Radioactive Waste Management

WPSGD no. WPS/230/01

Geological Disposal:

Generic Specification for waste packages containing depleted, natural and low enriched uranium

December 2015

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WASTE PACKAGE SPECIFICATION AND GUIDANCE DOCUMENTATION

GENERIC SPECIFICATION FOR WASTE PACKAGES CONTAINING DEPLETED, NATURAL AND LOW ENRICHED URANIUM

This document forms part of the Waste Package Specification and Guidance Documentation (WPSGD), a suite of documents prepared and issued by Radioactive Waste Management Ltd (RWM). The WPSGD is intended to provide a 'user-level' interpretation of the RWM packaging specifications, and other aspects of geological disposal, to assist UK waste packagers in the development of plans for the packaging of higher activity waste in a manner suitable for geological disposal.

Key documents in the WPSGD are the *Waste Package Specifications* (WPS) which define the requirements for the transport and geological disposal of waste packages manufactured using standardised designs of waste container. The WPS are based on the high level requirements for all waste packages as defined by the generic *Disposal System Specification* and are derived from the bounding requirements for waste packages containing a specific category of waste, as defined by the relevant *Generic Specification*.

The purpose of this Generic Specification is to define the generic requirements for waste packages containing depleted, natural and low enriched uranium (DNLEU). The packaging requirements defined herein are derived from the high-level requirements defined in the Disposal System Specification, as part of the suite of documents that describe RWM's plans for a GDF.

This Generic Specification also acts as the basis for the definition of the WPS which define the requirements for the waste packages containing DNLEU that would result from the use of standardised designs of waste container.

The WPSGD is subject to periodic enhancement and revision. Users are therefore advised to refer to the RWM website to confirm that they are in possession of the latest version of any documentation used.

WPSGD DOCUMENT NUMBER WPS/230 - VERSION HISTORY		
VERSION	**DATE**	**COMMENTS**
WPS/230/01	December 2015	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.

Abbreviations and acronyms used in this document

ACT	accident conditions of transport
ALARP	as low as reasonably practicable
BSL	Basic Safety Level
DNLEU	depleted, natural and low enriched uranium
DSS	Disposal System Specification
DSSC	Disposal System Safety Case
EBS	engineered barrier system
ESC	Environmental Safety Case
EVR	evaporite rock
GDF	geological disposal facility
GDFD	Generic Disposal Facility Design
GTSD	Generic Transport System Design
GWPS	Generic Waste Package Specification
HEU	highly enriched uranium
HSE	Health and Safety Executive
HSR	high strength rock
IAEA	International Atomic Energy Agency
ILW	intermediate level waste
LEU	low enriched uranium
LSSR	lower strength sedimentary rock
NCT	normal conditions of transport
NDA	Nuclear Decommissioning Authority
NM	nuclear material
ONR	Office for Nuclear Regulation
OSC	Operational Safety Case
RWM	Radioactive Waste Management Ltd
SAPs	Safety Assessment Principles
SWTC	standard waste transport container
TDC	transport and disposal container
TSC	Transport Safety Case
U-IPT	Uranium Integrated Project Team
WAC	waste acceptance criteria

List of Contents

1 Introduction

The Nuclear Decommissioning Authority (NDA) has established Radioactive Waste Management Ltd (RWM) as the body responsible for implementing UK Government policy for the management of higher activity radioactive wastes, as set out in the 2014 *Implementing Geological Disposal* White Paper [1]. The White Paper 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 as the ultimate receiver of wastes for disposal, RWM 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 precursor to WAC, RWM produce packaging specifications, the primary purpose of which is to enable the holders of radioactive wastes to condition that waste into a form that will be compatible with the anticipated needs of transport to and disposal in a GDF.

The packaging specifications, together with a wide range of explanatory material and guidance that users will find helpful in the development of proposals to package waste, make up a suite of documentation known as the *Waste Package Specification and Guidance Documentation* (WPSGD). For further information on the extent and the role of the WPSGD, all of which can be accessed via the RWM website, reference should be made to the *Introduction to the RWM Waste Package Specification and Guidance Documentation* [2].

