) Automatic Makeup

The start and stop of the automatic makeup are controlled according to level signals of the VCT.

The flowrate of demineralised water is set as a constant value, while the flowrate of boric acid solution is calculated automatically according to the boron concentrations of the boric acid in the storage tank and the primary coolant.

2) Boration

Boration is used to provide 7000mg/kg boric acid solution to the RCP [RCS] and to decrease reactivity of the reactor. Operators set the boric acid makeup flowrate and total volume in the main control room manually.

3) Dilution

Dilution is used to provide demineralised water to the RCP [RCS] to increase reactivity of the reactor. The flowrate and total volume of demineralised water are set by operators in the main control room manually.

4) Manual Makeup

Manual makeup applies to the following conditions:

- Filling the VCT;
- Makeup of the IRWST or spent fuel during plant normal operation.

Operators set demineralised water and boric acid makeup flowrate and total makeup volume according to the demands for boron concentration.

The detailed information is presented in the SDM, Reference [23].

10.4.4.4.2 System Operation

a) Plant Normal Conditions

1) Normal Steady-state Operation

- Power Operation

  During power operation, the REA [RBWMS] generally operates in 'automatic makeup' mode to provide boric acid solution as the same boron concentration of the primary coolant, so as to compensate for minor leakage of reactor coolant.

- Hot Shutdown or Hot Standby

  In hot shutdown or hot standby conditions, the REA [RBWMS] operates basically in the same manner as in power operation. If the duration of the hot shutdown is long, the boron concentration of coolant shall be regulated to compensate for reactivity changes caused by the xenon poisoning effect.

- RIS [SIS] Cooling Normal Shutdown or Maintenance Cold Shutdown

  When three RCP [RCS] reactor coolant pumps of the RCP [RCS] system stop, the demineralised water makeup pipeline shall be isolated to isolate the dilution source of the REA [RBWMS]. The outlet of the boric acid injection pump can be switched to the IRWST to meet the makeup demands.

- Refuelling Cold Shutdown

  At refuelling cold shutdown, the REA [RBWMS] will not be put into service to allow maintenance of all REA [RBWMS] components.

2) Normal Transient-state Operation

- Plant Start-up

  During plant start-up, boric acid solution of the required concentration is injected into the RCP [RCS] via the RCV [CVCS] to fill the RCP [RCS]. In hot shutdown conditions, demineralised water is injected to reduce boron concentration in the coolant and increase the positive reactivity of the reactor.

  In the process of plant start-up, boric acid storage tanks must be able to store boric acid recovered by the TEP [CSTS]

- Plant Shutdown

  After shutdown rods are inserted into the core, the primary coolant is borated to the boron concentration for cold shutdown before cooling and depressurisation of the reactor coolant.

  During cooling of the primary coolant, the REA [RBWMS] provides boric acid solution of the required boron concentration to compensate for

coolant contraction automatically.

The boron concentration of the primary system shall be adjusted to the refuelling shutdown concentration before the unit is set into maintenance or refuelling shutdown mode.

In the process of unit shutdown, boric acid storage tanks must be able to store boric acid recovered by the TEP [CSTS].

- Daily Load Following Operation and Xenon Poisoning Transient State

  During daily load following operation and the xenon poisoning transient state, operators perform ‘boration’ or ‘dilution’ operations according to the requirements of reactivity control and maintain the position of control robs in the allowable range.

b) Plant Accident Conditions

In accident conditions, the REA [RBWMS] will operate in the same way as in normal operation as long as the system is available, to carry out the function of reactivity control and volume control for the primary loop with boric acid solution at the required concentration, until the charging line is isolated or the charging pump suction is switched to the IRWST.

The emergency diesel generator provides a back-up power supply to the pumps and valves of the boric acid storage and injection subsystem and demineralised water makeup subsystem of the REA [RBWMS]. Therefore, the components can still operate normally during LOOP.

In Anticipated Transient Without Scram (ATWS) conditions, the two boric acid injection pumps can be put into operation and the two boric acid control valves can be at the fully open position.

The detailed information is presented in the SDM, Reference [23].

10.4.4.5 Preliminary Design Substantiation

In this section, the system design is demonstrated to satisfy the safety functional requirements presented in Sub-chapter 10.4.4.1 and the General Design Requirements stated in Sub-chapter 10.2.4.

Since the general principles are newly developed at this stage, the system design is still based on the reference design and the information presented in this section is preliminary. A review of the consistency of the system design against the newly developed principles is currently being undertaken.

10.4.4.5.1 Compliance with Safety Functional Requirements

The system configuration and capability of the components comply with the safety

functional requirements; detailed design of the system is presented in the SDM [24], [21] and [23]. Furthermore, design substantiation of the REA [RBWMS] has been estimated in the fault study in Chapters 12 and 13.

a) Control of Reactivity

The REA [RBWMS] is designed to fulfil the safety function of control of reactivity by the following system design:

1) Prevention of reactor coolant unexpected dilution in plant normal operating condition:

   In power operation condition, the maximum flowrate of demineralised water is restricted by an orifice on the demineralised water makeup header to prevent unexpected dilution. The flowrate of demineralised water is restricted to be within a maximum accepted value. In the case of high deviations between the set flow value and the measured value, the makeup system will automatically stop to prevent unexpected dilution.

   In the shutdown state, while the reactor coolant pumps are not in operation, the demineralised water injection subsystem is isolated. The suction of the boric acid injection pump is switched to the IRWST and further dilution is prevented.

2) Provision of borated makeup water to the RCP [RCS] via the RCV [CVCS] to control the boron concentration in the RCP [RCS] and compensate for the slow reactivity change in plant normal operation:

   The REA [RBWMS] system has two trains of boric acid storage and injection pipelines as well as two trains of demineralised and deaerated water injection pipelines equipped with control valves, such that the flowrate and concentration can be adjusted according to requirements.

   Operation modes such as “boration”, “dilution”, “automatic makeup” and “manual makeup” are designed to satisfy different operating modes.

3) Adjustment of boron concentration in the RCP and the VCT level by providing borated water makeup in DBC-2 conditions:

   The valves and pumps on the boric acid and demineralised water injection pipelines of the REA [RBWMS] are all provided with emergency power supplies. Under the conditions of short term LOOP, the required makeup fluid can be provided by the REA [RBWMS] to regulate the liquid level of the VCT (not switching the suction inlet of the high pressure charging pump of the RCV [CVCS] to the IRWST).

b) Removal of Heat

Not applicable. The REA [RBWMS] does not directly contribute to the removal of heat function.

c) Confinement

The part of the REA [RBWMS] containing radioactive substances is functionally classified as F-SC3 and the design provision class is B-SC3, such that confinement capability is guaranteed.

d) Extra Safety Functions

The REA [RBWMS] does not indirectly contribute to the three safety functions.

Detailed information is presented in Reference [24].

10.4.4.5.2 Compliance with Design Requirements

a) Safety Classification

The REA [RBWMS] design is compliant with the requirements described in Chapter 4. The safety classification of the REA [RBWMS] functions is listed in Table T-10.4-14 and the safety classification of main components is listed in Table T-10.4-15.

T-10.4-14 System Function Categorisation

System Function	Function Category
Boron Acid Mixing and Distribution	NC
Boric Acid Storage and Injection	FC3
Demineralised Water Injection	FC3
Demineralised Water Restriction	FC3
Confinement of radioactive substances	FC3

T-10.4-15 Safety Classification of main Components

Component	Function Class	Design Provision Category	Design Provision Class	Seismic Category

Component	Function Class	Design Provision Category	Design Provision Class	Seismic Category
Boric Acid Mixing Tank	NC	DPL	NC	NO
Boric Acid Feed Pump	NC	DPL	NC	NO
Boric Acid Storage Tank	F-SC3	DPL	B-SC3	SSE2
Boric Acid Injection Pump	F-SC3	DPL	B-SC3	NO
Demineralised Water Injection Pump	F-SC3	DPL	B-SC3	NO
Demineralised Water Injection Orifice	F-SC3	DPL	B-SC3	SSE1

b) Engineering Design Requirements

1) Reliability Design of SSCs

- Single Failure Criterion (SFC)

  Not applicable.

- Independence

  In order to ensure the operability and reliability of the plant, some components performing operating functions are designed to be redundant, such as the boric acid injection pumps, boric acid storage tanks, demineralised water injection pumps, etc. The redundant components are arranged in different rooms for physical separation.

- Diversity

  Not applicable.

- Fail-safe

  Not applicable.

- Ageing and Degradation

  The plant design lifetime is 60 years. The service life of some of the

main components of the system is also 60 years. For example the boric acid mixing tank, boric acid storage tank, boric acid injection pump, demineralised water injection pump, etc.

The REA [RBWMS] system considers the requirements stated in Sub-chapter 10.2.4, and the design considerations and measures described in Sub-chapter 10.2.4 are applied in the design of the REA [RBWMS].

The detailed design arrangement of EMIT and equipment monitoring is presented in the SDM, Reference [23].

2) Human Factors

The REA [RBWMS] system considers the requirements stated in Sub-chapter 10.2.4, and the design considerations and measures described in Sub-chapter 10.2.4 are applied in the design of the REA [RBWMS].

The system design of the REA [RBWMS] does not require short term operator intervention. In addition, operating modes such as “boration”, “dilution”, “automatic makeup” and “manual makeup” are designed to be operated from the MCR to facilitate operator control of the boron concentration in the primary circuit. Detailed information about automatic control design of the system is presented in the SDM, Reference [23].

3) Autonomy

- Autonomy in Respect of Operators

  The design principles relevant to the autonomy in respect of operators are detailed in Reference [1]. The design of the REA [RBWMS] fulfils these principles via control functional design, detailed information is presented in the SDM, Reference [23]. In addition, the demineralised water injection orifice is designed to be in the REA [RBWMS] to restrict the flowrate of demineralised water injecting into the primary circuit. Therefore even when the isolation of dilution fails, the system can still guarantee autonomy in respect of operators in 30 minutes.

- Autonomy in Respect of the Heat Sink

  Not applicable.

- Autonomy in Respect of Power Supply Systems

  To ensure the operation of the REA [RBWMS] in case of LOOP, the actuators of the pumps and valves of the boric acid storage and injection subsystem and the demineralised water injection subsystem (REA2~5) are equipped with emergency power supplies.

4) Other Design Requirements

- Prevention of Harmful Interactions of Systems Important to Safety

  Provisions have been made to prevent the design pressure of the system operating at the lower pressure from being exceeded. Check valves between the REA [RBWMS] and interfacing systems such as the RIS [SIS] are designed to protect the REA [RBWMS] system from overpressure, Reference [24];

- Considerations Related to the Electrical Power Grid

  The design of active components such as the boric acid feed pump, boric acid injection pump and the demineralised water injection pump in the REA [RBWMS] has taken the disturbances in the electrical power grid into consideration. Detailed design information related to the electrical power grid is presented in Reference [24].

c) Equipment Qualification

Equipment qualification applies to mechanical and electrical equipment that perform FC3 functions required to prevent the actuation of the reactor trip and engineering safety systems during deviation from normal operation, including those designed to maintain the main plant parameters with in the normal range of operation of the plant.

All the seismically classified components of the REA [RBWMS] shall be capable of operating during and after the SSE. The demineralised water injection orifice is seismically designed and qualified for SSE loads.

The documents relevant to the equipment qualification will be delivered before the step 4 of GDA..

d) Protection Design against Internal and External Hazards

The REA [RBWMS] system considers the requirements stated in Sub-chapter 10.2.4, and the design considerations and measures described in Sub-chapter 10.2.4 are applied in the design of the REA [RBWMS] system.

e) Commissioning

Before operation, commissioning and tests are carried out to verify that the performance of the REA [RBWMS] meets the design requirements. The content of the tests includes preparation and distribution of 4% boric acid solution, storage of 4% boric acid solution, and boric acid and demineralised water make-up capability.

Documents related to the commissioning will be delivered before the step 4 of GDA.

f) Examination, Inspection, Maintenance and Testing

1) Inspections and Surveillance

In-service inspection and pre-service inspection are required for some main components of the REA [RBWMS] such as the boric acid storage tanks and the related relief valves.

The tanks (boric acid mixing tank and boric acid storage tanks) of the REA [RBWMS] are provided with redundant instrumentations to provide surveillance of the equipment. The boric acid mixing tank is equipped with online level measurement, the boric acid mixing tank is provided with on-line level measurements as well as remote pressure and temperature measurements for the operators.

All the pump inlets of the REA [RBWMS] system are provided with pressure measurements. The pump motor's winding stator and the bearing are all provided with temperature measurements.

The local pressure measurements upstream and downstream of the pumps are used to confirm the operational parameters and operating status of the pumps.

Upstream and downstream of the minimum flow lines heat exchangers at the hot side is provided with temperature measurement instrumentations, to monitor the heat transfer of the heat exchangers. The cold side of the heat exchangers is provided with pressure measurement and flow measurement instrumentations, used to measure the flow rate of cooling water of the RRI [CCWS]. These instrumentations can indicate the status of the equipment and provide surveillance to avoid equipment failure.

Documents related to in-service inspection for the equipment of the REA [RBWMS] requiring in-service inspections and testing and their requirements will be delivered before the step 4 of GDA.

2) Maintenances

The maintenance plans for the REA [RBWMS] are to be determined, where the overall principles in determining the plans are as follows:

- Maintenance of storage tanks must be conducted when the pipelines are out of service.
- For the boric acid and demineralised water makeup pipelines, the maintenance of a piece of equipment can be conducted during unit power operation based on the premise of not affecting the availability of the system.

3) Periodic Tests

Periodic tests are not taken into consideration for the items put in to long-term service in the REA [RBWMS]. However, periodic tests shall be taken into consideration for the items not in long-term service (e.g. the isolation valve at the outlet of the boric acid storage tank is in the open position for long time).

For the UK HPR1000, the periodic test design will be adapted from those developed for the HPR1000 (FCG3). Documents related to periodic tests of REA [RBWMS] for the UK HPR1000 will be delivered before the step 4 of GDA.

g) Decommissioning

The design of the REA [RBWMS] considers the decommissioning. A certain gradient is set in the pipeline layout to prevent liquid accumulation and all equipment and pipes can be drained by draining lines.

h) Material Selection

To avoid corrosion, all the parts of the REA [RBWMS] containing boric acid and reactor coolant are made of austenitic stainless steel, such as pumps, valves, pipes and tanks.

To prevent leakage, all the pipes and equipment of the system have welded connections, except for those which require flanged connections for the purpose of maintenance and inspection.

i) Special Thermal-hydraulic Phenomena

In order to ensure the functional reliability of system and to prevent challenges in performing the safety function, the hydraulic phenomenon listed below shall be carefully considered in REA [RBWMS] design:

1) Phenomenon regarding the water hammer

Before the system is put into operation, it is full filled with fluid and sufficiently vented to avoid the phenomenon of water hammer in the process of system start-up or shut down.

j) Insulation

The pipes and components containing fluid with a temperature more than 60°C require insulation design to protect the workers, including the boric acid mixing tank and its connected pipes, and the pipes from the TEP [CSTS] to the boric acid storage tanks.

10.4.4.6 Simplified Diagram

The simplified system functional diagram is presented in Figure F-10.4-2, the detailed

system functional diagram is in Reference [25].

10.4.5 Coolant Storage and Treatment System (TEP [CSTS])

The TEP [CSTS] falls into the category of auxiliary systems, and performs the functions of receiving, separating and degassing reusable primary coolant. The TEP [CSTS] consists of coolant storage tanks, evaporation unit, condensate degasification unit and the coolant degasification unit. The main components of the TEP [CSTS] are located in the nuclear auxiliary building. Information of the system is presented in the SDM, Reference [26].

10.4.5.1 Safety Functional Requirements

10.4.5.1.1 Control of Reactivity

The TEP [CSTS] does not contribute to this function.

10.4.5.1.2 Removal of Heat

The TEP [CSTS] does not contribute to this function.

10.4.5.1.3 Confinement

The TEP [CSTS] contributes to achieve confinement of radioactive waste in normal operation.

10.4.5.1.4 Extra Safety Functions

The TEP [CSTS] does not contribute to this function.

10.4.5.2 Design Requirements

In this sub-chapter, the applicability of design requirements listed in Sub-chapter 10.2.4 are analysed for the TEP [CSTS].

The design requirements not applicable in the design of the TEP [CSTS] are identified as follows:

a) Reliability Design of SSCs

   1) Single Failure Criterion (SFC)

      Not applicable, since the TEP [CSTS] does not perform any FC1-level security functions, the single failure criterion does not apply to this system.

   2) Diversity

      Not applicable. There’s no diversity design in the TEP [CSTS].

   3) Fail-safe

Not applicable. There's no fail-safe designed equipment in the TEP [CSTS].

b) Autonomy in Respect of the Heat Sink

Not applicable, because the TEP [CSTS] doesn't provide a heat sink to the power plant.

c) Prevention of Harmful Interactions of Systems Important to Safety

Not applicable, because the TEP [CSTS] doesn't have any harmful interactions of systems important to safety.

The substantiation analysis of the TEP [CSTS] to other design requirements is shown in 10.4.5.5.

10.4.5.3 Design Bases

This sub-chapter aims to provide the main design assumptions considered in the system design.

10.4.5.3.1 General Assumptions

a) Safety Classification

The confinement of radioactive substances function of the TEP [CSTS] is required to prevent radioactivity release in all conditions, the function category is FC3.

b) Ageing and Degradation

According to Chapter 2, the operational design life of the UK HPR1000 is 60 years. The main components of the TEP [CSTS] are required to have a service life of 60 years.

c) Considerations Related to the Electrical Power Grid

The functionality of items important to safety at the nuclear power plant shall not be compromised by disturbances in the electrical power grid, including anticipated variations in the voltage and frequency of the grid supply, which is considered as 49.5Hz-50.5Hz according to the design of the HPR1000 (FCG3). It will be adjusted in the future design phases based on the actual conditions of the UK.

10.4.5.3.2 Design Assumptions

a) Control of Reactivity

Not applicable. The TEP [CSTS] does not contribute to the function of control of reactivity.

b) Removal of Heat

Not applicable. The TEP [CSTS] does not contribute to the safety function of removal of heat.

c) Confinement

Not applicable. There's no quantitative safety-related design assumption for the TEP [CSTS].

d) Extra Safety Functions

Not applicable. There's no quantitative safety-related design assumption for TEP [CSTS].

10.4.5.4 System Description and Operation

10.4.5.4.1 System Description

a) General System Description

The TEP [CSTS] is divided into the following subsystems:

1) Coolant Storage and Supply Subsystem

The coolant storage and supply subsystem is mainly comprised of the following components:

- Six coolant storage tanks;
- One borated water pipeline;
- One demineralised water pipeline.

Each coolant storage tank is connected to the borated water pipeline and demineralised water pipeline through an isolation valve. During normal operation of the NPP (Nuclear Power Plant), one coolant storage tank is permanently connected to the borated water pipeline and the other to the demineralised water pipeline. Therefore, borated water and demineralised water can be received and supplied at the same time.

The tanks are constantly swept with nitrogen taken from the TEG [GWTS] to prevent accumulation of flammable gas mixtures in the system free spaces. Additionally, the tanks are operated below atmospheric pressure to prevent hydrogen leakage from the system.

The detailed information is presented in the SDM, Reference [27].

2) Coolant Purification Subsystem

The coolant purification subsystem consists of:

- Two makeup pumps of the boric acid distillation tower;

- One mixed bed demineraliser;
- One cartridge filter (resin trapper).

The mixed bed demineraliser and downstream resin trapper are installed among the coolant storage and supply subsystem (TEP [CSTS] 1) and coolant treatment subsystem (TEP [CSTS] 3, 5 and 6).

3) Coolant Treatment Subsystem

The coolant treatment subsystem consists of:

- One evaporation unit;
- One condensate degasification unit.

The TEP [CSTS] 3, 5 and 6 subsystems separate reactor coolant into demineralised water and boric acid solution. Redundancy shall be considered for all important active components to improve system availability.

4) Coolant Degasification Subsystem

The coolant degasification subsystem mainly consists of:

One coolant degasification unit.

The degasification vacuum pump will depressurise the coolant when its temperature reaches the boiling point of 50°C. Meanwhile, the vacuum pump is used to extract gases originating out of the degasification tower.

The detailed information is presented in the SDM, Reference [27].

a) Description of Main Equipment

The main equipment is described as follows:

1) Coolant Storage Tanks

Coolant storage tanks are vertical cylindrical vessels which receive reusable primary coolant or demineralised water (distillate) from the coolant treatment subsystem.

2) Evaporator

The evaporator in the evaporation unit is a packed column separating reusable primary coolant into demineralised water and 7000mg/kg boric acid solution, which is returned to the REA [RBWMS] for reuse.

3) Degasification Columns

The degasification columns of the coolant and condensate degasification

units are packed columns degasifying the liquid to be treated, so as to reduce its radioactivity.

The TEP [CSTS] is equipped with multiple centrifugal pumps to provide the drive required for fluid flowing in the system.

4) Mixed Bed Demineraliser

The mixed bed demineraliser in the coolant purification subsystem is a cylindrical pressure vessel with hemispherical heads. It is filled with anion and cation resins to remove ionic and solvent impurities from the coolant.

5) Pumps and Compressors

The TEP [CSTS] is equipped with multiple centrifugal pumps to provide the drive required for fluid flowing in the system.

The vapour compressor is a rotary compressor with a sufficient compression ratio to produce enough heat to maintain sufficient evaporation in the evaporator.

The vacuum pump is a liquid ring vacuum pump which provides the coolant degasification column with the required operation pressure (negative pressure), so that the coolant will evaporate at a temperature near the letdown temperature.

6) Heat Exchangers

The TEP [CSTS] is equipped with multiple heat exchangers to recover system heat and cool fluid. The heat exchangers are of tube-shell type.

The detailed information is presented in the SDM, Reference [27].

b) Description of Main Layout

The TEP [CSTS] is arranged in the BNX.

The detailed information is presented in the SDM, Reference [28].

c) Description of System Interfaces

1) Operational Chilled Water System DER [OCWS]

The DER [OCWS] supplies the sealing liquid cooler of the degasifier vacuum pump with chilled water.

2) Nuclear Auxiliary Building Ventilation System (DWN [NABVS])

In case the activity released by the TEP [CSTS] 4 does not result in a high activity in the stack, the extracted gases can be exhausted towards the DWN [NABVS].

3) NI Demineralised Water Distribution System (SED [DWDS (NI)])

The SED [DWDS (NI)] flushes the equipment and provides demineralised water to replenish it.

4) Nuclear Island Vent and Drain System (RPE [VDS])

The RPE [VDS] provides a number of vents and drains for the TEP [CSTS].

The borated water line of the coolant storage and supply subsystem is accepts reactor coolant effluents from the RPE [VDS].

5) Nuclear Sampling System (REN [NSS])

The REN [NSS] determines the decontamination factor or chemical composition of the reactor coolant and sweeping gas.

6) Component Cooling Water System (RRI [CCWS])

The RRI [CCWS] supplies the condenser, gas cooler and several heat exchangers with component cooling water.

7) Service Compressed Air Distribution System (SAT [SCADS])

The SAT [SCADS] provides compressed air in case of the outage of the TEP [CSTS] tanks and columns.

8) Nitrogen Distribution System (SGN [NDS])

The SGN [NDS] can supply nitrogen to the TEP [CSTS] 4 and serve the TEP [CSTS] in coolant storage tank outage.

9) Gaseous Waste Treatment System (TEG [GWTS])

The TEG [GWTS] supplies nitrogen for flushing purposes as well as exhausting extracted gases.

10) Solid Waste Treatment System (TES [SWTS])

The spent resins are transported out of the mixed bed filter of the TEP [CSTS] 2 to the resin waste tanks by the TES [SWTS].

11) Nuclear Island Liquid Waste Discharge System (TER [NLWDS])

Condensate can be discharged to the TER [NLWDS] for tritium balancing after treatment (evaporation and subsequent degasification).

12) Reactor Boron and Water Makeup System (REA [RBWMS])

The demineralised water stored in one coolant storage tank is delivered to the REA [RBWMS]. Boric acid collected in the evaporation unit is sent to the REA [RBWMS]. The make-up water electrical preheater is used for the

supply of heated demineralised water to the REA [RBWMS].

13) Chemical and Volume Control System (RCV [CVCS])

The borated water line of the coolant storage and supply subsystem accepts coolant from the RCV [CVCS]. The coolant coming from the RCV [CVCS] enters the coolant degasification system for degassing. The degassed coolant is transferred back to the RCV [CVCS].

The detailed information is presented in the SDM, Reference [27].

d) Description of Instrumentation and Control

The TEP [CSTS] is a fully automated system. Therefore it is provided with a set of group commands, controllers and instrumentations. The normal operation of the TEP system is automatic. However, the operator also has the ability to operate the system manually.

The detailed information is presented in the SDM, Reference [29].

10.4.5.4.2 System Operation

a) Plant Normal Conditions

1) Coolant Storage and Supply Subsystem (TEP [CSTS] 1)

TEP1 is comprised of six coolant storage tanks of the same volume, one demineralised water header, and one coolant header. Each coolant storage tank is connected to the coolant header or the demineralised water header by an electric valve. During normal operation of the NPP, one coolant storage tank is permanently connected to the coolant header and the other coolant storage tanks are permanently connected to the demineralised water header. Coolant or demineralised water can be received and delivered at the same time.

2) Coolant Purification Subsystem (TEP [CSTS] 2)

TEP [CSTS] 2 transfers coolant from TEP [CSTS] 1 to TEP [CSTS] 3, 5 and 6. The coolant is demineralised and filtered by the demineraliser of TEP [CSTS] 2. The mixed bed demineraliser is filled with H+ and OH- ions, to remove residual lithium and caesium, while other isotope ions will not be removed by the demineraliser of the RCV [CVCS].

3) Coolant Treatment Subsystem (TEP [CSTS] 3, 5 and 6)

TEP [CSTS] 3, 5 and 6 operate in four modes:

- Distillation Separation without Degasification and Reuse after Treatment

Coolant is pumped to the boric acid column by its makeup pump after a

two-stage regenerative heat exchange (the heat of boric acid and distillate from the boric acid column are recovered). When the coolant is heated to boiling, the vapour generated is extracted by two vapour compressors and delivered to the heat exchanger shell side of the boric acid column. Condensate is collected in the condensate container and tank, and its vapour and water are separated. The condensate is cooled to 50°C and pumped by the condensate transfer pump to the coolant storage tanks of TEP [CSTS] 1 for reuse.

- Distillation Separation with Degasification and Reuse after Treatment

  Operations of this mode are the same as those of the mode outlined above except that the condensate flows into TEP [CSTS] 6 through a bypass before entering the regenerative preheater. It is degasified and cooled to 50°C by the regenerative preheater and subsequent cooler, and then transferred to the coolant storage tanks of TEP [CSTS] 1 for reuse.

- Distillation Separation with Degasification and Condensate Discharge after Treatment

  The treated condensate will be subject to the operations in the mode described above and then transferred to the TER [NLWDS] directly instead of TEP [CSTS] 1 for discharge. This occurs when the quality of the condensate cannot meet the required standard or be reused, such as when the tritium content in the primary loop is higher than the standard amount and needs to be discharged.

- Degasification of Makeup Water

  Demineralised water makeup is required when the condensate is partially discharged. The makeup water is supplied by the SED [DWDS (NI)], heated by the makeup water preheater, piped to TEP [CSTS] 6, degasified, cooled to 50°C, and transferred to the coolant storage tanks of TEP [CSTS] 1 for storage and reuse.

4) Coolant Degasification Subsystem (TEP [CSTS] 4)

Coolant is piped from the RCV [CVCS] to the coolant degasification subsystem (TEP [CSTS] 4) via the letdown pipeline. Degasified coolant is returned to the RCV [CVCS]. Gases removed from the primary coolant are transferred to the TEG [GWTS] or the DWN [NABVS].

Reactor coolant at about 50°C is piped from the RCV [CVCS] to the top of the coolant degasification tower. It flows in the opposite direction to the rising vapour, and the non-condensable gases dissolved in it are removed. The operating pressure shall be maintained at 0.0125MPa (a) to boil the feedwater. Most gases dissolved in the coolant will be evaporated in these

conditions.

b) Plant Accident Conditions

There is no demand for the TEP [CSTS] to operate in plant accident conditions.

10.4.5.5 Preliminary Design Substantiation

In this sub-chapter, the system design is demonstrated to satisfy the Safety Functional Requirements presented in Sub-chapter 10.4.5.1 and the general design requirements stated in Sub-chapter 10.2.4.

Since the general principles are newly developed at this stage, the system design is still based on the reference design and the information presented in this sub-chapter is preliminary. A review of the consistency of the system design against the newly developed principles is currently being undertaken.

10.4.5.5.1 Compliance with Safety Functional Requirements

a) Control of Reactivity

The TEP [CSTS] does not contribute to this function.

b) Removal of Heat

The TEP [CSTS] does not contribute to this function.

c) Confinement

The confinement of radioactive material is ensured by the sealing of the mechanical boundaries. Moreover, the TEP [CSTS] is located within the BNX building and the civil engineering structure acts as a barrier to the environment.

d) Extra Safety Functions

The TEP [CSTS] does not contribute to this function.

10.4.5.5.2 Compliance with Design Requirements

a) Safety Classification

The TEP [CSTS] design is compliant with the requirements described in the Chapter 4. The safety classification of the TEP [CSTS] is listed in Table T-10.4-16 and the main components in Table T-10.4-17 .

T-10.4-16 Function Categorisation of the TEP [CSTS]

System Function	Function Categorisation
Coolant Supply and Storage Subsystem	FC3

System Function	Function Categorisation
Coolant Purification Subsystem	FC3
Coolant Treatment Subsystem (Except seal water circuit for vapour compressors)	FC3
Coolant Treatment Subsystem (seal water circuit for vapour compressors)	NC
Collection of condensates degasification	NC
Coolant Degasification Subsystem	FC3

T-10.4-17 Classification for Components

Component	Function Class	Design Provision Category	Design Provision Class	Seismic Category
Coolant Storage Tanks	F-SC3	DPL	B-SC3	NO
Evaporator	F-SC3	DPL	B-SC3	NO
Boric Acid Column	F-SC3	DPL	B-SC3	NO
Degasifier Column (TEP [CSTS] 4)	F-SC3	DPL	B-SC3	NO
Degasifier Column (TEP [CSTS] 6)	NC	NC	NC	NO
Mixed Bed Demineraliser	F-SC3	DPL	B-SC3	NO
Compressors	F-SC3	DPL	B-SC3	NO

b) Engineering Design Requirements

1) Reliability Design of SSCs

- Single Failure Criterion (SFC)

  Not applicable.

- Independence

In order to ensure the operability and reliability of the plant, some components performing operational functions are designed to be redundant, such as the boric acid column feed pumps and circulation pumps, etc. The redundant components are arranged in different rooms for physical separation.

- Diversity

  Not applicable.

- Fail-safe

  Not applicable.

- Ageing and Degradation

  The plant design life is 60 years. The service life of some of the main components of the system is also 60 years.

  The TEP [CSTS] considers the requirements stated in Sub-chapter 10.2.4, and the design considerations and measures described in Sub-chapter 10.2.4 are applied in the design of the TEP [CSTS].

  The detailed design arrangement around EMIT and equipment monitoring is presented in the SDM, Reference [29].

2) Human Factors

The TEP [CSTS] considers the requirements stated in Sub-chapter 10.2.4, and the design considerations and measures described in Sub-chapter 10.2.4 are applied in the design of the TEP [CSTS].

The TEP [CSTS] does not require short term operator intervention. Detailed information about automatic control design of the system is presented in the SDM, Reference [29].

3) Autonomy

- Autonomy in Respect of Operators

  The design principles relevant to the autonomy in respect of operators are detailed in Reference [1]. The design of the TEP [CSTS] fulfils these principles via control functional design, detailed information is presented in the SDM, Reference [29].

- Autonomy in Respect of the Heat Sink

  Not applicable.

- Autonomy in Respect of Power Supply Systems

To ensure the operation of the TEP [CSTS] in case of LOOP, the actuators of valves of the coolant supply and storage subsystem are equipped with emergency power supplies.

4) Other Design Requirements

- Prevention of Harmful Interactions of Systems Important to Safety

  Not applicable.

- Considerations Related to the Electrical Power Grid

  The design of active components such as the sample backfeed pumps in the TEP [CSTS] has taken the disturbances in the electrical power grid into consideration. Detailed design information of the electrical power grid is presented in the Reference [30].

c) Equipment Qualification

Not applicable.

d) Protection against Internal and External Hazards

The TEP [CSTS] considers with the requirements stated in Sub-chapter 10.2.4, and the design considerations and measures described in Sub-chapter 10.2.4 are applied in the design of the TEP [CSTS].

e) Commissioning

The TEP [CSTS] will be subject to commissioning tests before putting it into operation, to verify that its component performance meets the requirements.

f) Examination, Inspection, Maintenance and Testing

1) Inspections and Surveillances

In-service inspections are implemented for the equipment of the TEP [CSTS], including the coolant storage tanks and columns.

2) Maintenance

Some components will need to be replaced at the end of their individual designed life. The layout design will take into consideration the need to remove old parts and the installation of replacements.

3) Periodic Tests

Periodic tests are not required for the TEP [CSTS].

g) Decommissioning

The design of the TEP [CSTS] considers the decommissioning. A certain gradient

is set in the pipeline layout to prevent liquid accumulation and all equipment and pipes can be drained by draining lines.

h) Material Selection

To avoid corrosion, all the parts of the TEP [CSTS] containing boric acid and reactor coolant are made of austenitic stainless steel, such as the pumps, valves, pipes and tanks.

i) Special Thermal-hydraulic Phenomena

In order to ensure the functional reliability of the system and to prevent challenges in performing the safety functions, the hydraulic phenomena listed below shall be carefully considered in TEP [CSTS] design:

1) Phenomenon regarding the dead leg;

2) Phenomenon regarding the hot water and cold water mixing;

3) Phenomenon regarding the thermal stratification;

4) Phenomenon regarding the water hammer.

j) Insulation

The pipes and components containing fluid with a temperature grater 60 °C require insulation design to protect workers.

10.4.5.6 Simplified Diagrams

The simplified system diagram is presented in Figure F-10.4-3, the detailed system functional diagram is in Reference [31].

10.4.6 Nuclear Sampling System (REN [NSS])

The Nuclear Sampling System (REN [NSS]) falls into the category of auxiliary systems. The REN [NSS] mainly enables centralised analysis and determination of the chemical and radio-chemical characteristics of samples taken from the RCP [RCS], secondary side of the SGs, nuclear auxiliary systems and liquid waste and gaseous waste treatment system. The REN [NSS] comprises three subsystems: the primary sampling system, secondary sampling system and post-accident sampling system. The main components of the REN [NSS] (sampling coolers, pumps, tanks, glove boxes and analysers) are located in the Fuel Building (BFX) and Nuclear Auxiliary Building (BNX) of the Nuclear Island (NI). Information of the system is presented in the SDM, Reference [32].

10.4.6.1 Safety Functional Requirements

10.4.6.1.1 Control of Reactivity

The REN [NSS] contributes to the control of reactivity by isolating the high

temperature sampling cooler to prevent dilution accidents in DBC-4 conditions.

10.4.6.1.2 Removal of Heat

The REN [NSS] does not directly contribute to this safety function.

10.4.6.1.3 Confinement

The REN [NSS] contributes to the confinement of radioactive substances:

a) Containment isolation: Sample lines penetrating the containment shall be isolated to prevent the leakage of radioactive fluid in accident conditions (as the third containment barrier);

b) RCPB isolation: Isolation valves in the three primary sampling lines connected to the reactor coolant system shall be isolated in the event of a line failure outside the containment to maintain RCPB integrity (as the third containment barrier);

c) SG sampling lines isolation: The SG sampling lines shall be isolated in the event of SGTR to confine activity in the failed SG (as the second containment barrier);

d) Confinement of radioactive substances: The REN [NSS] primary sampling lines shall confine the radioactive substances when transporting radioactive substances in normal operating conditions. The secondary sampling lines shall confine the radioactive substances when the primary fluid leaks into the secondary circuit.

10.4.6.1.4 Extra Safety Functions

a) The REN [NSS] shall provide boron concentration monitoring of the primary coolant to support the control of reactivity.

b) The REN [NSS] shall provide samples for activity monitoring to support the confinement of radioactive substances:

    1) The REN [NSS] shall provide appropriate liquid samples for evaluation of the primary coolant activity to detect the integrity of the fuel cladding;

    2) The REN [NSS] shall provide appropriate liquid samples for evaluation of the secondary fluid activity to detect the integrity of the SGs;

    3) The REN [NSS] shall provide appropriate liquid samples from the IRWST after accidents to evaluate the effect of accidents on the environment;

    4) The REN [NSS] shall provide appropriate gaseous samples inside the containment after accidents to evaluate the effect of accidents on the environment.

10.4.6.2 Design Requirements

The general design requirements of the nuclear auxiliary systems which need to be considered are shown in Sub-chapter 10.2.4, among which the following requirements

are not applicable for the REN [NSS]:

a) Autonomy in Respect of the Heat Sink

Not applicable, because the REN [NSS] doesn't provide a heat sink to the power plant.

b) Diversity

Not applicable. There's no diversity design in the REN [NSS].

c) Fail-safe

Not applicable. There's no fail-safe designed equipment in the REN [NSS].

The substantiation analysis of the REN [NSS] to other design requirements is shown in the Sub-chapter 10.4.6.5.

10.4.6.3 Design Bases

This sub-chapter aims to provide the main design assumptions considered in the system design.

10.4.6.3.1 General Assumptions

a) Safety Classification

The RCPB isolation function is required to confine the radioactive substances in DBC-3/4 conditions, the function category is FC2.

The containment isolation function is required to confine the radioactive substances after a design basis accident, the function category is FC1.

The high temperature sampling cooler isolation function is required to prevent dilution accident in DBC-4 conditions, the function category is FC2.

The primary sampling function is required to provide boron concentration monitoring of the primary coolant, the function category is FC3.

The SG secondary side sampling (to the Plant Radiation Monitoring System (KRT [PRMS])) function is required to detect the leakage of the SG tubes, the function category is FC2.

The SG sampling isolation function is required to confine activity in the failed SG in a SGTR accident, the function category is FC2.

The confinement of radioactive substances function is required to prevent release of radioactivity in normal operating condition, the function category is FC3.

The post-accident IRWST sampling function is required to provide information of the effects of the accident on the environment in accident conditions, the function category is FC3.

The post-accident sampling of the containment gaseous phase function is required to provide information of the effects of the accident on the environment in accident conditions, the function category is FC3.

b) Ageing and Degradation

According to Chapter 2, the operational design life of the UK HPR1000 is 60 years. The main components of the REN [NSS] are required to have a service life of 60 years.

The ageing effect must be considered in the design of components such as the heat exchangers. A sufficient margin must be taken in the sizing of high temperature heat exchangers of the REN [NSS].

c) Considerations Related to the Electrical Power Grid

The functionality of items important to safety at the nuclear power plant shall not be compromised by disturbances in the electrical power grid, including anticipated variations in the voltage and frequency of the grid supply, which is considered as 49.5Hz-50.5Hz according to the design of the HPR1000 (FCG3). It will be adjusted in the future design phases based on the actual conditions of the UK.

10.4.6.3.2 Design Assumptions

This sub-chapter aims to provide the main design assumptions considered in the system design.

a) Control of Reactivity

Not applicable. The REN [NSS] system does not directly contribute to the safety function of control of reactivity.

b) Removal of Heat

Not applicable. The REN system does not directly contribute to the safety function of removal of heat.

c) Confinement

There’s no quantitative safety-related design assumption.

d) Extra Safety Functions

Not applicable. There’s no quantitative safety-related design assumption for the REN [NSS].

10.4.6.4 System Description and Operation

10.4.6.4.1 System Description

a) General System Description

1) Primary Sampling System

The REN [NSS] comprises two subsystems: the primary sampling system and secondary sampling system.

The primary sampling system collects liquid and gaseous samples from the primary coolant system, primary auxiliary systems, liquid and gaseous waste treatment systems to determine the physical and chemical characteristics of these samples by measurements and analysis. These samples are categorised as active liquid, slightly active liquid or gaseous ones.

The primary sampling lines are equipped with a boron meter, a hydrogen meter, an oxygen meter and a phase separator. Each of the analysers mentioned above is connected to the sampling lines of the RCP [RCS], RIS [SIS] and RCV [CVCS]. Gaseous samples are collected via degassers from nozzles.

The backfeed tank recycles the primary samples for the RCV [CVCS] or transfers them to the Nuclear Island Vent and Drain System (RPE [VDS]).

The sampling line upstream of the backfeed tank is equipped with an activity measurement device which belongs to the KRT [PRMS].

2) Secondary Sampling System

The secondary sampling system collects liquid samples from the SGs, Steam Generator Blowdown System (APG [SGBS]) and the APG [SGBS] purification to analyse the water quality and radioactivity.

Each sampling line of the APG [SGBS] is equipped with a pH meter, a conductivity meter and an activity measurement device which belongs to the KRT [PRMS]. A sodium meter is connected to the three SG sampling lines.

Each sampling line of the APG [SGBS] purification is equipped with a conductivity meter. A sodium meter is connected to the two APG anion demineralization beds sampling lines.

There is a backfeed tank which recycles the secondary samples to the APG [SGBS] or transfers them to the RPE [VDS].

3) Post-Accident Sampling System

The post-accident sampling system is used to obtain gaseous and liquid samples in the containment after accidents. The sampling points are as

follows:

- Containment atmosphere;
- In-containment Refuelling Water Storage Tank (IRWST), through the Containment Heat Removal System (EHR [CHRS]).

The post-accident sampling system is mainly composed of the following parts:

- Containment isolation valves;
- Two trains of containment atmosphere sampling lines;
- Two trains of EHR [CHRS] sampling lines;
- Sample return lines;
- Sample processing module;
- Local control cabinet.

Detailed information of the systems is presented in the SDM, Reference [33].

b) Description of Main Equipment

1) High Temperature Heat Exchangers

The primary and secondary heat exchangers are designed to cool down the samples of the RCP [RCS] and SGs.

2) Sample Coolers

The sample Coolers are designed to provide the constant inlet temperatures required by the on-line analysers and grab sampling.

3) Backfeed Pumps

The sample backfeed pumps are designed to recycle the samples from the backfeed vessel to the RCV [CVCS] (for primary samples) or APG [SGBS] (for secondary samples).

4) Sampling Glove Boxes

Sampling glove boxes are provided with gloves and a hatch. Both the inlet and outlet of glove boxes are provided with filters. All the glove boxes are equipped with fans and are connected to the DWN [NABVS] to evacuate the air in the glove box to the venting system and ensure the negative pressure to prevent gas from leaking to the laboratory atmosphere. Design parameters are shown in the Table T-10.4-18, detailed information is presented in the SDM, Reference [33].

T-10.4-18 Parameters of sampling glove boxes

Parameter	Technical Data
Design pressure	0.0025MPa g
Design temperature	50°C
Material	Stainless steel
Component classification	NC

5) Online Analysers

The parameters of primary and secondary samples are monitored continuously by on-line analysers. The REN [NSS] contains the following on-line analysers: a boron meter, a hydrogen meter, an oxygen meter, two sodium meters, three pH meters and seven conductivity meters.

The detailed information of the equipment design is presented in the SDM, Reference [33].

b) Description of Main Layout

Most of the REN [NSS] is arranged in the Nuclear Auxiliary Building (BNX) except for the high temperature heat exchangers and high pressure reducing valves in the Fuel Building (BFX).

Detailed design information about the system layout is presented in the SDM, Reference [34].

c) Description of System Interfaces

1) RRI [CCWS]

The RRI [CCWS] supplies cooling water to primary and secondary sample high temperature heat exchangers.

2) Operational Chilled Water System (DER [COWS])

The DER [COWS] supplies chilled water to the sample coolers to cool down the sample streams upstream of the on-line analysers and for grab sampling.

3) KRT [PRMS]

This system provides on-line monitoring for the activity of primary and secondary samples.

Detailed information of the interface systems is presented in the SDM, Reference [33].

d) Description of Instrumentation and Control

During normal plant operation, continuous monitoring of the primary coolant and SG blowdown water is performed by online analysers. These sample lines are automatically isolated at the containment isolation signal.

Detailed information of the system I&C design is presented in the SDM, Reference [35].

10.4.6.4.2 System Operation

a) Plant Normal Conditions

1) Primary Sampling Lines

During normal operation, the sampling lines of the primary coolant operate continuously and the samples are transported to the online analysers in the BNX. Furthermore, liquid and gaseous grab samples could be taken intermittently and sent to the laboratory for further analysis.

During plant shutdown and reactor refuelling conditions while in RHR mode, samples are taken from the RIS [SIS].

The content of the tank is recycled continuously.

2) Secondary Sampling Lines

During normal operation, the sampling lines of the SG blowdown water and the APG [SGBS] purification operate continuously and the samples are transported to the online analysers in the BNX. Furthermore, grab samples could be taken intermittently and sent to the laboratory for further analysis.

The sampling lines of nozzles on the SG feedwater are isolated.

3) Post-Accident Sampling System

The post-accident sampling system is not used during normal conditions. All the valves of the system are closed and pipe tracing is shut off. The NI Dematerialised Water Distribution System (SED [DWDS (NI)]) is on standby.

b) Plant Accident Conditions

1) Post-Accident Sampling of Primary Coolant

During accident conditions, the containment isolation valves of the primary sampling lines are automatically closed when receiving the containment isolation signal. After a certain time, if it is required to know the boron concentration and activity of the primary coolant, the primary sampling lines can be reopened when sampling can be conducted in the radiological conditions of the sampling room. The samples are re-injected in to the containment through the RPE [VDS].

2) Post-Accident Sampling of SGs

During accident conditions, the containment isolation valves of the secondary sampling lines are automatically closed when receiving the containment isolation signal. After a certain time, if it is required to know the state of the SGs, the secondary sampling lines can be reopened when sampling can be conducted in the radiological conditions of the sampling room.

The SG blowdown sampling lines in the BFX will be isolated automatically from the BNX by motor-operated isolation valves when there is a pipe pinch or break in the BNX, to ensure the flow to the KRT [PRMS] in the BFX and thus maintain the activity monitoring.

Detailed information of the system operation is presented in the SDM, Reference [35].

3) Post-accident Sampling System

In accident conditions, the post-accident sampling system is used to monitor the radioactivity of the containment atmosphere and water in the IRWST. Measurement results are used to evaluate the core status and potential radiological risks.

10.4.6.5 Preliminary Design Substantiation

In this section, the system design is demonstrated to satisfy the safety functional requirements presented in Sub-chapter 10.4.6.1 and the general design requirements stated in Sub-chapter 10.2.4.

Since the general principles are newly developed at this stage, the system design is still based on the reference design and the information presented in this section is preliminary. A review of the consistency of the system design against the newly developed principles is currently being undertaken.

10.4.6.5.1 Compliance with Safety Functional Requirements

a) Control of Reactivity

The isolation valves of the high temperature sampling cooler are closed manually to prevent dilution accidents in DBC-4 conditions.

b) Removal of Heat

Not applicable.

c) Confinement

1) Containment isolation: Sample lines penetrating the containment are equipped with two containment isolation valves. In accident conditions, the valves are isolated at the containment isolation signal from the reactor

protection system to prevent the leakage of radioactive fluid;

2) RCPB isolation: Each of the three primary sampling lines connected to the reactor coolant system are equipped with two containment isolation valves and a motor-operated isolation valve. In the event of failure of a line outside the containment or equipment containing radioactivity, these valves are closed manually to isolate the failed line and limit the loss of reactor coolant and thus limit radioactivity release;

3) SG sampling lines isolation: Each of the three SG sampling lines is equipped with two containment isolation valves and a motor-operated isolation valve which belongs to upstream system (APG [SGBS] or RCP [RCS]). In the event of SGTR, these valves are closed manually to confine activity in the failed SG;

4) Confinement of radioactive substances: The part of REN [NSS] containing radioactive substances is functionally classified as F-SC3, the design provision class is B-SC3, such that the confinement capability is ensured.

d) Extra Safety Functions

1) To support the control of reactivity:

The REN [NSS] can provide the required boron concentration of the primary coolant, an online boron meter is designed in the system with a sufficient designed flow rate.

2) To support the confinement:

The REN [NSS] can ensure a sufficient flow rate of samples for activity evaluation by the KRT [PRMS].

The REN [NSS] can ensure that the samples provided are representative, the time for sending the samples from sampling points to on-line analysers or the grab sampling rack is limited and that the sample flowrate and pipe diameter are selected to fulfil the sampling requirements. The sampling flow in the pipes is ensured to be a turbulent flow to avoid pipe deposits. There are as few low points and dead zones as possible in the arrangement of sampling pipes, to avoid deposits of solid particles in the pipes.

Detailed design information is presented in Reference [36] and [33].

10.4.6.5.2 Compliance with Design Requirements

a) Safety Classification

The REN [NSS] design is compliant with the requirements described in the Chapter 4. The safety classification of the REN [NSS] functions is listed in Table T-10.4-19 and the safety classification of main components is listed in Table

T-10.4-20.

T-10.4-19 Function Categorisation of the REN [NSS]

System Function	Function Category
RCPB isolation	FC2
Containment isolation	FC1
High temperature sampling cooler isolation	FC2
Primary sampling	FC3
SG secondary side sampling (to the Plant Radiation Monitoring System (KRT [PRMS]))	FC2
SG sampling isolation	FC2
Confinement of radioactive substances	FC3
Post-accident IRWST sampling	FC3
Post-accident sampling of the containment gaseous phase	FC3

T-10.4-20 Classification for Components

Component	Function Class	Design Provision Category	Design Provision Class	Seismic Category
Sampling line of the RCP [RCS]				
To the first isolation valve (including isolation valve)	F-SC1	DPA	B-SC2	SSE1
To the containment isolation valve	F-SC3	DPL	B-SC3	SSE2
Containment penetration (including containment isolation valve)	F-SC1	DPA	B-SC2	SSE1
High temperature sampling cooler	F-SC2	DPL	B-SC3	SSE1
Rest of the system	F-SC3	DPL	B-SC3	NO

Component	Function Class	Design Provision Category	Design Provision Class	Seismic Category
Sampling line of RIS [SIS] accumulators				
To the containment isolation valve	F-SC3	DPL	B-SC3	SSE2
Containment penetration (including containment penetration)	F-SC1	DPA	B-SC2	SSE1
Rest of the system	F-SC3	DPL	B-SC3	NO
Sampling line of the steam generator				
To the containment isolation valve	F-SC2	DPL	B-SC3	SSE1
Containment penetration (including containment penetration)	F-SC1	DPA	B-SC2	SSE1
Fuel building line	F-SC2	DPL	B-SC3	SSE1
Nuclear auxiliary building line	F-SC3	DPL	B-SC3	NO
Sampling line of APG [SGBS] purification	NC	-	NC	NO
Sampling line of containment atmosphere (normal operation)				
Containment penetration (including containment isolation valve)	F-SC1	DPA	B-SC2	SSE1
Rest of the system	F-SC3	DPL	B-SC3	SSE2
Sampling line of containment atmosphere and In-containment Refuelling Water Storage Tank (IRWST) water (post-accident)				
Containment penetration (including containment isolation valve)	F-SC1	DPA	B-SC2	SSE1
Rest of the system	F-SC3	-	NC	SSE1

b) Engineering Design Requirements

1) Reliability Design of SSCs

- Single Failure Criterion (SFC)

  Each sampling line crossing the double wall of the containment is equipped with two classified isolation valves (one inside and the other outside), each of which is powered by an independent electrical train, to fulfil redundancy requirements (mechanical and electrical).

  The SG sampling lines can measure the activity of the SG liquid phases (SG activity monitoring function), which is not redundant. The functional redundancy of the SG activity monitoring function can be performed by SG steam phase activity measurement.

- Independence

  The two containment isolation valves are physically separated by the installation location, one inside and the other outside the containment.

  The SG sampling lines used to measure the activity of the SGs are functionally redundant to the activity measurement in the Main Steam System (VVP [MSS]). The KRT [PRMS] measurements in the REN [NSS] and in the VVP [MSS] are physically separated by the installation location, one in the BFX, and the other in the Reactor Building (BRX).

- Diversity

  Not applicable.

- Fail-safe

  Not applicable.

- Ageing and Degradation

  The plant design life is 60 years. The service life of some of the main components of the system is also 60 years. For example the sample backfeed pump, sample backfeed tank, high/low temperature sampling coolers, etc.

  The REN [NSS] considers the requirements stated in Sub-chapter 10.2.4, and the design considerations and measures described in Sub-chapter 10.2.4 are applied in the design of the REN [NSS].

  The detailed design arrangement of EMIT and equipment monitoring is presented in the SDM, Reference [35].

2) Human Factors

The REN [NSS] considers the requirements stated in Sub-chapter 10.2.4, and the design considerations and measures described in Sub-chapter 10.2.4 are applied in the design of the REN [NSS].

The REN [NSS] does not require short term operator intervention. Detailed information about automatic control design of the system is presented in the SDM, Reference [35].

3) Autonomy

- Autonomy in Respect of Operators

  The design principles relevant to the autonomy in respect of operators are detailed in Reference [1]. The design of the REN [NSS] fulfils these principles via control functional design. Detailed information is presented in the SDM, Reference [35].

- Autonomy in Respect of the Heat Sink

  Not applicable.

- Autonomy in Respect of Power Supply Systems

  The safety classified components, such as the primary sample backfeed pump, are all provided with emergency diesel generators.

4) Other design requirements

- Prevention of Harmful Interactions of Systems Important to Safety

  When the water level exceeds the overflow level, and that overflow to the RPE [VDS] fails, a protection signal is triggered and all the sampling lines (RCP [RCS], RIS [SIS] RHR, RCV [CVCS]) are isolated to prevent samples from overflowing into the Gaseous Waste Treatment System (TEG [GWTS]), causing damage to equipment of the TEG [GWTS].

- Considerations Related to the Electrical Power Grid

  The design of active components such as the sample backfeed pumps in the REN [NSS] has taken the disturbances in the electrical power grid into consideration. Detailed design information of the electrical power grid is presented in Reference [36].

c) Equipment Qualification

All the components of the REN [NSS] required to perform safety functions, such as the containment isolation valves, are capable of operating under both normal and accident conditions. As a result, the components can withstand the most adverse environmental conditions expected.

All the seismically classified components of the REN [NSS] shall be capable of operating during and after the SSE. The secondary high temperature coolers and the containment isolation valves are seismic designed and qualified for the SSE load.

The documents relevant to the equipment qualification will be delivered before the step 4 of GDA.

d) Protection Design against Internal and External Hazards

The REN [NSS] considers the requirements stated in Sub-chapter 10.2.4, and the design considerations and measures described in Sub-chapter 10.2.4 are applied in the design of the REN [NSS].

e) Commissioning

Before operation, commissioning and tests are carried out to verify that the performance of the REN [NSS] meets the design requirements. The main commissioning test of the REN [NSS] includes tests for pumps, tanks, the heat exchanger, on-line analyser and sampling grove box.

Documents related to the commissioning will be delivered before the step 4 of GDA.

f) Examination, Inspection, Maintenance and Testing

1) Inspections and Surveillance

In-service inspection is implemented for the equipment of the REN [NSS], including the primary backfeed tank and high temperature sampling coolers for primary and secondary sampling.

2) Maintenance

Instrument maintenance of the REN [NSS] includes calibration and validation of chemical analysers (boron meter, hydrogen analyser, oxygen analyser, sodium meter, pH meter and conductivity meter). The maintenance period depends on:

- Plant operation technical specifications;
- Feedback of operating experience;
- Manufactures' recommendations.

The maintenance of valves of the REN [NSS] and other mechanical equipment mainly depends on the manufacturers' recommendations and feedback of operating experience. It's determined according to the availability of equipment and usually arranged during the shutdown state. Equipment maintenance is performed according to equipment operation and the maintenance manual.

3) Periodic Tests

Equipment performing safety functions shall be subject to periodic testing,

mainly consisting of the containment isolation valves. Detailed information on components requiring periodic tests is shown in the SDM, Reference [35].

For the UK HPR1000, the periodic test design will also be adapted from those developed for the HPR1000 (FCG3). Documents related to the periodic tests will be delivered before the step 4 of GDA.

a) Decommissioning

The design of the REN [NSS] considers the decommissioning. A certain gradient is set in the pipeline layout to prevent liquid accumulation and all equipment and pipes can be drained by draining lines.

g) Material Selection

All parts of the REN [NSS] are made of stainless steel to prevent corrosion and facilitate decontamination after sampling. Only the pipelines transporting the cooling water are made of carbon steel.

h) Special Thermal-hydraulic Phenomena

In order to ensure the function reliability of the system and to prevent challenges to performing the safety functions, the hydraulic phenomena listed below shall be carefully considered in REA [RBWMS] design:

1) Phenomenon regarding the dead leg;

2) Phenomenon regarding the hot water and cold water mixing;

3) Phenomenon regarding the thermal stratification;

4) Phenomenon regarding the water hammer.

i) Insulation

Insulation is mainly considered for operators' safety. Accessible equipment or pipelines with a high surface temperature shall be insulated to prevent burns.

Insulation is required since the operating temperature of the following lines is above 60 °C:

- The sampling lines from the Reactor Coolant System (RCP [RCS]) up to the high temperature sampling cooler;
- The sampling lines from the Safety Injection System (RIS [SIS]) RHR heat exchangers up to the high temperature sampling cooler;
- The sampling lines from the end of the boron concentration monitoring circuit up to the sampling cooler;
- The sampling lines from the SG up to the high temperature sampling

cooler.

Anti-condensation measures are required for the lines of the Operational Chilled Water System (DER [OCWS]) and the shell side of the low temperature sampling coolers since the operating temperature of the DER [OCWS] is between 7°C and 12°C.

10.4.6.6 Simplified Diagrams

The simplified system diagrams are presented in Figures F-10.4-4 and F-10.4-5.

10.4.7 Fuel Pool Cooling and Treatment System (PTR [FPCTS])

The Fuel Pool Cooling and Treatment System (PTR [FPCTS]) falls into the category of auxiliary system. The PTR [FPCTS] shall supply the sub-critical margin and remove the decay heat for the fuel assemblies stored in the Spent Fuel Pool (SFP). The cooling function is performed by three cooling trains arranged in the BFX. The penetration in to the PTR [FPCTS] should ensure the integrity of the containment, to ensure the confinement of radioactive substances. Furthermore, the PTR [FPCTS] provides the water purification, filling and discharge for the reactor pools, BFX pools, IRWST and the In-Vessel Retention (IVR) tank. Skimming of the reactor pools and the BFX pools is also performed by the PTR [FPCTS]. Information of the system is presented in the SDM, Reference [37].

10.4.7.1 Safety Functional Requirements

10.4.7.1.1 Control of Reactivity

The PTR [FPCTS] does not directly contribute to the reactivity control of the reactor core and spent fuel, but shall provide a sub-critical margin for the spent fuel in the SFP.

10.4.7.1.2 Removal of Heat

The PTR [FPCTS] shall remove the decay heat of the fuel assemblies stored in the SFP in normal and accident conditions (DBC-1/2/3/4 and DEC-A) by cooling the SFP.

For the residual heat removal, the water temperature of the SFP shall be limited to ensure the spent fuel cooling.

The level of water in the pools shall be maintained to prevent uncovering the spent fuel during fuel assembly handling.

10.4.7.1.3 Confinement

The PTR [FPCTS] shall ensure the confinement of radioactive substances to prevent discharge to the environment by the isolation of the containment.

10.4.7.1.4 Extra Safety Functions

The PTR [FPCTS] shall perform extra safety functions, such as:

a) Monitoring of the reactor pools level, SFP level and temperature in normal and accident conditions (DBC-1/2/3/4 and DEC-A) to provide information supporting the removal of heat safety function;

b) Detection of a decrease in the water level in the SFP in normal and accident conditions (DBC-1/2/3/4 and DEC-A);

c) Detection of a high or low temperature in the SFP in normal and accident conditions (DBC-1/2/3/4 and DEC-A).

Detailed safety functional requirements are presented in SDM, Reference [38].

10.4.7.2 Design Requirements

The general design requirements of the nuclear auxiliary systems need to be considered are shown in Sub-chapter 10.2.4, among which the following requirements are not applicable for the PTR [FPCTS] system:

a) Fail-safe

Not applicable. There's no fail-safe designed equipment in the PTR [FPCTS].

b) Autonomy in Respect of the Heat Sink

Not applicable, the PTR [FPCTS] system doesn't provide heat sink to the power plant.

c) Prevention of Harmful Interactions of Systems Important to Safety

Not applicable, the PTR [FPCTS] doesn't have harmful interactions of systems important to safety.

d) Insulation

Not applicable, the temperature of the fluid in pipelines and components of the PTR [FPCTS] doesn't exceed 50 °C in normal operation.

The substantiation analysis of the PTR [FPCTS] system to other design requirements is shown in the section 10.4.7.5.2 *Compliance with Design Requirements*.

10.4.7.3 Design Bases

This sub-chapter aims to provide the main assumptions considered in the PTR [FPCTS] design.

10.4.7.3.1 General Assumptions

a) Safety Classification

The safety classification for the PTR [FPCTS] is based on the following methodology:

The containment isolation function is required to confine the radioactive substances in DBC conditions, the function category is FC1.

The isolation function of the SFP cooling trains and of the draining lines at the bottom of the BRX and BFX pools (except the SFP) is required to stop the drainage of the pools in DBC conditions, the function category is FC1.

The cooling function of the SFP is required to remove the residual heat in accident conditions, the function category is FC2.

The accident overflow function from the BRX Pools to the IRWST is required to maintain the dynamic balance between the reactor pool and IRWST in accident conditions, the function category is FC1.

The accident water make-up function of the SFP is required to compensate for the water loss during the event of total loss of cooling trains, the function category is FC3.

b) Ageing and Degradation

According to Chapter 2, the operational design life of the UK HPR1000 is 60 years. The main components of the PTR [FPCTS] are required to have a service life of 60 years.

c) Considerations Related to the Electrical Power Grid

The functionality of items important to safety at the nuclear power plant shall not be compromised by disturbances in the electrical power grid, including anticipated variations in the voltage and frequency of the grid supply, which is considered as 49.5Hz-50.5Hz according to the design of the HPR1000 (FCG3). It will be adjusted in the future design phases based on the actual conditions of the UK.

10.4.7.3.2 Design Assumptions

a) Control of Reactivity

There is no quantitative assumption for the PTR [FPCTS].

b) Removal of Heat

For the residual heat removal, the PTR [FPCTS] cooling trains shall meet the following assumptions:

1) The design basis heat load is considered to be the maximum value in the SFP during reactor power operation and reactor complete discharge mode;

2) The water temperature of the SFP shall not exceed the limited values as follows: 50°C under the DBC-1 conditions (the maximum temperature of cooling water is 38°C) and 80°C under the DBC-2/3/4 conditions (the maximum temperature of cooling water is 45°C);

3) The water temperature of the SFP shall not exceed 95°C under DEC conditions except following the total loss of cooling (the maximum temperature of cooling water is 45°C);

4) The cooling trains can be recovered when the water boils in the SFP.

Considering the thermal load of the SFP and the design of heat exchangers, the minimum flow rate of the cooling train is designed as { }. The level of water in the pools shall not be lower than +14.1m in case of drainage accidents to prevent uncovering of the fuel assembly in handling.

In the accident condition of total loss of the cooling trains, the flowrate of the SFP emergency makeup water is designed based on the maximum thermal load.

c) Confinement

There is no quantitative design assumption for the PTR [FPCTS].

d) Extra Safety Functions

There is no quantitative design assumption for the PTR [FPCTS].

10.4.7.4 System Description and Operation

10.4.7.4.1 System Description

a) General System Description

The PTR [FPCTS] consists of four parts which are described as below.

1) The SFP Cooling

Three cooling trains are arranged in the fuel building for the PTR [FPCTS]. Each cooling train is equipped with one suction line, one SFP cooling pump, one heat exchanger and one discharge line. Cooling trains A and B are supplied with cooling water by train A and B of the RRI [CCWS], while the backup cooling is provided by train A and B of the ECS [ECS]. Train C is supplied with cooling water only by train C of the RRI [CCWS].

The trains are separately supplied with power by different electrical divisions. Trains A and B are supplied with backup power by Emergency Diesel Generators (EDGs) and SBO diesel generators, and train C is supplied with backup power only by EDGs.

Each cooling train is arranged with two motorised isolation valves in series at the suction, which can receive the automatic isolation signals in the case of low liquid level of the SFP. These two motorised isolation valves are supplied with power by different electrical divisions. Each cooling train is arranged with one check valve at the discharge to prevent siphoning caused by an upstream break.

There are lines connected to each other downstream of the three cooling pumps. The pump in one train can be connected to the heat exchanger of another train if necessary, thus a new cooling train to cool the SFP can be arranged.

The suction and discharge of the cooling trains (except the suction of train C) are arranged with siphon breakers to prevent an unacceptable decrease of the SFP after accidental draining. The suction location of train C is lower than trains A and B. When there is a break on train A or B, and the pool liquid level decreases below the elevation of the train A or B penetrations, train C can still operate to cool the SFP.

The cooling train sampling is used to inspect the water quality of the SFP, including boron concentration, chemical impurity content and radioactivity level.

2) Purification and Water Transfer

The maximum operating temperature of purification shall consider the technological limitation of the resin, and the flowrate of purification is considered to be able to purify the water in the SFP or the reactor pool in about 24 hours.

The filtration filters must be fine enough to ensure clarity of the pool water so that fuel handling operations can be monitored under water and to ensure the protection of the operators.

The purification system of the SFP is equipped with one purification pump, one filter, one mixed bed demineraliser and one resin trap filter. The pipeline from the bottom of the fuel building pools (except the SFP) to the pump inlet is equipped with two motorised isolation valves which will be automatically closed in the case of low water level in the SFP. In the case of accidental draining, these two isolation valves can ensure automatic double isolation.

The purification system of the reactor pool is equipped with one purification pump and one filter. The pipeline from the bottom of the reactor pool to the pump inlet is also equipped with two motorised isolation valves.

The purification pumps are supplied with power by different electrical divisions. These two pumps can be backed up by each other. The reactor pool

purification filter can be the backed up by the SFP purification filter.

If required, the purification unit for the SFP can also be used for purifying the IRWST and IVR tank.

The purification pumps can also be used to transfer water between the fuel building transfer compartment and the cask loading pit. In this case, the purification unit (including two filters and the demineraliser) is bypassed.

Before unloading, the purification pumps can be used to fill the reactor pool from the IRWST. After reloading, the water in the reactor pool can be drained to the IRWST by gravitational drain pipeline or by the purification pumps.

3) Skimming

The surface skimming shall ensure the sufficient clarity of the water and also enables the reduction of radiation due to activation of impurities at the pool surface.

The skimming system for the SFP is equipped with one skimming pump and one filter.

The skimming system for the reactor pool uses floating skimming device to ensure that the skimming function is available when the pool liquid level changes. This circuit is equipped with one skimming pump. The outlet of the skimming pump is connected to the inlet of the reactor pool purification pump.

4) Water Return to the IRWST

In case of a Loss of Coolant Accident (LOCA) during the power operation, the draining lines at the bottom of the reactor pools in the PTR [FPCTS] ensures that water is returned to the IRWST for the operation of the RIS [SIS] pumps.

After shutdown, when a small break which can’t be isolated occurs on the primary circuit, or a when TLOCC or SBO occurs, the RIS [SIS] pump must be started to inject fluid into the primary circuit. Furthermore, the isolation valves on the accident overflow line for the reactor pool must be opened to achieve a dynamic balance between the reactor pool and the IRWST to maintain an appropriate water level.

5) Filling and Water Makeup

The REA [RBWMS] provides the initial water filling or the borated water makeup to the SFP, IRWST and IVR tank.

The SED [DWDS (NI)] can be used to compensate for the normal evaporation loss of the SFP.

In the case of total loss of the PTR [FPCTS] cooling trains, the following means can be used for the SFP makeup:

- The gravitational makeup pipeline of the ASP [SPHRS] water tank;
- The emergency makeup line through the external makeup interface.

b) Description of Main Equipment

The main equipment of the PTR [FPCTS] is described below, and detailed information of other equipment is presented in the SDM, Reference [39].

1) Cooling Pumps

Each cooling train has a cooling pump to drive fluid from the SFP to the exchanger.

The cooling pumps are horizontal centrifugal pumps. The nominal flowrate of the pump is based on the required mass flowrate of the exchanger. The following table gives the characteristics of the pumps:

T-10.4-21 Characteristics of the Cooling Pumps

Parameters	Value	Unit
Type	Centrifugal Pump	
Nominal Flowrate	640	m^3/h
Discharge Head at Nominal Flowrate	36	mWc
Material	Stainless Steel	

2) Exchangers

Each cooling train has an exchanger to remove the decay heat of the fuel assemblies stored in the SFP. The design flowrate ensure that the decay heat of the SFP can be removed in normal and accident conditions. The following table gives the characteristics of the exchangers:

T-10.4-22 Characteristics of the Exchanger

Parameters	Value		Unit
Type	Shell & Tube		
	Hot Side	Cold Side	---
Design Thermal Load	{ }		MW
Medium	Borated Water	Component Cooling Water	---
Design Pressure	1	2.9 (Train A and B) 1.35 (Train C)	MPa (g)
Design Temperature	110	90	°C
Design Flowrate	{ }	{ } (All Normal Operation Modes Except Refuelling	t/h

Parameters	Value		Unit
		Cold Shutdown and Reactor Complete Discharge Mode, it is then supplied by the RRI [CCWS]), { } (Refuelling Cold Shutdown and Reactor Complete Defueling Mode, it is then supplied by the RRI [CCWS]) { } (supplied by the ECS [ECS])	
Material	SS	CS	---

c) Description of Main Layout

The three PTR [FPCTS] cooling trains are arranged in three different areas in the BFX, which are physically separated from each other.

The filters and demineraliser are located in the BNX.

The skimming pump of the reactor pool, pipelines for purification and water transfer connected to the BRX pools are located in the BRX.

The rest of the PTR [FPCTS] is located in the BFX.

d) Description of System Interfaces

1) ASP [SPHRS]

When the cooling trains fail, the ASP [SPHRS] will make up water to the SFP to compensate for the loss due to evaporation.

2) ECS [ECS]

The ECS [ECS] cools the heat exchanger of train A and B.

3) The Containment Heat Removal System (EHR [CHRS])

The PTR [FPCTS] can purify the IVR tank.

4) RCV [CVCS]

For the PTR [FPCTS], the RCV [CVCS] can:

Provide suction from the IRWST for purification or water transfers. The purification pump suction is connected to the RCV [CVCS] lines allowing suction from the IRWST;

Transfer nitrogen from the Nitrogen Distribution System (SGN [NDS]) to

perform maintenance operations on the demineraliser.

5) REA [RBWMS]

The REA [RBWMS] carries out initial filling of the IRWST, IVR tank, SFP and one of the compartments of the transfer compartment and cask loading pit with borated water through the PTR [FPCTS] lines.

The borated water makeup of the SFP, IRWST and IVR tank can also be carried out via the REA [RBWMS].

6) REN [NSS]

The REN [NSS] must be able to take samples from the SFP, IRWST, IVR tank and the reactor pool to monitor the radioactivity and boron concentration.

7) RIS [SIS]

The PTR [FPCTS] enables for water to drain from the reactor pool to the IRWST. This makeup to the IRWST ensures a sufficient level in the IRWST for the operation of the RIS [SIS]/EHR [CHRS] pumps required in a small LOCA, SBO or TLOCC after the reactor pressure vessel is opened.

The PTR [FPCTS] can also purify the IRWST.

8) RRI [CCWS]

The RRI [CCWS] cools the heat exchangers of the three cooling trains.

9) SED [DWDS (NI)]

The SED [DWDS (NI)] provides makeup to the SFP to compensate for normal evaporation.

a) Description of Instrumentation and Control

According to the PTR [FPCTS] functions and configurations, the main control and monitoring requirements are as follows:

1) Containment Isolation

The PTR [FPCTS] closes the containment isolation valves automatically when the signal of containment first stage isolation is received from the reactor protection system.

2) Volume Control of the SFP

The level set points of the SFP are arranged to avoid the loss of water and uncovering of the fuel assemblies. When the level in the SFP decreases, automatic isolating actions will be implemented.

The level of the SFP is monitored by redundant sensors, the safety function can be performed by them.

3) Volume Control of the Reactor Pool

The level set points of the reactor pool are arranged to avoid the loss of water and uncovering of a fuel assembly during handling. When the level decreases, the valves at the bottom of the reactor pool and at the suction of the RIS [SIS] trains will be isolated.

The level of the reactor pool is monitored by redundant sensors, the safety function can be performed by them.

4) Cooling of the SFP

The start-up operation of the cooling pumps can be carried out manually by operators in the main control room.

The temperature of the SFP is monitored by redundant sensors. The flowrate of each cooling train is also monitored by sensor to ensure the cooling function.

10.4.7.4.2 System Operation

a) Plant Normal Conditions

1) Cooling Trains of the SFP

The SFP cooling trains operate continuously as long as there are spent fuel assemblies stored in the pool.

During power operation, one cooling train is required to be in operation. The other two cooling trains are on standby.

During normal refuelling shutdown, two cooling trains operate simultaneously, and one is left on standby.

During normal operation, the flowrate of each cooling train for the SFP is { }, and the flowrate at the RRI [CCWS] side is { } (during refuelling cold shutdown and reactor complete discharge mode) or { } (except refuelling cold shutdown and reactor complete discharge mode).

2) Purification and Skimming of the SFP

The purification of SFP shall be undertaken during long-term operation. When the purification units of the SFP are used to purify the IRWST, the purification of the SFP will be temporarily interrupted. The reactor pool purification pump and the SFP purification pump can be backed up by each other. During replacement of the demineraliser resin or replacement of filter element, the purification will be interrupted.

SFP skimming operates intermittently according to the surface impurity degree in the SFP.

3) Water Makeup of the SFP

When it is required to make up the borated water to the SFP after a leak, this will be performed by the REA [RBWMS].

The SED [DWDS (NI)] can compensate for the normal evaporation of water in the SFP.

4) Purification and Skimming of the BRX Pools

During power operation, the reactor pool purification filter can be backed up by the SFP purification filter.

During refuelling shutdown, the reactor pool purification pump and the reactor pool filter can be put into operation as well as the skimming system to ensure sufficient visibility when the reactor pool is filled with water. The reactor pool can also be purified by the RCV [CVCS] purification unit.

The IRWST and IVR tank can be purified by the SFP purification unit through the EHR [CHRS]/RCV [CVCS] connections and the EHR [CHRS] connections if required.

5) Filling and Draining of the Reactor Pool

Before unloading, the purification pumps can fill the reactor pool. After reloading, the purification pumps can also drain the reactor pool to the IRWST. The water in the reactor pool can also flow gravitationally to the IRWST through the pipeline at the bottom of the reactor pool.

b) Plant Accident Conditions

In DBC conditions, one cooling train is sufficient to meet the requirements of the SFP cooling considering a single failure. The SFP temperature will be maintained below 80°C.

In the conditions of a SBO or TLOCC, the RRI [CCWS] is not available and the ECS [ECS] is required to provide the cooling water. The flowrate of the cooling train is { } and the flowrate at the ECS [ECS] side is { }. The SFP temperature will be maintained below 95°C.

When total loss of the PTR [FPCTS] cooling trains occurs, the operator can use the ASP [SPHRS] makeup line or external makeup connection to compensate for the loss of water due to boiling.

After shutdown, when a small break which can’t be isolated occurs on the primary circuit, or a TLOCC or SBO occurs, the RIS [SIS] pump must be started

to inject fluid into the primary circuit. Furthermore the isolation valves on the accident overflow line for reactor pool must be opened to achieve a dynamic balance between the reactor pool and the IRWST to maintain an appropriate water level.

10.4.7.5 Preliminary Design Substantiation

In this section, the system design is demonstrated to satisfy the safety functional requirements presented in Sub-chapter 10.4.7.1 and the general design requirements stated in Sub-chapter 10.2.4.

Since the general principles are newly developed at this stage, the system design is still based on the reference design and the information presented in this section is preliminary. A review of the consistency of the system design against the newly developed principles is currently being undertaken.

10.4.7.5.1 Compliance with Safety Functional Requirements

The system configuration and the capability of the components complies with the safety functional requirements, detailed information of the system design is presented in the SDM, Reference [38], [39], [40]. Furthermore, design substantiation of the PTR [FPCTS] has been estimated in the fault study in Chapters 12 and 13.

a) Control of Reactivity

Not applicable.

b) Removal of Heat

The PTR [FPCTS] is designed with three cooling trains to remove the decay heat of the fuel assemblies stored in the SFP in DBC and DEC accident conditions.

During normal power operation, the SFP average temperature is maintained below 50°C by operating one cooling train of the PTR [FPCTS]. During the reactor refuelling period, the SFP average temperature is maintained below 50°C by operating two cooling trains of the PTR [FPCTS]. The relevant analysis is presented in the Pre-Construction Environmental Report Chapter 3.

In the accident conditions of DBC-2/3/4, the SFP average temperature is maintained below 80°C by operating one cooling train of the PTR [FPCTS]. In case of a SBO or TLOCC, the SFP average temperature is maintained below 95°C by operating one cooling train of the PTR [FPCTS].

When total loss of the PTR [FPCTS] cooling trains occurs, there are two ways to make up water to the SFP to compensate for the loss of water due to boiling. One way is the ASP [SPHRS] gravitational makeup, and the other is external water makeup. The flowrate of the makeup water is more than $50m^3/h$.

Pipe penetrations which are equipped with siphon breakers and pipe suctions

which are without siphon breakers are all set above the fuel assembly in the pool to prevent the direct uncovering of fuel assemblies either in the storage racks or during handling in the event of a pipe break. Various measures are considered to guarantee the water level requirements for SFP during normal operation and accident conditions, such as leakage monitoring and collection for the SFP, water level monitoring for the SFP, the arrangement of elevations of connected pipelines, siphon breaking for connected pipelines and automatic isolation actions when the pool level decreases.

c) Confinement

To ensure the integrity of the containment, each containment penetration in the PTR [FPCTS] is equipped with two containment isolations valves. One motor-operated valve outside the containment and one motor-operated or check valve inside the containment.

d) Extra Safety Functions

The PTR [FPCTS] ensures the monitoring of the reactor pool and SFP level, and also ensures the temperature monitoring of the SFP. The instruments of water level and temperature measurement are designed for the specific monitoring function.

10.4.7.5.2 Compliance with Design Requirements

a) Safety Classification

The safety classification of the PTR [FPCTS] functions is listed in T-10.4-23 and the safety classification (including seismic categorisation) of main components in Table T-10.4-24.

T-10.4-23 Function Categorisation of the PTR [FPCTS] System

System Function	Function Category
Containment Isolation	FC1
Cooling Train Isolation from SFP	FC1
Draining Line Isolation from bottom of the BRX and BFX Pools (Except the SFP)	FC1
The Accident Return Lines to the IRWST	FC1
The PTR [FPCTS] Side of SFP Cooling	FC2
the RRI [CCWS] Side of SFP Cooling	FC1
Water Makeup of the SFP when Total Loss of the PTR [FPCTS] Cooling Trains occurs	FC3
Other Parts of the PTR [FPCTS]	FC3

T-10.4-24 Classification for Components

Component	Function Class	Design Provision Category	Design Provision Class	Seismic Category
Containment Isolation Valves	F-SC1	DPA	B-SC2	SSE1
Cooling Trains Isolation Valves	F-SC1	DPA	B-SC2	SSE1
Draining Lines Isolation Valves from the Bottom of the BRX and BFX Pools (Except the SFP)	F-SC1	DPA	B-SC2	SSE1
The Accident Return Lines Isolation Valves to the IRWST	F-SC1	DPA	B-SC2	SSE1
The SFP Cooling Pumps	F-SC2	DPL	B-SC3	SSE1
The SFP Exchangers	F-SC1	DPL	B-SC3	SSE1
Purification and Skimming Pumps	F-SC3	DPL	B-SC3	SSE2
Filters and Demineraliser	F-SC3	DPL	B-SC3	NO
Valves of Water Makeup of the SFP when Total Loss of the PTR [FPCTS] Cooling Trains occurs	F-SC3	NC	NC	SSE1
Other Components of the PTR [FPCTS]	F-SC3	DPL	B-SC3	SSE2 (BRX and BFX)
				NO (BNX)

b) Engineering Design Requirements

1) Reliability Design of SSCs

- Single Failure Criterion (SFC)

  The three redundant cooling trains meet the single failure criterion. If one cooling train fails, the other two cooling trains ensure the cooling function.

  The isolation of containment and drainage lines at the bottom of compartments (except the SFP) meets the single failure criterion with two redundant isolation valves.

  Detailed information is presented in the SDM, Reference [38].

- Independence

The PTR [FPCTS] has three redundant cooling trains which have independent suction and discharge lines. The connection lines downstream of the cooling pumps are usually isolated from each other and between any two cooling trains there are two isolation valves.

The three cooling trains are arranged in three separate parts of the BFX. The three pumps of the cooling trains are supplied by three independent electrical divisions.

The two containment isolation valves are arranged separately to each other, and they are supplied by different electrical divisions.

The two isolation valves at the bottom of the pools (except the SFP) are supplied by different electrical divisions.

Detailed information is presented in the SDM, Reference [41][38] .

- Diversity

  The three heat exchangers of the cooling trains are cooled respectively by the three trains of the RRI [CCWS]. The heat exchangers of cooling trains A and B of the PTR [FPCTS] are also cooled by the ECS [ECS].

  The three cooling trains are supplied by EDGs. Cooling trains A and B are also supplied by SBO diesel generators.

- Fail-safe

  Not applicable.

- Ageing and Degradation

  The plant design life is 60 years. Some components will need replacing at the end of their individual design life. The management of equipment ageing and degradation follows the considerations stated in Sub-chapter 10.4.1. The main components of the PTR [FPCTS] have been designed with a service life of 60 years, such as the pumps and heat exchangers.

  The performance of equipment is guaranteed through life examination, inspection, maintenance and testing, as well as the monitoring during normal operation, which will ensure that ageing effects do not compromise safety performance.

2) Human Factors

The concept of human factors is taken into consideration in the system design. The PTR [FPCTS] system complies with the requirements stated in Sub-chapter 10.2.4, and design considerations and measures described in Sub-chapter 10.2.4 are applied in the design of the PTR [FPCTS].

In addition, if an action is required within 30 minutes after accidents, it is designed to occur automatically, such as the isolation of valves at the bottom of the pools when the low level threshold is reached.

Detailed design information is presented in the SDM, Reference [40].

3) Autonomy

- Autonomy in Respect of Operators

  The design principles relevant to the autonomy in respect of operators are detailed in Reference [1]. The design of the PTR [FPCTS] fulfils these principles via control functional design, detailed information is presented in the SDM, Reference [40]. If the action is required within 30 minutes after accidents, it will be designed to occur automatically, such as the isolation of valves at the bottom of the pools when the low level threshold is reached. The design result is estimated in the safety analysis.

