Nuclear Waste Services

Waste Package Specification and Guidance Documentation: Specification for High Heat Generating Waste Precursor Product

WPS/240/02

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Executive Summary

This Waste Package Specification (WPS/240/02) fully replaces the previous version (WPS/240/01) that was issued for trial use and comment only. The purpose of this Waste Package Specification is to define the precursor product requirements for High Heat Generating Waste to ensure that processing and storage arrangements do not preclude disposal of these products in the future.

A precursor product, for the purposes of this specification, is defined as waste, spent fuel or nuclear material that has been appropriately managed for packaging into a disposal container (DC). The waste, spent fuel or nuclear material may potentially be dried, conditioned and / or loaded into cans prior to final packaging, transport and disposal.

This Waste Package Specification is derived from an understanding of Advanced Gas-cooled Reactor (AGR) Spent Fuel, Pressurised Water Reactor (PWR) Spent Fuel, intact Metallic Spent Fuels and High Level Waste (HLW). More detail on the precursor products can be found in Section 2. Other precursor products could be added to the scope of this Waste Package Specification in the future, subject to a compelling use case and positive outcome of formal Disposal System Specification change, including consideration of feasibility for disposal.

Requirements for the precursor product have been defined, per precursor product type, for the following categories:

- Drying;
- Heat output;
- External dimensions;
- Stacking;
- Mass;
- Internal furniture and physical state;
- Materials;
- Enrichment;
- Identification markers;
- Assurance, Records and Management Systems;
- Criticality safety;
- Maximum temperature (HLW only);
- Vitrified HLW properties (HLW only).

This Waste Package Specification will enable endorsement of the precursor product via a Nuclear Waste Services Disposability Assessment. The disposal container that will ultimately form the waste package, will be developed at a later date in parallel with the Geological Disposal Facility design for specific sites.

WPSGD Document Number WPS/240/02 – Version History		
Version	Date	Comments
WPS/240/01	February 2016	Based on 2015 drafts of the 2016 DSS, GTSD and GDFD and the 2010 safety cases for transport and the GDF operational and post-closure periods. Issued for trial use by and comments from waste producers.
WPS/240/02	October 2024	Specification has been updated to focus on the HHGW precursor products, based on current NWS understanding and knowledge.

Abbreviations and Acronyms

ADR	Agreement concerning the International Carriage of Dangerous Goods by Road
AGR	Advanced Gas-Cooled reactor
ARM	Assurance, Records and Management
BEP0	British Experimental Pile Zero
CCAD	Criticality Compliance Assurance Document
CSA	Criticality Safety Assessment
DC	Disposal Container
DCTC	Disposal Container Transport Container
DFR	Dounreay Fast Reactor
DSS	Disposal System Specification
EBS	Engineered Barrier System
EPR	Environmental Permitting Regulations
EVR	Evaporite Rock
GDF	Geological Disposal Facility
gDFD	generic Disposal Facility Designs
gDSSC	generic Disposal System Safety Case
gTSD	generic Transport System Designs
HAL	High Activity Liquor
HAW	Higher Activity Waste
HHGW	High Heat Generating Waste
HHPP	High Heat Precursor Product
HLW	High Level Waste
HSR	Higher Strength Rock
IAEA	International Atomic Energy Agency
IGD	Inventory for Geological Disposal
IWMP	Integrated Waste Management Programme
LHGW	Low Heat Generating Waste
LLWR	Low Level Waste Repository
LSSR	Lower Strength Sedimentary Rock
NCT	Normal Conditions of Transport
NDA	Nuclear Decommissioning Authority
NWS	Nuclear Waste Services (formerly RWM)
PFR	Prototype Fast Reactor
PRS	Package Records Specification
PSSR	Pressure Systems Safety Regulations
PWR	Pressurised Water Reactor
RWM	Radioactive Waste Management Ltd
SF	Spent Fuel
VPS	Vitrified Product Store
WAC	Wase Acceptance Criteria
WPS	Waste Package Specification
WPrS	Waste Product Specification
WPSGD	Waste Package Specification and Guidance Documentation
WVP	Waste Vitrification Plant (Sellafield)

Contents

1. Introduction

The Nuclear Decommissioning Authority (NDA) has established Nuclear Waste Services (NWS)[1] (formerly known as Radioactive Waste Management Ltd (RWM)) as the custodian for implementing UK Government policy for the management of Higher Activity (radioactive) Waste (HAW), as set out in the UK policy framework for managing radioactive substances and nuclear decommissioning [1]. The policy outlines a framework for managing those wastes in the long-term through geological disposal, which will be implemented alongside the ongoing interim storage of waste packages and supporting research.

As implementer of a Geological Disposal Facility (GDF), and therefore the ultimate receiver of wastes for disposal, NWS will be responsible for establishing Waste Acceptance Criteria (WAC) for such a facility. The plans for the construction of a GDF are at an early stage and the information necessary to define final WAC is not available. In the meantime, and as a predecessor to a defined set of WAC, NWS has produced a number of Waste Package Specifications (WPS), the primary purpose of which is to enable the holders of radioactive wastes to condition waste into a form that will be compatible with the anticipated needs of transport to, and disposal in, a GDF.

The purpose of this WPS is to define the precursor product requirements for High Heat Generating Waste (HHGW) to ensure that processing and storage arrangements do not preclude disposability of these products in the future. A precursor product is waste, spent fuel or nuclear material that has been appropriately managed for eventual packaging into a disposal container. The waste, spent fuel or nuclear material may potentially be dried, conditioned and / or loaded into cans prior to final packaging, transport and disposal.

This Waste Package Specification is derived from an understanding of Advanced Gas-cooled Reactor (AGR) Spent Fuel, Pressurised Water Reactor (PWR) Spent Fuel, intact Metallic Spent Fuels and High Level Waste (HLW). More detail on the precursor products can be found in Section 2. Other precursor products could be added to the scope of this Waste Package Specification in the future, subject to a compelling use case and positive outcome of formal Disposal System Specification change, including consideration of feasibility for disposal.

Waste packagers are encouraged to engage with NWS about their approach to processing and storage of HHGW in order to maximise the potential that the waste will be accepted for GDF disposal.

[1] On 31 January 2022, NDA created its waste division trading as NWS, integrating Low Level Waste Repository (LLWR), RWM, and the NDA group's Integrated Waste Management Programme (IWMP). RWM remains a limited liability company incorporated under English law. References to RWM in the text of this document may be read as referring to NWS.

This will enable conceptual endorsement of the precursor product via GDF Disposability Assessment. Unlike Low Heat Generating Waste (LHGW), the detailed design of the HHGW disposal container is yet to be undertaken, therefore the requirements are set out for the precursor product and not the waste package. However, the requirements have been derived based on our assumed use of the illustrative concepts and generic Disposal System Safety Case (gDSSC) containers. The waste container will be developed in future by NWS to accommodate the precursor products in parallel with the detailed design development for a GDF.

The precursor product is analogous to the wasteform as outlined in the gDSSC [2, 3]. The precursor product will at some point in the future be packaged within a high integrity disposal container before being transported to a GDF for disposal.

It should be noted that all assumptions captured within this document are based on generic concepts and understanding and are subject to change once GDF development progresses to site specific. Consequently, the application of this specification is limited to Conceptual stage endorsement via Disposability Assessment.

The remainder of this document is structured in the following manner:

- Section 2 provides descriptions of the precursor products covered within this WPS;
- Section 3 details the precursor product requirements, one set per defined HHGW type;
- Section 4 details the Assurance, Records and Management (ARM) requirements for the precursor products.

2. The Precursor Products Covered by This Specification

This section details the conditioned form, or precursor product, of the legacy AGR SF, PWR SF, Metallic SF and HLW, as outlined in the Inventory for Geological Disposal (IGD) 2019 [4]. These were selected as the focus of this specification as they represent the largest volume of legacy HHGW, with minimum associated complexity. The precursor product will contribute to the overall performance of the waste package over very long timescales and therefore requirements are needed to ensure contributions are, at a minimum, passive.

A precursor product is waste, spent fuel or nuclear material that has been appropriately managed for eventual packaging into a disposal container. The waste, spent fuel or nuclear material may potentially be dried, conditioned and / or loaded into cans prior to final packaging, transport and disposal. The HHGW precursor product is distinct from LHGW interim products, the latter typically being ILW that has been packed into final disposal containers and placed in interim storage awaiting final conditioning prior to transport to and disposal in a GDF. Precursor HHGW products on the other hand will not be placed in their final disposal containers potentially for several decades.

Other precursor products could be added to the scope of this WPS in the future, subject to a compelling use case and positive outcome of formal Disposal System Specification change, including consideration of feasibility for disposal.

2.1 AGR SF Precursor Product

In the case of AGR SF, the precursor product comprises a cylindrical stainless steel slotted can and its contents, i.e., the uranium dioxide (UO_2) fuel pellets encased in stainless steel cladding and any associated containers within the slotted can.

Figure 1: Stainless steel slotted can

An AGR fuel element has an overall length of ~1,000 mm and consists of an array of 36 fuel pins, each comprising a stack of UO_2 fuel pellets clad in a stainless steel tube. The fuel pin

array is held in place by an assembly of stainless steel grids, guide tubes and braces, the whole array being placed inside a graphite sleeve.

When AGR fuel elements are received at Sellafield, they are ‘consolidated’ by separating the fuel pins from the other components of the fuel element including the graphite sleeve and loading pins, and placing the former into stainless steel slotted cans, see Figure 1, each of which holds up to 108 fuel pins. The slotted cans are then stored under water in ponds.

Fuel elements selected for post-irradiation examination (PIE) and those identified as having failed during reactor operations or suffering damage during dismantling at Sellafield are segregated and the damaged fuel pins placed within welded steel capsules. These welded capsules are then stored under water in ponds in the Sellafield fuel ponds alongside slotted cans. For disposal it is envisaged that the welded capsules would be placed inside slotted cans and packaged as for intact fuel.

It is expected that most consolidated AGR fuel ‘bundles’ will have the same basic physical properties (external dimensions, shape and gross mass) but there may be significant variations in their radiological properties.

2.2 PWR Spent Fuel Precursor Product

The legacy PWR Spent Fuel precursor product consists of the whole of the fuel assembly between the top and bottom nozzles with maximum dimensions of 4,100 mm length and 240 mm × 240 mm square section, see Figure 2. The precursor product for PWR does not currently include non-fuel core components. However, it is recognised that future consideration and development of appropriate packaging strategies may lead to this position changing in future iterations of this WPS.

The SF assemblies that arise from the Sizewell B PWR (Figure 2) consist of a square array of fuel pins held together by a structural skeleton made up of top and bottom nozzles, intermediate spacer grids and guide tubes. The standard Sizewell B fuel assembly consists of 264 fuel pins, each comprising a stack of UO_2 pellets in a sealed Zircaloy tube. The skeleton’s components are a combination of Zircaloy, Inconel and stainless steel, the details of which varies between different fuel assembly designs.

The majority of SF arising at Sizewell B is currently stored under water in on-site cooling ponds. However, in 2017 dry storage was implemented at Sizewell B and spent fuel is now being transferred from the ponds to dry storage in a series of campaigns. The spent fuel will remain in dry storage until it can be repackaged for transport to, and disposal at a GDF.

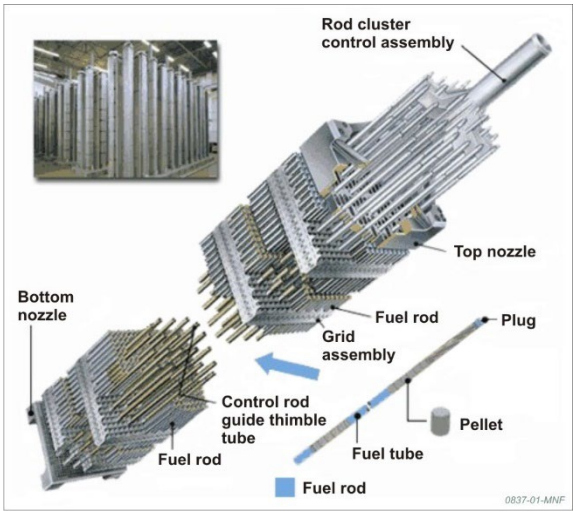

Figure 2: PWR fuel

It should be noted that this specification does not currently cover proposed new build UK European Pressurised Reactor and AP1000 reactor fuels. These, and other precursor products, could be added to the scope of this WPS in the future, subject to a compelling use case and positive outcome of formal Disposal System Specification change, including consideration of feasibility for disposal.

2.3 Metallic SF Precursor Product

In the case of the intact Metallic SF, the precursor product consists of a series of commercial Magnox fuel and Pile fuel placed in a fuel canister. The precursor products should contain uranium that has an enrichment level of U-235 <1.5%. It is assumed that 26 Metallic SF elements, or an equivalent mass of uranium (circa 311 kg uranium based on Wylfa MK1B), will be placed into a fuel canister, of which 3 of these will be placed in the disposal container.

A number of different Metallic SFs are present in the UK inventory, arising from different commercial and experimental reactors. The bulk of the metallic SF is from the UK's decommissioned fleet of Magnox reactors. While the precise design of the fuel element varied from reactor to reactor, there are a number of common features.

A Magnox fuel element consists of a solid uranium rod of natural or slightly elevated U-235 enrichment, with a uranium mass of up to 12 kg. The uranium rods were clad in a magnesium non-oxidising alloy, called Magnox. There is up to ~2 kg of Magnox metal per element depending on the specific design. The Magnox fuel elements range in size from ~482 mm to 1,067 mm. Some designs include Magnox splitters and graphite struts. Typically, Magnox SF was de-splittered / de-strutted, and in some cases, de-lugged, prior to consignment to Sellafield site.

A variety of Magnox fuel elements are shown in Figure 3.

Figure 3: Magnox Fuel Elements

In preparation for reprocessing, the Magnox can was stripped[2] from the uranium bars a process referred to as decanning. Reprocessing and the associated decanning of Magnox fuel stopped in 2022. The remaining Magnox fuel is currently stored in skips, under water in fuel storage ponds. Some metallic fuel has been stored in these conditions for several decades and as such, the Magnox cladding may have corroded, resulting in fuel elements with variable degree of cladding cover. As a result, the proportion of cladding associated with the Metallic SF inventory at Sellafield ranges from fully clad elements to bare uranium bars.

Small quantities of additional metallic uranium fuels also exist and have been considered within the scope of this WPS. These include Windscale Pile fuel cartridges and British Experimental Pile Zero (BEP0) fuel, see Figure 4 and Figure 5 respectively.

The Windscale Pile fuel cartridges consist of uranium metal rods clad in finned aluminium cans which were attached to a graphite boat to facilitate operations. Various versions, or marks, of fuel cartridge were developed, most containing natural uranium metal, but some include slight pre-irradiation enrichment.

The length of the cartridges is approximately 300 mm and the outer diameter up to 7- mm; this includes the fins of the aluminium can.

[2] This operation was undertaken at the Sellafield site.

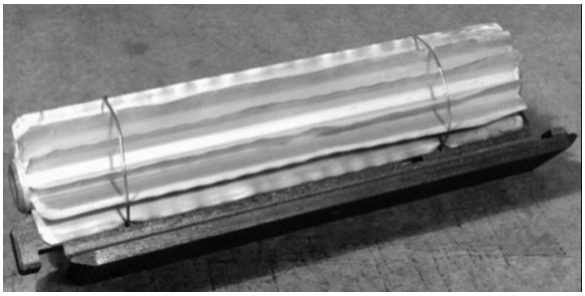

Figure 4: Windscale fuel cartridge and graphite boat (representative of Mk V, VI and X designs)

BEP0 fuel cartridges are described as nominally consisting of a 305 mm long uranium bar, having either a diameter of 23 mm or 20.5 mm (later designs), encased in a finned aluminium canister with the fuel pre-irradiation enrichment varying according to need.

The aluminium canisters are either flat or longitudinally spirally finned, some being helium filled, the two main variants are shown in Figure 5.

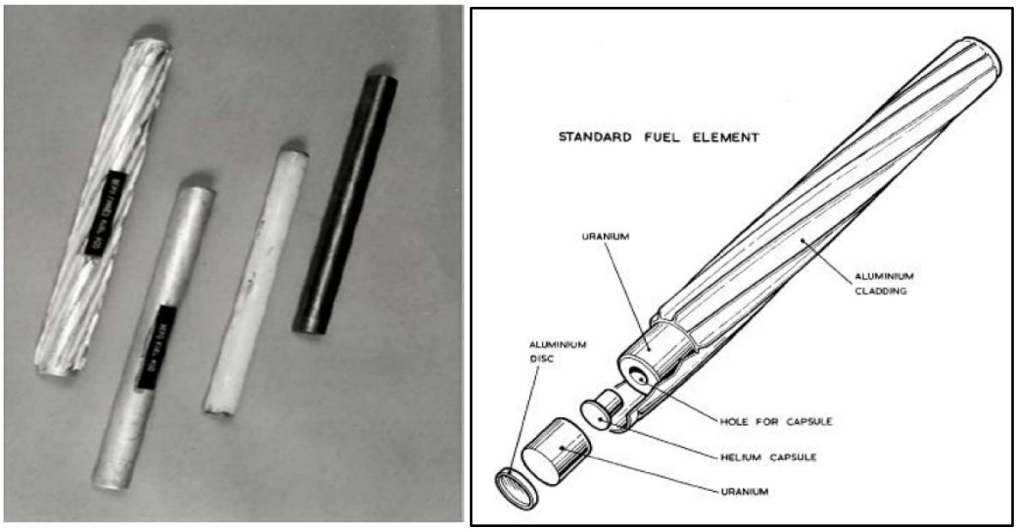

Figure 5: (From the left) BEP0 fuel cartridge types: finned and non-finned cladding, and respective uranium fuel bars. (Right) components of the BEP0 fuel cartridge (Mk VII shown)

The fuel pre-irradiation enrichment and rod design varies. Fuel rods are present as either a single rod, or two separate slugs with a blind, helium filled hole in between. The maximum length and diameter of a BEP0 fuel cartridge, including the finned aluminium canister, are 347 mm and 32 mm respectively.