The RWM packaging specifications form a hierarchy defined in such a manner to ensure that the needs of all users are satisfied. Generic Specifications, such as this document, form the second tier of this hierarchy and are aimed at those involved in the development of concepts for the packaging of specific categories of waste for geological disposal.

The specific purpose of this Generic Specification is to apply the high-level packaging requirements defined by the *Generic Waste Package Specification* (GWPS) [3] to waste packages containing predominantly uranic materials that fall into the category of 'depleted, natural and low enriched uranium' (DNLEU). The generic requirements defined herein are derived from the anticipated needs for the transport and geological disposal of waste packages containing such wastes. These requirements are applied to specific designs of waste package, manufactured using a standardised design of waste container, in the form of *Waste Package Specifications* (WPS).

This Generic Specification makes no assumptions regarding the geographical location of a GDF, the geological environment in which it will be constructed, or a specific concept which could be adopted for the disposal of waste packages containing DNLEU. Accordingly, the packaging requirements are defined so as to be bounding of a number of illustrative disposal concepts that could be implemented for the disposal of DNLEU in a range of geological environments that exist at a number of locations throughout the UK.

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

- Section 2 provides background information on geological disposal in general, and on RWM's approach to defining the requirements for, and demonstrating the safety of, a GDF. It also summarises the role played by the packaging specifications in assessing the disposability of proposed waste packages.
- Section 3 explains the nature and role of the RWM packaging specifications, and of this Generic Specification in particular.

- Section 4 describes the sources and properties of the DNLEU to which this Generic Specification applies.
- Section 5 outlines the approach adopted in the development of this Generic Specification and defines the basis for the definition of the packaging requirements and the assumptions that are made as part of that process.
- Section 6 defines the packaging requirements together with a brief commentary on their derivation.
- A glossary of important terms and phrases used in this Generic Specification is included as Appendix A.

2 Background

2.1 Geological disposal of radioactive waste

A key aspect of UK Government policy for the long-term management of the UK's higher activity wastes[1] is the geological disposal of such waste, following a period of safe and secure interim storage. Whilst the precise manner in which geological disposal would be implemented in the UK is not yet defined it is envisaged that it would comprise a number of distinct stages. These could include:

- The manufacture of passively safe and disposable waste packages;
- A period of interim surface storage, usually at the site of waste arising or packaging;
- Transport of the waste packages to a GDF;
- Transfer of waste packages underground and emplacement in the disposal areas;
- Back-filling of the disposal areas; and
- Eventual sealing and closure of the facility.

The exact nature, timing and duration of each stage would depend on a number of factors, including the geographical location and host geology of a GDF, as well as the nature of the waste and the disposal concept selected for implementation for that waste type.

The key aim of all of the geological disposal systems implemented or under development worldwide is the containment and isolation of radionuclides and other hazardous materials associated with the waste [4]. Containment and isolation are provided by a system of engineered and natural barriers which, for a typical geological disposal system, include those provided by the waste package and any back filling material[2], and the geology surrounding the disposal facility. Safety is achieved by these mutually complementary barriers working together to ensure that radionuclides, and other hazardous materials associated with the waste, will not return to the surface at concentrations that could cause harm to people or the environment.

2.2 The Disposal System Specification

As part of RWM's programme for the implementation of geological disposal in the UK, and to set out a clear definition of the requirements of the disposal system, the generic Disposal System Specification (DSS) has been developed [5]. The DSS includes regulatory and stakeholder requirements, as well as a consideration of the nature, characteristics and quantities of the higher activity wastes and other radioactive materials that may be destined for geological disposal.

The DSS is a starting point for the development of designs for the geological disposal system, which includes those for the transport of waste packages from their site of manufacture and/or interim storage to a GDF. The details of the current illustrative designs can be found in the following documents:

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1 The description 'higher activity waste' encompasses all wastes and radioactive materials identified in the 2014 White Paper as being potentially destined for geological disposal.