- Autonomy in Respect of the Heat Sink

  Not applicable.

- Autonomy in Respect of Power Supply Systems

  The design of the PTR [FPCTS] fulfils the principles relevant to the autonomy in respect of power supply systems. The three cooling trains are supplied by the EDGs, and two of them are also supplied by the SBO diesel generators.

4) Other Design Requirements

- Prevention of Harmful Interactions of Systems Important to Safety

  Not applicable.

- Considerations Related to the Electrical Power Grid

  Electrical power fluctuation has been considered in the equipment design such as the capability of pumps to ensure the operation of functions important to safety.

c) Equipment Qualification

All of the components required to perform safety functions are capable of operating under both normal and accident conditions. As a result, the components can withstand the most adverse environmental conditions expected.

Active components such as containment isolation valves, cooling pumps and the valves at the cooling trains shall be qualified.

All the seismically classified components shall be capable of operating during

and after the SSE. The components are seismically designed and qualified for SSE loads.

The documents relevant to the equipment qualification will be delivered before the step 4 of GDA.

d) Protection Design against Internal and External Hazards

The PTR [FPCTS] system considers the requirements stated in Sub-chapter 10.2.4, and the design considerations and measures described in Sub-chapter 10.2.4 are applied in the design of the PTR [FPCTS].

e) Commissioning

Commissioning and tests are going to be carried out for the PTR [FPCTS] to validate the functionality of its components, such as pumps, exchangers, instruments and valves. Documents related to the commissioning will be delivered before the step 4 of GDA.

f) Examination, Inspection, Maintenance and Testing

1) Examination and Inspection

There is no equipment of the PTR [FPCTS] requiring in-service inspection.

2) Maintenances

Maintenance of the cooling circuit of the spent fuel pool is usually implemented during power operation and the optimal period is at the end of cycle. Only one train is maintenance at a time. During the maintenance of one train, another train will be used for cooling while train C is kept on standby for preventive startup.

Except for the equipment within the reactor building, the purification and water transfer loops can be maintained during the power operation of the unit.

Under refuelling shutdown conditions, after the reactor pool has been completely drained, maintenance can be performed for the components of the purification loop for the reactor pool inside the containment and the skimming pump for the reactor pool. The purification loop for the reactor pool outside the reactor building can be maintained during the power operation of the unit.

Except for the fuel transfer period, the skimming system of the spent fuel pool can be maintained during the power operation of the unit.

3) Periodic Tests

The equipment of the PTR [FPCTS] which implements safety functions is

required to be tested periodically, such as the containment isolation valves, isolation valves at the bottom of the pools, cooling trains and the isolation valves at the suction of the cooling trains.

g) Decommissioning

The design of the PTR [FPCTS] considers the decommissioning. A gradient is set in the pipeline layout to prevent liquid accumulation. All equipment and pipes can be drained by draining lines.

h) Material Selection

The material of the PTR [FPCTS] side is stainless steel, and the RRI [CCWS]/ECS [ECS] side of heat exchangers is carbon steel.

i) Special Thermal-hydraulic Phenomena

The design of the PTR [FPCTS] considers the prevention of harmful thermal-hydraulic phenomena such as dead leg. A bypass line with a check valve is set to the inner containment isolation valve at the suction line of the reactor pool purification.

j) Insulation

Not applicable.

10.4.7.6 Simplified Diagrams

The simplified functional diagram of the PTR [FPCTS] is presented in Figure F-10.4-6, the detailed system functional diagram is in Reference [42].

10.4.8 Component Cooling Water System (RRI [CCWS])

The Component Cooling Water System (RRI [CCWS]) falls into the category of auxiliary systems. The RRI [CCWS] provides cooling water for the users of Nuclear Island (NI) systems (including nuclear auxiliary systems and safety-classified systems) under normal operating conditions and accident conditions. The RRI [CCWS] consists of three trains, and the main components of the RRI [CCWS] (pumps, heat exchangers and surge tanks) are located in the Safeguard Buildings (BSX) of Nuclear Island (NI). Information of the system is presented in the SDM, Reference [43].

10.4.8.1 Safety Functional Requirements

10.4.8.1.1 Control of Reactivity

The RRI [CCWS] does not directly contribute to the reactivity control function.

10.4.8.1.2 Removal of Heat

The RRI [CCWS] does not participate in the removal of heat function directly.

10.4.8.1.3 Confinement

The RRI [CCWS] shall contribute to the control of reactivity by performing the following functions:

a) Under accident conditions, the isolation valves set on the pipes that penetrate the containment perform containment isolation functions to ensure radioactive confinement.

b) The closure circuit of the system acts as a barrier between the users and the environment to ensure that radioactive substances are not released in case of the break of users' heat exchangers.

10.4.8.1.4 Extra Safety Functions

The extra safety functional requirements of the RRI [CCWS] are identified as follows:

a) Providing cooling water to the Safety Injection System (RIS [SIS]) pumps and heat exchangers to remove the residual heat of the primary circuit under normal operation and accident conditions (Design Basis Condition (DBC) 2/3/4 or some Design Extension Condition (DEC) A).

b) Providing cooling water to the Fuel Pool Cooling and Treatment System (PTR [FPCTS]) heat exchangers to remove the residual heat of the fuel pool under normal operation and accident conditions (DBC-2/3/4 and some DEC-A) as long as the RRI [CCWS] is available.

c) Providing cooling water to the Containment Heat Removal System (EHR [CHRS]) pumps and heat exchangers under accident conditions to remove the residual heat of the containment.

d) Providing cooling water to the Safety Chilled Water System (DEL [SCWS]) chillers by train C of the RRI [CCWS] under some accident conditions.

e) Providing cooling water to the Chemical and Volume Control System (RCV [CVCS]) during normal operation .

f) Providing cooling water to the Reactor Coolant System (RCP [RCS]) thermal barriers of the primary pump to contribution to the confinement of radioactive under DBC-1/2/3/4.

g) Providing cooling water to the Nuclear Sampling System (REN [NSS]) heat exchangers under normal operation and DBC-2/3/4.

h) Providing cooling water to the Reactor Boron and Water Makeup System (REA [RBWMS]) during normal operation.

Detailed safety functional requirements are presented in SDM, Reference [44].

10.4.8.2 Design Requirements

The general design requirements of the RRI [CCWS] which need to be considered are shown in Sub-chapter 10.2.4.

10.4.8.3 Design Bases

This sub-chapter aims to provide the main design assumptions considered in the system design.

10.4.8.3.1 General Assumptions

a) Safety Classification

1) The RRI [CCWS] is required to provide cooling water to the RIS [SIS] pumps and heat exchangers to remove the residual heat of the primary circuit under the Safety Injection (SI) signal, the function category is FC1.

2) The RRI [CCWS] is required to provide cooling water to the PTR [FPCTS] heat exchangers to remove the residual heat of the fuel pool under accident conditions (DBC 2/3/4 or some DEC-A), the function category is FC2.

3) The RRI [CCWS] is required to provide cooling water to the EHR [CHRS] pumps and heat exchangers under accident conditions (some DEC-A), the function category is FC3.

4) The RRI [CCWS] is required to provide cooling water to the DEL [SCWS] to remove the residual heat of the chiller under accident conditions (DBC 2/3/4 or some DEC-A), the function category is FC2.

5) The RRI [CCWS] is required to provide cooling water to the thermal barriers of primary pumps under DBC 2/3/4, the function category is FC2.

b) Ageing and Degradation

According to Chapter 2, the operational design life of the UK HPR1000 is 60 years. The main components of the RRI [CCWS] are required to have a service life of 60 years.

c) Considerations Related to the Electrical Power Grid

The functionality of items important to safety at the nuclear power plant shall not be compromised by disturbances in the electrical power grid, including anticipated variations in the voltage and frequency of the grid supply, which is considered as 49.5Hz-50.5Hz according to the design of the HPR1000 (FCG3). It will be adjusted in the following future design phases based on the actual conditions of the UK.

10.4.8.3.2 Design Assumptions

a) Control of Reactivity

There is no dedicated design assumption for the RRI [CCWS].

b) Removal of Heat

The RRI [CCWS] is not required to perform this safety function.

c) Confinement

There is no quantitative design assumption for the RRI [CCWS].

d) Extra Safety Functions

The RRI [CCWS] shall provide enough cooling water, of which the temperature is between 15°C and 38°C in normal conditions, to users to support the safety functions of users. To satisfy the requirement mentioned above, the rated flowrate of RRI [CCWS] pumps of train A and train B is no less than { }; the rated flowrate of RRI [CCWS] train C pumps is no less than { }. The heat load of RRI [CCWS] heat exchangers of train A is no less than { }; the heat load of RRI [CCWS] heat exchangers of train B is no less than { }, while the flowrate of the Essential Service Water System (SEC [ESWS]) is { } and the temperature is 33.5°C. The heat load of RRI [CCWS] heat exchangers of train C is no less than { } while the flowrate of the SEC [ESWS] is { } and the temperature is 33.5°C.

10.4.8.4 System Description and Operation

10.4.8.4.1 System Description

a) General System Description

The RRI [CCWS] is required to provide cooling water to the safety systems. Based on the safety classification and design requirements which are presented in Sub-chapter 10.2.4, the RRI [CCWS] is designed as three safety-classified and separated trains (train A, train B and train C). Each train is cooled by the SEC [ESWS] through the RRI [CCWS] heat exchanger.

For train A or train B of the RRI [CCWS], each train is composed of two pumps, two heat-exchangers, one surge tank, common users, which are cooled by two trains such as thermal barriers of primary pumps and REN [NSS] Secondary Sampling heat exchangers, and dedicated users. Train C is composed of one pump, one heat exchanger, one surge tank and dedicated users.

The detailed information is presented in the SDM, Reference [45].

b) Description of Main Equipment

The main components are described below:

1) RRI [CCWS] Pumps

The RRI [CCWS] pumps are of the horizontal centrifugal type.

The RRI [CCWS] pump motors are powered by a 10kV switchboard and are cooled down by the RRI [CCWS].

The design of the maximum flow of the pumps of train A and B is based on the power operation conditions, and at this moment, the RRI [CCWS] pumps provide cooling water for the PTR [FPCTS] heat exchangers and the common users simultaneously.

The minimum flow of the pumps of train A and B is based on the accident conditions, and at this moment, this RRI [CCWS] train only provides cooling water for the dedicated users.

The maximum flow design of the pumps of train C is based on the refuelling cold shutdown condition, and at this time, the RRI [CCWS] pumps provide cooling water for the RIS [SIS] heat exchangers and PTR [FPCTS] heat exchangers simultaneously.

The minimum flow design of the pumps of train C is based on the accident conditions (The DEL [SCWS] is in operation), and at this time, the RRI [CCWS] train only provides cooling water for dedicated users.

T-10.4-25 Data Sheet of the RRI [CCWS] Pumps

Parameters	Value		Unit
	Train A and Train B	Train C	
Type	centrifugal pump		---
Design Life	60	60	yr.
Nominal Flowrate	3000	2000	m^3/h
Discharge Head at Nominal Flowrate	64_0^{+4}	64_0^{+4}	mWc
Material	Carbon Steel		

2) RRI [CCWS] Heat Exchanger

The design capacity of the RRI [CCWS] heat exchangers must meet the cooling requirements of the check condition when there is only one train of the RIS [SIS] available (in Residual Heat Removal (RHR) mode, RIS [SIS] system connecting to the primary circuit at 180ºC); the heat exchanger RRI [CCWS] outlet temperature shall not be higher than 45ºC.

T-10.4-26 Data Sheet of the RRI [CCWS] Heat Exchanger

Type	Plate		Unit
	Hot Side	Cold Side	
Train A			

Type	Plate		Unit
	Hot Side	Cold Side	
Design Thermal Load	{ }		MW
Medium	RRI [CCWS] water	Seawater	---
Design Pressure	1.35	1.2	MPa (g)
Design Temperature	90	65	°C
Design Flowrate	{ }	{ }	kg/s
Train B			
Design Thermal Load	{ }		MW
Medium	RRI [CCWS] water	Seawater	---
Design Pressure	1.35	1.2	MPa (g)
Design Temperature	90	65	°C
Design Flowrate	{ }	{ }	kg/s
Material	Titanium		
Train C			
Design Thermal Load	{ }		MW
Medium	RRI [CCWS] water	Seawater	---
Design Pressure	1.35	1.2	MPa (g)
Design Temperature	90	65	°C
Design Flowrate	{ }	{ }	kg/s
Material	Titanium		

3) Surge Tank

The sizing of the surge tank meets the following three volume change requirements:

- The water inventory increase caused by the leak into the tank from the break of a heat transfer tube of user for 30 minutes;
- The water volume increase caused by the expansion of water due to the temperature variation;
- The water volume used to compensate for the leakage of the break of users section before it was isolated.

T-10.4-27 Data Sheet of Surge Tank

Parameters	Value	Unit
Type	Cylindrical Tank	
Medium	RRI [CCWS] water	---
Design Pressure	1.35	MPa (g)
Design Temperature	90	°C
Usable Volume	27.3/20 (train A and train B/train C)	m^3
Material	Carbon Steel	

The detailed information is presented in the SDM, Reference [45] .

c) Description of Main Layout

The main equipment of each train of the RRI [CCWS] is situated in the Safeguard Building A (BSA), Safeguard Building B (BSB) and Safeguard Building C (BSC) respectively. The pipelines connect to the main equipment of the RRI [CCWS] with different users located in NI buildings (Reactor Building (BRX), the Safeguard Building (BSX), Fuel Building (BFX) and Nuclear Auxiliary Building (BNX)).

The detailed information is presented in the SDM, Reference [46].

d) Description of System Interfaces

1) SEC [ECWS]

The SEC [ECWS] system provides cooling water for the RRI [CCWS] heat exchangers and transfers the heat to the ultimate heat sink.

2) Nuclear Island (NI) Dematerialised Water Distribution System (SED [DWDS (NI)])

Every surge tank of the RRI [CCWS] system is provided with SED [DWDS (NI)] water charging lines.

3) Plant Radiation Monitoring System (KRT [PRMS])

The radioactive level of the RRI [CCWS] system is monitored by the KRT [PRMS] at the downstream of the RRI [CCWS] pump of each train.

The detailed information is presented in the SDM, Reference [45].

e) Description of Instrumentation and Control

1) Providing Cooling Water to RIS [SIS] under Safety Injection Signal

Under the Safety Injection (SI) signal, one RRI [CCWS] pump of the standby train start up and the supply to non-classified users is automatically isolated. Thus the RIS [SIS] heat exchangers and pumps in all three trains would receive cooling water.

2) Control Supply Water Temperature under SI Signal

Under the SI signal, the supply temperature is controlled to be between 15°C and 45°C by the control valves on the downstream pipeline and bypass pipeline of the heat exchanger. While the temperature is over 45°C, the control valve on the bypass pipeline would be fully opened. While the temperature is below 15°C, the control valve on downstream pipeline would be closed.

3) Containment Isolation in Phase A

Under the signal of containment isolation phase A, the containment isolation valves on the pipelines to the Containment Cooling and Ventilation System (EVR [CCVS]) and Nuclear Island Vent and Drain System (RPE [VDS]) will be closed.

4) Containment Isolation in Phase B

Under the signal of containment isolation phase B, the containment isolation valves on the pipelines to the letdown heat exchanger will be closed.

5) Start-up Standby Pump Automatically in Train A or Train B

The standby pump will start up automatically when the operating pump in train A or train B fails, except the Loss of Offsite Power (LOOP) and SI conditions.

6) Switchover for Supply Pipelines of Primary Pump

Train A or train B of the RRI [CCWS] provides cooling water to motors, bearings and thermal barriers of the primary pumps. All three primary pumps are supplied by the same RRI [CCWS] train.

Under the signal of loss of the train supplying the primary pumps, which is not leaded by the break of motors, bearings and thermal barriers of primary pumps, the corresponding isolation valves will open or close to switch the supplying pipeline to the other train.

The detailed information is presented in the SDM, Reference [47].

10.4.8.4.2 System Operation

a) Plant Normal Conditions

1) Reactor power operation

During reactor power operation conditions, two trains of the RRI [CCWS] operate.

Under this condition, the RRI [CCWS] provides cooling water for the following equipment:

- RRI [CCWS] pump motors;
- RIS [SIS] pump motors;
- PTR [FPCTS] heat exchangers;
- RCV [CVCS] heat exchanger and RCV [CVCS] pump motors;
- RCP [RCS] pumps (motors, bearings and thermal barriers);
- REN [NSS] heat exchangers;
- EVR [CCVS] containment ventilation cooling coils;
- RPE [VDS] heat exchangers;
- Coolant Storage and Treatment System (TEP [CSTS]) coolers;
- Operational Chilled Water System (DER [OCWS]) water chillers;
- Safety Chilled Water System (DEL [SCWS]) chillers;
- Reactor Boron and Water Makeup System (REA [RBWMS]) heat exchangers.

2) Start-up

During reactor start-up operation conditions, requirements for the RRI [CCWS] are as follows:

- One pump and one heat exchanger of train A operate.
- One pump and one heat exchanger of train B operate.
- Train C operates to cool the RIS [SIS] heat exchanger, while the unit in RHR mode with coolant temperature being between 80°C and 120°C.
- Other pumps and heat exchangers will be on standby.

3) Hot shutdown (coolant temperature no less than140°C)

During RHR mode, with the coolant temperature no less than 140°C, requirements for the RRI [CCWS] are the same with Start-up.

4) Cold shutdown (coolant temperature: 140°C~100°C)

During RHR mode, when the coolant temperature is between 140°C and 100°C, requirements for the RRI [CCWS] are as follows:

- Two pumps and two heat exchangers of train A operate.
- Two pumps and two heat exchangers of train B operate.
- Train C remains on standby.

5) Cold shutdown (coolant temperature: 100°C~60°C)

When the coolant temperature is between 100°C and 60°C with the RIS [SIS] connected, requirements for the RRI [CCWS] are as follows:

- Two pumps and two heat exchangers of train A operate.
- Two pumps and two heat exchangers of train B operate.
- Train C is in operation.

6) Cold shutdown (coolant temperature no more than 60°C)

When the coolant temperature is no more than 60°C, requirements for the RRI [CCWS] are as follows:

- All three trains of the RRI [CCWS] operate while the coolant temperature is at 60°C.
- After Reactor Complete Discharge (RCD), one of the three trains is not required to continue operating.

7) Switchover

Pumps and heat exchangers in the same train (only train A and train B) will switchover periodically to balance service life.

Switchover of pumps and heat exchangers for the RRI [CCWS] will lead to start-up of the corresponding SEC [ESWS] pumps.

b) Plant Accident Conditions

The RRI [CCWS] operates under all the DBC-2/3/4 conditions. Under some DEC, if the RRI [CCWS] is available, it is also required to be put into operation.

1) Loss of Offsite Power (LOOP)

During the LOOP accident condition, every RRI [CCWS] pump is powered by the emergency diesel generator, and all three trains of the RRI [CCWS] are available. Only one pump operates in each train at same time.

2) Loss of Coolant Accident (LOCA)

The standby train will start up one pump while receiving the safety injection signal.

The non-classified users which are located in the BNX, BRX and BWX

(Radioactive Waste Treatment Building) are isolated from the RRI [CCWS].

3) The RIS [SIS] Connected while Coolant temperature is at 180°C

During DBC 3-4 condition, the RIS [SIS] has to connect to the primary loop while the coolant temperature is at 180°C. Each train will put one pump and one heat exchanger of the RRI [CCWS] into operation to cool the RIS [SIS] heat exchanger under this condition. The corresponding non-classified users will be isolated.

4) DEC Accident Condition

During some DEC conditions, once the RRI [CCWS] is available, it will supply cooling water for users such as the EHR [CHRS] heat exchangers and pumps, the RIS [SIS] pumps and heat exchangers, and the PTR [FPCTS] heat exchangers.

The detailed information is presented in SDM, Reference [47].

10.4.8.5 Preliminary Design Substantiation

In this section, the system design is demonstrated to satisfy the Safety Functional Requirements presented in Sub-chapter 10.4.8.1 and the general design requirements stated in Sub-chapter 10.2.4.

Since the general principles are newly developed at this stage, the system design is still based on the reference design and the information presented in this section is preliminary. Review of consistency of the system design against the newly developed principles is undertaken currently.

10.4.8.5.1 Compliance with Safety Functional Requirements

The system configuration and the capability of the components are compliant with the safety functional requirements. Detailed information of the system design is presented in the SDM, Reference [44], [45] and [47]. Furthermore, design substantiation of the RRI [CCWS] has been estimated in the fault study in Chapters 12 and 13.

a) Control of reactivity

The RRI [CCWS] is not required to perform this safety function.

b) Removal of Heat

The RRI [CCWS] is not required to perform this safety function.

c) Confinement

To ensure the integrity of the containment, each containment penetration is equipped with two containment isolation valves in the RRI [CCWS].

d) Extra Safety Functions

The RRI [CCWS] can provide enough cooling water to users to support the safety function of users. The rated flowrate of RRI [CCWS] pumps of train A and train B are designed to be { }; the rated flowrate of RRI [CCWS] train C pumps is designed to be { }. The heat load of RRI [CCWS] heat exchangers of train A is designed to be { }; the heat load of RRI [CCWS] heat exchangers of train B is designed to be { }, the heat load of RRI [CCWS] heat exchangers of train C is designed to be { }.

10.4.8.5.2 Compliance with Design Requirements

a) Safety Classification

The RRI [CCWS] system design is compliant with the requirements described in the Sub-chapter 10.4.8.1. The safety classification of RRI [CCWS] functions and the safety classification of main components are listed in Table T-10.4-28 and T-10.4-29.

T-10.4-28 Function Categorisation of the RRI [CCWS]

System Function	Function Category
Control of RRI [CCWS] temperature	FC2
Cooling of RIS [SIS] heat exchangers	FC1/FC2/FC3
Cooling of RIS [SIS] pumps	FC1/FC2/FC3
Cooling of PTR [FPCTS] heat exchangers	FC2
Cooling of RCP [RCS] thermal barriers	FC2
Cooling of DEL [SCWS] chillers	FC2
Maintaining the RRI [CCWS] temperature upper than 15°C	FC1/FC2/FC3
Switchover for supply of RCP [RCS] thermal barrier cooling lines	FC1
Cooling of RCV [CVCS] charging pumps	FC3
RRI [CCWS] Containment isolation stage 1	FC1/FC2
RRI [CCWS] Containment isolation stage 2	FC1/FC2
Cooling of EHR [CHRS]	FC3

T-10.4-29 Classification for Components

Component	Safety Class	Design Provision Category	Design Provision Class	Seismic Category
Pump	F-SC1	DPL	B-SC3	SSE1
Surge Tank and Heat Exchanger	F-SC1	DPL	B-SC3	SSE1
Containment Isolation Valve	F-SC1	DPA	B-SC2	SSE1

Component	Safety Class	Design Provision Category	Design Provision Class	Seismic Category
Pipeline to RIS [SIS]	F-SC1	DPL	B-SC3	SSE1
Pipeline to thermal barrier of Primary Pump	F-SC2	DPL	B-SC3	SSE1
Pipeline to PTR [FPCTS]	F-SC1	DPL	B-SC3	SSE1
Pipeline of Train C to DEL [SCWS]	F-SC1	DPL	B-SC3	SSE1
Pipeline to Primary Sampling of REN [NSS]	F-SC2	DPL	B-SC3	SSE1
Pipeline to Secondary Sampling of REN [NSS]	F-SC2	DPL	B-SC3	SSE1
Pipeline to RCV [CVCS] Heat Exchanger	F-SC2	DPL	B-SC3	SSE1
Pipeline to RCV [CVCS] Pump	F-SC2	DPL	B-SC3	SSE1

The detailed information is presented in the SDM, Reference [45] .

b) Engineering Design Requirements

1) Reliability Design of SSCs

- Single Failure Criterion (SFC)

The three RRI [CCWS] trains performing the safety function are redundant and meet the single failure criterion. If one cooling train fails, the other two cooling trains ensure the cooling function.

The redundant users are cooled by another RRI [CCWS] train when one train of the RRI [CCWS] fails its cooling function.

The isolation of containment meets the single failure criterion with two redundant isolation valves.

Detailed information is presented in the SDM, Reference [44].

- Independence

  The three RRI [CCWS] trains performing the safety function are independent. The parts mentioned above are arranged in different buildings physically isolated from each other for protection.

  The three trains of the RRI [CCWS] are powered by different electrical safety trains.

  Detailed information is presented in the SDM, Reference [44].

- Diversity

  The containment isolation valves outside containment are equipped with SBO diesel generators, 12-hour battery and mobile power supply devices. The isolation valves inside containment are equipped with SBO diesel generators and 2-hour battery.

  The break of heat exchangers can be detected by different signals (pressure, temperature, level, etc.).

- Fail-safe

  The isolation valves of the non-classified users of the RRI [CCWS] are air-operated valves which is close when the air supply fails, aimed to maintain the safety function.

- Ageing and Degradation

  The plant design life is 60 years. Some components will require replacing at the end of their individual design life. The management of equipment ageing and degradation follows the considerations stated in Sub-chapter 10.2.4.

  The performance of equipment is guaranteed through life examination, inspection maintenance and testing, as well as the monitoring during normal operation, which will ensure that ageing effects do not compromise safety performance.

2) Human Factors

The concept of human factors is taken into consideration in the system design. The system design of the RRI [CCWS] does not require short term operator intervention, while there are operator actions during plant normal operation, of which the effect needs to be estimated.

Detailed design information about automatic control design of the system is presented in the SDM, Reference [47].

3) Autonomy

- Autonomy in Respect of Operators

  The design principles relevant to the autonomy in respect of operators are detailed in Reference [1]. The design of the RRI [CCWS] fulfils these principles via control functional design, detailed information is presented in the SDM, Reference [45].

- Autonomy in Respect of the Heat Sink

  The design principles relevant to the autonomy in respect of the heat sink are applicable for RRI [CCWS] design. The RRI [CCWS] is cooled by SEC [ESWS] and the cooling water originates from sea water.

- Autonomy in Respect of Power Supply Systems

  The design of the RRI [CCWS] fulfils the principles relevant to the autonomy in respect of power supply systems. The three cooling trains are supplied by the EDGs. The containment isolation valves outside containment isolation valves are equipped with SBO diesel generators, 12-hour battery and mobile power supply devices. The inside containment isolation valves are equipped with SBO diesel generators and 2-hour battery.

4) Other Design Requirements

- Prevention of Harmful Interactions of Systems Important to Safety

  The RRI [CCWS] system takes the following measures to prevent the harmful interactions of systems:

  - Provide adequate isolation (e.g. using double isolating valves) between the RRI [CCWS] and the interfacing systems;
  - The design pressure of the isolation valve between the RRI [CCWS] and the interface system adopts the larger pressure;
  - The RRI [CCWS] system is equipped with safety valves to prevent the system from being damaged due to overpressure.

- Considerations Related to the Electrical Power Grid

  Electrical power fluctuation has been considered in equipment design such as the capability of pumps to ensure the functions important to safety.

c) Equipment Qualification

All the RRI [CCWS] components required to perform the safety functions should

be capable of operating under normal conditions and accident conditions, which requires the components to withstand the most adverse ambient environmental conditions expected.

Active components such as containment isolation valves, pumps and the valves shall be qualified.

All the RRI [CCWS] seismic classified components operate during and after the SSE. The components are seismic designed and qualified with SSE load.

The documents relevant to the equipment qualification will be delivered before the step 4 of GDA.

d) Protection against Internal and External Hazards

The RRI [CCWS] complies with the requirements stated in Sub-chapter 10.2.4 and design considerations and measures described in Sub-chapter 10.2.4 are applied in the design of the RRI [CCWS].

e) Commissioning

Commissioning and tests are going to be carried out for the main RRI [CCWS] equipment to validation its functionality, such as pumps, exchangers, instruments and valves. Documents related to the commissioning will be delivered before the step 4 of GDA.

f) Examination, Inspection, Maintenance and Testing

1) Examination and Inspection

There is no equipment of the RRI [CCWS] requiring in-service inspection.

2) Maintenance

During the normal operating conditions, the RRI [CCWS] should supply cooling water to non-classified users in the Nuclear Island (NI), to support the requirements for unit availability. Thus, maintenance of standby pumps and heat exchangers could be done during the power operation condition.

Maintenance of the other component could be done during shutdown of plant.

3) Periodic Tests

Some equipment performing safety function shall be subject to periodic test, mainly including containment isolation valves and user isolation valves. Also the cooling flow test of the dedicated users will be done.

g) Decommissioning

The design of the RRI [CCWS] considers the decommissioning. A gradient is set

in the pipeline layout to prevent the liquid accumulation and all equipment and pipes can be drained by draining lines.

h) Material Selection

The RRI [CCWS] side uses mostly carbon steel, except for the RRI [CCWS] heat exchangers which is made of titanium.

i) Special Thermal-hydraulic Phenomena

The design of the RRI [CCWS] considers the prevention of harmful thermal-hydraulic phenomena such as the hot water and cold water mixing.

j) Insulation

In order to reduce the heat dissipation from the pipelines to the environment, the pipelines of the RRI [CCWS] whose normal operating temperature is greater than or equal to 60°C should be insulated. The insulation type is PP (personnel protection) and the insulation will cover the cooling pipelines downstream RIS [SIS] heat exchangers and RCV [CVCS] heat exchangers.

10.4.8.6 Simplified Diagrams

The simplified system functional diagram is presented in Figures F-10.4-7, F-10.4-8 and F-10.4-9.

10.4.9 Essential Service Water System (SEC [ESWS])

The SEC [ESWS] falls into the category of auxiliary systems, as a support system for the RRI [CCWS], which cools the nuclear, island RRI [CCWS] and as such contributes indirectly to safety functions of the RRI [CCWS]. The SEC [ESWS] consists of coarse rack, fine rack, gate, chlorination frame, SEC [ESWS] pump, flushing pump, sump pump, electrical heater, debris filter, motor of the travelling band screen, and the motor of the trash rake and flushing filter. The main components are located in the essential service water pumping station, SEC [ESWS] water intake/outfall gallery and safeguard building. Information of the system is presented in the SDM, Reference [48].

10.4.9.1 Safety Functional Requirements

The requirements of the fundamental safety functions on the SEC [ESWS] design are described below.

10.4.9.1.1 Control of Reactivity

The SEC [ESWS] is not required to perform this safety function.

10.4.9.1.2 Removal of Heat

The SEC [ESWS] shall provide cooling water to the RRI [CCWS] in normal

operating conditions and accidental conditions.

10.4.9.1.3 Confinement

The SEC [ESWS] shall ensure the integrity of the Reactor Coolant Pressure Boundary (RCPB) indirectly by cooling the thermal barriers of reactor coolant pumps via the RRI [CCWS].

10.4.9.1.4 Extra Safety Functions

The SEC [ESWS] is a support system for the RRI [CCWS], and the RRI [CCWS] is required to perform the removal of heat and confinement function, so the SEC [ESWS] is not required to perform any extra safety functions

10.4.9.2 Design Requirements

The general design requirements of the nuclear auxiliary systems which need to be considered are shown in Sub-chapter 10.2.4, among which the following requirements are not applicable for the SEC [ESWS]:

a) Prevention of Harmful Interactions of Systems Important to Safety

   Not applicable, because the SEC [ESWS] doesn't have harmful interactions of systems important to safety.

b) Insulation

   Not applicable, because the SEC [ESWS] doesn't have insulation design.

c) Considerations Related to the Electrical Power Grid

   The functionality of items important to safety in the SEC [ESWS] is not compromised by disturbances in the electrical power grid.

d) Autonomy in Respect of Heat Sink

   The SEC [ESWS] system is the heat sink of the unit and therefore is not required to consider loss of the heat sink.

The substantiation analysis of the SEC [ESWS] to other design requirements is shown in Sub-chapter 10.2.4.

10.4.9.3 Design Bases

This sub-chapter aims to provide the main design assumptions considered in the system design.

10.4.9.3.1 General Assumptions

a) Safety Classification

   The SEC [ESWS] shall provide cooling water to the RRI [CCWS] in normal

operating conditions and accident conditions, so the safety classification is FC1.

b) Ageing and Degradation

The design lifespan of the main components (pumps, valves, filtration and instruments) is 60 years. The layout design will consider the need of removing old parts to install the replacement.

c) Equipment Qualification

1) Environmental Conditions under Normal Conditions is listed in Table T-10.4-30.

T-10.4-30 Environmental Conditions under Normal Conditions

Area	Minimum temperature	Maximum temperature	Relative humidity
Room of pumping stations	10°C	Mean temperature: 45°C Upper limit of external temperature: 50°C	Not checked
Galleries	5°C	Mean temperature: 45°C Upper limit of external temperature: 50°C	Not checked
Frequent and long occupation	18°C	30°C	0%-70%
Frequent and short or rare and long occupation	10°C	38°C	0%-70%
Rare and short occupation	10°C	45°C	0%-100%

2) Environmental Conditions under Accident Conditions is listed in Table T-10.4-31

T-10.4-31 Environmental Conditions under Accident Conditions

Area	Maximum temperature profile
Pumping stations	50°C
Galleries	60°C
Safeguard buildings	60°C

d) Protection against Internal and External Hazards

The main components of the SEC [ESWS] are installed in heated rooms to protect them from extremely low temperatures.

Chapter 3 provides generic site parameters to SEC [ESWS].

10.4.9.3.2 Design Assumptions

The SEC [ESWS] must ensure sufficient heat transfer from the RRI [CCWS]. A permanent minimum flow rate of filtered cold water to the RRI [CCWS]/SEC [ESWS] heat exchangers must thus be ensured. In addition, the environmental parameters based on the siting conditions such as temperature and water level must be considered in the design of the SEC [ESWS].

a) Control of Reactivity

The SEC [ESWS] is not required to perform this safety function.

b) Removal of Heat and Confinement

The SEC [ESWS] is composed of three independent trains, adapting to the RRI [CCWS] (detailed in Sub-chapter 10.4.8). Train A and train B operate in the normal power operating conditions of the reactor, train C is adapting to RRI [CCWS] train C. The heat load is { } for train A and train B. The flow rate of the SEC [ESWS] pump at an average sea water level is around 3680m^3/h.

c) Extra Safety Functions

The SEC [ESWS] is not required to perform extra safety functions.

10.4.9.4 System Description and Operation

10.4.9.4.1 System Description

a) General System Description

The SEC [ESWS], which is an open system, sucks cooling water from the sea to cool the RRI [CCWS]/SEC [ESWS] heat exchangers and then discharges thermal water back to the sea. Thus the safety function of delivering the heat load collected by RRI [CCWS] to the heat sink (the sea) is completed.

The SEC [ESWS] is composed of three independent trains, adapting to the RRI [CCWS] (detailed in Sub-chapter 10.4.8). Train A and train B operate in the normal power operating conditions of the reactor, while train C is on standby. One pump is in service in each of train A and train B, maintenance on the other pumps on standby in train A and train B can be performed after they are isolated.

Train A and train B have the same configuration, each has two redundant sets of equipment. Train C only has one set. Each set includes the following equipment:

1) Seawater filtering equipment;
2) Suction pipeline;
3) Essential service water pump;
4) Debris filter;
5) Discharge pipeline.

In each SEC [ESWS] train, seawater is sucked from the sea through a dedicated SEC [ESWS] suction pipeline. After being filtered by a rotating type screen, the seawater is pumped by the essential service water pump through the SEC [ESWS] supply gallery and then into the RRI [CCWS]/SEC [ESWS] heat exchangers to cool the component cooling water. After passing through the RRI [CCWS]/SEC [ESWS] heat exchangers, the seawater is distributed to the overflow well via the SEC [ESWS] drainage pipe and is finally then returned to the sea through the discharge structure.

The detailed information is presented in the SDM, Reference [49].

The lowest temperature value is different between Fangchenggang and GDA generic site, the configuration will be changed in step 4.

b) Description of Main Equipment

The main components are described as follows (The detailed information is presented in the SDM, Reference [49].).

1) Seawater Filtering Equipment

The seawater filtering equipment comprises of mainly the coarse rack, fine rack, travelling band screen and flushing system. They are installed in front of the essential service water pump for preliminary seawater filtering.

Detailed information of the travelling band screen is shown in Reference [49].

The main design characteristics of the travelling band screen are listed in Table T-10.4-32.

T-10.4-32 Data sheet of the SEC [ESWS] Travelling Band Screen

Parameters	Value	Unit
Structural Style	Full Frame	---
Medium	Seawater	---
Nominal Width	3.5	m
Nominal Flow rate	3700	m^3/h
Mesh size	Ø3	mm
Material	Seawater Stainless	

2) Essential Service Water Pump

The essential service water pump is a horizontal centrifugal pump which is provided with impellers made of seawater corrosion resistant stainless steel.

Each essential service water pump is capable of providing the flow rate required by RRI [CCWS]/SEC [ESWS] heat exchangers even at the minimum designed seawater level.

Detailed information of the essential service water pump is shown in Reference [49].

The main design characteristics of the essential service water pump are listed in Table T-10.4-33.

T-10.4-33 Main Design Characteristics of the Essential Service Water Pump

Parameters	Value	Unit
Type	Centrifugal Pump	---
Medium	Seawater	---
Flow Rate	2700~3960	m^3/h
Discharge Head at Nominal Flow Rate	41.5	mWc
Material	Seawater Stainless	

3) Debris Filter

The debris filter is made of seawater corrosion resistant material. It is capable of performing automatic backwashing. The debris filter is installed upstream of the RRI [CCWS]/SEC [ESWS] heat exchangers for screening out marine objects.

Detailed information of the debris filter is shown in Reference [49].

The main design characteristics of the debris filter are listed in Table T-10.4-34.

T-10.4-34 Main Design Characteristics of the SEC [ESWS] Debris Filter

Parameters	**Value**	**Unit**
Type	Self-flushing Online Debris Filter	---
Medium	Seawater	---
Design Pressure	1.2	MPa (g)
Nominal Flow rate	3700	m^3/h
Mesh size	Ø2	mm
Material	Seawater Stainless	

c) Description of Main Layout

The seawater filtering equipment and essential service water pumps are located in two independent essential service water pump stations. Train A and train C are located in the Essential Service Water Pump Station A (BPA) and are physically separated. Train B is located in the Essential Service Water Pump Station B (BPB). The debris filters are located in Safeguard Building A (BSA), Safeguard Building B (BSB) and Safeguard Building C (BSC). The connecting pipes between pumps and RRI [CCWS]/SEC [ESWS] heat exchangers are installed in independent galleries.

The detailed information is presented in the SDM, Reference [50].

d) Description of System Interfaces

The systems supporting the fulfilment of SEC [ESWS] functions are:

1) Circulating Water Treatment System (CTE [CWTS])

The CTE [CWTS] performs the chlorination of the pre-filtrated seawater

which supplies the essential service water pumps intake.

2) Potable Water System (SEP [PWS])

The SEP [PWS] performs:

— The first filling of the SEC [ESWS] circuit;

— The permanent flushing of the SEC [ESWS] cooling pumps shaft mechanical seals in normal operating conditions and in accident operating conditions as long as available.

3) Drain Systems

The SEC [ESWS] effluents are collected by:

— The Station Sewer System (SEO [SSS]) in the essential service water supply gallery and Safeguard Building (BSX);

— The SEC [ESWS] sumps and SEC [ESWS] sump pumps in BPA and BPB.

4) Essential Service Water Pumping Station Ventilation System (DXS [ESWVS])

The ventilation of the essential service water pump station and essential service water supply galleries is performed by the DXS [ESWVS].

5) Electrical Division of Safeguard Building Ventilation System (DVL [EDSBVS])

The ventilation of the rooms of the BSX with SEC [ESWS] debris filters installed inside is ensured by the DVL [EDSBVS].

6) Served Systems

The SEC [ESWS] ensures the cooling of the RRI [CCWS]. The RRI [CCWS] itself cools its users.

e) Description of Instrumentation and Control

The SEC [ESWS] is designed to be automatically controlled, remote controlled and continuously monitored.

The SEC [ESWS] is equipped with flow rate instrumentation to monitor the flow rate of cooling water during unit operation.

Both the inlet and outlet of the essential service water pump are equipped with pressure measurement instruments to protect pumps and monitor the circuits for abnormalities.

The SEC [ESWS] sump informs the operator of the working condition of the

sump by the water level alarm in the main control room.

The detailed information is presented in the SDM, Reference [51].

10.4.9.4.2 System Operation

a) Plant Normal Condition

During normal operation of the power plant, the SEC [ESWS] operating configuration aligns with the RRI [CCWS] (see Sub-chapter 10.4.8).

b) Plant Accident Conditions

In the conditions of DBC-2/3/4 and in the condition of DEC-A, the SEC [ESWS] operating configurations aligns with the RRI [CCWS] if it is available (see Sub-chapter 10.4.8).

The detailed information is presented in the SDM, Reference [51].

10.4.9.5 Preliminary Design Substantiation

In this section, the system design is demonstrated to satisfy the safety functional requirements presented in Sub-chapter 10.4.9.1 and the general design requirements stated in Sub-chapter 10.2.4.

Since the general principles are newly developed at this stage, the system design is still based on the reference design and the information presented in this section is preliminary. A review of the consistency of the system design against the newly developed principles is currently being undertaken..

10.4.9.5.1 Compliance with Safety Functional Requirements

a) Control of Reactivity

The SEC [ESWS] is not required to perform this safety function.

b) Removal of Heat and Confinement

The flow rate of the SEC [ESWS] pump is 2700~3960m^3/h, adapting to different sea water levels to meet the heat load removal requirements.

c) Extra Safety Functions

The SEC [ESWS] is not required to perform this safety function.

The detailed information is presented in the SDM, Reference [52]

10.4.9.5.2 Compliance with Design Requirements

a) Safety Classification

The SEC [ESWS] design is compliant with the principles described in Chapter 4. The safety classification of SEC [ESWS] functions is listed in Table T-10.4-35

and the safety classification of main components in Table T-10.4-36.

T-10.4-35 Function Categorisation of the SEC [ESWS]

System Function	Function Category
Start-up of a SEC [ESWS] Train	FC1/FC2/FC3
Stopping of the SEC [ESWS] Filter Flushing	FC1/FC2/FC3

T-10.4-36 Classification for Components

Component	Function Class	Design Provision Category	Design Provision Class	Seismic Category
Coarse Rack	F-SC3	DPA	NC	SSE2
Fine Rack	F-SC3	DPA	NC	SSE2
Travelling Band Screen	F-SC2	DPA	NC	SSE1
Flushing Filter	F-SC2	DPA	NC	SSE1
Flushing Pump	F-SC2	DPA	NC	SSE1
Essential Service Water Pump	F-SC1	DPA	NC	SSE1
Debris Filter	F-SC1	DPA	NC	SSE1
SEC [ESWS] Sump Pump	F-SC3	DPA	NC	NO

b) Engineering Design Requirements

1) Reliability Design of SSCs

- Single Failure Criterion(SFC)

  The three SEC [ESWS] trains performing the safety function meet the single failure criterion during the design process.

- Independence

  Each train of the SEC [ESWS] is arranged in a building or gallery physically isolated from the others for protection.

  The three trains of the SEC [ESWS] are powered by different electrical safety trains.

- Diversity

  The SEC [ESWS] is composed of three independent trains, adapting to the RRI [CCWS].

- Fail-safe

  The components of the SEC [ESWS] are designed in fail-safe positions.

- Ageing and Degradation

  The system is designed for the 60 year plant operation. The design lifespan of the main components (pumps, valves, filtrations, instruments) is 60 years. The layout design will consider the requirements of removing the old parts and installing the replacements.

  The SEC [ESWS] is composed of three independent trains; the out of service debris filter can be replaced.

2) Human Factors

   The SEC [ESWS] is composed of three independent trains; switchover between different trains is automatic. Loss of one train can't impact the operation of the other trains.

   Each train of the SEC [ESWS] is arranged in a building or gallery physically isolated from the others and has enough space for maintenance and replacement of components.

3) Autonomy

   - Autonomy in Respect of Operators

     The SEC [ESWS] has three independence trains, switch-over between different trains can be carried out automatically.

   - Autonomy in Respect of Power Supply Systems

     The main components of the SEC [ESWS] are at safe positions when loss of the power supply system occurs.

4) Other Design Requirements

   The SEC [ESWS] is not required to consider other design requirements.

c) Equipment Qualification

All components performing the safety functions shall operate in both normal conditions and accident conditions, which requires the components to withstand the most adverse ambient environments expected.

Each safety classified component, as shown in Table T-10.4-36 shall be qualified in accordance with the principles described in Chapter 4.

d) Protection against Internal and External Hazards

The three safety-related trains of the SEC [ESWS] are separated from each other

by being arranged in independent buildings and galleries respectively. Among the three trains, the safety redundant equipment and pipelines are arranged and isolated physically and/or spatially to meet the hazard protection requirements.

The safety-related pipelines and equipment of the SEC [ESWS] are designed to be seismically qualified.

e) Commissioning

The system performance will be validated by commissioning and testing. Documents related to the commissioning will be delivered before the step 4 of GDA.

Initial testing of SSCs before delivery to site (for example factory acceptance tests) will be undertaken in accordance with procurement/manufacturing and commissioning quality arrangements.

Following acceptance of the SSC by the commissioning organization, a structured, systematic and progressive test program will be implemented, which includes all the activities required for confirmation and demonstration of the plant SSC operational and safety functional performance requirements.

Chapter 30 (Commissioning) gives the arrangements for the development of commissioning and the management of commissioning activities. These activities include the requirements for system performance tests to establish and demonstrate the plant performance characteristics, which can be used subsequently to help demonstrating on-going SSC performance and potentially detect the onset of unacceptable degradation of SSCs. Remedies will be taken accordingly in the situation described.

The testing and commissioning arrangements will be adapted from those developed for the HPR1000 (FCG3) under construction. Further detailed site specific arrangements for the UK HPR1000 commissioning activities, in addition to those described in Chapter 30, will be presented during the nuclear site licencing phase in conjunction with the site licensee.

f) Examination, Inspection, Maintenance and Testing

1) Examination and Inspection

Pre-service examination and inspection is necessary:

— SEC [ESWS] pump: inspection of the function characters according to the periodic test programme of the pump, especially for the temperature and vibration of the shaft.

— Debris filter: inspect the operating condition of the backwash valve and the pressure loss of the filter.

2) Maintenance

The SEC [ESWS] must ensure sufficient cooling water flow to the RRI [CCWS]/ SEC [ESWS] heat exchanger during normal operation of the plant to meet the safe operational requirements of the unit. The SEC [ESWS] is designed to allow for outages of FC1 and FC2 safety functions during shutdown to free up the train and equipment for maintenance.

The design and layout of other equipment is facilitated during maintenance of the plant during refuelling.

3) Periodic Tests

Documents related to the periodic tests will be delivered before the step 4 of GDA.

g) Decommissioning

The SEC [ESWS] is still required to operate during decommissioning to remove the heat from the RRI [CCWS].

h) Material Selection

Materials of SEC components are chosen in order to withstand the effects induced by the seawater:

1) Pumps, swing and centre post guided check valves are made of stainless steel for resisting the effects of seawater;

2) Butterfly valves, filters are made of rubber-coated carbon steel.

i) Special Thermal-hydraulic Phenomena

The SEC [ESWS] is not required to consider special thermal-hydraulic phenomena

j) Insulation

The SEC [ESWS] is not required to consider insulation

10.4.9.6 Functional Diagrams

The simplified flow diagram of the SEC [ESWS] is shown in Figure F-10.4-10.

10.4.10 ALARP Assessment

A preliminary ALARP analysis has been performed on the nuclear auxiliary systems. The analysis is consistent with the arguments stated in the Sub-claim 3.3.6C of the route map presented in Appendix B:

Argument 3.3.6C-1: The SSCs meet the requirements of the relevant design principles (generic and system specific) and therefore of relevant good practice:

The detailed codes and standards list is presented in Reference [6]. At this stage, no gap has been identified at the system level. The consistency analysis is still under development to ensure that the design of the SSCs meets the requirements of the UK context.

A compliance analysis of the system design with respect to the UK HPR1000 general safety engineering principles is made in the system section of each sub-chapter. The analysis shows that the design of the SSCs meets relevant requirements and no gaps have been identified. Meanwhile, technical assessments such as the hazard schedule, fault schedule, probabilistic safety assessment, human factors, and instrumentation and control are being developed simultaneously. The analysis of the design against the requirements of these technical assessments needs to be reviewed periodically. A systematic review will be carried out on the system design to ensure that no new gaps are identified between the newly developed requirements and the design. Any potential enhancements identified during this review will be taken into account in the future design development.

Argument 3.3.2C-2: PSA indicates the SSCs are not a disproportionate contributor to risk:

Potential areas of improvement in the system design will be identified to reduce the risks during the process of fault analysis. Since the PSA and the fault analysis are still under development, further ALARP analysis will be performed once the fault schedule work is finished.

If any potential gap is identified during the systematic technical review, analysis and optioneering will be carried out to determine whether there are possible enhancements to the current system design, in order to reduce the risk as low as reasonably practicable.

Argument 3.3.2C-3: Design improvements have been considered in the SSCs and any reasonably practicable changes implemented:

The design improvements will be carried out once the potential areas of improvement in the design are identified. The ALARP assessment will be further developed to evaluate the design improvements.

In summary, the ALARP analysis and demonstration work is currently being carried out. A preliminary ALARP demonstration topic report to present the current analysis results as well as the arrangement for future ALARP analysis work is presented in Reference [13].

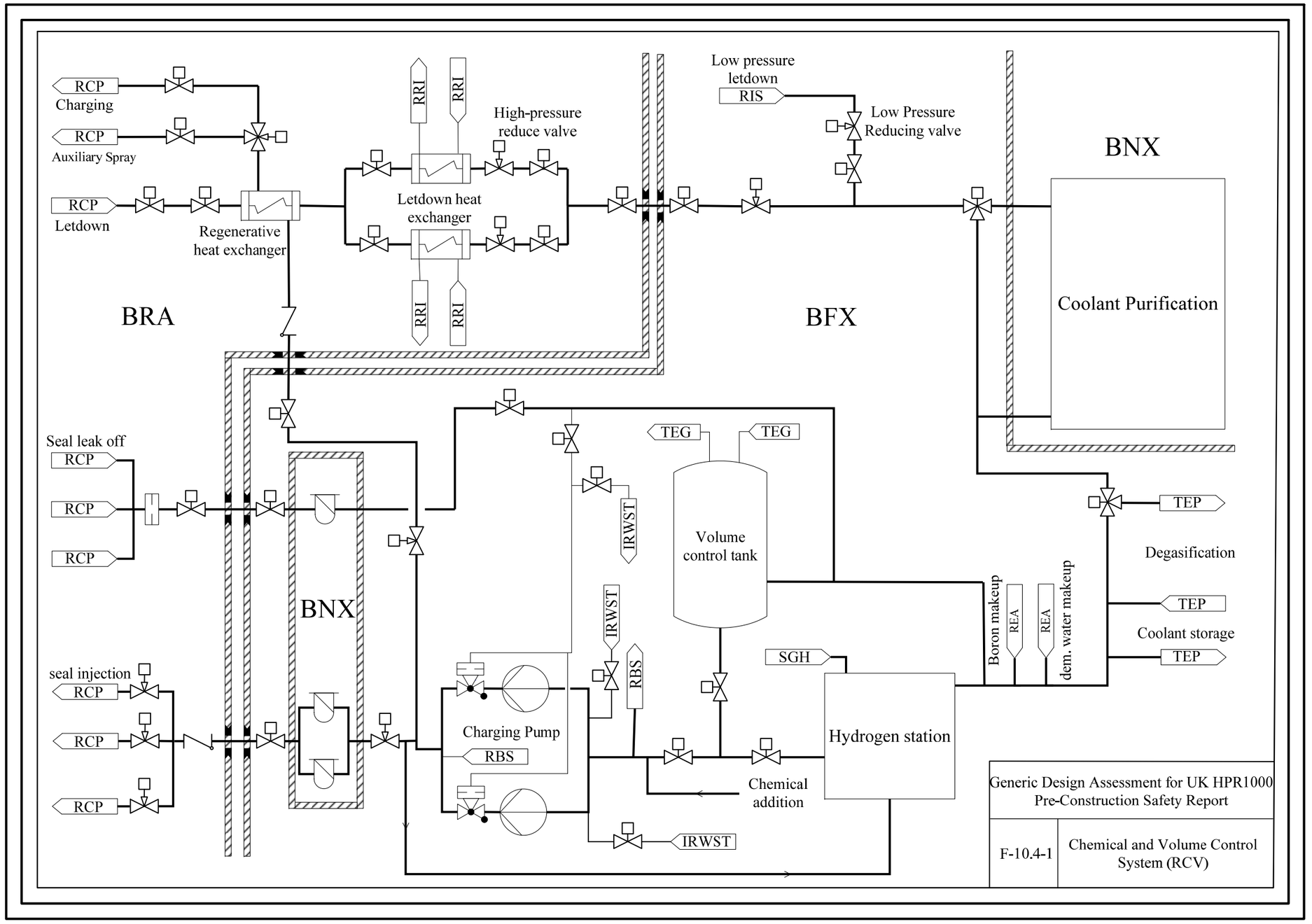
10.4.11 Concluding Remarks

This chapter provides an introduction on the design information of nuclear auxiliary systems in the UK HPR1000 nuclear power plant.

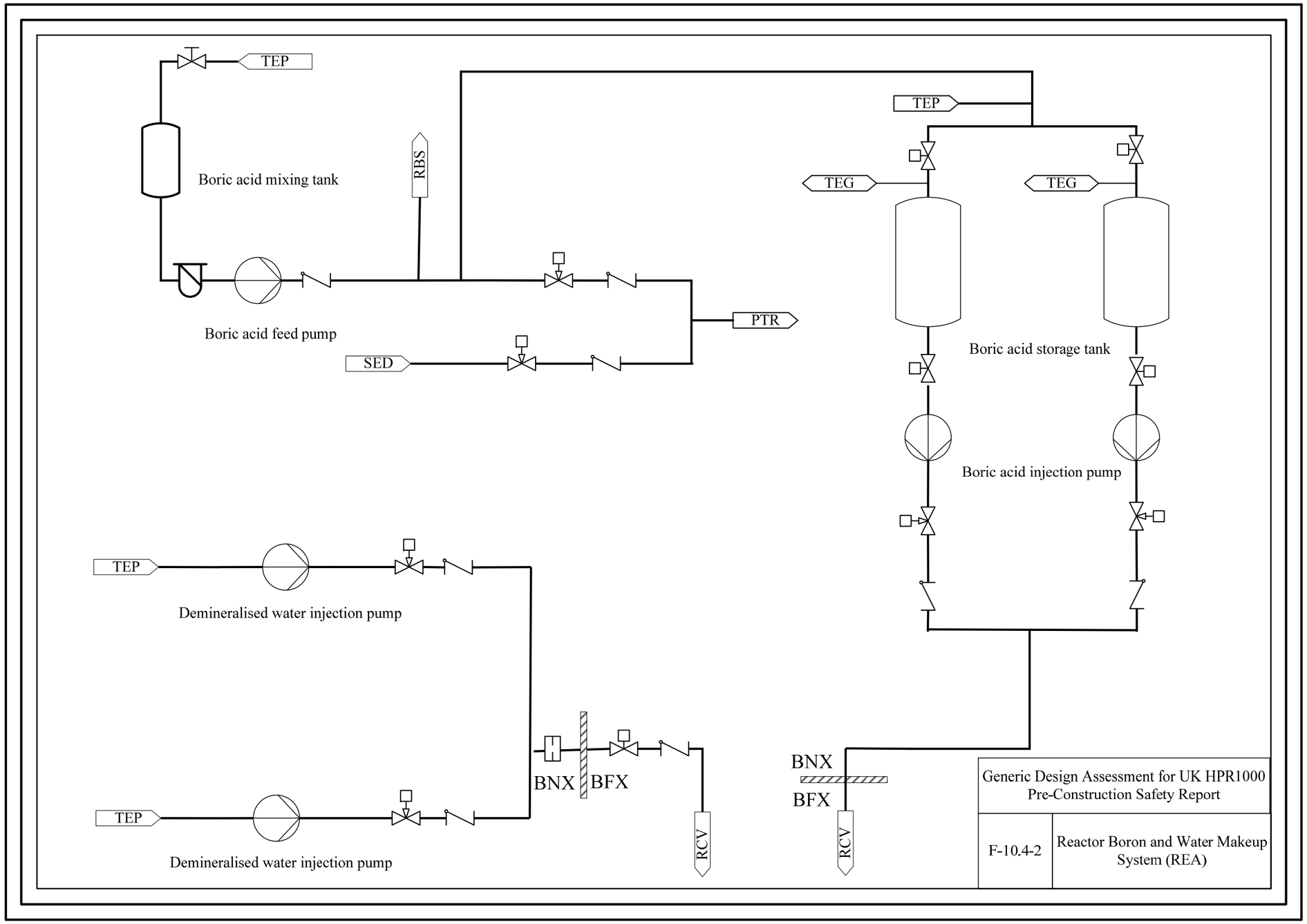
At this stage, the general safety engineering principles are newly developed for the preliminary assessment. At the same time, various technical areas are currently under development such as the hazard schedule, fault schedule, probabilistic safety assessment, human factors, instrumentation and control, etc. As the factors mentioned above may influence the current design, a systematic review will be carried out after the preliminary work has been finished. If any gap is identified during the technical review, an ALARP demonstration will be carried out and effort will be made to reduce the risk as low as reasonable practicable.

10.4.12 Simplified Diagrams

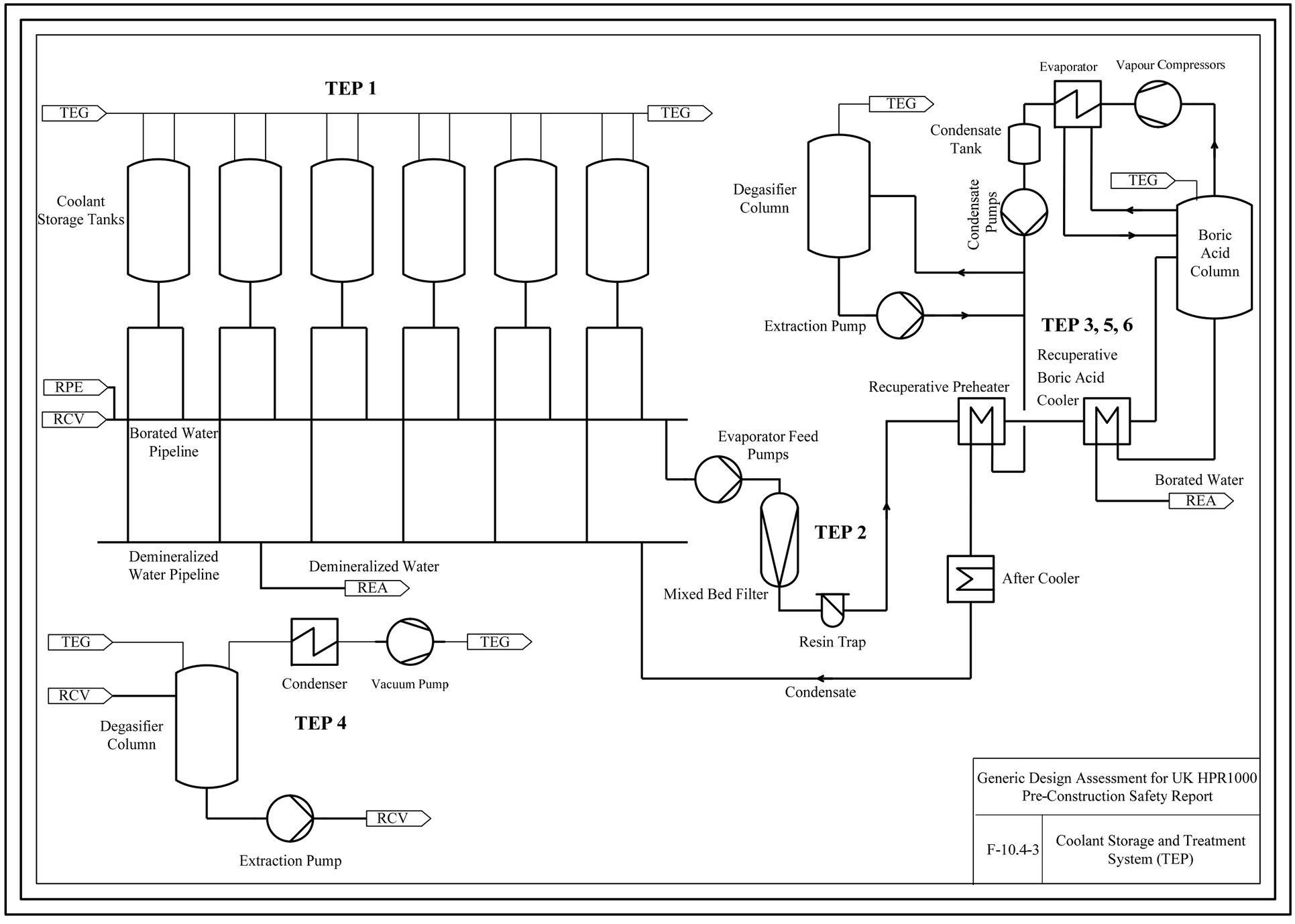
Simplified diagrams of nuclear auxiliary systems mentioned in Sub-chapters 10.4.3 to 10.4.9 are presented as follows:



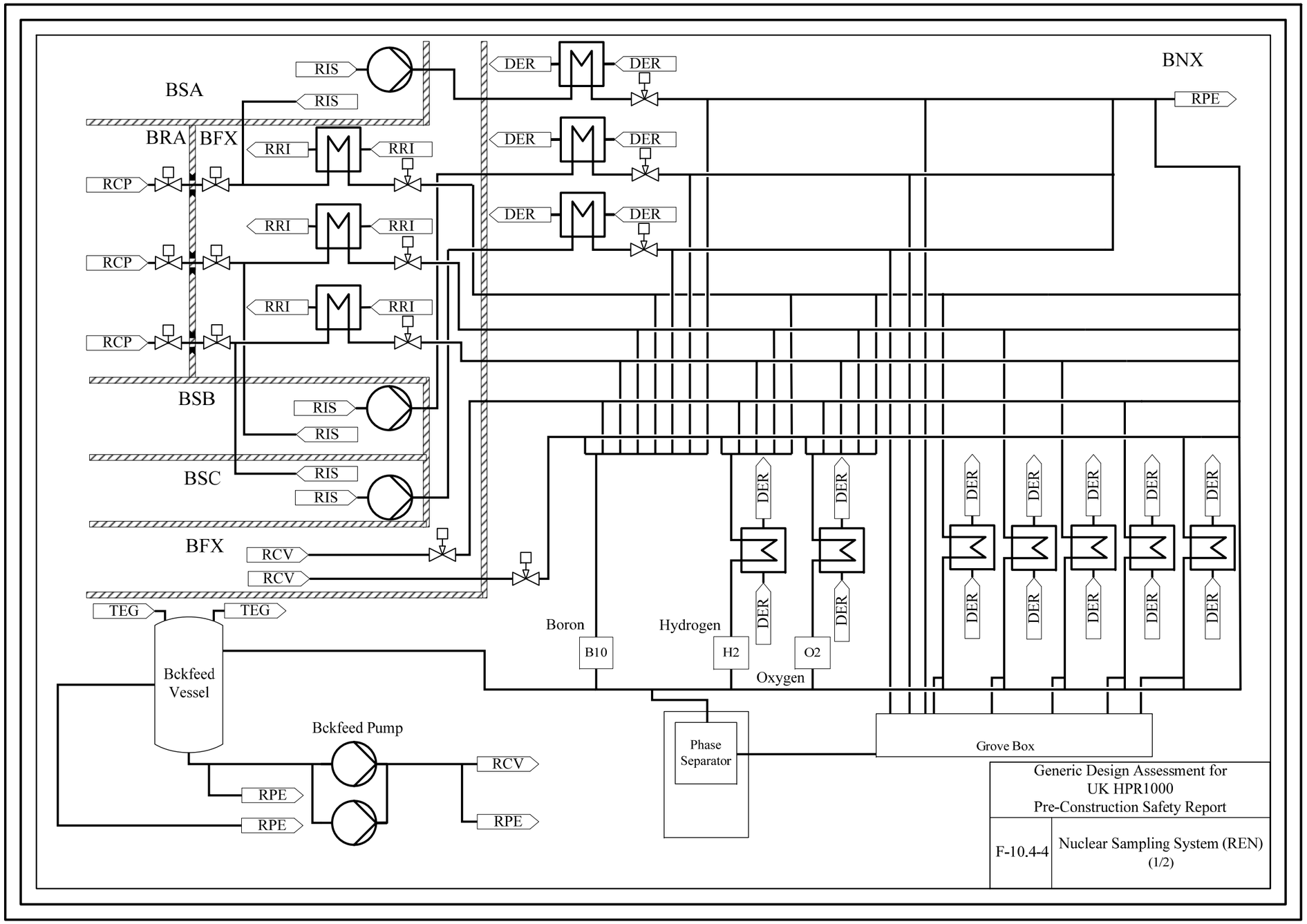
F-10.4-1 Simplified Diagram of the RCV [CVCS]



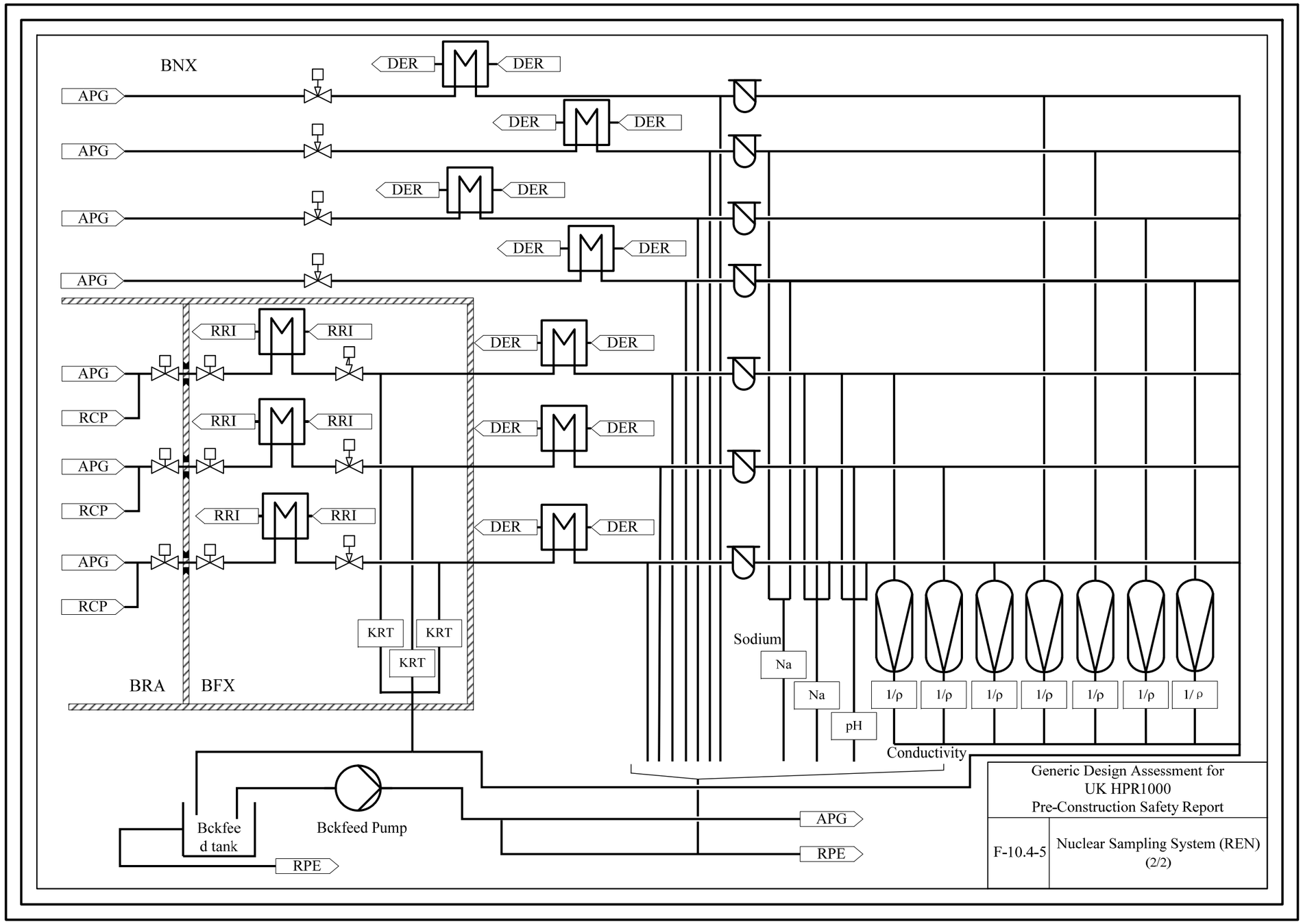
F-10.4-2 Simplified Diagram of the REA [RBWMS]



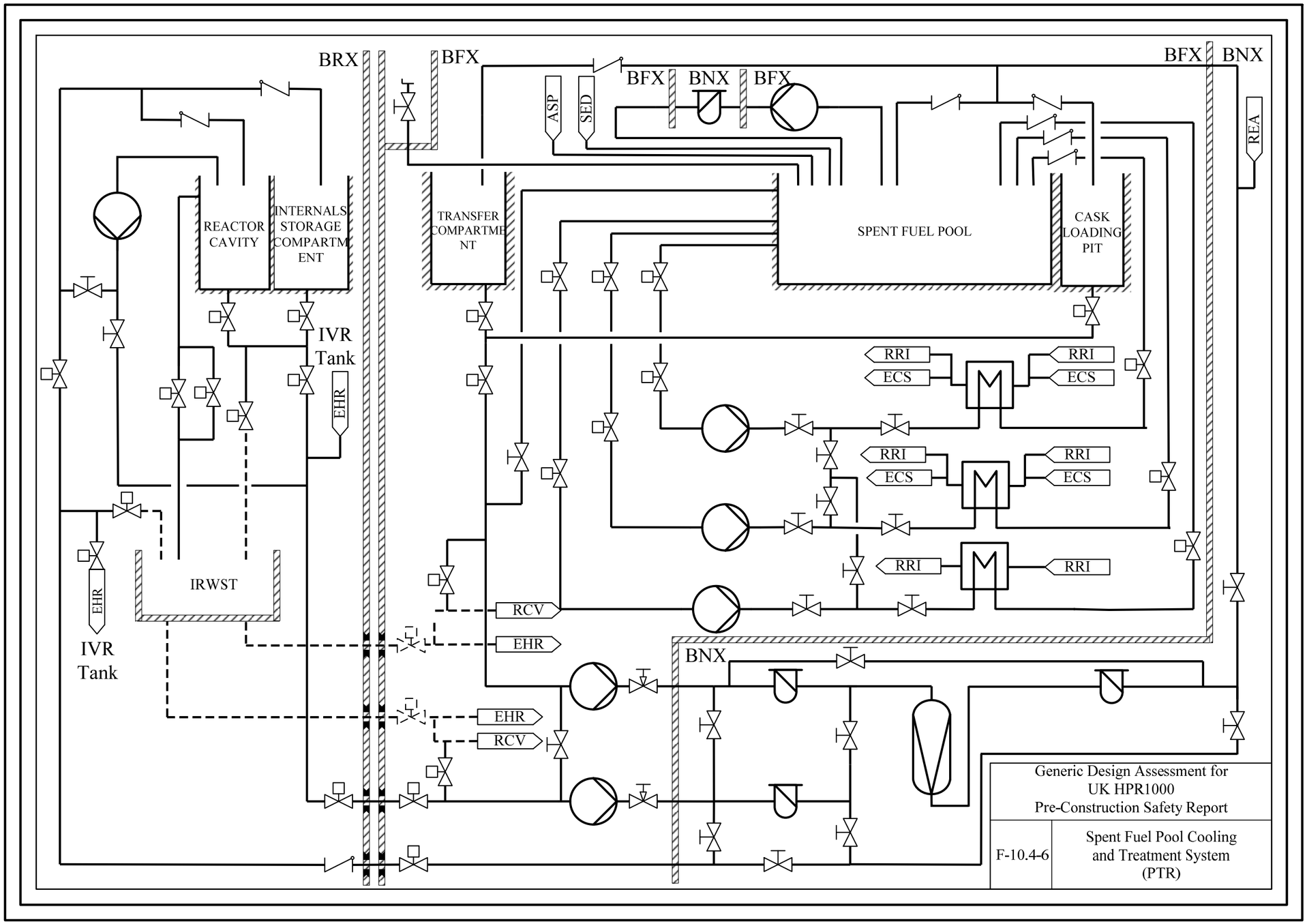
F-10.4-3 Simplified Diagram of the TEP [CSTS]



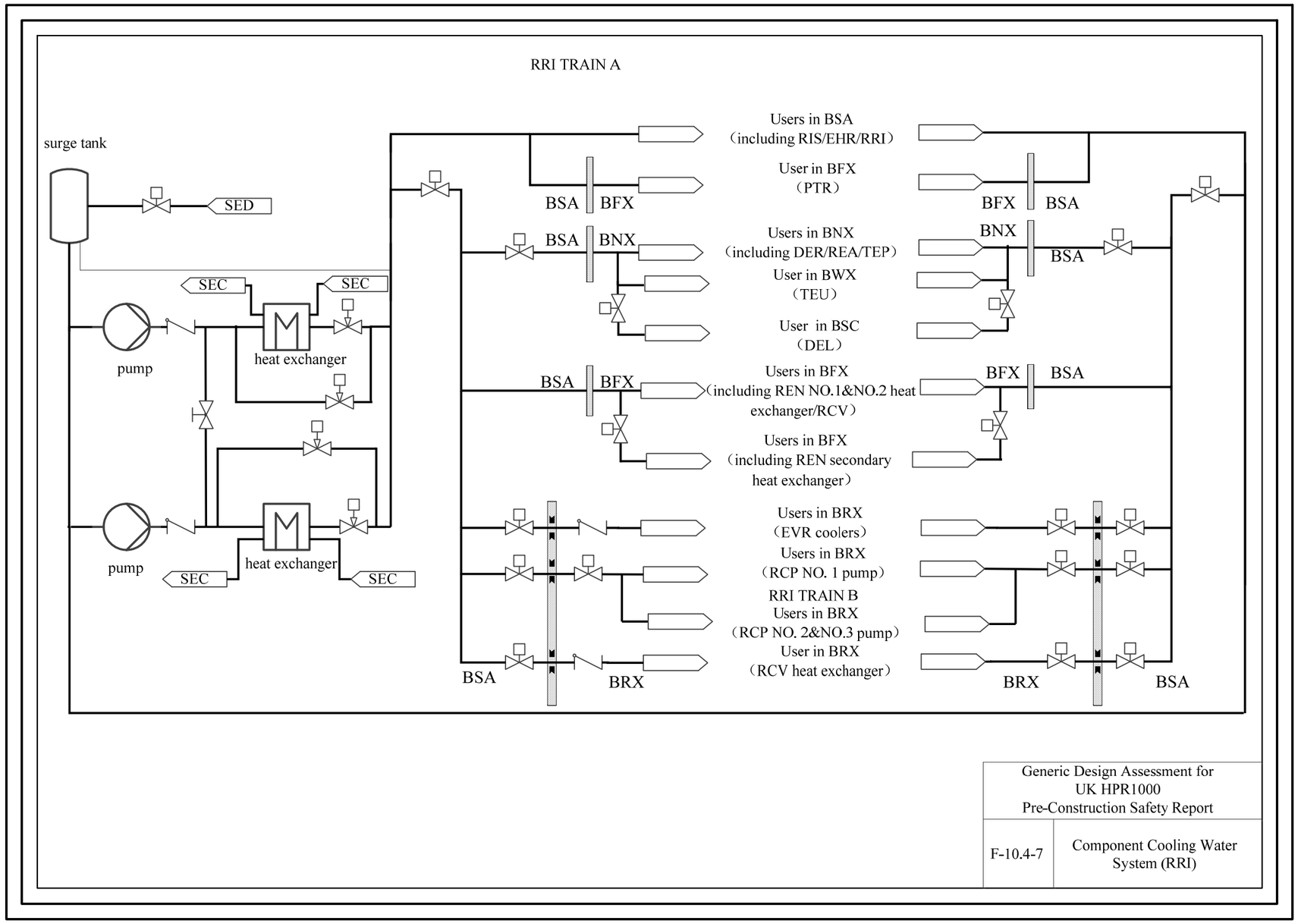
F-10.4-4 Simplified Diagrams of the REN [NSS] (1/2)



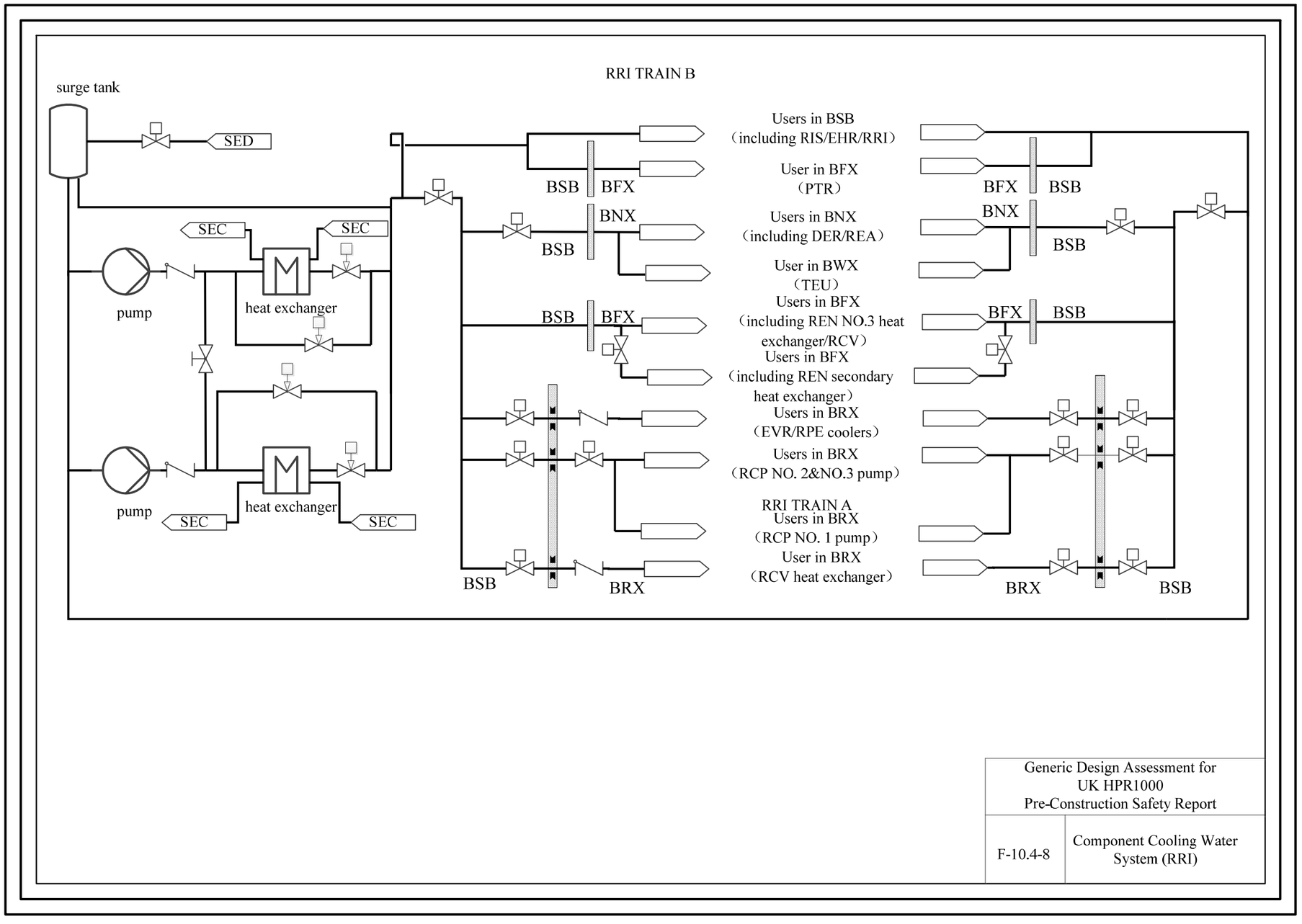
F-10.4-5 Simplified Diagrams of the REN [NSS] (2/2)



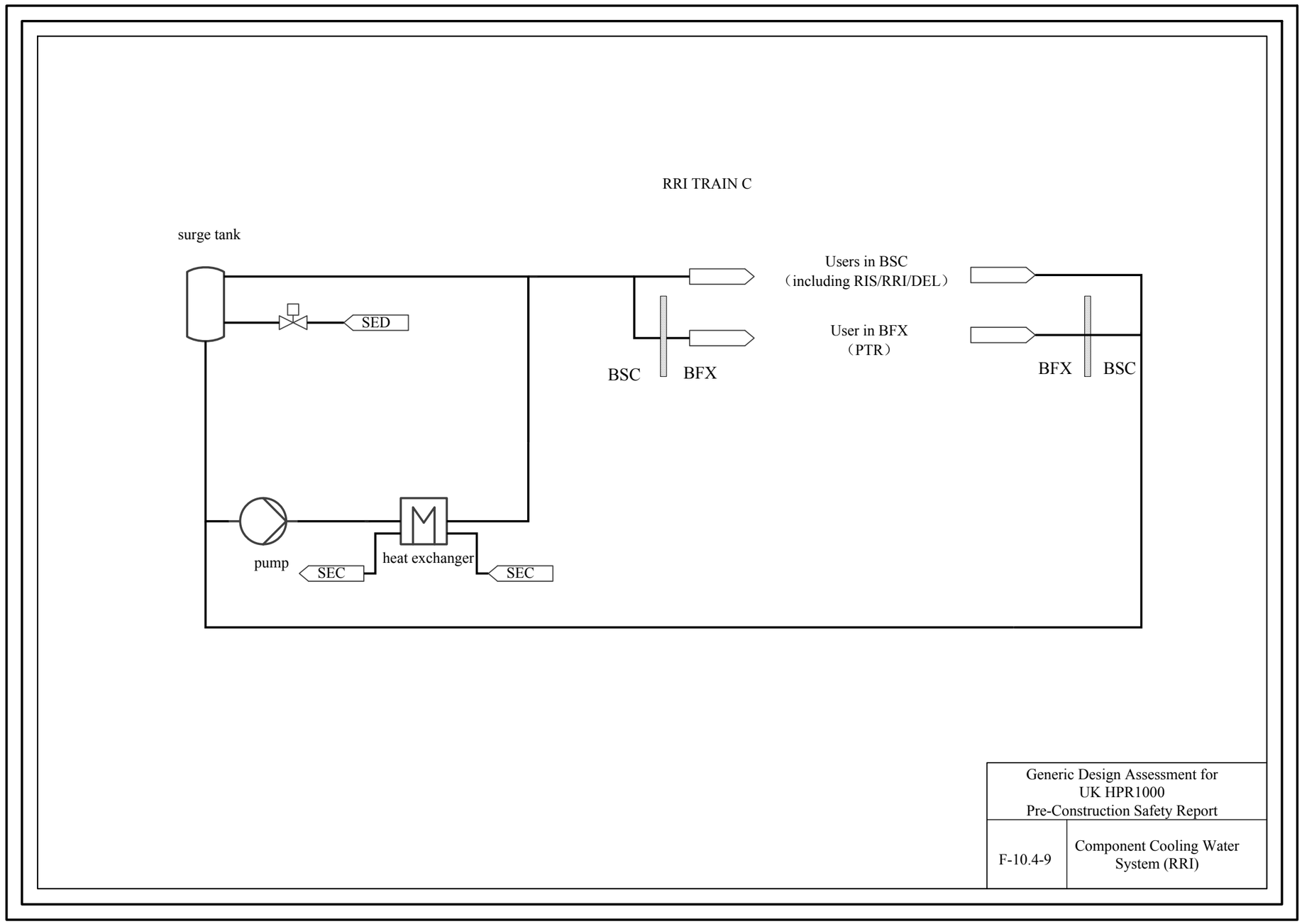
F-10.4-6 Simplified Diagram of the PTR [FPCTS]



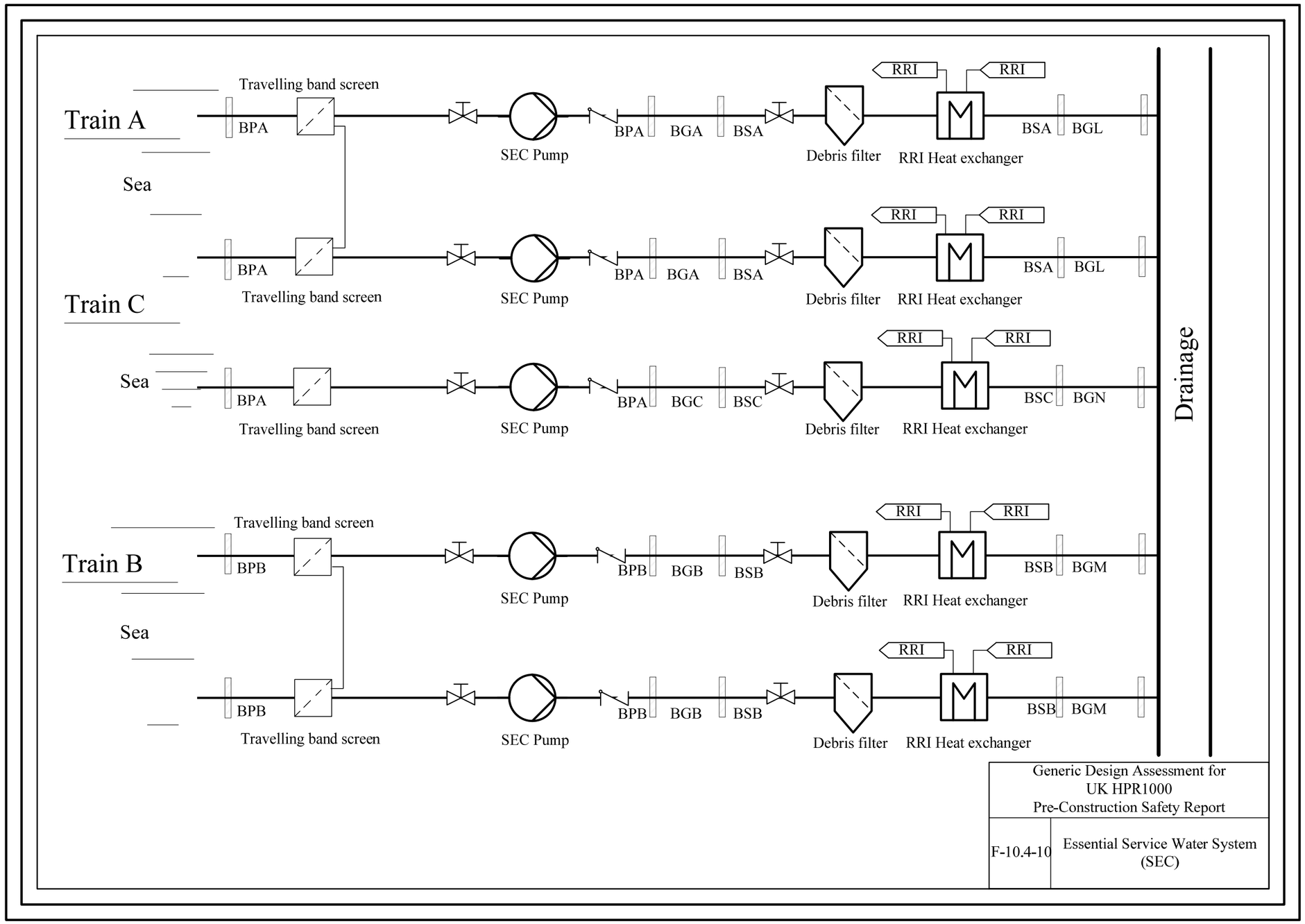
F-10.4-7 Simplified Diagram of the RRI [CCWS] (Train A)



F-10.4-8 Simplified Diagram of the RRI [CCWS] (Train B)



F-10.4-9 Simplified Diagram of the RRI [CCWS] (Train C)



F-10.4-10 Simplified Diagram of the SEC [ESWS]

10.5 Process Auxiliary Systems

10.5.1 Sub-chapter Structure

The structure of Sub-chapter 10.5 is as follows:

a) Sub-chapter 10.5.1 (Sub-chapter Structure) gives the overall structure of Sub-chapter 10.5;

b) The Sub-chapter 10.5.2 (Applicable Codes and Standards) presents the relevant codes and standards adopted in this chapter;

c) The Sub-chapters 10.5.3 to 10.5.6 present the following auxiliary systems:

   1) 10.5.3 NI Demineralised Water Distribution System (SED [DWDS (NI)])

   2) 10.5.4 Potable Water System (SEP [PWS (NI)])

   3) 10.5.5 nuclear island gas distribution systems, including Oxygen Distribution System (SGO [ODS]), Nitrogen Distribution System (SGN [NDS]), and Hydrogen Distribution System (SGH [HDS])

   4) 10.5.6 compressed air distribution systems, including Compressed Air Production System (SAP [CAPS]), Instrument Compressed Air Distribution System (SAR [ICADS]), and Service Compressed Air Distribution System (SAT [SCADS])

   These sub-chapters give the detailed description of the process auxiliary systems;

d) The Sub-chapter 10.5.7 (ALARP Assessment) gives the preliminary ALARP analysis of this sub-chapter;

e) The Sub-chapter 10.5.8 (Concluding Remarks) gives the summary and the on-going work of this sub-chapter;

10.5.2 Applicable Codes and Standards

The identification of applicable codes and standards in Sub-chapter 10.5 is compliant with the general principles of codes and standards selection stated in Chapter 4 and Reference [5].

