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UK HPR1000 GDA Project

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Pre-Construction Safety Report

Chapter 24

Decommissioning

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24.1 List of Abbreviations and Acronyms

ALARP	As Low As Reasonably Practicable
BAT	Best Available Technique
BFX	Fuel Building
BMX	Turbine Generator Building
BNX	Nuclear Auxiliary Building
BQZ	Interim Storage Facility
BRX	Reactor Building
BWX	Radioactive Waste Treatment Building
CGN	China General Nuclear Power Corporation
DECC	Department of Energy and Climate Change (UK)
EA	Environment Agency (UK)
GDA	Generic Design Assessment
GDF	Geological Disposal Facility
HPR1000	Hua-long Pressurized Reactor
HVAC	Heating, Ventilation and Air Conditioning
IAEA	International Atomic Energy Agency
ILW	Intermediate Level Waste
IWS	Integrated Waste Strategy
LLW	Low Level Waste
LLWR	Low Level Waste Repository Ltd (UK)
MSQA	Management of Safety and Quality Assurance
NDA	Nuclear Decommissioning Authority (UK)
ONR	Office for Nuclear Regulation (UK)
OPEX	Operating Experience
PCER	Pre-Construction Environmental Report
PCSR	Pre-Construction Safety Report
POCO	Post Operational Clean Out

PWR	Pressurised Water Reactor
RGP	Relevant Good Practice
RPE	Nuclear Island Vent and Drain System [VDS]
RPV	Reactor Pressure Vessel
SAP	Safety Assessment Principle (UK)
SFA	Spent Fuel Assembly
SFIS	Spent Fuel Interim Storage
SFP	Spent Fuel Pool
SG	Steam Generator
SSCs	Structures, Systems and Components
UK HPR1000	UK version of the Hua-long Pressurized Reactor
VLLW	Very Low Level Waste
WAC	Waste Acceptance Criteria
WENRA	Western European Nuclear Regulators Association

System codes (XXX) and system abbreviations (YYY) are provided for completeness in the format (XXX [YYY]), e.g. Nuclear Island Vent and Drain System (RPE [VDS]).

24.2 Introduction

Decommissioning is considered throughout the processes of design, construction and operation, although it is the last phase in the lifecycle of nuclear facilities as described in Reference [1]. This chapter presents the consideration of facilitating decommissioning, decommissioning strategy and the preliminary decommissioning plan for the UK HPR1000 and shows that the plant can be decommissioned safely, effectively and with minimal impact on the environment and the public. Decommissioning for the UK HPR1000 will be developed to meet UK regulatory requirements.

The following concepts are included in this chapter:

a) Design for safe decommissioning: the design of the UK HPR1000 ensures that decommissioning can be achieved with reduced doses to the workers and the public, minimised production of wastes and impacts on the environment, simplified demolition procedures and lower costs. Comprehensive records will be made and other measures will be prepared during the full lifecycle of the plant to aid the decommissioning process in References [2], [3] and [4]. Relevant information is provided in PCSR Sub-chapter 24.4;

b) Adequate preparation of a decommissioning strategy: the decommissioning strategy of the UK HPR1000 is considered, developed and integrated with other relevant strategies (e.g. radioactive waste management and spent fuel management). Relevant information is provided in PCSR Sub-chapter 24.5;

c) Adequate preparation of a decommissioning plan: the timing of the decommissioning strategy is discussed, a preliminary decommissioning plan is prepared and will be developed to reflect the developments in techniques and experiences, to ensure that the methods and techniques adopted for decommissioning are safe and protect the workers, the public and the environment. Relevant information is provided in PCSR Sub-chapter 24.6. As Low As Reasonably Practicable (ALARP) and Best Available Technique (BAT) considerations are part of the UK HPR1000 decommissioning plan. It should be noted that the decommissioning plan will be maintained and renewed during the operating phase by the licensee.

24.2.1 Chapter Route Map

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

To underpin this objective**,** five high level claims (Level 1 claims) and a number of Level 2 claims are developed and presented in Chapter 1. This chapter supports ***Claim 5.1*** and ***Claim 5.2*** derived from high level ***Claim 5***.

Claim 5: The UK HPR1000 will be designed, and is intended to be operated, so that it can be decommissioned safely, using current available technologies, and with minimal impact on the environment and people.

Claim 5.1: The design and intended operation will facilitate safe decommissioning using current available technologies;

Claim 5.2: The decommissioning strategy and plan are prepared and maintained for the generic design, which reflect UK policy.

To support Claim 5.1, this chapter has developed four Sub-claims:

a) ***Sub-claim 1:*** The UK HPR1000 design features facilitate safe and effective decommissioning;

b) ***Sub-claim 2:*** Documents and records required for decommissioning are identified and under preliminary preparation;

c) ***Sub-claim 3:*** Faults and hazards of UK HPR1000 decommissioning are identified, assessed and risks shown to be ALARP;

d) ***Sub-claim 4:*** The UK HPR1000 can be decommissioned using current methods and technologies.

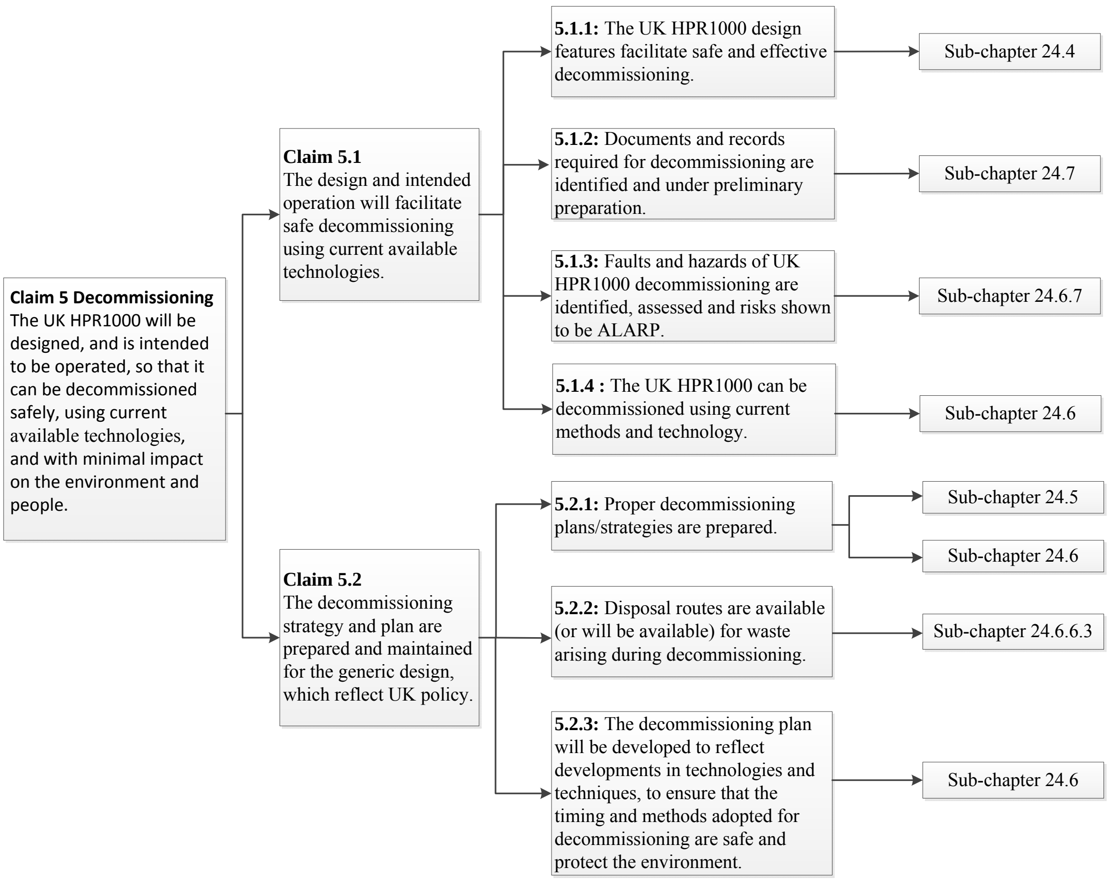
To support the Claim 5.2, three Sub-claims are developed:

a) ***Sub-claim 5:*** Proper preliminary decommissioning plans/strategies are prepared;

b) ***Sub-claim 6:*** Disposal routes are available (or will be available) for waste arising during decommissioning;

c) ***Sub-claim 7:*** The decommissioning plan will be developed to reflect developments in technologies and experiences, to ensure that the timing and methods adopted for decommissioning are safe and protect the environment.

Links between the safety claim and content of PCSR Chapter 24 are provided in F-24.2-1.



F-24.2-1 Links between the safety claim and content of PCSR Chapter 24

In addition, the mapping of decommissioning against relevant Safety Assessment Principle (SAP) requirements is provided in Reference [5].

24.2.2 Chapter Structure

The structure of Chapter 24 is as follows:

a) Sub-chapter 24.1 List of Abbreviations and Acronyms:

This section lists the abbreviations and acronyms that are used in PCSR Chapter 24.

b) Sub-chapter 24.2 Introduction:

This section gives the route map, chapter structure, interfaces with other chapters and key assumptions of PCSR Chapter 24.

c) Sub-chapter 24.3 Applicable Codes and Standards

This section lists the codes and standards that are used in PCSR Chapter 24.

d) Sub-chapter 24.4 Considerations of Facilitating Decommissioning

This section presents the considerations of design for facilitating decommissioning from eight aspects.

e) Sub-chapter 24.5 Decommissioning Strategy

This section gives the decommissioning strategy and the end state of the UK HPR1000.

f) Sub-chapter 24.6 Preliminary Decommissioning Plan

This section presents the main activities during decommissioning.

g) Sub-chapter 24.7 Records and Knowledge Management

This section presents documents, records and knowledge management that may be required for decommissioning.

h) Sub-chapter 24.8 ALARP Assessment

This section provides an overview of ALARP application in decommissioning.

i) Sub-chapter 24.9 Concluding Remarks

This section summarises the content of PCSR Chapter 24.

j) Sub-chapter 24.10 References

This section lists the supporting references of this chapter.