2 These two components of the geological disposal system are referred to collectively as the engineered barrier system (EBS).

- The *Generic Disposal Facility Designs* (GDFD) report [6] which describes the illustrative GDF designs developed for three generic geological environments, based on different host rock types (see Section 5.3). It presents RWM's understanding of how geological disposal could be carried out in a range of different geological environments.

- The *Generic Transport System Designs* (GTSD) report [7], which outlines potential designs for moving waste packages to a GDF, by road, rail and/or sea. It summarises the hardware, logistical and operational bases for the generic transport system.

The development of the DSS, and the associated system designs for the transport of waste packages and their disposal in a GDF, is an iterative process with the assessments of safety, environmental impacts and cost. The requirements that the DSS defines are periodically refined in light of the results from RWM's ongoing programmes of work. Updating the DSS will take into account the results from work on the waste inventory, engineering design, site investigations, safety, environmental and sustainability assessment, consideration of security and safeguards issues, research, and public and stakeholder engagement.

2.3 The Disposal System Safety Case

The generic *Disposal System Safety Case*[3] (DSSC) [8] has been developed as a means of presenting the methods, evidence and arguments by which RWM demonstrates the safety of plans for geological disposal. The DSSC, which is founded on the generic DSS and the associated designs for transport and disposal, comprises a suite of documents which consider the safety of all aspects of the long-term management of waste packages:

- Following their export from the site of interim storage to a GDF;

- Construction, operation, decommissioning and closure of the GDF; and

- The safety of the GDF in the long-term, after it has been sealed and closed.

Of direct relevance to the definition of the requirements for waste packages are the generic safety cases for these three periods of the management of waste packages, namely:

- The generic *Transport Safety Case* (TSC) [9], which summarises why RWM has confidence that the system for transporting wastes to a GDF would be safe. It gives an overview of how safety would be demonstrated for individual waste packages, and a summary of an illustrative safety assessment of the transport system as a whole.

- The generic *Operational Safety Case* (OSC) [10], which presents an illustrative safety case for a GDF under both normal operations and fault conditions, for each of the different geological environments. It provides a preliminary assessment of operational risk, including that during construction, against regulatory limits and targets.

- The generic *Environmental Safety Case* (ESC) [11], which considers the environmental safety of a GDF during the operational period and after closure of the facility. It explains in principle why RWM has confidence in the environmental safety of a GDF and the approach to developing the necessary safety case to

[3] It should be noted that this Generic Specification is based on the 2010 DSSC. The DSSC and its accompanying documents is to be updated during 2016 and this Generic Specification will be updated, as necessary, following the publication of the 2016 DSSC.

demonstrate that confidence, with reference to the different generic geological environments.

In addition, the generic *Environmental Assessment* [12] considers the environmental, socio-economic and health implications of implementing geological disposal. It explains how the design of waste packages, through consequent effects on GDF design and waste package transport, can influence the environmental and sustainability performance of the disposal system.

The generic DSSC also summarises the current status of RWM's underlying science base in key areas such as waste package evolution and longevity [13], accident performance [14], criticality safety [15], and the behaviour of radionuclides in a GDF [16].

2.4 Assessing the disposability of waste packages

The 'Letter of Compliance' Disposability Assessment process has been established as a means of supporting the UK nuclear industry's ongoing work on the conditioning and packaging of higher activity waste for disposal. The process has been extensively developed over a period of more than 20 years, in cooperation with the site operators and industry regulators, and in a manner that aligns with regulatory expectations for the long-term management of higher activity waste [17].

The main purposes of the Disposability Assessment process [18] are to:

- Give confidence to site operators that the implementation of their proposals to package waste will result in waste packages that meet the anticipated needs for transport to and disposal in a GDF;
- Aid in the identification of optimised solutions to the packaging of specific types of waste;
- Provide RWM with confidence that the geological disposal concepts considered within the DSS and DSSC will be appropriate for the wastes they are expected to accommodate; and
- Permit the identification of wastes and proposed approaches to packaging that could challenge current disposal concepts and, thereby, allow early consideration of what changes may be required to those concepts to permit the resulting waste packages to be accommodated.