Wherever possible, the selected codes and standards applied for the engineering substantiation are:

a) Commensurate with the categorisation of safety functions and classification of the SSCs;

b) Internationally good practice recognised by UK regulator in nuclear industry;

c) The latest version. Where to select an older version, gap analysis will be carried out.

Based on the selection principles and the selection process, the applicable codes and standards which are applied in Mechanical Engineering (ME) design are identified and evaluated in Reference [6]. Main applicable codes and standards for process auxiliary systems design are presented in Table T-10.5-1. Currently, the work of conformity analysis and gap analysis of the codes and standards is continuing.

T-10.5-1 Applicable Codes and Standards in Sub-chapter 10.5

Codes and Standards Number	Title
IAEA, SSR-2/1, 2016	Safety of Nuclear Power Plants: Design.
RCC-M, 2007	Design and Construction Rules for Mechanical Components of PWR Nuclear Islands
RSE-M, 2010+2012 Addenda	In-service Inspection Rules for Mechanical Components of PWR Nuclear Islands

10.5.3 NI Demineralised Water Distribution System (SED [DWDS (NI)])

The NI Demineralised Water Distribution System (SED [DWDS (NI)]) falls into the category of auxiliary system, and performs the functions of distributing demineralised water to consumers within the Nuclear Island (NI). SED [DWDS (NI)] consists of three systems parts and the pipelines are arranged in various building in NI to fulfil the requirement of different consumers.

10.5.3.1 Safety Functional Requirements

The motor-operated containment isolation valves of SED [DWDS (NI)] in the supply line of the consumers inside Reactor Building (BRX) are required to perform the safety functional requirement of containment. The safety functional requirements of containment isolation of the SED [DWDS (NI)] are in compliance with the demonstration in Sub-chapter 7.4.6.1 of PCSR Chapter 7.

10.5.3.2 Design Requirements

The design requirements of containment isolation of the SED [DWDS (NI)] are in compliance with the demonstration in Sub-chapter 7.4.6.2 of PCSR Chapter 7.

10.5.3.3 Design Bases

The design bases of containment isolation of the SED [DWDS (NI)] are in compliance with the demonstration in Sub-chapter 7.4.6.3 of PCSR Chapter 7.

10.5.3.4 System Description and Operation

10.5.3.4.1 System Description

a) General System Description

The SED [DWDS (NI)] is designed to ensure the supply of neutral demineralised water which is produced by the Demineralised Water Production System (SDA [DWPS]), and required for the various circuits and equipment contained within the Nuclear Island (NI).

The SED [DWDS (NI)] is divided into following three system parts

1) SED3: distributing demineralised water to consumers within the Radioactive Waste Processing Building (BWX);

2) SED4: distributing demineralised water to consumers within buildings in the nuclear island;

3) SED5: seal water system part to ensure the supply of demineralised water with high pressure.

Each system part of SED [DWDS (NI)] distributes demineralised water to consumers during the Design Basis Condition (DBC)-1, and the seal water system part also distributes seal water to consumers during the DBC-2.

b) Description of Main Equipment

1) Seal Water Pumps

2×100% centrifugal pumps are designed to ensure the pressure of seal water system part.

2) Startup Filter

At the inlet of the BNX a start-up filter is arranged to filter the demineralised water, the startup filter is installed during commissioning, no bypass or pressure gauges are needed. After commissioning the filter will be removed and replaced by a flanged spool piece.

3) Seal Water Storage Tank

A seal water storage is designed to provide inlet demineralised water to the seal water pumps.

c) Description of Main Layout

The SED [DWDS (NI)] piping in site enters into the BNX and BWX via the site gallery. Pipelines of SED [DWDS (NI)] are arranged in NI buildings including The BWX, BRX, BNX, Fuel Building (BFX), Safeguard Building A (BSA), Safeguard Building B (BSB), Safeguard Building C (BSC) and diesel generator

buildings.

d) Description of System Interfaces

The demineralised water in SED [DWDS (NI)] is pumped from the demineralised water storage tank by demineralised water pumps of SDA [DWPS]. The consumer systems of SED [DWDS (NI)] are listed as follows:

1) Radioactive Decontamination System (SBD [RDS]);
2) Solid Waste Treatment System (TES [SWTS]);
3) Liquid Waste Treatment System (TEU [LWTS]);
4) Steam Generator Blowdown System (APG [SGBS]);
5) Fuel Pool Cooling and Treatment System (PTR [FPCTS]);
6) Reactor Coolant System (RCP [RCS]);
7) Reactor Boron and Water Makeup System (REA [RBWMS]);
8) Nuclear Sampling System (REN [NSS]);
9) Nuclear Island Vent and Drain System (RPE [VDS]);
10) Component Cooling Water System (RRI [CCWS]);
11) Gaseous Waste Treatment System (TEG [GWTS]);
12) Coolant Storage and Treatment System (TEP [CSTS]);
13) Extra Cooling System (ECS [ECS]);
14) Safety Injection System (RIS [SIS]);
15) Auxiliary Steam Production System (XCA [ASPS]);
16) Atmospheric Steam Dump System (VDA [ASDS]);
17) Containment Filtration and Exhaust System (EUF [CFES]);
18) Chemical and Volume Control System (RCV [CVCS]);
19) NI 10kV Emergency Power Distribution System (LH [EPDS(NI-10kV)]);
20) Safety Chilled Water System (DEL [SCWS]);
21) Operational Chilled Water System (DER [OCWS]);
22) Waste Treatment Building Chilled water System (DEQ [WBCWS]);

10.5.3.4.2 System Operation

a) Plant Normal Condition

In plant normal condition, SED [DWDS (NI)] supplies demineralised water to the consumers in NI. The containment isolation valves are opened. One of the two seal water pumps is continuously running to deliver the seal water flow at the required pressure and flowrate.

b) Plant Fault or Accident Condition

The containment isolation valves are closed by the Reactor Protection System in case of LOCA.

10.5.3.5 Preliminary Design Substantiation

10.5.3.5.1 Compliance with Safety Functional Requirements

The compliance with safety requirements of the SED [DWDS (NI)] containment isolation is in compliance with the demonstration in Sub-chapter 7.4.6.5.1 of PCSR Chapter 7.

10.5.3.5.2 Compliance with Design Requirements

The compliance with design requirements of the SED [DWDS (NI)] containment isolation is in compliance with the demonstration in Sub-chapter 7.4.6.5.2 of PCSR Chapter 7.The system specific demonstration are listed as follows:

a) Compliance with Engineering Design Requirements

1) Reliability Design of SSCs

- Independence

  The two containment isolation valves are physically separated by the installation location, one inside and the other outside the containment.

- Diversity

  Not applicable.

- Ageing and Degradation

  The containment isolation valves and penetrations of SED [DWDS (NI)] are designed for the 60-year operation. The SED [DWDS (NI)] considers the requirements stated in Sub-chapter 10.2.4 and the design considerations and measures described in Sub-chapter 10.2.4 are applied in the design of SED [DWDS (NI)].

2) Human Factors

The SED [DWDS (NI)] considers the requirements stated in Sub-chapter 10.2.4 and the design considerations and measures described in Sub-chapter 10.2.4 are applied in the design of SED [DWDS (NI)].

3) Autonomy

- Autonomy in Respect of Operators

  The design principles relevant to the autonomy in respect of operators are detailed in Sub-chapter 10.2.4. The design of SED [DWDS (NI)] fulfils these principles via control functional design.

- Autonomy in Respect of Heat Sink

  Not applicable.

- Autonomy in Respect of Power Supply Systems

  The safety classified components, such as the containment isolation valves, are all provided with emergency diesel generators.

4) Other Design Requirements

- Prevention of Harmful Interactions of Systems Important to Safety

  Not applicable.

- Considerations Related to the Electrical Power Grid

  The design of active components such as the containment isolation valves has taken the disturbances in the electrical power grid into consideration.

b) Equipment Qualification

The SED [DWDS (NI)] containment isolation valves should be capable of operating under normal conditions and accidental conditions, which requires the components to withstand the most penalised ambient environment conditions.

The SED [DWDS (NI)] containment isolation valves which are seismic classified operate during and after the SSE. The components are seismic designed and qualified with SSE load.

c) Protection against Internal and External Hazards

The SED [DWDS (NI)] complies with the requirements stated in Sub-chapter 10.2.4 and design considerations and measures described in Sub-chapter 10.2.4 are applied in the design of SED [DWDS (NI)].

d) Commissioning

Commissioning and tests are going to be carried out for the SED [DWDS (NI)] containment isolation valves to valid their functionality.

e) Examination, Inspection, Maintenance and Testing

1) Inspections and Surveillances

The SED [DWDS (NI)] should be talked in the periodical testing, pressure test, nondestructive inspection for making the system safe. The safety valves should be tested periodical tests

2) Maintenances

Maintenance of the SED [DWDS (NI)] is performed according to the corresponding industrial codes and guidelines include pipes and valves should take periodical cleanliness. SED [DWDS (NI)] valves should be easily accessible.

Preventive maintenance on the SED [DWDS (NI)] components is performed according to the specifications of manufactures and category of materials. The safety classified components (containment penetration and containment isolation valves) are inspected periodically.

The valves may only be maintained when the plant is in shutdown. Annual testing should be performed to check that the various valves are operable and watertight.

3) Periodic Tests

Safety valves, isolation valves, check valves in SED [DWDS (NI)] should take periodically test.

f) Material Selection

All parts of the SED [DWDS (NI)] are made of stainless steel as untreated demineralised water can be corrosive.

g) Special Thermal-hydraulic Phenomena

The design of the SED [DWDS (NI)] considers the prevention of harmful thermal-hydraulic phenomena such as the water hammer.

h) Insulation

Not applicable.

10.5.4 Nuclear Island Potable Water System (SEP [PWS (NI)])

The SEP [PWS (NI)] falls into the category of Process Auxiliary System, and performs the functions of transferring potable water to each user.

10.5.4.1 Safety Functional Requirements

The SEP [PWS (NI)] is not required to perform safety functions. The SEP [PWS (NI)] needs to be physically separated from all radioactive sources and from any system that may contain substances dangerous to health, therefore, the SEP [PWS (NI)] does not

need to perform the nuclear safety basis event DBC-2, DBC-3, DBC-4 and DEC.

10.5.4.1.1 Control of Reactivity

Not applicable.

10.5.4.1.2 Removal of Heat

Not applicable.

10.5.4.1.3 Confinement

Not applicable

10.5.4.1.4 Extra Safety Functions

Not applicable

10.5.4.2 Design Requirements

The SEP [PWS (NI)] is not a safety classification system, therefore, most of the general design requirements listed in Sub-chapter 10.2.4 need not to be complied with except human factors.

10.5.4.3 Design Bases

There's no quantitative safety-related design assumption for the SEP [PWS (NI)].

10.5.4.4 System Description and Operation

10.5.4.4.1 System Description

a) General System Description

The SEP [PWS] (NI) distributes potable water to users with a piping network, arranged outside the wall in building. The system mainly consists of valves, pipes and water appliances.

The potable water systems are of two types:

1) Sanitary Needs

The potable water system in Nuclear Island provides potable water to the toilet, kitchen, dining room, tea room in safeguard building and bathroom, toilet in access building.

2) Industrial Needs

The potable water system in nuclear island provides potable water to eyewash equipment and hot laundry facility in waste treatment building and HAVC system, eyewash equipment in safeguard building.

b) Description of Main Equipment

The specific water appliances will be provided at the site specific stage.

c) Description of Main Layout

The branch of the SEP [PWS (NI)] can be connected from the outdoor loop piping network of site SEP [PWS (NI)]. The pipes of the SEP [PWS (NI)] are located separately in Safeguard Building A (BSA), Safeguard Building B (BSB), Safeguard Building C (BSC), Nuclear Auxiliary Building (BNX), Personnel Access Building (BPX), Radioactive Waste Treatment Building (BWX), Essential Service Water Pumps Station A (BPA), and Essential Service Water Pumps Station B (BPB).

d) Description of System Interfaces

The consumer systems of the SEP [PWS (NI)] are listed as follows:

1) Main Control Room Air Conditioning System (DCL [MCRACS]);

2) Electrical Division of Safeguard Building Ventilation System (DVL [EDSBVS);

3) Essential Service Water System (SEC [ESWS]);

4) Hot Laundry System (SBE [HLS]).

e) Description of Instrumentation and Control

There is no control function of the SEP [PWS (NI)].

10.5.4.4.2 System Operation

a) Plant Normal Condition

This system is an automatic system in normal condition, and is supplied by outdoor piping network of the SEP [PWS].

b) Plant Fault or Accident Condition

This system is not applicable in plant accident condition.

10.5.4.5 Preliminary Design Substantiation

a) Safety Requirements

The SEP [PWS (NI)] is not required to perform nuclear safety functions. This system can meet the requirement of both sanitary needs and industrial needs.

b) Commissioning and Testing

The SEP [PWS (NI)] is not subject to periodic tests. The equipment of the SEP [PWS (NI)], most are valves, should be maintained according to the maintenance manual supplied by equipment provider.

c) Human Factors

The concept of human factors is taken into consideration in the SEP [PWS (NI)] design. The layout of the equipment and the valves is designed to meet the requirement that the maintenance workers can be easily approached. The detailed layout will be provided during the nuclear site licensing phase.

10.5.5 Nuclear Island Gas Distribution Systems (SGO [ODS], SGN [NDS], SGH [HDS])

10.5.5.1 Safety Functional Requirements

The nuclear island gas distribution systems are classified as non-nuclear safety class, as it does not perform nuclear safety functions. However, pipelines running through containment building and related valves are required to be F-SC1 safety class.

10.5.5.2 Design Requirements

Due to the non-nuclear safety class of the systems, the general design requirements related to nuclear safety are not applicable for the nuclear island gas distribution systems. However, the design of nuclear island gas distribution systems shall not have a harmful impact on the safety systems.

The design requirements of containment isolation of the SGN [NDS] are in compliance with the demonstration in Sub-chapter 7.4.6.2.

10.5.5.3 Design Bases

10.5.5.3.1 General Assumptions

The specific site parameters are considered in the system design. The applicable equipment shall be purchased to ensure their performances and reliabilities in the site specific stage.

10.5.5.3.2 Design Assumptions

The nuclear island gas distribution systems are designed to meet the demand for nitrogen, oxygen and hydrogen of the plant under any operational conditions.

In the UK HPR1000, the operating parameters of the gas distribution systems are designed accordingly. The operating pressures of the SGH [HDS] and SGO [ODS] are designed to meet the requirements of the downstream users. Based on the different users, the SGN [NDS] are designed to be two subsystems, a high pressure nitrogen distribution system and a low pressure nitrogen distribution system.

In the SGN [NDS], the containment isolation valves are designed to reduce the leakage of radioactive material in the event of an accident.

Precautionary measures are taken to prevent the content of nitrogen, as an inert gas, from rising to a certain concentration that threatens the lives of the staff.

Measures are taken on the hydrogen pipelines to avoid possible explosions caused by gas leakage.

The single failure criterion is applicable to the containment isolation valves.

10.5.5.4 System Description and Operation

10.5.5.4.1 System Description

The nuclear island gas distribution systems provide nitrogen, oxygen and hydrogen for related systems and equipment of the nuclear island. The distribution networks consist of valves, pressure reducing valves, and pipelines connecting the user system and equipment. Nitrogen and oxygen come from the service gas storage zone and hydrogen from the hydrogen station, located in the Balance of Plant (BOP). The nuclear island gas distribution systems provide gas for the following systems:

a) Reactor Coolant System (RCP [RCS]);

b) Fuel Pool Cooling and Treatment System (PTR [FPCTS]);

c) Safety Injection System (RIS [SIS]);

d) Chemical and Volume Control System (RCV [CVCS]);

e) Coolant Storage and Treatment System (TEP [CSTS]);

f) Reactor Boron and Water Makeup System (REA [RBWMS]);

g) Gaseous Waste Treatment System (TEG [GWTS]);

h) Nuclear Sampling System (REN [NSS]);

i) Steam Generator Blowdown System (APG [SGBS]).

The nuclear island gas distribution systems include the SGN [NDS], SGO [ODS] and SGH [HDS]. They are designed respectively according to the maximum consumption of gas users under all operational conditions. The gas distribution system mainly includes the following pipelines:

a) Gas Distribution Pipelines;

b) Gas Pressure Reducing Pipelines;

c) Overpressure Protection Pipelines;

d) Test Relief and Drain Pipelines;

e) Containment Penetrations.

10.5.5.4.2 System Operation

a) Plant in the Normal Operational Conditions

The nuclear island gas distribution systems can operate under the plant normal operational conditions and during overhaul period.

The operability of any auxiliary system, which is a downstream user, will be affected by the failure of the gas distribution system. As the failure time increases, the hydrogen concentration in the reactor coolant cannot be maintained within the required operating range.

b) Plant in the Abnormal Conditions

The nuclear island gas distribution systems do not work when the nuclear power plant is in transient or accidental conditions.

c) Containment Isolations

When the safety signal is activated, the containment isolation valves of the nitrogen distribution system will be closed.

10.5.5.5 Preliminary Design Substantiation

10.5.5.5.1 Compliance with Safety Functional Requirements

The nuclear island gas distribution systems are not required to perform nuclear safety functions. The function category of the nuclear island gas distribution systems is NC. However, pipelines running through the containment building and related valves are designed to be F-SC1 safety class.

10.5.5.5.2 Compliance with Design Requirements

The operation pressures and temperature of the nuclear island gas distribution systems are designed to meet the requirements of downstream users.

The design substantiation of containment isolation of the SGN [NDS] is in compliance with the demonstration in Sub-chapter 7.4.6.5.

To ensure the reliability of the systems, the commissioning test of the nuclear island gas distribution system is completed before the start-up of the plant, and the system is subject to continuous monitoring to meet operational requirements. All equipment that operates periodically are additionally examined, checked and repaired.

10.5.6 Compressed Air Distribution Systems (SAP [CAPS], SAR [ICADS] SAT [SCADS])

10.5.6.1 Safety Functional Requirements

The compressed air distribution systems have neither safety functions nor safety classifications. However, pipelines running through the containment building and related valves are required to be F-SC1 safety class.

10.5.6.2 Design Requirements

Due to the non-nuclear safety class, the general design requirements related with nuclear safety are not applicable for the compressed air distribution systems. However, the design of the compressed air distribution systems shall not have a harmful impact on the safety systems.

To support essential systems, the availability of compressed air reserves should be sufficient to be consistent with the timescale for the availability of the equipment.

The design requirements of containment isolation of the SAT [SCADS] are in compliance with the demonstration in Sub-chapter 7.4.6.2.

10.5.6.3 Design Bases

10.5.6.3.1 General Assumptions

The specific site parameters are considered in the system design. The applicable equipment shall be purchased to ensure their performances and reliabilities in the site specific stage.

10.5.6.3.2 Design Assumptions

The compressed air systems are designed to meet the following requirements:

a) The requirements for the instrument and service compressed air from consumers, during normal operation and overhaul period;

b) The compressed air systems are designed without safety functions;

c) When the instrument compressed air is unavailable, all pneumatic valves will be in the fail-safe position;

d) Multiple air compressors are provided;

e) When one compressor is in trouble, the standby air compressors will start to pressurise the pipe network. During this period, the capacity of the dedicated storage tanks is sufficient to supply the required air to the pneumatic control devices;

f) In addition to the pressure gauge, each air storage tank is also equipped with safety valve to prevent over-pressure;

g) The SAP [CAPS] can produce filtered, dry, and oil-free compressed air. The compressed air quality of the SAR [ICADS] and SAT [SCADS] are different, and the SAR [ICADS] has a higher level of requirement.

10.5.6.4 System Description and Operation

10.5.6.4.1 System Description

The compressed air systems consist of the following systems:

a) SAP [CAPS];

b) SAR [ICADS];

c) SAT [SCADS].

The compressed air distribution systems provide clean and dry compressed air for related systems and equipment of the power plant. The distribution networks consist of valves, air storage tanks, and pipelines connecting the user system and equipment.

The SAP [CAPS] provides compressed air to the SAR [ICADS] and SAT [SCADS], which provide instrument and service compressed air to nuclear island, conventional island, and BOP buildings.

Several compressors and their auxiliary equipment (valves, dryers, filters, etc.) are design for the SAP [CAPS], which can produce compressed air to meet various demands for compressed air in the nuclear power plant.

The SAR [ICADS] and SAT [SCADS] consist of valves, air storage tanks, and pipelines. According to the different users, the SAR [ICADS] is divided into nuclear island pipe network, coventional pipe network and BOP pipe network. This also applies to the SAT [SCADS].

10.5.6.4.2 System Operation

When the pressure of the main air supply pipe drops to the pre-set threshold, the standby compressors start to operate. If all compressors have started and the pressure still drops, the back pressure control valves in the pipe network will be activated and an alarm signal will be sent to the main control room.

Both the SAT [SCADS] and SAR [ICADS] are connected to the SAP [CAPS]. However, there is no direct connection between the SAT [SCADS] and the SAR [ICADS]. The compressed air pipe networks are equipped with check valves and back-pressure control valves to ensure that:

a) For first isolation, priority is given to the demand of the SAR [ICADS] (cutting off air supply to the SAT [SCADS]);

b) For second isolation, priority is given to the demand of the SAR [ICADS] in the nuclear island (cutting off air supply to the SAR [ICADS] in the conventional island and BOP).

10.5.6.5 Preliminary Design Substantiation

10.5.6.5.1 Compliance with Safety Functional Requirements

The compressed air distribution systems are not required to perform nuclear safety functions. The compressed air distribution systems are designed as non-safety class systems. The classification of containment isolation valves is F-SC1 and it is consistent with the safety functional requirements.

10.5.6.5.2 Compliance with Design Requirements

For each system which carries out nuclear safety functions and has a requirement for compressed air, a compressed air storage tank is equipped in this system to ensure the availability of compressed air. The capacity of tank is determined according to the design requirement of each safety system.

The design substantiation of containment isolation of the SAT [SCADS] is in compliance with the demonstration in Sub-chapter 7.4.6.5. The containment isolations of the SAT [SCADS] are two manual cut-off valves, which are kept closed during normal operation of the nuclear power plant. During the overhaul period of the nuclear power plant, the containment isolation is not required and the two valves are opened to supply service compressed air for maintenance.

For ensuring the reliability of the systems and components, the following items are inspected on a regular basis during the service life of the nuclear power plant:

a) Operability of Isolation Valves in Pipe Networks;

b) Airtightness of Air Circuits;

c) Working Conditions of the Air Storage Tanks.

Periodic hydraulic testing is carried out on the air storage tanks of the compressed air systems. For the UK HPR1000, the hydraulic test pressure of the air storage tank is larger than the design pressure of the relevant system.

10.5.7 ALARP Assessment

Preliminary ALARP analysis has been performed on the process auxiliary systems:

The detailed codes and standards list is presented in Reference [12]. At this stage, no gap is identified. The consistency analysis is still under development to ensure that the design of the SSCs meets the requirements of the UK context.

Compliance analysis of the system design with the UK HPR1000 general safety engineering principles is made in the system sub-chapter of each sub-chapter. The analysis shows that the design of the SSCs meets relevant requirements and no gap is identified. Meanwhile, technical assessments such as hazard schedule, fault schedule, probabilistic safety assessment, and human factors are being developed

simultaneously, the analysis of the design against the requirements of these technical disciplines will be reviewed. A systematic review will be carried out on the system design to ensure that no new gap is identified between the newly developed requirements and the design. Any potential enhancements identified during this review will be taken into account in the further design development.

Potential areas of improving in the system design will be identified to reduce the risks ALARP through the further risk assessment. The ALARP demonstration topic report will be updated if any gap is identified.

In summary, the ALARP analysis and demonstration work is currently being carried out. A preliminary ALARP demonstration topic report to present the current analysis results as well as the arrangement for future ALARP analysis work is presented in Reference [13].

10.5.8 Concluding Remarks

This sub-chapter provides an introduction on the design information of the process auxiliary systems in UK HPR1000 nuclear power plant. At this stage, the general safety engineering principles are newly developed for preliminary assessment, at the same time, various technical disciplines are currently under development such as hazard schedule, fault schedule, probabilistic safety assessment, human factors, Instrumentation and Control, etc. As the factors mentioned above may have influences on the current design, a systematic review will be carried out after the preliminary work has been finished. If any gap is identified during technical review, ALARP demonstration will be carried out and effort will be made to reduce the risk as low as reasonable practicable.

10.6 Heating, Ventilation and Air Conditioning (HVAC) Systems

10.6.1 Sub-chapter Structure

The structure of Sub-chapter 10.6 is as follows:

a) Sub-chapter 10.6.1 (Sub-chapter Structure) gives the overall structure of Sub-chapter 10.6;

b) Sub-chapter 10.6.2 (Applicable Codes and Standards) presents the relevant codes and standards adopted in this Sub-chapter;

c) Sub-chapters 10.6.3 to 10.6.18 present the following HVAC systems:

   1) 10.6.3 Nuclear Auxiliary Building Ventilation System (DWN [NABVS]);

   2) 10.6.4 Fuel Building Ventilation System (DWK [FBVS]);

   3) 10.6.5 Containment Cooling and Ventilation System (EVR [CCVS]);

   4) 10.6.6 Containment Internal Filtration System (EVF [CIFS]);

   5) 10.6.7 Containment Sweeping and Blowdown Ventilation System (EBA [CSBVS]);

   6) 10.6.8 Annulus Ventilation System (EDE [AVS]);

   7) 10.6.9 Safeguard Building Controlled Area Ventilation System (DWL [SBCAVS]);

   8) 10.6.10 Electrical Division of Safeguard Building Ventilation System (DVL [EDSBVS]);

   9) 10.6.11 Main Control Room Air Conditioning System (DCL [MCRACS]);

   10) 10.6.12 Access Building Ventilation Systems (DVW [ABUAVS]-DWW [ABCAVS]);

   11) 10.6.13 Diesel Building Ventilation System (DVD [DBVS]);

   12) 10.6.14 Essential Service Water Pumping Station Ventilation System (DXS [ESWVS]);

   13) 10.6.15 Extra Cooling Water and NI Firefighting Building Ventilation System (DXE [ECW&FFB VS]);

   14) 10.6.16 Waste Treatment Building Ventilation System (DWQ [WTBVS])

   15) 10.6.17 Safety Chilled Water System (DEL [SCWS])

   16) 10.6.18 Operational Chilled Water System (DER [OCWS])

d) Sub-chapter 10.6.19 (ALARP Assessment) gives the preliminary ALARP analysis

of this Sub-chapter;

e) Sub-chapter 10.6.20 (Concluding Remarks) gives the summary and the on-going work of this Sub-chapter;

f) Sub-chapter 10.6.21 (Simplified Diagrams) present the simplified diagrams of the HVAC systems mentioned in Sub-chapters 10.6.3 to 10.6.18;

g) Sub-chapter 10.6.22 (Tables of Design Assumptions) gives common design assumptions used in Sub-chapters 10.6.3 to 10.6.18.

10.6.2 Applicable Codes and Standards

The identification of applicable codes and standards in Sub-chapter 10.6 is compliant with the general principles of codes and standards selection stated in Chapter 4 and Reference [5].

Wherever possible, the standards applied for the engineering substantiation should be:

a) Internationally recognised in nuclear industry;

b) The latest or currently applicable approved standards; and

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

Based on the principles mentioned above, the applicable codes and standards intended to be used in the UK HPR1000 design in the Mechanical Engineering (ME) discipline are identified in Reference [6]. Applicable codes and standards for HVAC systems design are presented in Table T-10.6-1. Currently, the work of conformity analysis and gap analysis of the codes and standards is continuing.

T-10.6-1 Applicable Codes and Standards in Sub-chapter 10.6

Codes and Standards Number	Title
BS ISO 26802, 2010	Nuclear Facilities — Criteria for the Design and the Operation of Containment and Ventilation Systems for Nuclear Reactors
ISO 17873, 2004	Nuclear Facilities — Criteria for the Design and Operation of Ventilation Systems for Nuclear Installations Other Than Nuclear Reactors
ES_0_1738-1, 2015	Ventilation Systems for Radiological Facilities Design Guide

10.6.3 Nuclear Auxiliary Building Ventilation System (DWN [NABVS])

The DWN [NABVS] is a ventilation system which provides fresh air and filters the

exhaust air for the nuclear auxiliary building, fuel building, safeguard building and reactor building to maintain the room ambient conditions and reduce airborne radioactivity released to the external environment during plant normal conditions.

10.6.3.1 Safety Functional Requirements

10.6.3.1.1 Control of Reactivity

The DWN [NABVS] does not contribute to this safety function.

10.6.3.1.2 Removal of Heat

The DWN [NABVS] does not contribute to this safety function.

10.6.3.1.3 Confinement

With respect to its contribution to confinement, the DWN [NABVS] must satisfy the following requirements:

a) Environmental Protection

The DWN [NABVS] system carries gaseous fluids containing radioactive material. So it must contribute:

1) to the confinement of this material with respect to the environment;

2) to the control and reduction of radioactive material discharge under normal operation.

b) Limiting Radiological Consequences

The DWN [NABVS] system must contribute to the static confinement of the Nuclear Auxiliary Building (BNX) in the event of multiple failures of systems in the BNX building following an earthquake.

10.6.3.1.4 Extra Safety Functions

The extra safety functional requirements of the DWN [NABVS] are identified below:

a) Supporting the Fundamental Safety Functions

The DWN [NABVS] contributes indirectly to the MSF of confinement of radioactive material as a support system as follows:

1) The DWN [NABVS] system must contribute to the provision of a pressure reference in order for:

- the Fuel Building Ventilation System (DWK [FBVS]) to confine the controlled area of the Fuel Building (BFX) during normal operation;
- the Safeguard Building Controlled Area Ventilation System (DWL [CSBVS]) to confine the controlled area of the Safeguard Buildings

(BSX) during normal operation;

- the Waste Treatment Building Ventilation System (DWQ [WTBVS]) to confine the controlled area of the waste treatment building during normal operation.

b) Prevent, Protect and Mitigate Hazards Impact

Internal fire:

In case of fire, the DWN [NABVS] contributes to limit fire spread.

10.6.3.2 Design Requirements

The general design requirements of the HVAC systems which need to be considered are shown in Sub-chapter 10.2.4, among which the following requirements are not applicable for the DWN [NABVS]:

a) Autonomy in Respect of Operators

Not applicable, because the design principles relevant to the autonomy in respect of operators are not applicable for DWN [NABVS] design.

b) Autonomy in Respect of the Heat Sink

Not applicable, because the DWN [NABVS] system doesn't provide a heat sink to the power plant.

c) Autonomy in Respect of Power Supply Systems

Not applicable, because the DWN [NABVS] system doesn't provide power supply to the power plant.

d) Prevention of Harmful Interactions of Systems Important to Safety

Not applicable, because the DWN [NABVS] doesn't have harmful interactions of systems important to safety.

The substantiation analysis of the DWN [NABVS] to other design requirements is shown in the Sub-chapter 10.6.3.5.2.

10.6.3.3 Design Bases

10.6.3.3.1 General Assumptions

The DWN [NABVS] air supply subsystem consists of 3×33% fresh air treatment trains and 4×50% air supply fans.

The DWN [NABVS] High Efficiency Particulate Air (HEPA) filtration line is made up of 7 trains and 4×50% air exhaust fans.

The DWN [NABVS] iodine adsorption units' line is made up of 4×25% trains and

4×25% booster fans. Each iodine adsorption train is capable of filtering the air flow coming from any DWN [NABVS] HEPA filtration cell.

10.6.3.3.2 Design Assumptions

a) Control of Reactivity

Not applicable. The DWN [NABVS] system does not contribute to the safety function of control of reactivity.

b) Removal of Heat

Not applicable. The DWN [NABVS] does not contribute to the safety function of removal of heat.

c) Confinement

1) Environmental Protection

- During normal operation, the DWN [NABVS] must contribute to the confinement of radioactive material by maintaining a negative pressure in the controlled area of the BNX building relative to the atmospheric pressure.
- During normal operation, the DWN [NABVS] must contribute to limiting the radioactivity of the air discharged into the vent stack. The filtration requirements for this criterion are:
  - HEPA filters: decontamination factor see Table T-10.6-40;
  - Iodine adsorption units: decontamination factor see Table T-10.6-41;
  - Iodine adsorption units' heaters: the heaters upstream of the iodine adsorbers are designed to maintain the relative humidity below 70%.

2) Limiting Radiological Consequences

Following an earthquake event, the DWN [NABVS] must ensure that the isolation of air entry and exhaust in the nuclear auxiliary building meets the air-tightness requirements stated in Table T-10.6-37.

d) Extra Safety Functions

1) Supporting the Fundamental Safety Functions

Not applicable. There is no quantitative safety-related design assumptions associated with the DWN [NABVS].

2) Prevent, Protect and Mitigate Hazards Impact

Internal fire

Not applicable. There's no quantitative safety-related design assumption for the DWN [NABVS].

e) Other Assumptions

1) Air Supply Conditions

Under design basis conditions, the required air supply temperatures in the DWN [NABVS] are the following:

- Summer: 18°C;
- Winter: 18°C (23°C during plant shutdown).

2) External Conditions

The external conditions to be taken into account for the DWN [NABVS] are defined in Table T-10.6-43.

3) Auxiliary Fluids

- During summer the air supply in the DWN [NABVS] is cooled by cooling coils supplied by the Operational Chilled Water System (DER [OCWS]).
- During winter, the air supply in the DWN [NABVS] system is heated by the heating coils supplied by the Hot Water Production and Distribution System (SES [HWPDS]).

4) Minimum Air Renewal Rates

In controlled areas, the minimum air renewal rate depends on the radiological risks associated with the room, shown in Table T-10.6-44.

10.6.3.4 System Description and Operation

10.6.3.4.1 System Description

a) General System Description

The DWN [NABVS] consists of an air supply subsystem, air exhaust subsystem with HEPA filters, iodine adsorption subsystem, local heating/cooling subsystem and air supply/exhaust duct networks and a vent stack.

The air supply subsystem includes:

1) Supply air Treatments- 3×33% (automatic isolation dampers, pre-filters, fine filters, heating coils and cooling coils are included in each train);

2) Air supply Fans- 4×50%.

The air exhaust subsystem includes:

1) Exhaust Air Treatments- 7 trains (each train is provided with a pre-filter and HEPA filter);

2) Air exhaust Fans- 4×50%.

The iodine adsorption subsystem:

1) Iodine adsorption trains- 4 trains (electric heater, iodine adsorber, fire dampers and automatic isolation dampers are included in each train);

2) Booster fans- 4×25%.

The local heating/cooling subsystem:

1) Local cooling units in rooms with large heat releases;

2) Electric convectors in rooms housing equipment or pipework containing boron to avoid boron crystallization;

3) Electrical heaters in the supply ducts for rooms allocated as work areas to maintain the room conditions.

Detailed information of the systems is presented in the SDM, Reference [53].

b) Description of Main Equipment

1) Fans

The fans are designed to provide air supply/exhaust and are centrifugal with direct–coupled motors modulated by frequency converters.

2) Pre-filters

The filters are designed to filter dust or aerosols in the air, which are made of cells with standard dimensions. The filter is made of glass fibre and an efficiency of pre-filter is more than 85% (weighting method).

3) Fine Filters

The filters are designed to filter dust in the air, and the efficiency is more than 85% (counting method).

4) HEPA Filters

The filters are designed to filter dust or aerosols in the air. Each HEPA filter cell is individually factory tested to verify an efficiency of at least 99.99%, corresponding to a 10000 filtering factor (sodium flame method).

5) Iodine Adsorbers

The iodine adsorbers are designed to remove radioactive iodine suspended in the air. Each adsorber is assembly through weld construction and 102mm

deep Type III rechargeable adsorber cell. When new, these filters have a filtering factor of at least 1000 (methyl iodide).

6) Heating/Cooling Coil

The coils are designed to provide cooling or heating to the air. They are made of copper tubes with several passes depending on the thermal characteristics, with copper or aluminium fins. The frames are made in galvanised steel or stainless steel.

7) Local Cooling Units

The local cooling units are designed to provide cooling to the air. A local cooling unit consists of a fan and a cooling coil supplied with chilled water.

8) Isolation Dampers

The isolation dampers are designed to ensure the isolation of air entry and exhaust in the nuclear auxiliary building.

Detailed information of the equipment design is presented in the SDM, Reference [53] and [54].

c) Description of Main Layout

No specific layout provisions are necessary for the DWN [NABVS].

All components of the DWN are located inside of the nuclear auxiliary building. The ventilation ducts stretch to all the rooms in which the supply or exhaust air is needed.

Detailed design information about the system layout is presented in the SDM, Reference [55].

d) Description of System Interface

The DWN [NABVS] is connected to the following mechanical systems (not including power supplies and I&C systems):

1) SES [HWPDS]

SES [HWPDS] provides hot water for the heating coils of the air supply trains.

2) DER [OCWS]

DER [OCWS] provides chilled water to the cooling coils of the air supply trains and local cooling units.

3) JDT [FAS]

JDT [FAS] provides fire signal to the fire dampers of the DWN [NABVS].

4) RPE [NIVDS]

RPE [NIVDS] collects drainage water from the DWN [NABVS] local cooling units and the heating/cooling coils.

5) JPI [FWSNI]

JPI [FWSNI] provides fire-fighting water to the iodine adsorbers.

6) KRT [PRMS]

KRT [PRMS] monitors the radiation of the exhaust air in the DWN [NABVS].

Moreover, the DWN [NABVS] system provides fresh air to the DWL [SBCAVS], DWK [FBVS], and EBA [CSBVS]. The DWN [NABVS] also filters the exhaust air from the DWL [SBCAVS], DWK [FBVS], EBA [CSBVS], CVI [CVS], TEP [CSTS], SGN [NDS], RCV [CVCS]), REA [RBWMS], REN [NSS] and TEG [GWTS].

Detailed information of the interface systems is presented in the SDM, Reference [53].

e) Description of Instrumentation and Control

Instruments controlling and monitoring the DWN [NABVS], and displaying of the actuator are provided in the MCR.

Detailed information of the system I&C design is presented in the SDM, Reference [56].

10.6.3.4.2 System Operation

a) Plant Normal Conditions

The DWN [NABVS] is in continuous operation during plant normal operation and plant normal shutdown:

1) to maintain ambient conditions in the nuclear auxiliary building;

2) to maintain the negative pressure in the nuclear auxiliary building;

3) to ensure during normal operation that contamination is contained at the source to avoid its spreading from potentially contaminated areas to potentially less contaminated areas;

4) to limit the concentration of aerosols and radioactive gases in the air of the rooms to ensure the operational extraction and filtration of the air;

5) to limit the radioactivity of the air discharged to the main vent stack during normal operation;

6) to ensure the conditioning, extraction and filtration of air supplied and

extracted by the DWK [FBVS];

7) ensure the operational extraction and filtration of the air extracted by the DWL [SBCAVS];

8) to ensure the conditioning, extraction and filtration of the air from the EBA [CSBVS].

b) Plant Accident Conditions

The DWN [NABVS] will stop, except for the electric convectors in the 7000 ppm boric acid rooms will be still in operation during a LOOP.

The isolation dampers of air entry and the check-back dampers of air exhaust in the nuclear auxiliary building are closed to ensure the static confinement of the BNX.

Detailed information of the system operation is presented in the SDM, Reference [56].

10.6.3.5 Preliminary Design Substantiation

In this sub-chapter, the system design is demonstrated to satisfy the Safety Functional Requirements presented in Sub-chapter 10.6.3.1 and the General Design Requirements stated in Sub-chapter 10.2.4.

Since the general principles are newly developed at this stage, the system design is still based on the reference design. A review of consistency of the system design against the newly developed principles is currently being undertaken. Detailed design of the system is presented in the SDM, Reference [53] and [55].

10.6.3.5.1 Compliance with Safety Functional Requirements

a) Control of Reactivity

Not applicable.

b) Removal of Heat

Not applicable.

c) Confinement

The DWN [NABVS] ensures the containment of radioactive material in normal operating conditions by:

1) using control dampers to control the negative pressure in the BNX;

2) ensuring the air transfers from the potentially low potential contamination rooms to the high potential contamination rooms;

3) filtering of the exhaust air by the HEPA filters before discharging it to the stack;

4) filtering of the exhaust air via iodine adsorption units before discharging it to the vent stack in the case of iodine presence.

The DWN [NABVS] ensures the containment of radioactive material by the isolation of air entry and exhaust in the nuclear auxiliary building following an earthquake event.

d) Extra Safety Functions

1) Supporting the Fundamental Safety Functions

The DWN [NABVS] provides an atmospheric pressure reference to the DWK [FBVS], DWL [SBCAVS] and DWQ [WTBVS] via its pressure reference pipework and its buffer tank.

2) Prevent, Protect and Mitigate Hazards Impact

Internal fire

- Containment and prevention of spread of fire

The contribution to the containment and prevention of spread of fire in the BNX is ensured by closure of the fire dampers, by active (automation by the JDT [FAS] system) or ultimately passive (fusible device) means.

Detailed design information is presented in Reference [57] .

10.6.3.5.2 Compliance with Design Requirements

a) Safety Classification

The DWN [NABVS] is compliant with the principles described in Chapter 4. The safety classification of DWN [NABVS] functions and the safety classification of the main components are as follows:

T-10.6-2 Function Categorisation of the DWN [NABVS]

System Function	Function Category
Nuclear Auxiliary Building confinement	FC3
Air exhaust and filtration	FC3
Iodine filtration	FC3
Maintaining negative pressure in Nuclear Auxiliary Building	FC3
Convectors for BO_2 boron rooms	FC3/NC [note]
Rest of system	NC

Note: The system function which services the F-SC3 classified BO_2 boron rooms are

classified as FC3. The system function which services the NC classified BO_2 boron rooms are classified as NC.

T-10.6-3 Classification of Main Components

Component	Function Class	Design Provision Category	Design Provision Class	Seismic Category
Air intake isolation dampers	F-SC3	NC	NC	SSE1
Isolation dampers downstream of the exhaust fans	F-SC3	NC	NC	SSE1
Pressure relief damper for exhaust fans	F-SC3	NC	NC	NO
Pressure relief damper for iodine fans	F-SC3	NC	NC	NO
HEPA filtration line	F-SC3	NC	NC	NO
Electric heaters upstream of the iodine adsorption units	F-SC3	NC	NC	NC
Iodine adsorption units line	F-SC3	NC	NC	NO
Air supply fans	NC	NC	NC	NC
Air exhaust fans	F-SC3	NC	NC	NO
Iodine fans	F-SC3	NC	NC	NO
Convectors for BO_2 boron rooms	F-SC3/NC note	NC	NC	NO
Local cooling units	NC	NC	NC	NC
Heating coils	NC	NC	NC	NC
Cooling coils	NC	NC	NC	NC

Note: The convectors which service the F-SC3 classified BO_2 boron rooms are classified as F-SC3. The convectors which service the NC classified BO_2 boron rooms are classified as NC.

b) Engineering Design Requirements

1) Reliability Design of SSCs

- Single Failure Criterion (SFC)

The DWN [NABVS] is not subject to passive single failures.

Although not subject to the application of the SFC, the DWN [NABVS] provides for the redundancy of available equipment achieved by the

multiplication of significant components such as fans and filter lines. The main air supply fans and the main exhaust fans are supplied by two different electrical trains and are cross connected.

- Independence

  Not applicable.

- Diversity

  According to the requirements of diversity in Chapter 4, the system functional requirements are currently being analysed. After the analysis is completed, the system design will be reviewed and analysed to identify if any gaps exist and modifications will be made if necessary.

- Fail-safe

  The fail-safe positions of the air intake isolation dampers and the isolation dampers downstream the air supply fans is the closed position.

- Ageing and Degradation

  The plant design life is 60 years. Some components will require replacing at the end of their individual design life. The performance of equipment is guaranteed through life examination, inspection, maintenance and testing, as well as the monitoring during normal operation, which will ensure that ageing effects do not compromise safety performance.

2) Human Factors

The system design of the DWN [NABVS] does not require short term operator intervention, however there are operator actions during plant normal operation, of which the effect needs to be estimated.

The DWN [NABVS] air supply and exhaust fans are centrally arranged so that they can be easily accessed. The DWN [NABVS] is controlled and monitored in the main control room. It is designed to be convenient for the operators to control.

3) Autonomy

- Autonomy in Respect of Operators

  The design principles relevant to the autonomy in respect of operators are not applicable for DWN [NABVS] design.

- Autonomy in Respect of the Heat Sink

  The design principles relevant to the autonomy in respect of the heat sink

are not applicable for DWN [NABVS] design.

- Autonomy in Respect of Power Supply Systems

  The design principles relevant to the autonomy in respect of the power supply are not applicable for DWN [NABVS] design.

4) Other Design Requirements

- Prevention of Harmful Interactions of Systems Important to Safety

  Not applicable.

- Considerations Related to the Electrical Power Grid

  The functionality of items important to safety in the DWN [NABVS] is not compromised by disturbances in the electrical power grid. Detailed design information of the electrical power grid is presented in Reference [53].

c) Equipment Qualification

The air intake isolation dampers and exhaust check back dampers of the DWN [NABVS] shall be qualified in accordance with SSE1.

The documents relevant to the equipment qualification will be delivered before the step 4 of GDA.

d) Protection against Internal and External Hazards

The DWN [NABVS] is protected from external and internal hazards; specific protection design is presented in the SDM, Reference [55] . The evaluation of the design is presented in Chapters 18 and 19.

e) Commissioning

Commissioning is going to be carried out for the DWN [NABVS] to validate its functionality. The documents relevant to the commissioning will be delivered before the step 4 of GDA.

f) Examination, Inspection, Maintenance and Testing

1) Examination and Inspection

There is no equipment of the DWN [NABVS] requiring in-service inspection.

The following functions of the DWN [NABVS] are monitored during normal operation by continuous monitoring:

- Temperature of air supply in the main ventilation lines;

- The exhaust air for any traces of iodine, on detection of which the system activates the iodine adsorption lines;
- The negative pressure in the controlled area of the BNX to guarantee dynamic containment.

2) Maintenances

Generally, scheduled maintenance is carried out preferentially during periods when the EBA [CSVS] is not in use (and therefore the overall DWN [NABVS] airflow is reduced).

The maintenance of supply and exhaust air fans can be performed during plant power operation as well as during plant shut down since these components are designed with a 4×50% capacity.

The 4 iodine booster fans are normally in standby during plant power operation. The maintenance can be performed during this period. In case of maintenance activities suddenly being required in one system, 3 iodine booster fans remain available.

3) Periodic Tests

The safety-classified parts of the DWN [NABVS] are subject to periodic tests:

- closing of the building isolation dampers in the supply and exhaust line;
- efficiency of HEPA filters;
- correct operation of the extraction fans;
- switchover to the iodine adsorption lines;
- efficiency of the iodine adsorption units.

g) Decommissioning

Decommissioning considerations for the DWN [NABVS] are still being undertaken at this stage.

h) Material Selection

1) The main distribution and exhaust air ducts are made out of concrete with a de-contaminable finish.

2) Other supply and exhaust air ducts are made out of galvanised metal sheet.

3) Airtight exhaust air ducts are made out of carbon steel welded with a finish that can be decontaminated.

4) The exhaust duct section from the laboratory to the concrete duct is made out

of austenitic stainless steel.

5) Components up to the first heater on the supply line are resistant against saline environments.

6) Pipework connected to the atmospheric buffer tank and the outside are resistant against saline environments.

10.6.3.6 Simplified Diagrams

The simplified system diagram is presented in Figure

F-10.6-1; the detailed system functional diagrams are presented in Reference [58].

10.6.4 Fuel Building Ventilation System (DWK [FBVS])

The DWK [FBVS] provides appropriate environmental conditions and confinement of radioactive material in the BFX.

10.6.4.1 Safety Functional Requirements

10.6.4.1.1 Control of Reactivity

The DWK [FBVS] does not contribute to this safety function.

10.6.4.1.2 Removal of Heat

The DWK [FBVS] does not contribute to this safety function.

10.6.4.1.3 Confinement

The DWK [FBVS] contributes to the confinement of radioactive substances:

a) Environmental Protection:

1) contain the radioactive material and prevent the risk of leaks;

2) limit radioactive discharges into the environment through treatment and control of the waste conveyed.

b) Limiting Radiological Consequences:

1) Dynamic Confinement

Not applicable.

2) Static Isolation

- In the event of a fuel handling accident in the BFX (DBC-4), the DWK [FBVS] automatically isolates the normal air supply and extraction of the fuel pool hall.
- In the event of a fuel handling accident in the BRX (DBC-4), the DWK [FBVS] automatically isolates the air supply of the room adjacent to the

emergency airlock.

- In the event of failure of the two main cooling trains of the pool (DEC-A), the DWK [FBVS] automatically isolates the normal air supply and extraction of the fuel pool hall.
- Emergency extraction is required in the event of fuel pool boiling in order to maintain the long-term confinement of the BFX and to limit the pressure in the fuel pool hall in DEC-A and DEC-B conditions.

3) Purification

Not applicable.

10.6.4.1.4 Extra Safety Functions

With respect to its contribution to the extra functions, the DWK [FBVS] must satisfy the following requirements:

a) Supporting the Fundamental Safety Functions

The DWK [FBVS] provides the environmental conditions required of the safety classified equipment under normal operating and accident conditions in the BFX.

b) Prevent, Protect and Mitigate Hazards Impact

Fire: Control and limit the spread of fire in the BFX.

10.6.4.2 Design Requirements

The general design requirements of the HVAC systems which need to be considered are shown in Sub-chapter 10.2.4, among which the following requirements are not applicable for the DWK [FBVS]:

a) Autonomy in Respect of Heat Sink

Not applicable, because the DWK [FBVS] doesn’t provide a heat sink to the power plant.

b) Autonomy in Respect of Power Supply Systems

Not applicable, because the DWK [FBVS] doesn’t provide a power supply system to the power plant.

c) Prevention of Harmful Interactions of Systems Important to Safety

Not applicable, because the DWK [FBVS] doesn’t have harmful interactions of systems important to safety.

The substantiation analysis of the DWK [FBVS] to other design requirements is shown in the Sub-chapter 10.6.4.5.2.

10.6.4.3 Design Bases

10.6.4.3.1 General Assumptions

The DWK [FBVS] air supply and extraction are provided by the DWN [NABVS].

Redundant isolation dampers are used to ensure the static confinement of the fuel pool hall, BFX and the room adjacent to the emergency airlock during accident conditions.

Local cooling units are used to remove the heat loads and to ensure the correct operation for the RBS [EBS] / RCV [CVCS] /PTR [FPCTS] pump rooms.

Redundant electrical heaters are used to maintain the minimum required temperature in all boron rooms.

10.6.4.3.2 Design Assumptions

a) Control of Reactivity

Not applicable. The DWK [FBVS] does not contribute to the safety function of control of reactivity.

b) Removal of Heat

Not applicable. The DWK [FBVS] system does not contribute to the safety function of removal of heat.

c) Confinement

1) Environmental Protection:

Maintaining a negative pressure in the controlled area of the BFX relative to the atmosphere.

Limit radioactive discharges into the environment through treatment of the DWN [NABVS] .

2) Limiting Radiological Consequences:

- Dynamic Confinement

Not applicable.

- Static Isolation

In order to isolate the fuel pool hall, the DWK [FBVS] isolation dampers located on the air supply / extraction system of the fuel pool hall must be closed quickly. These isolation dampers are reinforced to be leak tight, and the leakage rates shall meet the requirement defined in Table T-10.6-37.

In order to isolate the room adjacent to the emergency airlock, the DWK [FBVS] isolation dampers located on the air supply / extraction system

of the fuel pool hall must be closed quickly. These isolation dampers are reinforced to be leak tight, and the leakage rates shall meet the requirement defined in Table T-10.6-37.

In order to isolate the BFX, the DWK [FBVS] isolation dampers located on the air supply / extraction system of the fuel pool hall must be closed quickly. These isolation dampers are reinforced to be leak tight, and the leakage rates shall meet the requirement defined in Table T-10.6-37.

In the BFX fuel pool hall, the rupture disk internal opening pressure is set at { }.

- Purification

  Not applicable.

d) Extra Safety Functions

1) Supporting the Fundamental Safety Functions

- The external conditions to be taken into account for the DWK [FBVS] are defined in Table T-10.6-40.
- The internal room conditions to be taken into account for the DWK [FBVS] are defined in Table T-10.6-43.
- Cooling of the RBS [EBS] / RCV [CVCS] /PTR [FPCTS] pump rooms.
- The DWK [FBVS] local cooling units have been sized taking into account the following assumptions:
  - Heat loads dissipated by equipment and pipework in fault conditions;
  - Loss of general ventilation.
- Heating of the RBS [EBS] boron rooms

2) Prevent, Protect and Mitigate Hazards Impact

- Fire

  Not applicable. There's no quantitative safety-related design assumption for the DWK [FBVS].

e) Other Assumptions

1) Minimum Air Renewal Rate

The minimum air renewal rate in a room depends on the radiation zone and potential pollutants in the room are defined in Table T-10.6-44.

2) Cooling of the APG [SGBS] Pipe Rooms and PTR [FPCTS] Purifying

Pumps Rooms.

The DWK [FBVS] local cooling units have been sized taking into account the following assumptions:

- heat loads dissipated by equipment and pipework under normal conditions;
- internal room conditions are defined in Table T-10.6-42.

10.6.4.4 System Description and Operation

10.6.4.4.1 System Description

a) General System Description

The DWK [FBVS] is composed of one set of an air supply duct network and one set of an extraction duct network .The air supply and extraction duct network connects with the main air supply and extraction duct network of the Nuclear Auxiliary Building Ventilation System (DWN [NABVS]).

The summary of the main components are as follows:

1) Two supply air inlets with isolation dampers and control dampers;
2) Two extraction air outlets with isolation dampers;
3) Convectors which maintain the temperature in boron rooms;
4) Local cooling units which maintain the temperature in equipment rooms with large heat release;
5) Ducts for air supply and extraction of fuel pool hall with isolation dampers;
6) Ducts for air supply and extraction of emergency airlock with isolation dampers;
7) Fan air heaters which maintain the conditions in the fuel pool hall.

Detailed information of the systems is presented in the SDM, Reference [59].

b) Description of Main Equipment

1) Electrical Heaters

The electrical heaters are designed to maintain minimum temperatures in the boron rooms to avoid boron crystallization. They are made of copper tubes with several passes depending on the thermal characteristics.

2) Fan Air Heaters

The fan air heaters are designed to heat the air in the fuel pool hall. A fan air heater consists of a fan and an electrical heater.

3) Local Cooling Units

The local cooling units are designed to provide cooling to the air. A local cooling unit consists of a fan and a cooling coil supplied with chilled water.

4) Isolation Dampers

The isolation dampers are designed to ensure the isolation of the air supply and extraction of in the fuel pool hall, the fuel building and the room adjacent to the emergency airlock, in the fuel building.

Detailed information of the equipment design is presented in the SDM, Reference [59] and [60].

c) Description of Main Layout

The DWK [FBVS] main equipment is located in fuel building. The local cooling units are located in corresponding pump rooms.

Detailed design information about the system layout is presented in the SDM, Reference [61].

d) Description of System Interface

1) DWN [NABVS]

During normal conditions, it provides supply air and receives the exhaust air.

2) DEL [SCWS]

The DEL [SCWS] supplies chilled water to the local cooling units in the RBS [EBS] pump rooms, RCV [CVCS] pump rooms and the PTR [FPCTS] pump rooms.

3) DER [OCWS]

The DER [OCWS] supplies chilled water to the local cooling units of the PTR purification and skimming pump rooms and the APG pipe rooms.

4) JDT [FAS]

The Fire Alarm System (JDT [FAS]) provides signals to control the fire dampers of the DWK [FBVS].

5) RPE [NIVDS]

The Nuclear Island Vent and Drain System (RPE [NIVDS]) collects drainage water from the DWK [FBVS] local cooling units.

6) DWL [SBCAVS]

The Safeguard Building Controlled Area Ventilation System (DWL

[SBCAVS] provides the extraction for the pool hall in the event of a fuel handing accident.

7) EBA [CSBVS]

The Containment Sweeping and Blowndown Ventilation System (EBA [CSBVS]) provides the extraction for the fuel building in the event of a fuel handling accident in the BRX.

Detailed information of the interface systems is presented in the SDM, Reference [59].

e) Description of Instrumentation and Control

Instruments controlling and monitoring the DWK [FBVS], and displaying of the actuator are presented in the MCR.

10.6.4.4.2 System Operation

a) Plant Normal Conditions

The DWK [FBVS] operates continuously, to maintain the following operations:

1) Ensure ambient conditions for the normal operation of equipment and personnel work through the DWN [NABVS];

2) Maintain a negative pressure in the fuel building compared to the atmosphere;

3) Ensure that contamination is contained at source to avoid its spreading from potentially contaminated areas to potentially less contaminated areas;

4) Reduce the concentration of aerosols and radioactive gases in the control area.

b) Plant Accident Conditions

1) During a fuel handling accident (DBC-4) in fuel building, the air supply and extraction system of fuel pool hall is automatically isolated and dynamic containment of fuel pool hall is enforced by the DWL [SBCAVS] extraction and filtration system.

2) During a fuel handling accident (DBC-4) in the reactor building, the DWK [FBVS] will automatically isolate the extraction in front of the emergency airlock.

3) In case the two main trains of the PTR [FPCTS] fail (DEC-A), the air supply and extraction system of fuel pool hall is automatically isolated to realise static containment of fuel pool hall.

4) In the event of a LOCA (DBC-3/DBC-4), static confinement of the fuel

building is achieved by closing the isolation dampers located at the air supply and at the extraction of the normal ventilation of the fuel building. Moreover, the dynamic confinement (by the EBA [CSBVS] system) of the fuel building ensures collection and filtering before the release of any leak from the reactor building to the fuel building.

5) In the event of an SBO (DEC-A), static confinement of the fuel building is achieved: the isolation dampers located at the air supply and at the extraction of the normal ventilation of the fuel building have a fail-safe closed position in the event of a loss of the power supply.

6) In the event of Severe Accident (SA), the fuel building achieves dynamic containment when the EBA [CSBVS] extraction system receives a SI signal.

Detailed information of the system operation is presented in the SDM, Reference [59].

10.6.4.5 Preliminary Design Substantiation

In this sub-chapter, the system design is demonstrated to satisfy the safety functional requirements presented in Sub-chapter 10.6.4.1 and the general design requirements stated in Sub-chapter 10.2.4.

Since the general principles are newly developed at this stage, the system design is still based on the reference design. A review of the consistency of the system design against the newly developed principles is currently being undertaken. Detailed design of the system is presented in the SDM, Reference [59] and [61].

10.6.4.5.1 Compliance with Safety Functional Requirements

a) Control of Reactivity

Not applicable.

b) Removal of Heat

Not applicable.

c) Confinement

1) Environmental Protection:

The DWK [FBVS] ductwork and other HVAC system components are reinforced so as to reduce the risk of mechanical failures and protect the environment against potential radioactive leaks. Moreover, in order to limit potential radioactive discharges into the environment under normal operation, extracted air is filtered by the DWN [NABVS] before discharging it to the main unit ventilation stack.

A motorised control damper on the DWK [FBVS] supply line of each division is used to control the supply flow rate and maintain a negative

pressure of 100 Pa in the controlled area.

2) Limiting Radiological Consequences:

- Dynamic confinement

  Not applicable.

- Static isolation

  In order to isolate the fuel pool hall, redundant quick closing isolation dampers (on supply and exhaust lines) are closed on receipt of a KRT [PRMS] system signal. These isolation dampers are reinforced to be leak tight, and the leakage rates shall meet the requirement defined in Table T-10.6-37.

  In order to isolate the room adjacent to the emergency airlock, redundant quick closing isolation dampers (on supply and exhaust lines) are closed on receipt of a KRT [PRMS] system signal. These isolation dampers are reinforced to be leak tight, and the leakage rates shall meet the requirement defined in Table T-10.6-37.

  In order to isolate the BFX, redundant quick closing isolation dampers (on supply and exhaust lines) are closed on receipt of a SI signal. These isolation dampers are reinforced to be leak tight, and the leakage rates shall meet the requirement defined in Table T-10.6-37.

  In the fuel pool hall, the rupture disk pressure of the qualified overpressure protection device installed in the fuel pool area is set at { }.

d) Extra Safety Functions

1) Supporting the Fundamental Safety Functions

The DWK [FBVS] for the sizing of local cooling units enable room (RBS [EBS] / RCV [CVCS] /PTR [FPCTS] pump rooms) temperatures to be maintained under normal or accident conditions.
Local cooling units are started and turned off automatically based on temperature measurement or when the associated pump is started.

2) Prevent, Protect and Mitigate Hazards Impact

- Fire

  - Control and limit the spread of fire in the fuel building by closure of fire dampers:

  - Fire dampers qualification;

- Fire damper closure is ensured by active (automation by JDT [FDS] system) or ultimately passive (fusible device inside and outside the duct) means and is monitored by their position status.

Detailed design information is presented in Reference [62].

10.6.4.5.2 Compliance with Design Requirements

a) Safety Classification

The DWK [FBVS] design is compliant with the principles described in Chapter 4. The safety classification of DWK [FBVS] functions and the safety classification of main components are as follows:

T-10.6-4 Function Categorisation of DWK [FBVS]

System Function	Function Category
Isolation of the main supply and extraction in BFX building	FC2
Isolation of the supply and the exhaust of the fuel pool hall	FC1
Isolation of the supply of the room adjacent to the emergency airlock	FC1
Isolation of the extraction of the room adjacent to the emergency airlock	FC2
Cooling units in RCV [CVCS] pump rooms	FC3
Cooling units in PTR [FPCTS] purifying pump rooms	NC
Cooling units in RBS [EBS] pump rooms	FC2
Cooling units in APG [SGBS] pipe rooms	NC
Cooling units in PTR [FPCTS] cooling pump rooms	FC1
7000ppm boron rooms' electrical heaters	FC2
Control dampers for maintaining the sub pressure in the BFX	FC3
Pressure sensors for the control of sub pressure in the BFX	FC3
Fire dampers	FC2/ FC3

System Function	Function Category
Other parts	NC

T-10.6-5 Classification of Main Components

Component	Function Class	Design Provision Category	Design Provision Class	Seismic Category
Electrical heaters	F-SC2	NC	NC	SSE1
Fan Air Heaters	F-SC2	NC	NC	SSE1
Isolation dampers of the main supply and extraction in BFX	F-SC2	NC	NC	SSE1
Isolation dampers of the supply and the exhaust of the fuel pool hall	F-SC1	NC	NC	SSE1
Isolation dampers of the room adjacent to the emergency airlock	F-SC2	NC	NC	SSE1
Local cooling units in RCV [CVCS] pump rooms	F-SC3	NC	NC	SSE1
Local cooling units in APG [SGBS] pipe rooms	NC	NC	NC	SSE2
Local cooling units in PTR [FPCTS] purifying pump rooms	NC	NC	NC	SSE2
Local cooling units in RBS [EBS] pump rooms	F-SC2	NC	NC	SSE1
Local cooling units in PTR [FPCTS] cooling pump rooms	F-SC1	NC	NC	SSE1
Control dampers for maintaining the sub pressure	F-SC3	NC	NC	SSE1

Component	Function Class	Design Provision Category	Design Provision Class	Seismic Category
in the BFX				
Fire dampers	F-SC2/F-SC3	NC	NC	SSE1

b) Engineering Design Requirements

1) Reliability Design of SSCs

- Single Failure Criterion (SFC)

  Redundant isolation dampers are located on the supply / extraction of the fuel pool hall and installed in series;

  Redundant isolation dampers are located on the supply / extraction of the fuel building and installed in series;

  Redundant isolation dampers are located on the supply / extraction of the room adjacent to the emergency airlock and installed in series;

  Electrical heaters located in the RBS [EBS] pump rooms and boron rooms are installed according to the DWK [FBVS] winter sizing with an additional electrical heater in case of failure of one electrical heater;

  The fan air heaters (redundant) located in the fuel pool hall;

  Two fire dampers arranged in a parallel configuration which are set at the safety fire zone boundary.

  Regarding the cooling of the RBS [EBS] / RCV [CVCS] /PTR [FPCTS] system pumps, there is one local cooling unit for each RBS [EBS] system pump room. If the first RBS [EBS] / RCV [CVCS] /PTR [FPCTS] system pump is unavailable, the second pump takes over. It is the same reasoning for the local cooling units.
  In addition, each local cooling unit is associated with a specific DEL [SCWS] line.

- Independence

  Not applicable.

- Diversity

  According to the requirements of diversity in Chapter 4, the system functional requirements are currently being analysed. After the analysis is completed, the system design will be reviewed and analysed to identify if any gaps exist and modifications will be made if necessary.

- Fail-safe

  The DWK [FBVS] static confinement isolation dampers have a fail-safe closed position in the event of a loss of the power supply.

- Ageing and Degradation

  The plant design life is 60 years. Some components will need replacing at the end of their individual design life.

2) Human Factors

The system design of the DWK [FBVS] does not require short term operator intervention, however there are operator actions during plant normal operation, the effect of which needs to be estimated. The main equipment is located in the fuel building, where they are facilitated for the simplicity of applicable maintenance procedures. The DWK [FBVS] is controlled and monitored in the MCR. It is designed to be convenient for the operators to control.

3) Autonomy

- Autonomy in Respect of Operators

  The design principles relevant to the autonomy in respect of operators are detailed in Reference [1]. The design of the DWK [FBVS] fulfils these principles via control functional design; detailed information is presented in the SDM, Reference [63]. The design result is estimated in the safety analysis.

- Autonomy in Respect of the Heat Sink

  The design principles relevant to the autonomy in respect of the heat sink are not applicable for the DWK [FBVS] design.

- Autonomy in Respect of Power Supply Systems

  The design principles relevant to the autonomy in respect of the power supply are not applicable for the DWK [FBVS] design.

4) Other Design Requirements

- Prevention of Harmful Interactions of Systems Important to Safety

  Not applicable.

- Considerations Related to the Electrical Power Grid

  The functionality of items important to safety in the DWK [FBVS] is not compromised by disturbances in the electrical power grid. Detailed design information of the electrical power grid is presented in Reference

[59].

c) Equipment Qualification

All the components of the DWK [FBVS] required for performing safety functions are capable of operating under both normal and accident conditions. As a result, the components can withstand the most adverse environmental conditions expected.

All the seismically classified components of the DWK [FBVS] shall be capable of operating during and after the SSE. The components are seismically designed and qualified for the SSE loads.

The documents relevant to the equipment qualification will be delivered before the step 4 of GDA.

d) Protection against Internal and External Hazards

The DWK [FBVS] is protected from external and internal hazards; specific protection design is presented in the SDM, Reference [61]. The evaluation of the design is presented in Chapters 18 and 19.

e) Commissioning

Commissioning is going to be carried out for the DWK [FBVS] to validate its functionality. Documents related to the commissioning will be delivered before the step 4 of GDA.

f) Examination, Inspection, Maintenance and Testing

1) Examination and Inspection

There is no equipment of the DWK [FBVS] which requires in-service inspection.

The combined information of the DWK [FBVS] displayed in the MCR for the operator includes:

- Temperature of boron rooms;
- Temperature of rooms served by local cooling units;
- Temperature of fuel pool hall.

2) Maintenances

During normal operation conditions, the DWK [FBVS] operates continuously.

Maintenance of local cooling units could be done when the corresponding train serving users are in maintenance during shutdown of the plant.

3) Periodic Tests

FC1, FC2 and FC3 equipment should be tested if they are not in continuous operation. Some equipment performing safety functions shall be subject to periodic testing, mainly including operability of local cooling units.

g) Decommissioning

The decommissioning considerations of the DWK [FBVS] are still being undertaken at this stage.

h) Material Selection

The material of the duct is galvanised steel sheet except for the fuel pool hall and the emergency airlock.

The material of ducts in the fuel pool and the emergency airlock is carbon steel.

10.6.4.6 Simplified Diagrams

The simplified system diagram is presented in Figure F-10.6-2; the detailed system functional diagrams are presented in Reference [64].

10.6.5 Containment Cooling and Ventilation System (EVR [CCVS])

The EVR [CCVS] is designed to maintain the required ambient conditions for the normal operation of the equipment in the reactor building, to facilitate personnel access, to cool the Control Rod Drive Mechanism (CRDM), to cool the reactor pit and to provide ventilation for the dome.

10.6.5.1 Safety Functional Requirements

10.6.5.1.1 Control of Reactivity

The EVR [CCVS] does not contribute to this safety function.

10.6.5.1.2 Removal of Heat

The EVR [CCVS] does not contribute to this safety function.

10.6.5.1.3 Confinement

The EVR [CCVS] does not contribute to this safety function.

10.6.5.1.4 Extra Safety Functions

With respect to its contribution to the extra safety functions, the EVR [CCVS] must satisfy the following requirements:

a) Supporting the Fundamental Safety Functions

The safety function for the EVR [CCVS] is reactor pit cooling during SBO.

b) Prevent, Protect and Mitigate Hazards Impact

Not applicable.

10.6.5.2 Design Requirements

The general design requirements of the HVAC systems which need to be considered are shown in Sub-chapter 10.2.4, among which the following requirements are not applicable for the EVR [CCVS]:

a) Autonomy in Respect of Operators

Not applicable, because the EVR [CCVS] doesn't contribute to the autonomy objective.

b) Autonomy in Respect of the Heat Sink

Not applicable, because the EVR [CCVS] doesn't provide a heat sink to the power plant.

c) Autonomy in Respect of Power Supply Systems

Not applicable, because the EVR [CCVS] doesn't provide a power supply to the power plant.

d) Prevention of Harmful Interactions of Systems Important to Safety

Not applicable, because the EVR [CCVS] doesn't have harmful interactions of systems important to safety.

The substantiation analysis of the EVR [CCVS] to other design requirements is shown in the Sub-chapter 10.6.5.5.2.

10.6.5.3 Design Bases

10.6.5.3.1 General Assumptions

The main ventilation subsystem: 4×50% fans and air conditioning units;

The reactor pit ventilation subsystem: 4×50% fans;

The CRDM ventilation subsystem: 4×50% fan and cooling coils;

The dome ventilation subsystem: 2×100% fans.

10.6.5.3.2 Design Assumptions

a) Control of Reactivity

Not applicable. The EVR [CCVS] does not contribute to the safety function of control of reactivity.

b) Removal of Heat

Not applicable. The EVR [CCVS] does not contribute to the safety function of removal of heat.

c) Confinement

Not applicable. There's no quantitative safety-related design assumption for the EVR [CCVS].

d) Extra Safety Functions

1) Supporting the Fundamental Safety Functions

The internal room condition to be taken into account for the EVR [CCVS] is defined in Table T-10.6-42.

2) Prevent, Protect and Mitigate Hazards Impact

Not applicable.

e) Other Assumptions

The supply air temperature of the main ventilation subsystem is assumed to be 18°C.

The capacity of the air conditioning unit is determined by the maximum heat dissipation of the equipment and pipes under normal conditions.

The internal room condition to be taken into account for the EVR [CCVS] is defined in Table T-10.6-42.

10.6.5.4 System Description and Operation

10.6.5.4.1 System Description

a) General System Description

The EVR [CCVS] consists of a main circulation ventilation subsystem, reactor pit air supply subsystem, dome circulating ventilation subsystem and control rod drive mechanism ventilation subsystem. These subsystems are composed of components as follows:

1) Main circulating ventilation subsystem: 4×50% fans and air conditioning units;

2) Reactor pit air supply subsystem: fans 4×50%;

3) Ventilation subsystem of the CRDM area: fans 4×50%, cooling coils 4×50%;

4) Dome circulating ventilation subsystem: circulating fans are set in conformity with configuration 2×100%.

Detailed information of the systems is presented in the SDM, Reference [65].

b) Description of Main Equipment

1) Fans

The main ventilation fans are designed to provide circulating ventilation for the containment. Reactor pit fans are designed to provide air supply to the reactor pit. CRDM ventilation fans are designed to provide ventilation for the CRDM. Dome fans are designed to provide exhaust for the dome. CRDM ventilation fans are a centrifugal and direct-coupled drive type. The other fans are axial.

2) Cooling coils

The cooling coils are designed to cool the air, they are made of copper tubes with copper or aluminium fins. The frames are made of stainless steel.

3) Air conditioning units

The air conditioning units are designed to cool the air. An air conditioning unit is equipped with two cooling coils and two cooling coils installed on both sides of the air conditioning cabinet.

Detailed information of the equipment design is presented in the SDM, Reference [65] and [66].

c) Description of Main Layout

The EVR [CCVS] main equipment is located in the containment of the reactor building. The fans of the reactor pit ventilation subsystem are arranged in the special ventilated room.

Detailed design information about the system layout is presented in the SDM, Reference [67].

d) Description of System Interface

The EVR [CCVS] is connected to the following mechanical systems (not including power supplies and I&C systems):

1) DER [OCWS]

This system is used to provide chilled water for the cooling coil of the main air supply subsystem of the EVR [CCVS].

2) RRI [CCWS]

This system is used to provide cooling water for the cooling coil of the CRDM cooling ventilation subsystem.

3) EBA [CSBVS]

This system is used to send fresh air from the DWN [NABVS] to the main annular duct of the EVR [CCVS], to then send the air to all rooms through the duct network.

4) RPE [VDS]

This system is used to collect condensate from cooling coils of the EVR [CCVS].

5) REN [NSS]

This system is used for nuclear sampling of the air in the air supply duct of the EVR [CCVS].

Detailed information of the interface systems is presented in the SDM, Reference [65].

e) Description of Instrumentation and Control

Instruments controlling and monitoring the EVR [CCVS], and displaying of the actuator are presented in the Main Control Room.

Detailed information of the system I&C design is presented in the SDM, Reference [68].

10.6.5.4.2 System Operation

a) Plant Normal Conditions

During plant operation at normal power and normal shutdown with heat removal, the EVR [CCVS] continuously operates to maintain the necessary environmental conditions.

During cold shutdown of the plant, the EVR [CCVS] is out of service. Based on the environmental temperature in containment, one or two main fans of the EVR [CCVS] or another ventilation subsystem can be activated.

b) Plant Accident Conditions

1) Loss of Offsite Power (LOOP)

All the subsystems of the EVR [CCVS] are powered by the emergency diesel generators and the ventilation system continuously operates.

2) Fuel handling accident in containment

If the EVR [CCVS] is available, it can be activated as needed to discharge the released heat.

3) Station Black Out (SBO)

Only the fans of the reactor pit air supply subsystem are powered by SBO

diesel generators.

Detailed information of the system operation is presented in the SDM, Reference [68].

10.6.5.5 Preliminary Design Substantiation

In this sub-chapter, the system design is demonstrated to satisfy the safety functional requirements presented in Sub-chapter 10.6.5.1 and the general design requirements stated in Sub-chapter 10.2.4.

Since the general principles are newly developed at this stage, the system design is still based on the reference design. A review of the consistency of the system design against the newly developed principles is currently being undertaken. Detailed design of the system is presented in the SDM, Reference [65] and [67].

10.6.5.5.1 Compliance with Safety Functional Requirements

a) Control of Reactivity

Not applicable.

b) Removal of Heat

Not applicable.

c) Confinement

Not applicable.

d) Extra Safety Functions

1) Supporting the Fundamental Safety Functions

In the event of a SBO, only the fans associated with the reactor pit are supplied during an emergency, the subsystem is available.

2) Prevent, Protect and Mitigate Hazards Impact

Not applicable.

Detailed design information is presented in Reference [69].

10.6.5.5.2 Compliance with Design Requirements

a) Safety Classification

The EVR [CCVS] design is compliant with the principles described in Chapter 4. The safety classification of EVR [CCVS] functions and the safety classifications of main components are as follows:

T-10.6-6 Function Categorisation of the EVR [CCVS]

System Function	Function Category
Ventilation of Reactor pit	FC3
Rest of the system	NC

T-10.6-7 Classification of Main Components

Component	Function Class	Design Provision Category	Design Provision Class	Seismic Category
Main ventilation fan	NC	NC	NC	SSE2
Reactor pit fan	F-SC3	NC	NC	SSE1
CRDM ventilation fan	NC	NC	NC	SSE2
Dome fan	NC	NC	NC	SSE2
CRDM cooling coil	F-SC3	DPL	B-SC3	SSE2
Main ventilation subsystem air conditioning unit	NC	NC	NC	SSE2

b) Engineering Design Requirements

1) Reliability Design of SSCs

- Single Failure Criterion (SFC)

  Not applicable.