Metallic uranium fuel from the Dounreay Fast Reactor (DFR) and flat bar fuel from Chapelcross are currently excluded from the scope of this WPS due to their initial pre-irradiation enrichment exceeding 1.5 wt.% U-235. However, it is recognised that future consideration and development of appropriate packaging strategies may lead to this position changing in future iterations of this WPS.

2.4 HLW Precursor Product

In the case of HLW, the precursor product covers vitrified High Activity Liquor (HAL), and associated secondary wastes, in a stainless steel Waste Vitrification Plant (WVP) product container. The waste is usually referred to as vitrified HLW.

Vitrified HLW is generally produced as a result of the reprocessing of irradiated nuclear fuel. It is initially produced as a liquid but, after a period of cooling (to allow for the decay of short-lived radionuclides) it is 'vitrified' to convert it into a solid, more stable form. This is achieved, in the WVP, by immobilising the waste in a borosilicate glass matrix, which is poured into stainless steel containers to form vitrified product containers, see Figure 6.

Figure 6: Example of HLW in a stainless steel WVP product container

Vitrified product containers are currently held in the Sellafield Vitrified Product Store (VPS) where it is anticipated that they will remain until they are packaged in preparation for their export to a GDF. It is expected that all WVP vitrified product containers will have the same basic properties (external dimensions and shape), and similar gross mass, although there may be significant variations in the physical, chemical and radiological properties of their contents.

There are other secondary waste streams arising from the HLW vitrification process that are currently out of scope of this WPS e.g., 'technological wastes'.

3. Precursor Product Requirements

Waste packages shall be capable of being safely transported to a GDF in accordance with the systems defined by the generic Transport System Designs (GTSD) [5] and, following receipt at a GDF, shall be capable of being safely handled by way of the processes and equipment defined in generic Disposal Facility Designs (GDFD) [6]. Also included is a consideration of the required performance of waste packages in a GDF post-closure period, as defined by a set of environmental safety functions.

The precursor product contributes to the performance of the waste package, and therefore, identifying the precursor product requirements is key to enabling safe packaging, transport and disposal of the HHGW in a GDF. The precursor product requirements are defined within the following sub-sections, by precursor product type as defined in Section 2.

The Disposal System Specification (DSS) text presented within the requirement tables has been formatted to maintain consistency with the DSS e.g. bold, italic, red text [3]. The new HHGW requirements have been assigned new numbers with a High Heat Precursor Product (HHPP) prefix. Each requirement table also includes a full list of references from which the pertinent requirement information has been drawn.

3.1 AGR Spent Fuel Precursor Product Requirements

The AGR SF HHPP requirements have been defined in the tables below.

Table 1: AGR SF precursor product drying requirements

Identification No. / Name:	HHPP 1.1: AGR - Drying
Statement of Requirement:	The water carried over shall be minimised within the AGR SF precursor product to enable packaging in a disposal container.
Measure of Performance:	Criticality Safety Limit <5 kg of water carried over per disposal container (Galson Sciences, Section 6, Pg 63). Pressurisation Limit Currently not fully quantified as functional requirements for the disposal container are not yet defined.
Rationale	To prevent criticality and subsequent damage to engineered barriers in the GDF, and to protect people, property, and the environment from harmful effects of ionising radiation during transport and GDF operations. Maintaining disposal container integrity by preventing the build-up of excessive gas pressure.

Identification No. / Name:	HHPP 1.1: AGR - Drying
Justification:	Limiting the water carried over is necessary in order to prevent criticality, build-up of gas pressure, and inside-out corrosion of the disposal container. It is assumed that AGR slotted cans will be disposed of in a sealed disposal container containing 16 slotted cans (Arup, Section 2, Pg 11). The water carried over into a sealed disposal container initiates processes that could threaten the ability of the disposal container to provide complete containment. Such processes are corrosion of metallic items, including inside-out corrosion of the disposal container, and radiolysis of water generating gases and resulting in container pressurisation. For the AGR SF precursor product, radiolysis would be expected to be the main source of gas generation although the steel slotted can and fuel cladding will also corrode. In 2013/2014 work was undertaken to investigate the impact of water carry over and the extent of pressurisation in the variant 1 and 2 AGR spent fuel disposal container designs [AMEC, 17697/TR/06 & 17697/TR/04]. The results of the studies indicate that reasonable amounts of water (up to ~1.4 kg per disposal container) carried over from pond storage are unlikely to result in levels of internal pressurisation that are of concern (AMEC, 17697/TR/06, Section 7.3, Pg 80). The Variant 2 design was found to accommodate higher levels of gas build-up due to its higher ullage volume. The ullage space in a disposal container should be designed to accommodate the expected gas build up within. Water carry-over does lead to an inherent pressurisation hazard, which in accordance with the risk reduction hierarchy, if it cannot be eliminated, should be minimised as far as is reasonably practicable. Any pressurisation of the final disposal container would need to be managed in line with Pressure Systems Safety Regulations (PSSR) 2000. Results of the study indicated that internal corrosion associated with this carried-over water is unlikely to threaten the mechanical integrity of the disposal container before or after emplacement in a GDF. These results appear to be robust to reasonable variations in the assumptions that determine the temperature within the waste package. Notwithstanding this, in the case of AGR fuel, criticality safety is currently the bounding consideration for the water carried over. The current solution proposed by NWS for ensuring subcriticality during the transport of spent fuel is the incorporation of multiple water barriers into the design of the Disposal Container Transport Container (DCTC) to provide assurance of no water entering the disposal container (Galson Sciences, Section 3, Pg 13). Therefore, limiting the water carried over with spent fuel is an important safety argument in the criticality safety assessment in controlling the water present within the system.

Identification No. / Name:	HHPP 1.1: AGR - Drying
Traceability to DSS:	DSS Part B, Section 3.1.4.1 **Waste package safety functions that apply to transport and GDF operations** ***The waste packages are required to be able to provide the following… operational safety functions:*** • ***preclude criticality;*** DSS Part B, Section 3.1.4.2 ***The waste packages are required to be able to provide the following… post-closure safety functions:*** • ***contribute to ensuring that, following GDF closure, a criticality event is not a significant concern;***
Key References:	• AMEC, *Impact of Water Carry Over on the Extent of Structural Damage and Pressurisation on a Variant 1 AGR Spent Fuel Disposal Container*, AMEC Report 17697/TR/06 Issue 1, November 2014 (NWS document reference LL31817493). • AMEC, *Impact of Water Carry Over on the Extent of Structural Damage and Pressurisation on a Variant 2 AGR Spent Fuel Disposal Container*, AMEC Report 17697/TR/04 Issue 1, September 2013 (NWS document reference LL20166566). • Galson Sciences, *Demonstrating the Criticality Safety of Spent Fuel Disposal*, Galson Sciences Report 1649-5 Version 3.1, January 2018 (NWS document reference LL29164037). • RWM, *Geological Disposal: Disposal System Specification Part B – Technical Requirements*, DSSC/402/01, December 2016.

Table 2: AGR SF precursor product heat output requirements

Identification No. / Name:	HHPP 1.2: AGR – Heat Output
Statement of Requirement:	The combination of AGR SF precursor products placed in a disposal container shall not result in the disposal container exceeding the temperature constraints for transport to, and for disposal at, a GDF.
Measure of Performance:	The measure of performance will be based on the NWS assessment of the disposal package in the context of the illustrative concepts for the disposal of HHGW. Such assessment would provide illustrative cooling times required should this be necessary beyond an initial assumption for a date of transport and emplacement at a GDF of 2075 onwards.

Identification No. / Name:	HHPP 1.2: AGR – Heat Output
Rationale	Compliance with regulatory limits on the surface temperature of transport packages. Maintaining the integrity of the GDF engineered barrier system by preventing thermal damage to the waste packages / engineered barriers / host rock.
Justification:	It is assumed that 16 AGR precursor products will be placed into a disposal container (Arup, Section 2, Pg 11). Based on the illustrative concept for HHGW disposal in Higher Strength Rock (HSR), the temperature on the disposal container surface shall not exceed 100°C as this may lead to damage to the bentonite EBS. Disposal is assumed to start in 2075. Equivalent maximum temperatures for Lower Strength Sedimentary Rock (LSSR) and Evaporite Rock (EVR) concepts are 125°C (at the mid-point of the buffer material) and 200°C (in the backfill material) respectively. The International Atomic Energy Agency (IAEA) Transport Regulations (SSR-6 2012), as implemented in UK law, include the following: Para 655. Except as required in para. 619 for a package transported by air, the maximum temperature of any surface readily accessible during transport of a package under exclusive use shall not exceed 85°C in the absence of insolation under the ambient condition specified in para. 656. Account may be taken of barriers or screens intended to give protection to persons without the need for the barriers or screens being subject to any test. It is currently assumed that thermal performance during transport will not be constraining. A DCTC design report evaluated a higher heat load of 2,000 W would result in maximum external temperatures on the trunnions at approximately 83°C and 87°C indicates that thermal guards may be required to comply with limits (INS). The maximum seal temperature is 96°C, well below the seal material capability of 150°C.
Traceability to DSS:	DSS Part B, Section 3.1.5.3 **Heat output** ***The heat generated by the waste package shall be controlled to ensure that:*** • ***thermal effects result in no significant deterioration in the performance of the waste package, or of the disposal system as a whole.*** • ***regulatory limits on the surface temperature of transport packages are not exceeded.*** DSS Part B, Section 4.2.2.1 ***Transport of radioactive material shall use transport package designs that comply with the packaging requirements and test***

Identification No. / Name:	HHPP 1.2: AGR – Heat Output
	procedures specified in the International Atomic Energy Agency's regulations for the Safe Transport of Radioactive Material. DSS Part B, Section 9.9.6 Assumption: *For planning purposes, the following temperature limits have been used in the design of the disposal modules, taken from the illustrative concepts:* *The design of the HLW and spent fuel disposal modules in HSR is based on a temperature limit of 100°C on the surface of the bentonite at any time following emplacement.* *The design of the HLW and spent fuel disposal modules in LSSR is based on a temperature limit of 125°C at the outer half of the bentonite.* *The design of the HLW and spent fuel disposal modules in EVR is based on a temperature limit of 200°C on the backfill at any time following emplacement.*
Key References:	• Arup, *Disposal Container for HLW and Spent Fuel – Conceptual Design Report*, Arup Report 218762-01-03 Issue 5, June 2012 (NWS document reference LL21887947). • IAEA, *Regulations for the Safe Transport of Radioactive Material: 2012 Edition*, Safety Standards Series No. SSR-6, October 2012. • INS, *Summary Report: Concept Design of the Disposal Container Transport Container (DCTC)*, INS ENG R 15 146 Rev 3, April 2016 (NWS document reference LL24716838). • RWM, *Geological Disposal: Disposal System Specification Part B – Technical Requirements*, DSSC/402/01, December 2016.

Table 3: AGR SF precursor product external dimensions requirements

Identification No. / Name:	HHPP 1.3: AGR – External Dimensions
Statement of Requirement:	The AGR SF precursor product shall have external dimensions compatible with the disposal container when in the assumed disposal configuration of a 4-high stack.
Measure of Performance:	Individual precursor product dimensions: Should not exceed a length of 1,141 mm Shall not exceed a diameter of 249 mm (Graham Engineering, Drg Ref. P161/1660)

Identification No. / Name:	HHPP 1.3: AGR – External Dimensions
Rationale	Maintaining consistency with disposal container concept designs allows for assessment against illustrative disposal concepts and generic disposal system safety case.
Justification:	To be compatible with the assumed disposal container dimensions, the dimensions of the AGR slotted can need to be consistent at the time of packaging into a disposal container. This has the benefit of standardisation across all the disposal containers for AGR SF precursor products.
Traceability to DSS:	DSS Part B, Section 3.1.6 ***Design of the disposal system shall assume the need to handle waste packages manufactured using the following containers, some of which include specific variants:*** • ***Disposal Containers for High Level Waste (HLW) and Spent Fuel (SF)***
Key References:	• Arup, *Disposal Container for HLW and Spent Fuel – Conceptual Design Report*, Arup Report 218762-01-03 Issue 5, June 2012 (NWS document reference LL21887947). • Graham Engineering Ltd, *Slotted Can General Arrangement*, Drg.No. P161/1660 Issue P1, November 2009. • RWM, *Geological Disposal: Disposal System Specification Part B – Technical Requirements*, DSSC/402/01, December 2016.

Table 4: AGR SF precursor product stacking requirements

Identification No. / Name:	HHPP 1.4: AGR – Stacking
Statement of Requirement:	The AGR SF precursor product shall enable stacking when placed within the disposal container.
Measure of Performance:	Maximum height of stacked precursor products: 4,543 mm (Arup, Section 2, Pg 11) Minimum load bearing capacity of the precursor product: 528 kg
Rationale	Maintaining consistency with disposal container concept designs allows for assessment against illustrative disposal concepts and generic disposal system safety case.
Justification:	It is assumed that the AGR precursor product shall be stacked 4 high within the disposal container. To be compatible with the assumed disposal container dimensions, the dimensions of the AGR slotted can need to be consistent at the time of

Identification No. / Name:	HHPP 1.4: AGR – Stacking
	packaging into a disposal container. This has the benefit of standardisation across all the disposal containers for AGR SF precursor products. It is assumed that the minimum load bearing capacity of the AGR SF precursor product is 3 × maximum mass of a laden slotted can.
Traceability to DSS:	DSS Part B, Section 3.1.6 ***Design of the disposal system shall assume the need to handle waste packages manufactured using the following containers, some of which include specific variants:*** • ***Disposal Containers for High Level Waste (HLW) and Spent Fuel (SF)***
Key References:	• Arup, *Disposal Container for HLW and Spent Fuel – Conceptual Design Report*, Arup Report 218762-01-03 Issue 5, June 2012 (NWS document reference LL21887947). • RWM, *Geological Disposal: Disposal System Specification Part B – Technical Requirements*, DSSC/402/01, December 2016.

Table 5: AGR SF precursor product mass requirements

Identification No. / Name:	HHPP 1.5: AGR – Mass
Statement of Requirement:	The AGR precursor product should have a mass no greater than that of a standard loaded slotted can.
Measure of Performance:	Maximum gross mass of loaded AGR slotted can: 176 kg (Arup, Section 2, Pg 11).
Rationale	Mass to be compatible with the assumed disposal container and transport configuration. Maximum expected mass for 16 precursor products in a Variant 1 waste container: 27.73 t (Arup, Section 3, Pg 59).
Justification:	The maximum gross mass of waste packages must be such that it will permit them to be safely and efficiently handled using the systems defined for transport to, and emplacement in, a GDF. Maximum expected mass for 16 slotted cans: 2.82 t Expected maximum mass of loaded DCTC (based on current assumed designs laden with 16 slotted cans): 59.16 t (27.73 + 31.43 t, INS, Section 5, Pg 18). Maximum mass limit of DCTC inclusive of 5 t transport frame: 65 t (INS, Section 4, Pg 13).

Identification No. / Name:	HHPP 1.5: AGR – Mass
	Maximum mass limit of rail wagon: 91 t It is assumed that the handling equipment at a GDF will be capable of handling waste packages with a gross mass that is compatible with transport systems.
Traceability to DSS:	DSS Part B, Section 3.1.6 ***Design of the disposal system shall assume the need to handle waste packages manufactured using the following containers, some of which include specific variants:*** • ***Disposal Containers for High Level Waste (HLW) and Spent Fuel (SF)*** DSS Part B, Section 3.1.5.1 **Handling feature:** ***The waste package shall enable safe handling by way of the transport and GDF handling systems.*** DSS Part B, Section 3.1.5.3 **Gross Mass:** ***The gross mass of the waste package shall be compatible with the transport and GDF handling systems and with the requirement for the waste package to be safely stacked.***
Key References:	• Arup, *Disposal Container for HLW and Spent Fuel – Conceptual Design Report*, Arup Report 218762-01-03 Issue 5, June 2012 (NWS document reference LL21887947). • Graham Engineering Ltd, *Slotted Can General Arrangement*, Drg.No. P161/1660 Issue P1, November 2009. • INS, *Summary Report: Concept Design of the Disposal Container Transport Container (DCTC)*, INS ENG R 15 146 Rev 3, April 2016 (NWS document reference LL24716838). • RWM, *Geological Disposal: Disposal System Specification Part B – Technical Requirements*, DSSC/402/01, December 2016.

Table 6: AGR SF precursor product internal furniture of slotted can and physical state requirements

Identification No. / Name:	HHPP 1.6: AGR – Internal Furniture of Slotted Can and Physical State
Statement of Requirement:	The contents of the AGR SF precursor product shall maintain a fixed geometry during transport to a GDF and the operational phase.