In the event that a disposability assessment identifies no significant uncertainties in the ability of the proposed packaging approach to produce disposable waste packages, a Letter of Compliance can be issued to endorse it, and the waste packages that would result from its implementation.

3 Specifications for packaged waste

Packaging specifications define the standard properties and performance requirements for waste packages which are compatible with the anticipated systems and safety cases for their transport to and disposal in a GDF.

As discussed above, in the absence of the necessary information to permit the production of WAC for a GDF, RWM produces generic packaging specifications, their principal purpose being to expedite the conversion of unconditioned wastes into passively safe and disposable forms. The packaging specifications therefore play an important role in determining the disposability of waste packages (see Section 2.4) and, in this sense, may be considered to act as the 'preliminary' WAC for a future GDF. This approach is consistent with that outlined in guidance produced by the International Atomic Energy Agency (IAEA) [19] and with that adopted in a number of countries worldwide (e.g. Sweden, France, USA).

The packaging specifications are also produced with a number of other key purposes in mind, notably:

- To support the development of RWM's plans for the implementation of geological disposal for higher activity radioactive waste;
- To provide the UK nuclear industry and regulators with a clear definition of the requirements for packaged waste in advance of the construction of a GDF; and
- To permit scrutiny of this aspect of RWM's plans to implement geological disposal for higher activity waste in the UK.

3.1 The role of the waste package in geological disposal

The engineered and natural barriers provided by a geological disposal system are illustrated schematically in Figure 1 and can include those provided by:

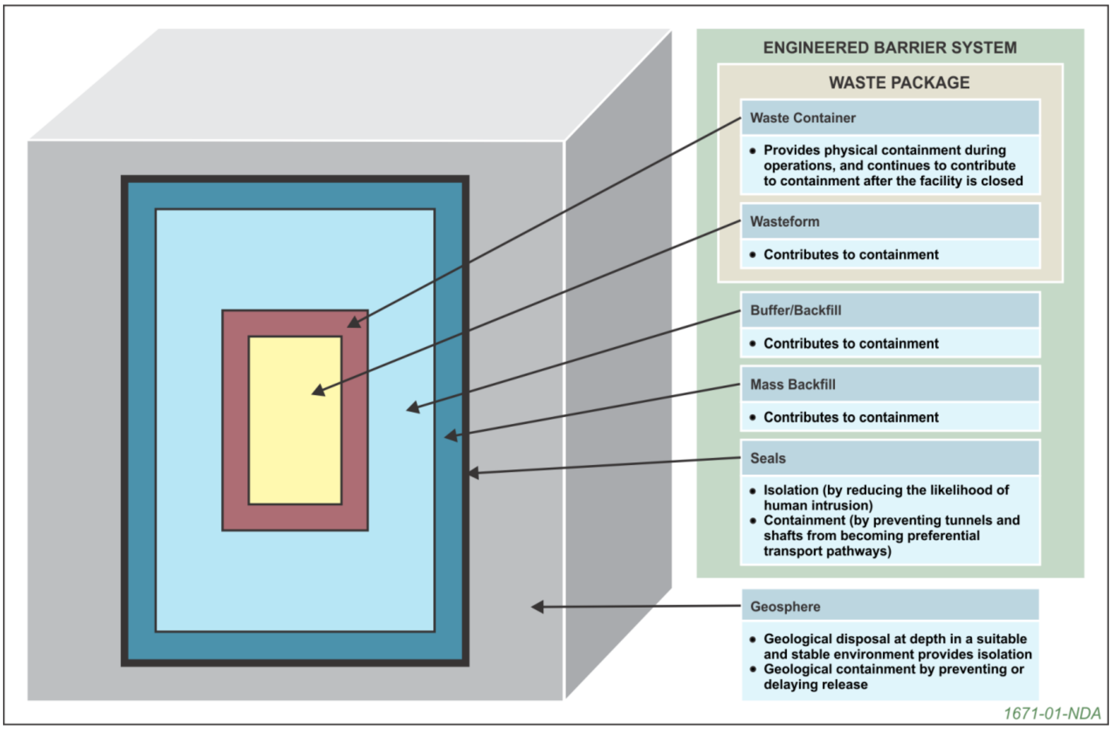
- The EBS comprising:
    - the waste package consisting of:
        - the contents of the waste package, or wasteform[4]; and
        - the waste container.
    - any local buffer/backfill placed around the waste package;
    - mass backfill in the rest of the underground excavations, and;
    - other sealing materials.
- The surrounding geology, consisting of:
    - host rocks; and
    - overlying strata.