- Independence

  Not applicable.

- Diversity

  Not applicable.

- Fail-safe

  There’s no fail-safe designed equipment in the EVR [CCVS].

- Ageing and Degradation

  The plant design life is 60 years. Some components will require replacing at the end of their individual design life.

2) Human Factors

The system design of the EVR [CCVS] does not require short term operator

intervention, however there are operator actions during plant normal operation, the effects of which needs to be estimated. The EVR [CCVS] is controlled and monitored in the main control room. It is designed to be convenient for the operators to control.

3) Autonomy

- Autonomy in Respect of Operators

  The design principles relevant to the autonomy in respect of operators are not applicable for EVR [CCVS] design.

- Autonomy in Respect of the Heat Sink

  The design principles relevant to the autonomy in respect of the heat sink are not applicable for EVR [CCVS] design.

- Autonomy in Respect of Power Supply Systems

  The design principles relevant to the autonomy in respect of the power supply are not applicable for EVR [CCVS] design.

4) Other Design Requirements

- Prevention of Harmful Interactions of Systems Important to Safety

  Not applicable.

- Considerations Related to the Electrical Power Grid

  The functionality of items important to safety in the EVR [CCVS] is not compromised by disturbances in the electrical power grid. Detailed design information of the electrical power grid is presented in Reference [65].

c) Equipment Qualification

All the components of the EVR [CCVS] required to perform safety functions are capable of operating under both normal and accident conditions. As a result, the components can withstand the most adverse environmental conditions expected.

All the seismically classified components of the EVR [CCVS] shall be capable of operating during and after the SSE. The components are seismically designed and qualified for the SSE loads.

The documents related to the equipment qualification will be delivered before the step 4 of GDA.

d) Protection Design against Internal and External Hazards

The EVR [CCVS] is protected from external and internal hazards; specific

protection design is presented in the SDM, Reference [67]. The evaluation of the design is presented in Chapters 18 and 19.

e) Commissioning

Commissioning is going to be carried out for the EVR [CCVS] to validate its functionality. Documents related to the commissioning will be delivered before the step 4 of GDA.

f) Examination, Inspection, Maintenance and Testing

1) Examination and Inspection

There is no equipment of the EVR [CCVS] requiring in-service inspection.

The combined information of the EVR [CCVS] displayed in the Main Control Room (MCR) for the operator includes:

- Temperature of supply and exhaust air;
- Flow of exhaust air;
- Temperature of rooms;
- Differential pressure of fans;
- Temperature of fan motor bearings.

2) Maintenances

During normal operating conditions, the EVR [CCVS] operates continuously. Maintenance of the main components can be done during shutdown of the plant.

3) Periodic Tests

FC1, FC2 and FC3 equipment should be tested if they are not in continuous operation. Some equipment performing safety functions shall be subject to periodic testing, mainly including:

- Switchover between the operating and backup train;
- Checking of room temperatures.

g) Decommissioning

Decommissioning considerations for the EVR [CCVS] are still being undertaken at this stage.

h) Material Selection

Stainless steel air ducts are preferred in the reactor building.

10.6.5.6 Simplified Diagrams

The simplified system diagram is presented in Figure F-10.6-3; the detailed system functional diagrams are presented in Reference [70].

10.6.6 Containment Internal Filtration System (EVF [CIFS])

During normal plant operation, the Containment Internal Filtration System (EVF [CIFS]) operates discontinuously in order to reduce the concentration of radioactive substances and aerosols in the containment.

10.6.6.1 Safety Functional Requirements

10.6.6.1.1 Control of Reactivity

The EVF [CIFS] does not contribute to this safety function.

10.6.6.1.2 Removal of Heat

The EVF [CIFS] does not contribute to this safety function.

10.6.6.1.3 Confinement

The EVF [CIFS] does not contribute to this safety function.

10.6.6.1.4 Extra Safety Functions

With respect to its contribution to the extra functions, the EVF [CIFS] must satisfy the following requirements:

a) Supporting the Fundamental Safety Functions

   The EVF [CIFS] does not contribute to supporting the fundamental safety functions.

b) Prevent, Protect and Mitigate Hazards Impact

   Fire: In case of fire, the EVF [CIFS] contributes to limiting the spread of fire.

10.6.6.2 Design Requirements

The general design requirements of the HVAC systems which need to be considered are shown in Sub-chapter 10.2.4, among which the following requirements are not applicable for the EVF [CIFS]:

a) Autonomy in Respect of the Heat Sink

   Not applicable, because the EVF [CIFS] doesn’t provide a heat sink to the power plant.

b) Autonomy in Respect of Power Supply Systems

   Not applicable, because EVF [CIFS] doesn’t provide a power supply to the power

plant.

c) Prevention of Harmful Interactions of Systems Important to Safety.

Not applicable, because the EVF [CIFS] doesn't have harmful interactions of systems important to safety.

The substantiation analysis of the EVF [CIFS] to other design requirements is shown in the Sub-chapter 10.6.6.5.2.

10.6.6.3 Design Bases

10.6.6.3.1 General Assumptions

a) 1×100% iodine adsorption train;

b) 2×100% exhaust fans.

10.6.6.3.2 Design Assumptions

a) Control of Reactivity

Not applicable. The EVF [CIFS] does not contribute to the safety function of control of reactivity.

b) Removal of Heat

Not applicable. The EVF [CIFS] does not contribute to the safety function of removal of heat.

c) Confinement

Not applicable. The EVF [CIFS] does not contribute to the safety function of confinement.

d) Extra Safety Functions

1) Supporting the Fundamental Safety Functions

Not applicable. The EVF [CIFS] does not contribute to supporting the fundamental safety functions.

2) Prevent, Protect and Mitigate Hazards Impact

Fire: Not applicable. There's no quantitative safety-related design assumption for the EVF [CIFS].

e) Other Assumptions

1) The internal room conditions of non-safety functional rooms for the EVF [CIFS] are defined in Table T-10.6-42;

2) The external conditions to be taken into account for the EVF [CIFS] are

defined in Table T-10.6-41;

3) For the filtration efficiency of HEPA filters and iodine adsorber see Tables T-10.6-38 and T-10.6-39;

4) Maintain the relative humidity of the iodine adsorber inlet below 70%;

5) Electric heater inlet environments is 40°C at 100%.

10.6.6.4 System Description and Operation

10.6.6.4.1 System Description

a) General System Description

The EVF [CIFS] includes a 1×100% iodine adsorption train, which consists of:

1) 1×100% iodine adsorption train (including an electric heater, pre-filter, HEPA filter and iodine adsorber);

2) 2×100% exhaust fans;

3) Dampers, duct network and a set of accessories.

Detailed information of the systems is presented in the SDM, Reference [71].

b) Description of Main Equipment

1) Fans

The fans are a centrifugal and direct-coupled drive type.

2) Electrical Heaters

The electric heaters are designed to maintain the relative humidity of the iodine adsorber inlet by heating the air, and they are comprised of reinforced tubular elements placed in a sheet metal box.

3) Pre-filters

The pre-filters are designed to filter dust in the air. Their efficiency is more than 85% (weighting method).

4) HEPA Filters

The HEPA filters are designed to filter dust in the air. Each HEPA filter cell is individually factory tested to verify an efficiency of at least 99.99%, corresponding to a 10000 filtering factor (sodium flame method).

5) Iodine Adsorbers

The iodine adsorbers are designed to remove radioactive iodine suspended in the air, each adsorber is assembly with a welded construction and a 102mm

deep Type III rechargeable adsorber cell. When new, these filters have a filtering factor of at least 1000 (methyl iodide).

Detailed information of the equipment design is presented in the SDM, Reference [71] and [72].

c) Description of Main Layout

The EVF [CIFS] is located in the reactor building.

Detailed design information about the system layout is presented in the SDM, Reference [73].

d) Description of System Interface

The EVF [CIFS] is connected to the following mechanical systems (not including power supplies and I&C systems):

1) EVR [CCVS])

Containment Cooling and Ventilation System (EVR [CCVS]) which supplies the mixing of the contaminated air.

2) JDT [FAS]

Fire Alarm System (JDT [FAS]) which can detect a fire in the iodine adsorbers, then in response closes the fire dampers and sets off an alarm in the control room.

3) JPI [NIFPS]

In the event of a fire in the charcoal filter of the iodine adsorption units, the Nuclear Island Fire Protection System (JPI [NIFPS]) can be manually activated to provide a water spray to extinguish the fire.

4) KRT [PRMS]

The Plant Radiation Monitoring System (KRT [PRMS]) which detects high activity in reactor building and triggers the automatic operation of the EVF [CIFS].

Detailed information of the interface systems is presented in the SDM, Reference [71].

e) Description of Instrumentation and Control

Instrumentation controlling and monitoring the EVF [CIFS] and displaying of the actuator are provided in the Main Control Room.

Detailed information of the system I&C design is presented in the SDM, Reference [74].

10.6.6.4.2 System Operation

a) Plant Normal Conditions

During power operation and hot shutdown, the EVF [CIFS] will operate to purge the reactor building if necessary.

b) Plant Accident Conditions

The EVF [CIFS] is not required during plant accident conditions.

Detailed information of the system operation is presented in the SDM, Reference [74].

10.6.6.5 Preliminary Design Substantiation

In this sub-chapter, the system design is demonstrated to satisfy the safety functional requirements presented in Sub-chapter 10.6.6.1 and the general design requirements stated in Sub-chapter 10.2.4.

Since the general principles are newly developed at this stage, the system design is still based on the reference design. A review of the consistency of the system design against the newly developed principles is currently being undertaken. Detailed design of the system is presented in the SDM, Reference [71] and [73].

10.6.6.5.1 Compliance with Safety Functional Requirements

a) Control of Reactivity

Not applicable.

b) Removal of Heat

Not applicable.

c) Confinement

Not applicable.

d) Extra Safety Functions

1) Supporting the Fundamental Safety Functions

Not applicable. The EVF [CIFS] does not contribute to supporting the fundamental safety functions.

2) Prevent, Protect and Mitigate Hazards Impact

Fire: Fire dampers are designed on the boundary of the fire compartment, which will be closed by a JDT [FAS] signal or damper fuse in case of a fire.

Detailed design information is presented in Reference [75].

10.6.6.5.2 Compliance with Design Requirements

a) Safety Classification

The EVF [CIFS] design is compliant with the principles described in Chapter 4. The safety classification of EVF [CIFS] functions and the safety classification of main components are as follows:

T-10.6-8 Function Categorisation of the EVF [CIFS]

System Function	**Function Category**
Fire dampers	FC3
Rest of the system	NC

T-10.6-9 Classification of Main Components

Component	**Function Class**	**Design Provision Category**	**Design Provision Class**	**Seismic Category**
Fire dampers	F-SC3	NC	NC	SSE1
Rest of the system	NC	NC	NC	SSE2

b) Engineering Design Requirements

1) Reliability Design of SSCs

- Single Failure Criterion (SFC)

  Since the EVF [CIFS] does not perform FC1 or FC2 safety functions, the SFC is not applicable, however 2×100% redundancy is considered for the exhaust fans.

- Independence

  Not applicable.

- Diversity

  According to the requirements of diversity in Chapter 4, the system functional requirements are currently being analysed. After the analysis is completed, the system design will be reviewed and analysed to identify if any gaps exist and modifications will be made if necessary.

- Fail-safe

  Not applicable.

- Ageing and Degradation

  The plant design life is 60 years. Some components will require replacing at the end of their individual design life.

2) Human Factors

The system design of the EVF [CIFS] does not require short term operator intervention, however there are operator actions during plant normal operation, the effect of which needs to be estimated. The EVF [CIFS] is controlled and monitored in the main control room. It is designed to be convenient for the operators to control.

3) Autonomy

- Autonomy in Respect of Operators

  The design principles relevant to the autonomy in respect of operators are detailed in Reference [1]. The design of the EVF [CIFS] fulfils these principles via control functional design, detailed information is presented in the SDM, Reference [74]. The design result is estimated in the safety analysis.

- Autonomy in Respect of the Heat Sink

  The design principles relevant to the autonomy in respect of the heat sink are not applicable for EVF [CIFS] design.

- Autonomy in Respect of Power Supply Systems

  The design principles relevant to the autonomy in respect of the power supply are not applicable for EVF [CIFS] design.

4) Other Design Requirements

- Prevention of Harmful Interactions of Systems Important to Safety

  Not applicable.

- Considerations Related to the Electrical Power Grid

  The functionality of items important to safety in the EVF [CIFS] is not compromised by disturbances in the electrical power grid. Detailed design information of the electrical power grid is presented in Reference [71].

c) Equipment Qualification

All the components of the EVF [CIFS] required to perform safety functions are capable of operating under both normal and accident conditions. As a result, the components can withstand the most adverse environmental conditions expected.

All the seismically classified components of the EVF [CIFS] shall be capable of operating during and after the SSE. The components are seismically designed and qualified for the SSE loads.

The documents relevant to the equipment qualification will be delivered before the step 4 of GDA.

d) Protection Design against Internal and External Hazards

The EVF [CIFS] is protected from external and internal hazards; specific protection design is presented in the SDM, Reference [73]. The evaluation of the design is presented in Chapters 18 and 19.

e) Commissioning

Commissioning is going to be carried out for the EVF [CIFS] to validate its functionality. Documents related to the commissioning will be delivered before the step 4 of GDA.

f) Examination, Inspection, Maintenance and Testing

1) Examination and Inspection

There is no equipment of the EVF [CIFS] requiring in-service inspection.

The combined information of the EVF [CIFS] displayed in the Main Control Room (MCR) for the operator includes:

- Temperature upstream and downstream of heaters;
- Position of isolated dampers;
- Position of fire dampers;
- Status of fan;
- Status of heaters.

2) Maintenances

Maintenance of the components can be done during shutdown of the plant.

3) Periodic Tests

FC3 equipment should be tested if they are not in continuous operation. Some equipment performing safety functions shall be subject to periodic testing, mainly including the operability of fire dampers.

g) Decommissioning

Decommissioning considerations about the EVF [CIFS] are still being undertaken at this stage.

h) Material Selection

Stainless steel air ducts are preferred in the reactor building.

10.6.6.6 Simplified Diagrams

The simplified system diagram is presented in Figure F-10.6-4; the detailed system functional diagram is presented in Reference [76].

10.6.7 Containment Sweeping and Blowdown Ventilation System (EBA [CSBVS])

The EBA [CSBVS] maintains the appropriate environmental conditions in the reactor building during plant shutdown and provides dynamic containment for the fuel building under accident conditions.

10.6.7.1 Safety Functional Requirements

10.6.7.1.1 Control of Reactivity

The EBA [CSBVS] does not contribute to this safety function.

10.6.7.1.2 Removal of Heat

The EBA [CSBVS] does not contribute to this safety function.

10.6.7.1.3 Confinement

With respect to its contribution to confinement, the EBA [CSBVS] must satisfy the following requirements:

a) Environmental Protection

1) Contain Radioactive Material

Limit the leakage of radioactive material into the environment in normal conditions.

2) Limit Discharge

When the EBA [CSBVS] low-capacity circuit operates in normal conditions, it shall limit the discharge of radioactive materials into the environment by filtration.

b) Limiting Radiological Consequences

1) Dynamic Confinement

In the case of an event involving an activity release in the containment (DBC-3, DBC-4, DEC-A, DEC-B), the exhaust of the low-capacity circuit ensures fuel building negative pressure to limit the spread of contamination, and aids the collection of any leaks from the containment penetrations.

In the event of a fuel handling accident in the reactor building or a LOCA in cold shutdown, the containment isolation valves are closed except for the exhaust of the low-capacity circuit. The exhaust of the low-capacity circuit ensures reactor building negative pressure to limit the spread of contamination.

2) Static Isolation

In the case of an event involving an activity release in the containment (DBC-3, DBC-4, DEC-A, DEC-B), the reactor building must be completely isolated by closure of the containment isolation valves.

3) Purification

Limiting of the discharge of radioactive materials into the environment by

filtration in accident conditions.

10.6.7.1.4 Extra Safety Functions

With respect to its contribution to the extra functions, the EBA [CSBVS] must satisfy the following requirements:

a) Supporting the Fundamental Safety Functions

The EBA [CSBVS] does not contribute to supporting the fundamental safety functions.

b) Prevent, Protect and Mitigate Hazards Impact

Fire: In case of fire, the system shall limit the spread of fire and prevent damage to safety classified equipment and personnel.

10.6.7.2 Design Requirements

The general design requirements of the HVAC systems which need to be considered are shown in Sub-chapter 10.2.4, among which the following requirements are not applicable for the EBA [CSBVS]:

a) Autonomy in Respect of the Heat Sink

Not applicable, because the EBA [CSBVS] doesn’t provide a heat sink to the power plant.

b) Autonomy in Respect of Power Supply Systems

Not applicable, because the EBA [CSBVS] doesn’t a provide power supply to the power plant.

c) Prevention of Harmful Interactions of Systems Important to Safety

Not applicable, because the EBA [CSBVS] doesn’t have harmful interactions of systems important to safety.

The substantiation analysis of the EBA [CSBVS] to other design requirements is shown in the Sub-chapter 10.6.7.5.2.

10.6.7.3 Design Bases

10.6.7.3.1 General Assumptions

The normal air supply and exhaust of the EBA [CSBVS] are supplied from the DWN [NABVS].

2×100% iodine filtration trains are set to be operational under accident conditions.

10.6.7.3.2 Design Assumptions

a) Control of Reactivity

Not applicable. The EBA [CSBVS] does not contribute to the safety function of control of reactivity.

b) Removal of Heat

Not applicable. The EBA [CSBVS] does not contribute to the safety function of removal of heat.

c) Confinement

The EBA [CSBVS] is subject to the following assumptions.

1) Environmental Protection

- Contain radioactive material

  The valves or dampers which are reinforced to be leak tight are closed if necessary. The characteristics related to how air leak tight the valves or dampers are is stated in Table T-10.6-37.

- Limit discharge

  - For the filtration efficiency of the HEPA filter and iodine adsorber see Tables T-10.6-38 and T-10.6-39;
  - Maintain the relative humidity of the iodine adsorber inlet below 70%;
  - The electric heater inlet environment is 40°C at 100%.

2) Limiting Radiological Consequences

- Dynamic confinement

  - Maintain negative pressure between the fuel building and the outside environment. For the negative pressure see Table T-10.6-35;
  - Maintain negative pressure between the reactor building and the outside environment, when the emergency personnel airlock is closed. For the negative pressure see Table T-10.6-35 .

- Static isolation

  - All of the containment isolation valves are closed. For characteristics relevant to how airtight the valves are see Table T-10.6-37.

- Purification

  - For the filtration efficiency of the HEPA filter and iodine adsorber see Tables T-10.6-38 and T-10.6-39.

- Maintain the relative humidity of the iodine adsorber inlet below 70%;
- The electric heater inlet environment is 40°C at 100%.

d) Extra Safety Functions

1) Supporting the Fundamental Safety Functions

Not applicable. The EBA [CSBVS] does not contribute to supporting the fundamental safety functions.

2) Prevent, Protect and Mitigate Hazards Impact

Fire: Not applicable. There's no quantitative safety-related design assumption for the EBA [CSBVS].

e) Other Assumptions

1) The internal room conditions of non-safety functional rooms for the EBA [CSBVS] are defined in Table T-10.6-42 .

2) The external conditions to be taken into account for the EBA [CSBVS] are defined in Table T-10.6-41.

3) During power operation, the system is to maintain a certain pressure range between the reactor building and the outside environment. For the pressure range see Table T-10.6-36.

10.6.7.4 System Description and Operation

10.6.7.4.1 System Description

a) General System Description

The EBA [CSBVS] includes the low-capacity subsystem and high-capacity subsystem.

1) The EBA [CSBVS] low-capacity subsystem consists of :

- Containment isolation valves;
- 2×100% iodine filtration trains (each train including an electric heater, pre-filter, HEPA filter, iodine adsorber and fan);
- Dampers, a duct network and a set of accessory.

2) The EBA [CSBVS] high-capacity subsystem consists of:

- Containment isolation valves;
- Dampers, a duct network and a set of accessory.

Detailed information of the systems is presented in the SDM, Reference [77].

b) Description of Main Equipment

1) Fans

The fans are designed to provide air exhaust. Centrifugal fans with direct-coupled drive are used.

2) Electrical Heaters

The electric heaters are designed to maintain the relative humidity of the iodine adsorber inlet by heating the air. They are comprised of reinforced tubular elements placed in a sheet metal box.

3) Pre-filters

The pre-filters are designed to filter dust in the air, and their efficiency is more than 85% (weighting method).

4) HEPA Filters

The HEPA filters are designed to filter dust or aerosols in the air. Each HEPA filter cell is individually factory tested to verify an efficiency of at least 99.99%, corresponding to a 10000 filtering factor (sodium flame method).

5) Iodine Adsorbers

The iodine adsorbers are designed to remove radioactive iodine suspended in the air. Each adsorber is assembly with a welded construction and a 102mm deep Type III rechargeable adsorber cell. When new, these filters have a filtering factor of at least 1000 (methyl iodide).

6) Containment Isolation Valves

The containment isolation valves are designed to close quickly and resist the accidental conditions.

Detailed information of the equipment design is presented in the SDM, Reference [77] and [78].

c) Description of Main Layout

The equipment of the iodine adsorption trains is located in different compartments of the fuel building.

The ducts are located in the reactor building and fuel building.

Detailed design information about the system layout is presented in the SDM, Reference [79].

d) Description of System Interface

The EBA [CSBVS] is connected to the following mechanical systems (not including power supplies and I&C systems):

1) DWN [NABVS]

   The DWN [NABVS] provides and conditions the EBA [CSBVS] supply of fresh air, and ensures the filtrating of the EBA [CSBVS] high-capacity extraction air to the stack.

2) EPP [CLRTMS]

   The Containment Leak Rate Testing and Monitoring System (EPP [CLRTMS]) recovers the leakage of the external containment isolation valves.

3) JDT [FAS]

   The Fire Alarm System (JDT [FAS]) provides a fire signal to control the fire dampers of the EBA [CSBVS].

4) JPI [NIFPS]

   In the event of a fire in the charcoal filter of the iodine adsorption units, the Nuclear Island Fire Protection System (JPI [NIFPS]) can be manually activated to provide a water spray to extinguish the fire.

5) KRT [PRMS]

   The Plant Radiation Monitoring System (KRT [PRMS]) detects high activity in the reactor building, and contamination downstream of adsorption for severe accident management.

6) EVR [CCVS]

   The Containment Cooling and Ventilation System (EVR [CCVS]), during cold shutdown, collects the fresh air supplied by the EBA [CSBVS] and then distributes it towards rooms of the reactor building.

7) RIS [SIS]

   In shutdown states, the EBA [CSBVS] is used to collect the Safety Injection System (RIS [SIS]) accumulator venting.

8) RPE [VDS]

   In the shutdown states, the EBA [CSBVS] is used to collect the venting from the Nuclear Island Vent and Drain System (RPE [VDS]).

Detailed information of the interface systems is presented in the SDM, Reference [77].

e) Description of Instrumentation and Control

Parameters of the controlling and monitoring of the EBA [CSBVS] and displaying of the actuator are provided in the MCR.

Detailed information of the system I&C design is presented in the SDM, Reference [80].

10.6.7.4.2 System Operation

a) Plant Normal Conditions

During power operation, the supplied or exhausted air of the EBA [CSBVS] low-capacity subsystem can be activated to control the pressure of containment.

During plant shutdown, the EBA [CSBVS] will operate in blowdown mode. The EBA [CSBVS] operates continuously to provide the necessary fresh air for personnel and to maintain the required temperature and humidity of the environment.

b) Plant Accident Conditions

In case of a fuel handling accident in the reactor building or a LOCA in cold shutdown, the containment isolation valves are quickly closed except for the exhaust low-capacity circuit. The iodine filtration operates continuously to maintain dynamic containment of the reactor building.

In case of a LOCA during power operation, all of the containment isolation valves will be closed. The iodine filtration operates continuously to maintain dynamic containment of the fuel building.

In case of LOOP, the EBA [CSBVS] iodine trains will remain available.

In case of SBO, the EBA [CSBVS] iodine trains will remain available.

In case of a severe accident with a LOCA initiator, all of the containment isolation valves will be closed. The iodine filtration operates continuously to maintain dynamic containment of fuel building.

In case of a loss all diesel generators, the internal containment isolation valves are powered by 2h batteries and the external containment isolation valves are powered by 12h batteries. These valves could be closed or confirmed to be in a closed state by operator.

Detailed information of the system operation is presented in the SDM, Reference [80].

10.6.7.5 Preliminary Design Substantiation

In this sub-chapter, the system design is demonstrated to satisfy the safety functional requirements presented in Sub-chapter 10.6.7.1 and the general design requirements stated in Sub-chapter 10.2.4.

Since the general principles are newly developed at this stage, the system design is still based on the reference design. A review of the consistency of the system design against the newly developed principles is currently being undertaken. Detailed design of the system is presented in the SDM, Reference [77] and [79].

10.6.7.5.1 Compliance with Safety Functional Requirements

a) Control of Reactivity

Not applicable.

b) Removal of Heat

Not applicable.

c) Confinement

1) Environmental Protection

- The containment isolation valves which are reinforced to be leak tight are closed during plant normal operation. For the air leak tightness characteristics see Table T-10.6-37.
- The HEPA filter and iodine adsorber are arranged on the iodine filter trains. For the filtration efficiency see Tables T-10.6-38 and T-10.6-39.
- Control the relative humidity of the iodine adsorber inlet to be below 60% to ensure the filtration efficiency of the iodine adsorber.
- Determine the electric heater capacity according to the highest possible temperature and humidity at the inlet of the iodine adsorber.
- Iodine filtration train components are to be designed in accordance with reinforcing them to be leak tight. For the characteristics of how air leak tight the components are see Table T-10.6-37.

2) Limiting Radiological Consequences

- Maintain negative pressure between the fuel building and the outside environment. For the negative pressure value see Table T-10.6-35.
- Collect leaks from containment penetrations.
- Maintain negative pressure between the reactor building and the outside environment when the emergency personnel gate is closed. For the negative pressure value see Table T-10.6-35.
- All of the containment isolation valves are closed within 3 seconds of receiving the shutdown command.
- Containment isolation valves are reinforced to be leak tight. For

characteristics related to how air leak tight the valves are see Table T-10.6-37.

- The HEPA filter and iodine adsorber are arranged on the iodine filter trains. For the filtration efficiency see Tables T-10.6-38 and T-10.6-39.
- Control the relative humidity of the iodine adsorber inlet to be below 60% to ensure the filtration efficiency of the iodine adsorber.
- Determine the electric heater capacity according to the highest possible temperature and humidity at the inlet of the iodine adsorber.
- Iodine filtration train components are to be designed in accordance with reinforcing them to be leak tight. For characteristics related to how air leak tight the components are see Table T-10.6-37.

d) Extra Safety Functions

1) Supporting the Fundamental Safety Functions

Not applicable. The EBA [CSBVS] does not contribute to supporting the fundamental safety functions.

2) Prevent, Protect and Mitigate Hazards Impact

Fire: Fire dampers can be closed by JDT [FAS] signal or a fire protection device to ensure containment of the fire and to maintain the fire compartment integrity.

Detailed design information is presented in Reference [81].

10.6.7.5.2 Compliance with Design Requirements

a) Safety Classification

The EBA [CSBVS] design is compliant with the principles described in Chapter 4. The safety classification of EBA [CSBVS] functions and the safety classification of main components are as follows:

T-10.6-10 Function Categorisation of the EBA [CSBVS]

System Function	**Function Category**
Containment isolation	FC1
Low-capacity extraction and iodine adsorption	FC2
Dampers and valves involved in leakage removal	FC2
Extraction in the reactor building	FC3

Opening of the connection dampers between low-capacity extraction and the DWK [FBVS] extraction network	FC2

T-10.6-11 Classification of Main Components

Component	Function Class	Design Provision Category	Design Provision Class	Seismic Category
Components of iodine filtration train	F-SC2	NC	NC	SSE1
Containment isolation valve	F-SC1	DPM	B-SC2	SSE1

b) Engineering Design Requirements

1) Reliability Design of SSCs

- Single Failure Criterion (SFC)

  The EBA [CSBVS] performs FC1 and FC2 safety functions. As such, the EBA [CSBVS] must be designed to consider credible single failures. The principle single failure design features for the EBA [CSBVS] are:

  2×100% iodine adsorption trains are provided in the EBA [CSBVS] low-capacity circuit:

  - Two containment isolation valves on each side of the reactor building;
  - Two isolation valves are installed in parallel on each leak collection line;
  - Two isolation dampers are installed in parallel on each connection line between the EBA [CSBVS] low-capacity extraction circuit and the DWK [FBVS] extraction network;
  - Two isolation dampers are installed in series on the supply and exhaust line.

- Independence

  The EBA [CSBVS] consists of two separate iodine filtration trains located in different equipment compartments that are physically isolated in the fuel building.

- Diversity

  According to the requirements of diversity in Chapter 4, the system functional requirements are currently being analysed. After the analysis is completed, the system design will be reviewed and analysed to

identify if any gaps exist and modifications will be made if necessary.

- Fail-safe

  The fail-safe position of isolation dampers/valves of the EBA [CSBVS] is in the closed position, which includes containment isolation valves and isolation dampers on the air supply or exhaust line

- Ageing and Degradation

  The plant design life is 60 years. Some components will require replacing at the end of their individual design life.

2) Human Factors

The system design of the EBA [CSBVS] does not require short term operator intervention, however there are operator actions during plant normal operation, the effect of which needs to be estimated. The equipment of each EBA [CSBVS] train is located in the same room, where the layout facilitates the ease of maintenance. The [CSBVS] is controlled and monitored in the main control room. It is designed to be convenient for the operators to control.

3) Autonomy

- Autonomy in Respect of Operators

  The design principles relevant to the autonomy in respect of operators are detailed in Reference [1]. The design of the EBA [CSBVS] fulfils these principles via control functional design, detailed information is presented in the SDM, Reference [80]. The design result is estimated in the safety analysis.

- Autonomy in Respect of the Heat Sink

  The design principles relevant to the autonomy in respect of the heat sink are not applicable for EBA [CSBVS] design.

- Autonomy in Respect of Power Supply Systems

  The design principles relevant to the autonomy in respect of the power supply are not applicable for EBA [CSBVS] design.

4) Other Design Requirements

- Prevention of Harmful Interactions of Systems Important to Safety

  Not applicable.

- Considerations Related to the Electrical Power Grid

The functionality of items important to safety in the EBA [CSBVS] is not compromised by disturbances in the electrical power grid. Detailed design information of the electrical power grid is presented in Reference [77].

c) Equipment Qualification

All the components of the EBA [CSBVS] required to perform safety functions are capable of operating under both normal and accident conditions. As a result, the components can withstand the most adverse environmental conditions expected.

All the seismically classified components of the EBA [CSBVS] shall be capable of operating during and after the SSE. The components are seismically designed and qualified for the SSE loads.

The documents relevant to the equipment qualification will be delivered before the step 4 of GDA.

d) Protection Design against Internal and External Hazards

The EBA [CSBVS] is protected from external and internal hazards; specific protection design is presented in the SDM, Reference [79]. The evaluation of the design is presented in Chapters 18 and 19.

e) Commissioning

Commissioning is going to be carried out for the EBA [CSBVS] to validate its functionality. Documents related to the commissioning will be delivered before the step 4 of GDA.

f) Examination, Inspection, Maintenance and Testing

1) Examination and Inspection

There is no equipment of the EBA [CSBVS] requiring in-service inspection.

The combined information of the EBA [CSBVS] displayed in the Main Control Room (MCR) for the operator includes:

- Containment isolation valve position status.

2) Maintenances

The maintenance of the EBA [CSBVS] can be performed during plant shutdown

The maintenance of iodine filtration trains and low-capacity containment isolation valves is performed during plant shutdown when there is no fuel handling operation.

3) Periodic Tests

FC1, FC2 and FC3 equipment should be tested periodically if they are not in continuous operation. Some equipment performing safety functions shall be subject to periodic testing, mainly including the efficiency of the HEPA filters, efficiency of iodine adsorbers, and how tight the containment isolation valves are.

g) Decommissioning

Decommissioning considerations about the EBA [CSBVS] are still being undertaken at this stage.

h) Material Selection

Galvanised steel when they are not classified as being airtight.

Welded and painted carbon steel when they are classified as being airtight.

10.6.7.6 Simplified Diagrams

The simplified system diagram is presented in Figure F-10.6-5; the detailed system functional diagrams are presented in Reference [82].

10.6.8 Annulus Ventilation System (EDE [AVS])

The EDE [AVS] maintains an acceptable temperature and provides dynamic containment to the annulus of the reactor building.

10.6.8.1 Safety Functional Requirements

The requirements of the fundamental safety functions on the EDE [AVS] for the UK HPR1000 are as identified below.

10.6.8.1.1 Control of Reactivity

The EDE [AVS] does not contribute to this safety function.

10.6.8.1.2 Removal of Heat

The EDE [AVS] does not contribute to this safety function.

10.6.8.1.3 Confinement

The EDE [AVS] provides a confinement function which is described below:

a) Environmental Protection

1) Contain Radioactive Material

Confine the leakage of radioactive material into the environment in normal conditions.

2) Limit Discharge

Limit the discharge of radioactive materials into the environment by filtration in normal conditions.

b) Limiting Radiological Consequences

1) Dynamic Containment

In accident conditions, the EDE [AVS] must maintain negative pressure in the annulus to ensure the dynamic confinement of radioactive material when there is a release of radioactive material in the annulus of the reactor building.

2) Static Isolation

In accident conditions, the containment barrier must be statically isolated.

3) Purification

Limit the discharge of radioactive materials into the environment by filtration.

10.6.8.1.4 Extra Safety Functions

The extra safety functional requirements of the EDE [AVS] are identified below:

a) Supporting the Fundamental Safety Functions

Maintain the acceptable temperature for the annulus of the reactor building.

b) Prevent, Protect and Mitigate Hazards Impact

Fire: In case of fire, the EDE [AVS] contributes to limit fire spread.

10.6.8.2 Design Requirements

The general design requirements of the HVAC systems which need to be considered are shown in Sub-chapter 10.2.4, among which the following requirements are not applicable for the EDE [AVS]:

a) Autonomy in Respect of the Heat Sink

Not applicable, because EDE [AVS] doesn’t provide a heat sink to the power plant.

b) Autonomy in Respect of Power Supply Systems

Not applicable, because EDE [AVS] doesn’t provide a power supply to the power plant.

c) Prevention of Harmful Interactions of Systems Important to Safety.

Not applicable, because the EDE [AVS] doesn’t have harmful interactions of systems important to safety.

The substantiation analysis of the EDE [AVS] to other design requirements is shown in the Sub-chapter 10.6.8.5.2.

10.6.8.3 Design Bases

10.6.8.3.1 General Assumptions

a) 1×100% operational train of EDE [AVS];

b) 2×100% safety trains of EDE [AVS].

10.6.8.3.2 Design Assumptions

a) Control of Reactivity

Not applicable. The EDE [AVS] does not contribute to this safety function.

b) Removal of Heat

Not applicable. The EDE [AVS] does not contribute to this safety function.

c) Confinement

The EDE [AVS] system must satisfy the functional requirements as follows:

1) Environmental Protection

- Maintain negative pressure in the annulus. For the specific negative pressure see Table T-10.6-36;
- Limit the discharge of radioactive materials into the environment by filtration in normal conditions. For the filtration efficiency of the HEPA filter see Table T-10.6-38.

2) Limiting Radiological Consequences

- Dynamic Confinement
  - Maintain negative pressure in the annulus. For the specific negative pressure see Table T-10.6-36.
  - Outdoor wind Speed: During DBC-2 to DEC-A or DEC-B accident conditions, the negative pressure on the reactor building external wall formed by the severe outdoor wind speeds should be considered.
  - Grace Period: In the event of a total loss of the power supply, the EDE [AVS] fan is shut down and the annulus pressure will start rising. The time between EDE [AVS] fan shut down and restart is referred to as the grace period. During this period, the annulus negative pressure must not reach a value higher than that set for severe accident conditions. The grace period should be considered for the safety train alignment on the batteries and to manually start the heaters and fans during total loss of

the power supply conditions.

- Leakage from the Containment: The maximum leak rate from the internal containment is assumed to be 0.3%/day (0.52MPa, 145°C) of the free volume of the internal containment.
- Internal Containment Displacement: During accident conditions, the expansion of the internal containment will increase the negative pressure of the annulus. The displacement of the internal containment diameter is assumed to be { }.
- Fan Specifications: The flow rate of the EDE [AVS] fan is sized based on the leak rate from the internal and external containment.
- The pressure of the EDE [AVS] fan is sized based on the negative pressure in the annulus and pressure drop of the EDE [AVS] ducts.

– Static Isolation

- Isolation dampers are installed to isolate the normal ventilation which will improve how leak tight the ventilation it. For the airtight requirements of the isolation dampers see Table T-10.6-37.

– Purification

- Air Filtering: For the filtration efficiency of the HEPA filter and iodine adsorber see Table T-10.6-38 and T-10.6-39.
- Electrical Heaters: The heaters upstream of the iodine adsorber have been designed to maintain the relative humidity below 70%. The temperature inlet of the heaters is 40°C and the relative humidity is 100%.

c) Extra Safety Functions

The EDE [AVS] must satisfy the safety functional requirements identified below:

1) Supporting the Fundamental Safety Functions

– The external conditions to be taken into account for the EDE [AVS] are defined in Table T-10.6-40 .

– The internal room conditions to be taken into account for the EDE [AVS] are defined in Tables T-10.6-42 and T-10.6-43.

2) Prevent, Protect and Mitigate Hazards Impact

– Fire: Not applicable. There’s no quantitative safety-related design assumption for the EDE [AVS].

d) Other Assumptions

Not applicable.

10.6.8.4 System Description and Operation

10.6.8.4.1 System Description

a) General System Description

The EDE [AVS] consists of one operational train and 2×100% safety trains.

The Annulus Ventilation System (EDE [AVS]) consists of:

1) An operational train (1×100%) equipped with :

- Motorised isolation dampers, pre-filter, HEPA filter, exhaust fan and non-return damper.

2) Two safety trains (2×100%), which are equipped with:

- Non-return damper, electrical heater, pre-filter, HEPA filter, iodine adsorber, exhausts fan and non-return damper.

Detailed information of the systems is presented in the SDM, Reference [83].

b) Description of Main Equipment

1) Fans

Safety fans are of a centrifugal and direct-coupled drive type.

2) Electrical Heaters

The electrical heaters are designed to maintain the relative humidity of the iodine adsorber inlet (the supply air temperature) by heating the air. They are comprised of reinforced tubular elements placed in a sheet metal box.

3) Pre-filters

The pre-filters are designed to filter dust or aerosols in the air and their efficiency is more than 85% (weighting method).

4) HEPA Filters

The HEPA filters are designed to filter dust in the air. Each HEPA filter cell is individually factory tested to verify an efficiency of at least 99.99%, corresponding to a 10000 filtering factor (sodium flame method).

5) Iodine Adsorbers

The iodine adsorbers are designed to remove radioactive iodine suspended in the air, each adsorber is assembly with a welded construction and a 102mm deep Type III rechargeable adsorber cell. When new, these filters have a filtering factor of at least 1000 (methyl iodide).

6) Isolation Dampers

The isolation dampers are designed to ensure the isolation of air exhaust in the annulus of the reactor building.

Detailed information of the equipment design is presented in the SDM, Reference [83] and [84].

c) Description of Main Layout

The main components of the EDE [AVS] are located in the fuel building.

The main ducts of the EDE [AVS] are located in the fuel building and annulus of the reactor building.

Detailed information can be found in the SDM, Reference [85].

d) Description of System Interfaces

The EDE [AVS] is connected to the following mechanical systems (not including power supplies and I&C systems):

1) JDT [FAS]

It detects fires in the EDE [AVS] rooms located in the fuel building. Moreover it sends an alarm signal to the supervisor in case of an iodine adsorber fire.

2) JPI [FWSNI]

In the event of a fire in the adsorber filter of the iodine adsorption units, the JPI [FWSNI] can be manually activated to provide water spray to extinguish the fire.

3) DWK [FBVS]

It provides the reference pressure used for the annulus pressure measurements. The pressure sensors are connected to the reference pressure line of the DWK [FBVS].

4) DWN [NABVS]

The interface is only with the stack of the nuclear auxiliary building.

5) EPP [CLRTMS]

It collects the leaks around the external containment valves using the negative pressure produced by the EDE [AVS].

6) KRT [PRMS]

It samples and monitors the exhaust air from the annulus.

7) RPE [VDS]

It collects the venting of the EDE [AVS] iodine adsorbers in the fuel building.

Detailed information of the interface systems is presented in the SDM, Reference [83].

e) Description of Instrumentation and Control

Instrumentation, controlling and monitoring the EDE [AVS] and displaying of the actuator are provided in the Main Control Room.

Detailed information of the system I&C design is presented in the SDM, Reference [86].

10.6.8.4.2 System Operation

a) Plant Normal Conditions

During normal operation, the operational train of the EDE [AVS] is in continuous operation in order to maintain the negative pressure of the annulus and enable the annulus to reach the initial negative pressure at the beginning of an accident. Exhaust air is filtered by the HEPA filter of the EDE [AVS] before being discharged to the vent stack.

b) Plant Accident Conditions

In the event of a DBC-2 to DBC-4 and DEC-A with the release of radioactivity inside containment, the ventilation system switches automatically to one of the two safety trains to process leakage from the reactor building containment. In the event of a DEC-B with the release of radioactivity inside containment, the safety trains (A or B) can be manually started by the operator. If safety train B is out of service, safety train A can be manually started by the operator.

On a containment isolation signal phase A, the operational train is automatically isolated by the motorised isolation dampers and the operational fan is stopped. The fan and the electric heater on one of the two safety trains are started, thus maintaining the minimum negative pressure required in the annulus.

10.6.8.5 Preliminary Design Substantiation

In this sub-chapter, the system design is demonstrated to satisfy the safety functional requirements presented in Sub-chapter 10.6.8.1 and the general design requirements stated in Sub-chapter 10.2.4.

Since the general principles are newly developed at this stage, the system design is still based on the reference design. A review of the consistency of the system design against the newly developed principles is currently being undertaken. Detailed design of the system is presented in the SDM, Reference [83] and [85].

10.6.8.5.1 Compliance with Safety Functional Requirements

a) Control of Reactivity

Not applicable.

b) Removal of Heat

Not applicable.

c) Confinement

1) Environmental Protection

- Requirement to confine the leakage of radioactive material into the environment in normal conditions:
  - Negative pressure to be maintained in the annulus. For the negative pressure see Table T-10.6-36.
- Requirement to limit the discharge of radioactive materials into the environment by filtration in normal conditions:
  - A HEPA filter is arranged on the operational train. For the filtration efficiency see Table T-10.6-38.

2) Limiting Radiological Consequences

Dynamic Containment

- In accident conditions, the EDE [AVS] must maintain the negative pressure in the annulus to ensure the dynamic confinement of radioactive material when there is a release of radioactive material in the annulus of the reactor building.
  - Maintain negative pressure in the annulus. For the specific negative pressure see Table T-10.6-36.
  - The normal air exhaust can be isolated when receiving the shutdown command. The isolation dampers are reinforced for them to be leak tight. For characteristics related to how air leak tight the isolation dampers are see Table T-10.6-37.
  - Ensure start-up of the safety trains.

Static Isolation

- In accident conditions, the containment barrier must be statically isolated.
  - Quick closing isolation dampers on the operational train are closed when receiving the shutdown command. For characteristics related to the air leak tightness see Table T-10.6-37.

Purification

- Requirement to limit the discharge of radioactive materials into the environment by filtration.

  - Sufficient filtration of the radioactive material released into the annulus of the EDE [AVS] must be ensured in order to limit the radioactive consequences in accident conditions. The HEPA filter and iodine adsorber are arranged on the safety trains. For the filtration efficiency see Tables T-10.6-38 and T-10.6-39.

  - The sizing of the electric heater can meet the requirements of relative humidity of the iodine adsorber inlet for it to be below 70%.

d) Extra Safety Functions

1) Supporting the Fundamental Safety Functions

The EDE [AVS] components will be sized to meet the acceptable temperature requirement in the annulus.

2) Prevent, Protect and Mitigate Hazards Impact

Fire: Fire dampers can be closed by the JDT [FAS] signal or a fire protection device to ensure the containment of fire and to maintain the fire compartment integrity.

Detailed design information is presented in Reference [87].

10.6.8.5.2 Compliance with Design Requirements

a) Safety Classification

The EDE [AVS] design is compliant with the principles described in Chapter 4. The safety classification of EDE [AVS] functions and the safety classification of main components are as follows:

T-10.6-12 Function Categorisation of the EDE [AVS]

System Function	Function Category
External containment penetration	FC1
Iodine adsorption by the safety trains	FC2
Operational train isolating	FC1
Rest of the Operational train	FC2 (for part in connection with the iodine safety train B) NC (for other equipment)
Firefighting function	FC3 / FC2

T-10.6-13 Classification of Main Components

Component	Function Class	Design Provision	Design Provision	Seismic Category

		Category	Class	
External containment penetration	F-SC1	NC	NC	SSE1
Equipment of safety trains	F-SC2	NC	NC	SSE1
Operational train isolating dampers	F-SC1	NC	NC	SSE1
Rest of the equipment of the Operational train	F-SC2 (for parts in connection with iodine safety train B) NC (for other equipment)	NC	NC	SSE1 (for parts in connection with iodine safety train B) SSE2 (for other equipment)
Fire dampers	F-SC2	NC	NC	SSE1

b) Engineering Design Requirements

1) Reliability Design of SSCs

- Single Failure Criterion (SFC)

  The single failure criterion is applied and fulfilled for:

  - The isolation of the operational train, with 2 isolation dampers in series.
  - Two fire dampers arranged in parallel which are set at the safety fire zone boundary.
  - The safety trains, which are redundant with 2×100% availability.

- Independence

  The safety trains of the EDE [AVS] consist of two separated trains located in different rooms of the fuel building.

  The safety trains of the EDE [AVS] and dampers are powered by different electrical safety trains respectively, which ensures redundancy.

- Diversity

  In accordance with the requirements of diversity in Chapter 4, the system functional requirements are currently being analysed. After the analysis is completed, the system design will be reviewed and analysed to identify if any gaps exist and modifications will be made if necessary.

- Fail-safe

  The fail-safe position of isolation dampers of the EDE [AVS] is the closed position.

- Ageing and Degradation

  The plant design life is 60 years. Some components will require replacing at the end of their individual design life.

2) Human Factors

The system design of the EDE [AVS] does not require short term operator intervention, however there are operator actions during plant normal operation, the effect of which needs to be estimated. The main equipment of the safety trains is located in separate rooms in the fuel building, where the layout facilitates their maintenance. The EDE [AVS] is controlled and monitored in the main control room. It is designed to be convenient for the operators to control.

3) Autonomy

- Autonomy in Respect of Operators

  The design principles relevant to the autonomy in respect of operators are detailed in Reference [1]. The design of the EDE [AVS] fulfils these principles via control functional design, detailed information is presented in the SDM, Reference [86]. The design result is estimated in the safety analysis.

- Autonomy in Respect of the Heat Sink

  The design principles relevant to the autonomy in respect of the heat sink are not applicable for EDE [AVS] design.

- Autonomy in Respect of Power Supply Systems

  The design principles relevant to the autonomy in respect of the power supply are not applicable for EDE [AVS] design.

4) Other Design Requirements

- Prevention of Harmful Interactions of Systems Important to Safety

  Not applicable.

- Considerations Related to the Electrical Power Grid

  The functionality of items important to safety in the EDE [AVS] is not compromised by disturbances in the electrical power grid. Detailed design information of the electrical power grid is presented in Reference [83].

c) Equipment Qualification

All the components of the EDE [AVS] required to perform safety functions are

capable of operating under both normal and accident conditions. As a result, the components can withstand the most adverse environmental conditions expected.

All the seismically classified components of the EDE [AVS] shall be capable of operating during and after the SSE. The components are seismically designed and qualified for the SSE loads.

The documents relevant to the equipment qualification will be delivered before the step 4 of GDA.

d) Protection against Internal and External Hazards

The EDE [AVS] is protected from external and internal hazards; the specific protection design is presented in the SDM, Reference [85]. The evaluation of the design is presented in Chapters 18 and 19.

e) Commissioning

Commissioning is going to be carried out for the EDE [AVS] to validate its functionality. Documents related to the commissioning will be delivered before the step 4 of GDA.

f) Examination, Inspection, Maintenance and Testing

1) Examination and Inspection

There is no equipment of the EDE [AVS] requiring in-service inspection.

In order to ensure the correct operation of system, surveillance equipment measuring system parameters and equipment status has been designed. These measurements can help operators manage the system status at any time.

The combined information of the EDE [AVS] displayed in the MCR for the operator includes:

- Temperature upstream and downstream of heaters;
- Position of isolated dampers;
- Position of fire dampers;
- Status of the fan;
- Status of the heater.

2) Maintenances

During normal operating conditions, the EDE [AVS] should maintain the negative pressure in the annulus. Maintenance of the components could be completed during shutdown of the plant.

The maintenance of safety trains is performed during the plant shutdown as

well.

3) Periodic Tests

FC1, FC2 and FC3 equipment should be tested if they are not in continuous operation. Some equipment performing safety functions shall be subject to periodic testing, mainly including the:

- Efficiency of HEPA filters;
- Efficiency of iodine adsorbers;
- Operation of the extraction fans and heaters;
- Operability of the motorised isolation dampers;
- Control of negative pressure.

g) Decommissioning

Decommissioning considerations about the EDE [AVS] are still being undertaken at this stage.

h) Material Selection

The extraction ducts are manufactured of carbon steel with a painted surface finish. The fireproof duct is contained within a fireproof wrap.

10.6.8.6 Simplified Diagrams

The simplified system functional diagram is presented in Figure F-10.6-6; the detailed system functional diagram is presented in Reference [88].

10.6.9 Safeguard Building Controlled Area Ventilation System (DWL [SBCAVS])

The DWL [SBCAVS] maintains the acceptable environmental conditions in the controlled area of the safeguard building during normal and accident conditions, and provides dynamic confinement for the safeguard building controlled area and fuel pool hall under accident conditions.

10.6.9.1 Safety Functional Requirements

The requirements of the fundamental safety functions on DWL [SBCAVS] design for the UK HPR1000 are as identified below.

10.6.9.1.1 Control of Reactivity

The DWL [SBCAVS] does not contribute to this safety function.

10.6.9.1.2 Removal of Heat

The DWL [SBCAVS] does not contribute to this safety function.

10.6.9.1.3 Confinement

The DWL [CSBVS] provides a confinement function which is described as follows:

a) Environmental Protection

To limit the leakage of radioactive material into the environment in normal conditions.

b) Limiting Radiological Consequences

1) Dynamic Confinement

- Provide a dynamic containment function for the controlled area of the safeguard building during accidents when activity is released in the reactor building.
- Provide a dynamic containment function for the controlled area and Safety Injection System (RIS [SIS]) rooms to prevent potential RIS [SIS] leak.
- Provide a dynamic containment function for the controlled area and Safety Injection System (RIS [SIS]) rooms for RIS [SIS] leaks when there is a break with the reactor coolant temperature below 100°C.
- Provide a dynamic containment function for the Containment Heat Removal System (EHR [CHRS]) rooms to prevent a potential leak when it operates during DEC-B conditions.
- Ensure the dynamic confinement function during a Severe Accident (SA).
- Provide a dynamic containment function to the room facing the personnel airlock during a fuel handling accident in the reactor building or a Loss of Coolant Accident (LOCA).
- During a fuel handling accident in the fuel building, the DWL [SBCAVS] provides a dynamic containment function for the fuel pool hall while the normal ventilation is isolated.

2) Static Isolation

- Provide static isolation for the controlled area of the safeguard building during accident conditions.
- Provide static isolation for the Safety Injection System (RIS [SIS]) rooms to prevent potential RIS [SIS] leak when it operates with the reactor coolant temperature above 100°C.
- Provide static isolation for the RIS [SIS] rooms in the division affected by a RIS [SIS] leak with the reactor coolant temperature above 100°C.

- Provide Static isolation for the controlled area and Safety Injection System (RIS [SIS]) rooms for RIS [SIS] leak when there is a break of RIS [SIS] pipe with the reactor coolant temperature below 100°C.
- Provide static isolation to the room facing the personnel airlock during a fuel handling accident in the reactor building or a Loss of Coolant Accident (LOCA).
- Provides static isolation for the fuel pool hall during fuel handling accidents in the fuel building.

3) Purification

- Purify the radioactive material before it is discharged into the environment.

10.6.9.1.4 Extra Safety Functions

The extra safety functional requirements of the DWL [SBCAVS] are identified below:

a) Supporting the Fundamental Safety Functions

Maintain the acceptable temperature for safety classified equipment and personnel in the controlled areas of the safeguard buildings during normal and accident conditions.

b) Prevent, Protect and Mitigate Hazards Impact

Fire: In case of fire, the DWL [SBCAVS] contributes to limit fire spread.

10.6.9.2 Design Requirements

The general design requirements of the HVAC systems which need to be considered are shown in Sub-chapter 10.2.4, among which the following requirements are not applicable for the DWL [SBCAVS]:

a) Autonomy in Respect of the Heat Sink

Not applicable, because the DWL [SBCAVS] doesn’t provide a heat sink to the power plant.

b) Autonomy in Respect of Power Supply Systems

Not applicable, because the DWL [SBCAVS] doesn’t provide a power supply to the power plant.

c) Prevention of Harmful Interactions of Systems Important to Safety.

Not applicable, because the DWL [SBCAVS] doesn’t have harmful interactions of systems important to safety.

The substantiation analysis of the DWL [SBCAVS] to other design requirements is

shown in the Sub-chapter 10.6.9.5.2.

10.6.9.3 Design Bases

10.6.9.3.1 General Assumptions

a) Air supply and exhaust provided by the DWN [NABVS] during normal operation conditions;

b) Iodine adsorptions set as 2×100%;

c) Rooms with high heat loads such as the RIS [SIS]/RRI [CCWS]/EHR [CHRS] (only divisions A and B)/RBS [EBS] are provided with 1×100% local cooling units.

10.6.9.3.2 Design Assumptions

a) Control of Reactivity

Not applicable. The DWL [SBCAVS] does not contribute to this safety function.

b) Removal of Heat

Not applicable. The DWL [SBCAVS] does not contribute to this safety function.

c) Confinement

1) Environmental Protection

Maintain the negative pressure in the controlled area of the safeguard building. For the specific negative pressure see Table T-10.6-35.

2) Limiting Radiological Consequences

- Dynamic Confinement

  - Maintain the negative pressure in the controlled area of the safeguard building and fuel pool hall. For the specific negative pressure see Table T-10.6-35.

- Static Isolation

  - Isolation dampers are installed to isolate the normal ventilation, the RIS [SIS] rooms' air supply and exhaust, personnel airlock air supply and exhaust and the EHR [CHRS] rooms' air supply. All the isolation dampers identified above are reinforced to be leak tight. For characteristics relevant to how airtight the isolation dampers are see Table T-10.6-37. The isolation dampers must be capable of withstanding an ambient pressure of at least { } in the event of a pipe break inside the RIS [SIS] rooms.

- Purification

- Air Filtering: To limit the discharge of radioactive materials into the environment through reduction, storage, filtering and control of the radioactive materials in the air.
- For the filtration efficiency of the HEPA filter and iodine adsorber sees Tables T-10.6-38 and T-10.6-39.
- The heaters upstream of the iodine adsorber have been designed to maintain the relative humidity below 70%.
- The temperature inlet of heaters is 40°C and the relative humidity is 100%.
- The flow rate of the DWL [SBCAVS] iodine adsorption line is 6800m³/h

d) Extra Safety Functions

1) Supporting the Fundamental Safety Functions

- The external conditions to be taken into account for the DWL [SBCAVS] are defined in Table T-10.6-40.
- The internal room conditions to be taken into account for the DWL [SBCAVS] are defined in Tables T-10.6-42 and T-10.6-43.
- The temperature of air supply is 18°C, which is provided by the DWN [NABVS].
- The capacity of the local cooling units is considered under accident conditions, when the normal ventilation is lost and considering the maximum heat dissipation of the equipment and pipes.

2) Prevent, Protect and Mitigate Hazards Impact

- Fire: Not applicable. There's no quantitative safety-related design assumption for the DWL [SBCAVS].

e) Other Assumptions

Requirements for the minimum air renew rate are detailed in Table T-10.6-44.

10.6.9.4 System Description and Operation

10.6.9.4.1 System Description

a) General System Description

The air supply and exhaust of the DWL [SBCAVS] are provided by the DWN [NABVS] during normal operating conditions. Three divisions of supply and exhaust are located in the corresponding safeguard buildings. The iodine

adsorption trains which provide dynamic confinement for the controlled area of the safeguard building and fuel pool hall are set as 2×100%. Rooms with high heat loads such as the RIS [SIS] / RRI [CCWS] /EHR [CHRS] (only divisions A and B) /RBS [EBS] are provided with 1×100% local cooling units which are provided chilled water by the DEL [SCWS].

1) Normal air supply line including:

   - The normal air supply lines from the DWN [NABVS] consist of two air supply isolation dampers and one volume control damper, which are arranged in series.
   - An internal supply distribution system, including the RIS [SIS] room isolation dampers, EHR [CHRS] (only divisions A and B) room isolation dampers and personnel airlock (only division C) isolation dampers.

2) Normal air exhaust line including:

   - The normal exhaust line to the DWN [NABVS] consists of two exhaust isolation dampers and one air volume control damper which are arranged series.
   - An internal exhaust distribution system, including RIS [SIS] room isolation dampers and the personnel airlock (only division C) isolation dampers.

3) Accidental exhaust line including:

   - The accidental exhaust line contains two accident isolation dampers arranged in a parallel configuration.
   - The emergency exhaust of the fuel pool hall consists of two accident exhaust isolation dampers.

4) 2×100% iodine adsorption trains including:

   - Electrical heater, pre-filter, HEPA filter, iodine adsorber and air exhaust fan.

5) Local cooling and heating including:

   - Local cooling units in the RIS [SIS] / RRI [CCWS] /EHR [CHRS] (only divisions A and B) /RBS [EBS] (only division C) rooms which contain an air cooler with a droplet separator and a supply fan.
   - Electric heaters in the RBS [EBS] rooms (only division C).

Detailed information of the systems is presented in the SDM, Reference [89].

b) Description of Main Equipment

1) Fans

Iodine adsorption fans are of a centrifugal and direct-coupled drive type.

2) Electrical Heaters

The electrical heaters are designed to maintain the relative humidity of the iodine adsorber inlet (the supply air temperature) by heating the air and are comprised of reinforced tubular elements placed in a sheet metal box.

3) Pre-filters

The pre-filters are designed to filter dust in the air, and their efficiency is more than 85% (weighting method).

4) HEPA Filters

The HEPA filters are designed to filter dust or aerosols in the air. Each HEPA filter cell is individually factory tested to verify an efficiency of at least 99.99%, corresponding to a 10000 filtering factor (sodium flame method).

5) Iodine Adsorbers

The iodine adsorbers are designed to remove radioactive iodine suspended in the air. Each adsorber is assembly with a welded construction and a 102mm deep Type III rechargeable adsorber cell. When new, these filters have a filtering factor of at least 1000 (methyl iodide).

6) Local Cooling Units

The local cooling units are designed to provide cooling to the air. A local cooling unit consists of a fan and a cooling coil supplied with chilled water.

7) Isolation Dampers

The isolation dampers are designed to ensure the isolation of the air supply and exhaust in the controlled area of the safeguard building, air exhaust in the fuel pool hall, RIS [SIS] rooms, supply and exhaust in the EHR [CHRS] (only divisions A and B) rooms and the personnel airlock (only division C).

Detailed information of the equipment design is presented in the SDM, Reference [90], [89].

c) Description of Main Layout

The equipment of the two iodine adsorption trains is located in separate rooms of the fuel building.

The other equipment contains local cooling units located in the safeguard building controlled area.

Detailed information can be found in the SDM, Reference [91].

d) Description of System Interfaces

The DWL [SBCAVS] is connected to the following mechanical systems (not including power supplies and I&C systems):

1) DEL [SCWS]

Provides chilled water to the DWL [SBCAVS] local cooling units.

2) DWN [NABVS]

During normal conditions, provides the supply air and receives the exhaust air.

3) JDT [FAS]

Provides the fire signal to control the fire dampers of the DWL [SBCAVS].

4) JPI [FWSNI]

In the event of a fire in the adsorber of the iodine adsorption units, the JPI [FWSNI] can be manually activated to provide a water spray to extinguish the fire.

5) KRT [PRMS]

Detects the radioactive level to close the isolation dampers of the personnel airlock and fuel pool hall.

6) RPE [VDS]

The RPE [VDS] collects condensation from the DWL [SBCAVS] cooling coils. The DWL [SBCAVS] also maintains the air space of the RPE [VDS] process train tanks at a slight sub-pressure.

7) DWK [FBVS]

The DWL [SBCAVS] interfaces with the DWK [FBVS] to extract air from the fuel pool hall through the iodine adsorption units in the event of a fuel handling accident inside the fuel building.

8) RRI [CCWS]

The DWL [SBCAVS] maintains the air space of the RRI [CCWS] expansion tanks at a slight sub-pressure.

9) EHR [CHRS]

The EHR [CHRS] accumulator vents are connected directly to the DWL [SBCAVS] (Division A and B only).

Detailed information of the interface systems is presented in the SDM, Reference [89].

e) Description of Instrumentation and Control

Instrumentation controlling and monitoring the DWL [SBCAVS] and displaying of the actuator are provided in the Main Control Room.

Detailed information of the system I&C design is presented in the SDM, Reference [92].

10.6.9.4.2 System Operation

a) Plant Normal Conditions

During normal operation of the plant, the DWL [SBCAVS] meets the appropriate ambient temperature and sanitary requirements for the normal operation of equipment and personnel work. For the safeguard building controlled area, the system provides containment, maintains negative pressure, prevents spread of radioactive materials and limits the concentration of aerosols.

The DWN [NABVS] provides a conditioned supply air to the air distribution ducts of all three DWL [SBCAVS] divisions. The DWL [SBCAVS] directs the normal room exhaust air to the DWN [NABVS].

b) Plant Accident Conditions

During a LOOP (DBC-2/DBC-3), the parts of the DWL [SBCAVS] which perform FC1/FC2 functions remain operational.

In case of a LUHS, the DWL [SBCAVS] local cooling units in Divisions A and B remain available.

During a LOCA (DBC-3/DBC-4)) which initiates a safety injection signal, the normal air supply and exhaust of controlled areas of the safeguard buildings are isolated. The iodine adsorption train operates to confine the area.

In the event of a RIS [SIS] leak (DBC-3/DBC-4) during RHR operation at <100°C, the isolation dampers in the supply and exhaust air ducts and the RIS [SIS] supply isolation dampers are preventively closed.

During RHR operation at ＞100°C, the isolation dampers in the supply and exhaust air ducts and the RIS [SIS] supply isolation dampers are preventively closed.

During a severe accident (DEC-B), the safeguard buildings are preventively isolated with the normal DWL [SBCAVS] supply and exhaust dampers from the DWN [NABVS]. Accidental exhaust isolation dampers are opened and a sub-pressure in each Safeguard Building is provided by one of the DWL

[SBCAVS] iodine adsorption trains.

For fuel handling accidents in the reactor building (DBC-4), the iodine adsorption train operates to contain the controlled areas of the safeguard buildings.

For fuel handling accidents in the fuel building (DBC-4), the DWL [SBCAVS] operating conditions in the safeguards buildings are not changed from the normal operating conditions. Only those sections of the DWL [SBCAVS] pertaining to the iodine adsorption trains are affected. The iodine adsorption train operates to contain the fuel pool pall.

Detailed information of the system operation is presented in the SDM, Reference [92].

10.6.9.5 Preliminary Design Substantiation

In this sub-chapter, the system design is demonstrated to satisfy the safety functional requirements presented in Sub-chapter 10.6.9.1 and the general design requirements stated in Sub-chapter 10.2.4.

Since the general principles are newly developed at this stage, the system design is still based on the reference design. A review of the consistency of the system design against the newly developed principles is currently being undertaken. Detailed design of the system is presented in the SDM, Reference [89], [91].

10.6.9.5.1 Compliance with Safety Functional Requirements

a) Control of Reactivity

Not applicable.

b) Removal of Heat

Not applicable.

c) Confinement

1) Environmental Protection

Requirement to limit the leakage of radioactive material into the environment in normal conditions.

A motorised control damper on the DWL [CSBVS] supply line of each division is used to control the supply flow rate and maintain a negative pressure of 100 Pa in the controlled area.

2) Limiting Radiological Consequences

Dynamic confinement

- Requirement to provide a dynamic containment function for the controlled area of the safeguard building during accidents where activity

is released in the reactor building:

- Maintain negative pressure in the controlled area of the safeguard building. For the specific negative pressure see Table T-10.6-35.
- Normal air supply and exhaust can be isolated when receiving the shutdown command.
- Ensure start-up of the iodine adsorption trains.

– Requirement to provide a dynamic containment function for the controlled area and Safety Injection System (RIS [SIS]) rooms to prevent potential RIS [SIS] leak:

- Isolate RIS [SIS] room air supply and exhaust, the isolation dampers are reinforced for to be leak tight. For characteristics of how air leak tight the isolation dampers are see Table T-10.6-37.
- Maintain negative pressure in the controlled area. For the specific negative pressure see Table T-10.6-35.

– Requirement to provide a dynamic containment function for the controlled area and Safety Injection System (RIS [SIS]) rooms for RIS [SIS] leak when there is a break of RIS [SIS] pipe with the reactor coolant temperature below 100°C:

- Ensure start-up of dynamic confinement trains.
- Isolate the affected normal ventilation supply and exhaust, the isolation dampers are reinforced to be leak tight. For characteristics of how air leak tight the isolation dampers are see Table T-10.6-37.
- Isolate the affected RIS [SIS] room air supply, the isolation dampers are reinforced to be leak tight. For characteristics of how air leak tight the isolation dampers are see Table T-10.6-37.
- The affected RIS [SIS] room normal supply and exhaust quick closing supply isolation dampers are closed on receipt of a safety injection signal, CIA isolation signal or signal actuated by a RIS [SIS] leak (high sump level or high pressure).

– Requirement to provide a dynamic containment function for the Containment Heat Removal System (EHR [CHRS]) rooms to prevent a potential leak when it operates during DEC-B conditions:

- Ensure start-up of the dynamic confinement trains.
- Isolate the normal ventilation supply and exhaust, the isolation dampers are reinforced to be leak tight. For characteristics of how

air leak tight the isolation dampers are see Table T-10.6-37.

- Isolate the EHR [CHRS] room air supply, the isolation dampers are reinforced to be leak tight. For characteristics of how air leak tight the isolation dampers are see Table T-10.6-37.
- The EVU [CHRS] room supply isolation dampers (in divisions A and B) are closed manually before start-up of the EVU [CHRS] pump.

– Requirement to ensure the dynamic confinement function during a Severe Accident (SA):

- Enable maintenance to be carried out on a faulty iodine adsorption train.
- When maintenance or repairs are required, the adsorption function is switched from the first to the second iodine adsorption train manually from the main control room. Manual isolation dampers are used to isolate the faulty train so that maintenance can be carried out.

– Requirement to provide a dynamic containment function to the room facing the personnel airlock during a fuel handling accident in the reactor building or a Loss of Coolant Accident (LOCA):

- Ensure start-up of the dynamic confinement trains.
- Isolate the air supply and exhaust of the room facing the personnel airlock, the isolation dampers are reinforced to be leak tight. For characteristics of how air leak tight the isolation dampers are see Table T-10.6-37.
- The redundant quick closing supply isolation dampers are closed on receipt of a high activity signal in the reactor building.

– Requirement to provide a dynamic containment function for the fuel pool hall during a fuel handling accident in the fuel building:

- Ensure start-up of the dynamic confinement trains with the completion time being derived from the radiological studies.
- Maintain the negative pressure in the fuel pool hall. For the specific negative pressure see Table T-10.6-35.
- Redundant accident isolation dampers are opened on receipt of a high activity signal in the fuel pool hall.

Static isolation

- Requirement to provide static isolation for the controlled area of the safeguard building during an accident conditions.

  - Related quick closing isolation dampers are closed when receiving the shutdown command. For characteristics relating to how air leak tight the equipment is see Table T-10.6-37.

- Requirement to provide static isolation for the Safety Injection System (RIS [SIS]) rooms to prevent a potential RIS [SIS] leak when it operates with the reactor coolant temperature above 100°C.

  - Related quick closing isolation dampers are closed manually. For characteristics relating to how air leak tight the equipment is see Table T-10.6-37.

- Requirement to provide static isolation for the RIS [SIS] rooms in the division affected by a RIS [SIS] leak with the reactor coolant temperature above 100°C.

  - Quick closing isolation dampers on the RIS [SIS] supply and exhaust lines are closed when receiving the shutdown command. For characteristics related to how air leak tight the equipment is see Table T-10.6-37.

- Requirement to provide static isolation for the controlled area and Safety Injection System (RIS [SIS]) rooms for a RIS [SIS] leak when there is a break of RIS [SIS] pipe with the reactor coolant temperature below 100°C.

  - Quick closing isolation dampers on the RIS [SIS] supply line are closed when receiving the shutdown command. For characteristics related to how air leak tight the equipment is see Table T-10.6-37.

- Requirement to provide static isolation to the room facing the personnel airlock during a fuel handling accident in the reactor building or a Loss of Coolant Accident (LOCA).

  - Quick closing isolation dampers on the air supply and exhaust lines of the room facing the personnel airlock are closed when receiving the shutdown command. For characteristics related to how air leak tight the equipment is see Table T-10.6-37.

- Requirement to provide static isolation for the Fuel Pool Hall during the fuel handling accident in Fuel Building.

  - Accident isolation dampers on air accident exhaust line of the Fuel Pool Hall are opened when receiving the signal. Air leak tightness characteristics see T-10.6-37.

Purification

- Requirement to purify the radioactive material before it is discharged into the environment.

  - Ensure radiological materials are filtered before release of the air to the environment via the vent stack. The HEPA filter and iodine adsorber are arranged on the iodine adsorption trains. For the filtration efficiency see Tables T-10.6-38 and T-10.6-39.

  - The sizing of the electric heater can meet the requirements of relative humidity of iodine adsorber inlet, which are to maintain it below 70%.

d) Extra Safety Functions

1) Supporting the Fundamental Safety Functions

The DWL [CSBVS] components are sized to meet the cooling requirements of its served rooms (RIS [SIS], EHR [CHRS], RRI [CCWS] and RBS [EBS]) under normal or accident conditions.

2) Prevent, Protect and Mitigate Hazards Impact

Fire: Fire dampers can be closed by the JDT [FAS] signal or fusible device to ensure the containment of fire and to maintain the fire compartment integrity.

Detailed design information is presented in Reference [93].

10.6.9.5.2 Compliance with Design Requirements

a) Safety Classification

The DWL [CSBVS] design is compliant with the principles described in Chapter 4. The safety classification of DWL [CSBVS] functions and the safety classification of main components are as follows:

T-10.6-14 Function Categorisation of the DWL [CSBVS]

System Function	**Function Category**
Normal air supply equipment	NC
Sub-pressure regulation of air supply	FC3
Normal air supply isolation	FC1
Air supply isolation in the RIS [SIS] room	FC1
Air supply isolation in the EHR [CHRS] room	FC3

System Function	Function Category
Air supply isolation in the air lock area	FC1
Normal air exhaust equipment	FC2
Normal air exhaust isolation	FC1
Air exhaust isolation in the air lock area	FC2
Air exhaust of iodine filter train in the Safeguard Building	FC2
Containment of fuel pool hall during fuel operation accidents	FC2
Air exhaust isolation in the RIS [SIS] room	FC2
Local cooling units of the RIS [SIS] room	FC1
Local cooling units of the RRI [CCWS] room	FC1
Local cooling units of the EHR [CHRS] room	FC3
Local cooling units of the RBS [EBS] room	FC2
Heating of the RBS [EBS] boric acid room	FC2
Firefighting of the iodine filter train and accident exhausting fire fighting	FC2
Firefighting of the Safeguard Building	FC1
General fire fighting	FC3

T-10.6-15 Safety Classification of Main Components

Component	Function Class	Design Provision Category	Design Provision Class	Seismic Category
Normal air supply equipment	NC	NC	NC	SSE2
Sub-pressure regulation dampers of air supply	F-SC3	NC	NC	SSE2
Normal air supply isolation dampers	F-SC1	NC	NC	SSE1
Air supply isolation dampers in the RIS [SIS] room	F-SC1	NC	NC	SSE1

Component	Function Class	Design Provision Category	Design Provision Class	Seismic Category
Air supply isolation dampers in the EHR [CHRS] room	F-SC3	NC	NC	SSE1
Air supply isolation dampers in the air lock area	F-SC1	NC	NC	SSE1
Normal air exhaust equipment	F-SC2	NC	NC	SSE1
Normal air exhaust isolation dampers	F-SC1	NC	NC	SSE1
Air exhaust isolation dampers in the air lock area	F-SC2	NC	NC	SSE1
Equipment of iodine filter train in the Safeguard Building	F-SC2	NC	NC	SSE1
Isolation dampers of fuel pool hall during fuel operation accidents	F-SC2	NC	NC	SSE1
Air exhaust isolation dampers in the RIS [SIS] room	F-SC2	NC	NC	SSE1
Local cooling units of the RIS [SIS] room	F-SC1	NC	NC	SSE1
Local cooling units of the RRI [CCWS] room	F-SC2	NC	NC	SSE1
Local cooling units of the EHR [CHRS] room	F-SC3	NC	NC	SSE1
Local cooling units of the RBS [EBS] room	F-SC2	NC	NC	SSE1
Heaters of the RBS [EBS] boric acid room	F-SC2	NC	NC	SSE1
Fire dampers of iodine filter train and accident exhausting fire dampers	F-SC2	NC	NC	SSE1
Fire dampers of the Safeguard Building	F-SC1	NC	NC	SSE1

Component	Function Class	Design Provision Category	Design Provision Class	Seismic Category
General fire dampers	F-SC3	NC	NC	SSE1

b) Engineering Design Requirements

1) Reliability Design of SSCs

- Single Failure Criterion (SFC)

The DWL [SBCAVS] performs FC1 and FC2 safety functions. As such, the DWL [SBCAVS] must be designed to consider credible single failures. The principle single failure design features for the DWL [SBCAVS] are:

- Two independent isolation dampers are provided in the ventilation supply line to the personnel air lock.
- Two independent isolation dampers are provided in the Nuclear Auxiliary Building Ventilation System DWN [NABVS] ventilation supply lines to the DWL [SBCAVS] to ensure the affected safeguard building supply line is isolated during a radiological accident.
- Two independent isolation dampers are provided in the DWL [SBCAVS] normal ventilation exhaust lines to ensure the affected safeguard building exhaust line is isolated during a radiological accident.
- 2×100% iodine adsorption trains are provided in the DWL [SBCAVS] accidental exhaust lines.
- Two isolation dampers arranged in parallel which connect each safeguard building accidental exhaust line to the common DWL [SBCAVS] iodine adsorption unit exhaust line.
- Two isolation dampers arranged in parallel which connect the fuel pool area exhaust to the iodine adsorption units.
- Two fire dampers arranged in parallel which are set at the safety fire zone boundary.

- Independence

The normal ventilation of the DWL [SBCAVS] consists of three separated trains (one train in each division of the safeguard building).

The accident ventilation of the DWL [SBCAVS] consists of two separated trains located in different rooms of the fuel building.

The three trains of the DWL [SBCAVS] and dampers are powered by different electrical safety trains respectively, to ensure redundancy of the power supply.

- Diversity

  According to the requirements of diversity in Chapter 4, the system functional requirements are currently being analysed. After the analysis is finished, the system design will be reviewed and analysed to identify if any gaps exist and modifications will be made if necessary.

- Fail-safe

  The isolation dampers of the normal and accident air supply and exhaust ventilation, RIS [SIS] room air supply and exhaust ventilation, EHR [CHRS] room air supply ventilation and personnel airlock air supply and exhaust ventilation have fail-safe positions. The fail-safe position of isolation dampers of the DWL [SBCAVS] listed above is the closed position.

- Ageing and Degradation

  The plant design life is 60 years. Some components will require replacing at the end of their individual design life.

2) Human Factors

The system design of the DWL [SBCAVS] does not require short term operator intervention, however there are operator actions during plant normal operation, the effect of which needs to be estimated. The main equipment of the iodine adsorption trains is located in separate rooms in the fuel building, where the layout facilitates their maintenance. The DWL [SBCAVS] is controlled and monitored in the main control room. It is designed to be convenient for the operator to control.

3) Autonomy

- Autonomy in Respect of Operators

  The design principles relevant to the autonomy in respect of operators are detailed in Reference [1]. The design of the DWL [SBCAVS] fulfils these principles via control functional design, detailed information is presented in the SDM, Reference [92]. The design result is estimated in the safety analysis.

- Autonomy in Respect of the Heat Sink

The design principles relevant to the autonomy in respect of the heat sink are not applicable for DWL [SBCAVS] design.

- Autonomy in Respect of Power Supply Systems

  The design principles relevant to the autonomy in respect of the power supply are not applicable for DWL [SBCAVS] design.

4) Other Design Requirements

- Prevention of Harmful Interactions of Systems Important to Safety

  Not applicable.

- Considerations Related to the Electrical Power Grid

  The functionality of items important to safety in the DWL [SBCAVS] is not compromised by disturbances in the electrical power grid. Detailed design information of the electrical power grid is presented in Reference [89].

c) Equipment Qualification

All the safety components of the DWL [SBCAVS] required to perform safety functions are capable of operating under both normal and accident conditions. As a result, the components can withstand the most adverse environmental conditions expected.

All the seismically classified components of the DWL [SBCAVS] shall be capable of operating during and after the SSE. The components are seismically designed and qualified for the SSE loads.

The documents relevant to the equipment qualification will be delivered before the step 4 of GDA.

d) Protection against Internal and External Hazards

The DWL [SBCAVS] is protected from external and internal hazards; specific protection design is presented in the SDM, Reference [91]. The evaluation of the design is presented in Chapters 18 and 19.

e) Commissioning

Commissioning is going to be carried out for the DWL [SBCAVS] to validate its functionality. Documents related to the commissioning will be delivered before the step 4 of GDA.

f) Examination, Inspection, Maintenance and Testing

1) Examination and Inspection

There is no equipment of the DWL [SBCAVS] requiring in-service inspection.

The combined information of the DWL [SBCAVS] displayed in the Main Control Room (MCR) for the operator includes:

- Differential pressure between internal and external areas ;
- Room temperature monitoring;
- Temperature downstream of the electric heaters;
- System exhaust volume measurement;
- Position of isolated dampers;
- Position of the volume control dampers;
- Position of fire dampers;
- Status of fans;
- Status of electric heaters.

2) Maintenances

During normal operating conditions, the DWL [SBCAVS] should provide suitable environmental conditions for the controlled area of the safeguard building. Maintenance of the components could be done during shutdown of the plant.

The maintenance of iodine adsorption trains is performed during plant shutdown when there is no fuel handling operations.

3) Periodic Tests

FC1, FC2 and FC3 equipment should be tested if they are not in continuous operation. Some equipment performing safety function shall be subject to periodic testing, mainly including:

- Efficiency of HEPA filters;
- Efficiency of iodine adsorbers;
- Operation of the extraction fans and heaters;
- Operability of the motorised isolation dampers;
- Operability of local cooling units.

g) Decommissioning

Decommissioning considerations about the DWL [SBCAVS] are still being

undertaken at this stage.

h) Material Selection

Ducts of the DWL [SBCAVS] usually use galvanised steel plate.

In the areas which require equipment to be air tight, the air tight duct is used.

The duct is made of carbon steel or stainless steel with a painted surface.

In the fire resistant duct area, the duct fireproof package is required.

10.6.9.6 Simplified Diagrams

The simplified system functional diagram is presented in Figure F-10.6-7; the detailed system functional diagrams are presented in Reference [94].

10.6.10 Electrical Division of Safeguard Building Ventilation System (DVL [EDSBVS])

The DVL [EDSBVS] provides ventilation for uncontrolled areas of the safeguard building.

10.6.10.1 Safety Functional Requirements

10.6.10.1.1 Control of Reactivity

The DVL [EDSBVS] does not contribute to this safety function.

10.6.10.1.2 Removal of Heat

The DVL [EDSBVS] does not contribute to this safety function.

10.6.10.1.3 Confinement

The DVL [EDSBVS] does not contribute to this safety function.

10.6.10.1.4 Extra Safety Functions

With respect to its contribution to the extra functions, the DVL [EDSBVS] system must satisfy the following requirements:

a) Supporting The Fundamental safety Functions

The DVL [EDSBVS] provides the acceptable ambient conditions for safety classified equipment in uncontrolled areas of the safeguard building during plant normal conditions and plant accident conditions.

b) Prevent, Protect and Mitigate Hazards Impact

1) Fire

The DVL [EDSBVS] must prevent fire from affecting the operation of safety-related equipment and safety of staff in the Safeguard Buildings

(BSX).

The DVL [EDSBVS] must maintain the acceptable environment of the Remote Shutdown Station (RSS) in the event of fire in the MCR.

2) External Explosion

The DVL [EDSBVS] must prevent external explosions from affecting the operation of safety-related equipment located in the BSX.

3) Internal Explosion

The DVL [EDSBVS] must ensure the concentration of hydrogen in the battery rooms is below the explosive limit.

10.6.10.2 Design Requirements

The general design requirements of the HVAC systems which need to be considered are shown in Sub-chapter 10.2.4, among which the following requirements are not applicable for the DVL [EDSBVS]:

a) Autonomy in Respect of the Heat Sink

Not applicable, because the DVL [EDSBVS] doesn't provide a heat sink to the power plant.

b) Autonomy in Respect of Power Supply Systems

Not applicable, because the DVL [EDSBVS] doesn't provide a power supply to the power plant.

c) Prevention of Harmful Interactions of Systems Important to Safety

Not applicable, because the DVL [EDSBVS] doesn't have harmful interactions of systems important to safety.

The substantiation analysis of the DVL [EDSBVS] to other design requirements is shown in the Sub-chapter 10.6.10.5.2.

10.6.10.3 Design Bases

10.6.10.3.1 General Assumptions

a) For each safeguard building division, there is a 100% normal operation train and a 100% maintenance train.

b) Exhaust air from I&C and switchgear cabinet rooms is recirculated, but exhaust air from the mechanical areas is directly discharged outside.

c) There is a 100% local cooling unit serving each RRI [CCWS] pump, and it also serves the ASG [EFS] Pump.