Identification No. / Name:	HHPP 1.6: AGR – Internal Furniture of Slotted Can and Physical State
Measure of Performance:	<20% change in the external dose rate from the transport package when subject to tests for Normal Conditions of Transport (NCT). Maintaining a criticality safe geometry during transport and GDF operations.
Rationale	Maintaining compliance with the IAEA, Regulations For the Safe Transport of Radioactive Materials, 2018, SSR-6.
Justification:	The precursor product shall be maintained in the as-made physical state. Transport It is currently assumed that the DCTC is a Type B(U) transport package (see DSSC/411/01 Generic Transport System Design). The International Atomic Energy Agency (IAEA) Transport Regulations (SSR-6 2012), as implemented in UK law, include the following: Requirements for Type B(U) Packages: 648. A package shall be so designed that if it were subjected to the tests specified in paras 719–724, it would prevent: (b) More than a 20% increase in the maximum radiation level at any external surface of the package. 652. Type B(U) packages shall be designed to meet the requirements specified in paras 607–618, the requirements specified in paras 619–621 if carried by air, and in **paras 636–649**, except as specified in para. 648(a), and, in addition, the requirements specified in paras 653–666. This is also the case in SSR-6 Rev 1 (2018), noting that this has not yet been implemented in the DSS. Criticality safety In addition to the change in dose rate, calculations made for criticality safety during transport and operations are based on fixed known geometry of the precursor product in the disposal container.
Traceability to DSS:	DSS Part B, Section 3.1.4.1 ***The waste packages are required to be able to provide the following… operational safety functions:*** • ***preclude criticality*** DSS Part B, Section 4.2.2.1 ***Transport of radioactive material shall use transport package designs that comply with the packaging requirements and test procedures specified in the International Atomic Energy Agency's regulations for the Safe Transport of Radioactive Material.***

Identification No. / Name:	HHPP 1.6: AGR – Internal Furniture of Slotted Can and Physical State
Key References:	• RWM, *Geological Disposal: Generic Transport System Designs*, DSSC/411/01, December 2016. • IAEA, *Regulations for the Safe Transport of Radioactive Material: 2012 Edition*, Safety Standards Series No. SSR-6, October 2012. • RWM, *Geological Disposal: Disposal System Specification Part B – Technical Requirements*, DSSC/402/01, December 2016.

Table 7: AGR SF precursor product materials requirements

Identification No. / Name:	HHPP 1.7: AGR – Materials
Statement of Requirement:	The AGR SF precursor product materials shall be compatible with the transport and disposal systems.
Measure of Performance:	• Demonstration that materials are compatible and will not accelerate degradation of the disposal or transport container. • Exclusion of further materials listed as hazardous substances or non-hazardous pollutants being introduced to the precursor product in addition to the precursor product types as defined in Section 2. • Exclusion of further materials that increase the mobility of radionuclides being introduced to the precursor product in addition to the precursor product types as defined in Section 2.
Rationale	Maintaining disposal container integrity by preventing reactions between the precursor product and the container, the container and the DCTC, or the precursor product and the DCTC. Compliance with Environmental Permitting (England and Wales) Regulations (EPR) 2016. Prevent mobility of radionuclides post closure of the GDF.
Justification:	It is currently assumed that the DCTC is a Type B(U) transport package (see DSSC/411/01 Generic Transport System Design). The International Atomic Energy Agency (IAEA) Transport Regulations (SSR-6 2012), as implemented in UK law, include the following: 614. The materials of the packaging and any components or structures shall be physically and chemically compatible with each other and with the radioactive contents. Account shall be taken of their behaviour under irradiation.

Identification No. / Name:	HHPP 1.7: AGR – Materials
	Waste package required to contribute to relevant safety functions that apply to the post-closure period, including containment of hazardous materials and contribution to the overall performance of the engineered barrier system. (DSS Part B, Section 3.1.4.2). There is a requirement to prevent input of hazardous substances and limit input of non-hazardous pollutants into groundwater. (EPR 2016). It is assumed that the degradation of a metallic slotted can through corrosion is unlikely to compromise a GDF safety case.
Traceability to DSS:	DSS Part B, Section 3.1.4.2 Waste package safety functions that apply to the post-closure period: ***The waste packages are required to be able to provide the following four post-closure safety functions:*** • ***provide containment of radionuclides and other hazardous materials;*** • ***contribute to the overall performance of the EBS;*** • ***contribute to ensuring that, following GDF closure, a criticality event is not a significant concern;*** • ***withstand internal and external loads.*** DSS Part B, Section 3.4 ***It shall be demonstrated that the location and design of a geological disposal facility ensures environmental safety during the period of authorisation and subsequently.*** ***In accordance with the groundwater protection provisions of the Environmental Permitting (England and Wales) Regulations (EPR) 2010, it shall be demonstrated that all necessary technical precautions will be taken to:*** • ***prevent the input of hazardous substances to groundwater;*** • ***limit the input of non-hazardous pollutants to groundwater so as to ensure that such inputs do not cause pollution of groundwater.***
Key References:	• RWM, *Geological Disposal: Generic Transport System Designs*, DSSC/411/01, December 2016. • RWM, *Geological Disposal: Disposal System Specification Part B – Technical Requirements*, DSSC/402/01, December 2016. • IAEA, *Regulations for the Safe Transport of Radioactive Material: 2012 Edition*, Safety Standards Series No. SSR-6, October 2012. • *Environmental Permitting (England and Wales) Regulations 2016*, Statutory Instrument 2016 No. 1154, December 2016.

Table 8: AGR SF precursor product enrichment requirements

Identification No. / Name:	HHPP 1.8: AGR – Enrichment
Statement of Requirement:	The initial fissile pre-irradiation enrichment of the fuel contained within the AGR SF precursor product shall be ≤ 3.78 wt% U-235.
Measure of Performance:	Evidence that manufactured composition is within the fuel specifications (contained in records pack).
Rationale	Maintaining sub-critical conditions during transport and GDF operational periods, and ensuring the likelihood and consequence of post closure criticality are low.
Justification:	Criticality safety To undertake generic criticality safety assessments, a bounding uranium pre-irradiation enrichment level has been assumed. Exceeding this pre-irradiation enrichment would lead to the generic assessment not being applicable (RWM, DSSC/458/01, Section 5). A criticality event poses a potential threat to containment due to damaging barriers and alteration of the inventory.
Traceability to DSS:	DSS, Part B, Section 3.1.4.1 **Waste package safety functions that apply to transport and GDF operations** ***The waste packages are required to be able to provide the following… operational safety functions:*** • ***preclude criticality;*** DSS, Part B, Section 3.1.4.2 ***The waste packages are required to be able to provide the following… post-closure safety functions:*** • ***contribute to ensuring that, following GDF closure, a criticality event is not a significant concern;*** DSS, Part B, Section 3.1.5.3 Criticality safety ***The presence of fissile material, neutron moderators and reflectors in the waste package shall be controlled to ensure that:*** • ***criticality during transport is prevented;*** • ***the risk of criticality during the GDF operational period is tolerable and as low as reasonably practicable;*** • ***in the GDF post-closure period both the likelihood and the consequences of criticality are low.***

Identification No. / Name:	HHPP 1.8: AGR – Enrichment
	DSS, Part B, Section 4.2.2.4 ***Design of the transport system shall ensure that criticality during transport is prevented.*** DSS, Part B, Section 9.9.7 ***Design of a geological disposal facility shall ensure that in the post-closure period both the likelihood and the consequences of criticality are low.***
Key References:	• RWM, *Geological Disposal: Disposal System Specification Part B – Technical Requirements*, DSSC/402/01, December 2016. • RWM, *Geological Disposal: Criticality Safety Status Report*, DSSC/458/01, December 2016.

Table 9: AGR SF precursor product identification markers requirements

Identification No. / Name:	HHPP 1.9: AGR – Identification Markers
Statement of Requirement:	The AGR SF precursor product shall have a unique identifier placed on it (i.e. on each slotted can) that is linked to its enabling data set.
Measure of Performance:	Each precursor product identifier shall be readable on each slotted can at the time of packaging the slotted cans into the disposal container.
Rationale	Allows assessment of each waste package based on contents being known and identifiable and linked to the waste package record.
Justification:	It is assumed that each precursor product identifier will be read prior to packaging and a record kept of which precursor products are packaged into each disposal container. Assessments made on the waste package will rely on knowing which precursor products have been placed within each disposal container. Therefore, identifiers on the product ties the contents to the records giving the required details.
Traceability to DSS:	DSS, Part B, Section 3.1.5.4 ***Adequate controls shall be established and applied to ensure that manufactured waste packages have the properties and performance required of them.*** ***Adequate controls shall be applied during any period of interim storage to ensure that waste packages retain their required properties and performance for the duration of such a period.***

Identification No. / Name:	HHPP 1.9: AGR – Identification Markers
Key References:	• RWM, *Geological Disposal: Disposal System Specification Part B – Technical Requirements*, DSSC/402/01, December 2016.

Table 10: AGR SF assurance, records and management system requirements

Identification No. / Name:	HHPP 1.10: AGR – Assurance, Records and Management System (ARM)
Statement of Requirement:	The AGR SF precursor product shall have records that have been assured and produced within management system arrangements as outlined in Section 4.
Measure of Performance:	Records to include, but not be limited to: • Irradiation and in-reactor history of the fuel assemblies contributing to the precursor product; • Unique identifier of the fuel assemblies contributing to the precursor product; • The initial fissile pre-irradiation enrichment level of the fuel; • The isotopic composition of the uranium used in the fuel; • The as-manufactured details of the fuel assemblies and confirmation of compliance; • A detailed radionuclide inventory (including fission and activation products) at a specified reference date (or the means to calculate one). See Section 4 for further detail.
Rationale	Allows assessment of each waste package based on contents being known and identifiable, allowing confirmation of disposability.
Justification:	The purpose of the ARM requirements for the precursor product is to contribute to ensuring that manufactured waste packages can be demonstrated to be disposable to the future disposal system operator, stakeholders and regulators.
Traceability to DSS:	DSS, Part B, Section 3.1.5.4 • ***Adequate controls shall be established and applied to ensure that manufactured waste packages have the properties and performance required of them.*** • ***Adequate controls shall be applied during any period of interim storage to ensure that waste packages retain their required properties and performance for the duration of such a period.*** DSS, Part B, Section 5.3

Identification No. / Name:	HHPP 1.10: AGR – Assurance, Records and Management System (ARM)
	The geological disposal facility design shall include facilities for: • ***monitoring and record checks at package receipt*** • ***management and storage of waste package records*** ***Arrangements shall be made for the preservation of details of a geological disposal facility and records of the type and location of wastes.***
Key References:	• RWM, *Geological Disposal: Disposal System Specification Part B – Technical Requirements*, DSSC/402/01, December 2016.

Table 11: AGR SF precursor product criticality safety requirements

Identification No. / Name:	HHPP 1.11: AGR – Criticality safety
Statement of Requirement:	The AGR SF precursor product shall contribute to the waste package demonstrating criticality safety during the transport, operational, and post-closure phases.
Measure of Performance:	Consistency with the Criticality Safety Assessment (Criticality Safety Status Report, 2016).
Rationale	A criticality event poses a potential threat to containment.
Justification:	DSS Part B, Section 3.1.5.3 **Requirements for waste packages** Criticality Safety The presence of fissile material, neutron moderators and reflectors in the waste package shall be controlled to ensure that: • criticality during transport is prevented; • the risk of criticality during a GDF operational period is tolerable and as low as reasonably practicable; • in a GDF post-closure period both the likelihood and the consequences of criticality are low.
Traceability to DSS:	DSS Part B, Section 3.1.4.1 **Waste package safety functions that apply to transport and GDF Operations.** ***The waste packages are required to be able to provide the following… operational safety functions:*** • ***preclude criticality;*** DSS Part B, Section 3.1.4.2

Identification No. / Name:	HHPP 1.11: AGR – Criticality safety
	The waste packages are required to be able to provide the following… post-closure safety functions: • ***contribute to ensuring that, following GDF closure, a criticality event is not a significant concern;***
Key References:	• RWM, *Geological Disposal: Disposal System Specification Part B – Technical Requirements*, DSSC/402/01, December 2016. • Galson Sciences, *Demonstrating the Criticality Safety of Spent Fuel Disposal*, Galson Sciences Report 1649-5 Version 3.1, January 2018 (NWS document reference LL29164037). • RWM, *Geological Disposal: Criticality Safety Status Report*, DSSC/458/01, December 2016.

3.2 PWR Spent Fuel Precursor Product Requirements

The PWR SF HHPP requirements have been defined in the tables below.

Table 12: PWR SF precursor product drying requirements

Identification No. / Name:	HHPP 2.1: PWR – Drying
Statement of Requirement:	The water carried over shall be minimised within the PWR SF precursor product to enable packaging in the disposal container.
Measure of Performance:	Criticality Safety Limit <5 kg of water carried over per disposal container. (Galson Sciences, Section 6, Pg 63). Pressurisation Limit Currently not fully quantified as functional requirements for the disposal container are not yet defined.
Rationale	To prevent criticality and subsequent damage to engineered barriers in the GDF and alteration of the inventory during transport and GDF operation. Maintaining disposal container integrity by preventing the build-up of excessive gas pressure.
Justification:	Limiting the water carried over is necessary in order to prevent criticality, build-up of gas pressure, and inside-out corrosion of the disposal container. It is assumed that PWR fuel assemblies will be disposed of in a sealed disposal container containing 4 fuel assemblies (Arup, Section 2, Pg 11).

Identification No. / Name:	HHPP 2.1: PWR – Drying
	The water carried over into a sealed disposal container initiates processes that could threaten the ability of the disposal container to provide complete containment. Such processes are corrosion of metallic items, including inside-out corrosion of the disposal container, and radiolysis of water generating gases and resulting in container pressurisation. For the PWR SF precursor product, radiolysis would be expected to be the main source of gas generation although the steel components of the fuel assemblies will also corrode. In 2013/2014 work was undertaken to investigate the impact of water carry over and the extent of pressurisation in the variant 1 and 2 AGR spent fuel disposal container designs [AMEC, 17697/TR/06 & 17697/TR/04]. It is acknowledged that the container designs for AGR and PWR are subtly different, however, the water carried over from AGR spent fuel is considered to drive the bounding conditions for pressurisation. Therefore, work to date has focussed on the AGR container design for pressurisation. The results of the studies indicate that reasonable amounts of water carried over from pond storage are unlikely to result in levels of internal pressurisation that are of concern (AMEC, 17697/TR/06, Section 7.3, Pg 80). The Variant 2 design was found to accommodate higher levels of gas build-up due to its higher ullage volume. The ullage space in a disposal container should be designed to accommodate the expected gas build up within. Water carry-over does lead to an inherent pressurisation hazard, which in accordance with the risk reduction hierarchy, if it cannot be eliminated, should be minimised as far as is reasonably practicable. Any pressurisation of the final disposal container would need to be managed in line with Pressure Systems Safety Regulations (PSSR) 2000. Results of the study indicated that internal corrosion associated with this carried-over water is unlikely to threaten the mechanical integrity of the disposal container before or after emplacement in a GDF. These results appear to be robust to reasonable variations in the assumptions that determine the temperature within the waste package. Notwithstanding this, in the case of PWR fuel criticality is currently the bounding consideration for the water carried over. The current solution proposed by NWS for ensuring subcriticality during the transport of spent fuel is the incorporation of multiple water barriers into the design of the Disposal Container Transport Container (DCTC) to provide assurance of no water entering the disposal container (Galson Sciences, Section 3, Pg 13). Therefore, limiting the water carried over with spent fuel is an important safety argument in the criticality safety assessment in controlling the water present within the system.
Traceability to DSS:	DSS Part B, Section 3.1.4.1

Identification No. / Name:	HHPP 2.1: PWR – Drying
	Waste package safety functions that apply to transport and GDF operations ***The waste packages are required to be able to provide the following… operational safety functions:*** • ***preclude criticality;*** DSS Part B, Section 3.1.4.2 ***The waste packages are required to be able to provide the following… post-closure safety functions:*** • ***contribute to ensuring that, following GDF closure, a criticality event is not a significant concern;***
Key References:	• AMEC, *Impact of Water Carry Over on the Extent of Structural Damage and Pressurisation on a Variant 1 AGR Spent Fuel Disposal Container*, AMEC Report 17697/TR/06 Issue 1, November 2014 (NWS document reference LL31817493). • AMEC, *Impact of Water Carry Over on the Extent of Structural Damage and Pressurisation on a Variant 2 AGR Spent Fuel Disposal Container*, AMEC Report 17697/TR/04 Issue 1, September 2013 (NWS document reference LL20166566). • Galson Sciences, *Demonstrating the Criticality Safety of Spent Fuel Disposal*, Galson Sciences Report 1649-5 Version 3.1, January 2018 (NWS document reference LL29164037). • RWM, *Geological Disposal: Disposal System Specification Part B – Technical Requirements*, DSSC/402/01, December 2016.

Table 13: PWR SF precursor product heat output requirements

Identification No. / Name:	HHPP 2.2: PWR – Heat Output
Statement of Requirement:	The combination of PWR SF precursor products placed in a disposal container shall not result in the disposal container exceeding the temperature constraints for transport to, and for disposal at, a GDF.
Measure of Performance:	The measure of performance will be based on the NWS assessment of the disposal package in the context of the illustrative concepts for the disposal of HHGW. Such assessment would provide illustrative cooling times required should this be necessary beyond an initial assumption for date of transport and emplacement at a GDF of 2075.