24.2.3 Interfaces with Other Chapters

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

T-24.2-1 Interfaces between Chapter 24 and Other Chapters

PCSR Chapter	Interface
PCSR Chapter 1 Introduction	Chapter 1 provides the Fundamental Objective, Level 1 Claims and Level 2 Claims, Chapter 24 provides chapter claims, sub-claim to supports relevant claims that are addressed in Chapter 1.
PCSR Chapter 4 General Safety and Design Principles	PCSR Chapter 4 covers the selection principles of design codes and standards to be applied for decommissioning.
PCSR Chapter 6 Reactor Coolant System	PCSR Chapter 6 provides the design substantiation of the principles that facilitate decommissioning.
PCSR Chapter 7 Safety Systems	PCSR Chapter 7 provides the design substantiation of the principles that facilitate decommissioning.
PCSR Chapter 15 Human Factors	PCSR Chapter 15 provides the principles and methodology of HF integration that shall be considered in decommissioning design.
PCSR Chapter 16 Civil Works & Structures	PCSR Chapter 16 covers the requirements of civil works and structures to be applied for decommissioning.
PCSR Chapter 17 Structural Integrity	PCSR Chapter 17 covers material selection to minimise waste generation.
PCSR Chapter 18 External Hazards	PCSR Chapter 18 covers the external hazards requirements to be applied for decommissioning.
PCSR Chapter 19 Internal Hazards	PCSR Chapter 19 covers the internal hazards requirements to be applied for decommissioning.
PCSR Chapter 20 Management of Safety and Quality Assurance (MSQA) and Safety Case Management	The organisational arrangements and quality assurance arrangements set out in PCSR Chapter 20 are implemented in the design process and in the production of this chapter.
PCSR Chapter 21 Reactor	PCSR Chapter 21 provides optimum reactor

PCSR Chapter	Interface
Chemistry	chemistry controls on the minimisation of source term, which contributes to the reduction of decommissioning waste generation.
PCSR Chapter 22 Radiological Protection	PCSR Chapter 22 describes the definition of radioactive sources for the UK HPR1000 and covers the various source terms for normal operation.
PCSR Chapter 23 Radioactive Waste Management	PCSR Chapter 23 covers the radioactive waste management system to be used for decommissioning if necessary.
PCSR Chapter 25 Conventional Safety and Fire Safety	PCSR Chapter 25 covers decommissioning conventional safety identification and the corresponding measures.
PCSR Chapter 28 Fuel Route and Storage	PCSR Chapter 28 covers the fuel handling and storage system to be used during decommissioning.
PCSR Chapter 29 Interim Storage of Spent Fuel	PCSR Chapter 29 covers interim storage of spent fuel as part of decommissioning.
PCSR Chapter 33 ALARP Evaluation	PCSR Chapter 33 covers the ALARP approach adopted for the UK HPR1000.

24.2.4 Key Assumptions

For GDA, the following assumptions relating to decommissioning are made:

a) The operational life of the UK HPR1000 is 60 years;

b) The beginning of decommissioning is when the station is shut down with no intention of further use for the purpose of electricity generation;

c) The strategy and preliminary decommissioning plan reflect today’s technologies and will be maintained by the licensee;

d) Buildings and facilities will be utilised during the decommissioning process if risks are ALARP and measures are beneficial for waste minimisation;

e) Spent fuel will be stored in Spent Fuel Pool (SFP) for several years, followed by storage in the Spent Fuel Interim Storage (SFIS) facility until the Geological Disposal Facility (GDF) is available;

f) Intermediate Level Waste (ILW) generated during decommissioning will be safely stored in the Interim Storage Facility (BQZ) until the GDF is available;

g) Low Level Waste (LLW) or conventional waste generated during decommissioning will be disposed of immediately;

h) Under certain conditions disposal of solid radioactive waste may fall under the exemption provision for the disposal of low volumes of solid radioactive waste (previously referred to as Very Low Level Waste (VLLW)). Waste falling under the exemption provision will be disposed of at available licensed disposal sites;

i) The end of decommissioning is considered to be when all station buildings and facilities have been removed and the site has been returned to an agreed end state (e.g. green field) with the regulators and the planning authority.

24.3 Applicable Codes and Standards

According to the selection principles of codes and standards specified in PCSR Chapter 4 and *General Principles for Application of Laws, Regulations, Codes and Standards* in Reference [6], the codes and standards are explored with considering the design characteristics of the UK HPR1000, the UK regulatory requirements and expectations etc., and at least three principles are considered:

a) Internationally recognised in nuclear industry;

b) Latest or currently applicable approved standards;

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

Of particular focus, is development of the UK HPR1000 decommissioning plan in line with UK regulatory requirements. Guidance from International Atomic Energy Agency (IAEA), Office for Nuclear Regulation (ONR) and Environment Agency (EA) are considered. A number of sources including UK, Western European Nuclear Regulators Association (WENRA) and IAEA are analysed and determined in *Analysis Report of Applicable Codes and Standards* in Reference [7]. The main legislation, national policy and regulatory guidance related to decommissioning are:

a) Environmental Permitting Regulations 2016, in Reference [8];

b) Hazardous Waste Regulations 2005 (as amended 2016), in Reference [9];

c) Review of radioactive waste management policy: Final Conclusions (CM 2919), 1995, in Reference [10];

d) The Decommissioning of the UK Nuclear Industry's Facilities, in Reference [11];

e) Nuclear Reactors (Environmental Impact Assessment for Decommissioning) Regulations 1999 (as amended 2006), in Reference [12];

f) The Construction (Design and Management) Management Regulations 2015, in

Reference [13];

g) UK Strategy for Radioactive Discharges 2011-2020, in Reference [14];

h) The Ionizing Radiations Regulations 2017, in Reference [15];

i) Funded Decommissioning Programme Guidance for New Nuclear Power Stations 2011, in Reference [16];

j) Guidance on Managing Human and Organisational Factors in Decommissioning 2010, in Reference [17];

k) Joint guidance, The Management of Higher Activity Radioactive Waste on Nuclear Licensed sites 2015, in Reference [18];

l) Industry Guidance-Interim Storage of Higher Activity Waste Package – Integrated Approach 2017, in Reference [19];

m) WENRA Decommissioning Safety Reference Levels 2015, in Reference [20];

n) IAEA Decommissioning Facilities - GSR part 6, 2016, in Reference [1];

o) IAEA Safety Assessment for the Decommissioning of Facilities Using Radioactive Material No. WS-G-5.2, 2008, in Reference [21];

p) IAEA Decommissioning of Nuclear Power Plants and Research Reactors No.WS-G-2.1, 1999, in Reference [22].

Detailed analysis of applicable codes and standard is presented in Reference [7] where Relevant Good Practice (RGP) is identified and supports the design of UK HPR1000.

24.4 Considerations of Facilitating Decommissioning

Experience from decommissioning projects suggests that the process could be made easier if decommissioning is considered at the design phase. From the IAEA Safety Guide *WS-G-2.1* in Reference [22], the critical activities during decommissioning of nuclear power plants are: radiological survey, fuel removal, decontamination, dismantling and waste management. These categories will be examined during the design phase to ease decommissioning.

No HPR1000 has currently entered decommissioning and therefore HPR1000 specific Operating Experience (OPEX) related to decommissioning does not exist. However, there are several Pressurised Water Reactors (PWRs) that have been decommissioned or are undertaking decommissioning and lessons learnt from decommissioning of other nuclear facilities are globally available and relevant. OPEX of decommissioning including design for decommissioning, decontamination, dismantling and knowledge management is taken into account and the relevant report is under development and will be delivered during step 3.

To facilitate decommissioning, the design measures play important roles. A thorough review of the design is repeatedly performed during the design phase to challenge whether the design has incorporated sufficient features to reduce worker exposure, ensure easy decontamination, ease dismantling and reduce wastes production.

Facilitating decommissioning through design requires:

a) Systematic and progressive reduction of hazards;

b) Minimisation of environmental impacts;

c) Facilitation of the decontamination and dismantling process;

d) Minimisation of radioactive waste generation.

The design features not only assist maintenance and inspection during the operational lifetime but also assist future decommissioning. The specific design considerations for facilitating decommissioning include site selection, general layout, selection of materials, equipment design, process design, building and structure design, layout design and waste management.

Detailed information to be considered for facilitating decommissioning is introduced in the Supporting Document: *Consistency Evaluation for Design of Facilitating Decommissioning* in Reference [23].

24.4.1 Site Selection

The siting of nuclear power plants depends on many factors, such as areas covered by the grid, availability of cooling water, etc. Also it is expected that siting of UK HPR1000 will follow the UK policy set out in *EN6 Vol. I and II* in Reference [24]. Siting standards also involve other features related to decommissioning as follows, and most of them will be considered in detail during site licensing phase.

a) During siting, a detailed initial investigation including physical contamination, chemical contamination and radiological contamination of the site will be performed and relevant records kept as one of the important references for site acceptance in the future.

   A baseline background radiological and chemical characterisation of the UK HPR1000 site will be undertaken. This includes appropriate radiological and chemical monitoring of the site and its surroundings to establish baseline levels of radiation and pollution for assessing the future impact of the reactor on the site. The environmental impact assessment will be carried out during the decommission phase.

b) The impact on long-term integrity of buildings and other structures is considered, especially with regards to the effect of external hazards. For the buildings that contain items important to safety, the civil structures of these buildings are designed to withstand the impact loads of design basis accidental aircraft crash, earthquakes, extreme wind, external missiles, external explosions, external flooding, sleet snow, etc. This contributes to the transition from operation to decommissioning of the plant, and supports operations during decommissioning.

c) Transport infrastructure, such as waterways, railways, etc., around the site will be evaluated, to make sure that the wastes generated during decommissioning of nuclear power plants can be disposed of off-site.

d) Space at or near the site is considered for locating decommissioning facilities and storing the wastes generated during decommissioning. For example, the design lifetime of the BQZ building is 100 years, and the scale of BQZ building can be extended to meet the storage needs of the ILW generated during decommissioning. The conditioned ILW will be stored in the plant for a long period until the GDF is available, during which time radiation levels will reduce through decay.

e) Utilities (such as fire water supply, potable water supply and blowdown system) are organised and set out so that they can provide continuous services during decommissioning. For instance:

   1) The UK HPR1000 is equipped with the outdoor piping network, including the piping network of the Potable Water System and Site Fire-fighting Water Distribution System. During decommissioning, both of these systems will be operational to facilitate the decontamination and dismantling process;

   2) There is power supply between different trains in the repower scheme used during maintenance, which can supply power to equipment during dismantling of different trains during decommissioning. The new loads, such as the mobile decontamination device or dismantling device, can be powered by the local electrical distribution cabinet. The equipment will eventually be dismantled and will be powered by an off-site temporary power source;

   3) During operating of the nuclear power plant, the Nuclear Island Vent and Drain System (RPE [VDS]) serves to collect, store temporarily and transfer radioactive effluents from the nuclear island. The collected effluents are transferred to different downstream systems for treatment according to type. During the decommissioning phase, the RPE [VDS] can perform the same function as it does during the operating phase.