As shown in Figure 1, the barrier provided by the waste package can be considered to comprise two components, these being provided by the waste container and the wasteform. The relative contributions of each of these two components will depend on the

[4] A wasteform may comprise waste which has been immobilised (e.g. by the use of an encapsulant), that which has received more limited treatment prior to packaging (e.g. size reduction or drying), or that which may require no additional treatment prior to disposal.

physical and chemical nature of the waste, the manner in which it has been prepared for disposal (i.e. 'conditioned'), and the design of the waste container.

Figure 1 Schematic representation of the barriers considered in developing geological disposal concepts



3.2 The definition of packaging specifications

Much of the waste destined for geological disposal does not arise in a form that is immediately suitable for such disposal. It must therefore be conditioned and packaged in such a way as to render it:

- Passively safe, such that it can be managed safely with the minimum need for active safety systems, monitoring or prompt human intervention;
- Capable of safe handling during interim storage[5], transport to and emplacement in a GDF; and
- 'Disposable', in that it can be shown to be compliant with all the relevant regulations and safety cases for transport to and disposal in a GDF.

In order for packaging specifications to play an effective role in assessing the disposability of waste packages, they must reflect all of the relevant aspects of the disposal system. Specifically waste packages must be physically compatible (i.e. by virtue of their dimensions, weight and handling features) with the handling systems anticipated for transport and disposal. It will also be necessary that their contents and performance can be shown to be compliant with the assumptions underpinning the safety cases for both transport and disposal.

By considering the role played by the waste package as part of a multiple barrier geological disposal system the DSS identifies a number of safety functions that must be achieved by

[5] It is expected that many waste packages will need to be stored for an extended period (i.e. several decades), either at their site of manufacture or elsewhere, pending the availability of a GDF.

waste packages destined for geological disposal. These may be provided by the waste container or the wasteform, or by a combination of the two, and comprise:

- During transport and the GDF operational period:
  - provide containment of radionuclides during normal operations and under accident conditions;
  - limit radiation dose to workers and members of the public;
  - preclude criticality;
  - provide the means of safe handling; and
  - withstand internal and external loads.
- During the GDF post-closure period:
  - provide containment of radionuclides;
  - contribute to the overall performance of the EBS;
  - contribute to ensuring that, following GDF closure, a criticality event is not a significant concern; and
  - withstand internal and external loads.

To provide a basis for judging the ability of specific waste package designs to satisfy these safety functions the packaging specifications define requirements for the 14 packaging criteria[6], as shown in Table 1.