Identification No. / Name:	HHPP 2.2: PWR – Heat Output
Rationale	Compliance with regulatory limits on the surface temperature of transport packages. Maintaining the integrity of the GDF engineered barrier system by preventing thermal damage to the waste packages / engineered barriers / host rock.
Justification:	It is assumed that 4 PWR precursor products will be placed into a disposal container (Arup, Section 2, Pg 11). Based on the illustrative concept for HHGW disposal in HSR, the temperature on the disposal container surface shall not exceed 100°C as this may lead to damage to the bentonite Engineered Barrier System. Disposal is assumed to start in 2075 and within the disposal container shown in Requirement 2.1 above. Equivalent maximum temperatures for LSSR and EVR concepts are 125°C (at the mid-point of the buffer material) and 200°C (in the backfill material) respectively. The International Atomic Energy Agency (IAEA) Transport Regulations (SSR-6 2012), as implemented in UK law, include the following: Para 655. Except as required in para. 619 for a package transported by air, the maximum temperature of any surface readily accessible during transport of a package under exclusive use shall not exceed 85°C in the absence of insolation under the ambient condition specified in para. 656. Account may be taken of barriers or screens intended to give protection to persons without the need for the barriers or screens being subject to any test. It is currently assumed that thermal performance during transport will not be constraining. A DCTC design report evaluated a higher heat load of 2,000 W would result in maximum external temperatures on the trunnions at approximately 83°C and 87°C, indicating that thermal guards may be required to comply with limits (INS). The maximum seal temperature is 96°C, well below the seal material capability of 150°C.
Traceability to DSS:	DSS Part B, Section 3.1.5.3 **Heat output** ***The heat generated by the waste package shall be controlled to ensure that:*** • ***thermal effects result in no significant deterioration in the performance of the waste package, or of the disposal system as a whole.*** • ***regulatory limits on the surface temperature of transport packages are not exceeded.*** DSS Part B, Section 4.2.2.1 ***Transport of radioactive material shall use transport package designs that comply with the packaging requirements and test***

Identification No. / Name:	HHPP 2.2: PWR – Heat Output
	procedures specified in the International Atomic Energy Agency's regulations for the Safe Transport of Radioactive Material. DSS Part B, Section 9.9.6 Assumption: *For planning purposes, the following temperature limits have been used in the design of the disposal modules, taken from the illustrative concepts.* *The design of the HLW and spent fuel disposal modules in HSR is based on a temperature limit of 100°C on the surface of the bentonite at any time following emplacement.* *The design of the HLW and spent fuel disposal modules in LSSR is based on a temperature limit of 125°C at the outer half of the bentonite.* *The design of the HLW and spent fuel disposal modules in EVR is based on a temperature limit of 200°C on the backfill at any time following emplacement.*
Key References:	• Arup, *Disposal Container for HLW and Spent Fuel – Conceptual Design Report*, Arup Report 218762-01-03 Issue 5, June 2012 (NWS document reference LL21887947). • IAEA, *Regulations for the Safe Transport of Radioactive Material: 2012 Edition*, Safety Standards Series No. SSR-6, October 2012. • INS, *Summary Report: Concept Design of the Disposal Container Transport Container (DCTC)*, INS ENG R 15 146 Rev 3, April 2016 (NWS document reference LL24716838). • RWM, *Geological Disposal: Disposal System Specification Part B – Technical Requirements*, DSSC/402/01, December 2016.

Table 14: PWR SF precursor product external dimension requirements

Identification No. / Name:	HHPP 2.3: PWR – External Dimensions
Statement of Requirement:	The PWR SF precursor product shall have external dimensions compatible with the assumed disposal configuration.
Measure of Performance:	Individual precursor product dimensions: Should not exceed a length of 4,063 mm

Identification No. / Name:	HHPP 2.3: PWR – External Dimensions
	Shall not exceed a square section of 214 x 214 mm (Arup, Section 2, Pg 11)
Rationale	Maintaining consistency with disposal container concept designs allows for assessment against illustrative disposal concepts and generic disposal system safety case.
Justification:	To be compatible with the assumed disposal container dimensions, the dimensions of the PWR fuel assemblies need to be consistent at the time of packaging into a disposal container. This has the benefit of standardisation across all the disposal containers for PWR SF precursor products.
Traceability to DSS:	DSS Part B, Section 3.1.6 ***Design of the disposal system shall assume the need to handle waste packages manufactured using the following containers, some of which include specific variants:*** • ***Disposal Containers for High Level Waste (HLW) and Spent Fuel (SF)***
Key References:	• Arup, *Disposal Container for HLW and Spent Fuel – Conceptual Design Report*, Arup Report 218762-01-03 Issue 5, June 2012 (NWS document reference LL21887947). • RWM, *Geological Disposal: Disposal System Specification Part B – Technical Requirements*, DSSC/402/01, December 2016.

Table 15: PWR SF precursor product mass requirements

Identification No. / Name:	HHPP 2.4: PWR – Mass
Statement of Requirement:	The PWR SF precursor product shall have a mass no greater than that of a PWR fuel assembly.
Measure of Performance:	Maximum gross mass of PWR fuel assembly - 677 kg (Arup, Section 2, Pg 11).
Rationale	Mass to be compatible with the assumed disposal container and transport configuration. Maximum expected mass for 4 precursor products in a Variant 1 waste container - 24.53t (Arup, Section 3, Pg 59).
Justification:	The maximum gross mass of waste packages must be such that it will permit them to be safely and efficiently handled using the systems defined for transport to, and emplacement in, a GDF.

Identification No. / Name:	HHPP 2.4: PWR – Mass
	Expected maximum mass of loaded DCTC (based on current assumed designs laden with 4 fuel assemblies): 55.96 t (24.53 + 31.43 t, INS, Section 5, Pg 18). Maximum mass limit of DCTC inclusive of 5 t transport frame: 65 t (INS, Section 4, Pg 13). Maximum mass limit of rail wagon: 91 t It is assumed that the handling equipment at a GDF will be capable of handling waste packages with a gross mass that is compatible with transport systems.
Traceability to DSS:	DSS Part B, Section 3.1.6 ***Design of the disposal system shall assume the need to handle waste packages manufactured using the following containers, some of which include specific variants:*** • ***Disposal Containers for High Level Waste (HLW) and Spent Fuel (SF)*** DSS Part B, Section 3.1.5.1 **Handling feature:** ***The waste package shall enable safe handling by way of the transport and GDF handling systems.*** DSS Part B, Section 3.1.5.3 **Gross Mass**: ***The gross mass of the waste package shall be compatible with the transport and GDF handling systems and with the requirement for the waste package to be safely stacked.***
Key References:	• Arup, *Disposal Container for HLW and Spent Fuel – Conceptual Design Report*, Arup Report 218762-01-03 Issue 5, June 2012 (NWS document reference LL21887947). • INS, *Summary Report: Concept Design of the Disposal Container Transport Container (DCTC)*, INS ENG R 15 146 Rev 3, April 2016 (NWS document reference LL24716838). • RWM, *Geological Disposal: Disposal System Specification Part B – Technical Requirements*, DSSC/402/01, December 2016.

Table 16: PWR SF precursor product internal furniture and physical state requirements

Identification No. / Name:	HHPP 2.5: PWR - Internal Furniture and Physical State
Statement of Requirement:	The PWR SF precursor product shall maintain a fixed geometry during transport to a GDF and the operational phase.
Measure of Performance:	<20% change in the external dose rate from the transport package when subject to tests for Normal Conditions of Transport (NCT). Maintaining a criticality safe geometry during transport and GDF operations.
Rationale	Maintaining compliance with the IAEA, Regulations For the Safe Transport of Radioactive Materials, 2018, SSR-6.
Justification:	The precursor product shall be maintained in the as-made physical state. Transport It is currently assumed that the DCTC is a Type B(U) transport package (see DSSC/411/01 Generic Transport System Design). The IAEA Transport Regulations (SSR-6 2012), as implemented in UK law, include the following: Requirements for Type B(U) Packages: 648. A package shall be so designed that if it were subjected to the tests specified in paras 719–724, it would prevent: (b) More than a 20% increase in the maximum radiation level at any external surface of the package. 652. Type B(U) packages shall be designed to meet the requirements specified in paras 607–618, the requirements specified in paras 619–621 if carried by air, and in **paras 636–649**, except as specified in para. 648(a), and, in addition, the requirements specified in paras 653–666. This is also the case in SSR-6 Rev 1 (2018), noting that this has not yet been implemented in the DSS. Criticality safety In addition to the change in dose rate, calculations made for criticality safety during transport and operations are based on fixed known geometry of the precursor product in the disposal container.
Traceability to DSS:	DSS Part B, Section 3.1.4.1 ***The waste packages are required to be able to provide the following… operational safety functions:*** • ***preclude criticality*** DSS Part B, Section 4.2.2.1 ***Transport of radioactive material shall use transport package designs that comply with the packaging requirements and test***

Identification No. / Name:	HHPP 2.5: PWR - Internal Furniture and Physical State
	procedures specified in the International Atomic Energy Agency's regulations for the Safe Transport of Radioactive Material.
Key References:	• RWM, *Geological Disposal: Generic Transport System Designs*, DSSC/411/01, December 2016. • IAEA, *Regulations for the Safe Transport of Radioactive Material: 2012 Edition*, Safety Standards Series No. SSR-6, October 2012. • RWM, *Geological Disposal: Disposal System Specification Part B – Technical Requirements*, DSSC/402/01, December 2016.

Table 17: PWR SF precursor product materials requirements

Identification No. / Name:	HHPP 2.6: PWR – Materials
Statement of Requirement:	The PWR SF precursor product materials shall be compatible with the transport and disposal systems.
Measure of Performance:	• Demonstration that materials are compatible and will not accelerate degradation of the disposal or transport container. • Exclusion of further materials listed as hazardous substances or non-hazardous pollutants being introduced to the precursor product in addition to the precursor product types as defined in Section 2. Exclusion of further materials that increase the mobility of radionuclides being introduced to the precursor product in addition to the precursor product types as defined in Section 2.
Rationale	Maintaining disposal container integrity by preventing reactions between the precursor product and the container, the container and the DCTC, or the precursor product and the DCTC Compliance with Environmental Permitting (England and Wales) Regulations (EPR) 2016. Prevent mobility of radionuclides post closure of the GDF.
Justification:	It is currently assumed that the DCTC is a Type B(U) transport package (see DSSC/411/01 Generic Transport System Design). The International Atomic Energy Agency (IAEA) Transport Regulations (SSR-6 2012), as implemented in UK law, include the following: 614. The materials of the packaging and any components or structures shall be physically and chemically compatible with each other and with the radioactive contents. Account shall be taken of their behaviour under irradiation.

Identification No. / Name:	HHPP 2.6: PWR – Materials
	Waste package required to contribute to relevant safety functions that apply to the post-closure period, including containment of hazardous materials and contribution to the overall performance of the engineered barrier system. (DSS Part B, Section 3.1.4.2). There is a requirement to prevent input of hazardous substances and limit input of non-hazardous pollutants into groundwater. (EPR 2016). It is assumed that the degradation of a PWR fuel assembly through corrosion is unlikely to compromise a GDF safety case.
Traceability to DSS:	DSS Part B, Section 3.1.4.2 Waste package safety functions that apply to the post-closure period: ***The waste packages are required to be able to provide the following four post-closure safety functions:*** • ***provide containment of radionuclides and other hazardous materials;*** • ***contribute to the overall performance of the EBS;*** • ***contribute to ensuring that, following GDF closure, a criticality event is not a significant concern;*** • ***withstand internal and external loads.*** DSS Part B, Section 3.4 ***It shall be demonstrated that the location and design of a geological disposal facility ensures environmental safety during the period of authorisation and subsequently.*** ***In accordance with the groundwater protection provisions of the Environmental Permitting (England and Wales) Regulations 2010, it shall be demonstrated that all necessary technical precautions will be taken to:*** • ***prevent the input of hazardous substances to groundwater;*** • ***limit the input of non-hazardous pollutants to groundwater so as to ensure that such inputs do not cause pollution of groundwater.***
Key References:	• RWM, *Geological Disposal: Generic Transport System Designs*, DSSC/411/01, December 2016. • RWM, *Geological Disposal: Disposal System Specification Part B – Technical Requirements*, DSSC/402/01, December 2016. • IAEA, *Regulations for the Safe Transport of Radioactive Material: 2012 Edition*, Safety Standards Series No. SSR-6, October 2012. • *Environmental Permitting (England and Wales) Regulations 2016*, Statutory Instrument 2016 No. 1154, December 2016.

Table 18: PWR SF precursor product enrichment requirements

Identification No. / Name:	HHPP 2.7: PWR - Enrichment
Statement of Requirement:	The initial fissile pre-irradiation enrichment of the fuel contained within the PWR SF precursor product shall be ≤ 5 wt% U-235.
Measure of Performance:	Evidence that manufactured composition is within the fuel specifications (contained in records pack).
Rationale	Maintaining sub-critical conditions during transport and GDF operational periods, and ensuring the likelihood and consequence of post closure criticality are low.
Justification:	Criticality safety To undertake generic criticality safety assessments, a bounding pre-irradiation enrichment level of 5 wt% U-235 has been assumed. Exceeding this pre-irradiation enrichment would lead to the generic assessment not being applicable (RWM, DSSC/458/01, Section 5). A criticality event poses a potential threat to containment due to damaging barriers and alteration of the inventory.
Traceability to DSS:	DSS, Part B, Section 3.1.4.1 **Waste package safety functions that apply to transport and GDF operations** ***The waste packages are required to be able to provide the following… operational safety functions:*** • ***preclude criticality;*** DSS, Part B, Section 3.1.4.2 Waste package safety functions that apply to the post-closure period: ***The waste packages are required to be able to provide the following… post-closure safety functions:*** • ***contribute to ensuring that, following GDF closure, a criticality event is not a significant concern;*** DSS, Part B, Section 3.1.5.3 Criticality safety ***The presence of fissile material, neutron moderators and reflectors in the waste package shall be controlled to ensure that:*** • ***criticality during transport is prevented;*** • ***the risk of criticality during the GDF operational period is tolerable and as low as reasonably practicable;***

Identification No. / Name:	HHPP 2.7: PWR - Enrichment
	• ***in the GDF post-closure period both the likelihood and the consequences of criticality are low.*** DSS, Part B, Section 4.2.2.4 ***Design of the transport system shall ensure that criticality during transport is prevented.*** DSS, Part B, Section 9.9.7 ***Design of a geological disposal facility shall ensure that in the post-closure period both the likelihood and the consequences of criticality are low.***
Key References:	• RWM, *Geological Disposal: Disposal System Specification Part B – Technical Requirements*, DSSC/402/01, December 2016. • RWM, *Geological Disposal: Criticality Safety Status Report*, DSSC/458/01, December 2016.

Table 19: PWR SF precursor product identification markers requirements

Identification No. / Name:	HHPP 2.8: PWR – Identification Markers
Statement of Requirement:	The PWR SF precursor product shall have a unique identifier placed on it (i.e. on each fuel assembly) that is linked to its enabling data set.
Measure of Performance:	Each precursor product identifier shall be readable on each fuel assembly at the time of packaging the PWR assembly into the disposable container.
Rationale	Allows assessment of each waste package based on contents being known and identifiable and linked to the waste package record.
Justification:	It is assumed that each precursor product identifier will be read prior to packaging and a record kept of which precursor products are packaged into each disposal container. Assessments made on the waste package will rely on knowing which precursor products have been placed within each disposal container. Therefore, identifiers on the product ties the contents to the records giving the required details.
Traceability to DSS:	DSS, Part B, Section 3.1.5.4 ***Adequate controls shall be established and applied to ensure that manufactured waste packages have the properties and performance required of them.***

Identification No. / Name:	HHPP 2.8: PWR – Identification Markers
	Adequate controls shall be applied during any period of interim storage to ensure that waste packages retain their required properties and performance for the duration of such a period.
Key References:	• RWM, *Geological Disposal: Disposal System Specification Part B – Technical Requirements*, DSSC/402/01, December 2016.

Table 20: PWR SF assurance, records and management system requirements

Identification No. / Name:	HHPP 2.9: PWR – Assurance, Records and Management System (ARM)
Statement of Requirement:	The PWR SF precursor product shall have records that have been assured and produced within management system arrangements as outlined in Section 4.
Measure of Performance:	Records to include, but not be limited to: • Irradiation and in-reactor history of the fuel assembly forming the precursor product; • Unique identifier of the fuel assembly forming the precursor product; • The initial fissile pre-irradiation enrichment level of the fuel; • The isotopic composition of the uranium used in the fuel; • The as-manufactured details of the fuel assemblies and confirmation of compliance; • A detailed radionuclide inventory (including fission and activation products) at a specified reference date (or the means to calculate one). See Section 4 for further detail.
Rationale	Allows assessment of each waste package based on contents being known and identifiable, allowing confirmation of disposability.
Justification:	The purpose of the ARM requirements for the precursor product is to contribute to ensuring that manufactured waste packages can be demonstrated to be disposable to the future disposal system operator, stakeholders and regulators.
Traceability to DSS:	DSS, Part B, Section 3.1.5.4 ***Adequate controls shall be established and applied to ensure that manufactured waste packages have the properties and performance required of them.*** ***Adequate controls shall be applied during any period of interim storage to ensure that waste packages retain their required properties and performance for the duration of such a period.***

Identification No. / Name:	HHPP 2.9: PWR – Assurance, Records and Management System (ARM)
	DSS, Part B, Section 5.3 ***The geological disposal facility design shall include facilities for:*** • ***monitoring and record checks at package receipt*** • ***management and storage of waste package records*** ***Arrangements shall be made for the preservation of details of a geological disposal facility and records of the type and location of wastes.***
Key References:	• RWM, *Geological Disposal: Disposal System Specification Part B – Technical Requirements*, DSSC/402/01, December 2016.