24.4.2 General Layout

The general layout considers the reservation of space and areas for transport of material, dismantling and decontamination. The space for decommissioning facilities as well as the efficient and effective logistics within the site is taken into account:

a) Construction space is to be reserved for:

   1) The extension of the processing facilities for normal operating waste. It is

highlighted that the plant area is reserved space and area for development, and the land use scale is determined according to the planning capacity;

2) The guarantee of integrity and availability of public and auxiliary facilities, structures and equipment after permanent shutdown and partial dismantling. For example, the treatment of decommissioned waste will make the best use of the existing waste management facilities;

3) The setting of auxiliary facilities and special facilities after permanent shutdown if necessary;

4) The arrangement of temporary facilities for waste turnover. It is necessary to evaluate whether the construction of large temporary facilities (such as waste temporary storage) will be built according to the site conditions;

5) The entrance, exit and manoeuvring of large handling appliances e.g. cranes and telehandlers used for dismantling. The optimisation and rational arrangement of the construction plant and machinery, office, road and site entrance are fully considered;

6) The premises for contractors at the site. Temporary facilities during construction can be practically planned and arranged by the contractor according to the technical requirements.

b) General layout of facilities is convenient for the different phases of dismantling without influencing the operation and maintenance of remaining facilities. The following aspects are considered:

1) The function and needs of ventilation facilities are considered during operation and decommissioning, as well as the order of demolition;

2) The effect of the dismantling order is considered in the decommissioning plan. Demolition of buildings and structures is usually ordered from simple to complex, i.e. from the peripheral auxiliary facilities (the conventional island buildings) to the nuclear island buildings;

3) Positions of facilities are convenient for equipment, personnel ingress and egress, air flow and material transfer during the different phases of decommissioning;

4) The general layout facilitates site area partitioning during decommissioning. For example, the system of zoning management can be established, and a sufficiently conservative design source is used to complete the radiation partition;

5) The general layout facilitates staged dismantling and decommissioning works. Sufficient space and area are reserved for the staged dismantling and decommissioning works around the nuclear island building.

24.4.3 Selection of Materials

The following aspects are considered in the selection of materials in Reference [22] to realise easier decontamination, dismantling and minimise waste generation:

a) To minimise the creation of radioactive waste, easily activated elements are avoided and controlled as far as is reasonably practicable, and the impurity content in materials is strictly limited.

   1) The use of easily activated materials is minimised. Stellite is avoided for equipment and valves which are in contact with primary coolant so far as is reasonably practicable, which reduces activation and corrosion products. The use of copper alloy is prohibited for all the assemblies in contact with the reactor coolant, because any copper within the reactor coolant could be activated and contribute to dose rates in the primary circuit;

   2) The content of easily activated impurities in materials is strictly limited. For Structures, Systems and Components (SSCs) in the UK HPR1000, the amounts of sensitive elements (especially Co, Ag and Sb) which could easily be activated and significantly contribute to dose rate are strictly controlled. The cobalt content requirements of materials in contact with the UK HPR1000 primary coolant are more stringent than Design and Construction Rules for the Mechanical Components of PWR Nuclear Islands. The dense aggregate materials of concrete, such as barites, limonites, magnetites and ilmenites are not used in order to reduce the section thickness and meet attenuation requirements. During the site specific stage, easily activated elements will be avoided and controlled when the aggregate is selected to meet the local requirements.

b) Contamination is avoided as much as possible, to minimise the amount of radioactive waste due to corrosion. The content of impurity is limited to guarantee that the selected materials are highly resistant to various forms of corrosion. Noxious chemical elements of the consumables are limited to prevent corrosion on SSCs. Surface condition requirements on all surfaces of SSCs which could be exposed to contamination are defined to prevent penetration of the contaminant and facilitate decontamination.

c) The material surfaces are easy to decontaminate to reduce the deposition of contaminants. Materials with a dense surface, good corrosion resistance and that are easy-to-clean are selected and porous materials are avoided for pollution-prone areas, which facilitates decontamination during decommissioning. For example, castings are practically replaced by forgings with the progress seen in manufacturing processes and design optimisation; most of the materials for the Reactor Coolant System are forgings and plates. The surface of carbon steels, low alloy steels and concrete is coated appropriately to avoid the penetration and absorption of radioactive and hazardous products.

d) To reduce the spread of contamination, the application of corrosive, toxic and hazardous materials on the surface of SSCs is prohibited in all stages including manufacturing, transportation, installation, commissioning, and maintenance, etc., and the use of materials which could release corrosive, toxic and hazardous substances during operation is also minimised. Flammable materials and fibrous materials, which need particular protection measures to be removed before decontamination, are restricted for use. For example, the use of asbestos for thermal insulation material is prohibited due to the serious health hazards it will cause during installation/dismantling. Hydrophobic glass wool is selected for heat insulation material. The glass wool is protected with stainless steel shells which could prevent the material from contacting with the flammable fluid. The choice of reusable or recyclable materials is considered at the design phase to reduce the amount of radioactive waste generated. The recyclability of the selected materials has been considered in the design process. For example, metals and concrete could be reused or recycled after the decontamination process, and conventional rubber could also be reused.

Additionally, reactor chemistry plays an important role in minimising contamination in the reactor circuit (avoidance of corrosion products). The minimisation of waste generation during decommissioning in reactor chemistry is presented in PCSR Chapter 21.

24.4.4 Equipment Design

The following equipment design aspects are considered to facilitate decommissioning, Reference [25]:

a) The equipment is designed with a simple structural form to make it easier for drainage, decontamination and dismantling. For instance:

   1) Equipment which needs to be drained is usually designed with a simple drain nozzle in the bottom area;

   2) The inner and outer surfaces are smooth without hollows or blind holes to ease decontamination;

   3) Equipment connecting to the floor is usually designed with bolted connections for easy dismantled and equipment nozzles are welded to the piping which makes it easier to be dismantled by cutting.

b) Internal and external surfaces of equipment and pipes are smooth to reduce the contaminant accumulation.

   1) For primary loop equipment, such as the Steam Generator (SG), Pressuriser, Main Coolant Line, Surge Line and Reactor Pressure Vessel (RPV), the

roughness of internal and external surfaces is no more than Ra6.3;

2) For lifting equipment and equipment with carbon steel surfaces, the surfaces are painted.

c) Components with simple structures and smooth shapes without hollows or blind holes are adopted for plant and equipment connectors, fasteners, fixing devices and supporting devices, which will contribute to decontamination and reduce the accumulation of contamination. For example, the pressuriser supporting heater plates are smooth and bolted to the pressuriser. In addition, the plate has many holes without hollows or blind holes which make the liquid easier to drain, so that the accumulation of contamination is effectively reduced.

d) Equipment and pipes collecting and transferring liquids are easy to drain, and appropriate slopes or emptying traps are designed into the system. For example:

1) Pipes are designed as sloping towards drain points as much as practicable to prevent accumulation and build-up;

2) Equipment is usually designed with a drain nozzle in the bottom area.

e) Decontamination equipment and liquids are easy to introduce and attach to equipment and pipes. In addition, the appropriate connectors for decontamination of equipment are designed.

f) Aids used for installation and dismantling activities, such as connections and fixings to walls, ceiling and floors are considered. The design life, the ease of equipment replacement and the specific characteristics associated with equipment installation and dismantling activities have therefore been taken into account during the design phases:

1) Overall dimensions of the items of equipment to be installed or dismantled;

2) Use of lifting equipment, such as the Polar Crane, needed for installation/dismantling operations needs to be specified;

3) Procedures for monitoring lifting equipment need to be defined, including:

- Lifting accessories, such as the lifting beam, slings, chains, overturn device, etc.;

- Lifting path.

4) Areas requiring operator access and associated walkways are considered;

5) Equipment passages used during dismantling, including the route from the installation room to the components service deck (inside/outside Reactor Building (BRX)) are considered;

6) Environment criteria for dismantling operations that might propose problems

for operating personnel:

- Risk of radioactive intake within the BRX;
- Difficulties gaining access to equipment being dismantled;
- Visibility, temperature and humidity not suitable for operating personnel.

24.4.5 Process Design

For the process design, how decommissioning will be facilitated during the dismantling works is considered, including: Emptying of equipment and systems; Water filling, drainage and filtration of pool; Waste disposal; Equipment lifting; Ventilation of radioactive areas, fire monitoring and protection; Environmental monitoring; Sump and ground drainage; Power supplies, compressed air supplies and production water supplies. In addition, the following principles are considered:

a) Measures to reduce any residual radioactive sources inside the facilities after the final shutdown are adopted.

1) Measures to reduce the generation of residual radioactive sources. In the process design, the systems are provided with adequate and reliable isolations to reduce potential leaks. E.g. two isolation valves are provided for the Reactor Coolant Pressure Boundary and for containment penetrations of radioactive fluids. For components in contact with radioactive fluids, austenitic stainless steel is adopted in order to reduce potential corrosion in the components.

2) Measures to reduce the retention of radioactive sources. The systems are required to fulfil the functions using simple configurations, and the quantity of components is optimised to reduce the retention of radioactive sources in the system. Components in contact with radioactive fluids, such as those associated with tanks and sumps, are designed with simple structures and surfaces. Accordingly, the accumulation and retention of radioactive sources can be reduced.

3) Measures to facilitate the decontamination. Connecting points for decontamination, draining and sampling are provided in the systems to facilitate decommissioning of the contaminated components and pipes. The design of tanks and sumps avoids potential radioactive sediment and provides measures for concrete tanks and sumps to facilitate cleaning. Tanks and sumps are equipped with steel liners (such as In-containment Refuelling Water Storage Tank, Reactor Pit Flooding Tank, Spent Fuel Pool, etc.) or coatings (e.g. Reactor Pools) to ensure simplified decontamination.

b) Emptying and decontamination methods are considered to facilitate decommissioning and maintenance. For example:

1) Some container bottoms are designed as a sphere with an outlet which facilitates emptying;

2) In pipeline layout, a certain gradient is set to prevent liquid accumulation and encourage flow;

3) The decontamination system is used to remove or reduce contaminated. In addition, decontamination equipment will also have an associated pipeline as required for the decontamination process.

c) Primary coolant chemistry is controlled to reduce the migration and deposition of activation and corrosion products. For example, a high concentration of $^{7}LiOH$ is used to optimise pH in the primary circuit, which will minimise the corrosion of structural materials and minimise the transport of corrosion products to the reactor core. Control of the pH also maintains the integrity of the fuel cladding material, reducing the potential for fission product release. Further supporting information surrounding management of water chemistry can be found in PCSR Chapter 21: Reactor Chemistry.

d) Measures which reduce the exposure dose of workers during decontamination are considered during design. For example:

1) An appropriate decontamination process used to reduce the exposure dose of workers during decontamination is considered in the design;

2) Some interfaces reserved by container-type decontamination objects are physically isolated from decontamination objects themselves, which reduces the dose received by the decontamination operator;

3) The opening and closing of equipment related to filtration, evaporation, desalination and associated valves will be remotely operated where reasonably practicable;

4) Equipment will be located in the appropriate radiation zone according to the radioactivity level. When workers enter the different radiation zones, the appropriate protection measures will be taken to reduce the exposure dose.