Table 1 Packaging criteria

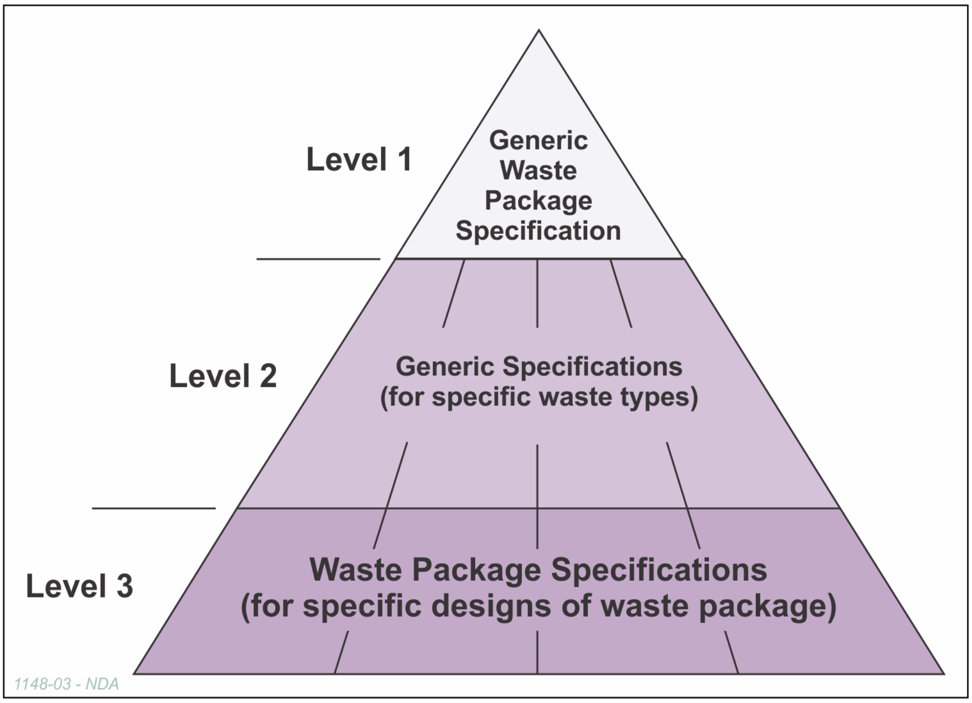
External dimensions	Handling feature	Identification
Stackability	Durability of waste container integrity	Wasteform properties
Gross mass	Surface contamination	Activity content
Gas generation	External dose rate	Heat output
Criticality safety	Accident performance	

6 The manner by which the packaging criteria are derived from the waste package safety functions is explained in the GWPS [3].

3.3 The form of the RWM packaging specifications

In order to ensure that the packaging specifications satisfy the needs of all users, RWM has devised a hierarchical structure as illustrated in Figure 2.

Figure 2 Hierarchy of the RWM packaging specifications



The hierarchy comprises three 'levels' of packaging specifications in which each successive level represents an increasing degree of specificity, both to the nature of the waste and the design of the waste package. Each of the levels in the hierarchy satisfies a specific function and is produced for a particular audience:

- The GWPS[7], which defines high-level requirements for all waste packages destined for disposal in a GDF. It is aimed at industry regulators and stakeholders who are not directly involved with the packaging of waste.
- Generic Specifications, which define the requirements for all waste packages that will be disposed of in accordance with a specified range of concepts, and which will contain wastes with similar radiological characteristics. They are produced for industry regulators and for use by waste packagers involved in the development of new or innovative approaches to the packaging of waste.
- WPS, which define, where applicable, quantitative requirements for waste packages containing a specific type of waste and manufactured using a standardised design of waste container[8]. They are produced for use by waste packagers intending to use such a waste container for the packaging of waste.

This document is the 'Level 2' Generic Specification for waste packages containing DNLEU.

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7 It should be noted that this role will be assumed by the 2016 DSS.

8 These are designs which have been shown to be suitable for the manufacture of waste packages that are compatible with the anticipated needs of transport and disposal.

3.4 Generic Specifications

For the purposes of GDF design the GDFD report splits the full range of higher activity wastes[9], into two broad categories; low heat generating waste (LHGW) and high heat generating waste (HHGW), and further sub-divides these categories as shown in Table 2 [6].