Table 21: PWR SF precursor product criticality safety requirements

Identification No. / Name:	HHPP 2.10: PWR – Criticality Safety
Statement of Requirement:	The PWR precursor product shall contribute to the criticality safety of the waste package during the transport, operational, and post-closure phases.
Measure of Performance:	Consistency with the Criticality Safety Assessment (Criticality Safety Status Report, 2016).
Rationale	A criticality event poses a potential threat to containment.
Justification:	**DSS Part B, Section 3.1.5.3** **Requirements for waste packages** Criticality Safety The presence of fissile material, neutron moderators and reflectors in the waste package shall be controlled to ensure that: • criticality during transport is prevented; • the risk of criticality during a GDF operational period is tolerable and as low as reasonably practicable; • in a GDF post-closure period both the likelihood and the consequences of criticality are low.
Traceability to DSS:	DSS Part B, Section 3.1.4.1 **Waste package safety functions that apply to transport and GDF Operations** ***The waste packages are required to be able to provide the following… operational safety functions:*** • ***preclude criticality;***

Identification No. / Name:	HHPP 2.10: PWR – Criticality Safety
	DSS Part B, 3.1.4.2 ***Waste package safety functions that apply to the post-closure period. The waste packages are required to be able to provide the following.post-closure safety functions:*** • ***contribute to ensuring that, following GDF closure, a criticality event is not a significant concern;***
Key References:	• RWM, *Geological Disposal: Disposal System Specification Part B – Technical Requirements*, DSSC/402/01, December 2016. • Galson Sciences, *Demonstrating the Criticality Safety of Spent Fuel Disposal*, Galson Sciences Report 1649-5 Version 3.1, January 2018 (NWS document reference LL29164037). • RWM, *Geological Disposal: Criticality Safety Status Report*, DSSC/458/01, December 2016.

3.3 Metallic Spent Fuel Precursor Product Requirements

The metallic SF HHPP requirements have been defined in the tables below.

Table 22: Metallic SF precursor product drying requirements

Identification No. / Name:	HHPP 3.1: Metallic - Drying
Statement of Requirement:	The water carried over shall be minimised within the Metallic SF precursor product to enable packaging in the disposal container.
Measure of Performance:	Pressurisation Limit The pressurisation limit is not currently fully quantified as functional requirements for the disposal container are not yet defined.
Rationale	Maintaining disposal container integrity by preventing the build-up of excessive gas pressure.
Justification:	Limiting the water carried over is necessary in order to maintain disposal container integrity by preventing the build-up of excessive gas pressure and inside out corrosion of the disposal container. It is assumed that 26 Magnox fuel elements (or equivalent mass of uranium) will be placed in the fuel canister (Sellafield, 0 BE 2702861 C), of which 3 of these will be placed in the disposal container. Gas Build-up

Identification No. / Name:	HHPP 3.1: Metallic - Drying
	The water carried over into a sealed disposal container initiates processes that could threaten the ability of the disposal container to provide complete containment. Such processes are corrosion of metallic items and radiolysis of water generating gases and resulting in container pressurisation. The Metallic SF precursor product includes reactive metals such as aluminium and Magnox clad and the uranium metal of the fuel, these will corrode on contact with water, generating hydrogen. It should be noted that uranium corrosion will only generate gas under anaerobic conditions. In 2013/2014 work was undertaken to investigate the impact of water carry over and the extent of pressurisation in the variant 1 and 2 AGR spent fuel disposal container designs [AMEC, 17697/TR/06 & 17697/TR/04]. It is acknowledged that the container designs for the Metallic SF are less mature than those for AGR and PWR, noting that these are conceptual only. Therefore, work to date has focussed on the AGR container design for pressurisation. The results of the studies indicate that reasonable amounts of water carried over from pond storage are unlikely to result in levels of internal pressurisation that are of concern (AMEC, 17697/TR/06, Pg 80). The Variant 2 design was found to accommodate higher levels of gas build-up due to its higher ullage volume. The ullage space in a disposal container should be designed to accommodate the expected gas build up within. Water carry-over does lead to an inherent pressurisation hazard, which in accordance with the risk reduction hierarchy, if it cannot be eliminated, should be minimised as far as is reasonably practicable. Any pressurisation of the final disposal container would need to be managed in line with Pressure Systems Safety Regulations (PSSR) 2000. Results of the study indicated that internal corrosion associated with this carried-over water is unlikely to threaten the mechanical integrity of the disposal container before or after emplacement in a GDF. These results appear to be robust to reasonable variations in the assumptions that determine the temperature within the waste package. It is assumed that the disposal container will be a pressure vessel subject to PSSR 2000 and will be designed accordingly. <u>Criticality Safety</u> Criticality safety is not significant if pre-irradiation enrichment <2.5 wt.% U-235. The current solution proposed by NWS for ensuring subcriticality during the transport of spent fuel is based on the incorporation of multiple water barriers into the design of the DCTC However, it has been demonstrated that fuel with a pre-irradiation enrichment of <2.5 wt.% U-235 in a fully flooded container is safely subcritical and therefore there is

Identification No. / Name:	HHPP 3.1: Metallic - Drying
	not a requirement in this regard for the water carried over (Galson Sciences, Section 3, Pg 37).
Traceability to DSS:	DSS Part B, Section 3.1.4.1 **Waste package safety functions that apply to transport and GDF operations** ***The waste packages are required to be able to provide the following… operational safety functions:*** • ***preclude criticality;*** DSS Part B, Section 3.1.4.2 ***The waste packages are required to be able to provide the following… post-closure safety functions:*** • ***contribute to ensuring that, following GDF closure, a criticality event is not a significant concern;***
Key References:	• AMEC, *Impact of Water Carry Over on the Extent of Structural Damage and Pressurisation on a Variant 1 AGR Spent Fuel Disposal Container*, AMEC Report 17697/TR/06 Issue 1, November 2014 (NWS document reference LL31817493). • AMEC, *Impact of Water Carry Over on the Extent of Structural Damage and Pressurisation on a Variant 2 AGR Spent Fuel Disposal Container*, AMEC Report 17697/TR/04 Issue 1, September 2013 (NWS document reference LL20166566). • Galson Sciences, *Demonstrating the Criticality Safety of Spent Fuel Disposal*, Galson Sciences Report 1649-5 Version 3.1, January 2018 (NWS document reference LL29164037). • Sellafield Ltd, *Magnox Fuel Drying and Storage Canister Weld Assembly Design Proposal Drawing*, 0 BE 2702861 Issue C, August 2012 (NWS document reference LL25344747). • RWM, *Geological Disposal: Disposal System Specification Part B – Technical Requirements*, DSSC/402/01, December 2016.

Table 23: Metallic SF precursor product heat output requirements

Identification No. / Name:	HHPP 3.2: Metallic - Heat Output
Statement of Requirement:	The combination of Metallic SF precursor products placed in a disposal container shall not result in the disposal container exceeding the temperature constraints for transport to, and for disposal at, a GDF.
Measure of Performance:	The measure of performance will be based on the NWS assessment of the disposal package in the context of the illustrative concepts for the disposal of HHGW. Such assessment would provide illustrative cooling times required should this be necessary beyond an initial assumption for date of transport and emplacement at a GDF of 2075.
Rationale	Compliance with regulatory limits on the surface temperature of transport packages. Maintaining the integrity of the GDF engineered barrier system by preventing thermal damage to the waste packages / engineered barriers / host rock.
Justification:	It is assumed that 3 Metallic SF precursor products will be placed into a disposal container. Based on the illustrative concept for HHGW disposal in HSR, the temperature on the disposal container surface shall not exceed 100°C as this may lead to damage to the bentonite Engineered Barrier System. Disposal is assumed to start in 2075. Equivalent maximum temperatures for LSSR and EVR concepts are 125°C (at the mid-point of the buffer material) and 200°C (in the backfill material) respectively. The International Atomic Energy Agency (IAEA) Transport Regulations (SSR-6 2012), as implemented in UK law, include the following: Para 655. Except as required in para. 619 for a package transported by air, the maximum temperature of any surface readily accessible during transport of a package under exclusive use shall not exceed 85°C in the absence of insolation under the ambient condition specified in para. 656. Account may be taken of barriers or screens intended to give protection to persons without the need for the barriers or screens being subject to any test. It is currently assumed that thermal performance during transport will not be constraining. A DCTC design report evaluated a higher heat load of 2,000 W would result in maximum external temperatures on the trunnions at approximately 83°C and 87°C, indicating that thermal guards may be required to comply with limits (INS). The maximum seal temperature is 96°C, well below the seal material capability of 150°C.
Traceability to DSS:	**Heat output** ***The heat generated by the waste package shall be controlled to ensure that:***

Identification No. / Name:	HHPP 3.2: Metallic - Heat Output
	• ***thermal effects result in no significant deterioration in the performance of the waste package, or of the disposal system as a whole.*** • ***regulatory limits on the surface temperature of transport packages are not exceeded.*** DSS Part B, Section 9.9.6 Assumption: *For planning purposes, the following temperature limits have been used in the design of the disposal modules, taken from the illustrative concepts.* *The design of the HLW and spent fuel disposal modules in HSR is based on a temperature limit of 100°C on the surface of the bentonite at any time following emplacement.* *The design of the HLW and spent fuel disposal modules in LSSR is based on a temperature limit of 125°C at the outer half of the bentonite.* *The design of the HLW and spent fuel disposal modules in EVR is based on a temperature limit of 200°C on the backfill at any time following emplacement.*
Key References:	• Arup, *Disposal Container for HLW and Spent Fuel – Conceptual Design Report*, Arup Report 218762-01-03 Issue 5, June 2012 (NWS document reference LL21887947). • IAEA, *Regulations for the Safe Transport of Radioactive Material: 2012 Edition*, Safety Standards Series No. SSR-6, October 2012. • INS, *Summary Report: Concept Design of the Disposal Container Transport Container (DCTC)*, INS ENG R 15 146 Rev 3, April 2016 (NWS document reference LL24716838). • RWM, *Geological Disposal: Disposal System Specification Part B – Technical Requirements*, DSSC/402/01, December 2016.

Table 24: Metallic SF precursor product external dimensions requirements

Identification No. / Name:	HHPP 3.3: Metallic – External Dimensions
Statement of Requirement:	The Metallic SF precursor product shall have external dimensions compatible with the disposal container when in the assumed disposal configuration of a 3-high stack.
Measure of Performance:	Individual precursor product dimensions: Should not exceed a length of 1,470 mm

Identification No. / Name:	HHPP 3.3: Metallic – External Dimensions
	Shall not exceed a diameter of 610 mm (OD) (Sellafield, 0 BE 2702861 C)
Rationale	Maintaining consistency with disposal container concept designs allows for assessment against illustrative disposal concepts and generic disposal system safety case.
Justification:	To be compatible with the assumed disposal container dimensions, the dimensions of the Metallic SF precursor products need to be consistent at the time of packaging into a disposal container. This has the benefit of standardisation across all the disposal containers for Metallic SF precursor products.
Traceability to DSS:	DSS Part B, Section 3.1.6 ***Design of the disposal system shall assume the need to handle waste packages manufactured using the following containers, some of which include specific variants:*** • ***Disposal Containers for High Level Waste (HLW) and Spent Fuel (SF)***
Key References:	• Sellafield Ltd, *Magnox Fuel Drying and Storage Canister Weld Assembly Design Proposal Drawing*, 0 BE 2702861 Issue C, August 2012 (NWS document reference LL25344747). • RWM, *Geological Disposal: Disposal System Specification Part B – Technical Requirements*, DSSC/402/01, December 2016.

Table 25: Metallic SF precursor product stacking requirements

Identification No. / Name:	HHPP 3.4: Metallic – Stacking
Statement of Requirement:	The Metallic SF precursor product shall enable stacking when placed within the disposal container.
Measure of Performance:	Maximum height of stacked precursor products: 4,260 mm (Derived from Sellafield, 0 BE 2702861 C) Minimum load bearing capacity of the precursor product: 1,230 kg
Rationale	Maintaining consistency with disposal container concept designs allows for assessment against illustrative disposal concepts and generic disposal system safety case.
Justification:	It is assumed that the Metallic SF precursor product shall be stacked 3 high within the disposal container.

Identification No. / Name:	HHPP 3.4: Metallic – Stacking
	To be compatible with the assumed disposal container dimensions, the dimensions of the Metallic Spent Fuel cannister need to be consistent at the time of packaging into a disposal container. This has the benefit of standardisation across all the disposal containers for Metallic SF precursor products. It is assumed that the minimum load bearing capacity of the Metallic SF precursor product is 2 × maximum mass of a laden fuel canister.
Traceability to DSS:	DSS Part B, Section 3.1.6 ***Design of the disposal system shall assume the need to handle waste packages manufactured using the following containers, some of which include specific variants:*** • ***Disposal Containers for High Level Waste (HLW) and Spent Fuel (SF)***
Key References:	• Sellafield Ltd, *Magnox Fuel Drying and Storage Canister Weld Assembly Design Proposal Drawing*, 0 BE 2702861 Issue C, August 2012 (NWS document reference LL25344747). • RWM, *Geological Disposal: Disposal System Specification Part B – Technical Requirements*, DSSC/402/01, December 2016.

Table 26: Metallic SF precursor product mass requirements

Identification No. / Name:	HHPP 3.5: Metallic – Mass
Statement of Requirement:	The Metallic precursor product shall have a mass no greater than that of a standard loaded fuel canister.
Measure of Performance:	Maximum gross mass of Metallic SF precursor product (loaded fuel canister): 615 kg. (Sellafield, 0 BE 2702861 C).
Rationale	Mass to be compatible with the assumed disposal container and transport configuration. Estimated maximum expected mass for 3 fuel canisters in a Variant 1 waste container: 23.17t. (DSS Part B, Table 9, Page 46).
Justification:	The maximum gross mass of waste packages must be such that it will permit them to be safely and efficiently handled using the systems defined for transport to, and emplacement in, a GDF. Estimated maximum expected mass for 3 loaded fuel canisters (containing 26 fuel elements or equivalent): 1.845t Expected maximum mass of loaded DCTC (based on current assumed designs laden with 3 fuel cannisters) - 54.60 t (23.17 + 31.43 t, INS, Section 5, Pg 18).

Identification No. / Name:	HHPP 3.5: Metallic – Mass
	Maximum mass limit of DCTC inclusive of 5 t transport frame: 65 t (INS, Section 4, Pg 13). Maximum mass limit of rail wagon: 91 t It is assumed that the handling equipment at a GDF will be capable of handling waste packages with a gross mass that is compatible with transport systems.
Traceability to DSS:	DSS Part B, Section 3.1.6 ***Design of the disposal system shall assume the need to handle waste packages manufactured using the following containers, some of which include specific variants:*** • ***Disposal Containers for High Level Waste (HLW) and Spent Fuel (SF)*** DSS Part B, Section 3.1.5.1 **Handling feature:** ***The waste package shall enable safe handling by way of the transport and GDF handling systems.*** DSS Part B, Section 3.1.5.3 **Gross Mass:** ***The gross mass of the waste package shall be compatible with the transport and GDF handling systems and with the requirement for the waste package to be safely stacked.***
Key References:	• Sellafield Ltd, *Magnox Fuel Drying and Storage Canister Weld Assembly Design Proposal Drawing*, 0 BE 2702861 Issue C, August 2012 (NWS document reference LL25344747). • INS, *Summary Report: Concept Design of the Disposal Container Transport Container (DCTC)*, INS ENG R 15 146 Rev 3, April 2016 (NWS document reference LL24716838). • RWM, *Geological Disposal: Disposal System Specification Part B – Technical Requirements*, DSSC/402/01, December 2016.

Table 27: Metallic SF precursor product internal furniture and physical state requirements

Identification No. / Name:	HHPP 3.6: Metallic - Internal Furniture and Physical State
Statement of Requirement:	The contents of the Metallic SF precursor product shall maintain a fixed geometry during transport to a GDF and the operational phase.