24.4.6 Building and Structure Design

The following principles are adopted for concrete buildings and steel structures (steel lining, steelwork, etc.) to facilitate decommissioning:

a) There are coatings or metal liners for all the surfaces of buildings (structures) which may be in contact with radioactive fluids during operation. The lining material corrosion resistance, radiation resistance, shock resistance and flame resistance are considered. For instance:

1) For the pools within the nuclear island, the stainless steel liner is applied to

the concrete walls and slabs of the pools;

2) For the internal containment, the sealing steel liner is anchored to the internal concrete including the internal surface of the dome, cylinder wall and bottom plate;

3) Coatings are applied to structures which may be in contact with radioactive fluids. These structures include concrete walls, slabs, floors and ceilings, steel structures, embedded plates, and doors, etc.;

4) The lining materials used in the UK HPR1000 are divided into non-alloy and alloy steels. The parameters of the metal liners, including corrosion resistance, radiation resistance, shock resistance and flame resistance are consistent with the applicable codes and standards.

b) Floors, walls, coatings and metal liners are flat, smooth and easy to decontaminate, and the penetration positions are reduced and sealed. For instance:

1) The architectural design of buildings considers the general flatness requirements of the floors and walls;

2) For surface coatings, decontamination tests are carried out in accordance with the requirements of the specification. The decontamination percentage and contamination sensitivity rate are controlled to ensure that the coating is easy to decontaminate;

3) The penetrations are typically divided into four types, Equipment Access Hatch, Personnel Access Airlocks, Mechanical (Fluid) Penetrations and Electrical Penetration. Some moderate-energy penetrations contain two or more pipework sections in the same penetration.

c) Removable plates, barrier shields and access openings are adapted to improve the accessibility of personnel and equipment during decommissioning. The emergency personnel gates, stairs and elevators are set up for personnel entering and leaving, and equipment gates, movable cover-plates and movable shielding walls are set up for equipment introduction and delivery. An example given is the movable shielding wall of the SG room: the movable wall is connected to the floor and walls on both sides through bolts, and the movable wall can be easily removed to facilitate the dismantling of the equipment during decommissioning.

d) Consideration is given to the position of cutting and packing of main components for dismantling and storage, lifting equipment is provided for heavy or large components.

1) Space for equipment replacement, dismantling and storage is considered, and the corridor and entrance for personnel to approach the main components during decommissioning are provided. An example is given for dismantling

and transportation of a large motor, which is the biggest component of the RCV charge pump. The position and the space to approach the component has been verified by 3D models, in order to ensure the space for equipment replacement, dismantling and storage;

2) Removable slabs or blocks are provided in order to ease transportation of equipment during decommissioning, and temporary measures such as removable panels, shielding walls and access hatches are carried out to protect personnel from exposure.

e) The bearing capacity of floors is considered for dismantling of large components and the floors may need to be removed during dismantling of large components, and this is facilitated through use of easily removed plates or blocks. The use of temporary shielding is considered which may add to the floor loading.

1) The bearing capacity of floors is considered for ingress and egress of equipment and dismantling of large components, which may facilitate future dismantling operations;

2) For facilitating the dismantling and egress of large equipment or components, access routes through the floor (and a cover plate) are designed as a possible solution;

3) Temporary shielding measures may increase the load of the floor because of the uncertainty of the load value in the design phase. The evaluation of the bearing capacity of the floor can be undertaken during the decommissioning phase, and temporary support at the bottom of the floor is set up when it is necessary.

f) The possibility of staged dismantling of buildings (structures) is considered.

1) The design of the separate raft foundations of buildings (structures) facilitates the staged dismantling of buildings, such as BRX, Fuel Building (BFX), Nuclear Auxiliary Building (BNX), and Turbine Generator Building (BMX) which are located on different rafts. For example, the dismantling of the BMX does not affect the stability of the BNX or BRX;

2) Each of the above buildings is an independent structure, and there are no shared load-bearing walls or floors between buildings. Demolition of a building will not affect the structural integrity of another building.

g) Consider to reduce or practically eliminate the use of pre-stressed concrete. For the buildings in the UK HPR1000, the pre-stressed concrete structure is only used for internal containment to ensure that accidental pressures can be resisted during the service period, and the leakage of the containing radioactive substances can be prevented. For the other buildings, ordinary reinforced concrete structures or steel structures (non-pre-stressed structures) are adopted.

h) Long term integrity of structures and structural design for decommissioning.

1) The safety classification and the seismic categorisation of the plant are identified to achieve relevant safety functions: support to SSCs in the building, prevent damage from external hazards or limit internal hazards consequences, provide support and radioactive barrier functions for SSCs during decommissioning phase, etc.;

2) The analysis and design of the structures are undertaken. The design method is divided into two types: design method based on deterministic theory (also known as: structural design analysis) and design method based on probabilistic theory (also known as: PSA analysis).

24.4.7 Layout Design

The following principles in layout design are considered for the convenience of facility decommissioning:

a) The arrangement is as compact as possible and reduces the number of radioactive areas, and radioactive areas are isolated from non-radioactive areas and are also classified into different zones according to radiation levels. Radioactive equipment or pipes are separated whenever possible and arranged together to reduce the number of radioactive areas. Dead angles for decontamination and dismantling are avoided as far as is reasonably practicable and pipe runs are sloped downwards for gravity-assisted drainage, preventing the accumulation of fluids and radioactive corrosion deposits;

b) The accessibility of personnel and equipment, and laydown areas during decommissioning is considered. For instance, appropriate space and adequate access are provided for the maintenance, inspection and decommissioning of equipment. The arrangement of access to various plant components will facilitate dismantling, unit construction techniques such as bolted precast concrete elements, structural blocks or bolted structural steelworks connections, are adopted in the design. Separate personnel, equipment passages and entrances are also provided for decommissioning.

c) The retention and deposition of radioactive substances in systems are avoided as far as is reasonably practicable:

1) Surface-smooth materials for the radioactive systems make them easy to clean. For example, stainless steel tubes are usually used for the radioactive system piping and stainless steel plates are widely used for the storage pools;

2) Rational structure design is considered, e.g. proper designing for the pipe fittings to ensure no retention and deposition in piping system, bevelling the edge of storage pool steel liners, using butt welds for piping instead of socket welds. Pipe runs are sloped downwards for gravity-assisted drainage,

preventing the accumulation of fluids. Minimisation of the number of elbows and tees, and use of large radius elbows, etc.;

3) Proper piping operation strategy is considered to avoid the retention and deposition of radioactive substances. For example, waste treatment system pipes are flushed with water when the transportation of radioactive material is finished.

d) Embedded pipes, fittings and equipment in walls and floors are practically avoided:

1) Optimise the routing, making pipe runs as short as practicable, minimising the use of pipe penetrations, and sleeves are usually used in order to avoid the need to embed pipes into civil structures if the need for them to pass through the walls cannot be avoided;

2) When embedded pipes are necessary, the following measures are carried out:

– Collection points are set to reduce the number of embedded pipes;

– Pipes run in straight lines to ensure the embedded pipe length is short;

– Embedded pipes are designed as double pipe structures, where the inner pipe is used to carry the medium and lays on the external pipe without welding.

e) The layout facilitates the decommissioning work and provides effective shielding during dismantling, for example, removable slabs and walls provided for maintenance and dismantling. Biological shielding, such as shielding walls and shielding doors, is considered during operation and can also be used to reduce the exposure of workers during decommissioning. In addition, mobile biological shielding is provided during dismantling if necessary, e.g. movable lead sheet.

24.4.8 Waste Management

Based on the principle of minimising waste generation, the design of nuclear power plants will reduce the generation of wastes and consider the disposal of waste generated.

a) An Integrated Waste Strategy (IWS) is planned. The waste system will be designed, constructed and operated together with the nuclear power plant operational system. The radioactive waste management system has been developed for the UK HPR1000 as described in PCSR Chapter 23, and the accumulation of a large amount of waste can be avoided.

b) The operating on-site transportation route is designed so that it is capable of being adapted for decommissioning. The final destination of wastes generated during decommissioning will be considered during the nuclear site licensing phase.

c) Use of the IWS over the plant lifecycle. An integrated waste management has been planned for decommissioning waste. The design lifetime of the BQZ building is 100 years, and the scale of BQZ building will be extended to meet the storage needs of the ILW generated during decommissioning. After interim storage, the packaged ILW will be retrieved and transferred to the GDF. The packaged LLW will be transferred to a suitable facility (e.g. Low Level Waste Repository Ltd (LLWR)) for disposal.

d) Use of waste hierarchy (reduction, re-use and refurbishment, recycling, disposal).

  1) Minimising waste through fuel design, manufacture, management and effective use of fuel to facilitate future decommissioning are considered and more details are presented in PCER Sub-chapter 3.4.1 in Reference [26];

  2) Minimising radioactive waste through optimising water chemistry in the primary coolant to facilitate decommissioning is considered and more details are presented in PCER Sub-chapter 3.4.1 in Reference [26];

  3) Minimising the radioactive waste through reactor structures and components material selection to improve decommissioning convenience is considered in PCER Sub-chapter 3.4.1 in Reference [26]. It is mentioned that materials that are less susceptible to activation, corrosion and deposition, and are more recyclable are used in the UK HPR1000 as far as is reasonably practicable.

24.5 Decommissioning Strategy

A decommissioning strategy is being prepared and will be developed for the UK HPR1000 and integrated with other relevant strategies e.g. waste management (including spent fuel management). Radioactive waste generation is a direct result of the radioactive facilities dismantling during decommissioning and the timing of dismantling influences the extent of waste arising. For spent fuel management, it is noted that the removal of spent fuel from the facility is a prerequisite for the implementation of major dismantling activities. Generally, the spent fuel will be removed off-site or to a facility independent of the nuclear plant as soon as possible.

The decommissioning strategy for the UK HPR1000 is consistent with UK government policies and strategies, including policy aims on sustainable development, and identifies and explains any differences.

The UK HPR1000 decommissioning strategy provides information to address the following:

a) The UK HPR1000 can be safely, environmentally and effectively decommissioned at the end of its operational life;

b) The design, and intended construction and operation, and decommissioning of the UK HPR1000 will be developed to reduce, the impact on the workers, the public, and the environment, in accordance with BAT and ALARP principles.

The decommissioning strategy will be presented in the Preliminary Decommissioning Plan.