10.6.10.3.2 Design Assumptions

a) Control of Reactivity

Not applicable. The DVL [EDSBVS] does not directly contribute to the safety function of control of reactivity.

b) Removal of Heat

Not applicable. The DVL [EDSBVS] does not directly contribute to the safety function of removal of heat.

c) Confinement

Not applicable. The DVL [EDSBVS] does not directly contribute to the safety function of confinement.

d) Extra Safety Functions

1) Supporting The Fundamental safety Functions

- The external conditions to be taken into account for the DVL [EDSBVS] are defined in Table T-10.6-40.
- The internal conditions to be taken into account for the DVL [EDSBVS] are defined in Tables T-10.6-42 and T-10.6-43.
- The temperature of the supply air is 18°C.
- The capacity of the ventilation system considers the maximum heat dissipation of the equipment and pipes under plant normal operation and plant accident conditions.
- The capacity of the local cooling units is considered for plant normal operation and plant accident conditions, when the normal ventilation is lost and with regards to the maximum heat dissipation of the equipment and pipes.
- Requirements for the minimum air renewal rate are detailed in Table T-10.6-44.

2) Prevent, Protect and Mitigate Hazards Impact

- Fire

  Not applicable. There’s no quantitative safety-related design assumption for the DVL [EDSBVS].

- External Explosion

  The parameters of external explosions are given in Chapter 18 (External Hazards).

- Internal Explosion

  The DVL [EDSBVS] must ensure the minimum air renewal rate and continual ventilation in the battery rooms.

10.6.10.4 System Description and Operation

10.6.10.4.1 System Description

a) General System Description

The DVL [EDSBVS] consists of three independence ventilation divisions. Each ventilation division contains one normal operation train and one maintenance train. Both of them have the ability to manage air through filtering, heating and cooling (normal operation train is cooled by the DEL [SCWS], maintenance train is cooled by the DER [OCWS]) individually.

The local cooling units are installed in the mechanical area of each safeguard building division to provide cooling for the RRI [CCWS] and ASG [EFS] rooms.

The RSS is physically located in safeguard building division C, and is ventilated by DVL [EDSBVS] division C normally. DVL [EDSBVS] division A is used in the event of a fire in safeguard building division C or unavailability of DVL [EDSBVS] Division C.

Each air conditioning division of the DVL [EDSBVS] includes the following equipment:

1) A single fresh air intake equipped with explosion pressure wave dampers;
2) Supply air treatment train -100% (the filter, electric heater, cooling coil, humidifier and fan are included);
3) Exhaust air treatment train -100% (one recirculation fan);
4) Special Exhaust air treatment train -100% (one exhaust fan);
5) An exhaust outlet equipped with explosion pressure wave dampers;
6) Dampers, duct network and a set of accessory.

Detailed information of the systems is presented in the SDM, Reference [95].

b) Description of Main Equipment

1) Fans

Fans are centrifugal and direct-coupled drive type.

2) Cooling Coils

The coils are designed to cool the air and they are made of copper tubes with

several passes depending on the thermal characteristics, with copper or aluminium fins. The frames are made of galvanised steel or stainless steel.

3) Electrical Heaters

The electric heaters are designed to maintain the air temperature by heating the air and are comprised of reinforced tubular elements placed in a sheet metal box.

4) Pre-filters

The pre-filters are designed to filter dust in the air and their efficiency is more than 85% (weighting method).

5) Fine Filters

The fine filters are designed to filter dust in the air and their efficiency is more than 90% (counting method).

6) Local Cooling Units

The local cooling units are designed to provide cooling to the air. A local cooling unit consists of a fan and a cooling coil supplied with chilled water.

7) Humidifiers

The humidifiers are designed to ensure the necessary relative humidity conditions. They are independent units that inject steam at the required rate directly into the duct.

8) Isolation Dampers

The isolation dampers are designed to ensure the isolation of air entry and exhaust in the BSX.

Detailed information of the equipment design is presented in the SDM, Reference [95] and [96].

c) Description of Main Layout

The main equipment of each DVL [EDSBVS] division is located in the corresponding safeguard building division.

Detailed design information about the system layout is presented in the SDM, Reference [97].

d) Description of System Interfaces

The DVL [EDSBVS] system is connected to the following mechanical systems (not including power supplies and I&C systems):

1) DEL [SCWS]

This system provides chilled water to the safety classified DVL [EDSBVS] cooling coils of the normal operation trains.

2) DER [OCWS]

This system provides chilled water to the non-safety classified DVL [EDSBVS] cooling coils of the maintenance train.

3) JDT [FAS]

This system provides fire signals to control the fire dampers of the DVL [EDSBVS].

4) Station Sewer System (SEO [SSS])

This system collects drainage water from the DVL [EDSBVS] main cooling coils located in the normal operation train and maintenance train.

5) RPE [VDS]

This system collects drainage water from the DVL [EDSBVS] local cooling units.

Detailed information of the interface systems is presented in the SDM, Reference [95].

e) Description of Instrumentation and Control

Instruments, controlling and monitoring the DVL [EDSBVS] and displaying of the actuator are provided in the Main Control Room.

Detailed information of the system I&C design is presented in the SDM, Reference [98].

10.6.10.4.2 System Operation

a) Plant Normal Conditions

The DVL [EDSBVS] operates in recycling mode with fresh makeup air, and all of the three normal operation divisions are in operation during plant normal operation train use.

If the normal operational train is unavailable, the maintenance train will be activated.

b) Plant Accident Conditions

Normal operation trains of the DVL [EDSBVS] remain in operation in the event of a LOOP.

Normal operation trains of the DVL [EDSBVS] train A and B remain in operation in the event of a SBO.

Normal operation trains of the DVL [EDSBVS] train A and B will remain in operation in the event of the LUHS.

10.6.10.5 Preliminary Design Substantiation

In this sub-chapter, the system design is demonstrated to satisfy the safety functional requirements presented in Sub-chapter 10.6.10.1 and the general design requirements stated in Sub-chapter 10.2.4.

Since the general principles are newly developed at this stage, the system design is still based on the reference design. A review of the consistency of the system design against the newly developed principles is currently being undertaken. Detailed design of the system is presented in the SDM, Reference [95] and [97].

10.6.10.5.1 Compliance with Safety Functional Requirements

a) Control of Reactivity

Not applicable.

b) Removal of Heat

Not applicable.

c) Confinement

Not applicable.

d) Extra Safety Functions

1) Supporting The Fundamental safety Functions

The DVL [EDSBVS] components are sized to meet the environmental requirements of equipment in the BSX under all summer and winter conditions as defined in Table T-10.6-40.

2) Prevent, Protect and Mitigate Hazards Impact

- Fire

Fire dampers will be closed to ensure the containment of fire and to maintain the fire compartment integrity by the JDT [FAS] signal or fuse.

The ventilation of the RSS will be switched to DVL [EDSBVS] train C.

- External Explosion

EPW dampers are installed at the intake of the DVL [EDSBVS] to prevent external explosions from affecting the system function.

- Internal Explosion

The DVL [EDSBVS] fans are sized to meet the minimum air renewal

rate requirements and a backup fan will be started if the main fan is lost.

Detailed design information is presented in Reference [99].

10.6.10.5.2 Compliance with Design Requirements

a) Safety Classification

The DVL [EDSBVS] design is compliant with the principles described in Chapter 4. The safety classification of DVL [EDSBVS] functions and the safety classification of main components are as follows:

T-10.6-16 Function Categorisation of the DVL [EDSBVS]

System Function	Function Category
Normal operation train of filtering, air conditioning and ventilation	FC1
Maintenance train of filtering, air conditioning and ventilation	NC
Heating of communication device room	NC
Ventilation of the RSS	FC3
Local cooling units	FC1

T-10.6-17 Classification of Main Components

Component		Function Class	Design Provision Category	Design Provision Class	Seismic Category
Normal operation train	Fans	F-SC2	NC	NC	SSE1
	Filters	F-SC2	NC	NC	SSE1
	Electric heaters	F-SC2	NC	NC	SSE1
	Cooling coils	F-SC2	NC	NC	SSE1
	Silencers	F-SC2	NC	NC	SSE1
	Dampers	F-SC2	NC	NC	SSE1
Maintenance train	Fans	NC	NC	NC	SSE2
	Filters	NC	NC	NC	SSE2
	Electric heaters	NC	NC	NC	SSE2
	Cooling coils	NC	NC	NC	SSE2
	Silencers	NC	NC	NC	SSE2

Component		Function Class	Design Provision Category	Design Provision Class	Seismic Category
	Dampers	NC	NC	NC	SSE2
Dampers in the RSS		F-SC3	NC	NC	SSE1
Local cooling units for the pump		F-SC1	NC	NC	SSE1
Other local cooling units		F-SC2	NC	NC	SSE1
Heaters of the communication device room		NC	NC	NC	SSE2
Humidifiers		NC	NC	NC	SSE2

b) Engineering Design Requirements

1) Reliability Design of SSCs

- Single Failure Criterion (SFC)

  The DVL [EDSBVS] is designed to ensure the single failure criterion is met. In case of failure of one component, its 3×100 % structure ensures that the other two divisions remain available in the event of failure of one of the trains.

  Two fire dampers arranged in parallel which are set at the safety fire zone boundary.

- Independence

  The DVL [EDSBVS] consists of three separated divisions (one division in each safeguard building division).

- Diversity

  According to the requirements of diversity in Chapter 4, the system functional requirements are currently being analysed. After the analysis is completed, the system design will be reviewed and analysed to identify if any gaps exist and modifications will be made if necessary.

- Fail-safe

  There’s no fail-safe designed equipment in the DVL [EDSBVS].

- Ageing and Degradation

  The plant design life is 60 years. Some components will require replacing at the end of their individual design life. For the fan design, vibration ageing and thermal ageing are taken into consideration. The differential pressure of the fan is monitored and recorded in real time, which is convenient for the operator to judge the performance of the fan.

2) Human Factors

The system design of the DVL [EDSBVS] does not require short term operator intervention, however there are operator actions during plant normal operation, the effect of which needs to be estimated. The fan, filter, coil and heater of each DVL [EDSBVS] train are located in adjacent equipment rooms, where the layout facilitates their maintenances. The DVL [EDSBVS] is controlled and monitored in the main control room. It is designed to be easy to control for the operator.

3) Autonomy

- Autonomy in Respect of Operators

  The design principles relevant to the autonomy in respect of operators are detailed in Reference [1]. The design of the DVL [EDSBVS] fulfils these principles via control functional design, detailed information is presented in the SDM, Reference [98]. The design result is estimated in the safety analysis.

- Autonomy in Respect of the Heat Sink

  The design principles relevant to the autonomy in respect of the heat sink are not applicable for DVL [EDSBVS] design.

- Autonomy in Respect of Power Supply Systems

  The design principles relevant to the autonomy in respect of the power supply are not applicable for DVL [EDSBVS] design.

4) Other Design Requirements

- Prevention of Harmful Interactions of Systems Important to Safety

  Not applicable.

- Considerations Related to the Electrical Power Grid

  The functionality of items important to safety in the DVL [EDSBVS] is not compromised by disturbances in the electrical power grid. Detailed design information of the electrical power grid is presented in Reference [95].

c) Equipment Qualification

All the safety classified components of the DVL [EDSBVS] required to perform safety functions are capable of operating under both normal and accident conditions. As a result, the components can withstand the most adverse environmental conditions expected.

All the seismically classified components of the DVL [EDSBVS] shall be capable of operating during and after the SSE. The components are seismically designed and qualified for the SSE loads.

The documents relevant to the equipment qualification will be delivered before the step 4 of GDA.

d) Protection against Internal and External Hazards

The DVL [EDSBVS] is protected from external and internal hazards; specific protection design is presented in the SDM, Reference [97]. The evaluation of the design is presented in Chapters 18 and 19.

e) Commissioning

Commissioning is going to be carried out for the DVL [EDSBVS] to validate its functionality. Documents related to the commissioning will be delivered before the step 4 of GDA.

f) Examination, Inspection, Maintenance and Testing

1) Examination and Inspection

There is no equipment of the DVL [EDSBVS] requiring in-service inspection.

The combined information of the DVL [EDSBVS] displayed in the Main Control Room (MCR) for the operator includes:

- Temperature of supplied air;
- Temperature in the mechanical and electrical rooms.

2) Maintenances

Maintenance can be done when users served by the corresponding train are in maintenance during the shutdown of plant.

3) Periodic Tests

FC1, FC2 and FC3 equipment should be tested if they are not in continuous operation. Some equipment performing safety functions shall be subject to periodic test, including:

- RSS isolation dampers opening operability;
- Operability of local cooling units;
- Availability test of the main heaters.

g) Decommissioning

Decommissioning considerations about the DVL [EDSBVS] are still being undertaken at this stage.

h) Material Selection

The equipment in contact with outside air is made of stainless steel.

The duct material is galvanised steel.

The fireproof duct is made of a metal duct and a fireproof wrap.

10.6.10.6 Simplified Diagrams

The simplified system diagram is presented in Figure F-10.6-8; the detailed system functional diagrams are presented in Reference [100].

10.6.11 Main Control Room Air Conditioning System (DCL [MCRACS])

The DCL [MCRACS] maintains the environment (including temperature, humidity, concentration of radioactive materials) of the MCR and associated rooms in normal operating condition and accident condition.

10.6.11.1 Safety Functional Requirements

10.6.11.1.1 Control of Reactivity

The DCL [MCRACS] does not contribute to this safety function.

10.6.11.1.2 Removal of Heat

The DCL [MCRACS] does not contribute to this safety function.

10.6.11.1.3 Confinement

The DCL [MCRACS] does not contribute to this safety function.

10.6.11.1.4 Extra Safety Functions

With respect to its contribution to the extra functions, the DCL [MCRACS] must satisfy the following requirements:

a) Supporting the Fundamental safety Functions

During plant normal operation and accidents, the DCL [MCRACS] maintains acceptable temperatures and humidity inside the MCR and associated rooms for proper operation of equipment and the wellbeing of personnel. The DCL [MCRACS] also provides habitability protection for the MCR, technical support centre and associated rooms during events which lead to radiological contamination of the environment.

b) Prevent, Protect and Mitigate Hazards Impact

1) Fire

The DCL [MCRACS] must prevent fire from affecting the operation of safety-related equipment by maintaining fire compartment integrity.

2) External explosion

The DCL [MCRACS] must prevent external explosions from affecting the classified equipment.

10.6.11.2 Design Requirements

The general design requirements of the HVAC systems which need to be considered are shown in Sub-chapter 10.2.4, among which the following requirements are not applicable for the DCL [MCRACS]:

a) Autonomy in Respect of the Heat Sink

Not applicable, because the DCL [MCRACS] doesn't provide a heat sink to the power plant.

b) Autonomy in Respect of Power Supply Systems

Not applicable, because the DCL [MCRACS] doesn't provide a power supply to the power plant.

c) Prevention of Harmful Interactions of Systems Important to Safety

Not applicable, because the DCL [MCRACS] doesn't have harmful interactions of systems important to safety.

The substantiation analysis of the DCL [MCRACS] to other design requirements is shown in the Sub-chapter 10.6.11.5.2.

10.6.11.3 Design Bases

10.6.11.3.1 General Assumptions

The DCL [MCRACS] system has 3×100% air conditioning trains with the mix of fresh and return air and 2×100% iodine filtration trains with return filtering. When the minimum temperature of some rooms cannot be maintained, the air duct heater is designed

10.6.11.3.2 Design Assumptions

a) Control of Reactivity

Not applicable. The DCL [MCRACS] does not contribute to the safety function of control of reactivity.

b) Removal of Heat

Not applicable. The DCL [MCRACS] does not contribute to the safety function of removal of heat.

c) Confinement

Not applicable. The DCL [MCRACS] does not contribute to the safety function of confinement.

d) Extra Safety Functions

1) Supporting the Fundamental safety Functions

- The internal conditions to be taken into account for the DCL [MCRACS] are defined in Tables T-10.6-42 and T-10.6-43.
- The external conditions to be taken into account for the DCL [MCRACS] are defined in Table T-10.6-40.
- The temperature of the supply air is 17°C.
- The capacity of the DCL [MCRACS] considers the fresh air load and the maximum heat load of the equipment and lighting.
- During radioactive contamination accidents at the plant, maintain a positive pressure of 30Pa in the MCR habitable area.

2) Prevent, Protect and Mitigate Hazards Impact

- Fire

  Not applicable. There's no quantitative safety-related design assumption for the DCL [MCRACS].

- External explosion

  The parameters of external explosion which must be taken into consideration are given in Chapter 18 (External Hazards).

e) Other Assumptions

Not applicable. There's no other quantitative design assumption for the DCL [MCRACS].

10.6.11.4 System Description and Operation

10.6.11.4.1 System Description

a) General System Description

The DCL [MCRACS] consists of three separate air conditioning trains and two separate iodine filtration trains. The kitchen and bathroom have separate exhaust fans. The main components of the system are as follows:

1) Two fresh air inlets equipped with EPW dampers;

2) 3×100% supply air conditioning trains, each train includes a filter, cooling

coil, fan and humidifier;

3) 1×100% exhaust fan;

4) 2×100% iodine filtration two trains, each train includes a pre-filler, pre-HEPA filter, iodine adsorber, post- HEPA filter and fan;

5) Dampers, a duct network and a set of accessories.

Detailed information of the systems is presented in the SDM, Reference [101].

b) Description of Main Equipment

1) Fans

The fans are centrifugal or axial, depending on the system flow rate and head loss. The safety fans are a direct-coupled drive type.

2) Electrical Heaters

The electric heaters heat outside air during periods of cold weather to ensure the DCL [MCRACS] supply air temperature requirements are met. They are also designed to maintain the relative humidity of the iodine adsorber inlet (the supply air temperature) by heating the air and are comprised of reinforced tubular elements placed in a sheet metal box.

3) HEPA Filters

The HEPA filters are designed to filter dust or aerosols in the air. Each HEPA filter cell is individually factory tested to verify an efficiency of at least 99.99%, corresponding to a 10000 filtering factor (sodium flame method).

4) Iodine Adsorbers

The iodine adsorbers are designed to remove radioactive iodine suspended in the air. Each adsorber is assembly with a welded construction and a 102mm deep Type III rechargeable adsorber cell. When new, these filters have a filtering factor of at least 1000 (methyl iodide).

5) Air handling units

The air handling units are designed to manage the air intake, they consist of pre-filters, fine filters, cooling coils, fan and humidifier.

- Pre-filters

  The filters are designed to filter dust in the air and their efficiency is more than 85% (weighting method).

- Fine Filters

  The filters are designed to filter dust in the air and their efficiency is

more than 90% (counting method).

- Cooling Coils

  The cooling coils are designed to cool the air and they are made of copper tubes with several passes depending on the thermal characteristics, with copper or aluminium fins. The frames are made of galvanised steel or stainless steel.

- Humidifier

  The humidifier is designed to ensure the necessary relative humidity conditions are met. They are independent units that inject steam at the required rate directly into the air handling units.

Detailed information of the equipment design is presented in the SDM, Reference [101] and [102].

c) Description of Main Layout

The equipment and duct of the DCL [MCRACS] are located in safeguard building train C.

Detailed design information about the system layout is presented in the SDM, Reference [103].

d) Description of System Interface

The DCL [MCRACS] system is connected to the following mechanical systems (not including power supplies and I&C systems):

1) DEL [SCWS]

   This system provides chilled water to the cooling coils of the DCL [MCRACS].

2) Radiation Monitoring System (KRT [PRMS])

   This system detects site contamination and develops a switch signal for the DCL [MCRACS].

3) Fire Alarm System (JDT [FAS])

   This system provides the fire signal to the fire dampers of the DCL [MCRACS].

4) Domestic Water Distribution System (SEP [PWS])

   This system provides water to the DCL [MCRACS] humidifiers.

5) Nuclear Island Fire-fighting water distribution system (JPI [NIFPS])

This system provides water to the charcoal filter in case of a fire.

Detailed information of the interface systems is presented in the SDM, Reference [101].

e) Description of Instrumentation and Control

Parameters, controlling and monitoring of the DCL [MCRACS] and displaying of the actuator are provided in the Main Control Room.

Detailed information of the system I&C design is presented in the SDM, Reference [104].

10.6.11.4.2 System Operation

a) Plant Normal Conditions

One of the three air conditioning trains operates continuously during plant normal conditions and the DCL [MCRACS] operates in recycling mode with fresh air makeup.

b) Plant Accident Conditions

Under plant accident conditions, one of the three air conditioning trains operating continuously can meet the cooling requirements.

In case of LOOP, each train is powered by a corresponding emergency diesel generator. As such, one of the three trains will remain operable during any LOOP event which is sufficient to maintain continuous operation of the components served by the DCL [MCRACS].

In case of a SBO, the equipment of trains A and train B are powered by the SBO diesel generators. Train C will not be able to operate.

In case of Loss of Ultimate Heat Sink (LUHS), trains A or train B can remain operational. Train C will not remain operational.

In case of a radiological site contamination event, train A with the iodine absorption line or the train B with the iodine absorption line will remain operational.

Detailed information of the system operation is presented in the SDM, Reference [104].

10.6.11.5 Preliminary Design Substantiation

In this sub-chapter, the system design is demonstrated to satisfy the safety functional requirements presented in Sub-chapter 10.6.11.1 and the general Design requirements stated in Sub-chapter 10.2.4.

Since the general principles are newly developed at this stage, the system design is

still based on the reference design. A review of the consistency of the system design against the newly developed principles is currently being undertaken. Detailed design of the system is presented in the SDM, Reference [101] and [103].

10.6.11.5.1 Compliance with Safety Functional Requirements

a) Control of Reactivity

Not applicable.

b) Removal of Heat

Not applicable.

c) Confinement

Not applicable.

d) Extra Safety Functions

1) Supporting the Fundamental Safety Functions

Components of the DCL [MCRACS] will be sized to meet the cooling requirements in the MCR area under normal or accident conditions.

Under the accident conditions, the pressure of the main control room can be maintained at 30Pa through the sufficient air supply.

2) Prevent, Protect and Mitigate Hazards Impact

- Fire

  In the event of fire, the fire dampers are closed to maintain the fire compartment integrity.

- External explosion

  EPW dampers which are installed in the intake of the DCL [MCRACS] will close to prevent the external explosion affecting internal systems.

Detailed design information is presented in Reference [105].

10.6.11.5.2 Compliance with Design Requirements

a) Safety Classification

The DCL [MCRACS] design is compliant with the principles described in Chapter 4. The safety classification of DCL [MCRACS] functions and the safety classification of main components are as follows:

T-10.6-18 Function Categorisation of the DCL [MCRACS]

System Function	Function Category
Air conditioning and heating of the Main Control Room area	FC1
Iodine filtration	FC2
Electrical heaters in rooms	NC
Exhaust air line	NC
Fire protection	FC3

T-10.6-19 Classification of Main Components

Component	Function Class	Design Provision Category	Design Provision Class	Seismic Category
Components of the air condition train except for the humidifier	F-SC2	NC	NC	SSE1
Humidifier	NC	NC	NC	SSE2
Fresh air isolation	F-SC2	NC	NC	SSE1
Electrical heaters in rooms	NC	NC	NC	SSE2
Exhaust fan	NC	NC	NC	SSE2
Components of the iodine filtration train	F-SC2	NC	NC	SSE1

b) Engineering Design Requirements

1) Reliability Design of SSCs

- Single Failure Criterion (SFC)

  The DCL [MCRACS] performs FC1/FC2 safety functions. The DCL [MCRACS] must be designed to consider credible single failures. 3×100% independent air conditioning trains and 2×100% iodine filtration trains are provided to meet the single failure criteria.

- Independence

  The DCL [MCRACS] consists of three separated air conditioning trains

and two separated iodine filtration trains.

- Diversity

  According to the requirements of diversity in Chapter 4, the system functional requirements are currently being analysed. After the analysis is completed, the system design will be reviewed and analysed to identify if any gaps exist and modifications will be made if necessary.

- Fail-safe

  There's no fail-safe designed equipment in the DCL [MCRACS].

- Ageing and Degradation

  The plant design life is 60 years. Some components will require replacing at the end of their individual design life.

2) Human Factors

The system design of the DCL [MCRACS] does not require short term operator intervention, however there are operator actions during plant normal operation, the effect of which needs to be estimated. The equipment of each DCL [MCRACS] train is located in the same room, where the layout facilitates their maintenance. The DCL [MCRACS] is controlled and monitored in the main control room. It is designed to be convenient for the operator to control.

3) Autonomy

- Autonomy in Respect of Operators

  The design principles relevant to the autonomy in respect of operators are detailed in Reference [1]. The design of the DCL [MCRACS] fulfils these principles via control functional design, detailed information is presented in the SDM, Reference [104]. The design result is estimated in the safety analysis.

- Autonomy in Respect of the Heat Sink

  The design principles relevant to the autonomy in respect of the heat sink are not applicable for DCL [MCRACS] design.

- Autonomy in Respect of Power Supply Systems

  The design principles relevant to the autonomy in respect of the power supply are not applicable for DCL [MCRACS] design.

4) Other Design Requirements

- Prevention of Harmful Interactions of Systems Important to Safety

Not applicable.

- Considerations Related to the Electrical Power Grid

  The functionality of items important to safety in the DCL [MCRACS] is not compromised by disturbances in the electrical power grid. Detailed design information of the electrical power grid is presented in Reference [101].

c) Equipment Qualification

All the components of the DCL [MCRACS] required to perform safety functions are capable of operating under both normal and accident conditions. As a result, the components can withstand the most adverse environmental conditions expected.

All the seismically classified components of the DCL [MCRACS] shall be capable of operating during and after the SSE. The components are seismically designed and qualified for the SSE loads.

The documents relevant to the equipment qualification will be delivered before the step 4 of GDA.

d) Protection Design against Internal and External Hazards

The DCL [MCRACS]] is protected from external and internal hazards; the specific protection design is presented in the SDM, Reference [103]. The evaluation of the design is presented in Chapters 18 and 19.

e) Commissioning

Commissioning is going to be carried out for the DCL [MCRACS] to validate its functionality. Documents related to the commissioning will be delivered before the step 4 of GDA.

f) Examination, Inspection, Maintenance and Testing

1) Examination and Inspection

There is no equipment of the DCL [MCRACS] requiring in-service inspection.

The combined information of the DCL [MCRACS] displayed in the Main Control Room (MCR) for the operator includes:

- Temperature of supply air;
- Temperature of room;
- Relative humidity of room;

- Temperature downstream of heaters;
- Differential pressure of filters;
- Differential pressure of fans.

2) Maintenance

The maintenance of the DCL [MCRACS] can be performed during the plant shutdown.

3) Periodic Tests

FC1, FC2 and FC3 equipment should be tested if they are not in continuous operation. Some equipment performing safety functions shall be subject to periodic testing, mainly including the efficiency of the HEPA filters, the efficiency of iodine adsorbers and the pressure of the MCR.

g) Decommissioning

Decommissioning considerations about the DCL [MCRACS] are still being undertaken at this stage.

h) Material Selection

The duct material is galvanised steel sheets.

For the air tight duct, the material is painted carbon steel or stainless steel.

The fireproof duct is made of a metal duct and a fireproof wrap.

10.6.11.6 Simplified Diagrams

The simplified system diagram is presented in Figure F-10.6-9; the detailed system functional diagrams are presented in Reference [106].

10.6.12 Access Building Ventilation Systems (DVW [ABUAVS]-DWW [ABCAVS])

There are two systems (including the DVW [ABUAVS] which serves the access building uncontrolled area and the DWW [ABCAVS] which serves the access building controlled area) in the access building. The two systems operate in fresh air mode to carry out air supply and exhaust of all rooms in the access building. Only the Access Building Controlled Area Ventilation System (DWW [ABCAVS]) is described in this sub-chapter.

10.6.12.1 Safety Functional Requirements

10.6.12.1.1 Control of Reactivity

The DWW [ABCAVS] does not contribute to this safety function.

10.6.12.1.2 Removal of Heat

The DWW [ABCAVS] does not contribute to this safety function.

10.6.12.1.3 Confinement

With respect to its contribution to confinement, the DWW [ABCAVS] must satisfy the following requirement:

a) Environmental Protection:

1) Contain radioactive material and prevent the risk of leaks;

2) Limit radioactive discharges into the environment through treatment and control of the waste transported.

10.6.12.1.4 Extra Safety Functions

With respect to its contribution to the extra safety functions, the DWW [ABCAVS] system must satisfy the following requirements:

a) Supporting the Fundamental Safety Functions

The DWW [ABCAVS] provides the environmental conditions required of the safety classified equipment under normal operating conditions in the access building.

b) Prevent, Protect and Mitigate Hazards Impact

Fire: Control and limit the spread of fire in the access building.

10.6.12.2 Design Requirements

The general design requirements of the HVAC systems which need to be considered are shown in Sub-chapter 10.2.4, among which the following requirements are not applicable for the DWW [ABCAVS]:

a) Autonomy in Respect of Operators

Not applicable, because the DWW [ABCAVS] doesn’t contribute to the autonomy objective.

b) Autonomy in Respect of the Heat Sink

Not applicable, because the DWW [ABCAVS] doesn’t provide a heat sink to the power plant.

c) Autonomy in Respect of Power Supply Systems

Not applicable, because the DWW [ABCAVS] doesn’t provide a power supply to the power plant.

d) Prevention of Harmful Interactions of Systems Important to Safety

Not applicable, because the DWW [ABCAVS] doesn't have harmful interactions of systems important to safety.

The substantiation analysis of the DWW [ABCAVS] to other design requirements is shown in the Sub-chapter 10.6.12.5.2.

10.6.12.3 Design Bases

10.6.12.3.1 General Assumptions

The external conditions to be taken into account for the DWW [ABCAVS] are defined in Table T-10.6-41. The DWW [ABCAVS] air supply is provided by the DVW [ABUAVS. It consists of three filtration trains, each sized for 50% of the flow rate and two fan trains, each sized for 100% of the flow rate will be used for the DWW [ABCAVS].

10.6.12.3.2 Design Assumptions

a) Control of Reactivity

Not applicable.

b) Removal of Heat

Not applicable. The DWW [ABCAVS] system does not contribute to the safety function of removal of heat.

c) Confinement

1) Environmental Protection:

In the exhaust filter trains, one manual airtight isolation damper is set upstream of the pre-filter and one manual airtight isolation damper is set downstream of the HEPA filter. The ducts downstream of the pre-filter have a requirement to be airtight. The specific airtight requirements are listed in Table T-10.6-37.

The DWW [ABCAVS] has a pre-filter and HEPA filter to keep the air clean in plant normal conditions. The efficiency of the filters is listed in Table T-10.6-38.

d) Extra Safety Functions

Not applicable. There's no quantitative safety-related design assumption for the DWW [ABCAVS].

e) Other Assumptions

1) Minimum Rate of Ventilation

The minimum rate of ventilation of the access building controlled area is listed in Table T-10.6-44.

2) Plant External Environmental Conditions

The specific external environmental conditions are listed in Table T-10.6-41.

3) Required Indoor Conditions

The specific indoor conditions are listed in Table T-10.6-42.

10.6.12.4 System Description and Operation

10.6.12.4.1 System Description

a) General System Description

Main components of the DWW [ABCAVS] are described as follows:

1) Air supply and exhaust duct network;

2) Three filtration trains, each sized for 50% of the flow rate;

3) Two fan trains, each sized for 100% of the flow rate.

The three exhaust filter trains are made up of:

1) Two manual airtight isolation dampers for each train;

2) One pre-filter for each train;

3) One HEPA filter for each train;

4) One manual balance damper for each train.

The two fan trains consist of:

1) Two manual isolation dampers for each train;

2) One centrifugal fan for each train;

3) One non return damper for each train.

Detailed information of the systems is presented in the SDM, Reference [107].

b) Description of Main Equipment

1) Exhaust fans

The exhaust fans of the controlled area are of a centrifugal design. They can transfer the exhaust air to the outlet via the stack.

2) Pre-filters

The pre-filters are located upstream of the HEPA-filters in order to increase the service life of the HEPA-filters. They are installed in leak tight casings.

They are equipped with local differential pressure gauges which indicate the degree of load. They are made of cells with standard dimensions. The filter is

made of glass fibre, and the efficiency of the pre-filter is more than 85% (weighting method).

3) HEPA Filters

They are installed in leak tight casings. The HEPA filters are equipped with local differential pressure measurement instruments which indicate the degree of load. They are made of cells with standard dimensions. Each HEPA filter cell is individually shop tested to verify an efficiency of at least 99.99%, corresponding to a 10000 filtering factor (sodium flame method).

Detailed information of the equipment design is presented in the SDM, Reference [107] and [108].

c) Description of Main Layout

The DWW [ABCAVS] is located in the controlled area of the access building. Filters and fans are located in the air exhaust room controlled area.

Detailed design information about the system layout is presented in the SDM, Reference [109].

d) Description of System Interface

1) JDT [FAS]

The JDT [FAS] provides signals of fire protection to the DWW [ABCAVS]

2) DVW [ABUAVS]

The DVW [ABUAVS] ensures the supply air of controlled area rooms.

3) DFL [SCS]

The DFL [SCS] ensures, in case of fire, that the protected rescue routes or compartments are pressurised and it can also create a sub-pressure in the room with a fire.

Detailed information of the interface systems is presented in the SDM, Reference [107].

e) Description of Instrumentation and Control

The states of the DWW [ABCAVS] equipment are displayed in the Main Control room.

Detailed information of the system I&C design is presented in the SDM, Reference [110].

10.6.12.4.2 System Operation

a) Plant Normal Conditions

The system normally operates during normal operation of the plant.

The DWW [ABCAVS] provides the air supplied from the DVW [ABUAVS] for all rooms in the controlled area. The exhaust air is discharged by the DWW [ABCAVS] through the stack.

b) Plant Accident Conditions

Not applicable.

Detailed information of the system operation is presented in the SDM, Reference [110].

10.6.12.5 Preliminary Design Substantiation

In this sub-chapter, the system design is demonstrated to satisfy the safety functional requirements presented in Sub-chapter 10.6.12.1 and the general design requirements stated in Sub-chapter 10.2.4.

Since the general principles are newly developed at this stage, the system design is still based on the reference design. A review of the consistency of the system design against the newly developed principles is currently being undertaken. Detailed design of the system is presented in the SDM, Reference [107] and [109].

10.6.12.5.1 Compliance with Safety Functional Requirements

a) Control of Reactivity

Not applicable.

b) Removal of Heat

Not applicable.

c) Confinement

1) Environmental Protection

The flow rate of exhaust air is larger than the supply air to keep the air flowing from less polluted areas to more polluted areas. Limited radioactive discharges into the environment are achieved by setting HEPA filters in the exhaust trains of the DWW [ABCAVS].

d) Extra Safety Function

The fire dampers of the DWW [ABCAVS] will close to prevent fire spreading when receiving the relevant signal from the JDT [FAS].

Detailed design information is presented in Reference [111].

10.6.12.5.2 Compliance with Design Requirements

a) Safety Classification

The DWW [ABCAVS] design is compliant with the principles described in Chapter 4. The safety classification of DWW [ABCAVS] functions and the safety classification of main components are as follows:

T-10.6-20 Function Categorisation of the DWW [ABCAVS]

System Function	**Function Category**
Extraction and filtration of the controlled area	FC3
Rest of the system	NC

T-10.6-21 Classification of Main Components

Component	**Function Class**	**Design Provision Category**	**Design Provision Class**	**Seismic Category**
Fans	F-SC3	NC	NC	NO
Filters	F-SC3	NC	NC	NO

b) Engineering Design Requirements

1) Reliability Design of SSCs

- Single Failure Criterion (SFC)

  Not applicable.

- Independence

  Not applicable.

- Diversity

  Not applicable.

- Fail-safe

  There’s no fail-safe designed equipment in the DWW [ABCAVS].

- Aging and Degradation

  The plant design life is 60 years. Some components will require replacing at the end of their individual design life. For example, the design life of border filters is designed to be no less than 60 years. For the filter design, vibration ageing and radiation ageing are taken into consideration.

2) Human Factors

The system design of the DWW [ABCAVS] does not require short term operator intervention, however there are operator actions during plant normal

operation, the effect of which needs to be estimated. The fans and filters are located in the air exhaust room controlled area, where the equipment layout facilitates their maintenance. The DWW [ABCAVS] is controlled and monitored in the main control room. It is designed to be easy for the operator to control.

3) Autonomy

Not applicable.

4) Other Design Requirements

- Prevention of Harmful Interactions of Systems Important to Safety

  Not applicable.

- Considerations Related to the Electrical Power Grid

  The functionality of items important to safety in the DWW [ABCAVS] is not compromised by disturbances in the electrical power grid. Detailed design information of the electrical power grid is presented in Reference [107].

c) Equipment Qualification

All the components of the DWW [ABCAVS] required to perform safety functions are capable of operating under normal conditions. The documents relevant to the equipment qualification will be delivered before the step 4 of GDA.

d) Protection Design against Internal and External Hazards

The DWW [ABCAVS] is protected from external and internal hazards; the specific protection design is presented in the SDM, Reference [109]. The evaluation of the design is presented in Chapters 18 and 19.

e) Commissioning

Commissioning is going to be carried out for the DWW [ABCAVS] to validate its functionality. Documents related to the commissioning will be delivered before the step 4 of GDA.

f) Examination, Inspection, Maintenance and Testing

1) Examination and Inspection

There is no equipment of the DWW [ABCAVS] requiring in-service inspection.

The combined information of the DWW [ABCAVS] displayed in the Main Control Room (MCR) for the operator includes:

- Differential pressure of filters;
- Differential pressure of fans.

2) Maintenance

During the normal operating conditions, the DWW [ABCAVS] should provide ventilation and cooling for the controlled areas of the access building. As there are three filtration trains, each sized for 50% of the flow rate and two fan trains, each sized for 100% of the flow rate in the DWW [ABCAVS], one filtration train and one fan train can be maintained during normal operation of the plant.

3) Periodic Tests

Not applicable.

g) Decommissioning

Decommissioning considerations about the DWW [ABCAVS] are still being undertaken at this stage.

h) Material Selection

Equipment in contact with outside air is protected against corrosion due to the saline atmosphere by a coating of paint.

The entire DWW [ABCAVS] equipment is made of carbon steel.

10.6.12.6 Simplified Diagrams

The simplified system diagram is presented in Figure F-10.6-10; the detailed system functional diagrams are presented in Reference [112].

10.6.13 Diesel Building Ventilation System (DVD [DBVS])

The DVD [DBVS] provides ventilation for the diesel building.

10.6.13.1 Safety Functional Requirements

10.6.13.1.1 Control of Reactivity

The DVD [DBVS] does not contribute to this safety function.

10.6.13.1.2 Removal of Heat

The DVD [DBVS] does not contribute to this safety function.

10.6.13.1.3 Confinement

The DVD [DBVS] does not contribute to the confinement of radioactive substances.

10.6.13.1.4 Extra Safety Functions

With respect to its contribution to the extra functions, the DVD [DBVS] must satisfy the following requirements:

a) Supporting The Fundamental safety Functions

The DVD [DBVS] provide acceptable ambient conditions for safety classified equipment in three trains of emergency diesel generator buildings and two trains of SBO diesel generator buildings (trains A and B) during plant normal conditions and plant accident conditions.

b) Prevent, Protect and Mitigate Hazards Impact

1) Fire

The DVD [DBVS] must prevent fire from affecting the operation of safety-related equipment and safety of staff in the Diesel Generator Buildings (BDX).

2) External Explosion

The DVD [DBVS] must prevent external explosions from affecting the operation of safety-related equipment located in the BDX.

10.6.13.2 Design Requirements

The general design requirements of the HVAC systems which need to be considered are shown in Sub-chapter 10.2.4, among which the following requirements are not applicable for the DVD [DBVS]:

a) Autonomy in Respect of the Heat Sink

Not applicable, because the DVD [DBVS] doesn’t provide a heat sink to the power plant.

b) Autonomy in Respect of Power Supply Systems

Not applicable, because the DVD [DBVS] doesn’t provide a power supply to the power plant.

c) Prevention of Harmful Interactions of Systems Important to Safety

Not applicable, because the DVD [DBVS] doesn’t have harmful interactions of systems important to safety.

The substantiation analysis of the DVD [DBVS] to other design requirements is shown in the Sub-chapter 10.6.13.5.2.

10.6.13.3 Design Bases

10.6.13.3.1 General Assumptions

a) For each diesel building division, a ventilation subsystem and an air conditioning subsystem were designed to cooling the electrical room.

b) The air conditioning train operates during plant normal operation, and the ventilation train operates during LOOP or SBO events.

10.6.13.3.2 Design Assumptions

a) Control of Reactivity

Not applicable. The DVD [DBVS] does not directly contribute to the safety function of control of reactivity.

b) Removal of Heat

Not applicable. The DVD [DBVS] does not directly contribute to the safety function of removal of heat.

c) Confinement

The DVD [DBVS] does not directly contribute to the safety function of confinement.

d) Extra Safety Functions

1) Supporting The Fundamental safety Functions

The capacity of the ventilation subsystem considers the following assumptions:

- The external conditions to be taken into account for the DVD [DBVS] are defined in Table T-10.6-40.
- The internal conditions to be taken into account for the DVD [DBVS] are defined in Tables T-10.6-42 and T-10.6-43.
- The capacity of the air conditioning train considers the maximum heat dissipation of the equipment and pipes under plant normal operation.
- The capacity of the ventilation train considers the maximum heat dissipation of the equipment and pipes under plant accident conditions.

2) Prevent, Protect and Mitigate Hazards Impact

- Fire

Not applicable. There’s no quantitative safety-related design assumption for the DVD [DBVS].

- External Explosion

  The parameters of external explosions which must be taken into consideration are given in Chapter 18 (External Hazards).

10.6.13.4 System Description and Operation

10.6.13.4.1 System Description

a) General System Description

The DVD [DBVS] provides ventilation for three trains of emergency diesel generator buildings and two trains of SBO diesel generator buildings (trains A and B).

For each diesel generator building, the rooms have their own ventilation system with no connection to the other divisions.

The DVD [DBVS] of each diesel generator building consists of the following independent subsystems:

1) Ventilation of Diesel Hall:

   - Air inlet with Explosion Pressure Wave (EPW) dampers, silencers and filter;
   - 2×50% capacity air supply fans;
   - 2×50% capacity exhaust fans;
   - Exhaust outlet with EPW dampers and silencers.

2) Air conditioning of the electrical rooms:

   - Air inlet;
   - An air handling unit (containing: pre-filter, fine filter, electric heater, cooling coil with an independent heat sink and one air supply fan);
   - Ductwork (supply and recycled air).

3) Ventilation of electrical rooms:

   - Air supply fan with 100% capacity;
   - Exhaust fan with 100% capacity;
   - Air supply ductwork;
   - Exhaust air ductwork;
   - Motorised isolation damper.

4) Ventilation of fuel tank rooms:

- Air inlet (from the diesel hall to the daily fuel tank room and main fuel tank room);
- Exhaust fan with 100% capacity.

Detailed information of the systems is presented in the SDM, Reference [113].

b) Description of Main Equipment

1) Fans

The fans of the ventilation subsystem are axial and the fans in air handling units are centrifugal, all of them are a direct-coupled drive type.

2) Air handling units

The air handling units are designed to manage air, they consist of pre-filters, fine filters, electric heaters, cooling coils and fans.

- Cooling Coils

  The coils are made of copper tubes with several passes depending on the thermal characteristics, with copper or aluminium fins. The frames are made of galvanised steel or stainless steel.

- Electrical Heaters

  The electric heaters are designed to maintain the air temperature by heating the air and are comprised of reinforced tubular elements placed in a sheet metal box made of galvanised steel.

- Pre-filters

  The pre-filters are designed to filter dust in the air and their efficiency is more than 85% (weighting method).

- Fine Filters

  The fine filters are designed to filter dust and their efficiency is more than 90% (counting method).

3) Isolation Dampers

The isolation dampers are designed to ensure the isolation of air entry and exhaust in the BDX.

Detailed information of the equipment design is presented in the SDM, Reference [113] and [114].

c) Description of Main Layout

The main equipment of each DVD [DBVS] train is located in the corresponding

diesel generator building.

Detailed design information about the system layout is presented in the SDM, Reference [115].

d) Description of System Interfaces

The DVD [DBVS] is connected to the following mechanical systems (not including power supplies and I&C systems):

1) JDT [FAS]

This system provides signals to the fire dampers of the DVD [DBVS].

2) SEH [WONWDS]

This system collects drainage water from the DVD [DBVS] air handling unit.

Detailed information of the interface systems is presented in the SDM, Reference [113].

e) Description of Instrumentation and Control

Instruments controlling and monitoring the DVD [DBVS] and displaying of the actuator are provided in the MCR.

Detailed information of the system I&C design is presented in the SDM, Reference [116].

10.6.13.4.2 System Operation

a) Plant Normal Conditions

During plant normal operation, the air conditioning of electrical ventilation rooms operates permanently, and the ventilation of the fuel tank rooms operates continuously.

The air conditioning train also serves the diesel hall through the transfer duct.

If the air conditioning of electrical rooms is out of service, the ventilation of electrical rooms will be started.

b) Plant Accident Conditions

1) Loss of Offsite Power (LOOP)

In the event of LOOP, the ventilation of the EDG diesel hall and the ventilation of electrical rooms will be operational.

2) Station Black Out (SBO)

In the event of a SBO, the ventilation of the SBO diesel hall and the ventilation of electrical rooms will be operational.

10.6.13.5 Preliminary Design Substantiation

In this sub-chapter, the system design is demonstrated to satisfy the safety functional requirements presented in Sub-chapter 10.6.13.1 and the general design requirements stated in Sub-chapter 10.2.4.

Since the general principles are newly developed at this stage, the system design is still based on the reference design. A review of the consistency of the system design against the newly developed principles is currently being undertaken. Detailed design of the system is presented in the SDM, Reference [113] and [115].

10.6.13.5.1 Compliance with Safety Functional Requirements

a) Control of Reactivity

Not applicable.

b) Removal of Heat

Not applicable.

c) Confinement

Not applicable.

d) Extra Safety Functions

1) Supporting The Fundamental safety Functions

The DVD [DBVS] components are sized to meet the cooling requirements of equipment in the BDX under all summer and winter conditions as defined in Table T-10.6-40.

2) Prevent, Protect and Mitigate Hazards Impact

- Fire

Fire dampers will close to ensure the containment of fire and to maintain the fire compartment integrity by the JDT [FAS] signal or fuse.

- External Explosion

EPW dampers are installed at the intake of the DVD [DBVS] to prevent external explosions from impacting internal systems.

Detailed design information is presented in Reference [117].

10.6.13.5.2 Compliance with Design Requirements

a) Safety Classification

The DVD [DBVS] design is compliant with the principles described in Chapter 4. The safety classification of DVD [DBVS] functions and the safety classification

of main components are as follows:

T-10.6-22 Function Categorisation of the DVD [DBVS]

System Function		Function Category
Ventilation of the Emergency Diesel Generator room	Ventilation of the Diesel Generator room	FC1
	Ventilation of the Electrical room and control room	FC1
	Air conditioning of the Electrical room and control room	NC
	Ventilation of the auxiliary room	NC
Ventilation of the SBO Diesel Generator room	Ventilation of the Diesel Generator room	FC3
	Ventilation of the Electrical room and control room	FC3
	Air-conditioning of the Electrical room and control room	NC
	Ventilation of the auxiliary room	NC

T-10.6-23 Classification of Main Components

Component		Function Class	Design Provision Category	Design Provision Class	Seismic Category
Ventilation of the Emergency Diesel Generator room	Ventilation equipment of the Diesel Generator room	F-SC1	NC	NC	SSE1
	Ventilation equipment of the Electrical room and control room	F-SC1	NC	NC	SSE1
	Air conditioning	NC	NC	NC	SSE2

Component		Function Class	Design Provision Category	Design Provision Class	Seismic Category
	equipment of the Electrical room and control room				
	Ventilation equipment of the auxiliary room	NC	NC	NC	SSE2
Ventilation of the SBO Diesel Generator room	Ventilation equipment of the Diesel Generator room	F-SC3	NC	NC	SSE1
	Ventilation equipment of the Electrical room and control room	F-SC3	NC	NC	SSE1
	Air conditioning equipment of the Electrical room and control room	NC	NC	NC	SSE2
	Ventilation equipment of the auxiliary room	NC	NC	NC	SSE2

b) Engineering Design Requirements

1) Reliability Design of SSCs

- Single Failure Criterion (SFC)

  The DVD [DBVS] is designed to ensure the single failure criterion is met.

  In case of failure of one component in any ventilation train of the EDG diesel generator building, its 3×100 % structure ensures that the other two trains remain available.

  The single failure criterion is not applied to the ventilation of the SBO diesel generator rooms, as the ventilation system is FC3 safety classified.

- Independence

  The DVD [DBVS] EDG diesel generator building ventilation system consists of three separated trains (one train in each division of the EDG

diesel generator building).

The DVD [DBVS] SBO diesel generator building ventilation system consists of two separated trains (one train in each division of the SBO diesel generator building).

- Diversity

  According to the requirements of diversity in Chapter 4, the system functional requirements are currently being analysed. After the analysis is completed, the system design will be reviewed and analysed to identify if any gaps exist and modifications will be made if necessary.

- Fail-safe

  There's no fail-safe designed equipment in the DVD [DBVS].

- Ageing and Degradation

  The plant design life is 60 years. Some components will require replacing at the end of their individual design life. For the fan design, vibration ageing and thermal ageing are taken into consideration. The differential pressure of the fan is monitored and recorded in real time, which is convenient for the operator to assess the performance of the fan.

2) Human Factors

The system design of the DVD [DBVS] does not require short term operator intervention, however there are operator actions during plant normal operation, the effect of which needs to be estimated. The fan and filter of each DVD [DBVS] train are located in adjacent equipment rooms, where the equipment layout facilitates their maintenance. The DVD [DBVS] is controlled and monitored in the main control room. It is designed to be easy for the operator to control.

3) Autonomy

- Autonomy in Respect of Operators

  The design principles relevant to the autonomy in respect of operators are detailed in Reference [1]. The design of the DVD [DBVS] fulfils these principles via control functional design, the detailed information is presented in SDM, Reference [116]. The design result is estimated in the safety analysis.

- Autonomy in Respect of the Heat Sink

  The design principles relevant to the autonomy in respect of the heat sink are not applicable for DVD [DBVS] design.

- Autonomy in Respect of Power Supply Systems

  The design principles relevant to the autonomy in respect of the power supply are not applicable for DVD [DBVS] design.

4) Other Design Requirements

- Prevention of Harmful Interactions of Systems Important to Safety

  Not applicable.

- Considerations Related to the Electrical Power Grid

  The functionality of items important to safety in the DVD [DBVS] is not compromised by disturbances in the electrical power grid. Detailed design information of the electrical power grid is presented in Reference [113].

c) Equipment Qualification

All the safety classified components of the DVD [DBVS] required to perform safety functions are capable of operating under both normal and accident conditions. As a result, the components can withstand the most adverse environmental conditions expected.

All the seismically classified components of the DVD [DBVS] shall be capable of operating during and after the SSE. The components are seismically designed and qualified for the SSE loads.

The documents relevant to the equipment qualification will be delivered before the step 4 of GDA.

d) Protection Design against Internal and External Hazards

The DVD [DBVS] is protected from external and internal hazards; the specific protection design is presented in the SDM, Reference [115]. The evaluation of the design is presented in Chapters 18 and 19.

e) Commissioning

Commissioning is going to be carried out for the DVD [DBVS] to validate its functionality. Documents related to the commissioning will be delivered before the step 4 of GDA.

f) Examination, Inspection, Maintenance and Testing

1) Examination and Inspection

There is no equipment of the DVD [DBVS] requiring in-service inspection.

The combined information of the DVD [DBVS] displayed in the Main

Control Room (MCR) for the operator includes:

- Temperature in the Diesel generator rooms;
- Air supply temperature of the electrical room air conditioning subsystem;
- Temperature in each of the control and electrical rooms.

2) Maintenances

Maintenance can be done when the corresponding diesel generator is in maintenance during shutdown of plant.

3) Periodic Tests

FC1, FC2 and FC3 equipment should be tested if they are not in continuous operation. Some equipment performing safety functions shall be subject to periodic testing, including:

Availability of the diesel hall fans for the EDG buildings.

g) Decommissioning

Decommissioning considerations about the DVD [DBVS] are still being undertaken at this stage.

h) Material Selection

The duct material is galvanised steel.

10.6.13.6 Simplified Diagrams

The simplified system diagram is presented in Figure F-10.6-11; the detailed system functional diagrams are presented in Reference [118].

10.6.14 Essential Service Water Pumping Station Ventilation System (DXS [ESWVS])

The DXS [ESWVS] provides ventilation for the essential service water pumping station.

10.6.14.1 Safety Functional Requirements

10.6.14.1.1 Control of Reactivity

The DXS [ESWVS] does not contribute to this safety function.

10.6.14.1.2 Removal of Heat

The DXS [ESWVS] does not contribute to this safety function.

10.6.14.1.3 Confinement

The DXS [ESWVS] does not contribute to this safety function.

10.6.14.1.4 Extra Safety Functions

With respect to its contribution to the extra safety functions, the DXS [ESWVS] must satisfy the following requirements:

a) Supporting the Fundamental safety Functions

The DXS [ESWVS] provides the acceptable ambient conditions for safety classified equipment in the essential service water pumping station during plant normal conditions and plant accident conditions.

b) Prevent, Protect and Mitigate Hazards Impact

1) Fire

The DXS [ESWVS] must prevent fire from affecting the operation of safety-related equipment.

2) External Explosion

The DXS [ESWVS] must prevent external explosions from affecting the operation of safety-related equipment located in the essential service water pumping station.

10.6.14.2 Design Requirements

The general design requirements of the HVAC systems which need to be considered are shown in Sub-chapter 10.2.4, among which the following requirements are not applicable for the DXS [ESWVS]:

a) Autonomy in Respect of the Heat Sink

Not applicable, because the DXS [ESWVS] doesn’t provide a heat sink to the power plant.

b) Autonomy in Respect of Power Supply Systems

Not applicable, because the DXS [ESWVS] doesn’t provide a power supply to the power plant.

c) Prevention of Harmful Interactions of Systems Important to Safety

Not applicable, because the DXS [ESWVS] doesn’t have harmful interactions of systems important to safety.

The substantiation analysis of the DXS [ESWVS] to other design requirements is shown in the Sub-chapter 10.6.14.5.2.

10.6.14.3 Design Bases

10.6.14.3.1 General Assumptions

For each essential service water pumping station division, there is a 100% ventilation train.

10.6.14.3.2 Design Assumptions

a) Control of Reactivity

Not applicable. The DXS [ESWVS] does not directly contribute to the safety function of control of reactivity.

b) Removal of Heat

Not applicable. The DXS [ESWVS] does not directly contribute to the safety function of removal of heat.

c) Confinement

Not applicable. The DXS [ESWVS] does not directly contribute to the safety function of confinement.

d) Extra Safety Functions

1) Supporting the Fundamental safety Functions

- The inside conditions to be taken into account for the DXS [ESWVS] are defined in Tables T-10.6-42 and T-10.6-43.
- The outside conditions to be taken into account for the DXS [ESWVS] are defined in Table T-10.6-40.
- The capacity of the DXS [ESWVS] considers the maximum heat load of the equipment and lighting.

2) Prevent, Protect and Mitigate Hazards Impact

- Fire

  Not applicable. There's no quantitative safety-related design assumption for the DXS [ESWVS].

- External explosion

  The parameters of external explosions which must be taken into consideration are given in Chapter 18 (External Hazards).

e) Other Assumptions

Not applicable. There's no quantitative design assumption for the DXS [ESWVS].

10.6.14.4 System Description and Operation

10.6.14.4.1 System Description

The DXS [ESWVS] is made up of three trains. Train A and B are configured with two 100% capacity sub ventilation trains, and train C is configured with a 100% capacity ventilation train.

a) General System Description

Each DXS [ESWVS] sub train consists of the following:

1) Supply air train-100% each (an EPW damper, pre-filter, a fan);

2) Exhaust air train-100% each (an EPW damper, a manual damper);

3) Duct network and a set of accessory.

b) Description of Main Equipment

1) Fans

The fans are axial and a direct-coupled drive type.

2) Pre-filters

The pre-filters are designed to filter dust in the air and their efficiency is more than 85% (weighting method).

c) Description of Main Layout

The main equipment of each DXS [ESWVS] train is located in the corresponding essential service water pumping station.

d) Description of System Interfaces

The DXS [ESWVS] is connected to the following mechanical systems (not including power supplies and I&C systems):

The JDT [FAS] provides signals to the fire dampers of the DXS [ESWVS].

e) Description of Instrumentation and Control

Instruments controlling and monitoring the DXS [ESWVS] and displaying of the actuator are provided in the MCR.

10.6.14.4.2 System Operation

a) Plant Normal Conditions

If the temperature of the SEC [ESWS] Pump station is higher than 30°C, the supply and exhaust fans of the corresponding train shall be started.

b) Plant Accident Conditions

In the LOOP event, the DXS [ESWVS] should operate when the SEC [ESWS] pump is used.

10.6.14.5 Preliminary Design Substantiation

In this sub-chapter, the system design is demonstrated to satisfy the safety functional requirements presented in Sub-chapter 10.6.14.1 and the general design requirements stated in Sub-chapter 10.2.4.

Since the general principles are newly developed at this stage, the system design is still based on the reference design. A review of the consistency of the system design against the newly developed principles is currently being undertaken.

10.6.14.5.1 Compliance with Safety Functional Requirements

a) Control of Reactivity

Not applicable.

b) Removal of Heat

Not applicable.

c) Confinement

Not applicable.

d) Extra Safety Functions

1) Supporting the Fundamental safety Functions

The DXS [ESWVS] components are sized to meet the cooling requirements of equipment in the SEC [ESWS] pump station under all summer and winter conditions as defined in Table T-10.6-40.

2) Prevent, Protect and Mitigate Hazards Impact

- Fire

  Fire dampers are designed on the boundary of the fire compartment, which will be closed by the JDT [FAS] signal or damper fuse in case of a fire.

- External explosion

  The EPW dampers which are installed in the intake of the DXS [ESWVS] will close to prevent external explosions from affecting internal systems.

10.6.14.5.2 Compliance with Design Requirements

a) Safety Classification

The DXS [ESWVS] design is compliant with the principles described in Chapter

4. The safety classification of DXS [ESWVS] functions and the safety classification of main components are as follows:

T-10.6-24 Function Categorisation of the DXS [ESWVS]

System Function	Function Category
Ventilation for the SEC [ESWS] pump rooms	FC1
The others	NC

T-10.6-25 Classification of Main Components

Component	Function Class	Design Provision Category	Design Provision Class	Seismic Category
Ventilation equipment for the SEC [ESWS] pump rooms	F-SC1	NC	NC	SSE1
The other equipment	NC	NC	NC	SSE2/NO

b) Engineering Design Requirements

1) Reliability Design of SSCs

- Single Failure Criterion (SFC)

  The DXS [ESWVS] performs FC1 safety functions. The DXS [ESWVS] must be designed to consider credible single failures. Therefore, 3×100% independent air conditioning trains are provided.

- Independence

  The DXS [ESWVS] system consists of three separate trains.

- Diversity

  According to the requirements of diversity in Chapter 4, the system functional requirements are currently being analysed. After the analysis is completed, the system design will be reviewed and analysed to identify if any gaps exist and modifications will be made if necessary.

- Fail-safe

  There’s no fail-safe designed equipment in the DXS [ESWVS].

- Ageing and Degradation

  The plant design life is 60 years. Some components will require replacing at the end of their individual design life. For the fan design, vibration ageing and thermal ageing are taken into consideration. The differential pressure of the fan is monitored and recorded in real time, which is convenient for the operator to assess of the performance of the fan.

2) Human Factors

The system design of the DXS [ESWVS] does not require short term operator intervention, however there are operator actions during plant normal operation, the effect of which needs to be estimated. The fan and filter of each DXS [ESWVS] train are located in adjacent equipment rooms, where the equipment layout facilitates their maintenance. The DXS [ESWVS] is controlled and monitored in the main control room. It is designed to be easy for the operator to control.

3) Autonomy

- Autonomy in Respect of Operators

  The design principles relevant to the autonomy in respect of operators are detailed in Reference [1]. The design of the DXS [ESWVS] fulfils these principles via control functional design. The design result is estimated in the safety analysis.

- Autonomy in Respect of the Heat Sink

  The design principles relevant to the autonomy in respect of the heat sink are not applicable for DXS [ESWVS] design.

- Autonomy in Respect of Power Supply Systems

  The design principles relevant to the autonomy in respect of the power supply are not applicable for DXS [ESWVS] design.

4) Other Design Requirements

- Prevention of Harmful Interactions of Systems Important to Safety

  Not applicable.

- Considerations Related to the Electrical Power Grid

  The functionality of items important to safety in the DXS [ESWVS] is not compromised by disturbances in the electrical power grid.

c) Equipment Qualification

All the components of the DXS [ESWVS] required to perform safety functions are capable of operating under both normal and accident conditions. As a result, the components can withstand the most adverse environmental conditions expected.

All the seismically classified components of the DXS [ESWVS] shall be capable of operating during and after the SSE. The components are seismically designed and qualified for the SSE loads.

d) Protection Design against Internal and External Hazards

The DXS [ESWVS] is protected from external and internal hazards. The evaluation of the design is presented in Chapters 18 and 19.

e) Commissioning

Commissioning is going to be carried out for the DXS [ESWVS] to validate its functionality.

f) Examination, Inspection, Maintenance and Testing

1) Examination and Inspection

There is no equipment of the DXS [ESWVS] requiring in-service inspection.

The information of the DXS [ESWVS] displayed in the Main Control Room (MCR) for the operator consists of the temperature in the rooms.

2) Maintenances

Maintenance can be done when the corresponding diesel generator is in maintenance during shutdown of plant.

3) Periodic Tests

Because of continuous operation, there is no requirement of periodic testing for equipment of the DXS [ESWVS].

g) Decommissioning

Decommissioning considerations about the DXS [ESWVS] are still being undertaken at this stage.

h) Material Selection

The duct material is galvanised steel.

10.6.14.6 Simplified Diagrams

The simplified system diagram is presented in Figure F-10.6-12.

10.6.15 Extra Cooling Water and NI Firefighting Building Ventilation System

(DXE [ECW&FFB VS])

The DXE [ECW&FFB VS] provides ventilation for extra cooling water and the NI firefighting building.

10.6.15.1 Safety Functional Requirements

10.6.15.1.1 Control of Reactivity

The DXE [ECW&FFB VS] does not contribute to this safety function.

10.6.15.1.2 Removal of Heat

The DXE [ECW&FFB VS] does not contribute to this safety function.

10.6.15.1.3 Confinement

The DXE [ECW&FFB VS] does not contribute to this safety function.

10.6.15.1.4 Extra Safety Functions

With respect to its contribution to the extra safety functions, the DXE [ECW&FFB VS] must satisfy the following requirements:

a) Supporting The Fundamental safety Functions

The DXE [ECW&FFB VS] provide the acceptable ambient conditions for safety classified equipment in the extra cooling water and NI firefighting building during plant normal conditions and plant accident conditions.

b) Prevent, Protect and Mitigate Hazard Impact

Not applicable.

10.6.15.2 Design Requirements

The general design requirements of the HVAC systems which need to be considered are shown in Sub-chapter 10.2.4, among which the following requirements are not applicable for the DXE [ECW&FFB VS]:

a) Autonomy in Respect of Operators

Not applicable, because the DXE [ECW&FFB VS] doesn’t contribute to the autonomy objective.

b) Autonomy in Respect of the Heat Sink

Not applicable, because the DXE [ECW&FFB VS] doesn’t provide a heat sink to the power plant.

c) Autonomy in Respect of Power Supply Systems

Not applicable, because the DXE [ECW&FFB VS] doesn’t provide a power

supply to the power plant.

d) Prevention of Harmful Interactions of Systems Important to Safety

Not applicable, because the DXE [ECW&FFB VS] doesn't have harmful interactions of systems important to safety.

The substantiation analysis of the DXE [ECW&FFB VS] to other design requirements is shown in the Sub-chapter 10.6.15.5.2.

10.6.15.3 Design Bases

10.6.15.3.1 General Assumptions

For each diesel building division, there is a 100% ventilation train.

10.6.15.3.2 Design Assumptions

a) Control of Reactivity

Not applicable. The DXE [ECW&FFB VS] does not directly contribute to the safety function of control of reactivity.

b) Removal of Heat

Not applicable. The DXE [ECW&FFB VS] does not directly contribute to the safety function of removal of heat.

c) Confinement

Not applicable. The DXE [ECW&FFB VS] does not directly contribute to the safety function of confinement.

d) Extra Safety Functions

1) Supporting The Fundamental safety Functions

- The internal conditions to be taken into account for the DXE [ECW&FFB VS] are defined in Tables T-10.6-42 and T-10.6-43.
- The external conditions to be taken into account for the DXE [ECW&FFB VS] are defined in Table T-10.6-40.
- The capacity of the DXE [ECW&FFB VS] considers the maximum heat dissipation of the equipment and pipes under plant normal operation and accident conditions.

2) Prevent, Protect and Mitigate Hazards Impact

Not applicable.

10.6.15.4 System Description and Operation

10.6.15.4.1 System Description

a) General System Description

The DXE [ECW&FFB VS] is made up of three trains. Train A and B provide services for the corresponding ECS [ECS] /JAC [FWPS] and train C provides services for JAC [FWPS] train C. Train A and B are configured with two 50% capacity fans and two 50% capacity exhaust fans, and train C is configured with a 100% capacity fan and a 100% capacity exhaust fan.

The DXE [ECW&FFB VS] consists of the following:

1) Air supply and exhaust duct network;
2) Two air supply trains - 50% each (train A and B) (including one pre-filter and fan);
3) One air supply train - 100% (train C) (including one pre-filter and fan); Two exhaust air trains - 50% each;
4) One exhaust air train - 100% (train C);
5) Dampers and a set of accessories.

b) Description of Main Equipment

1) Fans

The fans are axial and a direct-coupled drive type.

2) Pre-filters

The pre-filters are designed to filter dust in the air and their efficiency is more than 85% (weighting method).

c) Description of Main Layout

The main equipment of each DXE [ECW&FFB VS] train is located in the corresponding extra cooling water and NI firefighting building.

d) Description of System Interfaces

The DXE [ECW&FFB VS] is connected to the following mechanical systems (not including power supplies and I&C systems):

The JDT [FAS] provides signals to the fans of the DXE [ECW&FFB VS].

e) Description of Instrumentation and Control

Instruments, controlling and monitoring the DXE [ECW&FFB VS] and displaying of the actuator are provided in the MCR.

10.6.15.4.2 System Operation

a) Plant Normal Conditions

The DXE [ECW&FFB VS] operates according to the internal temperature

b) Plant Accident Conditions

If the temperature of the ECS [ECS] pump station is higher than 30°C, one of the supply and exhaust fans of the corresponding train shall be started. Furthermore, if the temperature is higher than 40°C, both of the two supply and exhaust fans shall be started.

10.6.15.5 Preliminary Design Substantiation

In this sub-chapter, the system design is demonstrated to satisfy the safety functional requirements presented in Sub-chapter 10.6.15.1 and the general design requirements stated in Sub-chapter 10.2.4.

Since the general principles are newly developed at this stage, the system design is still based on the reference design. A review of the consistency of the system design against the newly developed principles is currently being undertaken.

10.6.15.5.1 Compliance with Safety Functional Requirements

a) Control of Reactivity

Not applicable.

b) Removal of Heat

Not applicable.

c) Confinement

Not applicable.

d) Extra Safety Functions

1) Supporting The Fundamental safety Functions

The DXE [ECW&FFB VS] components are sized to meet the cooling requirements of equipment in the ECS [ECS] pump station under all summer and winter conditions as defined in Table T-10.6-40.

2) Prevent, Protect and Mitigate Hazards Impact

Not applicable.

10.6.15.5.2 Compliance with Design Requirements

a) Safety Classification

The DXE [ECW&FFB VS] design is compliant with the principles described in Chapter 4. The safety classification of DXE [ECW&FFB VS] functions and the safety classification of main components are as follows:

T-10.6-26 Function Categorisation of the DXE [ECW&FFB VS]

System Function	Function Category
Ventilation train A	FC3
Ventilation train B	FC3
Ventilation train C	FC3

T-10.6-27 Classification of Main Components

Component	Function Class	Design Provision Category	Design Provision Class	Seismic Category
Fans	F-SC3	NC	NC	SSE1
Filters	F-SC3	NC	NC	SSE1
Damper	F-SC3	NC	NC	SSE1

b) Engineering Design Requirements

1) Reliability Design of SSCs

- Single Failure Criterion (SFC)

  Not applicable.

- Independence

  The DXE [ECW&FFB VS] consists of three separate trains.

- Diversity

  Not applicable.

- Fail-safe

  There’s no fail-safe designed equipment in the DXE [ECW&FFB VS].

- Ageing and Degradation

  The plant design life is 60 years. Some components will require replacing at the end of their individual design life. For the fan design, vibration ageing and thermal ageing are taken into consideration. The

differential pressure of the fan is monitored and recorded in real time, which is convenient for the operator to assess the performance of the fan.

2) Human Factors

The system design of DXE [ECW&FFB VS] does not require short term operator intervention, however there are operator actions during plant normal operation, the effect of which needs to be estimated. The fan and filter of each DXE [ECW&FFB VS] train are located in adjacent equipment rooms, where the equipment layout facilitates their maintenance. The DXE [ECW&FFB VS] is controlled and monitored in the main control room. It is designed to be easy for the operator to control.

3) Autonomy

- Autonomy in Respect of Operators

  The design principles relevant to the autonomy in respect of operators are not applicable for DXE [ECW&FFB VS] design.

- Autonomy in Respect of the Heat Sink

  The design principles relevant to the autonomy in respect of the heat sink are not applicable for DXE [ECW&FFB VS] design.

- Autonomy in Respect of Power Supply Systems

  The design principles relevant to the autonomy in respect of the power supply are not applicable for DXE [ECW&FFB VS] design.

4) Other Design Requirements

- Prevention of Harmful Interactions of Systems Important to Safety

  Not applicable.

- Considerations Related to the Electrical Power Grid

  The functionality of items important to safety in the DXE [ECW&FFB VS] is not compromised by disturbances in the electrical power grid.

c) Equipment Qualification

All the safety classified components of the DXE [ECW&FFB VS] required to perform safety functions are capable of operating under both normal and accident conditions. As a result, the components can withstand the most adverse environmental conditions expected.

All the seismically classified components of the DXE [ECW&FFB VS] shall be capable of operating during and after the SSE. The components are seismically designed and qualified for the SSE loads.

d) Protection Design against Internal and External Hazards

Not applicable.

e) Commissioning

Commissioning is going to be carried out for the DXE [ECW&FFB VS] to validate its functionality.

f) Examination, Inspection, Maintenance and Testing

1) Examination and Inspection

There is no equipment of the DXE [ECW&FFB VS] requiring in-service inspection.

The combined information of the DXE [ECW&FFB VS] displayed in the Main Control Room (MCR) for the operator includes:

Temperature in the rooms;

2) Maintenances

Maintenance can be done when the corresponding diesel generator is in maintenance during shutdown of the plant.

3) Periodic Tests

Because of the continuous operation of the system, there is no requirement for periodic testing for equipment of the DXE [ECW&FFB VS].

g) Decommissioning

Decommissioning considerations about the DXE [ECW&FFB VS] are still being undertaken at this stage.

h) Material Selection

The duct material is galvanised steel.

10.6.15.6 Simplified Diagrams

The simplified system diagram is presented in Figure F-10.6-13.

10.6.16 Waste Treatment Building Ventilation System (DWQ [WTBVS])

The DWQ [WTBVS] serves the Waste Treatment Building (BWX), maintains proper environmental conditions for equipment operation and personnel access and provides dynamic confinement for the building under normal conditions. It also keeps the building in static containment in case of multiple failures after an earthquake

10.6.16.1 Safety Functional Requirements

The requirements of the fundamental safety functions on DWQ [WTBVS] design for the UK HPR1000 are as identified below.

10.6.16.1.1 Control of Reactivity

The DWQ [WTBVS] does not contribute to this safety function.

10.6.16.1.2 Removal of Heat

The DWQ [WTBVS] does not contribute to this safety function.

10.6.16.1.3 Confinement

With respect to its contribution to confinement, the (DWQ [WTBVS]) must satisfy the following requirements:

a) Environmental Protection

The DWQ [WTBVS] must limit the leakage of radioactive material into the environment in normal conditions.

b) Limiting Radiological Consequences

1) Purification

To reduce the radioactivity released to the environment, the Waste Treatment Building (BWX) controlled area exhaust air must be filtered before releasing it to the environment.

2) Dynamic Confinement

To reduce the radioactivity released to the environment, the DWQ [WTBVS] must keep the controlled area of the Waste Treatment Building (BWX) in dynamic confinement in normal operation.

3) Static Confinement

The DWQ [WTBVS] must keep the building in static containment in case of multiple failures after an earthquake.

10.6.16.1.4 Extra Safety Functions

With respect to its contribution to the extra safety functions, the DWQ [WTBVS] must satisfy the following requirements:

a) Supporting the Fundamental Safety Functions

Maintain the acceptable temperature for safety classified equipment and personnel in the controlled areas of the BWX Buildings during normal conditions.

b) Prevent, Protect and Mitigate Hazards Impact

Fire: In case of fire, the DWQ [WTBVS] contributes to limit fire spread.

10.6.16.2 Design Requirements

The general design requirements of the HVAC systems which need to be considered are shown in Sub-chapter 10.2.4, among which the following requirements are not applicable for the DWQ [WTBVS]:

a) Autonomy in Respect of the Heat Sink

Not applicable, because the DWQ [WTBVS] doesn't provide a heat sink to the power plant.

b) Autonomy in Respect of Power Supply Systems

Not applicable, because the DWQ [WTBVS] doesn't provide a power supply system to the power plant.

c) Prevention of Harmful Interactions of Systems Important to Safety

Not applicable, because the DWQ [WTBVS] doesn't have harmful interactions of systems important to safety.

The substantiation analysis of the DWQ [WTBVS] to other design requirements is shown in the Sub-chapter 10.6.16.5.2.

10.6.16.3 Design Bases

10.6.16.3.1 General Assumptions

The outside conditions to be taken into account for the DWQ [WTBVS] system are defined in Table T-10.6-41 .

The controlled area ventilation adopts a once-through fresh air ventilation system. The supply system is designed as two trains. Fans are available at 2×100% while air treatment equipment is available at 2×50%. The exhaust train has four trains of filtration available at 4×33% while the exhaust fans are available at 2×100%.

The exhaust air of the DWQ [WTBVS] must be filtered to reduce its radioactivity. The filtration system is divided into three trains according to the ventilation system requirements, while another single standby train is designed considering the filter replacement.

Local electric heaters are designed for the rooms with lower temperature limits.

Local cooling units are designed for the rooms with a large quantity of heat being released.

10.6.16.3.2 Design Assumptions

a) Control of Reactivity

Not applicable. The DWQ [WTBVS] does not contribute to the safety function of control of reactivity.

b) Removal of Heat

Not applicable. The DWQ [WTBVS] does not contribute to the safety function of removal of heat.

c) Confinement

The DWQ [WTBVS] is designed to satisfy the confinement of the BWX controlled area. The functional requirements are as follows:

1) Environmental Protection

Maintain negative pressure in the controlled area of the Waste Treatment Building (BWX). For the specific negative pressure see Table T-10.6-35.

2) Limiting Radiological Consequences

- Dynamic Confinement

  The DWQ [WTBVS] is designed so that the volume of exhaust air is more than the supply air to maintain the controlled area at a negative pressure. This sets a pressure gradient which can ensure the air flows from low potential radioactive areas to high potential radioactive areas. For the specific negative pressure see Table T-10.6-35.

- Static Isolation

  Isolating dampers are designed in the opening to the controlled area of the DWQ [WTBVS] and non-return dampers in the outlet of the extraction fans, which can be closed on the occurrence of earthquakes, thus fulfilling the requirements of static isolation. These isolation dampers are reinforced, for characteristics of how air tight the isolation dampers are see Table T-10.6-37.

- Purification

  The DWQ [WTBVS] exhaust air filtration (including outlet iodine filtration) is designed to filtrate outlet air in order to reduce the radioactivity released to the environment.

  The filtration system is designed to meet the required air flow.

- Air Filtering

  For the filtration efficiency of HEPA filter see Table T-10.6-38.

- Iodine Adsorption

  For the efficiency of the iodine adsorber see Table T-10.6-39.

- Iodine Electrical Heater

  To preserve the efficiency of the iodine adsorber, an electric heater has been designed upstream of the iodine adsorber which can maintain the relative air humidity below 70%.

  The inlet temperature of the heater is assumed as 40°C, while the relative humidity is assumed as 100%.

d) Extra Safety Functions

1) Supporting the Fundamental Safety Functions

The external conditions to be taken into account for the DWQ [WTBVS] are defined in Table T-10.6-41.

The internal room conditions to be taken into account for the DWQ [WTBVS] are defined in Table T-10.6-42.

The temperature of the supply air is 18°C. The capacity of the local cooling units is calculated according to the volume of air flow and the state parameter of inlet and outlet air.

The capacity of the local cooling units considers the maximum heat dissipation of the equipment and pipes under the accident conditions and when the normal ventilation is lost.

The minimum air renewal rate is detailed in Table T-10.6-44.

2) Prevent, Protect and Mitigate Hazards Impact

Fire: There's no quantitative safety-related design assumption for the DWQ [WTBVS].

10.6.16.4 System Description and Operation

10.6.16.4.1 System Description

a) General System Description

The DWQ [WTBVS] consists of an air supply subsystem, exhaust subsystem with HEPA filters for continuous filtration in normal operation, iodine adsorption exhaust subsystem which will be used if necessary, air supply duct network, exhaust duct network, etc.

The air supply trains of the DWQ [WTBVS] include:

1) The external air inlets whose outer walls are provided with protective grids and rain covers;

2) The air treatment trains available at 2×50%, wherein each train includes

pre-filters, fine filters, cooling coils cooled by the DEQ [WTBCWS] and heating coils heated by the SES [HWPDS];

3) Supply Fans available at 2×100%.

The exhaust air trains include:

1) The filtering unit available at 4×33% wherein each train is composed of pre-filters and HEPA filters;

2) Exhaust fans available at 2×100%;

3) The concrete air ducts leading to the DWN [NABVS] main stack.

The iodine filter trains include:

1) The iodine filter trains available at 2×50%, wherein each train includes one electric heater, one iodine adsorber, upstream and downstream fire dampers and motorised isolation dampers;

2) Iodine Exhaust fans available at 2×50%.

There are two (2×50%) motor actuated isolating dampers designed in the opening to the controlled area of the DWQ [WTBVS].

For the boric rooms and laundry rooms, where lowest temperature is limited, the electric heaters are designed to operate according to the local heating requirements.

The rooms with a relatively large local heat release are equipped with a local cooling unit.

Detailed information of the systems is presented in the SDM, Reference [119].

b) Description of Main Equipment

The main equipment descriptions are as follows:

1) Fans

The fans are designed to supply or exhaust air, and are designed depending on the system flow rate and head loss. The air supply fans, air exhaust fans and iodine exhaust fans are centrifugal fans with a frequency conversion controller. The uncontrolled area exhaust fan is an axial fan. All the fans are of a direct-coupled motor type.

2) Cooling and Heating Coils

The cooling coils are designed to cool the supply air, and its cooling water is

supplied by the DEQ [WTBCWS]. The heating coils are designed to heat the supply air, and its heating water is supplied by the SES [HWPDS]. All of them are made of copper tubes with several passes, with copper or aluminium fins. The frames are made of galvanised steel or stainless steel.

3) Pre-filters

The pre-filters are designed to remove dust or aerosols from the air. They are made of glass fibre and each cell are has the same standard dimensions. The efficiency of the pre-filter is more than 85% (weighting method).

4) Fine Filters

The fine filters are designed to filter dust or aerosols in the air. They are made of glass fibre and each cell has the same standard dimensions. The efficiency of the fine filter is more than 90% (counting method).

5) HEPA Filters

The HEPA filters are designed to filter dust or aerosols in the air. They are made of cells with standard dimensions. Each HEPA filter cell is individually factory tested to verify an efficiency of at least 99.99%, corresponding to a 10,000 filtering factor (sodium flame method).

6) Iodine Adsorbers

The iodine adsorbers are designed to remove radioactive iodine suspended in the air and they are made of cells with standard dimensions. Each adsorber is assembled of a welded construction and a 102mm deep Type III rechargeable adsorber cell. When new, these filters have a filtering factor of at least 1000 (methyl iodide).

7) Local Cooling Units

The local cooling units are designed to cool the air. A local cooling unit consists of a fan and a cooling coil supplied with chilled water.

8) Local electric heater

The high concentration boric acid rooms and SBE rooms have local electric heaters installed in them to maintain the room minimum temperature requirement. They comprise of reinforced tubular elements placed in a sheet metal box made of stainless steel.

9) Electric heater of the iodine adsorption train

The electric heater upstream of the iodine adsorber heats exhaust air to meet the relative humidity requirement for air entering in to the iodine adsorber. The electric heater consists of a reinforced tubular lens set in a metal box.

10) Boundary Isolation Damper/ Non-return Damper

These dampers locate on the boundary of the controlled area and are classified as SSE1 to ensure the area's integrity during earthquakes

Detailed information of the equipment design is presented in the SDM, Reference [120] and [119].

c) Description of Main Layout

The DWQ [WTBVS] is located in the Waste Treatment Building (BWX). All the equipment is arranged in different DWQ [WTBVS] equipment rooms. The ventilation ducts stretch across all of the rooms which need supply or exhaust air.

Detailed design information about the system layout is presented in the SDM, Reference [121].

d) Description of System Interface

The DWQ [WTBVS] is connected to the following mechanical systems (not including power supplies and I&C systems):

1) SES [HWPDS]

Provides hot water to heating coils

2) DEQ [WTBCWS]

Provides chilled water to cooling coils

3) SRE [SRS]

Collects drainage water in the controlled area

4) SEO [SSS]

Collects drainage water in the uncontrolled area

5) JPI [FWSNI]

Provides fire-fighting water for the iodine adsorber in case of fire

6) KRT [PRMS]

The radioactivity monitoring system detects the radioactivity level of exhaust air.

7) JDT [FAS]

The system which detects fire and provides signals to the fire dampers of the DWQ [WTBVS]

8) SBE [HLS]

Collects the exhaust air of the hot laundry system

9) TEU [LWTS]

Collects the exhaust air of the liquid waste treatment system

10) TES [SWTS]

Collects the exhaust air of the solid waste treatment system

11) DWN [NABVS]

Receives the exhaust air of the DWQ [WTBVS].

Detailed information of the interface systems is presented in the SDM, Reference [119].

e) Description of Instrumentation and Control

Parameters, controlling and monitoring of the DWQ [WTBVS] and displaying of the actuator are provided in the MCR.

Detailed information of the system I&C design is presented in the SDM, Reference [122].