Identification No. / Name:	HHPP 3.6: Metallic - Internal Furniture and Physical State
Measure of Performance:	<20% change in the external dose rate from the transport package when subject to tests for Normal Conditions of Transport (NCT). Maintaining a criticality safe geometry during transport and GDF operations.
Rationale	Maintaining compliance with the IAEA, Regulations For the Safe Transport of Radioactive Materials, 2018, SSR-6.
Justification:	The precursor product shall be maintained in the as-made physical state. Transport It is currently assumed that the DCTC is a Type B(U) transport package (see DSSC/411/01 Generic Transport System Design). The International Atomic Energy Agency (IAEA) Transport Regulations (SSR-6 2012), as implemented in UK law, include the following: Requirements for Type B(U) Packages: 648. A package shall be so designed that if it were subjected to the tests specified in paras 719–724, it would prevent: (b) More than a 20% increase in the maximum radiation level at any external surface of the package. 652. Type B(U) packages shall be designed to meet the requirements specified in paras 607–618, the requirements specified in paras 619–621 if carried by air, and in **paras 636–649**, except as specified in para. 648(a), and, in addition, the requirements specified in paras 653–666. This is also the case in SSR-6 Rev 1 (2018), noting that this has not yet been implemented in the DSS. Criticality safety In addition to the change in dose rate, calculations made for criticality safety during transport and operations are based on fixed known geometry of the precursor product in the disposal container.
Traceability to DSS:	DSS Part B, Section 3.1.4.1 ***The waste packages are required to be able to provide the following… operational safety functions:*** • ***preclude criticality*** DSS Part B, Section 4.2.2.1 ***Transport of radioactive material shall use transport package designs that comply with the packaging requirements and test***

Identification No. / Name:	HHPP 3.6: Metallic - Internal Furniture and Physical State
	procedures specified in the International Atomic Energy Agency's regulations for the Safe Transport of Radioactive Material.
Key References:	• RWM, *Geological Disposal: Generic Transport System Designs*, DSSC/411/01, December 2016. • IAEA, *Regulations for the Safe Transport of Radioactive Material: 2012 Edition*, Safety Standards Series No. SSR-6, October 2012. • RWM, *Geological Disposal: Disposal System Specification Part B – Technical Requirements*, DSSC/402/01, December 2016.

Table 28: Metallic SF precursor product materials requirements

Identification No. / Name:	HHPP 3.7: Metallic - Materials
Statement of Requirement:	The Metallic SF precursor product materials shall be compatible with the transport and disposal systems.
Measure of Performance:	• Demonstration that materials are compatible and will not accelerate degradation of the disposal or transport container; • Exclusion of further materials listed as hazardous substances or non-hazardous pollutants being introduced to the precursor product in addition to the precursor product types as defined in Section 2. Exclusion of further materials that increase the mobility of radionuclides being introduced to the precursor product in addition to the precursor product types as defined in Section 2.
Rationale	Maintaining disposal container integrity by preventing reactions between the precursor product and the container, the container and the DCTC, or the precursor product and the DCTC. Compliance with Environmental Permitting (England and Wales) Regulations (EPR) 2016. Prevent mobility of radionuclides post closure of the GDF.
Justification:	It is currently assumed that the DCTC is a Type B(U) transport package (see DSSC/411/01 Generic Transport System Design). The International Atomic Energy Agency (IAEA) Transport Regulations (SSR-6 2012), as implemented in UK law, include the following: 614. The materials of the packaging and any components or structures shall be physically and chemically compatible with each other and with the radioactive contents. Account shall be taken of their behaviour under irradiation.

Identification No. / Name:	HHPP 3.7: Metallic - Materials
	Waste package required to contribute to relevant safety functions that apply to the post-closure period, including containment of hazardous materials and contribution to the overall performance of the engineered barrier system. (DSS Part B, Section 3.1.4.2). There is a requirement to prevent input of hazardous substances and limit input of non-hazardous pollutants into groundwater. (EPR 2016). It is assumed that the degradation of a canister through corrosion is unlikely to compromise a GDF safety case.
Traceability to DSS:	DSS Part B, Section 3.1.4.2 Waste package safety functions that apply to the post-closure period: ***The waste packages are required to be able to provide the following four post-closure safety functions:*** • ***provide containment of radionuclides and other hazardous materials;*** • ***contribute to the overall performance of the EBS;*** • ***contribute to ensuring that, following GDF closure, a criticality event is not a significant concern;*** • ***withstand internal and external loads.*** DSS Part B, Section 3.4 ***It shall be demonstrated that the location and design of a geological disposal facility ensures environmental safety during the period of authorisation and subsequently.*** ***In accordance with the groundwater protection provisions of the Environmental Permitting (England and Wales) Regulations 2010, it shall be demonstrated that all necessary technical precautions will be taken to:*** • ***prevent the input of hazardous substances to groundwater;*** • ***limit the input of non-hazardous pollutants to groundwater so as to ensure that such inputs do not cause pollution of groundwater.***
Key References:	• RWM, *Geological Disposal: Generic Transport System Designs*, DSSC/411/01, December 2016. • RWM, *Geological Disposal: Disposal System Specification Part B – Technical Requirements*, DSSC/402/01, December 2016. • IAEA, *Regulations for the Safe Transport of Radioactive Material: 2012 Edition*, Safety Standards Series No. SSR-6, October 2012. • *Environmental Permitting (England and Wales) Regulations 2016*, Statutory Instrument 2016 No. 1154, December 2016.

Table 29: Metallic SF precursor product enrichment requirements

Identification No. / Name:	HHPP 3.8: Metallic - Enrichment
Statement of Requirement:	The effective fissile enrichment of the fuel contained within the Metallic SF precursor product shall be ≤1.9 wt.% U-235 equivalent.
Measure of Performance:	Evidence that manufactured composition is within the fuel specifications (contained in records pack).
Rationale	Maintaining sub-critical conditions during transport and GDF operational periods, and ensuring the likelihood and consequence of post closure criticality are low.
Justification:	Criticality safety An effective fissile enrichment of ≤1.9 wt% U-235 equivalent has been selected as a suitable bounding value for UK metallic fuels for assessment purposes (RWM, DSSC/458/01, Section 5). It does not exactly correlate with pre-irradiation enrichments stated in the IGD but allows flexibility to allow for uncertainties that may exclude material if a more restrictive value was selected. It also remains sufficiently low that materials that would not fall into the current category of ”irradiated natural uranium” are not included (RWM, DSSC/458/01, Section 5). A criticality event poses a potential threat to containment due to damaging barriers and alteration of the inventory.
Traceability to DSS:	DSS, Part B, Section 3.1.4.1 **Waste package safety functions that apply to transport and GDF operations** ***The waste packages are required to be able to provide the following… operational safety functions:*** • ***preclude criticality;*** DSS, Part B, Section 3.1.4.2 ***The waste packages are required to be able to provide the following… post-closure safety functions:*** • ***contribute to ensuring that, following GDF closure, a criticality event is not a significant concern;*** DSS, Part B, Section 3.1.5.3 Criticality safety ***The presence of fissile material, neutron moderators and reflectors in the waste package shall be controlled to ensure that:***

Identification No. / Name:	HHPP 3.8: Metallic - Enrichment
	• ***criticality during transport is prevented;*** • ***the risk of criticality during the GDF operational period is tolerable and as low as reasonably practicable;*** • ***in the GDF post-closure period both the likelihood and the consequences of criticality are low.*** DSS, Part B, Section 4.2.2.4 ***Design of the transport system shall ensure that criticality during transport is prevented.*** DSS, Part B, Section 9.9.7 ***Design of a geological disposal facility shall ensure that in the post-closure period both the likelihood and the consequences of criticality are low.***
Key References:	• RWM, *Geological Disposal: Disposal System Specification Part B – Technical Requirements*, DSSC/402/01, December 2016. • RWM, *Geological Disposal: Criticality Safety Status Report*, DSSC/458/01, December 2016.

Table 30: Metallic SF precursor product identification markers requirements

Identification No. / Name:	HHPP 3.9: Metallic – Identification Markers
Statement of Requirement:	The Metallic SF precursor product shall have a unique identifier placed on it (i.e. on each fuel canister) that is linked to its enabling data set.
Measure of Performance:	Each precursor product identifier shall be readable on each fuel canister at the time of packaging the cans into the disposal container.
Rationale	Allows assessment of each waste package based on contents being known and identifiable and linked to the waste package record.
Justification:	It is assumed that each precursor product identifier will be read prior to packaging and a record kept of which precursor products are packaged into each disposal container. Assessments made on the waste package will rely on knowing which precursor products have been placed within each disposal container. Therefore, identifiers on the product ties the contents to the records giving the required details.
Traceability to DSS:	DSS, Part B, Section 3.1.5.4

Identification No. / Name:	HHPP 3.9: Metallic – Identification Markers
	Adequate controls shall be established and applied to ensure that manufactured waste packages have the properties and performance required of them. ***Adequate controls shall be applied during any period of interim storage to ensure that waste packages retain their required properties and performance for the duration of such a period.***
Key References:	• RWM, *Geological Disposal: Disposal System Specification Part B – Technical Requirements*, DSSC/402/01, December 2016.

Table 31: Metallic SF assurance, records and management system requirements

Identification No. / Name:	HHPP 3.10: Metallic – Assurance, Records and Management System (ARM)
Statement of Requirement:	The Metallic SF precursor product shall have records that have been assured and produced within management system arrangements as outlined in Section 4.
Measure of Performance:	Records to include, but not be limited to: • Irradiation history (or bounding assumptions) for each fuel element in the precursor product; • Unique identifier of the precursor product and a description of the type of metallic fuel contained therein; • The initial pre-irradiation enrichment level of each fuel element; • The isotopic composition of the uranium used in the fuel; • The as-manufactured details of the fuel elements and confirmation of compliance; • A detailed radionuclide inventory (including fission and activation products) at a specified reference date (or the means to calculate one). See Section 4 for further detail.
Rationale	Allows assessment of each waste package based on contents being known and identifiable, allowing confirmation of disposability.
Justification:	The purpose of the ARM requirements for the precursor product is to contribute to ensuring that manufactured waste packages can be demonstrated to be disposable to the future disposal system operator, stakeholders and regulators.
Traceability to DSS:	DSS, Part B, Section 3.1.5.4 • ***Adequate controls shall be established and applied to ensure that manufactured waste packages have the properties and performance required of them.***

Identification No. / Name:	HHPP 3.10: Metallic – Assurance, Records and Management System (ARM)
	• ***Adequate controls shall be applied during any period of interim storage to ensure that waste packages retain their required properties and performance for the duration of such a period.*** DSS, Part B, Section 5.3 ***The geological disposal facility design shall include facilities for:*** • ***monitoring and record checks at package receipt*** • ***management and storage of waste package records*** ***Arrangements shall be made for the preservation of details of a geological disposal facility and records of the type and location of wastes.***
Key References:	• RWM, *Geological Disposal: Disposal System Specification Part B – Technical Requirements*, DSSC/402/01, December 2016.

Table 32: Metallic SF precursor product criticality safety requirements

Identification No. / Name:	HHPP 3.11: Metallic – Criticality Safety
Statement of Requirement:	The Metallic SF precursor product shall contribute to the criticality safety of the waste package during the transport, operational, and post-closure phases.
Measure of Performance:	Consistency with the Criticality Safety Assessment (Criticality Safety Status Report, 2016).
Rationale	A criticality event poses a potential threat to containment.
Justification:	**DSS Part B, Section 3.1.5.3** **Requirements for waste packages** Criticality Safety The presence of fissile material, neutron moderators and reflectors in the waste package shall be controlled to ensure that: • criticality during transport is prevented; • the risk of criticality during a GDF operational period is tolerable and as low as reasonably practicable; • in a GDF post-closure period both the likelihood and the consequences of criticality are low.
Traceability to DSS:	DSS Part B, Section 3.1.4.1

Identification No. / Name:	HHPP 3.11: Metallic – Criticality Safety
	Waste package safety functions that apply to transport and GDF Operations ***The waste packages are required to be able to provide the following…operational safety functions:*** • ***preclude criticality;*** DSS Part B, 3.1.4.2 ***The waste packages are required to be able to provide the following… post-closure safety functions:*** • ***contribute to ensuring that, following GDF closure, a criticality event is not a significant concern;***
Key References:	• RWM, *Geological Disposal: Disposal System Specification Part B – Technical Requirements*, DSSC/402/01, December 2016. • Galson Sciences, *Demonstrating the Criticality Safety of Spent Fuel Disposal*, Galson Sciences Report 1649-5 Version 3.1, January 2018 (NWS document reference LL29164037). • RWM, *Geological Disposal: Criticality Safety Status Report*, DSSC/458/01, December 2016.

3.4 HLW Precursor Product Requirements

The HLW precursor product requirements have been defined in the tables below.

Table 33: HLW precursor product heat output requirements

Identification No. / Name:	HHPP 4.1: HLW – Heat Output
Statement of Requirement:	The combination of HLW precursor products placed in a disposal container shall not result in the disposal container exceeding the temperature constraints for transport to, and for disposal at, a GDF.
Measure of Performance:	The measure of performance will be based on the NWS assessment of the disposal package in the context of the illustrative concepts for the disposal of HHGW. Such assessment would provide illustrative cooling times required should this be necessary beyond an initial assumption for date of transport and emplacement at a GDF of 2075.
Rationale	Compliance with regulatory limits on the surface temperature of transport packages. Maintaining the integrity of the GDF engineered barrier system by preventing thermal damage to the waste packages / engineered barriers / host rock.

Identification No. / Name:	HHPP 4.1: HLW – Heat Output
Justification:	It is assumed that 3 HLW precursor products will be placed into a disposal container (Arup, Section 2, Pg 10). Based on the illustrative concept for HHGW disposal in HSR, the temperature on the disposal container surface shall not exceed 100°C as this may lead to damage to the bentonite EBS. Disposal is assumed to start in 2075 and within the disposal container shown in Requirement 3.1. Equivalent maximum temperatures for LSSR and EVR concepts are 125°C (at the mid-point of the buffer material) and 200°C (in the backfill material) respectively. The International Atomic Energy Agency (IAEA) Transport Regulations (SSR-6 2012), as implemented in UK law, include the following: Para 655. Except as required in para. 619 for a package transported by air, the maximum temperature of any surface readily accessible during transport of a package under exclusive use shall not exceed 85°C in the absence of insolation under the ambient condition specified in para. 656. Account may be taken of barriers or screens intended to give protection to persons without the need for the barriers or screens being subject to any test. It is currently assumed that thermal performance during transport will not be constraining. A DCTC design report evaluated a higher heat load of 2,000 W would result in maximum external temperatures on the trunnions at approximately 83°C and 87°C, indicating that thermal guards may be required to comply with limits (INS). The maximum seal temperature is 96°C, well below the seal material capability of 150°C.
Traceability to DSS:	DSS Part B, Section 3.1.5.3 **Heat output** ***The heat generated by the waste package shall be controlled to ensure that:*** • ***thermal effects result in no significant deterioration in the performance of the waste package, or of the disposal system as a whole.*** • ***regulatory limits on the surface temperature of transport packages are not exceeded.*** DSS Part B, Section 4.2.2.1 ***Transport of radioactive material shall use transport package designs that comply with the packaging requirements and test procedures specified in the International Atomic Energy Agency's regulations for the Safe Transport of Radioactive Material.*** DSS Part B, Section 9.9.6 Assumptions:

Identification No. / Name:	HHPP 4.1: HLW – Heat Output
	For planning purposes, the following temperature limits have been used in the design of the disposal modules, taken from the illustrative concepts: *The design of the HLW and spent fuel disposal modules in HSR is based on a temperature limit of 100°C on the surface of the bentonite at any time following emplacement.* *The design of the HLW and spent fuel disposal modules in LSSR is based on a temperature limit of 125°C at the outer half of the bentonite.* *The design of the HLW and spent fuel disposal modules in EVR is based on a temperature limit of 200°C on the backfill at any time following emplacement.*
Key References:	• Arup, *Disposal Container for HLW and Spent Fuel – Conceptual Design Report*, Arup Report 218762-01-03 Issue 5, June 2012 (NWS document reference LL21887947). • IAEA, *Regulations for the Safe Transport of Radioactive Material: 2012 Edition*, Safety Standards Series No. SSR-6, October 2012. • INS, *Summary Report: Concept Design of the Disposal Container Transport Container (DCTC)*, INS ENG R 15 146 Rev 3, April 2016 (NWS document reference LL24716838). • RWM, *Geological Disposal: Disposal System Specification Part B – Technical Requirements*, DSSC/402/01, December 2016.

Table 34: HLW precursor product external dimensions requirements

Identification No. / Name:	HHPP 4.2: HLW – External Dimensions
Statement of Requirement:	The HLW precursor product shall have external dimensions no greater than that of a WVP product container.
Measure of Performance:	Individual precursor product dimensions: Should not exceed a length of 1,339 mm Shall not exceed a diameter of 430 mm (Sellafield, 0 PR 411346 AB) (Arup, Section 2, Pg 11)
Rationale	Maintaining consistency with disposal container concept designs allows for assessment against illustrative disposal concepts and generic disposal system safety case.

Identification No. / Name:	HHPP 4.2: HLW – External Dimensions
Justification:	To be compatible with the assumed disposal container dimensions, the dimensions of the HLW vitrified waste product container need to be consistent. This has the benefit of standardisation across all the disposal containers for HLW precursor products.
Traceability to DSS:	DSS Part B, Section 3.1.6 ***Design of the disposal system shall assume the need to handle waste packages manufactured using the following containers, some of which include specific variants:*** • ***Disposal Containers for High Level Waste (HLW) and Spent Fuel (SF)***.
Key References:	• Sellafield Ltd, *Windscale Vitrification Plant Glass Product Container General Arrangement*, 0 PR 411346 Issue AB, October 2019 (NWS document reference LL43371117). • Arup, *Disposal Container for HLW and Spent Fuel – Conceptual Design Report*, Arup Report 218762-01-03 Issue 5, June 2012 (NWS document reference LL21887947). • RWM, *Geological Disposal: Disposal System Specification Part B – Technical Requirements*, DSSC/402/01, December 2016.