Table 2 Categories of higher activity waste

Waste category	Sub-division
LHGW	Low level waste (LLW)
	Shielded intermediate level waste[10] (ILW)
	Unshielded ILW[10]
	DNLEU
HHGW	High level waste (HLW)
	Spent fuel[11] (SF)
	Plutonium
	Highly enriched uranium (HEU)
	Mixed oxide fuel

In order that the packaging specifications are applicable to the full range of higher activity wastes, whist ensuring that a proportionate approach is adopted to the packaging and disposal of each category of waste, a suite of Generic Specifications will be required. As a means of identifying the extent of such a suite RWM has used two properties of radioactive waste, namely radiogenic heat output and fissile nuclide content, to divide the whole range of higher activity waste into groups of wastes for which distinct approaches to packaging and/or disposal may be required. This has resulted in RWM envisaging the production of at least four Generic Specifications, for waste packages containing:

- LHGW, such as ILW and LLW, for wastes with limited, but potentially significant, heat output and fissile nuclide content [20];
- HHGW, including HLW and SF, for wastes with high heat output and potentially significant fissile nuclide content [21];
- Fissile waste, including separated plutonium and HEU, for wastes with low to significant heat output and high fissile nuclide content; and

9 The 2014 White Paper defines these as HLW, ILW and LLW that is not suitable for near surface disposal, together with any other radioactive materials which may be declared as waste in the future (e.g. spent fuel, plutonium, and uranium).

10 These sub-categories of ILW are differentiated by the manner in which they are expected to be packaged.

11 This includes both ‘legacy’ SF from Magnox and Advanced Gas-cooled reactors, and that arising from a programme of new nuclear power stations.

- DNLEU (i.e. this Generic Specification) for predominantly uranic wastes with very low heat output and low to potentially significant fissile nuclide content.

It should be noted that heat output and fissile nuclide content are not the only two discriminators for waste types that could be used in this way. Other properties such as the specific activity of long-lived radionuclides, and/or the timescales required for the containment of radionuclides by the EBS could also be used.

Generic Specifications may also be produced for other types of waste with particular physical, chemical and/or radiological characteristics and for which disposal in accordance with bespoke geological disposal concepts may be necessary (e.g. irradiated graphite from the cores of commercial nuclear reactors).

4 The materials covered by this Generic Specification

4.1 The properties of uranium

Uranium is a naturally occurring radioactive element that can be found in low concentrations in most of the rocks and water on Earth. Uranium metal is a very dense material (19.0 tm^{-3}), as are its oxides (the densities of pure materials are: UO_2 = 11.0 tm^{-3}, UO_3 = 7.3 tm^{-3}, and U_3O_8 = 8.3 tm^{-3}).

Natural uranium consists of three isotopes; uranium-238 (~99.3% natural abundance), uranium-235 (~0.7%), and uranium-234 (~0.005%). All three are radioactive, emitting alpha particles, with half-lives of $4.5x10^9$ years, $7.0x10^8$ years and $2.5x10^5$ years respectively. A further 13 isotopes of uranium exist as a result of nuclear reactions, with half lives of between 0.5 seconds and 10^5 years. These isotopes are predominantly alpha emitters although a small number are beta/gamma emitters [22].

As well as containing the three naturally occurring isotopes of uranium, freshly mined uranium will contain a range of daughter products, most of which are radioactive. The most notable of these daughters are radium-226 and polonium-210, which are alpha emitters with very high specific activities, and a number of isotopes of radon which are gaseous alpha emitters. The concentrations of these daughter products will be in quasi-secular equilibrium[12] in freshly mined uranium but will be at much lower concentrations after the uranium has been chemically processed. Due to the long half-lives of the main uranium isotopes, it will take many billions of years for secular equilibrium to establish in processed uranium.

Following irradiation and reprocessing, a much wider range of additional radionuclides will be present in uranium, including those transuranic elements such as plutonium. This is discussed below for the DNLEU that arises from specific processes.

Two isotopes of uranium (uranium-233 and uranium-235) are fissile and two (uranium-234 and uranium-238) are fertile. Uranium-238 is also an efficient neutron absorber.

Owing to uranium being predominantly a low activity alpha emitter, DNLEU only constitutes a significant radio-toxic hazard when it is ingested in air, food or water. However, the presence of uranium daughter products, and other radionuclides that maybe present in some DNLEU (i.e. fission products and trans-uranics) can significantly contribute to the radio-toxic hazard presented by DNLEU.

In common with many other heavy metals, uranium is also a chemically toxic material.