24.5.1 General Principles of Decommissioning Strategy and End State

In general, the decommissioning objective and the end state of a nuclear site are the key factors to influence the decommissioning strategy. The following principles will be applied to achieve the agreed end state:

a) Strategies should take into account the views of stakeholders;

b) Strategies should be compliant with UK Government policies and legislation, including the policies on sustainable development;

c) Appropriate and scientific methods should be used to issue the decommissioning plan;

d) BAT should be adapted to reduce volumes of radioactive wastes and impact on the environment and the public;

e) ALARP strategy should be applied to protect the public and the workforce;

f) Strategies should be reviewed and updated periodically;

g) No foreclosure of options;

h) Optimisation of plans;

i) Decommissioning activities should be carried out as soon as reasonably practicable, and all relevant factors should be taken into account at the same time;

j) Consider all relevant factors in the decommissioning plan & strategy and transparently assess them, supported by robust objective information and arguments;

k) Avoid the creation of radioactive waste forms that may exclude options for safe and effective long-term waste disposal;

l) Reduce volumes of radioactive waste created;

m) Consider the benefits of delaying operations to take advantage of radioactive decay.

The site end state is assumed to achieve green field status (allowing for unrestricted access). Buildings and structures above -1m need to be dismantled after decontamination. Buildings and structures which are not contaminated and are below -1m will be left in place. Demolition products will be used as backfill for underground voids, trenches, basements, etc.

24.5.2 Decommissioning Strategy Options

Two viable strategies can be considered for completing decommissioning of nuclear power plants according to IAEA and international experience: Immediate dismantling and deferred dismantling. In principle, these two possible decommissioning strategies are applicable for all facilities.

a) Immediate dismantling: In this case, decommissioning actions begin shortly after the permanent shutdown. Equipment and structures, systems and components of a facility containing radioactive material will be decontaminated and removed to a level that permits the facility to be released from regulatory control for unrestricted use, or released with restrictions for its future use in Reference [1];

b) Deferred dismantling: In this case, as soon as the nuclear fuel is removed from the BRX, all or part of a facility containing radioactive material will be processed or placed under safe storage, so that the facility can be maintained until it is subsequently decontaminated and/or dismantled. Deferred dismantling may involve early dismantling of some parts of the facility as well as early processing and removal of some radioactive materials, which can ensure the safe storage of the remaining parts in Reference [1].

24.5.3 Decommissioning Strategy for UK HPR1000

Immediate dismantling is feasible and the recommended strategy according to UK Government policy and IAEA guidance, even if immediate dismantling requires serious consideration because of its higher radiation risk when compared to deferred dismantling. According to the Funded Decommissioning Programme Base Case in Reference [16], the initial decommissioning strategy for the UK HPR1000 is assumed to be immediate dismantling. However, the design of the UK HPR1000 is flexible so that the future licensee is able to choose an alternative strategy (Deferred dismantling). The strategy should be reviewed and upgraded periodically by the licensee.

The UK HPR1000 project prefers the immediate dismantling due to the following criteria:

a) Availability of facility workers:

    1) Allows re-employment of workers;

    2) Use of specific expertise.

b) Use of existing infrastructure, including an available repository;

c) Unrestricted use of the grounds for other purposes;

d) Public and political acceptance.

The process of decommissioning of the UK HPR1000 can be divided into four stages which are described in PCSR Sub-chapter 24.6.1.

24.6 Preliminary Decommissioning Plan

The Decommissioning plan is developed to an early stage and subsequently will be revised throughout the lifetime of the nuclear facility. This sub-chapter gives information on the implementation of the decommissioning strategy based on an assumed plant status at the end of the operational phase and an assumed target end point for decommissioning.

The operator will be responsible for updating decommissioning plans as required if UK legislation or best practice changes or if there are any changes to the assumptions made in this document. At appropriate periods in the future, detailed decommissioning plans will be developed by the operators. During the preparation of these detailed decommissioning plans, the operator will also develop or revise the relevant documents prior to decommissioning operations.

24.6.1 Timing of Decommissioning

Decommissioning should be carried out as soon as it is reasonably practicable, taking all relevant factors into account. The timing of decommissioning should be justified in the safety case.

The process of decommissioning the UK HPR1000 can be divided into four continuous stages. There may be some overlap among these stages, but for clarity, they are considered as four distinct stages.

24.6.1.1 Stage 1

Stage 1 is the preparatory work for decommissioning, which will be done before final closure of the nuclear power plant. The main work at this stage includes:

a) A feasibility study of nuclear power plant decommissioning;

b) Decommissioning license application;

c) Research and development of decommissioning design and technology;

d) Final decommissioning plan preparation after thorough investigation into the regulations and sufficient communication with other external stakeholders;

e) Review of organisational structure and programme for transitioning from an operating structure to a decommissioning structure;

f) Contract specification and contract management;

g) Evaluation of nuclear facilities and systems' availability e.g. workshops, RPE, etc. In order to ensure the availability of facilities, maintenance will be undertaken during the construction and operating phase;

h) Construction of temporary facilities or modification of existing facilities if necessary e.g. extension of ILW store if necessary.

The duration for this stage is estimated to be approximately five years.

24.6.1.2 Stage 2

Stage 2 refers to activities carried out shortly after final shutdown of a nuclear power plant. The organisational management and procedures begin to change from operations to decommissioning. The main work at this stage includes:

a) Removal of Spent Fuel Assemblies (SFA) from the reactor to the SFP;

b) Radiological survey;

c) Safety maintenance of plant and system;

d) Post Operational Clean Out (POCO) of operational waste (including solid waste, radioactive liquids, etc.);

e) Preliminary decontamination of the main circuit, auxiliary facilities and process building.

The duration for this stage is estimated to be approximately two years.

24.6.1.3 Stage 3

The decommissioning activities of Stage 3 are based on those of Stage 2, the main work at this stage includes:

a) Safe storage of SFAs in the SFP;

b) Dismantling of non-radioactive systems, non-decommissioning service systems and disposal and recycling of conventional waste;

c) Decontamination before carrying out some dismantling work (e.g. radioactive systems and radioactive equipment, etc.);

d) Dismantling of radioactive systems, radioactive equipment and buildings, including main circuit equipment, such as the SG, coolant pumps, pressuriser and main circuit piping, auxiliary systems and buildings, etc.;

e) Treatment, storage and disposal of radioactive waste in accordance with the provisions of regulations;

f) Shield and isolate the remaining reactor body structure to ensure the plant site achieves limited site-release standards.

The duration for this stage is estimated to be approximately eight years.

24.6.1.4 Stage 4

The main tasks of Stage 4 include:

a) Dismantle the reactor body, biological shield and pre-stressed concrete;

b) Maintenance of the BQZ and SFIS facility;

c) Removal and transportation of all decommissioning waste in the BQZ and SFIS facility to the GDF when available;

d) Demolish and de-plant the BQZ and SFIS facility;

e) Clean up the site and restore green spaces;

f) Final surveys;

g) De-licensing.

For the purposes of the planning decommissioning, the process is divided into a number of activities. Key activities include radiological survey, spent fuel management, decontamination, dismantling, waste management and safety management, which are provided in PCSR Sub-chapters 24.6.2 to 24.6.7.

More detailed information about the timescales of decommissioning will be developed in the Preliminary Decommissioning Plan.

24.6.2 Radiological Survey

In the early stages of decommissioning a comprehensive radiological survey of the nuclear power plant is carried out. It supports the decommissioning evaluation and planning. The radiological survey result is used for estimation of waste quantities, selection of decommissioning technology, timing of decommissioning, and design of radiological protection.

The radiological survey investigates the composition and distribution of radionuclides, the level and distribution of contamination, the nature and quantity of the pollutants and waste, etc. It is carried out by on-site surveys, document investigation, calculation and analysis. The history of the site and facilities is taken into account.

a) The on-site survey is carried out by sampling, analysis and radiation monitoring;

   The first step is to determine the numbers and locations of sampling to ensure that the obtained samples are sufficient and appropriate to represent the status of the site. The samples are then taken and sent to the laboratory for chemical and radiological analysis to determine the radionuclide composition. The accuracy of the result obtained by this method depends on the adequacy of the sampling. In addition, radiation monitoring is used to obtain the dose rate of components, and then the composition and activity of the radionuclides are deduced;

b) The knowledge archive is reviewed to obtain radiological information from the relevant documents of the nuclear power plant, such as design documents, operational records, and event and accident records. Also the records on plant construction and modification should be examined;

c) Material conservation and radioactive balance calculations can be used to gain an insight into the sources. Documents for design schemes, construction, operation and maintenance documents, examination of materials, and accident handling records are all important and valuable inputs for calculation and analysis. The decommissioning source terms for activated components and structures are mainly predicted by this method. In addition, based on the dose rate data obtained by onsite surveys, the source term of the contaminated components can also be estimated.

The radiological survey results provide details of the radiological status of the nuclear plant which helps to identify the risks and hazards for decommissioning and to establish the suitability of the decommissioning plan.

In decommissioning, the main radionuclides to be considered are fission products such as I-131, Cs-134 and Cs-137; and activation products such as Co-58, Co-60 and Fe-55. Prediction of the decommissioning source term for UK HPR1000 activated components and structures will be developed during step 3.

24.6.3 Spent Fuel Management

The spent fuel management plan for the UK HPR 1000 will be divided into the following three parts:

a) The SFAs are unloaded from the reactor core and need to be stored in the SFP for cooling due to their high radioactivity and decay heat. The cooling period will be set by the activity and heat decay of SFAs and physical capacity (approximately 11 refuelling cycles before the SFP reaches the design capacity) of the SFP. This process is considered to be short term storage;

b) The SFAs will be transferred into a transportation cask/canister and moved to the SFIS facility. The transfer process of SFAs to the SFIS facility during decommissioning will be the same as that during operation. Both dry and wet SFIS technology will be considered in the UK HPR1000. This is interim storage;

c) The storage facility of the UK HPR1000 will ensure easy retrieval of SFAs from SFIS. It is intended that the SFAs will be safely disposed of by being transferred to the GDF. Once the SFIS facility has reached its design lifetime, the SFAs will be transferred to the GDF. SFAs can be repackaged into appropriate casks as required, depending on the timing and readiness of final disposal facility. This process is called Retrieval and Final Disposal.

More information regarding fuel removal and spent fuel storage can be found in PCSR Chapter 28: Fuel Route and Storage and Chapter 29: Interim Storage of Spent Fuel.

24.6.4 Decontamination

Decontamination is performed to remove the accumulation of radioactive material to:

a) Reduce the dose received by workers during decommissioning;

b) Reduce the amount of higher category wastes.

The operator needs to determine the balance of decontamination performed against various factors, such as dose uptake, the secondary wastes generated in decontamination operations, the toxicity of chemicals and their effect on the environment and the public.

24.6.4.1 System Decontamination

The primary and auxiliary systems，including all components and pipework，need a high level of decontamination. As the components are connected by pipework they can be cleaned jointly in a ‘full system decontamination’ of the primary circuit by a chemical process.