Table 35: Table 23: Metallic SF precursor product stacking requirements

Identification No. / Name:	HHPP 4.3: HLW – Stacking
Statement of Requirement:	The HLW precursor product shall enable stacking when placed within the disposal container.
Measure of Performance:	Maximum height of stacked precursor products: 3,871 mm (Arup, Section 2, Pg 11) Minimum load bearing capacity of the precursor product: 1,100 kg
Rationale	Maintaining consistency with disposal container concept designs allows for assessment against illustrative disposal concepts and generic disposal system safety case.
Justification:	It is assumed that the HLW precursor product shall be stacked 3 high within the disposal container. To be compatible with the assumed disposal container dimensions, the dimensions of the HLW WVP product container need to be consistent at the time of packaging into a disposal container. This has the benefit of

Identification No. / Name:	HHPP 4.3: HLW – Stacking
	standardisation across all the disposal containers for HLW precursor products. It is assumed that the minimum load bearing capacity of the HLW precursor product is 2 × maximum mass of a filled WVP product container.
Traceability to DSS:	DSS Part B, Section 3.1.6 ***Design of the disposal system shall assume the need to handle waste packages manufactured using the following containers, some of which include specific variants:*** • ***Disposal Containers for High Level Waste (HLW) and Spent Fuel (SF)***
Key References:	• Arup, *Disposal Container for HLW and Spent Fuel – Conceptual Design Report*, Arup Report 218762-01-03 Issue 5, June 2012 (NWS document reference LL21887947). • RWM, *Geological Disposal: Disposal System Specification Part B – Technical Requirements*, DSSC/402/01, December 2016.

Table 36: HLW precursor product mass requirements

Identification No. / Name:	HHPP 4.4: HLW – Mass
Statement of Requirement:	The HLW precursor product shall have a mass no greater than that of a standard loaded WVP product container.
Measure of Performance:	Maximum gross mass of loaded vitrified waste canister: 550 kg (SL, WVP/WPS/01/02, Section 5).
Rationale	Mass to be compatible with the assumed disposal container and transport configuration. Maximum expected mass for 3 WVP product containers in a Variant 1 waste container: 25.88 t. (Arup, Section 3, Pg 59)
Justification:	The maximum gross mass of waste packages must be such that it will permit them to be safely and efficiently handled using the systems defined for transport to, and emplacement in, a GDF. Maximum expected mass for 3 WVP product containers: 1.65 t Expected maximum mass of loaded DCTC (based on current assumed designs laden with 3 WVP product containers): 57.31 t (25.88 + 31.43 t, INS, Section 5, Pg 18). Maximum mass limit of DCTC inclusive of 5 t transport frame: 65 t (INS, Section 4, Pg 13). Maximum mass limit of rail wagon: 91 t

Identification No. / Name:	HHPP 4.4: HLW – Mass
	It is assumed that the handling equipment at a GDF will be capable of handling waste packages with a gross mass that is compatible with transport systems.
Traceability to DSS:	DSS Part B, Section 3.1.6 ***Design of the disposal system shall assume the need to handle waste packages manufactured using the following containers, some of which include specific variants:*** • ***Disposal Containers for High Level Waste (HLW) and Spent Fuel (SF).*** DSS Part B, Section 3.1.5.1 **Handling feature:** ***The waste package shall enable safe handling by way of the transport and GDF handling systems.*** DSS Part B, Section 3.1.5.3 **Gross Mass:** ***The gross mass of the waste package shall be compatible with the transport and GDF handling systems and with the requirement for the waste package to be safely stacked.***
Key References:	• Sellafield Ltd., *Standard Vitrified High Level Waste (UK Retained), Waste Product Specification Part Two (Process Description)*, WVP/WPS/01/02 Issue 6, September 2022 (NWS document reference LL43050853). • Arup, *Disposal Container for HLW and Spent Fuel – Conceptual Design Report*, Arup Report 218762-01-03 Issue 5, June 2012 (NWS document reference LL21887947). • INS, *Summary Report: Concept Design of the Disposal Container Transport Container (DCTC)*, INS ENG R 15 146 Rev 3, April 2016 (NWS document reference LL24716838). • RWM, *Geological Disposal: Disposal System Specification Part B – Technical Requirements*, DSSC/402/01, December 2016.

Table 37: HLW precursor product internal furniture and physical state requirements

Identification No. / Name:	HHPP 4.5: HLW – Internal Furniture and Physical State
Statement of Requirement:	THE HLW precursor product shall maintain a fixed geometry during transport to a GDF and the operational phase.

Identification No. / Name:	HHPP 4.5: HLW – Internal Furniture and Physical State
Measure of Performance:	<20% change in the external dose rate from the transport package when subject to tests for Normal Conditions of Transport (NCT). Maintaining a criticality safe geometry during transport and GDF operations.
Rationale	Maintaining compliance with the IAEA, Regulations For the Safe Transport of Radioactive Materials, 2018, SSR-6.
Justification:	The precursor product shall be maintained in the as-made physical state. Transport It is currently assumed that the DCTC is a Type B(U) transport package (see DSSC/411/01 Generic Transport System Design). The IAEA Transport Regulations (SSR-6 2012), as implemented in UK law, include the following: Requirements for Type B(U) Packages: 648. A package shall be so designed that if it were subjected to the tests specified in paras 719–724, it would prevent: (b) More than a 20% increase in the maximum radiation level at any external surface of the package. 652. Type B(U) packages shall be designed to meet the requirements specified in paras 607–618, the requirements specified in paras 619–621 if carried by air, and in **paras 636–649**, except as specified in para. 648(a), and, in addition, the requirements specified in paras 653–666. This is also the case in SSR-6 Rev 1 (2018), noting that this has not yet been implemented in the DSS. Criticality safety In addition to the change in dose rate, calculations made for criticality safety during transport and operations are based on the fixed known geometry of the precursor product in the disposal container. Criticality is unlikely to be significant for the HLW precursor products.
Traceability to DSS:	DSS Part B, Section 3.1.4.1 ***The waste packages are required to be able to provide the following… operational safety functions:*** • ***preclude criticality*** DSS Part B, Section 4.2.2.1 ***Transport of radioactive material shall use transport package designs that comply with the packaging requirements and test***

Identification No. / Name:	HHPP 4.5: HLW – Internal Furniture and Physical State
	procedures specified in the International Atomic Energy Agency's regulations for the Safe Transport of Radioactive Material.
Key References:	• RWM, *Geological Disposal: Generic Transport System Designs*, DSSC/411/01, December 2016. • IAEA, *Regulations for the Safe Transport of Radioactive Material: 2012 Edition*, Safety Standards Series No. SSR-6, October 2012. • RWM, *Geological Disposal: Disposal System Specification Part B – Technical Requirements*, DSSC/402/01, December 2016.

Table 38: HLW precursor product materials requirements

Identification No. / Name:	HHPP 4.6: HLW – Materials
Statement of Requirement:	The HLW precursor product materials shall be compatible with the transport and disposal systems.
Measure of Performance:	• Demonstration that materials are compatible and will not accelerate degradation of the disposal or transport container; • Exclusion of further materials listed as hazardous substances or non-hazardous pollutants being introduced to the precursor product in addition to the precursor product types as defined in Section 2; • Exclusion of further materials that increase the mobility of radionuclides being introduced to the precursor product in addition to the precursor product types as defined in Section 2.
Rationale	Maintaining disposal container integrity by preventing reactions between the precursor product and the container, the container and the DCTC, or the precursor product and the DCTC. Compliance with Environmental Permitting (England and Wales) Regulations (EPR) 2016. Prevent mobility of radionuclides post closure of the GDF.
Justification:	It is currently assumed that the DCTC is a Type B(U) transport package (see DSSC/411/01 Generic Transport System Design). The International Atomic Energy Agency (IAEA) Transport Regulations (SSR-6 2012), as implemented in UK law, include the following: 614. The materials of the packaging and any components or structures shall be physically and chemically compatible with each other and with the radioactive contents. Account shall be taken of their behaviour under irradiation.

Identification No. / Name:	HHPP 4.6: HLW – Materials
	Waste package required to contribute to relevant safety functions that apply to the post-closure period, including containment of hazardous materials and contribution to the overall performance of the engineered barrier system. (DSS Part B, Section 3.1.4.2). There is a requirement to prevent input of hazardous substances and limit input of non-hazardous pollutants into groundwater. (EPR 2016). It is assumed that the degradation of a WVP product container through corrosion is unlikely to compromise a GDF safety case.
Traceability to DSS:	DSS Part B, Section 3.1.4.2 Waste package safety functions that apply to the post-closure period: ***The waste packages are required to be able to provide the following four post-closure safety functions:*** • ***provide containment of radionuclides and other hazardous materials;*** • ***contribute to the overall performance of the EBS;*** • ***contribute to ensuring that, following GDF closure, a criticality event is not a significant concern;*** • ***withstand internal and external loads.*** DSS Part B, Section 3.4 ***It shall be demonstrated that the location and design of a geological disposal facility ensures environmental safety during the period of authorisation and subsequently.*** ***In accordance with the groundwater protection provisions of the Environmental Permitting (England and Wales) Regulations 2010, it shall be demonstrated that all necessary technical precautions will be taken to:*** • ***prevent the input of hazardous substances to groundwater;*** • ***limit the input of non-hazardous pollutants to groundwater so as to ensure that such inputs do not cause pollution of groundwater.*** DSS Part B, Section 4.2.2.1 ***Transport of radioactive material shall use transport package designs that comply with the packaging requirements and test procedures specified in the International Atomic Energy Agency's regulations for the Safe Transport of Radioactive Material.***
Key References:	• RWM, *Geological Disposal: Generic Transport System Designs*, DSSC/411/01, December 2016.

Identification No. / Name:	HHPP 4.6: HLW – Materials
	• RWM, *Geological Disposal: Disposal System Specification Part B – Technical Requirements*, DSSC/402/01, December 2016. • IAEA, *Regulations for the Safe Transport of Radioactive Material: 2012 Edition*, Safety Standards Series No. SSR-6, October 2012. • *Environmental Permitting (England and Wales) Regulations 2016*, Statutory Instrument 2016 No. 1154, December 2016.

Table 39: HLW precursor product identification markers requirements

Identification No. / Name:	HHPP 4.7: HLW – Identification Markers
Statement of Requirement:	The HLW precursor product shall have a unique identifier placed on it that is linked to its enabling data set.
Measure of Performance:	Each precursor product identifier shall be readable on each precursor product at the time of packaging the WVP product container into the disposable container.
Rationale	Allows assessment of each waste package based on contents being known and identifiable and linked to the waste package record.
Justification:	It is assumed that each precursor product identifier will be read prior to packaging and a record kept of which precursor products are packaged into each disposal container. Assessments made on the waste package will rely on knowing which precursor products have been placed within each disposal container. Therefore, identifiers on the product ties the contents to the records giving the required details.
Traceability to DSS:	DSS, Part B, Section 3.1.5.4 ***Adequate controls shall be established and applied to ensure that manufactured waste packages have the properties and performance required of them.*** ***Adequate controls shall be applied during any period of interim storage to ensure that waste packages retain their required properties and performance for the duration of such a period.***
Key References:	• RWM, *Geological Disposal: Disposal System Specification Part B – Technical Requirements*, DSSC/402/01, December 2016.

Table 40: HLW assurance, records and management system requirements

Identification No. / Name:	HHPP 4.8: HLW – Assurance, Records and Management System
Statement of Requirement:	The HLW precursor product shall have records that have been assured and produced within management system arrangements as outlined in Section 4.
Measure of Performance:	Records to include, but not be limited to: • The radionuclide and chemical fingerprint of vitrification plant feed; • A detailed radionuclide inventory and applicable reference date (or the means to calculate one) for the precursor product; • Oxide incorporation rate; • Waste oxide composition (e.g. fuel type blend ratio); • Base glass formulation; • Creation and placement in store date; • Glass transition temperature. See Section 4 for further detail.
Rationale	Allows assessment of each waste package based on contents being known and identifiable, allowing confirmation of disposability.
Justification:	The purpose of the ARM requirements for the precursor product is to contribute to ensuring that manufactured waste packages can be demonstrated to be disposable to the future disposal system operator, stakeholders and regulators.
Traceability to DSS:	DSS, Part B, Section 3.1.5.4 • ***Adequate controls shall be established and applied to ensure that manufactured waste packages have the properties and performance required of them.*** • ***Adequate controls shall be applied during any period of interim storage to ensure that waste packages retain their required properties and performance for the duration of such a period.*** DSS, Part B, Section 5.3 ***The geological disposal facility design shall include facilities for:*** • ***monitoring and record checks at package receipt*** • ***management and storage of waste package records*** ***Arrangements shall be made for the preservation of details of a geological disposal facility and records of the type and location of wastes.***
Key References:	• RWM, *Geological Disposal: Disposal System Specification Part B – Technical Requirements*, DSSC/402/01, December 2016.

Table 41: HLW precursor product criticality safety requirements

Identification No. / Name:	HHPP 4.9: HLW – Criticality Safety
Statement of Requirement:	The HLW precursor product shall contribute to the criticality safety of the waste package during the transport, operational, and post-closure phases.
Measure of Performance:	Consistency with the Criticality Safety Assessment (Criticality Safety Status Report, 2016).
Rationale	A criticality event poses a potential threat to containment. Compliance with UK Specification results in insufficient fissile content within the waste product for it to pose a criticality safety risk.
Justification:	**DSS Part B, Section 3.1.5.3** **Requirements for waste packages** Criticality Safety The presence of fissile material, neutron moderators and reflectors in the waste package shall be controlled to ensure that: • criticality during transport is prevented; • the risk of criticality during a GDF operational period is tolerable and as low as reasonably practicable; • in a GDF post-closure period both the likelihood and the consequences of criticality are low.
Traceability to DSS:	DSS Part B, Section 3.1.4.1 **Waste package safety functions that apply to transport and GDF Operations** ***The waste packages are required to be able to provide the following…operational safety functions:*** • ***preclude criticality;*** DSS Part B, 3.1.4.2 Waste package safety functions that apply to the post-closure period: ***The waste packages are required to be able to provide the following… post-closure safety functions:*** • ***contribute to ensuring that, following GDF closure, a criticality event is not a significant concern***
Key References:	• RWM, *Geological Disposal: Disposal System Specification Part B – Technical Requirements*, DSSC/402/01, December 2016. • Galson Sciences, *Demonstrating the Criticality Safety of Spent Fuel Disposal*, Galson Sciences Report 1649-5 Version 3.1, January 2018 (NWS document reference LL29164037).

Identification No. / Name:	HHPP 4.9: HLW – Criticality Safety
	• RWM, *Geological Disposal: Criticality Safety Status Report*, DSSC/458/01, December 2016.

Table 42: HLW precursor product interim storage temperature requirements

Identification No. / Name:	HHPP 4.10: HLW – Maximum Temperature
Statement of Requirement:	The HLW precursor product shall have a temperature no greater than the glass transition temperature throughout its lifetime (including post closure) to prevent de-vitrification.
Measure of Performance:	Remain under the glass transition temperature throughout its lifetime. Glass transition temperature dependant on form of glass.
Rationale	To minimise dissolution rates for the wasteform under post-closure conditions.
Justification:	Glass will go through de-vitrification where structure becomes more crystalline and the dissolution rate increases if temperature rises above the glass transition temperature. It is noted that GDF design decisions will impact on the post closure temperature conditions, for example: spacing of containers, depth of GDF.
Traceability to DSS:	DSS Part B, Section 3.1.4.2 Waste package safety functions that apply to the post-closure period: ***The waste packages are required to be able to provide the following four post-closure safety functions:*** • ***provide containment of radionuclides and other hazardous materials;*** • ***contribute to the overall performance of the EBS;*** • ***contribute to ensuring that, following GDF closure, a criticality event is not a significant concern withstand internal and external loads.***
Key References:	• RWM, *Geological Disposal: Disposal System Specification Part B – Technical Requirements*, DSSC/402/01, December 2016.

Table 43: HLW precursor product specification requirements

Identification No. / Name:	HHPP 4.11: HLW – Vitrified HLW Properties
Statement of Requirement:	The properties of the vitrified HLW in the precursor product shall be consistent with the assumptions made in the DSSC.
Measure of Performance:	The waste feed composition, inactive feed materials and process envelope for manufacture of the vitrified HLW contents of the precursor product shall be consistent with specification WVP/WPS/01/02 up to, and including, Issue 6.
Rationale	Ensure product can be demonstrated to be disposable at a GDF.
Justification:	The properties of the glass must be maintained. The glass must be within the UK Specification to be suitable for disposal. Allows for consistent reproduction. Assumptions regarding the properties of vitrified HLW (instant release fraction, dissolution rate etc.) form the basis of the post-closure safety narrative and quantification of RN migration against risk guidance levels.
Traceability to DSS:	DSS Part B, Section 9.2 **Post-closure safety** ***The disposal system shall ensure that the quantities of radionuclides or toxic substances entering groundwater will not compromise safety.*** In order to meet the regulatory requirements specified in DSS Part A, NWS will be required to demonstrate that the disposal system will protect people and the environment both now and in the future. Safety after closure is achieved by developing a disposal system in which the various components work together to provide and to ensure the required level of safety.
Key References:	• Sellafield Ltd., *Standard Vitrified High Level Waste (UK Retained), Waste Product Specification Part Two (Process Description)*, WVP/WPS/01/02 Issue 6, September 2022 (NWS document reference LL43050853). • RWM, *Geological Disposal: Disposal System Specification Part B – Technical Requirements*, DSSC/402/01, December 2016.

4. Assurance, Records and Management Requirements

4.1 Introduction

The Assurance, Records and Management (ARM) requirements for the precursor product that are outlined in this section create a subset of information that will ultimately feed into the ARM requirements for the final waste package. The purpose of the ARM requirements for the precursor product is to contribute to ensuring that manufactured waste packages can be demonstrated to be disposable to the future disposal system operator, stakeholders and regulators. To fulfil these requirements, it is imperative that precursor products are developed and stored under an appropriate Management System.