10.6.16.4.2 System Operation

a) Plant Normal Conditions

During normal operation of the plant, the DWQ [WTBVS] operates continuously to meet the appropriate ambient temperature and sanitary requirements for the normal operation of equipment and for personnel work. For the waste treatment building (BWX) controlled area, the system provides containment, maintains negative pressure, prevents the spread of pollution and limits the concentration of aerosols.

The DWQ [WTBVS] provides conditioned supply air to the waste treatment building (BWX). The exhaust system will collect the corresponding TEU[LWTS] and TES[SWTS] processing discharge air as well as the SBE[HLS] laundry exhaust air, which will be directed with the normal room exhaust air to the DWN [NABVS] main stack after filtration treatment.

When the KRT [PRMS] detects an exhaust air radioactivity level higher than the setting point, the corresponding train switches to the iodine adsorption train automatically. At most two trains of the exhaust are allowed to switch to the iodine filtering trains. If more than two trains are to be switched, the DWQ [WTBVS] ventilation system shall operate at a reduced air volume.

In the event of fire in the iodine adsorber, fire dampers upstream and downstream of the iodine adsorber as well as the corresponding fan will be closed

automatically.

b) Plant Accident Conditions

Under plant accident conditions, the DWQ [WTBVS] can be operated continuously, except for LOOP and SBO conditions

In case of an earthquake, the isolating dampers, located on the inlet opening of the controlled area, can be closed to separate the BWX and the external environment.

Detailed information of the system operation is presented in the SDM, Reference [122].

10.6.16.5 Preliminary Design Substantiation

In this sub-chapter, the system design is demonstrated to satisfy the safety functional requirements presented in Sub-chapter 10.6.16.1 and the general design requirements stated in Sub-chapter 10.2.4.

Since the general principles are newly developed at this stage, the system design is still based on the reference design. A review of the consistency of the system design against the newly developed principles is currently being undertaken. Detailed design of the system is presented in the SDM, Reference [119] and [121].

10.6.16.5.1 Compliance with Safety Functional Requirements

a) Control of Reactivity

Not applicable.

b) Removal of Heat

Not applicable.

c) Confinement

1) Environmental Protection

The DWQ [WTBVS] ensures the containment of radioactive material in normal operating conditions by:

- using control dampers in order to control the negative pressure in the BWX;
- routing air transfers from the potentially less contaminated rooms to the potentially more contaminated rooms;
- routing the exhaust air through the HEPA filters to the main unit vent stack;
- routing the exhaust air via the iodine adsorption units to the main unit vent stack in case of iodine presence;

The DWQ [WTBVS] components which contribute to prevent minor radioactive release are designed to meet sufficient mechanical requirements.

2) Limiting Radiological Consequences

Contain the radioactive material and prevent the risk of leaks.

- The isolation dampers are closed if necessary.
- Ventilation dampers which are reinforced to be leak tight. For characteristics related to how air leak tight the equipment is see Table T-10.6-37.

  Limit radioactive discharge into the environment through storage, treatment and control of the waste transported.
- The HEPA filter and iodine adsorber are arranged on the exhaust system. For the filtration efficiency see Tables T-10.6-38 and T-10.6-39.
- Control the relative humidity of the iodine adsorber inlet below 70% to ensure the filtration efficiency of the iodine adsorber.
- Sizing the electric heater according to the highest temperature and humidity possible at the inlet of the iodine adsorber.
- Dampers of the iodine adsorption trains are reinforced to be leak tight. For characteristics related to how air leak tight the equipment is see Table T-10.6-37.

d) Extra Safety Functions

1) Supporting the Fundamental Safety Functions

Not applicable.

2) Prevent, Protect and Mitigate Hazards Impact

- Fire

  Fire dampers are designed on the boundary of the fire compartment, which will be closed by the JDT [FAS] signal or damper fuse in case of fire.

  Fire dampers are designed upstream and downstream of the iodine adsorber, which will be closed in case of a fire in the iodine adsorber.

Detailed design information is presented in Reference [123].

10.6.16.5.2 Compliance with Design Requirements

a) Safety Classification

The (DWQ [WTBVS]) design is compliant with the principles described in

Chapter 4. The safety classification of DWQ [WTBVS] functions and the safety classification of main components are as follows:

T-10.6-28 Function Categorisation of the DWQ [WTBVS]

System Function	**Function Category**
Air supply isolation of controlled area inlet	FC3
Normal air exhaust isolation	FC3
Air exhaust of the HEPA train in the Waste Treatment Building	FC3
Air exhaust of the iodine adsorption train in the Waste Treatment Building	FC3
Normal air supply equipment	NC
Uncontrolled area exhaust equipment	NC
Others	NC

T-10.6-29 Classification of Main Components

Component	**Function Class**	**Design Provision Category**	**Design Provision Class**	**Seismic Category**
Isolation dampers on the boundary of the controlled area	F-SC3	NC	NC	SSE1
Equipment of HEPA filtration	F-SC3	NC	NC	NC
Equipment of iodine absorption	F-SC3	NC	NC	NC
Dampers of negative pressure control	F-SC3	NC	NC	NC
Equipment of the Normal air supply	NC	NC	NC	NC
Dampers of the normal air exhaust	NC	NC	NC	NC

Component	Function Class	Design Provision Category	Design Provision Class	Seismic Category
Equipment of the uncontrolled area	NC	NC	NC	NC
General dampers	NC	NC	NC	NC

b) Engineering Design Requirements

1) Reliability Design of SSCs

- Single Failure Criterion (SFC)

  Not applicable.

- Independence

  Not applicable.

- Diversity

  The DWQ [WTBVS] is not designed with diversity.

  According to the requirements of diversity in Chapter 4, the system functional requirements are currently being analysed. After the analysis is completed, the system design will be reviewed and analysed to identify if any gaps exist and modifications will be made if necessary.

- Fail-safe

  The controlled area inlet isolating damper will be closed in case of a failure.

- Ageing and Degradation

  The plant design life is 60 years. Some components will require replacing at the end of their individual design life. All the vulnerable parts can be replaced, as the moving equipment is designed as being available at 2×100%.

  The performance of equipment is guaranteed through life examination, inspection, maintenance and testing, as well as the monitoring during normal operation, which will ensure that ageing effects do not compromise safety performance. The detailed design arrangement around EMIT and equipment monitoring is presented in the SDM, Reference [122].

The system layout design in the detailed design stage will ensure the accessibility and requirement for safety equipment in-service inspection and periodic tests including the necessary Non-Destructive Testing (NDT), as well as the requirements of emergency and scheduled maintenance on the SSCs. Detailed layout information is presented in Reference [121].

2) Human Factors

The DWQ [WTBVS] air supply and exhaust fans are arranged in the ventilation equipment rooms which can be easily accessed and equipment can be examined at any time. The DWQ [WTBVS] is controlled and monitored in the main control room which allows for convenient operation.

The system design of the DWQ [WTBVS] does not require short term operator intervention, however there are operator actions during plant normal operation, the effect of which needs to be estimated. Detailed design information about instrumentation and control is presented in the SDM, Reference [122].

3) Autonomy

- Autonomy in Respect of Operators

  The design principles relevant to the autonomy in respect of operators are not applicable for DWQ [WTBVS] design.

- Autonomy in Respect of the Heat Sink

  The design principles relevant to the autonomy in respect of the heat sink are not applicable for DWQ [WTBVS] design.

- Autonomy in Respect of Power Supply Systems

  The design principles relevant to the autonomy in respect of the power supply are not applicable for DWQ [WTBVS] design.

4) Other Design Requirements

- Prevention of Harmful Interactions of Systems Important to Safety

  Not applicable.

- Considerations Related to the Electrical Power Grid

  The functionality of items important to safety in the DWQ [WTBVS] is not compromised by disturbances in the electrical power grid. Detailed design information of the electrical power grid is presented in the Reference [119].

c) Equipment Qualification

Some components of the DWQ [WTBVS] required to perform safety functions are capable of operating under both normal and accident conditions.

All the seismically classified components of the DWQ [WTBVS] shall be capable of operating during and after the SSE. The components are seismically designed and qualified for the SSE loads.

The documents relevant to the equipment qualification will be delivered before the step 4 of GDA.

d) Protection Design against Internal and External Hazards

The DWQ [WTBVS] is protected from external and internal hazards; specific protection design is presented in the SDM, Reference [121]. The evaluation of the design is presented in Chapters 18 and 19.

e) Commissioning

Commissioning is going to be carried out for the DWQ [WTBVS] to validate its functionality. Documents related to the commissioning will be delivered before the step 4 of GDA.

f) Examination, Inspection, Maintenance and Testing

1) Examination and Inspection

The combined information of the DWQ [WTBVS] displayed in the Main Control Room (MCR) for the operator includes:

- Differential pressure between the BWX and the outside;
- Differential pressure between the supply fans outlet and the outside;
- Differential pressure between the exhaust air lines and the outside;
- Differential pressure between all the fans inlet and the outlet;
- Temperature of the supply air;
- Temperature of the monitoring room;
- Temperature of the electric heaters in the iodine train;
- Position of the isolated dampers;
- Position of the volume control dampers;
- Position of fire dampers;
- Status of fans;

- Status of the electric heaters.

2) Maintenances

Supply fans, exhaust fans and iodine fans have standby maintenance which can be completed while the DWQ [WTBVS] is in operation.

The maintenance of exhaust filtration trains including the iodine adsorption train can be performed at any time when there's a maintenance line available.

Component maintenance should be done during system shutdown.

3) Periodic Tests

FC3 equipment should be tested if they are not in continuous operation.

The controlled area inlet isolating damper should be tested periodically.

Efficiency of the Iodine adsorber and HEPA should be tested periodically.

Detailed design around EMIT is presented in the SDM, Reference [122].

g) Decommissioning

Decommissioning considerations about the DWQ [WTBVS] are still being undertaken at this stage.

h) Material Selection

The main supply and exhausts of the ducts are made of concrete.

Ducts for supply air distribution and exhaust air collection are folded and made of galvanised sheet metal.

Airtight exhaust air ducts are made of welded carbon steel with a painted surface.

10.6.16.6 Simplified Diagrams

The simplified system diagram is presented in Figure F-10.6-14.

10.6.17 Safety Chilled Water System (DEL [SCWS])

The DEL [SCWS] provides chilled water to safety-classified ventilation systems and the RIS [SIS] Low Head Safety Injection (LHSI) pumps in trains A and B.

10.6.17.1 Safety Functional Requirements

10.6.17.1.1 Control of Reactivity

The DEL [SCWS] does not contribute to this safety function.

10.6.17.1.2 Removal of Heat

The DEL [SCWS] does not contribute to this safety function.

10.6.17.1.3 Confinement

With respect to its contribution to confinement, the DEL [SCWS] must satisfy the following requirement:

Environmental protection: The DEL [SCWS] pipes and equipment connected with the RRI [CCWS] must prevent minor radioactive release following a mechanical failure.

10.6.17.1.4 Extra Safety Functions

With respect to its contribution to the extra safety functions, the DEL [SCWS] must satisfy the following requirements:

a) Supporting the Fundamental Safety Functions

The DEL [SCWS] must provide chilled water to safety classified cooling coils or cooling units for the following ventilation systems: the DVL [EDSBVS], DWL [SBCAVS], DCL [MCRACS] and DWK [FBVS].

In case of a failure of normal cooling the RIS [SIS] LHSI pumps of trains A and B (normally provided by the RRI [CCWS]) the DEL [SCWS] must provide emergency chilled water to these pumps instead.

b) Prevent, Protect and Mitigate Hazards Impact

External explosion: The DEL [SCWS] must prevent external explosions from affecting the operation of the air-cooled chiller units.

10.6.17.2 Design Requirements

The general design requirements of the HVAC systems which need to be considered are shown in Sub-chapter 10.2.4, among which the following requirements are not applicable for the DEL [SCWS]:

a) Autonomy in Respect of Heat Sink

Not applicable, because the DEL [SCWS] doesn’t provide a heat sink to the power plant.

b) Autonomy in Respect of Power Supply Systems

Not applicable, because the DEL [SCWS] doesn’t provide a power supply to the power plant.

c) Prevention of Harmful Interactions of Systems Important to Safety

Not applicable, because the DEL [SCWS] doesn’t have harmful interactions of systems important to safety.

The substantiation analysis of the DEL [SCWS] to other design requirements is shown in the Sub-chapter 10.6.17.5.2.

10.6.17.3 Design Bases

10.6.17.3.1 General Assumptions

The external conditions to be taken into account for the DEL [SCWS] are defined in Table T-10.6-40.

10.6.17.3.2 Design Assumptions

a) Control of Reactivity

Not applicable. The DEL [SCWS] does not contribute to the safety function of control of reactivity.

b) Removal of Heat

Not applicable. The DEL [SCWS] does not contribute to the safety function of removal of heat.

c) Confinement

Not applicable. There's no quantitative safety-related design assumption for the DEL [SCWS].

d) Extra Safety Functions

1) Supporting the Fundamental Safety Functions

The temperature of supply chilled water is 7°C and the temperature of return water is 12°C.

The capacity of the chiller unit is determined by the maximum sum of the loads of all consumers under each condition.

2) Prevent, Protect and Mitigate Hazards Impact

External explosion: The parameters of external explosions are given in Chapter 18 (External Hazards).

e) Other Assumptions

Not applicable. There's no quantitative design assumption for the DEL [SCWS].

10.6.17.4 System Description and Operation

10.6.17.4.1 System Description

a) General System Description

The DEL [SCWS] includes trains A, B and C. The three trains are mutually independent and physically separated. The chiller units of trains A and B are air-cooled, train C is water-cooled. Each train provides chilled water for the safety-classified cooling coils or cooling units of the DVL [EDSBVS], DWL

[SBCAVS], and DWK [FBVS] in the corresponding buildings and DCL [MCRACS]. Trains A and B can serve as a backup of the RRI [CCWS] to cool the RIS [SIS] LHSI pumps.

Each train consists of:

1) A main circuit supplying chilled water to the consumers, which includes:
   - A chiller unit;
   - A circulating pump;
   - A by-pass line equipped with a motorised control valve, in order to regulate the chilled water flow rate through the evaporator.
2) Connected to the main circuit:
   - An expansion tank to absorb the pressure variations in the circuit;
   - A safety valve to prevent a possible overpressure in the circuit.
3) Sub-circuits for the chilled water supply of each consumer.

Detailed information of the systems is presented in the SDM, Reference [124].

b) Description of Main Equipment

1) Chiller units

The chilled water distributed to consumers is provided by chiller units. There are three chiller units in the DEL [SCWS]. Trains A and B are air-cooled, train C is water-cooled. In the three chiller units, R134a is used as the refrigerant.

T-10.6-30 Main Data Sheet of Chiller Units

Chiller	**DEL [SCWS] train**		
	A	**B**	**C**
Type	Air-cooled	Air-cooled	Water-cooled
Chiller refrigerating capacity (kW)	1320	1320	1150
Coefficient Of Performance	2.4	2.4	5.1
Power (kW)	550	550	320

2) Circulating pumps

The circulating pumps allow the supply of chilled water to the consumers. The three pumps are identical single stage centrifugal pumps.

Detailed information of the equipment design is presented in the SDM, Reference [124] and [125].

c) Description of Main Layout

The chiller unit and pump of each DEL [SCWS] train are located in corresponding safeguard building.

Detailed design information about the system layout is presented in the SDM, Reference [126].

d) Description of System Interface

The DEL [SCWS] is connected to the following mechanical systems (not including power supplies and I&C systems):

1) SED [DWDS(NI)]

This system is used for main circulating circuit filling and possible make-up.

2) SIH [CDS]

This system is used for injecting chemical reagents discontinuously into the DEL [SCWS] to absorb oxygen and to prevent the occurrence of corrosion processes.

3) RPE [VDS]

This system is used to collect possible releases from the safety valves in case of exceeding the maximum pressure in the main circulating circuit. It is also used to collect the drains of the lines to the RPE [VDS] floor drain.

4) RRI [CCWS]

In train C, this system is used to cool the chiller unit condenser water providing a heat sink to the chiller unit.

Moreover, the DEL [SCWS] system provides chilled water to the DCL [MCRACS], DVL [EDSBVS], DWL [SBCAVS], DWK [FBVS] and RIS [SIS].

Detailed information of the interface systems is presented in the SDM, Reference [124].

e) Description of Instrumentation and Control

Instruments controlling and monitoring the DEL [SCWS] and displaying of the actuator are provided in the MCR.

Detailed information of the system I&C design is presented in the SDM, Reference [127].

10.6.17.4.2 System Operation

a) Plant Normal Conditions

The three trains of the DEL [SCWS] shall run permanently in plant normal

conditions.

b) Plant Accident Conditions

Under plant accident conditions, the three trains of the DEL [SCWS] operate continuously and the supplied refrigeration capacity depends on the need of the ventilation system.

Train C which is cooled by the RRI [CCWS] will be lost following a loss of the ultimate heat sink. Trains A and B which are cooled by outdoor air will not be affected.

In case of LOOP, each train is powered by a corresponding emergency diesel generator.

In case of SBO, the equipment of the trains A and B is powered by their corresponding SBO diesel generator. Train C will not be operational.

Detailed information of the system operation is presented in the SDM, Reference [127].

10.6.17.5 Preliminary Design Substantiation

In this sub-chapter, the system design is demonstrated to satisfy the safety functional requirements presented in Sub-chapter 10.6.17.1 and the general design requirements stated in Sub-chapter 10.2.4.

Since the general principles are newly developed at this stage, the system design is still based on the reference design. A review of the consistency of the system design against the newly developed principles is currently being undertaken. Detailed design of the system is presented in the SDM, Reference [124] and [126].

10.6.17.5.1 Compliance with Safety Functional Requirements

a) Control of Reactivity

Not applicable.

b) Removal of Heat

Not applicable.

c) Confinement

1) Environmental Protection

The DEL [SCWS] components which contribute to prevent minor radioactive release are designed to meet sufficient mechanical requirements.

d) Extra Safety Functions

1) Supporting the Fundamental Safety Functions

The DEL [SCWS] components are sized to meet the cooling requirements of its served HVAC systems (DVL [EDSBVS], DCL [MCRACS], DWL [SBCAVS] and DWK [FBVS]) under all summer and winter conditions as defined in Table T-10.6-40.

The DEL [SCWS] components are sized to meet the cooling requirements of the RIS [SIS] LHSI pump motors in the case of Total Loss of Cooling Chain (TLOCC) and SBO events.

2) Prevent, Protect and Mitigate Hazards Impact

- External explosion

  The DEL [SCWS] air-cooled chiller units are designed to endure the external explosion loads.

Detailed design information is presented in Reference [128].

10.6.17.5.2 Compliance with Design Requirements

a) Safety Classification

The DEL [SCWS] design is compliant with the principles described in Chapter 4. The safety classification of DEL [SCWS] functions and the safety classification of main components are as follows:

T-10.6-31 Function Categorisation of the DEL [SCWS]

System Function	Function Category
Expansion tanks humidity measurements	NC
Chemical adjustment and water supply	NC
Pumps bearings and windings temperature monitoring	NC
Circuit low pressure monitoring	NC
Chilled water distribution RIS [SIS] LHSI pumps	FC3
Other parts of the system (production and distribution)	FC1

T-10.6-32 Classification of Main Components

Component	Function Class	Design Provision Category	Design Provision Class	Seismic Category
Chiller unit	F-SC2	NC	NC	SSE1

Component	Function Class	Design Provision Category	Design Provision Class	Seismic Category
Pump	F-SC2	NC	NC	SSE1
Expansion tank	F-SC2	NC	NC	SSE1
Motorised control valve	F-SC2	NC	NC	SSE1

b) Engineering Design Requirements

1) Reliability Design of SSCs

- Single Failure Criterion (SFC)

  The DEL [SCWS] is designed to ensure that it meets the single failure criterion. In case of failure of one component, its 3×100 % structure ensures that the other two trains remain available.

- Independence

  Each train of the DEL [SCWS] is arranged in a safeguard building physically isolated from the others for protection.

- Diversity

  The DEL [SCWS] heat sink diversification is provided by the choice of the condenser type of the chiller units: trains A and B are air-cooled, train C is RRI [CCWS] water-cooled.

  According to the requirements of diversity in Chapter 4, the system functional requirements are currently being analysed. After the analysis is completed, the system design will be reviewed and analysed to identify if any gaps exist and modifications will be made if necessary.

- Fail-safe

  There’s no fail-safe designed equipment in the DEL [SCWS].

- Ageing and Degradation

  The plant design life is 60 years. Some components will require replacing at the end of their individual design life. For the chiller unit design, vibration ageing and radiation ageing are taken into consideration. The capacity of the chiller unit is monitored and recorded in real time, which is convenient for the operator to assess the performance of the chiller unit.

2) Human Factors

The system design of the DEL [SCWS] does not require short term operator

intervention, however there are operator actions during plant normal operation, the effect of which needs to be estimated. The chiller unit and pump of each DEL [SCWS] train are located in adjacent equipment rooms, where the equipment layout facilitates their maintenance. The DEL [SCWS] is controlled and monitored in the main control room. It is designed to be convenient for the operator to control.

3) Autonomy

- Autonomy in Respect of Operators

  The design principles relevant to the autonomy in respect of operators are detailed in Reference [1]. The design of the DEL [SCWS] fulfils these principles via control functional design, detailed information is presented in the SDM, Reference [127]. The design result is estimated in the safety analysis.

- Autonomy in Respect of the Heat Sink

  The design principles relevant to the autonomy in respect of the heat sink are not applicable for DEL [SCWS] design.

- Autonomy in Respect of Power Supply Systems

  The design principles relevant to the autonomy in respect of the power supply are not applicable for DEL [SCWS] design.

4) Other Design Requirements

- Prevention of Harmful Interactions of Systems Important to Safety

  Not applicable.

- Considerations Related to the Electrical Power Grid

  The functionality of items important to safety in the DEL [SCWS] is not compromised by disturbances in the electrical power grid. Detailed design information of the electrical power grid is presented in Reference [124].

c) Equipment Qualification

All the components of the DEL [SCWS] required to perform safety functions are capable of operating under both normal and accident conditions. As a result, the components can withstand the most adverse environmental conditions expected.

All the seismically classified components of the DEL [SCWS] shall be capable of operating during and after the SSE. The components are seismically designed and qualified for the SSE loads.

The documents relevant to the equipment qualification will be delivered before the step 4 of GDA.

d) Protection against Internal and External Hazards

The DEL [SCWS] is protected from external and internal hazards; specific protection design is presented in the SDM, Reference [126]. The evaluation of the design is presented in Chapters 18 and 19.

e) Commissioning

Commissioning is going to be carried out for the DEL [SCWS] to validate its functionality. Documents related to the commissioning will be delivered before the step 4 of GDA.

f) Examination, Inspection, Maintenance and Testing

1) Examination and Inspection

The combined information of the DEL [SCWS] displayed in the Main Control Room (MCR) for the operator includes:

- Differential pressure of the evaporator of the chiller;
- Temperature of the chilled water of the chiller outlet;
- The flow rate of cooling water of the RRI [CCWS].

2) Maintenances

During normal operating conditions, the DEL [SCWS] should supply chilled water to consumers continuously. Maintenance of the components of each train can be carried out when the corresponding train consumers are in maintenance during shutdown of the plant.

3) Periodic Tests

FC1, FC2 and FC3 equipment should be tested if they are not in continuous operation. Some equipment performing safety functions shall be subject to periodic testing, mainly including the normal operation point verification pump curve (flow rate/total delivery head) compared to the minimum safety required pump curve.

g) Decommissioning

The design of the DEL [SCWS] considers the decommissioning. A certain gradient is set in the pipeline layout to prevent liquid accumulation and all equipment and pipes can be drained by draining lines.

h) Material Selection

Equipment in contact with outside air is protected against corrosion due to the saline atmosphere through a paint coating.

The entire DEL [SCWS] equipment is made of carbon steel.

The insulation material of the chilled water pipe is made of glass fibre. The insulation thickness of pipes, which are more than DN100, is 50mm. The insulation thickness of pipes, which are less than DN100, is 30mm.

10.6.17.6 Simplified Diagrams

The simplified system diagram is presented in Figure F-10.6-15.

10.6.18 Operational Chilled Water System (DER [OCWS])

The DER [OCWS] provides chilled water to non-classified ventilation systems and other non-classified users.

10.6.18.1 Safety Functional Requirements

10.6.18.1.1 Control of Reactivity

The DER [OCWS] does not contribute to this safety function.

10.6.18.1.2 Removal of Heat

The DER [OCWS] does not contribute to this safety function.

10.6.18.1.3 Confinement

With respect to its contribution to confinement, the DER [OCWS] must satisfy the following requirement:

a) Environmental Protection

The DER [OCWS] pipes and equipment connected with the RRI [CCWS] must prevent minor radioactive release following a mechanical failure.

b) Third containment barrier

Under accident conditions, the DER [OCWS] must enable isolation of the containment at its containment penetration points. For details see Chapter 7 (Sub-chapter 7.4.6 Containment Isolation).

10.6.18.1.4 Extra Safety Functions

The DER [OCWS] does not contribute to these functions.

10.6.18.2 Design Requirements

The general design requirements of the HVAC systems which need to be considered are shown in Sub-chapter 10.2.4, among which the following requirements are not applicable for the DER [OCWS]:

a) Autonomy in Respect of Operators

Not applicable, because the DER [OCWS] doesn't contribute to the autonomy objective.

b) Autonomy in Respect of the Heat Sink

Not applicable, because the DER [OCWS] doesn't provide a heat sink to the power plant.

c) Autonomy in Respect of Power Supply Systems

Not applicable, because the DER [OCWS] doesn't provide a power supply to the power plant.

d) Prevention of Harmful Interactions of Systems Important to Safety

Not applicable, because the DER [OCWS] doesn't have harmful interactions of systems important to safety.

The substantiation analysis of the DER [OCWS] to other design requirements is shown in the Sub-chapter 10.6.18.5.2.

10.6.18.3 Design Bases

10.6.18.3.1 General Assumptions

Not applicable.

10.6.18.3.2 Design Assumptions

a) Control of Reactivity

Not applicable. The DER [OCWS] does not contribute to the safety function of control of reactivity.

b) Removal of Heat

Not applicable. The DER [OCWS] does not contribute to the safety function of removal of heat.

c) Confinement

Not applicable. There's no quantitative safety-related design assumption for the DER [OCWS].

d) Extra Safety Functions

Not applicable. The DER [OCWS] does not contribute to these functions.

e) Other Assumptions

Production and distribution of chilled water of DER [OCWS] subsystem A

consists of 4×33% capacity. Production and distribution of chilled water of DER [OCWS] subsystem B consists of 2×100% capacity.

The temperature of supply chilled water is 7°C and the temperature of return water is 12°C.

10.6.18.4 System Description and Operation

10.6.18.4.1 System Description

a) General System Description

The DER [OCWS] includes two subsystems, subsystem A and subsystem B.

1) DER [OCWS] subsystem A

Subsystem A of the DER [OCWS] consists of:

A main circuit supplying chilled water to the consumers (including four RRI [CCWS] water-cooled chiller units in parallel, four circulating pumps and a bypass line equipped with a motorised control valve);

It is connected to the main circuit (including two expansion tanks to maintain a suitable pressure in the circuit and a safety valve to prevent a possible overpressure in the circuit);

Sub-circuits for the chilled water supply of each consumer.

2) DER [OCWS] subsystem B

Subsystem B of the DER [OCWS] consists of:

A main circuit supplying chilled water to the consumers (including two RRI [CCWS] water-cooled chiller units in parallel, two circulating pumps and a bypass line equipped with a motorised control valve);

It is connected to the main circuit (including an expansion tank to maintain a suitable pressure in the circuit and a safety valve to prevent a possible overpressure in the circuit);

Sub-circuits for the chilled water supply of each consumer.

b) Description of Main Equipment

1) Chiller units

The chilled water distributed to consumers is provided by chiller units. There are six water-cooled chiller units in the DER [OCWS]. In these chiller units R134a is used as the refrigerant.

2) Circulating pumps

The circulating pumps allow the supply of chilled water to the consumers. The pumps are single stage centrifugal pumps.

c) Description of Main Layout

The chiller units and pumps of the DER [OCWS] are located in the nuclear auxiliary building.

d) Description of System Interface

The DER [OCWS] is connected to the following mechanical systems (not including power supplies and I&C systems):

1) SED [DWDS(NI)]

This system is used for main circulating circuit filling and possible make-up.

2) SIH [CDS]

This system is used for injecting chemical reagents discontinuously into the DER [OCWS] to absorb oxygen and to prevent the occurrence of corrosion.

3) RPE [VDS]

This system is used to collect possible releases from the safety valves in case of exceeding the maximum pressure in the main circulating circuit. It is also used to collect the drains of the lines to the RPE [VDS] floor drain.

4) RRI [CCWS]

This system is used to cool the chiller unit condenser, providing a heat sink to the chiller unit.

Moreover, the DER [OCWS] provides chilled water to non-classified consumers, such as: DWN [NABVS], DVL [EDSBVS], EVR [CCVS], DWQ [WTBVS], etc.

e) Description of Instrumentation and Control

Instruments controlling and monitoring the DER [OCWS] and displaying of the actuator are provided in the MCR.

10.6.18.4.2 System Operation

a) Plant Normal Conditions

The two DER [OCWS] subsystems shall run permanently in plant normal conditions.

b) Plant Accident Conditions

1) Loss of offsite power (LOOP)

If subsystem A of the DER [OCWS] fails, subsystem B of the DER [OCWS] is supplied by the emergency diesel generators when a loss of power outside the plant occurs.

2) Station black out (SBO)

The DER [OCWS] is lost in case of a SBO.

3) Loss of ultimate heat sink (LUHS)

The DER [OCWS] is lost in case of a LUHS, due to the loss of the condensers cooling water of the RRI [CCWS].

10.6.18.5 Preliminary Design Substantiation

In this sub-chapter, the system design is demonstrated to satisfy the safety functional requirements presented in Sub-chapter 10.6.18.1 and the general design requirements stated in Sub-chapter 10.2.4.

Since the general principles are newly developed at this stage, the system design is still based on the reference design. A review of the consistency of the system design against the newly developed principles is currently being undertaken.

10.6.18.5.1 Compliance with Safety Functional Requirements

a) Control of Reactivity

Not applicable.

b) Removal of Heat

Not applicable.

c) Confinement

1) Environmental Protection

The DER [OCWS] components which contribute to prevent minor radioactive release are designed to meet sufficient mechanical requirements.

2) Third containment barrier

The inlet penetration is fitted with a containment motorised isolation valve and a check valve. The outlet penetration is fitted with two containment motorised isolation valves. The three containment motorised isolation valves will close once receiving a phase 1 containment isolation signal under accident conditions.

d) Extra Safety Functions

Not applicable.

10.6.18.5.2 Compliance with Design Requirements

a) Safety Classification

The DER [OCWS] design is compliant with the principles described in Chapter 4. The safety classification of DER [OCWS] functions and the safety classification of main components are as follows:

T-10.6-33 Function Categorisation of the DER [OCWS]

System Function	Function Category
Containment isolation	FC1
Cooling by the RRI [CCWS]	FC3
Other functions of the system	NC

T-10.6-34 Classification of Main Components

Component	Function Class	Design Provision Category	Design Provision Class	Seismic Category
Containment penetrations	F-SC1	DPM	B-SC2	SSE1
Containment isolation valves	F-SC1	DPM	B-SC2	SSE1
Chiller unit	NC	NC	NC	NC
Pump	NC	NC	NC	NC
Expansion tank	NC	NC	NC	NC
Motorised control valve	NC	NC	NC	NC

b) Engineering Design Requirements

1) Reliability Design of SSCs

- Single Failure Criterion (SFC)

  Subsystem B of the DER [OCWS] containment isolation valves and containment penetrations are designed to ensure they meet the single failure criterion. The 2×100% isolation devices are redundant. The containment isolation valves are powered by diversified electrical switchboards.

- Independence

  The two isolation devices of the inlet or outlet penetration line of the DER [OCWS] are physically separated, one on the inside of the reactor

building, the other on the outside, in a connecting building.

- Diversity

  Not applicable.

- Fail-safe

  There's no fail-safe designed equipment in the DER [OCWS].

- Ageing and Degradation

  The plant design life is 60 years. Some components will require replacing at the end of their individual design life. For the chiller unit design, vibration ageing and radiation ageing are taken into consideration.

2) Human Factors

   The system design of the DER [OCWS] does not require short term operator intervention, however there are operator actions during plant normal operation, the effect of which needs to be estimated. The chiller unit and pump of each DER [OCWS] train are located in adjacent equipment rooms, where the equipment layout facilitates their maintenance. The DER [OCWS] is controlled and monitored in the main control room. It is designed to be convenient for the operator to control.

3) Autonomy

   Not applicable.

4) Other Design Requirements

   - Prevention of Harmful Interactions of Systems Important to Safety

     Not applicable.

   - Considerations Related to the Electrical Power Grid

     The functionality of items important to safety in the DER [OCWS] is not compromised by disturbances in the electrical power grid.

c) Equipment Qualification

All the components of the DER [OCWS] required to perform safety functions are capable of operating under both normal and accident conditions. As a result, the components can withstand the most adverse environmental conditions expected.

All the seismically classified components of the DER [OCWS] shall be capable of operating during and after the SSE. The components are seismically designed and qualified for the SSE loads.

d) Protection Design against Internal and External Hazards

The DER [OCWS] is protected from external and internal hazards. The evaluation of the design is presented in Chapters 18 and 19.

e) Commissioning

Commissioning is going to be carried out for the DER [OCWS] to validate its functionality.

f) Examination, Inspection, Maintenance and Testing

1) Examination and Inspection

The combined information of the DER [OCWS] displayed in the Main Control Room (MCR) for the operator includes:

- Temperature of the chilled water of the chiller outlet;
- The flow rate of cooling water of the RRI [CCWS].

2) Maintenance

During normal operating conditions, the DER [OCWS] should supply chilled water to consumers continuously. According to the configuration, maintenance of the standby pumps and chiller units could be done during power operation conditions.

3) Periodic Tests

FC1, FC2 and FC3 equipment should be tested if they are not in continuous operation. Some equipment performing safety functions shall be subject to periodic testing, mainly consisting of the containment isolation valves.

g) Decommissioning

The design of the DER [OCWS] considers the decommissioning. A certain gradient is set in the pipeline layout to prevent liquid accumulation and all equipment and pipes can be drained by draining lines.

h) Material Selection

Equipment in contact with the outside air is protected against corrosion due to the saline atmosphere through a paint coating.

The entire DER [OCWS] equipment is made of carbon steel.

The insulation material of the chilled water pipe is made of glass fibre. The insulation thickness of the pipes, which are more than DN100, is 50 mm. The insulation thickness of the pipes, which are less than DN100, is 30 mm.

10.6.18.6 Simplified Diagrams

The simplified system diagram is presented in Figure F-10.6-16.

10.6.19 ALARP Assessment

A preliminary ALARP analysis has been performed on the HVAC systems. The analysis is consistent with the arguments stated in Sub-claim 3.3.6C in the route map presented in Appendix C:

Argument 3.3.6C-1: The SSCs meet the requirements of the relevant design principles (generic and system specific) and therefore of relevant good practice:

The detailed codes and standards list is presented in Reference [6]; The consistency analysis is still under development to ensure that the design of the SSCs meets the requirements of the UK context.

The compliance analysis of the system design with the UK HPR1000 general safety engineering principles is made in each system sub-chapter. The analysis shows that the design of the SSCs meets relevant requirements and no gaps have been identified. Meanwhile, technical assessments such as the hazard schedule, fault schedule, probabilistic safety assessment, human factors, and instrumentation and control are being developed simultaneously. The analysis of the design against the requirements of these technical disciplines needs to be reviewed periodically. A systematic review will be carried out on the system design to ensure that no new gaps are identified between the newly developed requirements and the design. Any potential enhancements identified during this review will be taken into account in the future design development;

Argument 3.3.2C-2: PSA indicates the SSCs are not a disproportionate contributor to risk:

Potential areas of improvement in the system design will be identified to reduce the risks during the process of the fault analysis. Since the PSA and the fault analysis are still under development, further ALARP analysis will be performed once the fault schedule work is completed.

If any new gap is identified during the systematic technical review, analysis and optioneering will be undertaken to determine whether there are possible enhancements to the current system design, in order to reduce the risk as low as reasonably practicable.

Argument 3.3.2C-3: Design improvements have been considered in the SSCs and any reasonably practicable changes implemented:

The design improvements will be carried out once the potential areas of improvement in the design are identified. The ALARP assessment will be further developed to evaluate the design improvements.

In summary, the ALARP analysis and demonstration work is still in progress, a preliminary ALARP demonstration topic report (Reference [13]) to present the current analysis results as well as the arrangement for further ALARP analysis work is being carried out.

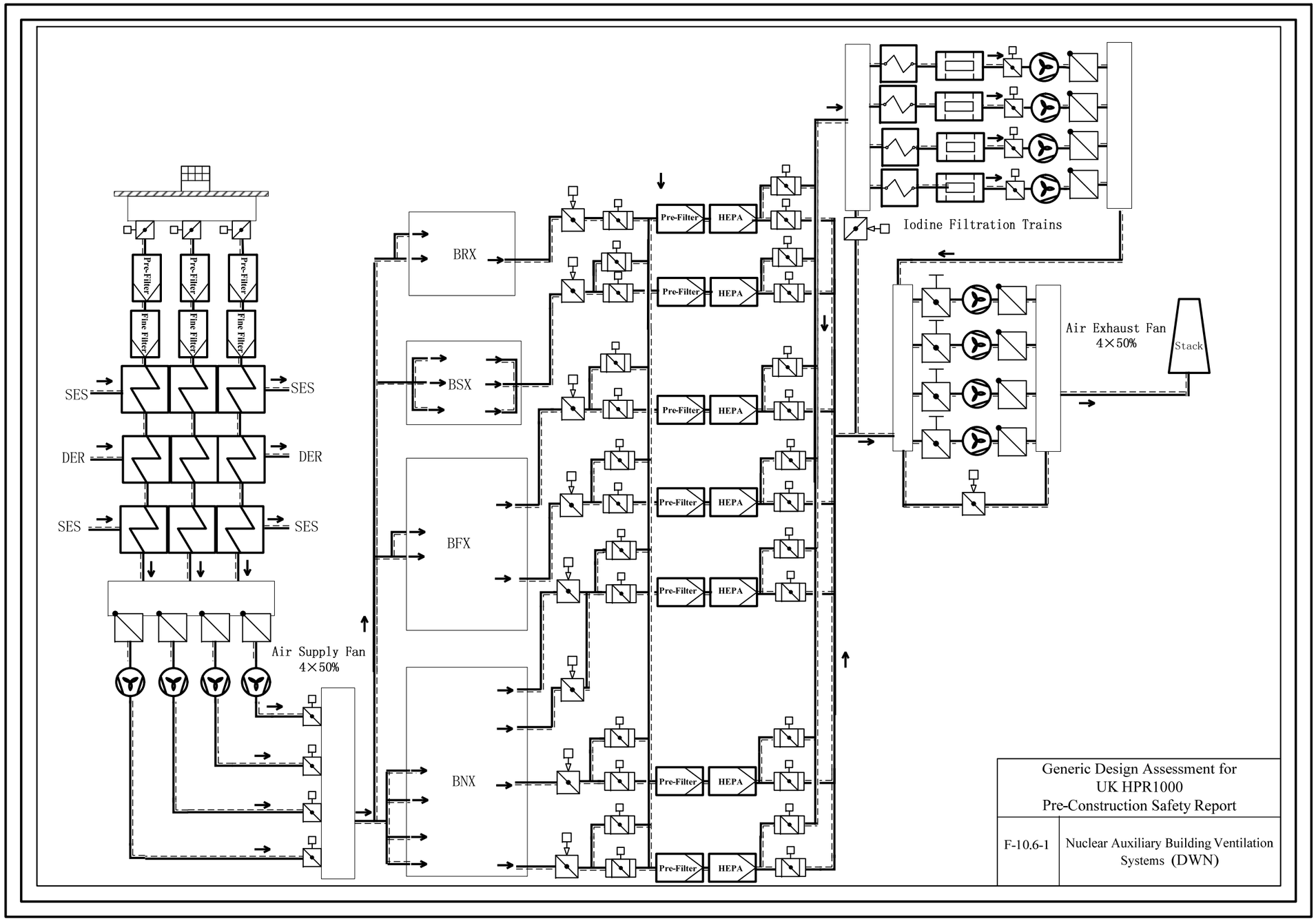
10.6.20 Concluding Remarks

At this stage, the general safety engineering principles are newly developed for the preliminary assessment, at the same time, various technical areas are under development such as the hazard schedule, fault schedule, probabilistic safety assessment, human factors, instrumentation and control, etc. As the factors mentioned above may affect the current design result, a systematic review will be carried out after the preliminary work has been completed. If any gaps are identified during the technical review, an ALARP demonstration will be carried out and efforts will be made to reduce the risk as low as reasonable practicable.

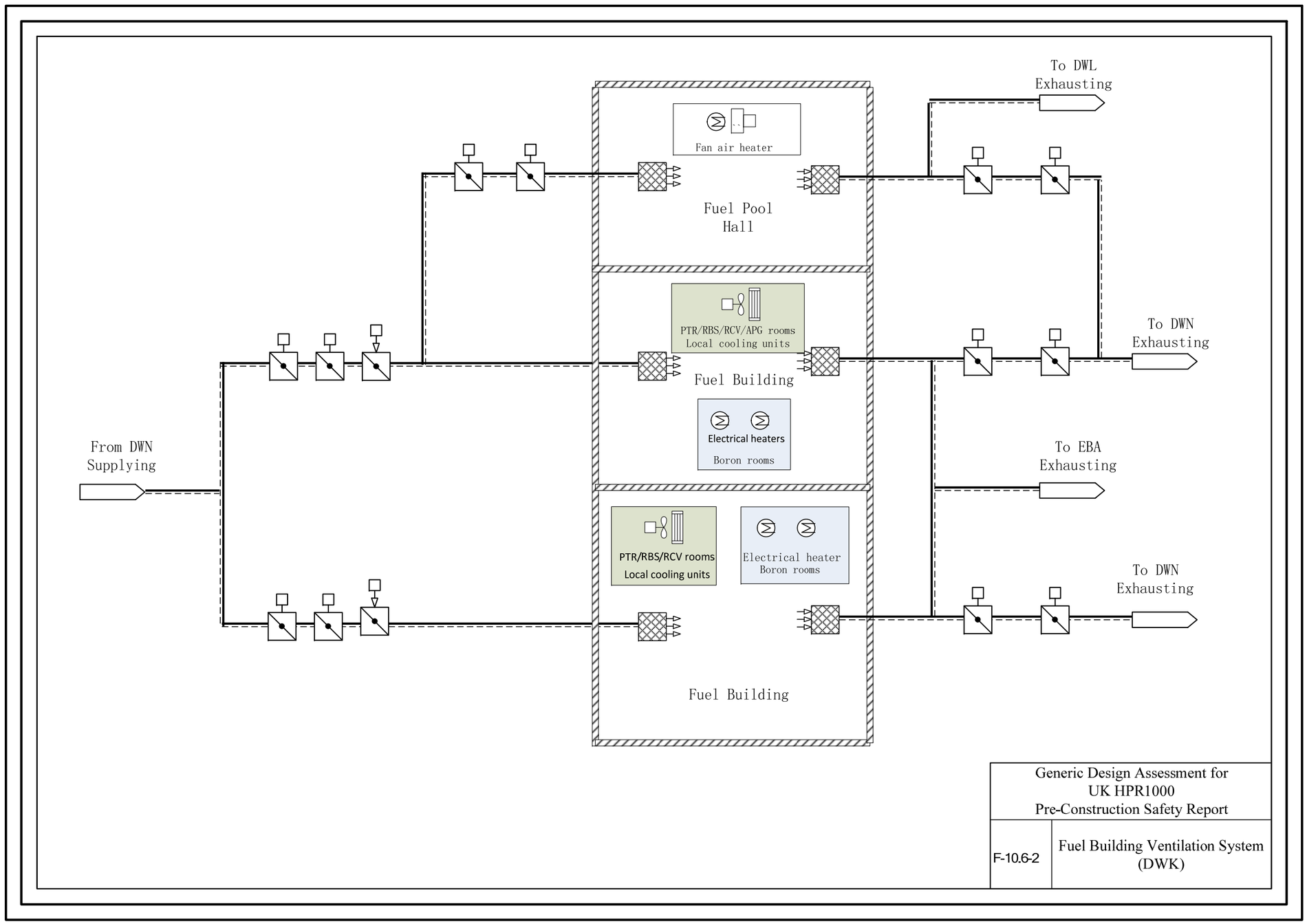
10.6.21 Simplified Diagrams

Simplified diagrams of HVAC systems mentioned in Sub-chapters 10.6.3 to 10.6.18 are presented in Figures

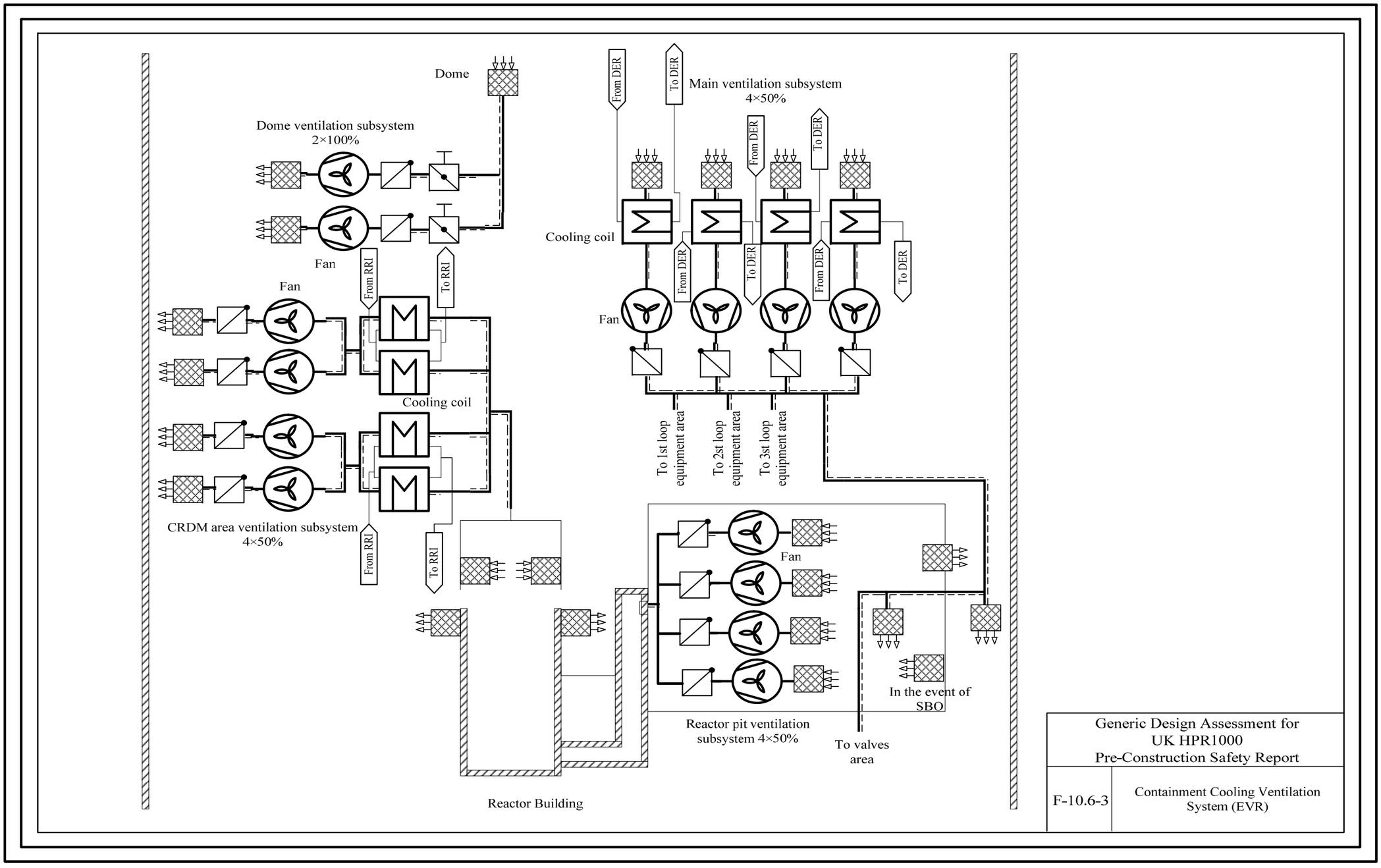
F-10.6-1 to F-10.6-16 :



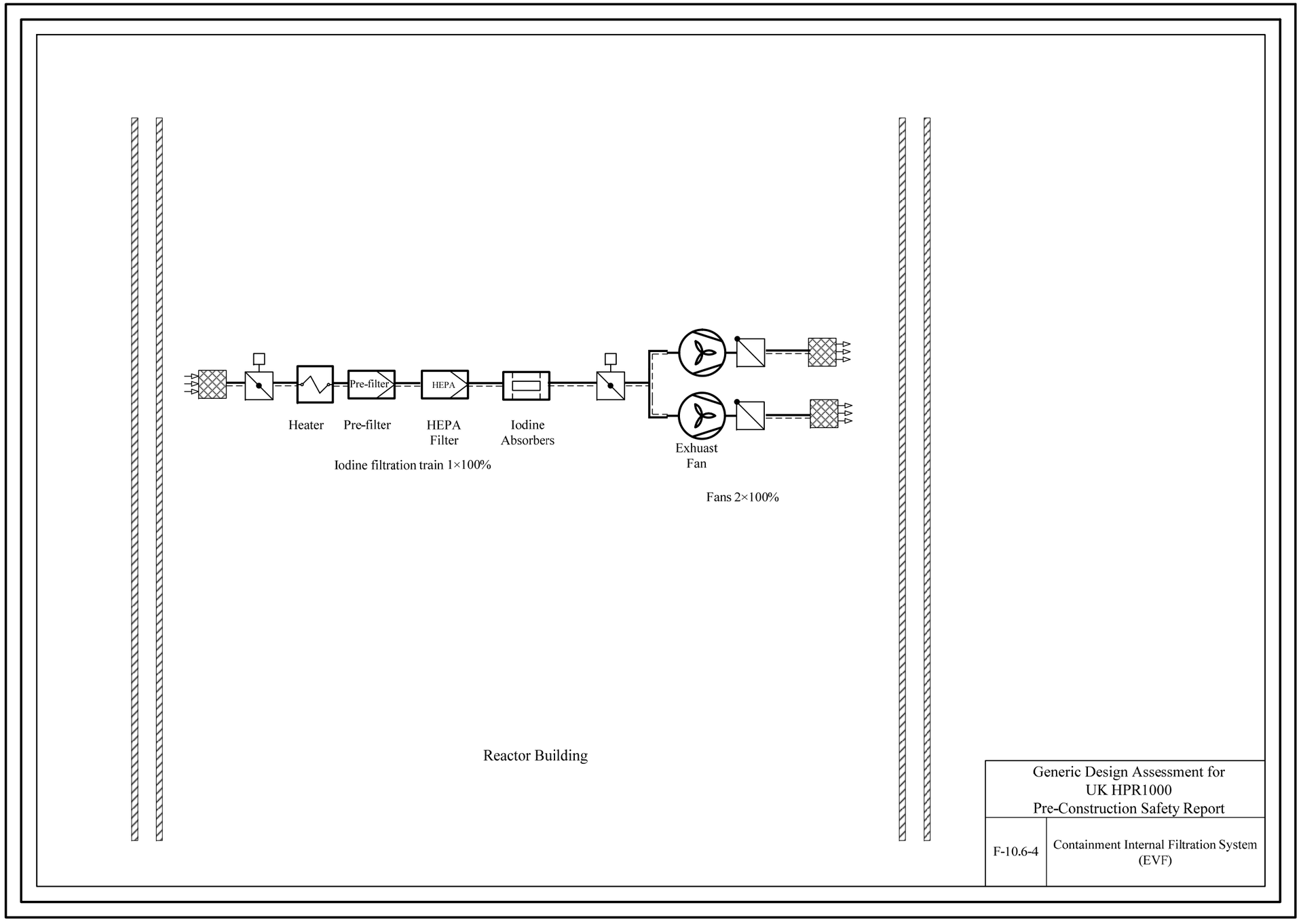
F-10.6-1 Simplified Diagram of the DWN [NABVS]



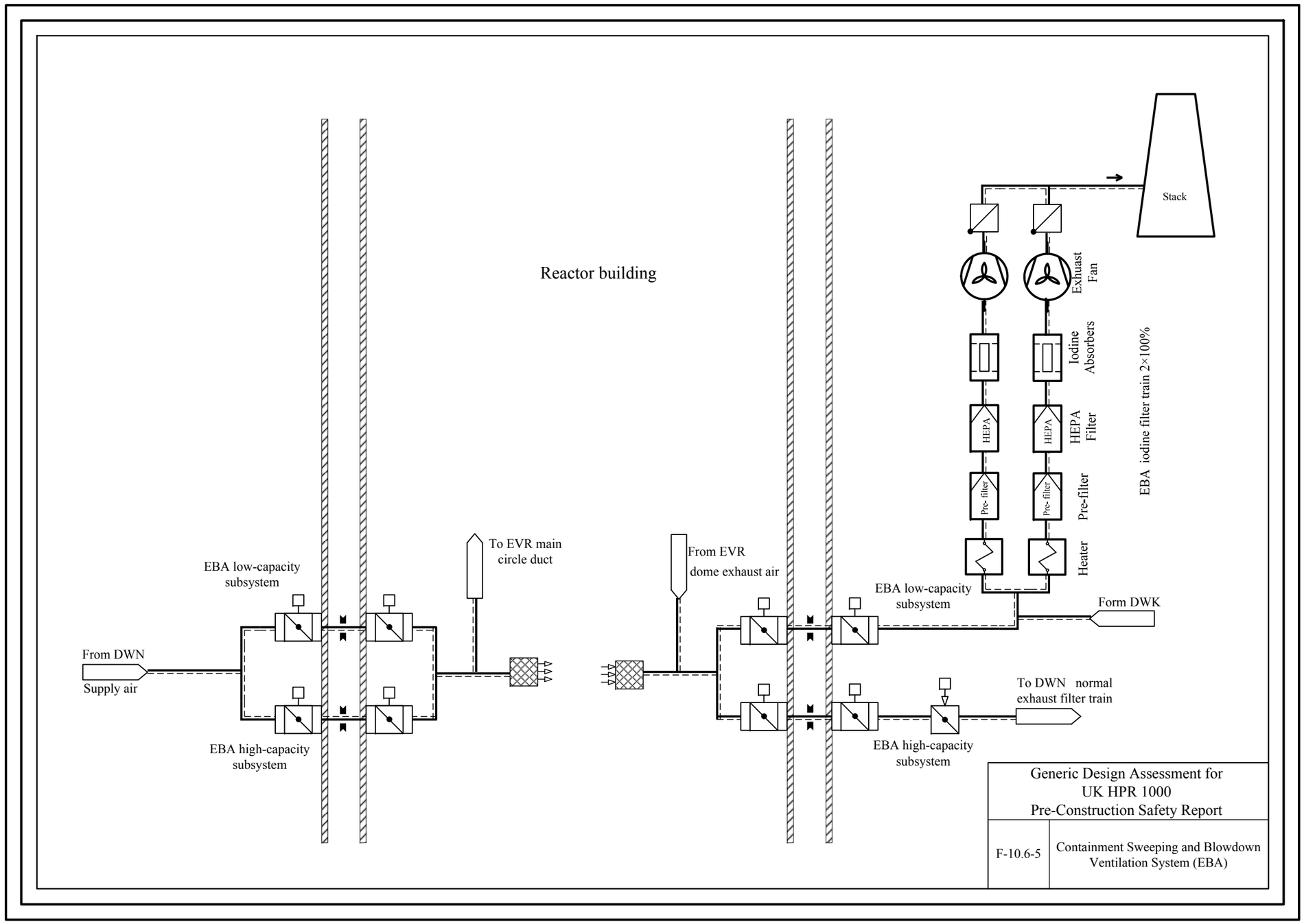
F-10.6-2 Simplified Diagram of the DWK [FBVS]



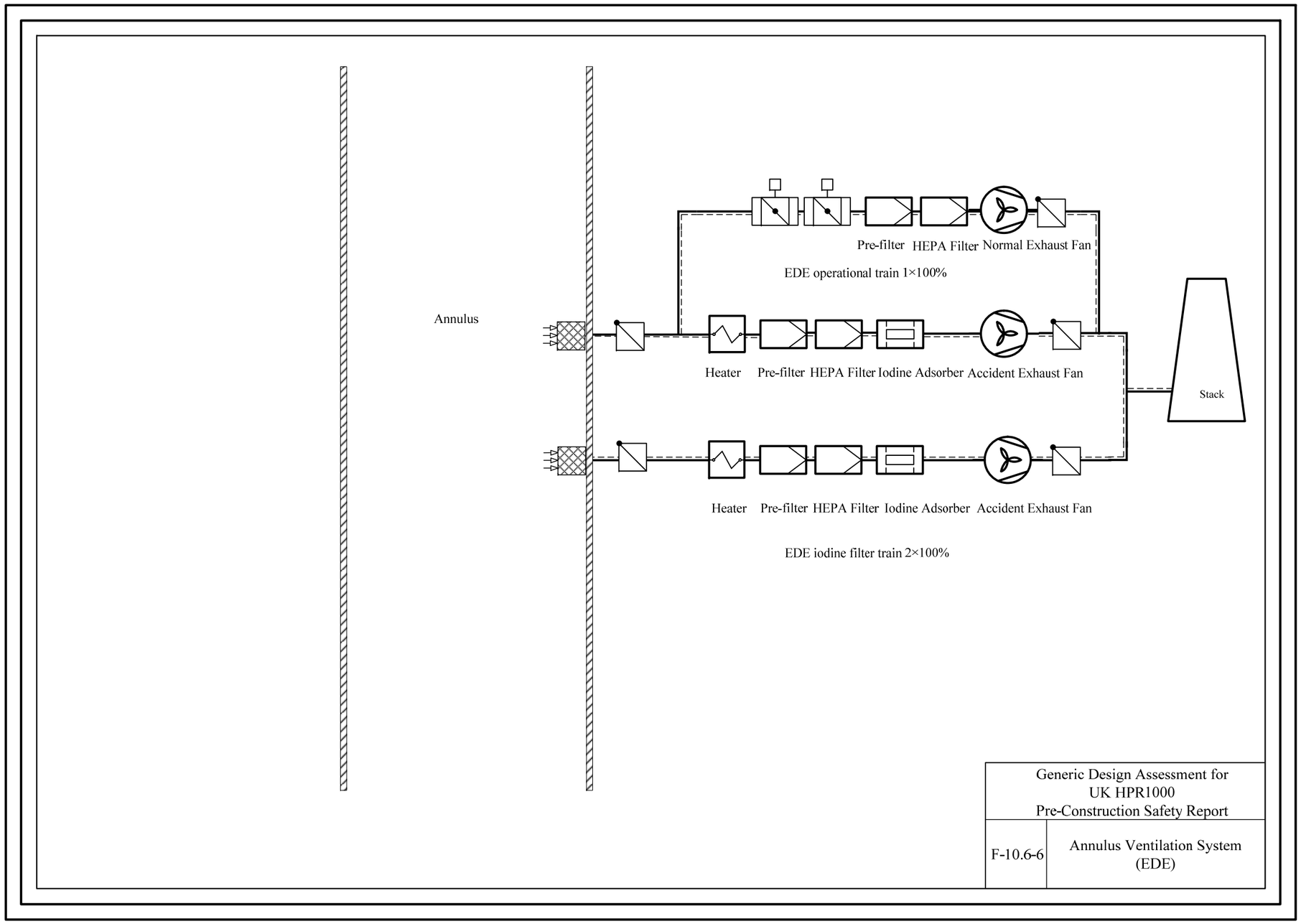
F-10.6-3 Simplified Diagram of the EVR [CCVS]



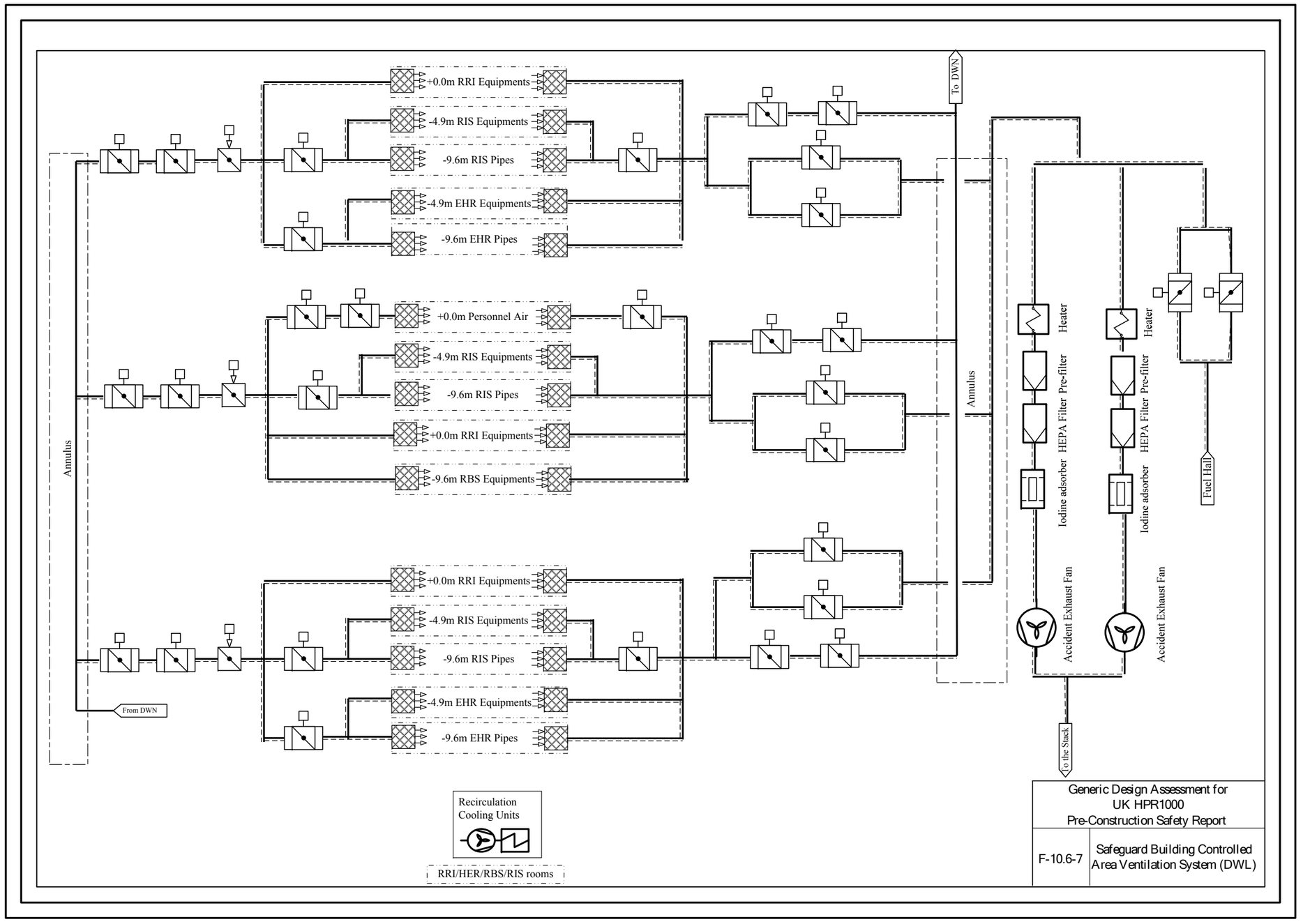
F-10.6-4 Simplified Diagram of the EVF [CIFS]



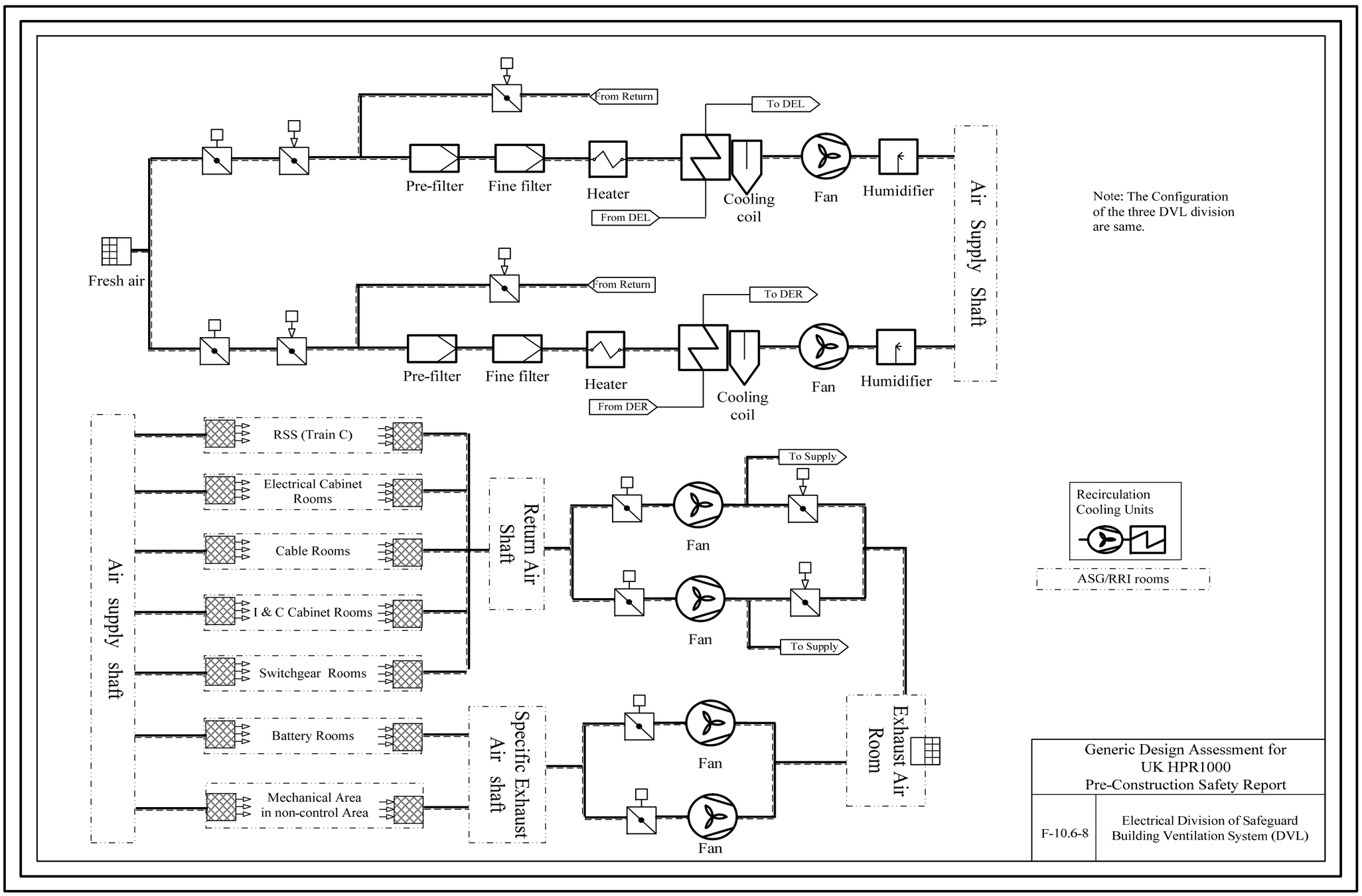
F-10.6-5 Simplified Diagram of the EBA [CSBVS]



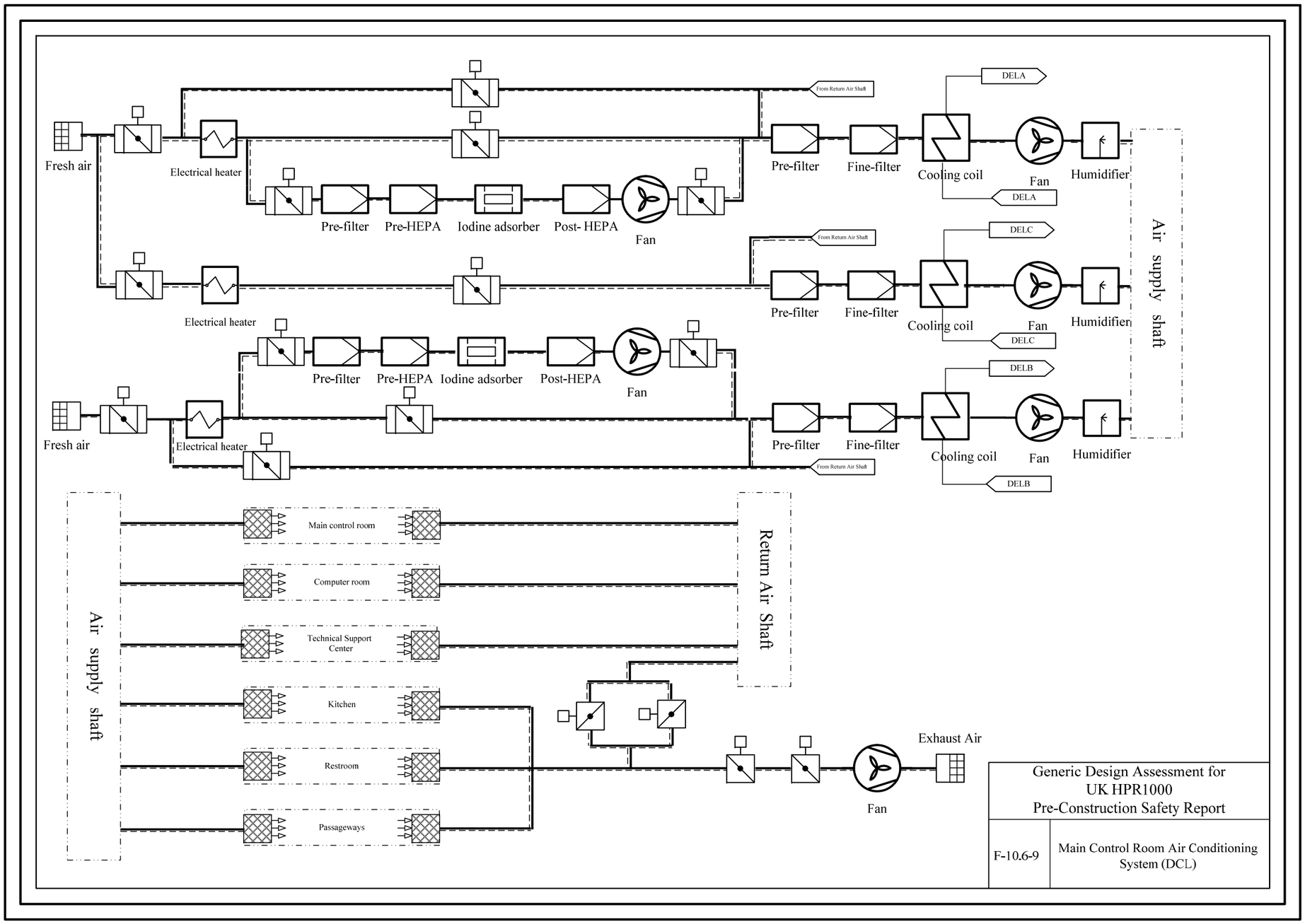
F-10.6-6 Simplified Diagram of the EDE [AVS]



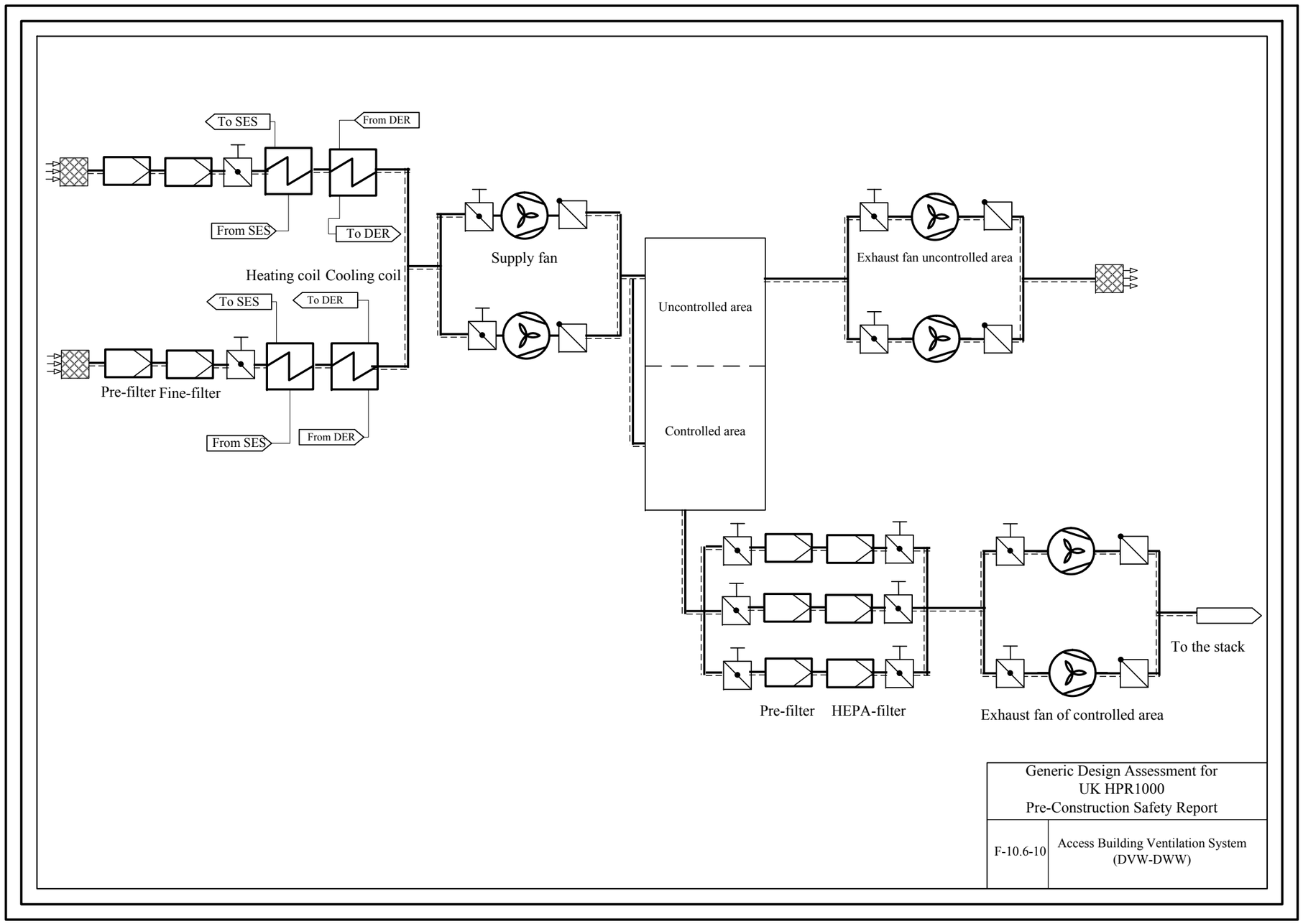
F-10.6-7 Simplified Diagram of the DWL [SBCAVS]



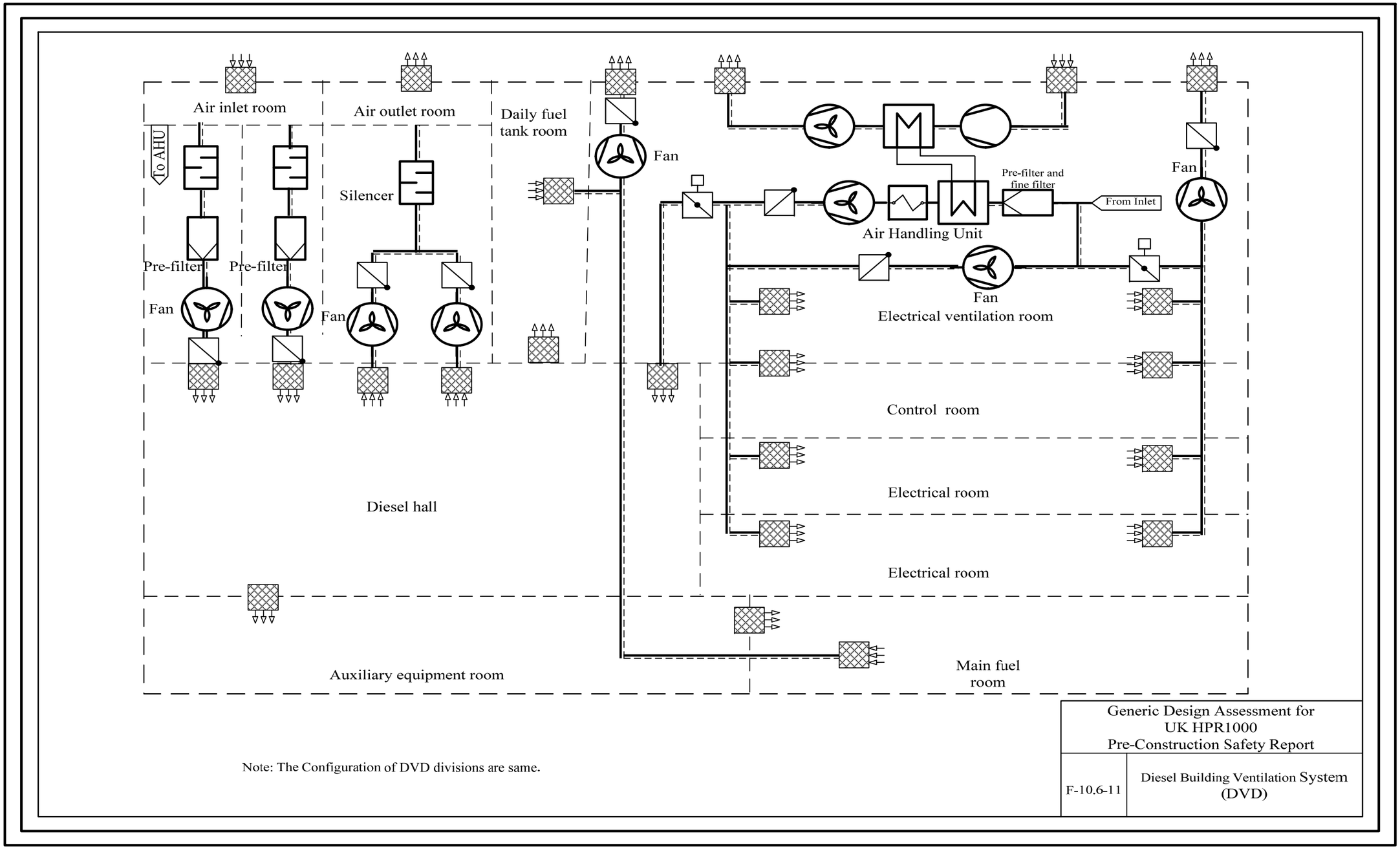
F-10.6-8 Simplified Diagram of the DVL [EDSBVS]



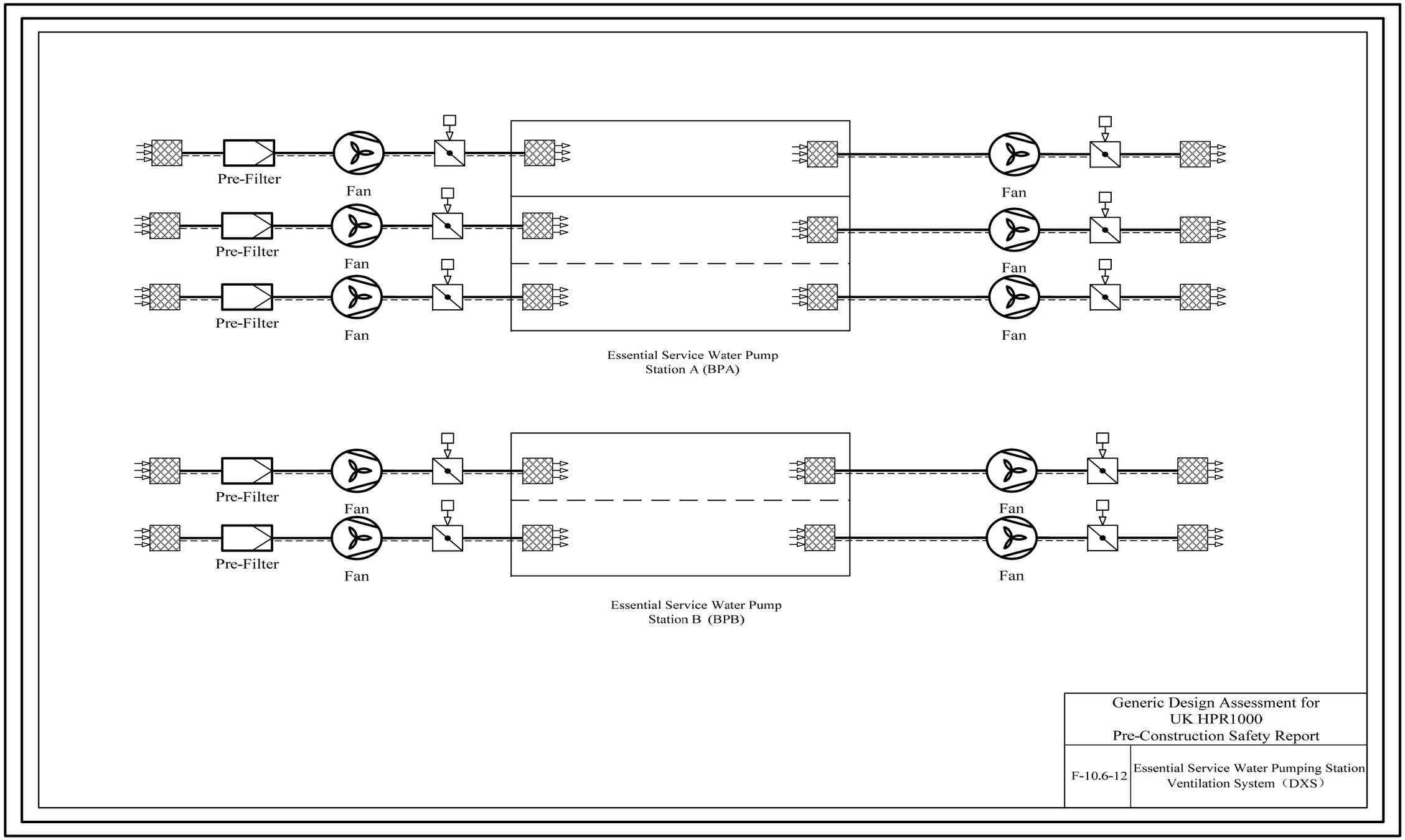
F-10.6-9 Simplified Diagram of the DCL [MCRACS]