Full system decontamination reduces the individual and total dose during decommissioning. The primary decontamination of components of the primary circuit is in situ. More details will be developed during step 3.

After full system decontamination, depending on the dose levels and transport arrangements, large components of the primary circuit can be transferred to a workshop for size reduction. Further chemical decontamination can be performed in the workshop as necessary.

Smaller (and mid-size) components are transferred to a hot workshop for size reduction and decontamination. These components are dismantled into their subcomponents and prepared for decontamination.

A secondary decontamination can be applied to the pipe segments after dismantling of the respective systems depending on the radiological needs.

24.6.4.2 Decontamination of Buildings, Structures and Components

The decontamination of concrete surfaces in radioactive areas should be carried out before the dismantling of structures. This can be by surface cleaning，or scabbling the concrete to a certain level to expose a non-contaminated layer. Decontamination of structures and plant components can reduce the amount of radioactive waste significantly.

24.6.4.3 Decontamination Techniques

For all decontamination techniques, consideration should be given to the amount of secondary waste produced, the safety and exposure of operators and the effect on the environment and the public.

a) High Pressure Spray Head Decontamination

The high pressure spray head decontamination normally uses a mobile system which can decontaminate internals of tanks and vessels in situ. The system components include pumps, heater, tanks and filter, used to provide pressurised water to the spray head.

The spray head is inserted into the tank and the pressurised water washes off the contamination. Contamination is captured by the filter and released through a bottom outlet to the treatment facility of the nuclear power plant. The operator can add cleaning agents to the water as appropriate.

This decontamination system can also be used on items, such as columns, filters, demineralisers and pumps. It can be operated without a spray head. The system can be designed as a closed loop containing the component to be decontaminated, and the circulating water (potentially supported by cleaning agents) can remove the contamination.

b) High Pressure Water Decontamination

The decontamination booth is an installation located in a hot workshop on site. It can receive larger items to be decontaminated which can be placed in an internal cabinet. High pressure water can remove surface contamination from items. The operator has the option to add cleaning agents to the water for certain applications. The decontamination booth can be designed for automated use (e.g. with a rotating table) to make unmanned decontamination possible. The contaminated water is collected and transferred to the treatment facility.

A decontamination booth can decontaminate both process related and non-process related equipment, such as pumps, valves, tools, containers, pipe pieces etc., in outages and during decommissioning.

c) Ultrasonic Bath Decontamination

The ultrasonic bath is an installation which can be located in a hot workshop on site. It can receive small or size-reduced metal parts at lower levels of contamination (e.g. instruments, tools, small valves). Items to be decontaminated are placed in the bath and then treated by ultrasonic wave motion. During the process contamination is removed from the surfaces due to the cavitation effects of the ultrasonic waves and the item is cleaned. The operator has the option to add cleaning agents to the water for certain applications. The process can decontaminate parts in operational and decommissioning phases.

d) Physical Abrasive Decontamination

Abrasive decontamination methods can be adopted when less aggressive methods are not sufficient or appropriate to achieve the required decontamination level.

They can also be applied on surfaces unavoidably contaminated during decommissioning. The contaminated material outer layer can be removed by this method in order to lower the overall contaminated waste volume. The rest of the structures or components can either be repaired for further utilisation or fully dismantled and released as conventional waste after radiological checking.

The following methods are presently available:

1) Abrasive grit blasting. Abrasive grit blasting is used to remove the contaminated surface of a metallic structure. Abrasive material (e.g. steel grit) is blasted onto a surface, so that the kinetic energy and the roughness of the grit on the surface can remove contamination as well as a small amount of the surface layer. The blasting grit is recycled and the contaminated particles can be collected and treated as radioactive waste. Frozen CO_2 and nitrogen can also be similarly applied for surface layer removal. This avoids secondary waste;

2) Milling. Concrete or steel milling is used to remove the contaminated surface of a wall floor or component;

3) Grinding. Grinding is used to remove the contaminated surface from items, such as casings or sheet metal;

4) Shaving or planning. Shaving uses a diamond armed steel wheel for surface removal. The wheel turns at high revolutions and removes material off the machined surface;

5) Scabbling on concrete surfaces.

e) Electro polishing

Electro polishing removes contaminated metallic surfaces by an electro-chemical process. It is applicable for geometrically complex metal parts (e.g. complex machine casings). Contaminated sludge is separated and treated as radioactive waste.

24.6.5 Dismantling

24.6.5.1 Dismantling of Systems and Components

Decommissioning plans should consider the feedback of relevant appropriate decommissioning experience, completed worldwide, especially that which is relevant to PWRs. The decommissioning conditions are often similar whilst not being exactly the same. Various dismantling techniques are available currently and they should be used, on a case-by-case basis.

In particular, various cutting techniques can be used to reduce the size of the equipment. The most appropriate technique should be chosen after feasibility studies have been undertaken. Some specific physical characteristics, such as size, thickness and material, radiological constraints as well as the access should be taken into account.

Feedback on dismantling nuclear power plants shows that the techniques, knowledge and skills are already available to manage the challenge presented by decommissioning.

The dismantling process should be determined using the following criteria:

a) The scheduling and nature of the dismantling works;

b) The final state of the facility;

c) The relevant origin, characteristics, quantity, packaging, transportation, disposal, recycling and management of both nuclear and non-nuclear waste;

d) The risks to the workers, public and environment. The measures applied to detect, prevent, limit and progressively reduce relevant risks;

e) The maintenance requirements for the facility and the auxiliary buildings during the dismantling operation;

f) The emergency plan during the operation.

The predicted impact of dismantling the UK HPR1000, and the logistical challenges, for example the transportation issues for the SG, presented by the reactor design are understood from the design phase. The baseline decommissioning strategy needs to demonstrate that both the reactor and the associated BQZ and SFIFS can be safely decommissioned.

The dismantling of the UK HPR1000 is based on the following methodology:

a) Remote dismantling of highly and moderately activated components under water, such as reactor vessel internals;

b) Dismantling of contaminated components and slightly activated components in air, such as reactor coolant piping;

c) Making maximum use of the UK HPR1000 facilities for containment and shielding purposes during the dismantling. The access routes to the reactor containment building have been designed to allow the import of dismantling equipment and export of large components, such as the SG;

d) Use of auxiliary buildings which will have a refurbished function especially during dismantling. While the reactor has been shut down, redundant auxiliary buildings can be refurbished in parallel to support decommissioning and waste management;

e) Removal of reactor coolant piping and reactor coolant pumps (primary cutting if necessary) from their location inside BRX to a workshop at the building floor service or in auxiliary buildings to be size-reduced for packaging;

f) Removal of the SGs as complete units from their respective shielded enclosures to a waste processing facility outside the BRX. Reverse handling and transportation design of large components, such as the SG, reactor coolant pumps and the pressuriser during the installation phase, give the possibility to remove the large component in one single piece, if appropriate;

g) The polar crane within BRX is designed for the handling of heavy equipment and reactor components during decommissioning. Lighter components can be handled by other means specific to the task and potentially added during the decommissioning phase;

h) The shielding treatments will be taken into account during the dismantling and transportation process.

The basic dismantling process for the primary circuit is given below:

a) Preparation (drainage, decontamination etc.) of primary circuit dismantling, dismantling of auxiliary pipes;

b) Removal of the SG from the BRX for dismantling in a dedicated workshop;

c) Removal and dismantling of the reactor coolant pumps;

d) Dismantling and removal of the reactor coolant piping;

e) Removal and dismantling of the pressuriser;

f) Preparation and dismantling of reactor vessel internals in the reactor pool under water;

g) Dismantling of RPV;

h) Dismantling of reactor vessel head (if not removed and packaged in one piece);

i) End of primary circuit dismantling.

24.6.5.2 Dismantling of Concrete and Steel Structures

a) Methods of Dismantling Structures

Various techniques are available for the dismantling of structures. Currently the following techniques are used:

1) Mechanical removal method, such as, impact breaking, mechanical chisels, shavers, pneumatic jackhammers, hydraulic hammers, etc.

These methods can be used suspended from hydraulic plant e.g. demolition tools, manual pneumatic tools are often employed because of space constraints.

2) High-pressure Water Sprayers or Shot Blasters

High pressure water jet cutting technologies uses a small amount of water at extremely high pressure, forcing the water through a hole at high speed to impact the concrete. Adding abrasive particles to the high pressure water can greatly enhance the abrasive quality on the concrete. Emery and garnet are commonly chosen abrasives.

3) Mechanical Cutting, Such as, Diamond Wire Sawing

Diamond wire saws (often used in the off-shore industry) can effectively cut concrete and steel.

4) Blasting (micro-mining)

This method has been commonly used in the removal of bulk concrete items.

5) Laser

Lasers generate high-energy light beams to heat and cut objects. Laser cutting can be used on most materials including iron, steel, concrete, etc.

All the above methods can be used to dismantle structures. The choice depends on safety, dust emission, noise reduction requirement, storage requirements, secondary waste generated, hazards associated with the technique.

b) Nuclear Island Plant Dismantling Considerations

The nuclear island includes all plant and buildings which present a radiological hazard during decommissioning. The scope of decommissioning of the nuclear island includes:

1) Reactor Building (internal containment, external containment, internal structure);
2) Safeguard Buildings (safeguard building A/B/C);
3) Fuel Building;
4) Nuclear Auxiliary Building;
5) Personnel Access Building;
6) Equipment Access Building;
7) Radioactive Waste Treatment Building.

All plant and equipment will be isolated, drained or vented and made safe before decommissioning. After the primary circuit components have been removed, the remainder of the plant and equipment within the BRX will be decommissioned.

The concrete surface in radioactive areas will be decontaminated before the structures are dismantled. Surface cleaning or scabbling to remove the surface of the concrete to a non-contaminated layer will be carried out.

The nuclear island buildings will be demolished after the equipment and components and have been removed.

BRX consists of both an internal and external containments. The walls are formed from pre-stressed concrete, with a stainless steel lining covering the internal surface sealing the structure to prevent the leakage of radioactivity. The external containment is a reinforced concrete dome covering the top of the internal containment. The external containment will be dismantled and then the internal containment demolished.

The other nuclear island buildings are all primarily concrete structures. Each item of plant will be cut into suitably sized segments, and then be sentenced, treated and packaged appropriately. The UK standard waste packages will be filled in-situ.

c) Dismantling Consideration of Conventional Plant

The conventional plant includes all plant and buildings which are associated with power generation or the operation of the site which do not present a radiological hazard. This therefore includes:

1) Turbine building;

2) Pumping station;

3) Substation and on-site transmission towers;

4) Other auxiliary buildings such as administration buildings, workshops, apartment buildings and other miscellaneous buildings on the site.

They will be decommissioned using current proven techniques for dismantling, in accordance with prevailing regulations, international guidance and best practice.