Consequently, the role of the precursor product Record is to provide assurance, to future generations, that precursor products were developed and stored in such a manner that they will ultimately contribute to the waste package being disposable.

ARM requirements are identified in the following areas:

- Management System arrangements for the design and manufacture of precursor products;
- Arrangements for the Interim Storage of precursor products, as far as these may influence disposability;
- Nuclear Safeguards;
- Nuclear Security;
- Production of records for precursor products that will help demonstrate compliance with the following specifications.:
    - Package Records Specification (PRS) for the precursor product (and final product);
    - Waste Product Specification (WPrS) for the precursor product (and final product);
    - Criticality Compliance Assurance Documentation (CCAD) for the precursor product (and final product).

The B level requirements (shown in bold, italic, red text) align with the DSS [3]; numbering has been maintained for consistency across the documents. The new HHGW level C requirements, while based on the level C LHGW requirements [7], have been assigned new numbers as the different waste types require separate consideration.

B50) ***Adequate controls shall be established and applied to ensure that manufactured waste packages have the properties and performance required of them.***

B50 refers to the final waste package, however it is essential that the precursor product is also processed and stored within control arrangements that will ensure the properties and performance are maintained, so that the final waste package can deliver the necessary safety functions.

Details of the requirements concerning these themes are provided below.

4.2 Management Systems

B52) ***Adequate management arrangements shall be applied to all aspects of the packaging of radioactive waste, and the storage of waste packages, that affect product quality. These arrangements shall be agreed with RWM prior to the start of the activities to which they relate.***

B52 refers to the final waste package, however it is essential that the precursor product also has management arrangements applied to the packing and storage of it.

HHPP 5.1. Management system arrangements *shall* be in place during development and storage of the precursor product, to control any activities that might affect the disposability of the final waste package, including:

a. Design and development of the precursor product.

b. Waste processing and packing.

c. Interim Storage of the precursor product.

d. Continuous activities that might apply during management of the waste and development of the precursor product, contributing to the formation of finalised Waste Package Records.

HHPP 5.2 Objective evidence *shall* be provided to NWS to demonstrate that management system arrangements:

a. Apply to the development and storage of the precursor product.

b. Demonstrate that implementation of the management system is verified by independent audit or assessment.

c. Demonstrate that the compliance data acquired during packaging is verified by independent audit or assessment.

HHPP 5.3 The management system arrangements *shall*:

a. Clearly state the factors that could affect precursor product quality and therefore need controlling, in order to produce a compliant precursor product and, ultimately, final waste package.

The reader is directed to Section 4.6 for PRS, WPrS, and CCAD, and requirements, respectively.

b. Include basic controlling documents for the activities recognised in Requirements HHPP 5.2 – HHPP 5.5.

c. Define the tests, measurements or inspection regimes that will be undertaken to confirm a compliant precursor product.

HHPP 5.4 Management system arrangements *shall*, if applicable, be in place during the design and development stage to control relevant activities including, but not limited to, the following:

a. Can and furniture design (where applicable).

b. Precursor product development.

c. Packing process development, including, but not limited to, any size reduction, drying, and conditioning steps.

d. Plant specification and design.

e. Producing submissions for Disposability Assessments and addressing any action points raised.

f. Any other activities that may be carried out that affect precursor product design and development.

HHPP 5.5 Management system arrangements *shall*, if applicable, be in place during the manufacture and / or conditioning of the precursor product to control activities including, but not limited to, the following:

a. Waste characterisation and inventory derivation.

b. Waste retrieval and packing.

c. Can and furniture manufacture (where applicable).

d. Plant commissioning.

e. Plant operations including raw materials storage.

f. Management of non-conforming precursor products.

g. Any other activities that may be carried out that affect the development and storage of the precursor product.

HHPP 5.6 Management system arrangements *shall*, if applicable, be in place during the storage of the precursor product to control the following, under asset management principles:

a. Environmental conditions in storage.

b. Monitoring and inspection of the store and storage conditions.

c. Monitoring and inspections of the precursor product in storage.

d. Any other activities that may be carried out that affect interim storage.

The reader is directed to Section 4.3 for further details.

HHPP 5.7 Management system arrangements *shall,* if applicable, be in place throughout the development and storage of the precursor product to control the following continuous activities:

a. Change control and continuous improvement.

b. Production of precursor product records.

c. Long-term retention of precursor product records.

d. Risk management.

e. Any other activities that may be carried out that affect the precursor product

HHPP 5.8 NWS *shall* be granted access to conduct Technical Audits of any activities during the development and storage of the precursor product.

In order to demonstrate that appropriate controls were applied during packing activities and storage, to produce a disposable product, relevant parts of the management system need to be included in the precursor product Record. Further details of which are provided in Section 4.6.

4.3 Storage

B51) ***Adequate controls shall be applied during any period of interim storage to ensure that waste packages retain their required properties and performance for the duration of such a period. Following storage, precursor product shall meet requirements.***

B51 refers to the final waste package, however it is essential that storage of the precursor product is controlled to ensure the precursor product shall meet the requirements.

HHPP 5.9 A strategy and implementation plan for the monitoring and inspection regime of the storage system *shall* be provided.

HHPP 5.10 Storage conditions and contaminants, which, during storage could affect the properties and performance of the precursor product such that the ability to produce the final waste package is impacted, *shall* be:

a. Controlled.

b. Monitored.

c. Recorded.

HHPP 5.11 Steps to mitigate the consequences of storage conditions foreseeably moving outside of the recommended ranges for prolonged periods of time *shall* be defined in advance.

Relevant parts of the storage arrangement documentation form part of the records that demonstrate the application of appropriate control of the storage of the precursor product.

The reader is directed to Section 4.6 for more details of the requirements for records on the precursor product.

4.4 Nuclear Safeguards

B54) ***The management of waste packages containing nuclear material shall comply with all relevant international safeguards obligations.***

B1018) ***The reporting requirements of [NSR19][3] shall be met in accord with the safeguards approach.***

B54 and B1018 refers to the final waste package. NWS will not be responsible for the safeguard arrangements of the precursor product. Nevertheless, any such arrangements should be compatible with fulfilling NWS requirements for the transfer of the final waste package into NWS ownership.

5.12 Where subjected to safeguard obligations, the handling and management of precursor products containing 'nuclear materials' *shall* be compliant with relevant safeguards controls.

NSR19 specifies six categories of qualifying nuclear material for the purposes of Nuclear Materials Accountancy Control and Safeguards (NMACS), and these are:

- Plutonium;
- High enriched uranium (20% pre-irradiation enrichment or greater);
- Low enriched uranium (higher than natural, less than 20% pre-irradiation enrichment);
- Natural uranium;
- Depleted uranium;
- Thorium.

5.13 The safeguards status, when applicable, of each precursor product *shall* be determined in accordance with extant safeguards authority regulations.

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[3] It is noted that the DSS currently references Euratom rather than NSR19; this will need to be updated through change control.

5.14 The safeguard status, when applicable, of the precursor product *shall* be recorded as part of the precursor product Record including evidence of agreement from the relevant authority.

The reader is directed to Section 4.6 for more details on the requirements of records on the precursor product.

The reader is further directed to WPS/923 for NWS guidance on this topic.

4.5 Nuclear Security

B55) ***The management of waste packages containing nuclear material shall comply with all relevant security requirements for their transport.***

B56) ***The management of waste packages containing nuclear material shall comply with all relevant security requirements for their disposal.***

B55 and B56 refers to the final waste package. NWS will not be responsible for the security arrangements of the precursor product. Nevertheless, any such arrangements should be compatible with fulfilling NWS requirements for the transfer of the final waste package into NWS ownership.

5.15 The precursor product record *shall* contain the information necessary to determine the security categorisation of the final waste package under relevant controlling arrangements.

The reader is directed to Section 4.6 for more details on the requirements of records on the precursor product.

4.6 Contribution to the Production of Waste Package Records

B53) ***Information shall be recorded for each waste package covering all relevant details of its manufacture and interim storage. This information shall be sufficient to enable assessment of the characteristics and performance of the waste package against the requirements of all stages of long-term management.***

B53 refers to the final waste package, however it is essential that information be recorded for each precursor product.

HHPP 5.16 Each precursor product *shall* have a quality assured record.

HHPP 5.17 A methodology *shall* be in place for acquiring, recording and managing the data, information and documentation required for precursor product Records.

HHPP 5.18 The precursor product Record *shall* be produced and managed to meet the requirements of IMP06: Managing NDA Information requirements.

a. Precursor product Records *shall* be designated as vital records.

b. All precursor product Records *shall* be managed in a manner compatible with long term accessibility, for example, by transfer to the Nucleus archive for long-term storage.

IMP06: Managing NDA Information requirements.

HHPP 5.19 The contents of each precursor product Record *shall* encompass three classes of information to cover the development and storage of the precursor product:

a. Class A: Underpinning and Justification documentation.

b. Class B: Compliance definition and control documentation.

c. Class C: Compliance demonstration documentation.

Class A: This class contains evidence sufficient to demonstrate that the precursor product, when manufactured, fulfils the requirements in this specification.

Class B: This class documents the details of the precursor product to be created and the requirements against which compliance is controlled to ensure the eventual disposability of the end product.

Class C: This class is made up of evidence which demonstrates that the proposed packing methodology was implemented and that the requirements in the Class B documents were met.

The requirements for each record Class are listed in Table 44. For further guidance the user is directed to the WPS/850 suite of guidance documents.

Table 44: Waste Package Records requirements for Classes A, B and C

Class	Requirement	Designated Category	Definition
Class A	**HHPP 5.20 The Class A record *shall* be comprised of documentation that fulfils the requirements for a record of:**		
	a. Background, nature and origin of the waste.	A1	As necessary to provide an unambiguous definition of the waste that has been packed.
	b. The development and performance of the precursor product.	A2	As necessary to provide evidence of process and precursor product development, including limits and exclusions, and expected performance of the precursor product in support of the final waste package.
	c. The design and development of the any container, can and / or furniture (where applicable) in line with above.	A3	To include any container, can and / or furniture design drawings and manufacturing specification (where applicable).
	d. The arrangements for assigning precursor product inventory and compositional information.	A4	To include methods and any fingerprints used to generate waste composition and radionuclide inventories. Parameters of interest may include: burn up, irradiation history, reactor history, age.
	e. Arrangements for storage, monitoring and inspection of manufactured precursor products.	A5	As necessary to provide evidence of the application of appropriate controls during the storage of precursor products. See section 4.3 for further requirements.
Class B	**HHPP 5.21 The Class B record *shall* be comprised of documentation that fulfils the requirements for a record of:**		
	a. The Package Record Specification (PRS).	B1	See section 4.6.1 for further requirements.

	b. The Waste Product Specification (WPrS).	B2	See section 4.6.2 for further requirements.
	c. The Precursor Product Criticality Compliance Assurance Documentation (CCAD).	B3	See section 4.6.3 for further requirements.
	d. Management system arrangements.	B4	As necessary to provide evidence of the application of appropriate controls in the packing process. See section 4.2 for further requirements.
Class C	**HHPP 5.22 A Class C record *shall* be comprised of evidence to demonstrate that the requirements have been met to provide a record of:**		
	a. Precursor product identifier.	C1	Evidence of unique identifier for the outer containment of the precursor.
	b. Statement of compliance with Class B records.	C2	As necessary a statement that identifies the version of the controlling documents (Class B) against which the particular precursor product has been manufactured and whether it is compliant.
	c. Compliance of any container, can and / or furniture (where applicable)	C3	Evidence to demonstrate that any container, can and / or furniture (where applicable) used to produce the particular precursor product complies with the relevant requirements of the Class B documents.
	d. Compliance of the waste.	C4	Evidence to demonstrate that the waste complies with the relevant limits or constraints placed on the waste in the Class B documents. This includes providing the radionuclide inventory and composition for the particular precursor product.
	e. Compliance with processing.	C5	Evidence to demonstrate that any necessary waste packing process has been applied as specified in the Class B documents.
	f. Compliance of the precursor product.	C6	Evidence to demonstrate compliance with any requirements and limits placed on the completed precursor product in the Class B documents.

	g. Precursor product management.	C7	Evidence to demonstrate that the precursor product has been managed and stored since manufacture in compliance with the arrangements detailed under Category A6 (see section 4.2).
	h. Resolution of non-compliance.	C8	Identification of any non-compliances for the particular precursor product and evidence of resolution.
	i. Other necessary precursor product-scale information.	C9	Other pertinent information relating to an individual precursor product to support the aims and principles of the waste package record. This includes Safeguards status and security-related information (see sections 4.4 and 4.5).

Additional guidance for the management of records can be found in WPS/850 suite of guidance documents.

4.6.1 Package Records Specification

HHPP 5.23 To demonstrate that the requirements of the precursor product Record are fulfilled and to facilitate their future use, the contents of a precursor product Record *shall*:

a. Be clearly recorded in an index which lists the original documents containing required data and information that are included in the Precursor Product Record that ultimately will contribute to the formation of a Waste Package Record for the final waste package.

b. Provide an explanation of how to use the precursor product Record.

NWS recommends that the arrangements that fulfil this requirement are captured as a Precursor Product Records Specification (PPRS).

HHPP 5.24 All relevant versions/issues of the documents that form the precursor product Records shall be listed in the index.

4.6.2 Waste Product Specification (WPrS)

HHPP 5.25 Each precursor product *shall* be produced in compliance with an agreed Waste Product Specification.

HHPP 5.26 Supporting documents referenced within the Waste Product Specification *shall* be included in the Specification for Precursor Product Records.

The reader is directed to section 4.6.1 for further details.

HHPP 5.27 Each iteration of the Waste Product Specification against which precursor products were made *shall* be included when specifying Precursor Product Records.

HHPP 5.28 The Waste Product Specification *shall*:

a. Define the precursor product that is to be produced.

b. Define the processes which will be used to create the precursor product.

c. Specify the attributes (features) of the precursor product against which compliance information is to be recorded.

d. Identify the limits and controls required during the production of a precursor product.

e. Identify the precursor product storage arrangements.

HHPP 5.29 The Waste Product Specification *shall* state the limitations and manufacturing specifications for the following factors:

a. Constraints on the waste to be packaged.

b. Any container, can and / or furniture.

c. Where relevant, the inactive waste conditioning materials and any formulation envelope used.

d. Process requirements and controls.

HHPP 5.30 The Waste Product Specification *should* provide references to supporting Research and Development to justify the limits and specifications cited therein, for example:

a. R&D to demonstrate that the precursor product will support compliance of the final proposed package with the requirements for disposal.

4.6.3 Precursor Product Criticality Compliance Assurance Documentation

HHPP 5.31 Assurance *shall* be provided that the fissile content, and other constraints, of each precursor product to be produced, is within the limits prescribed in the associated Criticality Safety Assessment (CSA) for the final proposed waste package.

HHPP 5.32 Supporting documents referenced within the justification for criticality compliance assurance arguments *shall* be included in the Package Record Specification.

HHPP 5.33 Each iteration of the Criticality Compliance Assurance Documentation, against which precursor products were made *shall* be retained and recorded in the CCAD section of the Package Records Specification.

HHPP 5.34 Assurance of criticality compliance *shall* be described in a manner that is easily identifiable as the Criticality Compliance Assurance Documentation.

HHPP 5.35 The description of criticality compliance assurance *shall*:

a. State the basis for assessment including: the safe fissile mass from each phase, the overall safe fissile mass that is being packaged to and any other constraints detailed in the criticality safety assessment that must be complied with.

b. Identify the arrangements that are used to ensure compliance with the constraints in the Criticality Safety Assessment (e.g. plant processes, controls, assay arrangements).

c. Identify the uncertainties that may result in the constraints in the Criticality Safety Assessment being exceeded.

d. Identify any potential faults that could result in the constraints in the Criticality Safety Assessment not being complied with.

e. Identify mitigation measures (controls) for each identified fault or uncertainty.

f. Explain how the arrangements and controls required to ensure criticality safety will be implemented within the management system and appropriate records generated.

HHPP 5.36 The description of assurance arrangements *shall* be approved by an individual with sufficient knowledge of the development and storage of the precursor product.

Through this requirement, NWS seeks confirmation from an individual with sufficient understanding of the development and storage of the precursor product, and its associated procedures, that the CSA will be adhered to. This is necessary to ensure that the CSA is implemented correctly.

5. References

1 DESNZ, *UK policy framework for managing radioactive substances and nuclear decommissioning*, Department for Energy Security and Net Zero, May 2024

2 RWM, *Geological Disposal, Generic Disposal System Specification Part A: High Level Requirements*, DSSC/401/01, December 2016.

3 RWM, *Geological Disposal, Generic Disposal System Specification Part B: Technical Specification*, DSSC/402/01, December 2016.

4 RWM, *Inventory for Geological Disposal: Main Report*, DSSC/403/03, May 2021.

5 RWM, *Geological Disposal: Generic Transport System Designs*, DSSC/411/01, December 2016.

6 RWM, *Geological Disposal: Generic Disposal Facility Designs*, DSSC/412/01, December 2016.

7 NWS, *Waste Package Specification and Guidance Documentation: Specification for Waste Packages Containing Low Heat Generating Waste: Part C – Fundamental Requirements*, WPS/220/01, March 2020.