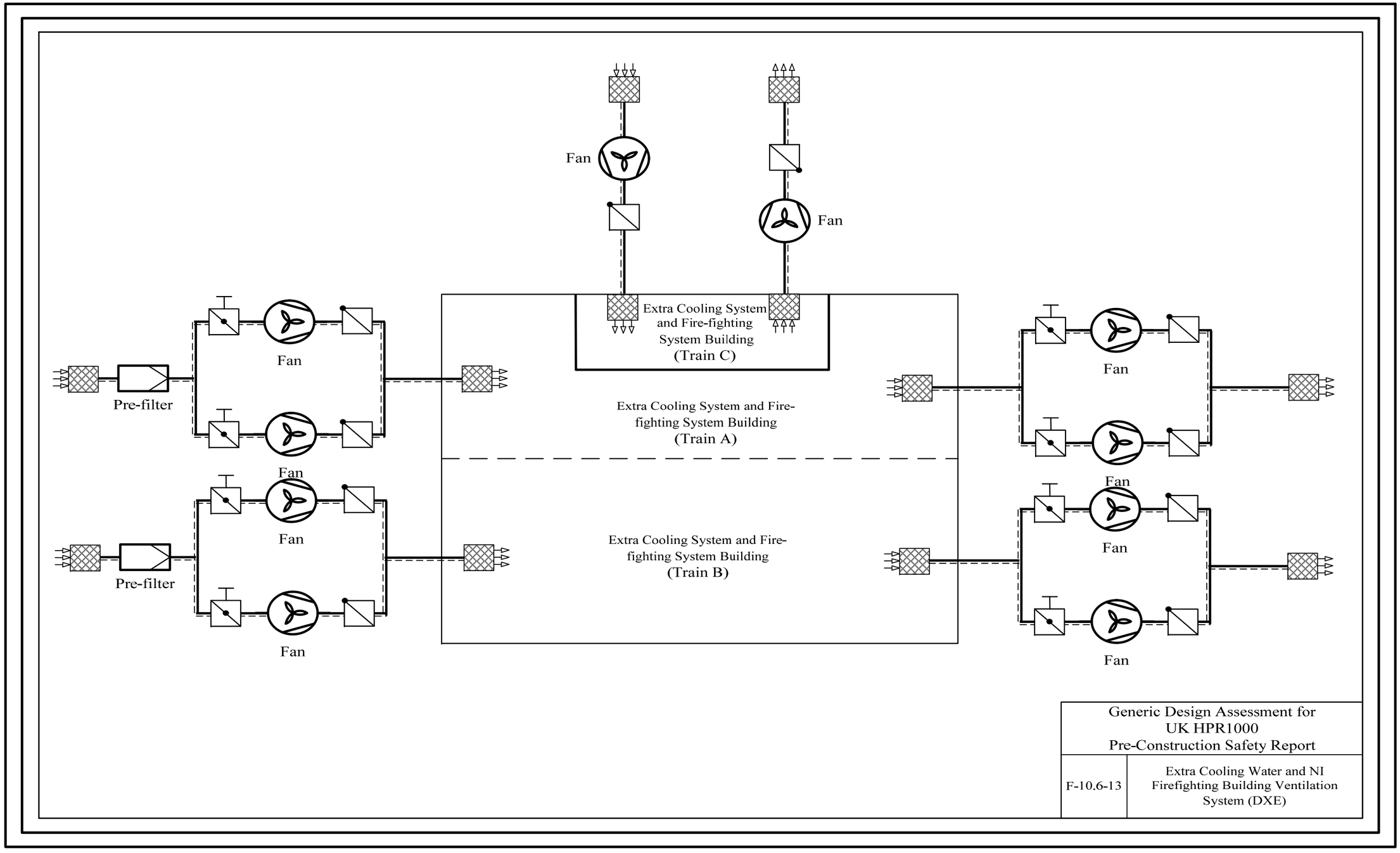
F-10.6-10 Simplified Diagram of the DVW [ABUAVS]-DWW [ABCAVS]



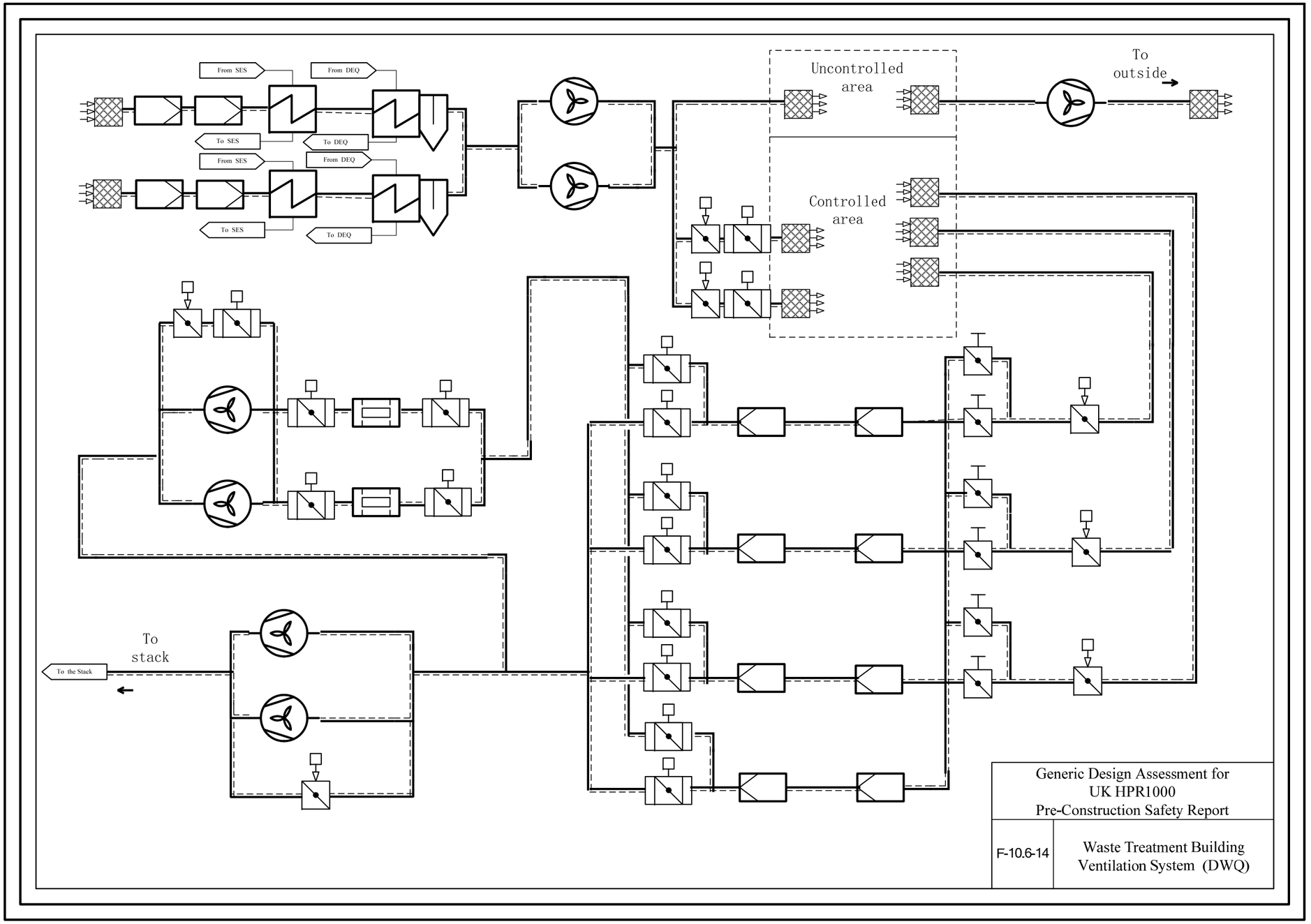
F-10.6-11 Simplified Diagram of the DVD [DBVS]



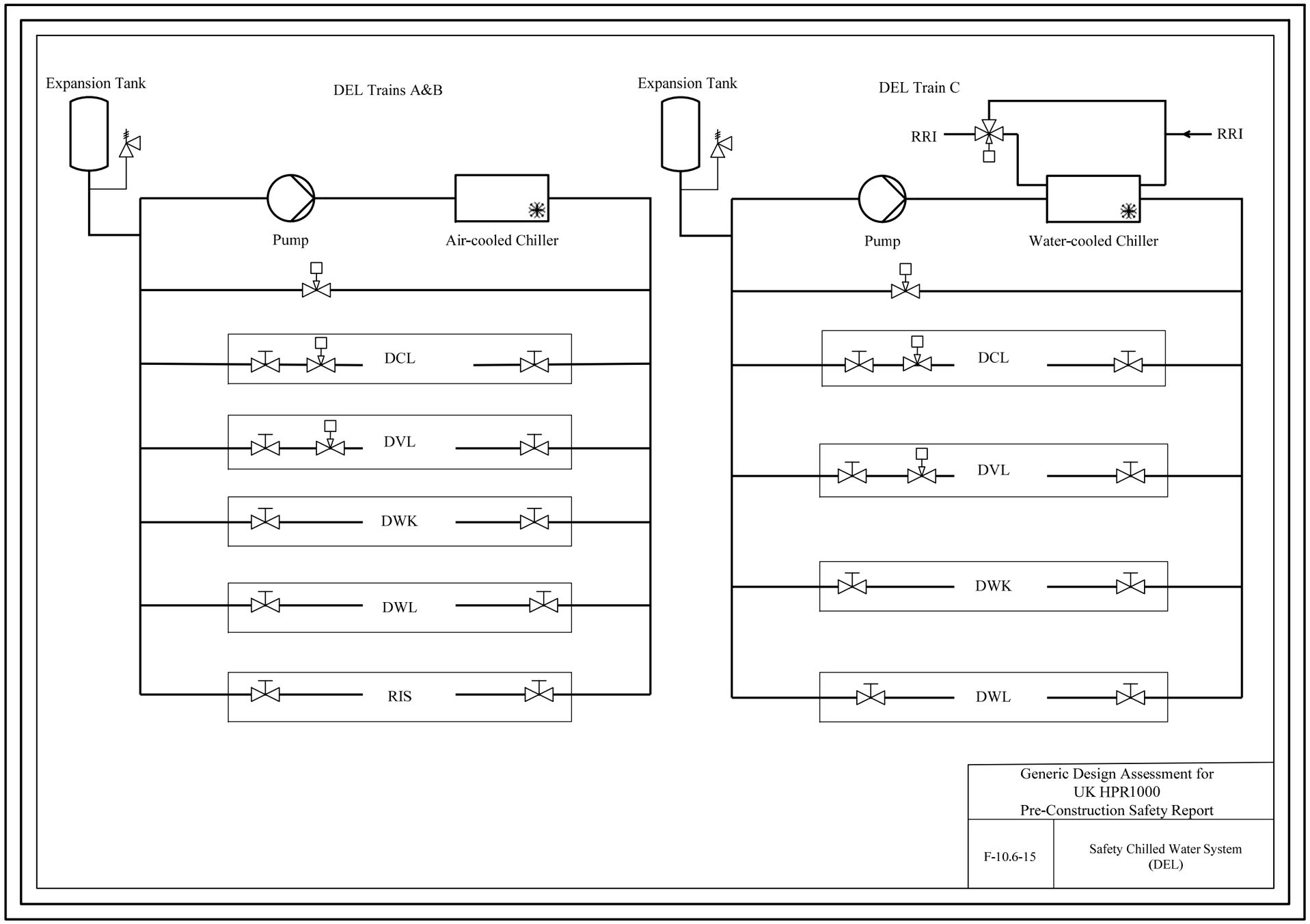
F-10.6-12 Simplified Diagram of the DXS [ESWVS]



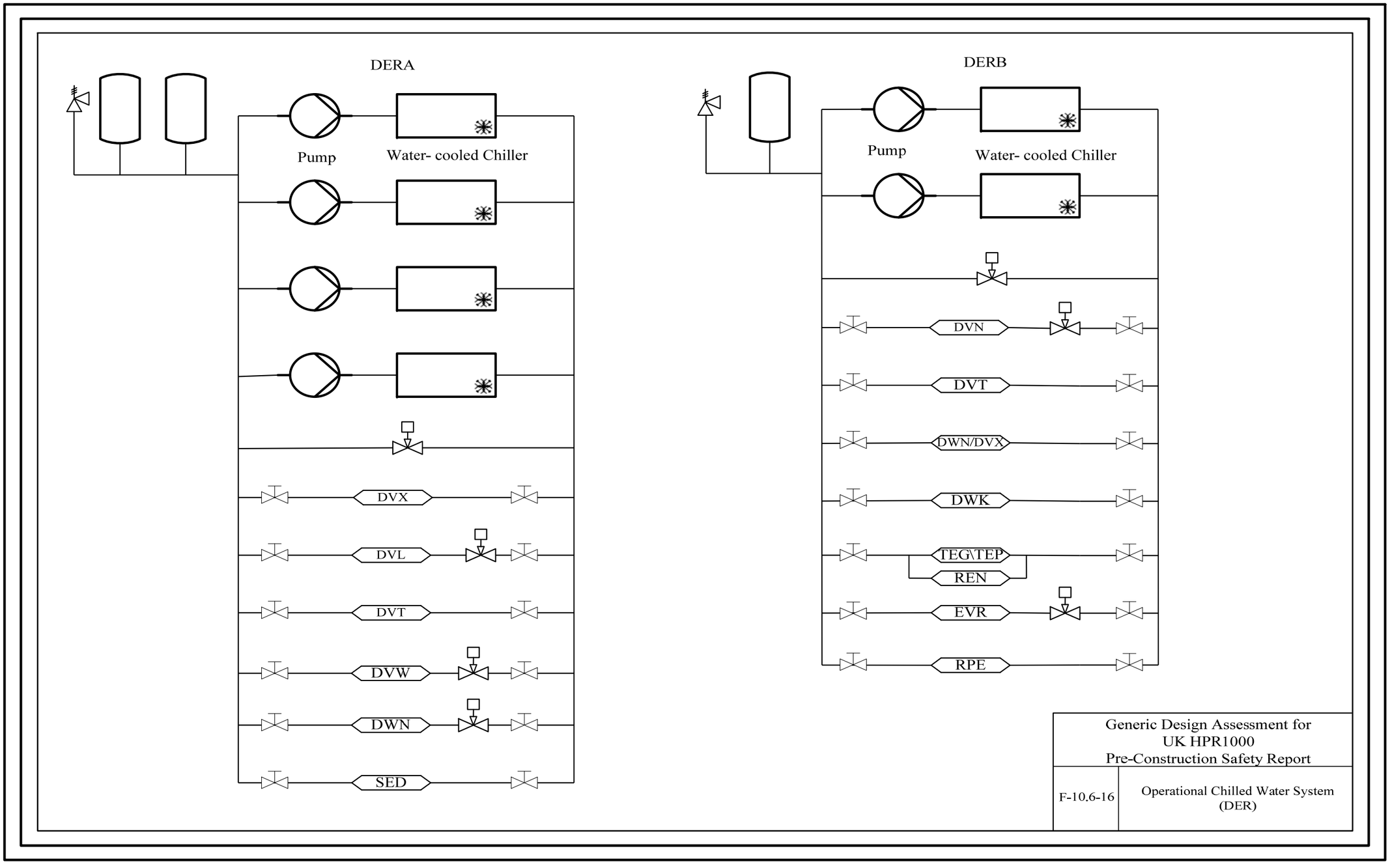
F-10.6-13 Simplified Diagram of the DXE [ECW&FFB VS]



F-10.6-14 Simplified Diagram of the DWQ [WTBVS]



F-10.6-15 Simplified Diagram of the DEL [SCWS]



F-10.6-16 Simplified Diagram of the DER [OCWS]

10.6.22 Tables of Design Assumptions

T-10.6-35 Pressure Gradients

No.	Area	Pressure gradient	Remark
1	Between the rooms with iodine contamination risk and the adjacent low pollution rooms	-20Pa	
2	Between controlled areas of the nuclear auxiliary building and the atmosphere	-100Pa	
3	Between controlled areas of the safeguard building and the atmosphere	-100Pa	
4	Between the fuel building and the atmosphere	-100Pa	
5	Between the reactor building and the atmosphere	-100Pa	
6	Between controlled areas of the waste treat building and the atmosphere	-100Pa	

T-10.6-36 Negative Pressure of Controlled Areas

No.	Area	Negative pressure	Remark
1	Annulus	-3000Pa ~-200Pa	
2	Reactor building	-4000Pa~+6000Pa	During normal operation

T-10.6-37 Airtightness of Isolation Dampers

No.	Airtightness level	Internal leaktightness	External leaktightness
1	Reinforced	≤0.1 $Nm^3/h/m^2$	≤0.01 $Nm^3/h/m^2$
2	Normal	≤10 $Nm^3/h/m^2$	≤1.5 $Nm^3/h/m^2$

T-10.6-38 Efficiency of HEPA Filters

No.	Efficiency	Remark

No.	Efficiency	Remark
1	99.99%	Factory test (sodium flame method)

T-10.6-39 Efficiency of Iodine Adsorbers

No.	Decontamination factor	Remark
1	1000	Methyl iodide

T-10.6-40 External Conditions for Safety Classified Systems

No.	Parameters	Value	Unit	Remark
1	Non-guaranteed 2-hour maximum dry-bulb temperature	36.1	°C	Coincident
2	Non-guaranteed 2-hour maximum coincident wet-bulb temperature	30.1	°C	
3	Non-guaranteed 2-hour minimum dry-bulb temperature	3.7	°C	Coincident
4	Non-guaranteed 2-hour minimum coincident wet-bulb temperature	3.2	°C	
5	Extreme high dry-bulb temperature	37.9	°C	
6	Extreme low dry-bulb temperature	-1.8	°C	

T-10.6-41 External Conditions for Non-classified Systems

No.	Parameters	Value	Unit	Remark
1	Dry-bulb temperature for air-conditioning in summer	32.2	°C	Coincident
2	Wet-bulb temperature for air-conditioning in summer	28.6	°C	
3	Daily mean dry-bulb temperature for air-conditioning in summer	31.9	°C	Coincident
4	Dry-bulb temperature for air-conditioning in winter	6.1	°C	
5	Relative humidity for air-conditioning in winter	75.5	%	
6	Dry-bulb temperature for ventilation in summer	30.6	°C	
7	Dry-bulb temperature for ventilation in winter	13.7	°C	

T-10.6-42 Environmental Requirements for Main Buildings under Normal Conditions

Environmental Conditions for the Reactor Building during Plant Normal Operation

Area	Min Temperature	Max Temperature	Relative Humidity	Remark
a) Operating platform				
— during Reactor in Power	15°C	38°C	Not required	The maximum inlet temperature of the CRDM is 40°C
— during Refuelling	18°C	30°C	Not required	Note1
b) Annulus	5°C	40°C	Not required	Contain pipes with 1400 ppm boracic acid
c) Reactor pit				
—Ventilation at the bottom of the pits to the area of the RPV support ring	—	50°C	Not required	
— Exhaust of the main duct hole at the pits area	—	75°C	Not required	
—Reactor pit concrete surface	—	95°C	Not required	
— Other	—	—	Not required	
d) Main equipment compartment	15°C	55°C	Not required	
e)Annular space	10°C	38°C	Not required	
f)staircases, elevator room	10°C	38°C	Not required	
g) Special area	—	—	—	

Area	Min Temperature	Max Temperature	Relative Humidity	Remark
h) Other rooms	15°C	45°C	Not required	Note2

Note 1: The maximum temperature during plant shutdown shall be determined by activity types and proper economic considerations.

Note 2: The maximum temperature of the rare occupation zone is 55°C, as long as the equipment in those areas can operate as intended.

Environmental Conditions for I&C, Electrical Areas and other Nuclear Island Buildings during Plant Normal Operation

Area	Min Temperature	Max Temperature	Relative Humidity	Remark
Main control room	18°C	24°C	40%<RH<60%	
I&C, computer rooms and RSS	18°C	26°C	30%<RH<70%	
Communication cabinet rooms	18°C	28°C	35%<RH<75%	
Switchgear rooms	10°C	35°C	RH<70%	
Cable floor	5°C	35°C	Not required	
Battery rooms	15°C	28°C	RH<70%	15°C - 28°C in floating charge condition; 15°C - 35°C in average charge condition

Environmental Conditions for Mechanical and Other Areas of the Other Nuclear Island Buildings during Plant Normal Operation

Area	Min Temperature	Max Temperature	Relative Humidity	Remark
Mechanical Area:				
Frequent and long occupation zone	18°C	30°C	Not required	The maximum temperature of the lounge and laboratory is 26°C
Frequent and short occupation zone	10°C	38°C	Not required	
Occasional and long occupation zone	10°C	38°C	Not required	The maximum temperature for long occupation is 30°C
Occasional and short occupation zone	10°C	45°C	Not required	Note1, note2
Rare occupation zone	10°C	45°C	Not required	
Special area	—	—	—	
Habitable areas**:**				
a) Offices, kitchen	18°C	26°C	Not required	
b) Sanitary, changing rooms	18°C	26°C	Not required	

Note 1: The maximum temperature range of the main feed and main steam valve rooms is 5°C~ 40°C.

Note 2: The maximum temperature of the TEG decay tank room is 38°C.

Environmental Conditions for Buildings during Plant Normal Operation

Area	Min Temperature	Max Temperature	Relative Humidity	Remark

Area	Min Temperature	Max Temperature	Relative Humidity	Remark
Diesel Building:				
Diesel electrical rooms	10°C	35°C	RH<70%	Note1
Diesel hall	10°C	45°C	Not required	The maximum temperature is 50°C when external temperature is extremely high.
Auxiliary equipment rooms	5°C	45°C	Not required	
Main fuel tank rooms	5°C	45°C	Not required	
Daily fuel tank rooms	5°C	45°C	Not required	
Lubricant oil tank rooms	5°C	45°C	Not required	According to the type of diesel.
Other rooms	5°C	—	Not required	
Essential Service Water Pumping Station:				
a) SEC pipe rooms	4°C	45°C	Not required	The maximum temperature is 50°C when external temperature is extremely high.
b) SEC pump rooms	4°C	45°C	Not required	
c) Other rooms	4°C	45°C	Not required	
Extra Cooling Water and NI Firefighting Building:				
All	4°C	45°C	Not required	The maximum temperature is 50°C when external temperature is extremely high.
Access Building:				
a) Sanitary installations, permanent working places, offices	18°C	26°C	Not required	
b) Other rooms	18°C	30°C	Not required	
Radioactive Waste Building:				
a) Sanitary, changing rooms	18°C	26°C	Not required	

Area	Min Temperature	Max Temperature	Relative Humidity	Remark
b) Laundry	18°C	26°C	Not required	
c) Control rooms	18°C	26°C	30%<RH<70 %	
d) Electrical rooms	10°C	35°C	RH<70%	
e) Other rooms	10°C	40°C	Not required	

Note1: The maximum temperature for transformers, electric commutators and converters is 45°C.

T-10.6-43 Environmental Requirements for Main Buildings under Accident Conditions

Building	Minimum Temperature	Maximum Temperature	Remark
Safeguard buildings			
Main control room	18°C	24°C	Extended to 13°C-35°C in 2 hours; Extended to 17°C-29°C in 24 hours
I&C cabinet room	18°C	26°C	Extended to 5°C-45°C in 24 hours.
Remote shutdown station	18°C	26°C	Extended to 13°C-35°C in 2 hours; Extended to 17°C-29°C in 24 hour
Switchboard room	10°C	35°C	a) The maximum temperature for the transformer, rectifier and inverter is 45°C; b) Extended to 5°C-50°C in 2 hours.
Battery room	15°C	28°C	15°C-28°C is the temperature for the floating charge state; the temperature for equalised charging is 15°C-35°C. Extended to 40°C in 24 hours.
Equipment ventilation room	5°C	45°C	---

Building	Minimum Temperature	Maximum Temperature	Remark
Communication cabinet room	18°C	28°C	Extended to 5°C-40°C in 24 hours.
Fire alarm equipment room	18°C	28°C	Extended to 0°C-40°C in 24 hours.
Cable room	5°C	40°C	Maximum temperature extended to 45°C in 2 hours
RRI [CCWS] pump station	5°C	45°C	---
RIS [SIS] pump station	5°C	45°C	The minimum temperature requirement is 10°C in 24 hours after DBC
EHR [CHRS] pump station	5°C	45°C	The minimum temperature requirement is 10°C in 24 hours after DEC-A and SA.
RBS [EBS] pump station	20°C	45°C	There are pipelines of 7000ppm boric acid in this room.
ASG [EFWS] pump station	5°C	45°C	---
DEL [SCWS] pump station	5°C	45°C	---
Concentrated area of nuclear grade valves	5°C	55°C	---
Nuclear grade boric acid pipes room	20°C	---	a) Pipelines of 7000ppm boric acid inside; b) Maximum temperature is required for the room itself.
Fuel building			
PTR [FPCTS] pump station	5°C	45°C	---
EUF [CFES] pump station	5°C	45°C	---

Building	Minimum Temperature	Maximum Temperature	Remark
RBS [EBS] pump station	20°C	45°C	There are pipelines of 7000ppm boric acid in this room.
Concentrated area of nuclear grade valves	5°C	55°C	---
Nuclear grade boric acid pipes room	20°C	---	a) Pipelines of 7000ppm boric acid inside; b) Maximum temperature is required for the room itself.
Fuel handling lobby	0°C	Not required	---
Other rooms	0°C	Not required	---
Nuclear auxiliary building			
Electrical room	5°C	50°C	Only for short term loss of offsite power accidents.
I&C cabinet room	5°C	45°C	Only for short term loss of offsite power accidents.
Other rooms	0°C	Not required	---
Emergency diesel generator buildings and SBO diesel generator buildings			
Diesel generator electrical room	10°C	40°C	The maximum temperature for transformer, rectifier and inverter is 45°C

Building	Minimum Temperature	Maximum Temperature	Remark
Diesel generator lobby	10°C	45°C	a) Maximum temperature is controlled at 55°C if there is an extreme outdoor temperature; b) Minimum temperature can reach 5°C if the diesel generators are not in operation.
Auxiliary equipment room	0°C	Not required	---
Main fuel tank room	5°C	Not required	---
Daily fuel tank room	5°C	Not required	---
Lubrication oil tank room	0°C	Not required	---
Other rooms	0°C	Not required	---
Essential service water pumps station and gallery			
SEC [ESWS] pump station	4°C	45°C	Maximum temperature is controlled at 55°C if there is an extreme outdoor temperature.
SEC [ESWS] gallery	0°C	Not required	---
Other areas	0°C	Not required	---
Extra cooling water and nuclear island fire-fighting pump station			
ECS [ECS] pump station	4°C	45°C	Maximum temperature is controlled at 55°C if there is an extreme outdoor temperature.

Building	Minimum Temperature	Maximum Temperature	Remark
JAC [FWPS] pump station	4°C	45°C	Maximum temperature is controlled at 55°C if there is an extreme outdoor temperature.
Other areas	0°C	Not required	---

T-10.6-44 Minimum Air Renewal Rates

No.	Area	Air renewal rate	Remark
1	Rooms with iodine risk	4 vol/h	
2	Rooms with aerosol or uncertain atmospheric contamination risk	2 vol/h	
3	Rooms without aerosol or uncertain atmospheric contamination risk	1 vol/h	
4	Uncontrolled area	0.5 vol/h	
5	Laboratory in the BNX	8 vol/h	

10.7 Fire Protection Systems

10.7.1 Sub-chapter Structure

The structure of Sub-chapter 10.7 is as follows:

a) Sub-chapter 10.7.1 (Sub-chapter Structure) gives the overall structure of Sub-chapter 10.7;

b) Sub-chapter 10.7.2 (Applicable Codes and Standards) presents the relative codes and standards adopted in this chapter;

c) Sub-chapters 10.7.3 to 10.7.5 present the following fire protection systems:

   1) 10.7.3 Fire Alarm System;

   2) 10.7.4 Fire-fighting System;

   3) 10.7.5 Smoke Control System for the Nuclear Island;

These sub-chapters give the detailed description of fire protection systems;

d) Sub-chapter 10.7.6 (ALARP Assessment) gives the preliminary ALARP analysis of this chapter;

e) Sub-chapter 10.7.7 (Concluding Remarks) presents the summary and the on-going work of this sub-chapter;

10.7.2 Applicable Codes and Standards

Standards have been adopted in Sub-chapter 10.7 and are identified in Table T-10.7-1. The conformity analysis and gap analysis of codes and standards is currently being undertaking.

T-10.7-1 Applicable Codes and Standards in Sub-chapter 10.7

Codes and Standards Number	Title	Scope of Application
IAEA No. NS-G-1.7	Protection Against Internal Fires and Explosions in the Design of Nuclear Power Plants Safety Guide	Fire-fighting systems, Fire alarm system
ETC-F 2010	EPR Technical Code for Fire Protection	
BS9999,2008	Code of Practice for Fire Safety in the Design, Management and Use of Buildings	
ETC-F 2010	EPR Technical Code for Fire Protection	Smoke

Codes and Standards Number	Title	Scope of Application
BS9999,2008	Code of Practice for Fire Safety in the Design, Management and Use of Buildings	Control System

10.7.3 Fire Alarm System

10.7.3.1 Safety Functional Requirements

10.7.3.1.1 Control of Reactivity

Not applicable. The fire alarm system does not directly contribute to the main safety function of control of reactivity.

10.7.3.1.2 Removal of Heat

Not applicable. The fire alarm system does not directly contribute to the main safety function of fuel heat removal.

10.7.3.1.3 Confinement

Not applicable. The fire alarm system does not directly contribute to the main safety function of confinement.

10.7.3.1.4 Extra Safety Functions

The fire alarm system is implemented for detecting fire at an early stage, and is generally incorporated in all buildings. The system also triggers the fire alarm, provides location information of the fire and in some cases sends the fire alarm signal to the DCS (Digital Control System) to initiate automatic actions.

10.7.3.2 Design Assumptions

10.7.3.2.1 Control of Reactivity

Not applicable.

10.7.3.2.2 Removal of Heat

Not applicable.

10.7.3.2.3 Confinement

Not applicable.

10.7.3.2.4 Extra Safety Functions

The following safety and qualification classifications shall be considered:

- Functional classification: FC3,

- Component Classification: F-SC3,
- Seismic classification: SSE1 in operation.

Mechanical classification does not apply to the JDT [FAS].

The fire alarm system is designed to be permanently in operation. The fire alarm system shall be ready to transmit a fire alarm or a disturbance signal in the MCR, whether it is supplied by a main or a secondary source.

The fire alarm system is designed to be able to ensure:

- The rapid detection of fires starting
- The location of the fire source
- The monitoring of the fire progress
- The triggering of an alarm and in some cases, the indirect control of the fire dampers and smoke vents

10.7.3.3 System Description and Operation

10.7.3.3.1 System Description

a) General System Description

The fire alarm system can continuously monitor the plant through fire detectors that are placed at various places within the plant. The system can quickly detect fires, automatically activate alarms, provide the exact location of a fire and monitor the development of the fire. The fire alarm system can initiate automatic actions when necessary. Fire alarm control units provide the DCS with all the fire information required for the operation of the fire protection system in the NI. The signal is confirmed by double detection.

The fire alarm system provides audible and/or visual alarms in the MCR.

b) Description of Main Equipment

1) Fire Detectors

Fire detectors are located at fixed points in various areas of the plant, which are divided into detection zones.

The type of detector at each location is chosen with respect to the particular fire phenomena applicable to the equipment or location being monitored (temperature, flame, smoke, combustion gas, etc.) and to the accessibility and atmospheric conditions of its installation.

Fire detectors of the following types are mainly used:

- Smoke detector

- Flame detector
- Heat detector
- Line-type heat detector
- Aspirating smoke detector
- Hydrogen detector

2) Fire Alarm Control Unit

The fire alarm control unit performs the fire alarm and fault alarm functions, and issues different audible and visual alarm signals in the event of a fire alarm and fault alarm. The fire alarm control unit is able to store and retrieve the alarm information. Fire detectors are linked to the fire alarm control unit.

3) Remote Control Unit

The remote control unit is located in the MCR, which is used for centralised indication and operations of the fire alarm units.

4) Supervisor

The supervisor is located in the MCR. It consists of a computer connected to the central fire alarm control units and a monitor to display the relevant information including audible and visible fire alarms, fire zoning drawings and location of the detector, etc.

5) Local Mimic Panel

Nuclear island buildings are equipped with local mimic panels, which indicate the location of the room where a fire has started. These panels help to locate the origin of the fire.

10.7.3.3.2 System Operation

a) Normal System Operating Conditions

1) During Plant Normal Operation

The fire alarm system shall be permanently in service.

However, it is possible to switch off a part of the detection temporarily under certain conditions (such as for preventive maintenance).

2) During Plant Degraded Operation

In case of a lack of the 220VAC uninterrupted power supply, the main equipment of the fire alarm system is supplied from 24V storage batteries dedicated to fire detection (8 hour autonomy) which are supplied by the backup main power supply. In case of earthquakes, the fire alarm system can

be functional after a SSE.

b) System Operation in Case of Failure

The system alarm function shall not be affected in case of a single point loop breaking. Single detection equipment failure shall not affect the rest of the detection equipment.

Fire alarm control units are set up in trains. The failure of the fire alarm unit of one train shall not affect the operation of the rest of the units in other trains.

The plant will lose fire alarm function after a fire alarm system failure.

10.7.3.4 Preliminary Design Substantiation

10.7.3.4.1 Compliance with Safety Functional Requirements

a) Control of Reactivity

Not applicable. The fire alarm system does not directly contribute to the main safety function of control of reactivity.

b) Removal of Heat

Not applicable. The fire alarm system does not directly contribute to the main safety function of fuel heat removal.

c) Confinement

Not applicable. The fire alarm system does not directly contribute to the main safety function of confinement.

d) Extra Safety Functions

The fire alarm system is implemented for detecting fire at an early stage, and is generally incorporated in all buildings. The system also triggers the fire alarm, provides the locational information of the fire and in some cases sends the fire alarm signal to the DCS to initiate automatic actions.

10.7.3.4.2 Compliance with Design Requirements

a) Safety Classification

The Fire alarm system design is compliant with the engineering principles described in Chapter 4. The classification of fire alarm system functions is listed in Table T-10.7-2.

T-10.7-2 Safety Category of System Function

System Function	Safety Category
Fire alarm system	FC3

b) Engineering Design Requirements

1) Single Failure Criterion (SFC)

- Single Failure Criterion (SFC)

  The fire alarm system in safety fire compartments and safety fire cells meets the random failure criterion. The random failure of an active equipment item of the fire alarm system shall not lead to a common failure mode on the systems required to perform the safety functions.

- Independence

  There is no independence requirement for the fire alarm system.

- Diversity

  The choice of detector depends mainly on the type of the fire and the environment in which the detector is installed. In some cases, some important equipment is covered by different types of detectors. For example, smoke and flame detectors are employed in the diesel building, fuel oil storage room and charge pump room in the nuclear auxiliary building.

- Fail-safe

  The concept of fail-safe is not considered in the design of the fire alarm system.

- Ageing and Degradation

  Periodic testing enables the following functions to be checked:

  Each fire alarm control unit, remote control unit, local mimic panel, supervisor and detector operates correctly;

  The fire alarm signal and fault alarm signal are transmitted and stored correctly.

  Testing and maintenance of the system equipment is implemented at the manufacturer’s recommended intervals.

2) Autonomy

Not applicable.

3) Human Factors

The principles of human factors shall be considered in the fire alarm system design.

Displays that are monitored during a control manipulation are located such

that they should be visible from the user's operating position. Equipment design should provide flexibility and be modular to allow future modifications to be made without imposing high demands on personnel for installation and maintenance.

Important or frequently used displays should be within 30 degrees on either side of the lateral line of sight at the user's normal operating position; not more than 35 degrees above and 25 degrees below the horizontal line of sight on vertical panels; and not more than 20 degrees above and 40 degrees below the horizontal line of sight at seated consoles.

The intensity of audible alarm signals should be approximately 10 dB above the normal ambient noise level but not greater than 15 dB above the normal ambient noise level. In relatively large local plant operating areas, each panel should be provided with its own sound source.

The color-coding on displays for the fire alarm system status should conform to Table T- 10.7-3"Colours for Displays".

T- 10.7-3 Colors for Displays

Colour	**Meaning**
Red	Fire alarm
Green	Normal condition
Yellow	Component or loop fault

4) Other Design Requirements

- Prevention of Harmful Interactions of Systems Important to Safety

  Not applicable.

- Considerations Related to the Electrical Power Grid

  Not applicable.

c) Equipment Qualification

The documents relevant to the equipment qualification will be delivered before the step 4 of GDA.

d) Protection Design against Internal and External Hazards

1) Internal Hazard Protection

Fire protection measures shall be designed so that in the event of a fire they

are functional.

2) External Hazard Protection

The design of fire protection systems takes into account:

- Earthquakes

  The fire alarm system is seismically classified, so that it can be functional after a SSE.

- The crash of an aircraft

  The fire alarm system is designed to fulfil its function after a crash of a small plane. The fire alarm system is installed in the interior of the NI, so we don't consider the crash of an aircraft further.

- Extreme heat

  The fire alarm system is located indoors, the temperature is maintained by the HVAC systems. The fire alarm system is designed according to the highest temperature in the room.

- Extreme cold

  The fire alarm system is located indoors, the temperature is maintained by the HVAC systems. The fire alarm system is designed according to the lowest temperature in the room.

- Flooding

  The rooms, where the fire alarm system is installed, are designed to defend against external flooding according to Chapter 18.

- Projectiles carried by the wind

  The buildings, where the fire alarm system is installed, are designed to defend against projectiles carried by the wind, which provides enough protection for the fire alarm system. Therefore, no further measures are considered for the fire alarm system.

e) Commissioning

Documents related to the commissioning will be delivered before the step 4 of GDA.

f) Examination, Inspection, Maintenance and Testing

1) Examination and Inspection

Not applicable.

2) Maintenances

Testing and maintenance of the system equipment are implemented at the manufacturer's recommended intervals.

3) Periodic Tests

Periodic testing enables the following functions to be checked:

- Each fire alarm control unit, remote control unit, local mimic panel, supervisor and detector operates correctly;
- The fire alarm signal and fault alarm signal are transmitted and stored correctly.

g) Decommissioning

Decommissioning about the fire alarm system is still undertaken in this stage.

h) Special Thermal-hydraulic Phenomena

Not applicable.

i) Insulation

Not applicable.

10.7.3.5 Simplified Diagrams

The simplified diagram is presented in Figure F-10.7-1.

10.7.4 Fire-fighting Systems

The fire-fighting systems which fall into the category of the fire protection system are used to extinguish the fires which have started, limit the spread of fire and to protect the safety functions of the facility. The fire-fighting systems consist of JAC [FWPS], JPI [FWSNI], and Fire Extinguishing System for Nuclear Island Diesel Generator Building (JPV [FSDB]).

10.7.4.1 Safety Functional Requirements

10.7.4.1.1 Control of Reactivity

Not applicable. The JAC [FWPS], JPI [FWSNI] and JPV [FSDB] do not directly contribute to the main safety function of control of reactivity.

10.7.4.1.2 Removal of Heat

Not applicable. The JAC [FWPS], JPI [FWSNI] and JPV [FSDB] do not directly contribute to the main safety function of heat removal.

10.7.4.1.3 Confinement

The containment isolation valves of the JPI [FWSNI] must also provide the basic safety function of "confinement of radioactive substances" to avoid dispersion of radiological substances outside of containment in DBC-2, DBC-3, DBC-4 or DEC conditions. It contributes to the function of "ensuring the integrity of the containment". The other parts of the JPI [FWSNI], JAC [FWPS] and JPV [FSDB] do not directly contribute to the main safety function of confinement.

10.7.4.1.4 Extra Safety Functional Requirement

a) Supporting the Fundamental Safety Functions

The fire-fighting tanks participate in emergency water supply for classified system in DEC-A conditions.

If the JAC [FWPS] and JPI [FWSNI] are available, the JAC [FWPS] support the RRI [CCWS] functions by providing water when the normal water supply system for the RRI [CCWS] is unavailable following a seismic event.

b) Protect and Mitigate Hazards Impact

1) Fire

The JAC [FWPS], JPI [FWSNI], JPV [FSDB] are used to extinguish the fire which do start, limit the spread of fire, and to protect the safety functions of the facility.

An independent fire is postulated to be able to break out during the following cases, The JAC [FWPS], JPI [FWSNI], JPV [FSDB] need be available:

- The long term phase after reaching the safe shutdown state, after a DBC-2, DBC-3, DBC-4.
- In the post-accident long-term phase no earlier than two weeks after the DEC event.
- In the post-earthquake long-term phase not earlier than two weeks after a design basis earthquake (only the fire- fighting system for FC1 and FC2 functions needs need be available).

2) Earthquake

The JAC [FWPS], JPI [FWSNI], and JPV [FSDB] must ensure the stability/integrity of components in order to not to adversely impact the availability of SSE1 items following a seismic event.

10.7.4.2 Design Requirements

The general design requirements of the fire-fighting systems which need to be

considered are shown in Sub-chapter 10.2.4, among which the following requirements are not applicable for the fire-fighting system:

a) Autonomy in Respect of Heat Sink

Not applicable, because the JAC [FWPS], JPI [FWSNI], and JPV [FSDB] doesn't provide a heat sink to the power plant.

b) Prevention of Harmful Interactions of Systems Important to Safety

Not applicable, because the JAC [FWPS], JPI [FWSNI], and JPV [FSDB] doesn't have harmful interactions of systems important to safety.

c) Insulation

Not applicable, because the JAC [FWPS], JPI [FWSNI], and JPV [FSDB] doesn't have insulation design.

The substantiation analysis of the JAC [FWPS], JPI [FWSNI], and JPV [FSDB] to other design requirements is shown in the section Compliance with Design Requirements.

10.7.4.3 Design Bases

10.7.4.3.1 General Assumptions

a) Safety Classification

The containment isolation valves of the JPI [FWSNI] must provide the basic safety function of "confinement of radioactive substances", they are FC1 items. The other parts of the system are used to prevent, protect and mitigate against the fire impact, therefore the safety classification is FC3.

b) Ageing and Degradation

The components of fire-fighting systems don't need to be designed for the 60 years plant operation by force. Some components will need to be replaced at the end of their individual designed life. The layout design will take into the consideration of the need to remove the old parts and to install the replacements.

The ageing effect concerning individual components have been taken into consideration in the system design. The selection of components shall meet the applicable British standard.

c) Autonomy

Not applicable.

d) Equipment Qualification

The fire-fighting system should be available in postulated fire condition and the

facilities which need to be operation operated should be approachable.

e) Considerations Related to the Electrical Power Grid

Not applicable.

f) Prevention of Harmful Interactions of Systems Important to Safety

Not applicable.

g) Protection against Internal and External Hazards

Not applicable.

10.7.4.3.2 Design Assumptions

a) Control of Reactivity

Not applicable.

b) Removal of Heat

Not applicable.

c) Confinement

The containment isolation valves of the JPI [FWSNI] must provide the basic safety function of “confinement of radioactive substances”. It contributes to the function of “ensuring the integrity of the containment”.

d) Extra Safety Functional Requirement

In design extension conditions, the JAC [FWPS] fire-fighting water tanks are used as emergency water compensatory source for classified systems.

If the JAC [FWPS] and JPI [FWSNI] available, the JAC [FWPS] supports the RRI [CCWS] functions by providing water by hose reel of JPI [FWSNI] system when the normal water supply system for RRI [CCWS] is lost.

Overall, the fire-fighting water systems are comprised of:

1) Fire water tanks and fire pumps for the fire-fighting water supply. This part of the JAC [FWPS] is designed to meet the demands of fires in the nuclear island, conventional island and BOP during operation and shutdown of the nuclear power plant. This includes the postulated fire which could break out in two weeks after earthquakes in the non-seismically qualified parts of the nuclear island. The design of the JAC [FWPS] meets the requirements of relevant standards (for example ETC-F 2010) and experience from the design or operation of nuclear power plants. It ensures that there is enough water volume and pressure to meet the demand of a fire when one pump or tank is unavailable. The power supply of the pumps is diverse so that the JAC

[FWPS] can achieve its function when the external electrical power is lost or one of the back-up power sources is lost.

The JAC [FWPS] network produces and distributes fire-fighting water to JPI [FWSNI] and JPV [FSDB] at a suitable pressure. The JPI [FWSNI] supplies the JPV [FSDB] with fire-fighting water from the safeguard buildings.

2) The stabilised pressure part of the JAC [FWPS] maintains the pressure in the fire-fighting systems while they are in standby, when the system is operational.

3) The standpipes used to transfer fire-fighting water to fire-fighting system in buildings.

4) The fixed extinguishing systems are installed according to fire hazard analysis. The following depiction is according to preliminary analysis.

- The sprinkler systems used to extinguish the fire where it has risk to spread or is difficult to extinguish manually according to analysis.
- The water spray systems used to extinguish oil fire, the flash point of oil is over 60°C and volume is more than 100L.
- The combined sprinkler- foam systems used to extinguish oil fire, the flash point of oil is below 60°C and volume is more than 100L.
- The combined deluge- foam systems used to extinguish oil tank fire, the flash point of oil is below 60°C and volume usually is large.
- The iodine filters containing more than 100kg active carbon are protected by a connection from the flood pipe to the fire hose station standpipe located close by.

10.7.4.4 System Description and Operation

10.7.4.4.1 System Description

a) General System Description

1) Piping Networks for Water Production

The JAC [FWPS] network is composed of two redundant fire-fighting water tanks of demineralised water and three fire-fighting pumps each supplying 100% of the requirement for the most adverse situation in the nuclear island. Note: two pumps are necessary for the largest requirement of the site which is located outside the nuclear island.

In an emergency, the staff can also supply the water by fire trucks or mobile fire pumps which suck water from the fire tanks and then feed it to the piping network through the interface installed on it.

The pumps can use either of the fire-fighting water tanks and discharge into a common collector which can be isolated into two parts and assures the supply to the looped piping network in the nuclear island and the diesel generator building. Each pump is powered by a different electrical train. The power supply for fire pumps is backed up by different diesel generator.

The JAC [FWPS], JPI [FWSNI] and JPV [FSDB] are maintained permanently under the standby pressure by the stabilised pressure part of the JAC [FWPS] in the Conventional Island. Since this function does not necessarily participate in nuclear island fire-fighting, it is not classified.

2) Networks for the JPI [FWSNI] and JPV [FSDB]

The fire-fighting system in the nuclear island buildings comprises of standpipes including fire hose stations as well as valve units required for the different fixed water sprinkler systems.

The JPI [FWSNI] and JPV [FSDB] are not strictly redundant and are made up of a single train. However, the available interconnections and the existence of sectioning valves must enable any point in the fire piping network to be supplied by at least two different routes.

The JPI [FWSNI] supplies the following buildings with fire-fighting water:

- Reactor Building (BRX) ;
- Fuel Building (BFX) ;
- Nuclear Auxiliary Building (BNX) ;
- Safeguard Building (BSX) ;
- Personnel Access Building (BPX);
- Radioactive Waste Treatment Building (BWX);
- Essential Service Water Pumps Station A (BPA), Essential Service Water Pumps Station B (BPB);
- Essential Service Water Inlet Gallery, Essential Service Water Supply Gallery A (BGA) and Essential Service Water Supply Gallery B (BGB) and Essential Service Water Supply Gallery C (BGC);

The Emergency Diesel Generator Buildings A and B and C, SBO Diesel Generator Buildings U and V, and the galleries to nuclear island are provided with fire-fighting water by the JPV [FSDB].

b) Description of Main Equipment

1) The water production part of JAC [FWPS]

The capacity of the each demineralised water tank can provide fire-fighting water in the following two assumed situations:

- Water sprinkling for the most demanding fire on site together with two nozzles connected to the site fire hydrants during two hours.
- Water sprinkling for the most demanding fire in the nuclear island together with two nozzles connected to fire hose stations during two hours.

The Fire-fighting Water Production System (JAC) for each unit is equipped with three fire-fighting pumps. The outlet pipes of three fire pumps are connected to each other with a pipe which is equipped with isolation valves. The suction pipes of three fire-fighting pumps are connected to each other with a header which is equipped with isolation valves, and two water intake horn sockets shall be installed on the header. Furthermore a 100% flow shall be able to pass through by via the suction header and any of the three water intake horn sockets, so that it can be realised each fire-fighting pump can suck water from any fire-fighting water tank.

Each unit shall be equipped with two fire-fighting water tanks, reinforced concrete structures, connected to each other by a header pipe equipped with isolation valves. Outside the fire-fighting water tank building, there are water suction wells so as the water can be provided by fire trucks and mobile fire-fighting pumps.

2) The Fire Hose Stations (FHS)

All levels of the buildings except the galleries and the areas which are difficult to enter must be equipped with a sufficient number of FHS linked to the internal water distribution piping network so that it is possible to reach any equipment in any room with a nozzle, even if the room is fitted with water sprinkler pipes.

3) The Wet Pipe System (Sprinkler)

Water pipes fitted with close-type sprinklers, activated by a temperature rise. Downstream of each isolation valve in these sprinkler pipes is a flow detector.

4) The Dry Pipes (Sprinkler)

Dry pipes fitted with close-type sprinklers, activated by a rise in temperature, with two manual isolation valves on the inlet pipe.

5) The Water Spray System

These pipes are empty of water and fitted with open sprayers.

There is a remote control valve unit to enable the RBS pumps and RCP pumps to be sprayed with water (JPI [FWSNI]).

6) The Flood System for Iodine Filter

The iodine filter is protected by a connection of the flood pipe to the fire hose station standpipe located close by.

7) The Combined Sprinkler-foam System

Dry pipes fitted with close-type sprinklers, sprinklers activated by a temperature rise, using a deluge valve to enable sprinkling. One foam-tank supplies foam to the pipe to form mixture. This fire protection measure is used for the diesel generators and daily oil tank.

8) The Combined Deluge-foam System

Dry pipes fitted with open-type sprinklers, using a deluge valve to enable sprinkling. One foam-tank supplies foam to the pipe to form mixture. This fire protection measure is used for the main oil tank of diesel generators.

c) Description of Main Layout

1) Extra Cooling System and Fire-fighting System Building (BEJ)

The water production part of the JAC [FWPS] system is in BEJ.

Protection for these locations is provided by water pipes associated with fire hose stations.

2) BRX

This system plays a part in the protection of the Nuclear Island buildings against fire.

Protection of the annulus is provided by column mounted fire hose stations supplied with water by the JPI [FWSNI] and is capable of being isolated by a manual valve located outside the reactor building.

The annulus is provided with water pipes fitted with close-type sprinklers to enable the main electrical cabling axes to be sprinkled.

Fire protection for each RCP pump is provided by a fixed open-type water spray extinguishing system.

The iodine filters in the reactor building ventilation system are protected by a connection from the flood pipe to the fire hose station standpipe located close by. These pipes are activated from the MCR manually.

The containment is protected by a network of fire hose stations connected to risers, which can be connected to the water supply of the JPI [FWSNI] via

two redundant lines.

Each of these lines contains a motor-driven valve and a check valve connected in series. The motor-driven valve is located outside the containment, the check valve is located inside the containment, both as close to the containment as possible.

3) BFX

Protection of the fuel building is ensured by fire hose stations mounted on water risers supplied by the JPI [FWSNI].

Pipes fitted with sprinklers are used to protect the main electrical cable tray or cable shaft if necessary.

The iodine filters are protected by a connection of the flood pipe to the fire hose station standpipe located close by. These pipes are activated manually.

4) BNX

Protection of the nuclear auxiliary building is provided by fire hose stations on standpipes linked to the JPI [FWSNI] network. The fire hose stations are located on all levels and are easily visible from the main accesses. They enable all points of the nuclear auxiliary building to be reached.

Cable trays above the control cabinet or electrical cabinet require protection. They are protected by dry pipes fitted with close-type sprinklers. Other cable trays which require protection are protected by wet pipes fitted with close-type sprinklers.

The iodine filters are protected by a connection of the flood pipe to the fire hose station standpipe located close by. These pipes are activated manually.

5) BSX

Protection of the three safeguard building divisions is provided by fire hose stations mounted on water risers supplied by JPI [FWSNI].

Cable trays above the control cabinet or electrical cabinet require protection. They are protected by dry pipes fitted with close-type sprinklers. Other cable trays which require protection are protected by wet pipes fitted with close-type sprinklers.

The iodine filters are protected by a connection of the flood pipe to the fire hose station standpipe located close by. These pipes are activated manually.

6) BPX

Protection of the personnel access building is ensured by fire hose stations on standpipes linked to the JPI [FWSNI] network.

7) BWX

Protection of the waste treatment building is provided by fire hose stations on standpipes linked to the JPI [FWSNI] network.

Pipes fitted with close-type sprinklers are used to protect the main cable vault or cable shaft if necessary. Cable trays above the control cabinet or electrical cabinet require protection. They are protected by dry pipes fitted with close-type sprinklers.

The iodine filters in the fuel building are protected by a connection of the flood pipe to the fire hose station standpipe located close by. These pipes are activated manually.

8) BGA, BGB and BGC

The Essential Service Water Inlet Gallery is fitted with sprinkler pipes to protect the cabling axes.

9) BPA and BPB

Protection of the SEC pump stations is ensured by fire hose stations on standpipes linked to the JPI [FWSNI] network.

10) The Diesel Generator Buildings

The diesel buildings are protected by fire hose stations mounted on water risers.

The diesel hall and daily oil tank: protection for these locations is provided by a fixed installation with spray water containing 3% Aqueous Film-forming Foam Concentrate (AFFF) with close-type sprinklers.

The fuel tank room: protection of the fuel tanks is provided by a network fitted with flood type open sprayers. The sprayed water contains 3% AFFF.

Cable trays above the control cabinet or electrical cabinet require protection. They are protected by dry pipes fitted with close-type sprinklers. Other cable trays which need protection are protected by wet pipes fitted with close-type sprinklers.

11) The Diesel Generator Building Galleries

The galleries are fitted with sprinkler pipes to protect the cabling axes.

12) All Locations

Portable CO_2, powder and clean gas extinguishers can be used depending on the kind of combustible.

d) Description of System Interface

If the JAC [FWPS] and JPI [FWSNI] system are available, the JAC [FWPS] supports the RRI system functions by providing water by via hose reels of the JPI [FWSNI] system when the normal water supply system for the RRI system is unavailable

e) Description of Instrumentation and Control

The JAC [FWPS] pumps are started automatically according to the reduction of pressure in the network or manually started from the Main Control Room or locally.

The wet pipe system (sprinkler) fitted with close-type sprinklers is activated by a rise in temperature. The flow detector shall activate an alarm if a continued flow appears in the pipe for example one sprinkler is open.

Dry pipes fitted with close-type sprinklers are activated by a temperature rise, with two manual isolation valves on the inlet pipe, open manually when the fire is confirmed.

There is a remote control valve unit for the water spray system.

These flood pipes of the iodine filter are activated manually (excluding the iodine filters in the BRX).

These flood pipes for the iodine filter in the BRX are activated by motor-driven valves manually.

For the combined sprinkler-foam system, sprinklers activated by a temperature rise, using a deluge valve to enable sprinkling. The deluge valve will open automatically if there are two different fire signals given by JDT [FAS], also can be manually started from the Main Control Room or locally

Combined deluge-foam system uses a deluge valve to enable sprinkling. The deluge valve will open automatically if there are two different fire signals given by JDT [FAS], also can be manually started from the Main Control Room or locally.

10.7.4.4.2 System Operation

a) Permanent Operation

The JAC [FWPS], JPI [FWSNI] and JPV [FSDB] are on standby. The containment isolation valves are closed. The JPI [FWSNI] piping network is filled with water and maintained under pressure (except for the part inside the containment). The flood pipe connections for spray to the iodine filters and the pipes for dry sprinkler are empty of water.

The JPV [FSDB] contains no water at downstream of the deluge valves.

b) Transient Operation

A fire may occur during power operation or shutdown states:

1) On equipment or in common locations in the nuclear island (JPI [FWSNI])

An alarm occurs in the MCR and the operator calls out the response team. As a general rule, the fire can be extinguished by the use of one or several fire hose stations.

2) On the ducting of the cables of the nuclear island (except inside containment) (JPI [FWSNI], JPV [FSDB])

For cable trays above the control cabinet or electrical cabinet, these pipes don't contain water in standby, and two manual isolation valves on the inlet pipe can be opened manually when the fire is confirmed.

For the other cable trays, these pipes contain water in system standby. The operation of sprinkler is automatic. System shutdown is performed by closing the isolation valve locally.

3) Inside the containment except for the primary pumps (JPI [FWSNI])

The piping network on standby contains water, but the containment isolation valves are closed. The JPI [FWSNI] piping network is activated by remote control of the containment isolation valves.

4) RCP pumps (JPI [FWSNI])

A fixed water spray extinguishing system of flood type controlled from the MCR or locally, provides fire protection for each pump.

The water supply is then activated by the remote control of the containment isolation valves.

5) In the diesel buildings (JPV [FSDB])

The protection of the diesel rooms and daily oil tanks is provided by flooding type pipes with close-type sprinklers. Protection of the fuel tank is ensured by flooding type pipes with open-type sprinklers. The pipes do not contain water during standby mode. The water is supplied by opening the deluge valve either automatically when a fire is detected, or manually. Spraying is stopped manually by closing one of the isolation valves.

In every situation, the pressure drop in the fire-fighting network caused by a protective system being opened automatically or manually, causes the fire pumps to start automatically.

In case of an earthquake, the part of the JPI [FWSNI] which is not seismically classified can be isolated from the MCR or locally.

10.7.4.5 Preliminary Design Substantiation

10.7.4.5.1 Compliance with Safety Functional Requirements

a) Control of Reactivity

Not applicable.

b) Removal of Heat

Not applicable.

c) Confinement

The containment isolation valves of JPI the [FWSNI] must provide the basic safety function of “confinement of radioactive substances”. It contributes to the function of “ensuring the integrity of the containment”. The other parts of JPI [FWSNI] system, JAC and JPV [FSDB] do not directly contribute to the main safety function of confinement.

d) Extra Safety Functions

In DEC conditions, the fire-fighting water tanks participate in the emergency water supply for classified system through well connect to the tanks.

The JAC [FWPS] can support the RRI [CCWS] functions by providing water by hose reel of JPI [FWSNI].

The JAC [FWPS], JPI [FWSNI] and JPV [FSDB] can be used to extinguish fire when required. The part use to protect the FC1, FC2 items are seismically designed and qualified for the SSE load, so they can be used when fire break out two weeks after SSE.

10.7.4.5.2 Compliance with Design Requirements

a) Safety Classification

The JAC [FWPS], JPI [FWSNI] and JPV [FSDB] design is compliant with the engineering principles described in Chapter 4. The classification of JAC [FWPS], JPI [FWSNI] and JPV [FSDB] functions is listed in Tables T-10.7-4 and T-10.7-5.

T-10.7-4 Safety Category of System Function

System Function	Safety Category
JAC[FWPS] (BEJ)	FC3
JPI [FWSNI] containment isolation function	FC1

System Function	Safety Category
The other part of the JPI [FWSNI]	FC3
JPV [FSDB]	FC3

T-10.7-5 Safety Classification of Main Components

Component	Design Provision Category	Barrier Classification	Seismic Classification
JAC [FWPS] (BEJ)	DPZ	Z-SC3	SSE1
JPI [FWSNI] containment isolation function	DPA	B-SC2	SSE1
JPI [FWSNI] (in BFX\BSA\BSB\BSC\BRX\ BGA\BGB\BGC\BPA\BPB, excluding the containment isolation function)	DPZ	Z-SC3	SSE1
JPI [FWSNI] (BNX\BPX\BWX)	DPZ	Z-SC3	NO
JPV [FSDB]	DPZ	Z-SC3	SSE1

b) Engineering Design Requirements

1) Single Failure Criterion (SFC)

- Single Failure Criterion (SFC)

  The design principles of Single Failure Criterion (SFC) presented in Chapter 4 shall be applied to JPI [FWSNI] containment penetration valves design. The SFC is not applied to the other part of JPI [FWSNI] system, JAC and JPV [FSDB] systems. The requirement of redundancy needs to consider in the pumps of JAC system design and the motor-driven valves of JPI [FWSNI] system design.

- Independence

  The design principle of independence present in the Chapter 4 shall be applied to the design of JPI [FWSNI] containment isolation valves.

- Diversity

Not applicable.

- Fail-safe

  The concept of fail-safe is not considered in the design of fire-fighting systems.

- Ageing and Degradation

  The selection of components for fire-fighting only shall meet the British Standard for example BS EN 12259, BS EN 671. The ageing and degradation is considered by the standard.

  Some part of fire-fighting system which is difficult to replace, for example water tanks will be design are design for the 60 years. Some components will need to be replaced at the end of their individual designed life, for example pipes.

  The layout design will take into the consideration of the need to remove the old parts and to install the replacement.

2) Human Factors

   The design of JAC pumps needs to avoid closed by human false, the local start and shut button will be installed in box.

   The valves of open-type fixed fire extinguishing systems of JPI [FWSNI] and JPV [FSDB] need avoid to be opened by human falsely, so we will call attention to operate them in standards of operating.

3) Autonomy

   Not applicable.

4) Other Design Requirements

   - Prevention of Harmful Interactions of Systems Important to Safety

     Not applicable.

   - Considerations Related to the Electrical Power Grid

     Not applicable.

c) Equipment Qualification

The containment isolation valves of JPI [FWSNI] should be capable of operating under normal conditions and accident conditions, so the valves will be required to withstand the most penalised ambient environmental conditions.

The fire pumps, hose stations, sprinklers and other components designed for fire-fighting specially shall be certificated by certification bodies for fire-fighting

equipment.

All the seismic classified components are seismic designed and qualified for SSE load.

The documents relevant to the equipment qualification will be delivered before the step 4 of GDA.

d) Protection Design against Internal and External Hazards

1) Internal Hazard Protection

Fire protection measures shall be designed so that in the event of fire they are functional.

2) External Hazard Protection

The design of fire protection systems takes in account:

- Earthquakes

  The JAC system installed in BEJ, JPI [FWSNI] system installed in BFX, BRX, BSX, BPA, BPB, BGA, BGB, BGC and JPV [FSDB] system are seismic classified, so that they can be functional after SSE.

- The crash of an aircraft

  The JAC system installed in BEJ is designed to fulfil function after crash of a small plane. The JPI [FWSNI] and JPV [FSDB] systems are installed interior of NI, so we don’t consider the crash of an aircraft added.

- Extreme heat

  The JAC [FWPS], JPI [FWSNI] and JPV [FSDB] pressurised part is in door, the temperature is conditioned by HVAC systems. The JAC [FWPS], JPI [FWSNI] and JPV [FSDB] pressurised part is designed according to the highest temperature in the room installed JAC [FWPS], JPI [FWSNI] and JPV [FSDB] systems.

- Extreme cold

  The JAC [FWPS], JPI [FWSNI] and JPV [FSDB] pressurised part is in door, the temperature is conditioned by HVAC systems. The temperature in the room installed JAC [FWPS], JPI [FWSNI] and JPV [FSDB] systems is above 0°C. In future if we find the temperature under 0°C in some seasons, we will consider dry systems for JPI [FWSNI] and JPV [FSDB] systems, and the pipe for the intake well and hydrants of JAC will be installed under frost line.

- Flooding

  The rooms installed JAC [FWPS], JPI [FWSNI] and JPV [FSDB] are designed to defend external flooding according to Chapter 18. The part of JAC system outdoor flooded will not impact on its function. So we don't need added measures.

- Projectiles carried by the wind

  The buildings installed JAC [FWPS], JPI [FWSNI] and JPV [FSDB] are designed to defend projectiles carried by the wind, it is enough for fire-fighting systems, so no added measures considered for JAC [FWPS], JPI [FWSNI] and JPV [FSDB].

e) Commissioning

Commissioning are going to be carried out for the JAC [FWPS], JPI [FWSNI], JPV [FSDB] to valid its functionality. Documents related to the commissioning will be delivered before the step 4 of GDA.

f) Examination, Inspection, Maintenance and Testing

1) Examination and Inspection

There is no equipment of JAC [FWPS], JPI [FWSNI], JPV [FSDB] systems requiring in-service inspection except containment isolation valves.

The synthesis information of the JAC [FWPS], JPI [FWSNI], JPV [FSDB] displayed on the Main Control Room (MCR) for the operator includes:

- Flow indicator status;
- Motor-driven valves position status;
- Fire pumps status;
- Water levels of the water tanks.

2) Maintenances

If the damage is found by periodic test or other causes, the maintenances shall be performed at once.

3) Periodic Tests

The fire-fighting equipment subject to periodic tests are the fire hose stations, the fixed systems for extinguishing fires and the fire-fighting water production and networks in conformance with the function requirements and operational experience.

g) Decommissioning

Decommissioning about JAC [FWPS], JPI [FWSNI], JPV [FSDB] systems is still undertaken in this stage.

h) Material Selection

The material of duct is stainless steel or carbon steel.

i) Special Thermal-hydraulic Phenomena

In order to ensure the function reliability of the system and to prevent challenges to performing the safety functions, phenomenon regarding the water hammer shall be carefully considered in JAC [FWPS] design.

j) Insulation

Not applicable.

10.7.4.6 Simplified Diagrams

The simplified flow diagram of the fire-fighting systems as a whole is shown in Figure F-10.7-2.

10.7.5 Smoke Control System (DFL [SCS])

The Smoke Control System (DFL [SCS]) exhausts smoke in rooms with a fire and protects the protected rescue routes against smoke ingress during a fire.

10.7.5.1 Safety Functional Requirements

10.7.5.1.1 Control of Reactivity

The DFL [SCS] does not contribute to this safety function.

10.7.5.1.2 Removal of Heat

The DFL [SCS] does not contribute to this safety function.

10.7.5.1.3 Confinement

The DFL [SCS] which forms an isolation barrier in the controlled area boundary contributes to the confinement of radioactive substances.

10.7.5.1.4 Extra Safety Functions

a) Supporting the Fundamental Safety Functions

The DFL [SCS] does not contribute to this safety function.

b) Prevent, Protect and Mitigate Hazards Impact

1) Fire

The DFL [SCS] must prevent smoke migration from affecting the classified equipment and safety of staff in the event of a fire.

2) External explosion

The DFL [SCS] must prevent external explosions from affecting the classified equipment.

10.7.5.2 Design Requirements

The general design requirements of the DFL [SCS] which need to be considered are shown in Sub-chapter 10.2.4, among which the following requirements are not applicable for the DFL [SCS]:

a) Autonomy in Respect of Operators

Not applicable, because the DFL [SCS] doesn't contribute to the autonomy objective.

b) Autonomy in Respect of the Heat Sink

Not applicable, because the DFL [SCS] doesn't provide a heat sink to the power plant.

c) Autonomy in Respect of Power Supply Systems

Not applicable, because the DFL [SCS] doesn't provide a power supply to the power plant.

d) Prevention of Harmful Interactions of Systems Important to Safety

Not applicable, because the DFL [SCS] doesn't have harmful interactions of systems important to safety.

e) Insulation

Not applicable, because the DFL [SCS] doesn't have insulation design.

The substantiation analysis of DFL [SCS] system to other design requirements is shown in the Sub-chapter 10.7.5.5.2.

10.7.5.3 Design Bases

10.7.5.3.1 General Assumptions

An independent pressurised subsystem is provided for each protected rescue route.

The exhaust subsystem is divided according to the layout, each exhaust subsystem can contain multiple fire compartments.

10.7.5.3.2 Design Assumptions

a) Control of Reactivity

Not applicable. The DFL [SCS] does not contribute to the safety function of control of reactivity.

b) Removal of Heat

Not applicable. The DFL [SCS] does not contribute to the safety function of removal of heat.

c) Confinement

Isolation dampers which are installed in the controlled area boundary are reinforced to be leak tight. For characteristics of how air leak tight the equipment is see Table T-10.6-37.

d) Extra Safety Functions

1) Supporting the Fundamental Safety Functions

Not applicable. The DFL [SCS] does not contribute to supporting the fundamental safety functions.

2) Prevent, Protect and Mitigate Hazards Impact

- Fire

  Not applicable. There is no quantitative safety-related design assumptions associated with the DFL [SCS].

- External explosion

  The parameters of external explosions which must be taken into consideration are given in Chapter 18 (External Hazards).

e) Other Assumptions

An overpressure of 20Pa to 80Pa is maintained for the protected rescue routes or compartments by the DFL [SCS] during a fire event.

The outside conditions to be taken into account for the DFL [SCS] are defined in Table T-10.6-41.

10.7.5.4 System Description and Operation

10.7.5.4.1 System Description

a) General System Description

The DFL [SCS] consists of two different subsystems:

1) Smoke Exhaust System

An exhaust system which mainly contains:

- A motorised isolation damper to isolate the building;
- A centrifugal extraction fan.

2) Pressurized System

A pressurized system which mainly contains:

- A motorised isolation damper;
- An axial air supply fan and a dedicated pressure measurement.

Detailed information of the systems is presented in the SDM, Reference [129]

b) Description of Main Equipment

1) Supply Air Fans

The fans are designed to provide the air supply for the protected rescue routes or compartments to maintain overpressure, and they are axial.

2) Smoke Exhaust Fans

The fans are designed to exhaust smoke within a fire room to create a negative pressure against smoke migration to adjacent rooms. The fans are a centrifugal and direct-coupled drive type.

3) Isolation Dampers

The isolation dampers can be isolated in the controlled areas of the buildings. The closing action provides the confinement function.

4) EPW Damper

The air intakes and outlets are protected against external explosions and tornados by EPW dampers installed in the classified buildings.

Detailed information of the equipment design is presented in the SDM, Reference [129] and [130].

c) Description of Main Layout

Each subsystem of the DFL [SCS] is arranged independently. The smoke control subsystem is included in the BSX、BDX、and BNX. The pressurized air supply subsystem is included in the BSX、BDX、BNX、BPX、BWX、BEJ、BFX and BPA/BPB.

Detailed design information about the system layout is presented in the SDM, Reference [129].

d) Description of System Interface

1) Fire Alarm System (JDT [FAS])

The JDT [FAS] provides the fire signal to control the DFL [SCS].

2) Electrical Division of Safeguard Building Ventilation System (DVL

[EDSBVS])

The DFL [SCS] uses the air intake and exhaust air plenums of the DVL [EDSBVS].

3) Main Control Room Air Conditioning System (DCL [MCRACS])

The DFL [SCS] uses the air intake plenum of the DCL [MCRACS].

4) Diesel Building Ventilation System (DVD [DBVS])

The DFL [SCS] uses the air intake and exhaust plenum of the DVD [DBVS].

Detailed information of the interface systems is presented in the SDM, Reference [129].

e) Description of Instrumentation and Control

Parameters, controlling and monitoring of the DFL [SCS] and displaying of the actuator are provided in the MCR.

Detailed information of the system I&C design is presented in the SDM, Reference [131].

10.7.5.4.2 System Operation

a) Plant Normal Conditions

The DFL [SCS] is not required to operate during plant normal operation. During plant operation and plant shutdown, the DFL [SCS] is in standby mode.

When the JDT [FAS]) detects fire in a fire compartment the corresponding pressurized subsystem of the DFL [SCS] will start automatically. The exhaust smoke subsystem of the DFL [SCS] for rooms with a fire is started manually by the operators.

b) Plant Accident Conditions

The DFL [SCS] has no requirement to operate in plant accident conditions.

Detailed information of the system operation is presented in the SDM, Reference [131].

10.7.5.5 Preliminary Design Substantiation

In this sub-chapter, the system design is demonstrated to satisfy the safety functional requirements presented in Sub-chapter 10.7.5.1 and the general design requirements stated in Sub-chapter 10.2.4.

Since the general principles are newly developed at this stage, the system design is still based on the reference design. A Review of the consistency of the system design against the newly developed principles is currently being undertaken. Detailed design

of the system is presented in the SDM, Reference [129] and [132].

10.7.5.5.1 Compliance with Safety Functional Requirements

a) Control of Reactivity

Not applicable.

b) Removal of Heat

Not applicable.

c) Confinement

Ducts penetrating the boundary of the controlled area are equipped with isolation dampers and these dampers are kept closed under plant normal conditions and these dampers are required to be air tight to a particular degree.

d) Extra Safety Functions

1) Supporting the Fundamental safety Functions

Not applicable.

2) Prevent, Protect and Mitigate Hazards Impact

- Fire

In case of the fire, the DFL [SCS] is put into operation to prevent smoke migration from rooms with fire to other rooms and the protected rescue routes.

- External Explosion

The DFL [SCS] EPW dampers close automatically in order to protect classified equipment in case of external explosions.

Detailed design information is presented in Reference [133].

10.7.5.5.2 Compliance with Design Requirements

a) Safety Classification

The DFL [SCS] design is compliant with the principles described in Chapter 4. The functional classification of the DFL [SCS] and the safety classification of the DFL [SCS] main components are listed in following tables:

T-10.7-6 Function Categorisation of the DFL [SCS]

System Function	Function Category
Radioactive Containment	FC2/FC3

System Function	Function Category
Fire Fighting	FC3
Protect Classified Equipment from External Explosions	FC3
Exhaust Smoke and Pressurizing	NC

T-10.7-7 Classification of Main Components

Component	Function Class	Design Provision Category	Design Provision Class	Seismic Category
Isolation dampers in the boundary of the BSX controlled areas and BFX	F-SC2	NC	NC	SSE1
EPW dampers in the BDX	F-SC3	NC	NC	SSE1
Smoke dampers in the BSX	F-SC3	NC	NC	SSE1
Equipment with impact on SSE1 equipment	NC	NC	NC	SSE2
Other equipment	NC	NC	NC	NC

b) Engineering Design Requirements

1) Reliability Design of SSCs

- Single Failure Criterion (SFC)

  Not applicable. The DFL [SCS] is not designed for single failures.

- Independence

  Not applicable. But the subsystems of the DFL [SCS] are dedicated to the division they are located in.

- Diversity

  Not applicable.

- Fail-safe

There's no fail-safe designed equipment in the DFL [SCS].

- Ageing and Degradation

  The plant design life is 60 years. Some components will require replacing at the end of their individual design life.

2) Human Factors

   The system design of DFL [SCS] does not require short term operator intervention, however there are operator actions during plant normal operation, the effect of which needs to be estimated. The DFL [SCS] is controlled and monitored in the main control room. It is designed to be convenient for operators to control.

3) Autonomy

   Not applicable.

4) Other Design Requirements

   - Prevention of Harmful Interactions of Systems Important to Safety

     Not applicable.

   - Considerations Related to the Electrical Power Grid

     Not applicable.

c) Equipment Qualification

All the components of the DFL [SCS] required to perform safety functions are capable of operating under both normal and accident conditions. As a result, the components can withstand the most adverse environmental conditions expected.

All the seismically classified components of the DFL [SCS] shall be capable of operating during and after the SSE. The components are seismically designed and qualified for the SSE loads.

The documents relevant to the equipment qualification will be delivered before the step 4 of GDA.

d) Protection Design against Internal and External Hazards

The DFL [SCS] is protected from external and internal hazards; specific protection design is presented in the SDM, Reference [132]. The evaluation of the design is presented in Chapters 18 and 19.

e) Commissioning

Commissioning is going to be carried out for the DFL [SCS] to validate its functionality. Documents related to the commissioning will be delivered before

the step 4 of GDA.

f) Examination, Inspection, Maintenance and Testing

1) Examination and Inspection

There is no equipment of the DFL [SCS] requiring in-service inspection.

The combined information of the DFL [SCS] displayed in the Main Control Room (MCR) for the operator includes:

- Smoke damper position status in the BSX;
- Inlet/outlet isolation damper position status in the controlled areas;
- Inlet/outlet isolation damper position status of the external explosion protection areas.

2) Maintenances

The maintenance of the DFL [SCS] can be performed during plant normal operation when the DFL [SCS] is not required.

3) Periodic Tests

FC1, FC2 and FC3 equipment should be tested if they are not in continuous operation. Some equipment performing safety functions shall be subject to periodic testing, including correct operation of the dampers

g) Decommissioning

Decommissioning considerations about the DFL [SCS] are still undertaken at this stage.

h) Material Selection

The duct material is galvanised steel sheet or carbon steel.

The fire resistance duct is covered with fireproof material.

i) Insulation

Not applicable.

10.7.5.6 Simplified Diagrams

The simplified system diagram is presented in Figure F-10.7-3 and Figure F-10.7-4.

10.7.6 ALARP Assessment

Preliminary ALARP analysis has been performed on the fire protection systems. The standards listed in Table T-10.7-1 are sources of relevant good practice for system and component design. The system is designed in accordance with appropriate codes and

standards;

Materials comply with specifications defined in technical codes. A basic principle for the selection of materials is to use proven and successfully tested materials;

The fire protection system design is based on OPEX from CGN (China General Nuclear Power Corporation) and other PWR power plants operating in the world;

A compliance analysis of the system design with the UK HPR1000 general safety engineering principles is conducted in the system section. The analysis shows that the design of the SSCs meets relevant requirements and no gaps have been identified. Meanwhile, technical assessments such as the hazard schedule, fault schedule, probabilistic safety assessment, human factors, instrumentation and control are being developed simultaneously. The analysis of the design against the requirements of these technical disciplines needs to be reviewed periodically. A systematic review will be carried out on the system design to ensure that no new gaps are identified between the newly developed requirements and the design. Any potential enhancements identified during this review will be taken into account in the future design development;

Potential areas of improving improvement in the system design will be identified to reduce the risks during the process of the fault analysis. Since the PSA and the fault analysis are still under development, further ALARP analysis will be performed once the fault schedule work is completed.

In summary, the ALARP analysis and demonstration work is currently being carried out. A preliminary ALARP demonstration topic report to present the current analysis results as well as the arrangement for future ALARP analysis work is presented in Reference [13].

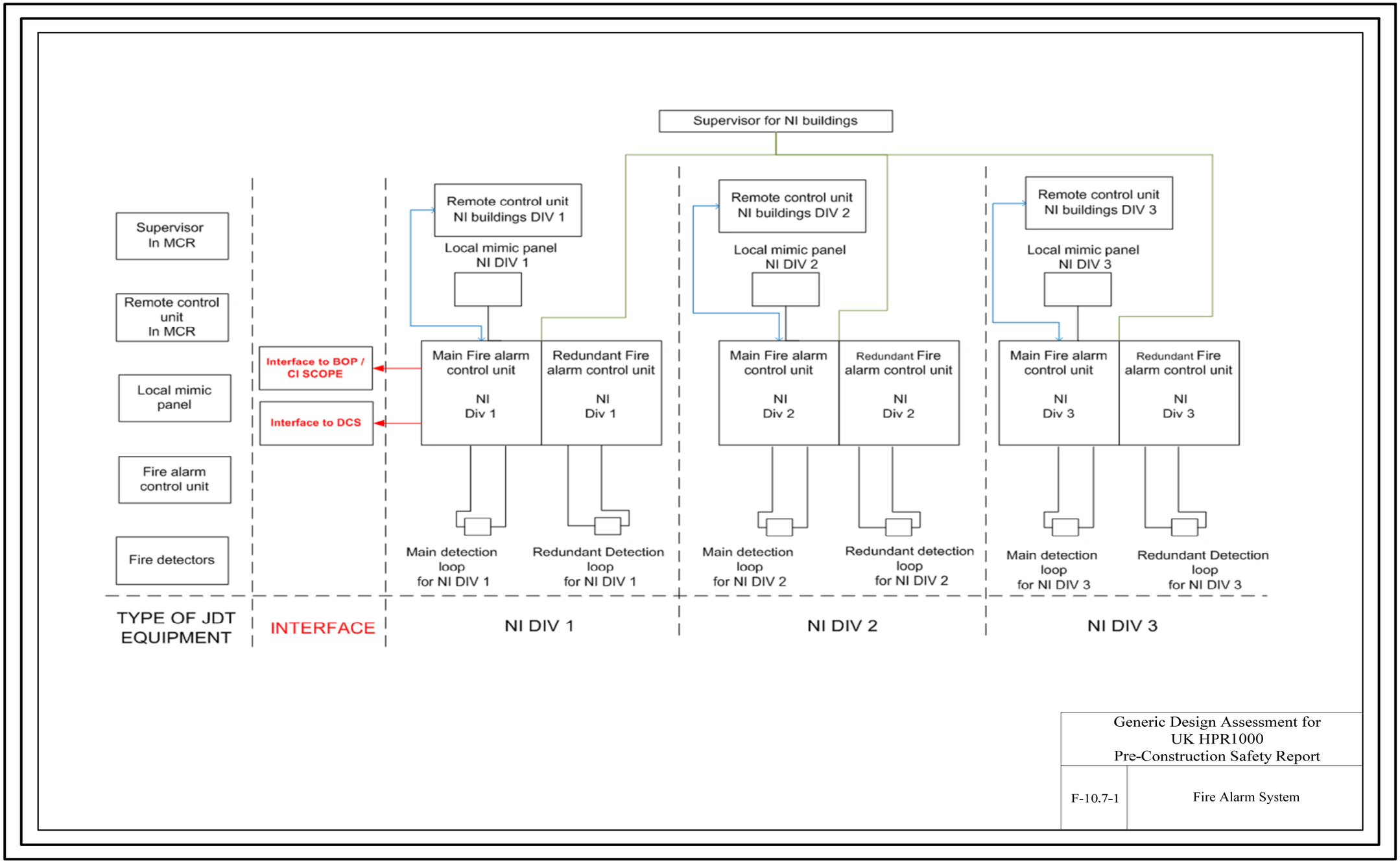
10.7.7 Concluding Remarks

This chapter provides an introduction of the design information of the fire protection systems in the UK HPR1000 nuclear power plant and demonstrates that the systems satisfy the performance requirements.