More information of dismantling will be developed during step 3.

24.6.6 Waste Management

Based on OPEX on decommissioning, the radioactive gaseous waste generated during decommissioning is limited and can be discharged by an existing or temporary Heating, Ventilation and Air Conditioning System (HVAC), and most radioactive liquid waste will be treated by the normal operating systems. Other liquid wastes can be treated by temporary waste treatment facilities.

Solid waste management is the most important part of decommissioning of the nuclear island as it generates the most and the greatest variety of radioactive waste.

For example, the dismantling of components and hot workshops will generate metallic and concrete waste. The decontamination facilities will generate ion exchange resin, filters, concentrate etc. All of these wastes will require appropriate disposal.

Waste management should consider:

a) Wherever possible reuse, recycling and disposal of material in order;

b) Waste characterisation, separation and segregation to maximise material recycling;

c) Use of an IWS;

d) Clearance and exemption for the disposal of solid radioactive waste;

e) Minimal production of waste which is difficult to dispose of;

f) Minimum production of secondary waste;

g) Waste generated will be processed in accordance with UK policy, guidance and legislation (see PCSR Chapter 21, PCER Chapter 3 and Chapter 4);

h) Discussions will be held with Nuclear Decommissioning Authority (NDA)/Radioactive Waste Management Limited during operation, to ensure compatibility of final waste packages for disposal in the GDF.

24.6.6.1 Waste Inventories

The wastes produced during decommissioning, such as metallic components, concrete, filters, ion exchange resin, dry wastes (disposable suits, vinyl, and scrap) etc., can be classified into ILW, LLW, VLLW and non-radioactive wastes.

The volumes of decommissioning waste will be assessed, allowing a number of waste streams to be identified.

a) ILW

After preliminary analysis, ILW may include RPV, spent resins, most spent filters, etc.

b) LLW

After preliminary analysis, LLW may include concentrates, heat exchanger, tanks, etc.

c) VLLW

After preliminary analysis, VLLW may include spent HVAC filters, dry active waste, cables, etc.

d) Non-radioactive Wastes

The non-radioactive wastes include non-decommissioning service systems from the turbine building and disposal/recycling of inert waste, some systems from the auxiliary building, as well as material from steel/concrete structures.

Detailed decommissioning waste inventories will be developed during step 3.

24.6.6.2 Waste Treatment

The Radioactive Waste Treatment Building (BWX) will be used for the reception, segregation, treatment and conditioning of solid radioactive wastes for as long as possible, as supported by new facilities if necessary. The new facilities will take over waste treatment after the BWX is dismantled.

Some of the items retrieved from the RPV internals will be so active that the heat produced must be managed. The reactor internals are often too hot for grout matrices as well as giving an intensely high radiation dose, therefore significant shielding is required. Different methods can be chosen to treat the reactor internals: they would be loaded into fuel flasks for decay storage with the spent fuel and repackaging into disposal containers at a later date or packaged directly into lead-lined cast iron disposal containers, for example.

The packaging of intermediate level metallic and concrete wastes will adopt UK standard container types with appropriate shielding. Ion exchange resin and solid LLW will be conditioned and packaged in appropriate standard UK containers. There is no special packaging for the solid VLLW. Secondary wastes will be packaged in a similar manner.

Appropriate monitoring and inspection ensures that only compliant waste packages are transferred to the interim storage facility (e.g. ILW) or transported off-site (e.g. LLW, VLLW). Temporary storage will be managed on site if necessary.

Decommissioning waste treatment (including information regarding ILW, and how this may decay to LLW during storage, etc.) will be developed during step 3.

24.6.6.3 Waste Disposal

a) Spent Fuel

The waste disposal for spent fuel can be found in PCSR Sub-chapter 24.6.3.

b) ILW

The ILW generated during the decommissioning of the nuclear island will be placed in appropriate packages and transported to the BQZ.

The packages will be transported in a shielded transport container if necessary. The container will be approved for safe transport of ILW.

The ILW packages will be stored in the BQZ and transported to the Geological

Disposal Facility (GDF) for final disposal.

The transfer of ILW packages to a GDF takes place before decommissioning of the BQZ. Before being transported to a GDF, the waste will be prepared if necessary (e.g. repacked, reconditioned etc.) in the BQZ to meet acceptance requirements at the GDF.

c) LLW and VLLW

The LLW and VLLW generated during decommissioning will be disposed of in the LLWR, where the solid waste is in accordance with the Waste Acceptance Criteria (WAC) in References [27], [28], [29], [30], [31] & [32].

Conditionally exempt solid VLLW will be disposed of with substantial quantities of non-radioactive waste for burial, incineration and recovery to sites (i.e. conventional landfills, waste incinerators), Reference [33].

PCER Chapter 4: *Waste Management Arrangement* in Reference [34] also discusses the disposal of decommissioning waste. In addition, more information on waste management (including how waste arising, waste category and waste amount, etc.) will be developed during step 3.

24.6.7 Safety Management

Identification, elimination or control of hazards and risks is a key aspect in decommissioning, and this includes the hazards and risks to workers, environment and the public. Systems and devices designed for the operational phase may become ineffective during dismantling in the decommissioning phase. For example some control systems will become redundant but others need to retain their function. Therefore the adequacy of safety measures needs to be re-evaluated as the work proceeds. New potential hazards and risks need to be identified and new safety measures adopted as necessary. Environmental protection measures should also be taken into account. Additional health and safety precautions will need to be implemented as decommissioning involves changing and evolving processes on the site and large numbers of temporary workers or augmented labour. A new organisation structure and administrative arrangements will need to be adopted. In addition, there are conventional safety risks associated with decommissioning and the use of dismantling techniques, e.g. use of lasers, toxicity of chemicals.

24.6.7.1 Hazards during Decommissioning

It will be demonstrated that decommissioning of the UK HPR1000 can be carried out safely (conventional safety) since all reasonably foreseeable hazards are identified, and suitable and sufficient safety measures will be available to reduce risks to ALARP levels. There will be radiological hazards, hazards from the changing environment due to the decommissioning and hazards due to new conventional safety issues. Further information on decommissioning conventional safety can be found in PCSR Chapter

25: Conventional Safety and Fire Safety.

The overall UK HPR1000 hazards identification and assessment process is considered in PCSR Chapter 18: External Hazards and Chapter 19: Internal Hazards. Only the decommissioning related hazards, such as dropped loads, fire and explosion, etc. are covered in this chapter. In addition, with the development of the decommissioning safety case, the consideration of hazards will also be developed.

24.6.7.2 Identify the Major Hazards

Different decommissioning methods will produce different hazards. In order to identify the potential hazards during decommissioning, the relevant process and activities are analysed. Major hazards from decommissioning and their mitigation are presented below during the GDA phase.

T-24.6-1 Preliminary Identification of Major Hazards

Hazard	Mitigation
Worker dose from cutting and removal of items, decontamination processes, also from transfer of materials (reactor internals)	Material selection (see PCSR Chapter 17), reactor chemistry (see PCSR Chapter 21), remote operations, characterisation, suitable transfer routes and packaging
Spread of contamination from decommissioning tasks such as equipment dismantling; Loss of ventilation will result in increased aerosol concentration	Temporary HVAC, local containment, decontamination prior to handling, remote operations, strippable coatings
Criticality from the process of removing of spent fuel	Review of fuel lifting and handling equipment (see PCSR Chapter 28)
Contaminated wounds from hands-on work	Remote operations, sharps protection
Loss of liquid containment of contaminated water, oils or liquors from system flushing and draining	Secondary containment e.g. bunds (see PCSR Chapter 19), leak detection (see PCSR Chapter 17)
Conventional safety of demolition operations will become principal hazard	Minimising cutting operations, access/egress arrangements
Dropped load, movement of large items	Design of lifting devices for decommissioning (see PCSR Chapter 19), planning of removal routes
Internal hazards: fire / explosion from cutting and grinding operations	Limit the combustibles with high fire loads (see PCSR Chapter 19), use of cold cutting techniques, good housekeeping

Hazard	Mitigation
External hazards as plant is taken apart there may be partial structures not designed to withstand external hazards	Demolition plan, time at risk, integrity of building structure

Once the decommissioning plan has been confirmed by the licensee, detailed hazard identification should be carried out.

24.6.7.3 Control Measures

Suitable and sufficient safety measures are taken to control the identified hazards according to the UK regulations, which include engineering measures, management measures, training and personal protective equipment, etc.

As mentioned above, at present the key hazards associated with decommissioning are internal fire, explosion and dropped loads.

a) Internal fire

There is a possibility of fire if there are combustible materials present in rooms. During decommissioning, cutting, flammable materials and the use of electrical equipment can lead to fire.

Protection and mitigation measures for internal fire include:

1) All of the materials used in the nuclear plant will be qualified by relevant institutions.

2) Low flammability or high flash-point fuel and lubrication oils will be employed where reasonably practicable. Where this is not the case, the use of bunds will be employed to ensure any leakage of oil is locally contained.

3) Passive fire protection measures have been used for high fire load equipment and systems.

4) Electrical equipment ignition sources are controlled through application of appropriate standards.

5) When there is a fire in the plant, mitigation measures will be taken immediately. To make sure the fire can be detected and extinguished as soon as possible, three fire protection systems are incorporated in the design:

   - Fire detection systems;
   - Fire-fighting systems;
   - Smoke control systems.

b) Explosion

Internal explosions are explosions which could occur within the site of the nuclear power plant. For example, when explosive material leaks into the environment or high voltage electrical equipment fails an explosion may occur. During decommissioning, explosions can also be triggered by cutting or demolition activities.

The radiological consequences of an explosion on a plant will depend on the plant layout and the quantity of radioactive material involved.

Protection and mitigation measures for internal explosion include:

1) The release of explosive gases from processes which generate these gases has been avoided or managed;
2) Limiting the use of explosive materials or pressurised tanks so far as is reasonably practicable in buildings important to safety, where this is not possible, amounts are strictly limited to the necessary quantity;
3) Detection system: 12.5% concentration safety margin;
4) Alarm system: The alarm system will warn the operator of the concentration of explosive gas.

c) Dropped loads

The scope of items having the possibility to drop includes collapsed structures, falling objects and dropped loads. For seismically classified structures and heavy items of plant equipment located at significant heights, their collapsing or falling can be prevented. Dropped loads are assumed to occur as a result of a lifting device failure if the lifting devices can no longer control the loads.

The impact of partial structure decommissioning or dismantling on the structures should be considered. And the lifting of equipment to be removed should consider the effect of dropped loads.

Protection and mitigation measures for dropped loads include:

1) Provide periodic inspection and early detection of incipient failure;
2) Provide operational procedures and operator training to reduce the human error.
3) The loads are not required to be carried over or near equipment that may lead to radioactive release when struck.
4) A safe lifting route should be defined to reduce the possibility the dropped loads onto specific plant;
5) For all major lifts, single straight-line movement of the crane is defined;
6) Lifting height should be limited.