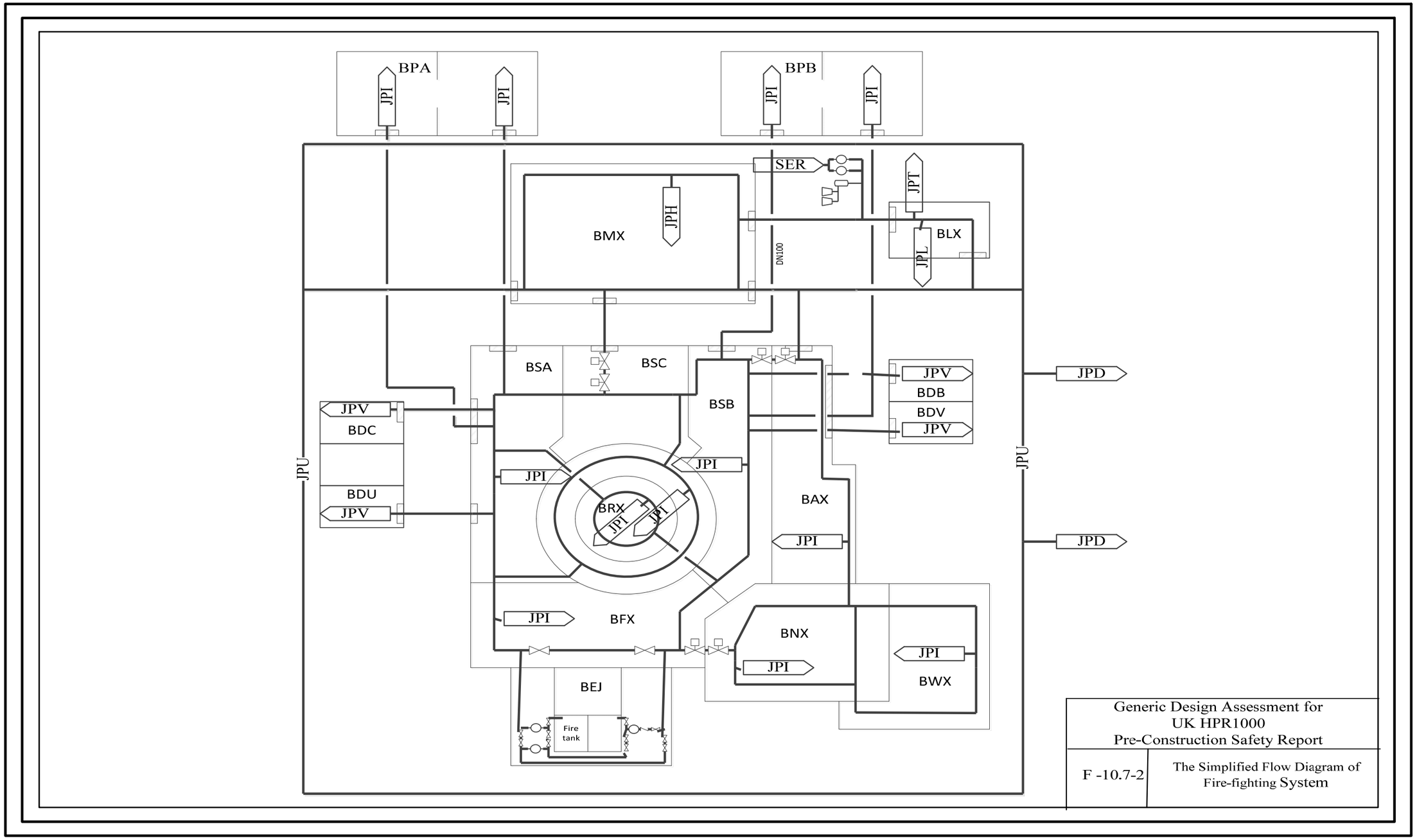
The PCSR design principles for the UK HPR1000 are based on the principles applied for the HPR1000 (FCG3) with suitable development to meet UK context expectations. An impact analysis will be carried out once safety and design principles have been specified.

10.7.8 Simplified Diagrams

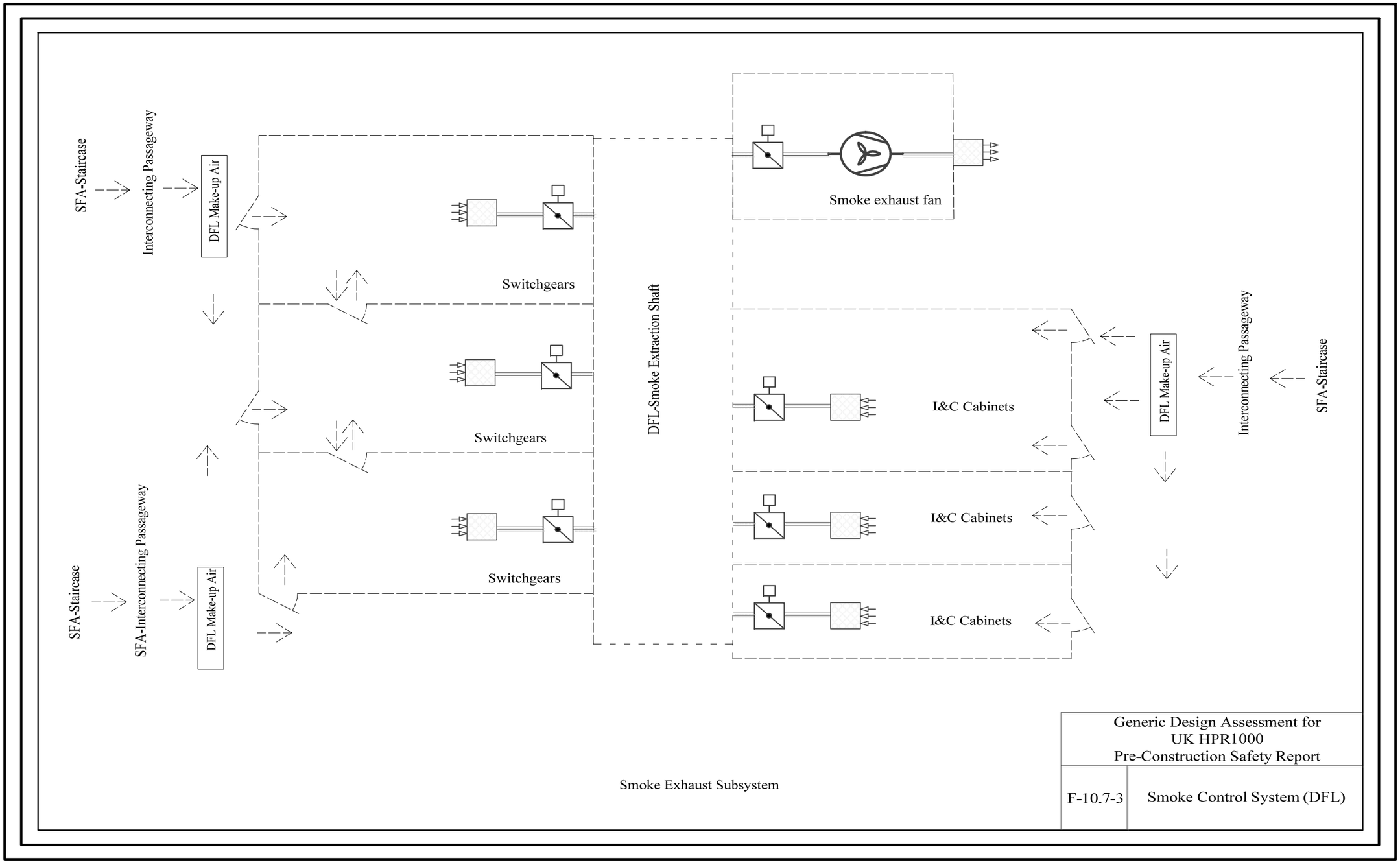
Simplified diagrams of nuclear auxiliary systems mentioned in Sub-chapters 10.7.3 to 10.7.5 are presented as follows:



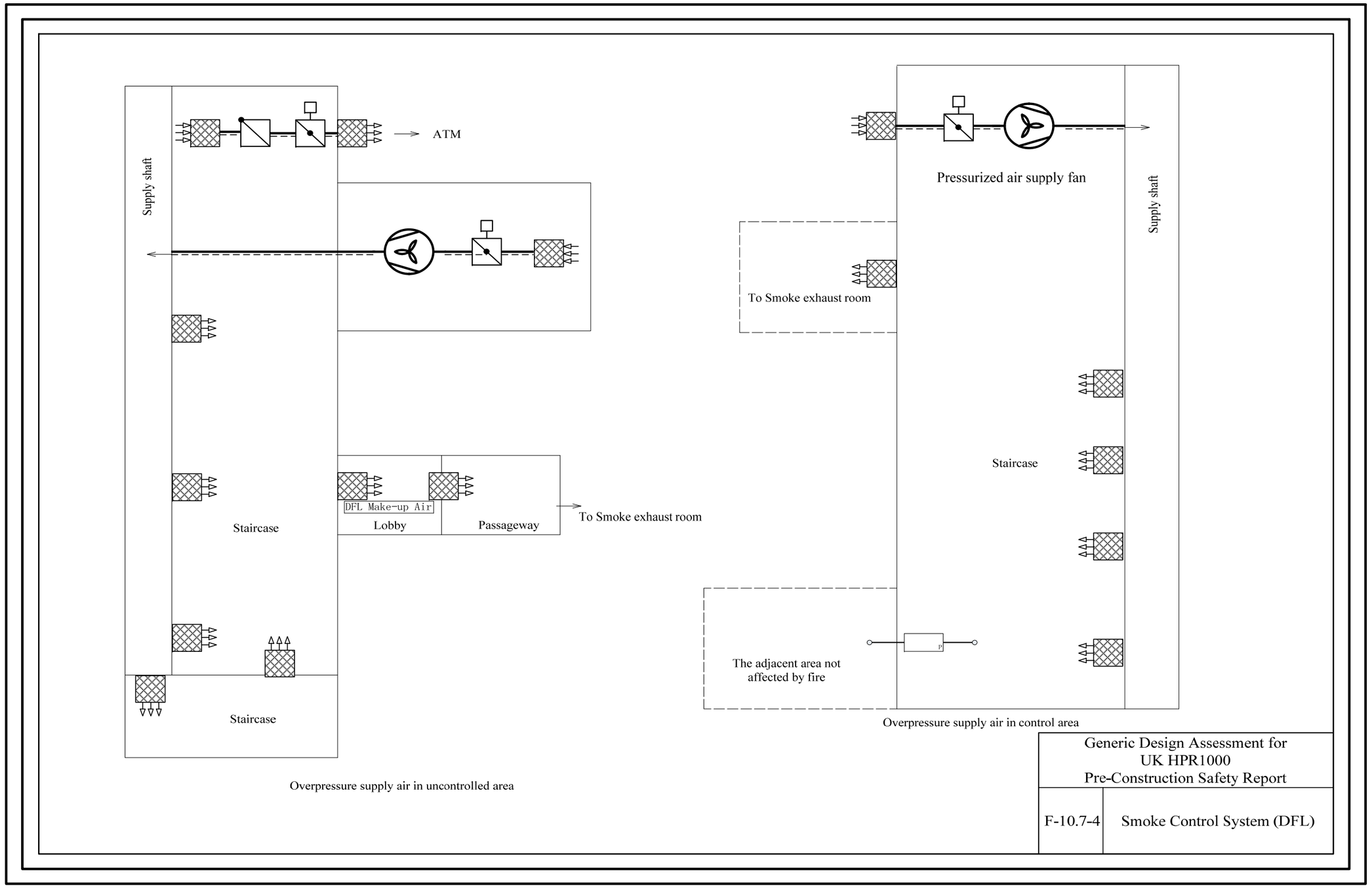
F-10.7-1 Simplified Diagram of the Fire Alarm System



F-10.7-2 Simplified Diagram of the Fire-fighting System



F-10.7-3 Simplified Diagram of the DFL [SCS] (1/2)



F-10.7-4 Simplified Diagram of the DFL [SCS] (2/2)

10.8 Diesel Generators

10.8.1 Sub-chapter Structure

The main objective of Sub-chapter 10.8 is to present the design information of auxiliary systems and mechanical equipment of the diesel generator (DG) in the UK HPR1000 nuclear power plant, including:

a) Auxiliary systems of the Emergency diesel generator (EDG);

b) Auxiliary systems of the SBO diesel generator (SBO DG).

The general structure of Sub-chapter 10.8 is presented as below:

a) Sub-chapter 10.8.1 - introduces the objective and the structure;

b) Sub-chapter 10.8.2 - presents the relative codes and standards, which are intended to be used in the UK HPR1000, with respect to the auxiliary systems of the DGs and their components design;

c) Sub-chapter 10.8.3 - presents the design information of the EDGs and auxiliary systems;

d) Sub-chapter 10.8.4 - presents the design information of the SBO DGs and auxiliary systems;

e) Sub-chapter 10.8.5 - presents the ALARP assessment;

f) Sub-chapter 10.8.6 - presents the concluding remarks;

g) Sub-chapter 10.8.7 - presents the simplified diagrams.

10.8.2 Applicable Codes and Standards

The identification of applicable codes and standards in Sub-chapter 10.8 is compliant with the selection principles and the selection process stated in Chapter 4 and Reference [5].

Wherever possible, the selected codes and standards applied for the engineering substantiation are:

a) Commensurate with the categorisation of safety functions and classification of the SSCs;

b) Internationally good practice recognised by UK regulator in nuclear industry;

c) The latest version. Where to select an older version, gap analysis will be carried out.

Based on the selection principles and the selection process, the applicable codes and standards which are applied in Mechanical Engineering (ME) design are identified

and evaluated. Main applicable codes and standards for the DGs and auxiliary systems are presented in T-10.8-1. Conformity analysis and gap analysis are presented in Reference [13].

T-10.8-1 Applicable Codes and Standards in Sub-chapter 10.8

Codes and Standards Number	Title
IEEE 387, 1995	Diesel-generator Units Applied as Standby Power Supplies for Nuclear Power Generating Stations
RCC-M, 2007	Design and Construction Rules for Mechanical Components of PWR Nuclear Islands
BS 2869, 2017	Fuel Oils for Agricultural, Domestic and Industrial Engines and Boilers Specification
BS ISO 8528 (series)	Reciprocating Internal Combustion Engine Driven Alternating Current Generating Sets (Series)

The application of the above standards in the system is described briefly as below.

a) The standard, IEEE 387, provides the principal design criteria, the design features, testing, and qualification requirements for the individual DG units that enable them to meet their functional requirements as a part of the standby power supply under the accidental conditions of nuclear power plant.

b) The standard, RCC-M, is applicable to the components performing the safety functions, including the piping, pumps, valves and vessels.

c) The BS 2869 is a local standard in United Kingdom, which provides the specification of fuel oils applicable to DGs. The fuel grades and chemical properties are specified in this standard.

d) The standards, BS ISO 8528 (series), are exclusive for DGs, which provide many technical specifications for the procurement of DGs in nuclear power plant, such as the rating, performance, test methods, control gear and switchgear, measurement of mechanical vibrations, etc.

10.8.3 Emergency Diesel Generator

10.8.3.1 Safety Functional Requirements

The requirements of the fundamental safety functions on EDG design for UK HPR1000 are identified as below.

10.8.3.1.1 Control of Reactivity

Not applicable. The auxiliary systems of EDGs do not contribute to the control of reactivity.

10.8.3.1.2 Removal of Heat

Not applicable. The auxiliary systems of EDGs do not contribute to this safety function.

10.8.3.1.3 Confinement

Not applicable. The auxiliary systems of EDGs do not contribute to the confinement of radioactive substances.

10.8.3.1.4 Extra Safety Functions

The detailed functional requirements of EDGs are shown in Sub-chapter 9.6.4.

10.8.3.2 Design Requirements

The general design requirements of the EDG auxiliary systems which need to be considered are shown in Sub-chapter 10.2.4, although some requirements are not fully applicable.

10.8.3.3 Design Bases

10.8.3.3.1 General Assumption

The site specific parameters are the input data for the design of the auxiliaries of the EDGs. The fuel oil and cooling water are selected according the environment temperature, ensuring that the mediums are not frozen even in extreme low temperature conditions. The applicable auxiliary equipment shall be purchased to ensure their performance and reliability in the possible extreme site conditions.

10.8.3.3.2 Design Assumption

a) Control of Reactivity

   Not applicable. The auxiliary systems of EDGs do not contribute to the control of reactivity.

b) Removal of Heat

   Not applicable. The auxiliary systems of EDGs do not contribute to this safety function.

c) Confinement

   Not applicable. The auxiliary systems of EDGs do not contribute to the confinement of radioactive substances.

d) Extra Safety Functions

The rated power of the EDGs is designed according to the operational requirements of various systems in accidental conditions. The sizes and parameters of auxiliary equipment shall match with the diesel engine. The preheating system and the pre-lubricating system must provide the required conditions to ensure diesel engine start-up, and they must be shut down after the EDG has been started up.

10.8.3.4 System Description and Operation

10.8.3.4.1 System Description

The EDG set is composed of five auxiliary systems, the fuel oil system, lubrication oil system, coolant system, compressed air start-up system and the air intake and exhaust system. The EDG performs FC1 safety functions. Its building, diesel generator body, relevant auxiliary equipment and cable channel are designed to withstand a SSE.

a) Fuel Oil System

The fuel oil system of the EDG set performs the function of supplying fuel oil to the EDG set. The main equipment of the fuel oil system includes: the main fuel storage tank, daily fuel tank and fuel delivery pumps.

There are two delivery pumps with 100% capacity between the main fuel storage tank and daily fuel tank.

The capacity of the main fuel storage tank of the EDG set can store enough fuel to enable the related EDG set to keep on running for 7 consecutive days under the maximum power output after an accident scenario accompanied by a loss of the offsite power. The fuel oil daily tank is installed above the EDG to ensure feeding fuel oil to the EDG, and it has sufficient capacity for 2 hours continuous operation of the EDG set at 110% rated power.

The main fuel storage tanks, daily fuel tanks, fuel delivery pumps and main system pipelines in the diesel generator buildings meet the seismic design requirements of SSE1.

The activated equipment of class FC1 shall be designed to meet the requirement that their operational functions can be maintained during and after an earthquake. The non-activated equipment of class FC1 shall be designed to meet the requirement that their integrity can be maintained after an earthquake.

b) Lubrication Oil System

This system is also referred to as the lube oil system. The lubrication oil system of each EDG mainly consists of the following equipment: lubricating oil pump in the set, motor-driven pre-lubricating oil pump, lubrication oil/water heat

exchangers, and lubrication oil filter.

During the operation of the EDG sets, the main lubricating oil pump driven by the diesel engine is able to provide sufficient lubricating oil to the main bearing, crankpin, camshaft bearing and other wearing parts which need to be lubricated.

Each EDG is equipped with a pre-lubricating system. It consists of a motor-driven pre-lubricating oil pump and a lubrication oil/water heat exchanger. When the EDG is in the standby state, the pre-lubricating oil pump sends lubricating oil to the components of the EDG which need lubrication to ensure the reliability of start-up.

c) Coolant System

Each EDG set is equipped with two cooling circulation systems, diesel cooling system and admission air cooling system. The systems are designed according to the requirements of SSE1.

1) Diesel Cooling System

This system is also referred to as the high temperature cooling water system. Each EDG is equipped with its own independent closed diesel cooling cycle system to remove heat from the crankcase and cylinder liner.

The diesel cooling system includes the following equipment: diesel-driven circulating pump, air-cooled heat radiator, expansion tank, motor-driven circulating pump, heat exchanger, and electrical heater.

Each EDG is equipped with a preheating system. When the EDG is on standby, cooling water, after being heated by the electrical heater, is forced to flow towards the end of the EDG by the motor-driven pump. It supplies water to the crankcase and cylinder liner for preheating.

2) Admission Air Cooling System

This system is also referred to as the low temperature cooling water system. The admission air cooling system includes the following equipment: diesel-driven circulating pump, air-cooled heat radiator, expansion tank, lubrication oil/water heat exchanger, and intermediate cooler.

When the EDG is in operation, the diesel-driven circulating pump can supply water to the intermediate cooler and lubrication oil/water heat exchanger for cooling.

d) Compressed Air Start-up System

Each EDG set is equipped with two independent air start-up systems which can start the EDG respectively.

When one start-up system of the EDG fails, the EDG set can be started by the other start-up system. When the EDG set has received the start-up signal, the two main start-up air valves actuate simultaneously in order to start the EDG set.

Each start-up system is composed of an air storage tank. According to the pressure of the air storage tank, the compressor starts up and shuts down automatically. The capacity of the air storage tank is sized to enable five successful start-ups without refilling from the air compressor.

e) Air Intake and Exhaust System

Each EDG set is equipped with the following equipment: air filter, turbine supercharger, intermediate cooler, pipeline and silencer.

The air intake and exhaust system of the EDG set supplies air to the diesel engine, which is needed for combustion, and the gaseous waste product is discharged into the atmosphere.

Exhaust fans are used by each EDG set to ensure strong ventilation in the diesel building. The EDG takes in burning air from the outside of the diesel building through pipelines. After being filtered, air is compressed in the EDG with its temperature rising. After being cooled in the intermediate cooler, the compressed air then enters the cylinder for burning. Gaseous waste after burning is dumped from the cylinder. It enters the turbine supercharger through the vent pipe of the EDG to propel the turbine. After that, it enters the vent pipe and finally the atmosphere through the silencer.

f) Description of Main Equipment

The main mechanical equipment includes the diesel engine and auxiliary equipment. The auxiliary equipment is presented in each system description.

The diesel engine is a four-stroke, water cooled, V-type cylinder, supercharged mechanical equipment driving the generator with a rated electrical power of approximately { }. The specific requirements about the EDG are presented in the *Technical Specification*, Reference [134].

g) Description of Main Layout

The three EDGs are located in three emergency diesel generator buildings separately, which are the emergency diesel generator building A, emergency diesel generator building B and emergency diesel generator building C. For each building, there are eight levels, including two underground levels and six over-ground levels.

The underground levels contain the main oil storage tank, fuel delivery pumps, pre-lubricating oil pumps, plate heat exchangers, electrical heater, and high temperature water preheating pumps.

The ground level contains the diesel generator, compressors, and air storage tanks.

The daily oil tank and air intake filter are located on the third over-ground floor. The exhaust silencer, expansion tanks, and air-cooled heat radiators are installed on the fifth over-ground floor.

10.8.3.4.2 System Operation

a) Plant Normal Conditions

In the normal conditions of the power plant, the EDG is in standby state. The engine can be pre-lubricated by the lubrication oil system, and pre-heated by the coolant system. The auxiliary systems are always available to ensure the start-up of the EDG at any time.

b) Plant Accidental Conditions

In the event of LOOP, the EDG can be started up immediately, and the auxiliary systems can ensure the stable operation of the diesel engine. When the off-site power supply is recovered, the EDG can only be stopped manually. The auxiliary systems of EDG enable the engine to run continuously for 7 days at the rated power.

10.8.3.5 Preliminary Design Substantiation

10.8.3.5.1 Compliance with Safety Functional Requirements

The EDG and its auxiliary systems do not directly contribute to fundamental safety functions. For the extra safety functional requirements, the substantiation is presented in Sub-chapter 9.6.4 in terms of electrical engineering, and in Sub-chapter 10.8.3 in terms of mechanical engineering.

10.8.3.5.2 Compliance with Design Requirements

a) Safety Classification

The EDGs perform FC1 safety functions.

b) Redundancy and Single Failure Criterion

The design principles of the SFC presented in Chapter 4 are applicable to the EDGs and auxiliary systems, therefore, three EDG sets are designed for a single nuclear unit and the EDG sets are redundant.

c) Independence

All DG buildings are physically separated, and the three EDGs are independent from one another.

d) Diversity

All auxiliary systems of the two EDGs are designed in the same way and there is no diversity requirement for the EDGs and auxiliary systems.

e) Fail-safe

The concept of fail-safe is considered in the design of EDG auxiliary systems. For example, the pneumatic valves in the compressed air system are in the shut-off state if the valves fail.

f) Ageing and Degradation

According to Chapter 2, the operational design life of the UK HPR1000 is 60 years. The main components of the systems are designed for the 60 year plant operation.

The ageing effect concerning individual components has been taken into consideration in the system design. A procedure of periodic testing and preventive maintenance is developed and implemented to prevent ageing and degradation. The periodic testing, preventive maintenance and replacement can ensure the system reliability.

g) Human Factors

The concept of human factors is taken into consideration in the system design. In the normal condition of the power plant, the EDGs are in standby state and no human intervention is needed. During commissioning or maintenance activities, the requirements and procedures about human factors are carried out and implemented.

h) Autonomy

The EDG can produce power autonomously for 7 days. For example, the main fuel oil storage tank has the capability to sustain 7 days of continuous operation of the EDG at the rated power.

i) Equipment Qualification

All the safety classified components in the EDG auxiliary systems, are qualified in accordance with the requirements described in Chapter 4.

The EDG performs class FC1 safety functions. For the related components, the item classification is F-SC1 and the seismic category is SSE1.

All the seismically classified components operate during and after the SSE. The components are seismically designed and qualified for the SSE loads.

j) Protection against Internal and External Hazards

Internal Hazards: The safety critical components in the EDG buildings are separated physically or by leaving space to satisfy the internal hazard protection

requirements.

External Hazards: The seismic category of the FC1 components is SSE1, and these components are arranged in the EDG buildings which are capable to of withstanding external hazards such as earthquakes, airplane crashes, external flooding, external explosions and tornados.

k) Commissioning and Tests

1) Initial testing of EDG and auxiliary equipment before delivery to site (for example factory acceptance tests) is undertaken in accordance with procurement, manufacturing and commissioning quality arrangements.

2) Following acceptance of the equipment by the commissioning organisation, a structured, systematic and progressive test programme, which includes all the activities required for confirmation and demonstration of the plant SSC operational and safety functional performance requirements, will be implemented. The test programme mainly includes start-up test, in-service inspection, and the periodic testing. The in-service inspection is implemented to ensure the normal operation of preheating system and pre-lubricating system. The start-up test and period testing are implemented to ensure the function of EDG.

l) Examination, Maintenance, Inspection and Testing

The EDGs are designed to permit examination, maintenance, inspection and testing, which is in accordance with the requirements from the maintenance strategy of the plant, equipment technical specification, equipment operating and maintenance manual, operation experience, etc. The total number of starts, operating hours at zero power and operating hours in loaded conditions will be recorded to perform the preventive maintenance of the EDGs.

1) Daily examinations of the EDGs and important parameters of the auxiliary systems are performed.

2) Periodic inspection and preventive maintenance is scheduled, which is mainly performed during the RCD mode.

3) The availability of the system and equipment is demonstrated by periodic testing, including the start-up test, load carrying test, power supply switchover test, etc. The typical frequency and items being periodically tested are:

- Every two months. Start up the engine, load it to a lower power and stabilise it for two hours.
- Every eighteen months. Test the full power operation for 2 hours, and sample the engine lube oil and cooling water.

10.8.3.6 Simplified Diagrams

The simplified system diagram is presented in Figure F-10.8-1.

10.8.4 SBO Diesel Generator

10.8.4.1 Safety Functional Requirements

The requirements of the fundamental safety functions on SBO design for UK HPR1000 are identified as below.

10.8.4.1.1 Control of Reactivity

Not applicable. The auxiliary systems of SBO DGs do not contribute to the control of reactivity.

10.8.4.1.2 Removal of Heat

Not applicable. The auxiliary systems of SBO DGs do not contribute to this safety function.

10.8.4.1.3 Confinement

Not applicable. The auxiliary systems of SBO DGs do not contribute to the confinement of radioactive substances.

10.8.4.1.4 Extra Safety Functions

The detailed functional requirements of SBO DGs are shown in Sub-chapter 9.6.5.

10.8.4.2 Design Requirements

The general design requirements of the SBO DG auxiliary systems which need to be considered are shown in Sub-chapter 10.2.4, although some requirements are not fully applicable.

10.8.4.3 Design Bases

10.8.4.3.1 General Assumption

The site specific parameters are the input data for the design of the auxiliaries of the SBO DGs. The fuel, oil and the cooling water are selected according the environment temperature, ensuring that the mediums are not frozen even in the extreme low temperature. The applicable auxiliary equipment shall be purchased to ensure their performances and reliabilities in the extreme site condition.

10.8.4.3.2 Design Assumption

a) Control of Reactivity

   Not applicable. The auxiliary systems of SBO DGs do not contribute to the control of reactivity.

b) Removal of Heat

Not applicable. The auxiliary systems of SBO DGs do not contribute to this safety function.

c) Confinement

Not applicable. The auxiliary systems of SBO DGs do not contribute to the confinement of radioactive substances.

d) Extra Safety Functions

According to the operation requirements of various systems in accident conditions, the rated powers of SBO DGs are designed, and the sizes and parameters of auxiliary equipment shall be matched with the diesel engine. The preheating system and the pre-lubricating system must provide the required condition to ensure the diesel engine start-up, and they must be shut down after the SBO DG has been started up.

10.8.4.4 System Description and Operation

The SBO DG set is composed of five auxiliary systems, including the fuel oil system, lubrication oil system, coolant system, compressed air start-up system and the air intake and exhaust system. The SBO DG performs FC3 safety functions. Its building, diesel generator body, relevant auxiliary equipment and cable channel are designed to withstand a SSE.

10.8.4.4.1 System Description

a) Fuel Oil System

The fuel system of the SBO DG set performs the function of supplying fuel to the SBO DG. The main equipment of the fuel system includes: the main fuel storage tank, daily fuel tank and fuel delivery pumps. The system is designed according to the requirements of SSE1.

There are two delivery pumps with 100% capacity between the main fuel storage tank and daily fuel tank.

The main fuel storage tank of the SBO DG set can store enough fuel to enable the related SBO DG to remain running for 3 days at maximum power after an accident accompanied by a SBO. The fuel oil daily tank is installed above the SBO DG to ensure feeding fuel oil to the SBO DG, and it has sufficient capacity for 2 hours continuous operation of the SBO DG set at 110% rated power.

b) Lubrication Oil System

This system is also referred to as the lube oil system. The lubrication oil system of every SBO DG mainly consists of the following equipment: lubricating oil

pump in the set, motor-driven pre-lubricating oil pump, lubrication oil/water heat exchangers, and lubrication oil filter.

During the operation of the SBO DG set, the main lubricating oil pump driven by the SBO DG is able to provide sufficient lubricating oil for the main bearing, crankpin, camshaft bearing, and other wearing parts which require lubrication.

Each SBO DG is equipped with a pre-lubricating system. It consists of a motor-driven pre-lubricating oil pump and a lubrication oil/water heat exchanger. When the SBO DG is in the standby state, the pre-lubricating oil pump sends lubricating oil to the components of the SBO DG which need lubricating to ensure start-up reliability.

c) Coolant System

Each SBO DG set is equipped with two cooling circulation systems, diesel cooling system and admission air cooling system. The systems are designed according to the requirements of SSE1.

1) Diesel Cooling System

This system is also referred to as the high temperature cooling water system. Each SBO DG set is equipped with its own independent closed diesel cooling cycle system to remove heat from the crankcase and cylinder liner.

The diesel cooling system includes the following equipment: the diesel-driven circulating pump, air-cooled heat radiator, expansion tank, motor-driven circulating pump, heat exchanger and electrical heater.

The SBO DG set is equipped with a preheating system. When the SBO DG is on standby, cooling water, after being heated by the electrical heater, is forced to flow towards the end of the SBO DG by the motor-driven pump. It supplies water to the crankcase and cylinder liner for preheating.

2) Admission Air Cooling System

This system is also referred to as the low temperature cooling water system. The admission air cooling system includes the following equipment: the diesel-driven circulating pump, air-cooled heat radiator, expansion tank, lubrication oil/water heat exchanger and intermediate cooler.

When the SBO DG is in operation the diesel-driven circulating pump can supply water to the intermediate cooler and lubrication oil/water heat exchanger for cooling.

d) Compressed Air Start-up System

Each SBO DG set is equipped with two independent air start-up systems which can start the SBO DG respectively.

When one start-up system of the SBO DG fails, the diesel generator set can be started by the other start-up system. When the SBO DG set has received the start-up signal, the two main start-up air valves actuate simultaneously in order to start the SBO DG set.

Each start-up system is composed of a compressor and an air storage tank. According to the pressure of the air storage tank, the compressor starts up and shuts down automatically. The capacity of the air storage tank is sized to enable five successful start-ups without requiring refilling from the air compressor.

e) Air Intake and Exhaust System

Each SBO DG is equipped with the following equipment: the air filter, turbine supercharger, intermediate cooler, pipeline and silencer.

The air intake and exhaust system of each SBO DG set supplies air to the SBO DG set, which is needed for combustion, and the gaseous waste product is discharged into the atmosphere.

Exhaust fans are used by each SBO DG set to ensure strong ventilation in the diesel building. The SBO DG takes in air for combustion from the outside of the diesel generator building through pipelines. After being filtered, the air is compressed in the SBO DG which increases its temperature. After being cooled in the intermediate cooler, the compressed air then enters the cylinder for combustion. The gaseous waste after combustion is dumped from the cylinder. It enters the turbine supercharger through the vent pipe of the SBO DG to propel the turbine. After that, it enters the vent pipe and is discharged to the atmosphere through the silencer.

f) Description of Main Equipment

The main mechanical equipment includes the diesel engine and auxiliary equipment. The auxiliary equipment is presented in each system description.

The diesel engine is a four-stroke, water cooled, V-type cylinder, supercharged mechanical equipment, driving the generator with a rated electrical power of approximately { }.

g) Description of Main Layout

The two SBO DGs are located in two SBO diesel generator buildings respectively, which are the SBO diesel generator building for train A and SBO diesel generator building for train B. For each building, there are eight levels, including two underground levels and six over-ground levels.

The underground level contains the main oil storage tank, fuel delivery pumps.

The ground level contains the SBO DG, compressors, and air storage tanks. The

pre-lubricating and preheating equipment is integrated on the diesel engine.

The daily oil tank and air intake filter are located on the third over-ground floor. The exhaust silencer, expansion tanks, and air-cooled heat radiators are installed on the fifth over-ground floor.

10.8.4.4.2 System Operation

a) Plant Normal Conditions

In the normal conditions of the power plant, the SBO DG is in the standby state. The engine can be pre-lubricated by the lubrication oil system and pre-heated by the coolant system. The auxiliary systems are always available to ensure the start-up of the SBO DGs at any time.

b) Plant Accidental Conditions

In the event of SBO, the SBO DGs can be started up manually, and the auxiliary systems can ensure the stable operation of the diesel engines. The SBO DGs can be stopped manually from the main control room. The auxiliary systems of the SBO DG enable the engine to run continuously for 3 day at the rated power.

10.8.4.5 Preliminary Design Substantiation

10.8.4.5.1 Compliance with Safety Functional Requirements

The SBO DGs and the auxiliary systems do not directly contribute to fundamental safety functions. For the extra safety functional requirements, the substantiation is presented in Sub-chapter 9.6.5 in terms of electrical engineering, and Sub-chapter 10.8.4 in terms of mechanical engineering.

10.8.4.5.2 Compliance with Design Requirements

a) Safety Classification

The SBO DGs and auxiliaries perform FC3 safety functions.

b) Redundancy and Single Failure Criterion

The design principles of the SFC presented in Chapter 4 are not applicable to the SBO DGs and auxiliary systems, because their role is to mitigate DEC-A situations. Two SBO DG sets are designed for a single nuclear unit and the SBO DG sets are redundant.

c) Independence

All DG buildings are physically separated, and the two SBO DGs are independent from each other.

d) Diversity

All auxiliary systems of the two SBO DGs are designed in the same way and there is no diversity requirement for the SBO DGs and auxiliary systems. However, there is a diversity requirement between the EDGs and SBO DGs, to avoid CCF. In compliance with the diversity requirement, the diesel engine and auxiliary systems of the SBO DGs are different from those of the EDGs. Many technical parameters between the EDGs and SBO DGs are different, such as the numbers of cylinders, cylinder bores, piston strokes, engine speeds, instrument and controls, etc. The auxiliary systems are also different, which are from different suppliers and have different technical parameters.

e) Fail-safe

The concept of fail-safe is considered in the design of SBO DG auxiliary systems. For example, the pneumatic valves in the compressed air system are in the shut-off state if the valves fail.

f) Ageing and Degradation

According to Chapter 2, the operational design life of the UK HPR1000 is 60 years. The main components of the systems are designed for the 60 year plant operation.

The ageing effects concerning individual components have been taken into consideration in the system design. A procedure of periodic testing and preventive maintenance is developed and implemented to prevent ageing and degradation. The periodic testing, preventive maintenance and replacement can ensure the system reliability.

g) Human Factors

The concept of human factors is taken into consideration in the system design. In the normal conditions of the power plant, the SBO DGs are in the standby state and no human intervention is required. During commissioning or maintenance activities, the requirements and procedures around human factors are carried out and implemented.

h) Autonomy

The SBO DG can produce power autonomously for 3 days. For example, the main fuel oil storage tank has the capability to sustain the 3 days of continuous operation of the SBO DG at the rated power.

i) Equipment Qualification

All the safety classified components in the SBO DG auxiliary systems, are qualified in accordance with the requirements described in Chapter 4.

The SBO DG performs class FC3 safety functions. For the related components,

the item classification is F-SC3, and the seismic category is SSE1.

All the seismically classified components operate during and after the SSE. The components are seismically designed and qualified for the SSE loads.

j) Protection against Internal and External Hazards

Internal Hazards: The safety critical components in the SBO DG buildings are separated physically or by free space to satisfy the internal hazard protection requirements.

External Hazards: The seismic category of the FC3 components is SSE1, and these components are arranged in the SBO DG buildings which are capable of withstanding external hazards such as earthquakes, airplane crashes, external flooding, external explosions and tornados.

k) Commissioning and Tests

1) Initial testing of the SBO DG and auxiliary equipment before delivery to site (for example factory acceptance tests) will be undertaken in accordance with the procurement, manufacturing and commissioning quality arrangements.

2) Following acceptance of the equipment by the commissioning organisation, a structured, systematic and progressive test programme, which includes all the activities required for confirmation and demonstration of the plant SSC operational and safety functional performance requirements, will be implemented. The test programme mainly includes the start-up test, in-service inspection and the periodic testing. The in-service inspection is implemented to ensure the normal operation of the preheating system and pre-lubricating system. The start-up test and periodic testing are implemented to ensure the function of the SBO DG.

l) Examination, Maintenance, Inspection and Testing

The SBO DGs are designed to permit examination, maintenance, inspection and testing, which are in accordance with the requirements from the maintenance strategy of the plant, equipment technical specification, equipment operating and maintenance manual, operation experience, etc. The total number of starts, operating hours at zero power and operating hours in loaded conditions will be recorded to perform the preventive maintenance of the SBO DG.

1) Daily examination of the diesel generator and important parameters of auxiliary systems is performed.

2) Periodic inspections and preventive maintenance is scheduled, which is mainly performed during the RCD mode.

3) The availability of the system and equipment is demonstrated by periodic

testing, including the start-up test, load carrying test, power supply switchover test, etc. The typical frequency and items being periodically tested are:

- Every two months. Start up the engine, load it to a lower power and stabilise it for two hours.
- Every eighteen months. Test the full power operation for 2 hours, and sample the engine lube oil and cooling water.

10.8.4.6 Simplified Diagrams

The simplified system diagram is presented in Figure F-10.8-2.

10.8.5 ALARP Assessment

A preliminary ALARP analysis has been performed on the DGs, in the Reference [13]. The applicable codes and standards list is presented in Sub-chapter 10.8.2. At this stage of GDA, no gap is identified. The consistency analysis is still under development to ensure that the design of the SSCs meets the requirements of the UK context.

The compliance analysis of the system design with the UK HPR1000 general safety engineering principles is made in the system section of each sub-chapter. The analysis shows that the design of the SSCs meets relevant requirements and no gap is identified. Meanwhile, technical assessments such as hazard schedule, fault schedule, probabilistic safety assessment, human factors, instrumentation and control are being developed simultaneously, and the analysis of the design against the requirements of these technical disciplines needs to be reviewed periodically. A systematic review will be carried out on the system design to ensure that no new gap is identified between the newly developed requirements and the design. Any potential enhancements identified during this review will be taken into account in the further design development;

If any potential gap is identified during the systematic technical review, analysis and optioneering will be undertaken to determine whether there are possible enhancements to the current system design, in order to reduce the risk as low as reasonably practicable.

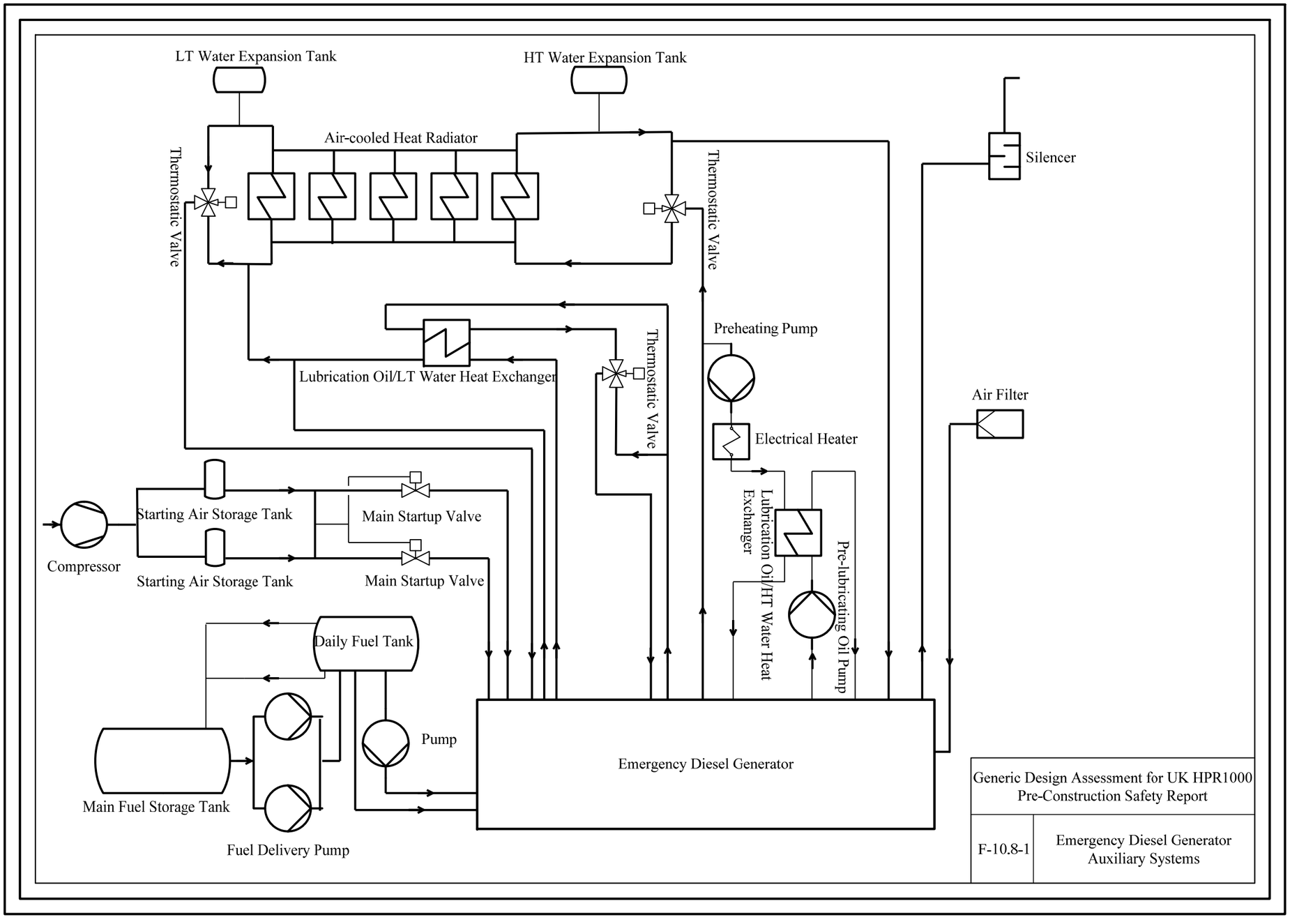
In summary, the ALARP analysis and demonstration work is still in progress, a preliminary ALARP demonstration topic report to present the current analysis results as well as the arrangement for the further ALARP analysis work is being carried out in Reference [13].

10.8.6 Concluding Remarks

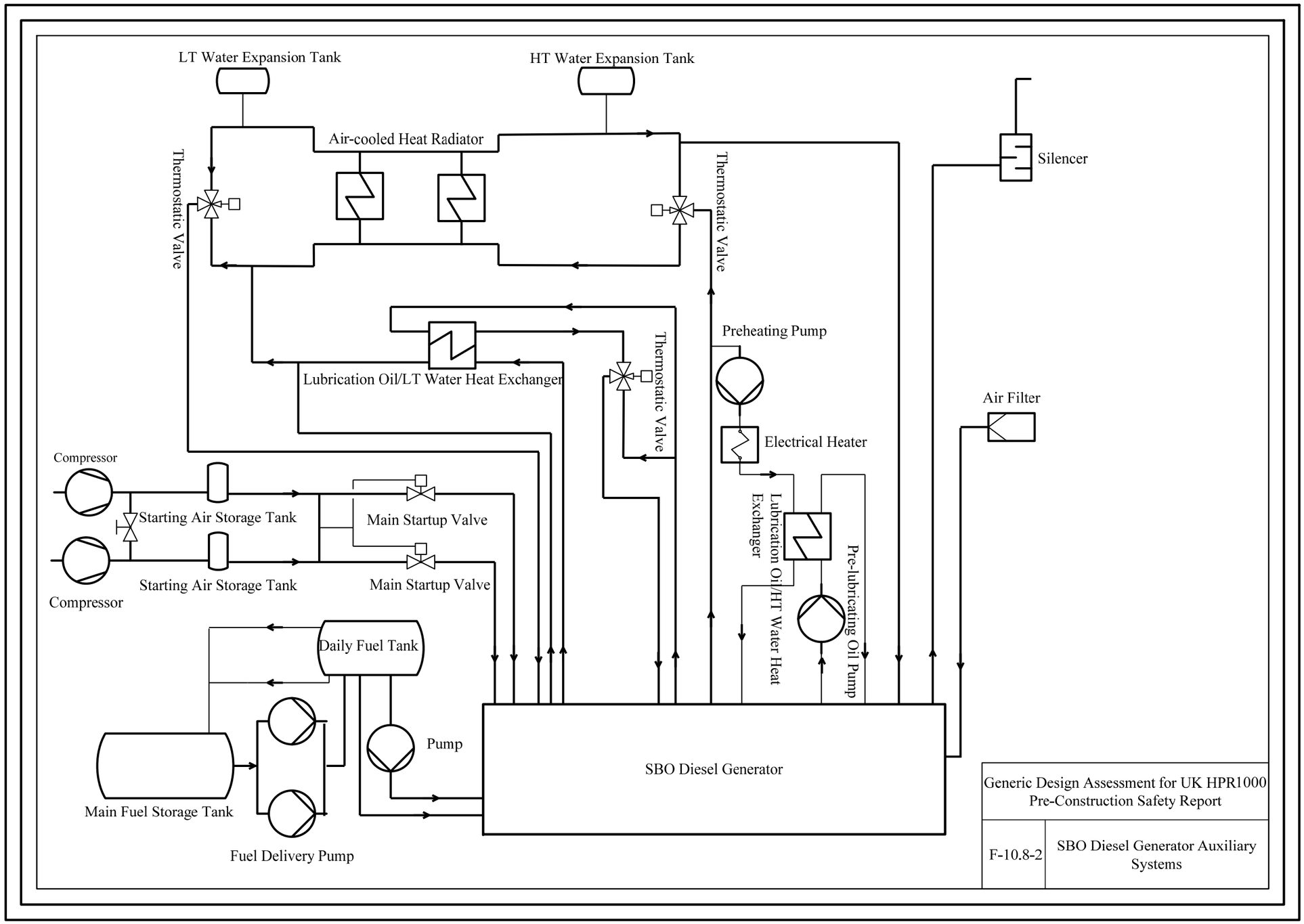
This sub-chapter provides an introduction of the design information of auxiliary systems of diesel generator in the UK HPR1000 nuclear power plant and demonstrates that the systems satisfy the performance requirements.

10.8.7 Simplified Diagrams

Simplified diagrams of Diesel Generator Auxiliary Systems mentioned in Sub-chapter 10.8.3 and 10.8.4 are presented in Figure F-10.8-1 and F-10.8-2.



F-10.8-1 Emergency Diesel Generator Auxiliary Systems



F-10.8-2 SBO Diesel Generator Auxiliary Systems

10.9 Concluding Remarks

Chapter 10 provides an introduction on the design information of auxiliary systems in UK HPR1000 nuclear power plant including system design considerations, design bases, system description and operation, design substantiation, etc.

The auxiliary systems design of UK HPR1000 is mainly based on the reference design, the consistency of the current design against the latest version of codes and standards based on the UK context is currently being analysed*)*. At this stage, the general safety engineering principles are newly developed for preliminary assessment, at the same time, various technical areas are under development. As the development of the principles may have an influence on the current design, a systematic review will be carried out after the preliminary work has been finished. If any gap is identified during the technical review, ALARP demonstration will be carried out to reduce the risk as low as reasonably practicable.

Based on the strategy of Mechanical Engineering safety case, there are various references under preparing at current stage, which will provide support for the PCSR in the future stages and will be submitted to the ONR.

Concluding remarks of each sub-chapter are presented in sections 10.3.6, 10.4.11, 10.5.8, 10.6.20, 10.7.7, 10.8.6.

10.10 References

[1] CGN, General Safety Requirements, GHX00100017DOZJ03GN, Revision C, 2018.

[2] CGN, Methodology of Safety Categorisation and Classification, GHX00100062DOZJ03GN, Revision B, 2018.

[3] CGN, The General Requirements of Protection Design against Internal and External Hazards, GHX00100028DOZJ03GN, Revision C, 2018.

[4] CGN, Material Selection Methodology, GHX00100006DPCH03GN, Revision B, 2018.

[5] CGN, General Principles for Application of Laws, Regulation, Codes and Standards, GHX00100018DOZJ03GN, Revision F, 2018.

[6] CGN, Applicable Codes and Standards in Context of Mechanical Engineering, GHX00800001DNHX02GN, Revision A, 2018.

[7] CGN, DMR-Reactor Building Handling Equipment System Manual Chapter 2 Brief Introduction to the System, GHX17DMR002DPZS45GN, Revision A, 2018

[8] CGN, DMR-Reactor Building Handling Equipment System Manual Chapter 3 System Functions and Design Bases, GHX17DMR003DPZS45GN, Revision A, 2018

[9] CGN, DMR-Reactor Building Handling Equipment System Manual Chapter 4 System and Component Design, GHX17DMR004DPZS45GN, Revision A, 2018

[10] CGN, DMK-Fuel Building Handling Equipment System Manual Chapter 2 Brief Introduction to the System, GHX17DMK002DPZS45GN, Revision A, 2018

[11] CGN, DMK-Fuel Building Handling Equipment System Manual Chapter 3 System Functions and Design Bases, GHX17DMK003DPZS45GN, Revision A, 2018

[12] CGN, DMK-Fuel Building Handling Equipment System Manual Chapter 4 System and Component Design, GHX17DMK004DPZS45GN, Revision A, 2018

[13] CGN, ALARP Demonstration for Auxiliary Systems, GHX00100053KPGB03GN, Revision B, 2018.

[14] CGN, RCV-Chemical and Volume Control System Design Manual Chapter 2 Brief Introduction to the System, GHX17RCV002DNHX45GN, Revision A,

2017.

[15] CGN, RCV-Chemical and Volume Control System Design Manual Chapter 5 Layout Requirements and Environment Condition, GHX17RCV005DNHX45GN, Revision A, 2017.

[16] CGN, RCV-Chemical and Volume Control System Design Manual Chapter 4 System and Component Design, GHX17RCV004DNHX45GN, Revision B, 2017.

[17] CGN, RCV-Chemical and Volume Control System Design Manual Chapter 6 System Operation and Maintenance, GHX17RCV006DNHX45GN, Revision B, 2017.

[18] CGN, RCV-Chemical and Volume Control System Design Manual Chapter 3 System Functions and Design Bases, GHX17RCV003DNHX45GN, Revision B, 2017.

[19] CGN, RCV-Chemical and Volume Control System Design Manual Chapter 9 Flow Diagrams, GHX17RCV009DNHX45GN, Revision B, 2017.

[20] CGN, REA-Reactor Boron and Water Makeup System Design Manual Chapter 2 Brief Introduction to the System, GHX17REA002DNHX45GN, Revision A, 2017.

[21] CGN, REA-Reactor Boron and Water Makeup System Design Manual Chapter 4 System and Component Design, GHX17REA004DNHX45GN, Revision A, 2017.

[22] CGN, REA-Reactor Boron and Water Makeup System Design Manual Chapter 5 Layout Requirements and Environment Condition, GHX17REA005DNHX45GN, Revision A, 2017.

[23] CGN, REA-Reactor Boron and Water Makeup System Design Manual Chapter 6 System Operation and Maintenance, GHX17REA006DNHX45GN, Revision B, 2017.

[24] CGN, REA-Reactor Boron and Water Makeup System Design Manual Chapter 3 System Functions and Design Bases, GHX17REA003DNHX45GN, Revision B, 2017.

[25] CGN, REA-Reactor Boron and Water Makeup System Design Manual Chapter 9 Flow Diagrams, GHX17REA009DNHX45GN, Revision B, 2017.

[26] CGN, TEP-Coolant Storage and Treatment System Design Manual Chapter 2 Brief Introduction to the System, GHX17TEP002DNFF45GN, Revision A, 2018.

[27] CGN, TEP-Coolant Storage and Treatment System Design Manual Chapter 4 System and Component Design, GHX17TEP004DNFF45GN, Revision B, 2018.

[28] CGN, TEP-Coolant Storage and Treatment System Design Manual Chapter 5 Layout Requirements and Environment Condition, GHX17TEP005DNFF45GN, Revision A, 2018.

[29] CGN, TEP-Coolant Storage and Treatment System Design Manual Chapter 6 System Operation and Maintenance, GHX17TEP006DNFF45GN, Revision A, 2018.

[30] CGN, TEP-Coolant Storage and Treatment System Design Manual Chapter 3 System Functions and Design Bases, GHX17TEP003DNFF45GN, Revision A, 2018.

[31] CGN, TEP-Coolant Storage and Treatment System Design Manual Chapter 9 Flow Diagrams, GHX17TEP009DNFF45GN, Revision B, 2018.

[32] CGN, REN-Nuclear Sampling System Design Manual Chapter 2 Brief Introduction to the System, GHX17REN002DNHX45GN, Revision A, 2017.

[33] CGN, REN-Nuclear Sampling System Design Manual Chapter 4 System and Component Design, GHX17REN004DNHX45GN, Revision A, 2017.

[34] CGN, REN-Nuclear Sampling System Design Manual Chapter 5 Layout Requirements and Environment Condition, GHX17REN005DNHX45GN, Revision A, 2017.

[35] CGN, REN-Nuclear Sampling System Design Manual Chapter 6 System Operation and Maintenance, GHX17REN006DNHX45GN, Revision B, 2017.

[36] CGN, REN-Nuclear Sampling System Design Manual Chapter 3 System Functions and Design Bases, GHX17REN003DNHX45GN, Revision B, 2017.

[37] CGN, PTR-Fuel Pool Cooling and Treatment System Design Manual Chapter 2 Brief Introduction to the System, GHX17PTR002DNHX45GN, Revision A, 2017.

[38] CGN, PTR-Fuel Pool Cooling and Treatment System Design Manual Chapter 3 System Functions and Design Bases, GHX17PTR003DNHX45GN, Revision A, 2017.

[39] CGN, PTR-Fuel Pool Cooling and Treatment System Design Manual Chapter 4 System and Component Design, GHX17PTR004DNHX45GN, Revision A, 2017.

[40] CGN, PTR-Fuel Pool Cooling and Treatment System Design Manual Chapter 6 System Operation and Maintenance, GHX17PTR006DNHX45GN, Revision B,

2017.

[41] CGN, PTR-Fuel Pool Cooling and Treatment System Design Manual Chapter 5 Layout Requirements and Environment Condition, GHX17PTR005DNHX45GN, Revision A, 2017.

[42] CGN, PTR-Fuel Pool Cooling and Treatment System Design Manual Chapter 9 Flow Diagrams, GHX17PTR009DNHX45GN, Revision B, 2017.

[43] CGN, RRI-Component Cooling Water System Design Manual Chapter 2 Brief Introduction to the System, GHX17RRI002DNHX45GN, Revision A, 2017.

[44] CGN, RRI-Component Cooling Water System Design Manual Chapter 3 System Functions and Design Bases, GHX17RRI003DNHX45GN, Revision B, 2017.

[45] CGN, RRI-Component Cooling Water System Design Manual Chapter 4 System and Component Design, GHX17RRI004DNHX45GN, Revision B, 2017.

[46] CGN, RRI-Component Cooling Water System Design Manual Chapter 5 Layout Requirements and Environment Condition, GHX17RRI005DNHX45GN, Revision A, 2017.

[47] CGN, RRI-Component Cooling Water System Design Manual Chapter 6 System Operation and Maintenance, GHX17RRI006DNHX45GN, Revision B, 2017.

[48] CGN, SEC-Essential Service Water System Manual Chapter 2 Brief Introduction to the System, GHX17SEC002DCSG45GN, Revision B, 2018.

[49] CGN, SEC-Essential Service Water System Manual Chapter 4 System and Component Design, GHX17SEC004DCSG45GN, Revision B, 2018.

[50] CGN, SEC-Essential Service Water System Manual Chapter 5 Layout Requirements and Environment Condition, GHX17SEC005DCSG45GN, Revision B, 2018.

[51] CGN, SEC- Essential Service Water System Manual Chapter 6 System Operation and Maintenance, GHX17SEC006DCSG45GN, Revision B, 2018.

[52] CGN, SEC-Essential Service Water System Manual Chapter 3 System Functions and Design Bases, GHX17SEC003DCSG45GN, Revision B, 2018.

[53] CGN, DWN-Nuclear Auxiliary Building Ventilation System Manual Chapter 4 System and Component Design, GHX17DWN004DCNT45GN, Revision A, 2018.

[54] CGN, DWN-Nuclear Auxiliary Building Ventilation System Manual Chapter 2

Brief Introduction to the System, GHX17DWN002DCNT45GN, Revision B, 2018.

[55] CGN, DWN-Nuclear Auxiliary Building Ventilation System Manual Chapter 5 Layout Requirements and Environment Condition, GHX17DWN005DCNT45GN, Revision B, 2018.

[56] CGN, DWN-Nuclear Auxiliary Building Ventilation System Manual Chapter 6 System Operation and Maintenance, GHX17DWN006DCNT45GN, Revision B, 2018.

[57] CGN, DWN-Nuclear Auxiliary Building Ventilation System Manual Chapter 3 System Functions and Design Bases, GHX17DWN003DCNT45GN, Revision A, 2018.

[58] CGN, DWN-Nuclear Auxiliary Building Ventilation System Manual Chapter 9 Flow Diagrams, GHX17DWN009DCNT45GN, Revision B, 2018.

[59] CGN, DWK-Fuel Building Ventilation System Manual Chapter 4 System and Component Design, GHX17DWK004DCNT45GN, Revision A, 2018.

[60] CGN, DWK-Fuel Building Ventilation System Manual Chapter 2 Brief Introduction to the System, GHX17DWK002DCNT45GN, Revision B, 2018.

[61] CGN, DWK-Fuel Building Ventilation System Manual Chapter 5 Layout Requirements and Environment Condition, GHX17DWK005DCNT45GN, Revision B, 2018.

[62] CGN, DWK-Fuel Building Ventilation System Manual Chapter 3 System Functions and Design Bases, GHX17DWK003DCNT45GN, Revision A, 2018.

[63] CGN, DWK-Fuel Building Ventilation System Manual Chapter 6 System Operation and Maintenance, GHX17DWK006DCNT45GN, Revision B, 2018.

[64] CGN, DWK-Fuel Building Ventilation System Manual Chapter 9 Flow Diagrams, GHX17DWK009DCNT45GN, Revision B, 2018.

[65] CGN, EVR-Containment Cooling and Ventilation System Manual Chapter 4 System and Component Design, GHX17EVR004DCNT45GN, Revision A, 2018.

[66] CGN, EVR-Containment Cooling and Ventilation System Manual Chapter 2 Brief Introduction to the System, GHX17EVR002DCNT45GN, Revision B, 2018.

[67] CGN, EVR-Containment Cooling and Ventilation System Manual Chapter 5 Layout Requirements and Environment Condition, GHX17EVR005DCNT45GN, Revision B, 2018.

[68] CGN, EVR-Containment Cooling and Ventilation System Manual Chapter 6 System Operation and Maintenance, GHX17EVR006DCNT45GN, Revision B, 2018.

[69] CGN, EVR-Containment Cooling and Ventilation System Manual Chapter 3 System Functions and Design Bases, GHX17EVR003DCNT45GN, Revision B, 2018.

[70] CGN, EVR-Containment Cooling and Ventilation System Manual Chapter 9 Flow Diagrams, GHX17EVR009DCNT45GN, Revision B, 2018.

[71] CGN, EVF-Containment Internal Filtration System Manual Chapter 4 System and Component Design, GHX17EVF004DCNT45GN, Revision A, 2018.

[72] CGN, EVF-Containment Internal Filtration System Manual Chapter 2 Brief Introduction to the System, GHX17EVF002DCNT45GN, Revision B, 2018.

[73] CGN, EVF-Containment Internal Filtration System Manual Chapter 5 Layout Requirements and Environment Condition, GHX17EVF005DCNT45GN, Revision B, 2018.

[74] CGN, EVF-Containment Internal Filtration System Manual Chapter 6 System Operation and Maintenance, GHX17EVF006DCNT45GN, Revision B, 2018.

[75] CGN, EVF-Containment Internal Filtration System Manual Chapter 3 System Functions and Design Bases, GHX17EVF003DCNT45GN, Revision B, 2018.

[76] CGN, EVF-Containment Internal Filtration System Manual Chapter 9 Flow Diagrams, GHX17EVF009DCNT45GN, Revision B, 2018.

[77] CGN, EBA-Containment Sweeping and Blowdown Ventilation System Manual Chapter 4 System and Component Design, GHX17EBA004DCNT45GN, Revision A, 2018.

[78] CGN, EBA-Containment Sweeping and Blowdown Ventilation System Manual Chapter 2 Brief Introduction to the System, GHX17EBA002DCNT45GN, Revision B, 2018.

[79] CGN, EBA-Containment Sweeping and Blowdown Ventilation System Manual Chapter 5 Layout Requirements and Environment Condition, GHX17EBA005DCNT45GN, Revision B, 2018.

[80] CGN, EBA-Containment Sweeping and Blowdown Ventilation System Manual Chapter 6 System Operation and Maintenance, GHX17EBA006DCNT45GN, Revision B, 2018.

[81] CGN, EBA-Containment Sweeping and Blowdown Ventilation System Manual Chapter 3 System Functions and Design Bases, GHX17EBA003DCNT45GN,

Revision B, 2018.

[82] CGN, EBA-Containment Sweeping and Blowdown Ventilation System Manual Chapter 9 Flow Diagrams, GHX17EBA009DCNT45GN, Revision B, 2018.

[83] CGN, EDE-Annulus Ventilation System Manual Chapter 4 System and Component Design, GHX17EDE004DCNT45GN, Revision A, 2018.

[84] CGN, EDE-Annulus Ventilation System Manual Chapter 2 Brief Introduction to the System, GHX17EDE002DCNT45GN, Revision B, 2018.

[85] CGN, EDE-Annulus Ventilation System Manual Chapter 5 Layout Requirements and Environment Condition, GHX17EDE005DCNT45GN, Revision B, 2018.

[86] CGN, EDE-Annulus Ventilation System Manual Chapter 6 System Operation and Maintenance, GHX17EDE006DCNT45GN, Revision B, 2018.

[87] CGN, EDE-Annulus Ventilation System Manual Chapter 3 System Functions and Design Bases, GHX17EDE003DCNT45GN, Revision A, 2018.

[88] CGN, EDE-Annulus Ventilation System Manual Chapter 9 Flow Diagrams, GHX17EDE009DCNT45GN, Revision B, 2018.

[89] CGN, DWL-Safeguard Building Controlled Area Ventilation System Manual Chapter 4 System and Component Design, GHX17DWL004DCNT45GN, Revision A, 2018.

[90] CGN, DWL-Safeguard Building Controlled Area Ventilation System Manual Chapter 2 Brief Introduction to the System, GHX17DWL002DCNT45GN, Revision B, 2018.

[91] CGN, DWL-Safeguard Building Controlled Area Ventilation System Manual Chapter 5 Layout Requirements and Environment Condition, GHX17DWL005DCNT45GN, Revision B, 2018.

[92] CGN, DWL-Safeguard Building Controlled Area Ventilation System Manual Chapter 6 System Operation and Maintenance, GHX17DWL006DCNT45GN, Revision B, 2018.

[93] CGN, DWL-Safeguard Building Controlled Area Ventilation System Manual Chapter 3 System Functions and Design Bases, GHX17DWL003DCNT45GN, Revision B, 2018.

[94] CGN, DWL-Safeguard Building Controlled Area Ventilation System Manual Chapter 9 Flow Diagrams, GHX17DWL009DCNT45GN, Revision B, 2018.

[95] CGN, DVL-Electrical Division of Safeguard Building Ventilation System Manual Chapter 4 System and Component Design,

GHX17DVL004DCNT45GN, Revision A, 2018.

[96] CGN, DVL-Electrical Division of Safeguard Building Ventilation System Manual Chapter 2 Brief Introduction to the System, GHX17DVL002DCNT45GN, Revision B, 2018.

[97] CGN, DVL-Electrical Division of Safeguard Building Ventilation System Manual Chapter 5 Layout Requirements and Environment Condition, GHX17DVL005DCNT45GN, Revision B, 2018.

[98] CGN, DVL-Electrical Division of Safeguard Building Ventilation System Manual Chapter 6 System Operation and Maintenance, GHX17DVL006DCNT45GN, Revision B, 2018.

[99] CGN, DVL-Electrical Division of Safeguard Building Ventilation System Manual Chapter 3 System Functions and Design Bases, GHX17DVL003DCNT45GN, Revision A, 2018.

[100] CGN, DVL-Electrical Division of Safeguard Building Ventilation System Manual Chapter 9 Flow Diagrams, GHX17DVL009DCNT45GN, Revision B, 2018.

[101] CGN, DCL-Main Control Room Air Conditioning System Manual Chapter 4 System and Component Design, GHX17DCL004DCNT45GN, Revision B, 2018.

[102] CGN, DCL-Main Control Room Air Conditioning System Manual Chapter 2 Brief Introduction to the System, GHX17DCL002DCNT45GN, Revision B, 2018.

[103] CGN, DCL-Main Control Room Air Conditioning System Manual Chapter 5 Layout Requirements and Environment Condition, GHX17DCL005DCNT45GN, Revision B, 2018.

[104] CGN, DCL-Main Control Room Air Conditioning System Manual Chapter 6 System Operation and Maintenance, GHX17DCL006DCNT45GN, Revision B, 2018.

[105] CGN, DCL-Main Control Room Air Conditioning System Manual Chapter 3 System Functions and Design Bases, GHX17DCL003DCNT45GN, Revision A, 2018.

[106] CGN, DCL-Main Control Room Air Conditioning System Manual Chapter 9 Flow Diagrams, GHX17DCL009DCNT45GN, Revision B, 2018.

[107] CGN, DWW-Access Building Controlled Area Ventilation System Manual Chapter 4 System and Component Design, GHX17DWW004DCNT45GN, Revision A, 2018.

[108] CGN, DWW-Access Building Controlled Area Ventilation System Manual Chapter 2 Brief Introduction to the System, GHX17DWW002DCNT45GN, Revision B, 2018.

[109] CGN, DWW-Access Building Controlled Area Ventilation System Manual Chapter 5 Layout Requirements and Environment Condition, GHX17DWW005DCNT45GN, Revision B, 2018.

[110] CGN, DWW-Access Building Controlled Area Ventilation System Manual Chapter 6 System Operation and Maintenance, GHX17DWW006DCNT45GN, Revision B, 2018.

[111] CGN, DWW-Access Building Controlled Area Ventilation System Manual Chapter 3 System Functions and Design Bases, GHX17DWW003DCNT45GN, Revision A, 2018.

[112] CGN, DWW-Access Building Controlled Area Ventilation System Manual Chapter 9 Flow Diagrams, GHX17DWW009DCNT45GN, Revision B, 2018.

[113] CGN, DVD-Diesel Building Ventilation System Manual Chapter 4 System and Component Design, GHX17DVD004DCNT45GN, Revision A, 2018.

[114] CGN, DVD-Diesel Building Ventilation System Manual Chapter 2 Brief Introduction to the System, GHX17DVD002DCNT45GN, Revision A, 2018.

[115] CGN, DVD-Diesel Building Ventilation System Manual Chapter 5 Layout Requirements and Environment Condition, GHX17DVD005DCNT45GN, Revision A, 2018.

[116] CGN, DVD-Diesel Building Ventilation System Manual Chapter 6 System Operation and Maintenance, GHX17DVD006DCNT45GN, Revision A, 2018.

[117] CGN, DVD-Diesel Building Ventilation System Manual Chapter 3 System Functions and Design Bases, GHX17DVD003DCNT45GN, Revision A, 2018.

[118] CGN, DVD-Diesel Building Ventilation System Manual Chapter 9 Flow Diagrams, GHX17DVD009DCNT45GN, Revision B, 2018.

[119] CGN, DWQ-Waste Treatment Building Ventilation System Manual Chapter 4 System and Component Design, GHX17DWQ004DCNT45GN, Revision A, 2018.

[120] CGN, DWQ-Waste Treatment Building Ventilation System Manual Chapter 2 Brief Introduction to the System, GHX17DWQ002DCNT45GN, Revision B, 2018.

[121] CGN, DWQ-Waste Treatment Building Ventilation System Manual Chapter 5 Layout Requirements and Environment Condition,

GHX17DWQ005DCNT45GN, Revision B, 2018.

[122] CGN, DWQ-Waste Treatment Building Ventilation System Manual Chapter 6 System Operation and Maintenance, GHX17DWQ006DCNT45GN, Revision A, 2018.

[123] CGN, DWQ-Waste Treatment Building Ventilation System Manual Chapter 3 System Functions and Design Bases, GHX17DWQ003DCNT45GN, Revision A, 2018.

[124] CGN, DEL-Safety Chilled Water System Manual Chapter 4 System and Component Design, GHX17DEL004DCNT45GN, Revision B, 2018.

[125] CGN, DEL-Safety Chilled Water System Manual Chapter 2 Brief Introduction to the System, GHX17DEL002DCNT45GN, Revision B, 2018.

[126] CGN, DEL-Safety Chilled Water System Manual Chapter 5 Layout Requirements and Environment Condition, GHX17DEL005DCNT45GN, Revision B, 2018.

[127] CGN, DEL-Safety Chilled Water System Manual Chapter 6 System Operation and Maintenance, GHX17DEL006DCNT45GN, Revision B, 2018.

[128] CGN, DEL-Safety Chilled Water System Manual Chapter 3 System Functions and Design Bases, GHX17DEL003DCNT45GN, Revision A, 2018.

[129] CGN, DFL-Smoke Control System Manual Chapter 4 System and Component Design, GHX17DFL004DCNT45GN, Revision A, 2018.

[130] CGN, DFL-Smoke Control System Manual Chapter 2 Brief Introduction to the System, GHX17DFL002DCNT45GN, Revision B, 2018.

[131] CGN, DFL-Smoke Control System Manual Chapter 6 System Operation and Maintenance, GHX17DFL006DCNT45GN, Revision B, 2018.

[132] CGN, DFL-Smoke Control System Manual Chapter 5 Layout Requirements and Environment Condition, GHX17DFL005DCNT45GN, Revision B, 2018.

[133] CGN, DFL-Smoke Control System Manual Chapter 3 System Functions and Design Bases, GHX17DFL003DCNT45GN, Revision B, 2018.

[134] CGN, Technical Specification for the Emergency Diesel Generator, GHX54100001DCCJ44DS, Revision A, 2018.

Appendix 10A Route Map of Sub-Chapter 10.3

Claim		Sub-claim		Argument		Evidence	
						PCSR links	Supporting Documents
3.3.6	The design of the Auxiliary Systems has been substantiated	3.3.6A	The safety functional requirements (Design Basis) have been derived for the system.	3.3.6A-1	The specific design principles are identified for the SSCs based on relevant good practice.	PCSR Sub-chapter 10.3.2. Applicable Codes and Standards	SDM Chapter 3 System Functions and Design Bases Applicable Code and Standards in Context of Mechanical Engineering
				3.3.6A-2	The design basis (requirements) of the SSCs has been derived from the safety analysis in accordance with the general design and safety principles.	PCSR Sub-chapter 10.2.4-General Design Requirements	SDM Chapter 3 System Functions and Design Bases
				3.3.6A-3	The Safety Class of the SSCs has been identified from the safety analysis.	PCSR Sub-chapter 10.3.X.5.2 - Compliance with Design Requirements (X is 3 or 4)	SDM Chapter 3 System Functions and Design Bases
		3.3.6B	The system design satisfies the safety functional requirements.	3.3.6B-1	Appropriate design methods have been identified for the SSCs including design codes and standards.	PCSR Sub-chapter 10.3.X.3 - Design Bases (X is from 3 or 4)	SDM Chapter 3 System Functions and Design Bases
				3.3.6B-2	The SSCs have been analysed using the appropriate design methods and meet the design basis requirements.	PCSR Sub-chapter 10.3.X.5.2 - Compliance with Design Requirements (X is 3 or 4)	SDM Chapter 4 System and Component Design
				3.3.6B-3	The SSCs analysis recognises interface requirements and effects from/to the interfacing SSCs.	PCSR Sub-chapter 10.3.X.5.2 - Compliance with Design Requirements (X is 3 or 4)	SDM Chapter 4 System and Component Design
		3.3.6C	All reasonably practicable measures have been adopted to improve the design.	3.3.6C-1	The SSCs meet the requirements of the relevant design principles (generic and system specific) and therefore of relevant good practice.	PCSR Sub-chapter 10.3.5 - ALARP	SDM Chapter 3 System Functions and Design Bases SDM Chapter 4 System and Component Design
				3.3.6C-2	PSA indicates the SSCs are not disproportionate contributor to risk.	PCSR Sub-chapter 10.3.5 - ALARP	
				3.3.6C-3	Design improvements have been considered in the SSCs and any reasonably practicable changes implemented.	PCSR Sub-chapter 10.3.5 - ALARP	
		3.3.6D	The system performance will be validated by suitable commissioning and testing.	3.3.6D-1	The SSCs have been designed to take benefit from a suite of pre-construction tests, to provide assurance of the initial quality of the manufacture.	PCSR Sub-chapter 10.3.X.5.2 - Compliance with Design Requirements (X is 3 or 4)	SDM Chapter 4 System and Component Design Classification List

Claim		Sub-claim		Argument		Evidence	
						PCSR links	Supporting Documents
				3.3.6D-2	The SSCs has been designed to take benefit from a suite of commissioning tests, to provide assurance of the initial quality of the build.	PCSR Sub-chapter 10.3.X.5.2 - Compliance with Design Requirements (X is 3 or 4)	
		3.3.6E	The effects of ageing of the system have been addressed in the design and suitable examination, inspection, maintenance and testing specified.	3.3.6E-1	An initial EMIT strategy has been developed for the SSCs that are expected to be examined, maintained, inspected and tested.	PCSR Sub-chapter 10.3.X.5.2 - Compliance with Design Requirements (X is 3 or 4)	
				3.3.6E-2	The SSCs that cannot be replaced have been shown to have adequate life, which includes the requirements during decommissioning.	PCSR Sub-chapter 10.3.X.5.2 - Compliance with Design Requirements (X is 3 or 4)	

Appendix 10B Route Map of Sub-Chapter 10.4

Claim		Sub-claim		Argument		Evidence	
						PCSR links	Supporting Documents
3.3.6	The design of the Auxiliary Systems has been substantiated	3.3.6A	The safety functional requirements (Design Basis) have been derived for the system.	3.3.6A-1	The specific design principles are identified for the SSCs based on relevant good practice.	PCSR Sub-chapter 10.4.2. Applicable Codes and Standards	SDM Chapter 3 System Functions and Design Bases Applicable Code and Standards in Context of Mechanical Engineering
				3.3.6A-2	The design basis (requirements) of the SSCs has been derived from the safety analysis in accordance with the general design and safety principles.	PCSR Sub-chapter 10.2.4-General Design Requirements	SDM Chapter 3 System Functions and Design Bases SDM Chapter 5 Layout Requirements and Environment Condition
				3.3.6A-3	The Safety Class of the SSCs has been identified from the safety analysis.	PCSR Sub-chapter 10.4.X.5.2 - Compliance with Design Requirements (X is from 3 to 9)	SDM Chapter 3 System Functions and Design Bases
		3.3.6B	The system design satisfies the safety functional requirements.	3.3.6B-1	Appropriate design methods have been identified for the SSCs including design codes and standards.	PCSR Sub-chapter 10.4.X.3 - Design Bases (X is from 3 to 9)	SDM Chapter 3 System Functions and Design Bases Design Manual for Valve Selection
				3.3.6B-2	The SSCs have been analysed using the appropriate design methods and meet the design basis requirements.	PCSR Sub-chapter 10.4.X.5.2 - Compliance with Design Requirements (X is from 3 to 9)	SDM Chapter 4 System and Component Design SDM Chapter 6 System Operation and Maintenance SDM Chapter 9 Flow Diagrams
				3.3.6B-3	The SSCs analysis recognises interface requirements and effects from/to the interfacing SSCs.	PCSR Sub-chapter 10.4.X.5.2 - Compliance with Design Requirements (X is from 3 to 9)	SDM Chapter 4 System and Component Design
		3.3.6C	All reasonably practicable measures have been adopted to improve the design.	3.3.6C-1	The SSCs meet the requirements of the relevant design principles (generic and system specific) and therefore of relevant good practice.	PCSR Sub-chapter 10.4.10 - ALARP	SDM Chapter 3 System Functions and Design Bases SDM Chapter 4 System and Component Design SDM Chapter 6 System Operation and Maintenance
				3.3.6C-2	PSA indicates the SSCs are not disproportionate contributor to risk.	PCSR Sub-chapter 10.4.10 - ALARP	
				3.3.6C-3	Design improvements have been considered in the SSCs and any reasonably practicable changes implemented.	PCSR Sub-chapter 10.4.10 - ALARP	

Claim		Sub-claim		Argument		Evidence	
						PCSR links	Supporting Documents
		3.3.6D	The system performance will be validated by suitable commissioning and testing.	3.3.6D-1	The SSCs have been designed to take benefit from a suite of pre-construction tests, to provide assurance of the initial quality of the manufacture.	PCSR Sub-chapter 10.4.X.5.2 - Compliance with Design Requirements (X is from 3 to 9)	SDM Chapter 4 System and Component Design Classification List
				3.3.6D-2	The SSCs has been designed to take benefit from a suite of commissioning tests, to provide assurance of the initial quality of the build.	PCSR Sub-chapter 10.4.X.5.2 - Compliance with Design Requirements (X is from 3 to 9)	SDM Chapter 6 System Operation and Maintenance
		3.3.6E	The effects of ageing of the system have been addressed in the design and suitable examination, inspection, maintenance and testing specified.	3.3.6E-1	An initial EMIT strategy has been developed for the SSCs that are expected to be examined, maintained, inspected and tested.	PCSR Sub-chapter 10.4.X.5.2 - Compliance with Design Requirements (X is from 3 to 9)	SDM Chapter 6 System Operation and Maintenance
				3.3.6E-2	The SSCs that cannot be replaced have been shown to have adequate life, which includes the requirements during decommissioning.	PCSR Sub-chapter 10.4.X.5.2 - Compliance with Design Requirements (X is from 3 to 9)	SDM Chapter 6 System Operation and Maintenance

Appendix 10C Route Map of Sub-Chapter 10.6

Claim		Sub-claim		Argument		Evidence	
						PCSR links	Supporting Documents
3.3.6	The design of the Auxiliary Systems has been substantiated	3.3.6A	The safety functional requirements (Design Basis) have been derived for the system.	3.3.6A-1	The specific design principles are identified for the SSCs based on relevant good practice.	PCSR Sub-chapter 10.6.2. Applicable Codes and Standards	SDM Chapter 3 System Functions and Design Bases Applicable Code and Standards in Context of Mechanical Engineering
				3.3.6A-2	The design basis (requirements) of the SSCs has been derived from the safety analysis in accordance with the general design and safety principles. The Safety Class of the SSCs has been identified from the safety analysis.	PCSR Sub-chapter 10.2.4-General Design Requirements	SDM Chapter 3 System Functions and Design Bases SDM Chapter 5 Layout Requirements and Environment Condition
				3.3.6A-3	Appropriate design methods have been identified for the SSCs including design codes and standards.	PCSR Sub-chapter 10.6.X.5.2 - Compliance with Design Requirements, (X is from 3 to 18)	SDM Chapter 3 System Functions and Design Bases
		3.3.6B	The system design satisfies the safety functional requirements.	3.3.6B-1	The SSCs have been analysed using the appropriate design methods and meet the design basis requirements. The SSCs analysis recognises interface requirements and effects from/to the interfacing SSCs.	PCSR Sub-chapter 10.6.X.3 - Design Bases PCSR Sub-chapter 10.6.X.5.2 - Compliance with Design Requirements (X is from 3 to 18)	SDM Chapter 3 System Functions and Design Bases Design Manual for Valve Selection
				3.3.6B-2	The SSCs meet the requirements of the relevant design principles (generic and system specific) and therefore of relevant good practice. PSA indicates the SSCs are not disproportionate contributor to risk.	PCSR Sub-chapter 10.6.X.3 - Design Bases (X is from 3 to 18)	SDM Chapter 4 System and Component Design SDM Chapter 6 System Operation and Maintenance SDM Chapter 9 Flow Diagrams
				3.3.6B-3	Design improvements have been considered in the SSCs and any reasonably practicable changes implemented.	PCSR Sub-chapter 10.6.X.5.2 - Compliance with Design Requirements (X is from 3 to 18)	SDM Chapter 4 System and Component Design
		3.3.6C	All reasonably practicable measures have been adopted to improve the design.	3.3.6C-1	The SSCs have been designed to take benefit from a suite of pre-construction tests, to provide assurance of the initial quality of the manufacture. The SSCs has been designed to take benefit from a suite of commissioning tests, to provide assurance of the initial quality of the build.	PCSR Sub-chapter 10.6.19 - ALARP	SDM Chapter 3 System Functions and Design Bases SDM Chapter 4 System and Component Design SDM Chapter 6 System Operation and Maintenance

Claim		Sub-claim		Argument		Evidence	
						PCSR links	Supporting Documents
				3.3.6C-2	An initial EMIT strategy has been developed for the SSCs that are expected to be examined, maintained, inspected and tested.	PCSR Sub-chapter 10.6.19 - ALARP	
				3.3.6C-3	The SSCs that cannot be replaced have been shown to have adequate life, which includes the requirements during decommissioning.	PCSR Sub-chapter 10.6.19 - ALARP	
		3.3.6D	The system performance will be validated by suitable commissioning and testing.	3.3.6D-1	The SSCs have been designed to take benefit from a suite of pre-construction tests, to provide assurance of the initial quality of the manufacture.	PCSR Sub-chapter 10.6.X.5.2 - Compliance with Design Requirements (X is from 3 to 18)	SDM Chapter 4 System and Component Design Classification List
				3.3.6D-2	The SSCs has been designed to take benefit from a suite of commissioning tests, to provide assurance of the initial quality of the build.	PCSR Sub-chapter 10.6.X.5.2 - Compliance with Design Requirements (X is from 3 to 18)	SDM Chapter 6 System Operation and Maintenance
		3.3.6E	The effects of ageing of the system have been addressed in the design and suitable examination, inspection, maintenance and testing specified.	3.3.6E-1	An initial EMIT strategy has been developed for the SSCs that are expected to be examined, maintained, inspected and tested.	PCSR Sub-chapter 10.6.X.5.2 - Compliance with Design Requirements (X is from 3 to 18)	SDM Chapter 6 System Operation and Maintenance
				3.3.6E-2	The SSCs that cannot be replaced have been shown to have adequate life, which includes the requirements during decommissioning.	PCSR Sub-chapter 10.6.X.5.2 - Compliance with Design Requirements (X is from 3 to 18)	SDM Chapter 6 System Operation and Maintenance