24.6.7.4 Organisation for Decommissioning

The operator should make sure that an effective safety management organisation is established and maintained to ensure safe and effective decommissioning of facilities. There are major changes for the organisation in the change from operation to decommissioning which should be reflected in a revised organisational structure.

Included in this revision is the need to ensure that emergency arrangements may well change during the decommissioning process. Although the overall hazard will decrease changes in routes and new hazards generated by the decommissioning process e.g. hot cutting processes mean that the emergency arrangements will need revising at regular intervals. Also there will be new workers on-site that will need to be adequately trained and briefed on all safety aspects.

The operator should learn from the experience of radiological and conventional safety in other decommissioning projects and improve and adapt the current safety measures and safety management to minimise the risks. A Decommissioning Safety Case for decommissioning operations will be produced in accordance with the overall Safety Case before the decommissioning phase and the safety case will be maintained until de-licensing of the site.

24.6.7.5 Human Factors

Human factors must be considered during decommissioning. The purpose is to:

a) Facilitate the implementation of decommissioning activities;

   Human factors consideration during the plant design and construction phase reduces worker exposure, and simplifies decontamination and dismantling procedures during decommissioning.

   In PCSR Sub-chapter 24.4, the consideration for facilitating decommissioning is presented.

b) Minimise human errors in decommissioning;

   Human errors during decommissioning will be minimised by adopting the following measures:

   1) Decommissioning devices and tools with sufficient robustness and fault tolerance are considered in the design phase;

   2) Decommissioning plan will be updated periodically on account of technological development of decommissioning;

   3) Decommissioning organisation will be built to enhance work/health/training management and safety culture.

c) Protect workers against potential harm.

In PCSR Sub-chapter 24.6.7.2, the hazards and corresponding safety measures are presented.

Further detail on Human factors is presented in PCSR Chapter 15: Human Factors.

24.6.8 Delicensing

The end-point of decommissioning includes decommissioning of all facilities including the BQZ and SFIS facility.

The end state is where all licensable activities have ceased and the site licence is revoked and the period of responsibility under the Nuclear Installation Act (1965) has ended i.e. Delicensing. The licensee will need to demonstrate there is no danger from ionising radiation. When there are no other interim or reuse states agreed, this end state should be assumed.

The Preliminary Decommissioning Plan will be continuously developed during step 3 to cover more information, e.g. use of demolition products as infill for underground voids, trenches, basements; design of electrical system to allow for progressive decommissioning and areas to be made 'cold and dark'; use of neutron shielding to reduce dose rate and activation of metals; and provisions for segmentation of large items of plant.

24.7 Records and Knowledge Management

Documents and records that may be required for decommissioning purposes are to be identified, prepared, updated, retained, and owned so that they will be available when needed. The process of making and preserving these documents and records starts at the design phase and will continue throughout the whole lifecycle. The records need to be in an appropriate manner and form, taking account of the long timescales over which they may need to be retained and accessed.

Knowledge management is an integrated, systematic approach to identifying, managing and sharing an organisation’s knowledge and enabling groups of people to create new knowledge collectively to help in achieving the organisation’s objectives. Knowledge management focuses on three aspects:

a) Organisational culture to stimulate and nurture sharing and use of knowledge;

b) Processes or methods to find, create, capture and share knowledge;

c) Technology to store and make knowledge accessible.

For decommissioning, knowledge management has three objectives:

a) Guarantee technical quality and safety standards;

b) Minimise risk during decommissioning;

c) Carry out effective training and enhance worker’s competence.

24.7.1 Design, Construction and Commissioning Phase

The following must be considered during the design, construction and commissioning phases:

a) Design documents, design specifications, drawings and charts related to siting, design, construction and modification;

b) A site survey that provides characterisation of radiological conditions on the site. Baseline surveys should consider both surface and sub-surface conditions as well as groundwater. Any soil or geotechnical issues not conforming to the specification should be recorded;

c) Photos and videos for important construction and installation processes need to be recorded, supplied with captions, dates and annotations, such as earthwork & stonework, particularly for concealed structure construction;

d) Supporting samples of materials should be taken so that they can be used to identify original constituency, and then following operation understand the levels of corrosion, activation and contamination;

e) Any concessions or changes to the design and materials noted and recorded, as built drawing should be produced at the end of construction; and

f) Any modification to the design, structures, systems and components during the commissioning stage should be noted and recorded.

24.7.2 Operational Phase

During the operational phase, the operator of the plant will be responsible for collecting and maintaining records for future decommissioning. The records include:

a) Operational history (including incident records);

b) Radiological surveys;

c) Radioactive substances and radioactive waste quantities, locations, condition, with specific focus at the end of normal operations;

d) Radioactive waste treatment and disposal records;

e) The physical condition of the facility, including examination, maintenance, inspection and testing records; and

f) The detailed records of modification and overhauling during the operational phase.

24.7.3 Decommissioning Phase

The following is required during the decommissioning phase:

a) Decommissioning plan and other relevant reports;

b) The detailed records of decommissioning; and

c) Waste treatment and disposal records.

24.7.4 Records and Knowledge Management Techniques

The decommissioning document information should be protectively stored and available for update, examination for the full lifecycle of the plant. Document records include drawings, diagrams and photographic records (particularly during construction of the plant) produced over the reactor lifetime.

Data gathering and information storage should be implemented and maintained with appropriate technology, from the beginning of the project design phase.

Knowledge management for decommissioning is necessary and important. And it will be well planned through all the life stages of nuclear facilities. A decommissioning project requires knowledge from previous phases, including modifications made to the facilities and any differences from what the design intended. Appropriate technical expertise and experience contribute tremendously to this.

Three approaches are useful for decommissioning knowledge management:

a) Establishment of knowledge acquisition methods necessary for decommissioning

   1) Extraction and arrangement for data and information from international decommissioning research results;

   2) Organisation and systematisation of information by establishing rules and methods to extract necessary information from plant specific data;

   3) Establishment of knowledge extraction methods based on the decommissioning taxonomy.

b) Formulation of knowledge acquisition from experienced engineers

   1) Externalisation of implicit knowledge of employees along with their occupational history;

   2) Establishment of method for extraction of knowledge and know-how from communication with experienced employees such as questionnaires interviews or event simulations for socialisation and externalisation.

c) Construction of management system

   1) Enhancement of information access system by knowledge engineering technologies;

   2) Enhancement of knowledge internalisation of present worker by discussion meetings;

3) Establishment of knowledge transfer by special lectures or training by retiring workers;

4) Knowledge transfer support form retirees by continuous communication even after retirement;

5) Information exchange with other decommissioning facilities.

In PCSR Chapter 20: MSQA and Safety Case Management, management system and quality assurance are presented, including safety culture, personnel allocation and training, knowledge and experience feedback, document and record control.

24.8 ALARP Assessment

According to the ALARP methodology specified in PCSR Chapter 33, this sub-chapter provides an overview of how ALARP has been taken into account in decommissioning.

It is mentioned that decommissioning will begin 60 years after the UK HPR1000 commences operation. Consideration of facilitating decommissioning, the decommissioning strategy and a preliminary decommissioning plan will be completed based on RGP and OPEX identified during the GDA phase to ensure that risks for decommissioning will be ALARP.

Utilising OPEX from worldwide PWR decommissioning projects is being examined and RGP identified in Reference [7] is adopted as appropriate, which provides guidance to decommissioning of the UK HPR1000. OPEX on decommissioning will be developed during step 3 and will contribute to demonstrating that the risks associated with decommissioning of the UK HPR1000 are ALARP.

The ALARP principle concerns the reduction in risk, the greatest risk reduction occurs in design for decommissioning. PCSR Sub-chapter 24.4 has provided details of how the design is developed to take account of decommissioning from eight aspects: site selection, general layout, selection of materials, equipment design, process design, building and structure design, layout design and waste management, and more evidence is provided in the Supporting Document in Reference [23]. Additionally reviews are undertaken by the design team to ensure that appropriate design for decommissioning has taken place. Associated hazards will be reduced during decommissioning by minimising contamination and activation through the plant's design and ensuring that it is in line with the ALARP methodology. The primary way to achieve this is through careful selection of materials, taking into account reliability, degradation, application of BAT and availability. Examples of this are as follow:

a) Use of copper alloy is prohibited for all the assemblies in contact with the reactor coolant;

b) Elements susceptible to activation (especially Co, Ag and Sb), which could significantly contribute to dose rate, are strictly controlled ;

c) Use of corrosion resistant materials in pipework.

The careful control of the water chemistry will help reduce contamination built up during the plant's lifecycle presented in PCSR Chapter 21: Reactor Chemistry. The POCO will be carried out before dismantling to reduce the level of contamination. In addition, PCSR Sub-chapter 24.6.7 has identified the relevant hazards and the corresponding safety measures during decommissioning.

The UK HPR1000 will accommodate immediate or delayed decommissioning. Immediate decommissioning is preferred. In addition, the preliminary decommissioning plan will be prepared during step 3, where a number of decommissioning techniques (including decontamination, dismantling and decommissioning waste management, etc.) will be presented. These decommissioning techniques will be evaluated to ensure their availability for the UK HPR1000. If there are advantages to allowing heat and activity decay, they will be considered in the decommissioning plan. Furthermore, decontamination, dismantling and decommissioning waste management are also being carried out to reduce the radiological impact to workers, the public, and the environment and to minimise the amount of waste generated.

The design of the UK HPR1000 is following RGP in the UK and Worldwide. Upon completion of safety case in PCSR Chapter 24, the plant can be safely decommissioned using technology available today and the doses to workers and the public can be demonstrated to be ALARP. However, options for future licensees have not been foreclosed.

24.9 Concluding Remarks

This chapter demonstrates that the generic design for the UK HPR1000 can be safely and effectively decommissioned at the end of its operational life. The UK HPR1000 will be designed, and will be constructed and operated so that it can be decommissioned reducing the radiological impact on the workers, public and environment, so far as is reasonably practicable.

The ALARP and BAT considerations are taken into account for UK HPR1000 decommissioning, this includes: design to minimise activation and contamination, consideration of decommissioning strategy, and production of a preliminary decommissioning plan. The ALARP approach will be considered in all aspects of decommissioning. The UK HPR1000 design is the result of combining the proven features of HPR1000 designs, especially FCG unit 3. All practicable measures to keep doses ALARP will be investigated. Design features will be retained to reduce the dose to operators and to minimise waste.

The requirements of the GDA phase and different regulation regimes between the UK and China mean that there are a number of forward actions identified for the UK HPR1000 project to ensure that decommissioning is developed to meet the UK requirements.

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