4.2 The definition of DNLEU

This Generic Specification defines the packaging requirements that are applicable to all waste packages containing a broad range of wastes which predominantly contain uranium in oxide form, and without significant quantities of other materials.

Much of the waste that is classed as ILW by the UK Radioactive Waste Inventory [23] contains uranium, the uranium in all ILW amounts to a total of ~1,500 tU. However, many of these waste streams also contain a wide range of non-radioactive materials, and significant quantities[13] of other nuclides (e.g. fission products and transuranics). This means that their safe disposal is best managed in accordance with geological disposal

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[12] True secular equilibrium will not have been reached due to the very long half-life of uranium-238.

[13] 'Significant' from the point of view of radionuclide-related properties such as radiation dose and heat generation.

concepts developed for wastes with those characteristics (i.e. LHGW) and the requirements for their packaging are not be covered by this Generic Specification.

For the purposes of this Generic Specification 'DNLEU' is defined as material which has arisen as a result of processes within the nuclear fuel cycle where uranium-bearing material has been chemically processed with the specific aim of producing uranium as a product. Such products can typically be broken down into number of distinct types of DNLEU on the basis of their uranium-235 content and their manner of arising. These mainly comprise:

- Depleted uranium, with a uranium-235 concentration of less than 0.7% and arising from two sources, namely:
    - Uranium enrichment plant 'tails'; and
    - Uranium product from the reprocessing of Magnox natural uranium fuel.
- Low enriched uranium (LEU) with uranium-235 concentrations of up to ~1%, arising from the reprocessing of enriched uranium fuels in the Thermal Oxide Reprocessing Plant (THORP).

The inclusion of this final category of uranium is intended to provide a proportionate approach to the disposal of uranium with a uranium-235 content slightly higher[14] than that of natural uranium. This is to avoid such materials being considered as 'fissile waste' for the purposes of their geological disposal (see Section 3.4). The value of 1% has been chosen on the basis that it is industry practice is to assume this value as the division between uranium which has no criticality issues and that which does. Furthermore, the IAEA Transport Regulations permit the 'fissile exception' of transport packages containing such material (see Section 6.3.7).

Uranium with a uranium-235 content of greater than ~1% may be suitable for disposal in accordance with concepts developed for DNLEU as defined above, but the disposability of waste packages containing such material would have to be assessed on a case by case basis. If disposability could not be demonstrated, the option would exist to dispose of this material in accordance with concepts developed for fissile waste and the Generic Specification developed for such wastes would be applicable to the waste packages.

Uranium also exists in the form of HEU, which is used in the manufacture of nuclear weapons and specialist nuclear fuels (e.g. for research reactors) and is present in wastes produced by the reprocessing of these fuels. HEU is defined as having a uranium-235 concentration of ~20% or greater, and, as distinct from DNLEU, wastes containing HEU could constitute a significant criticality hazard during their long-term management. Such wastes are therefore beyond the scope of this Generic Specification and would be covered by that which will be produced for waste packages containing fissile waste.

4.3 Sources and forms of DNLEU

DNLEU that may be the subject of geological disposal arises from a small number of distinct sources. The main distinction between the different types of DNLEU, apart from the manner of their creation, is the relative proportions of the uranium isotopes they contain (Table 3), their physico-chemical form and the potential presence of radionuclides other than isotopes of uranium.

[14] Noting that the definition of LEU generally applies to uranium with uranium-235 enrichments of up to 20%.

Table 3 Typical isotopic compositions of DNLEU

Source of DNLEU	Typical isotopic composition by mass (%)				
	U-232	U-234	U-235	U-236	U-238
Natural uranium	0	6E-03	0.7	0	~99
Enrichment plant 'tails'	0	1E-03	0.3	0	~99
Magnox depleted uranium (MDU)	2E-08	4E-03	0.3	0.1	~99
THORP product uranium (TPU)	1E-07	8E-05	~0.9[15]	0.3	~99

4.3.1 Enrichment plant tails

Uranium has been enriched at the Capenhurst site for over 50 years, by gaseous diffusion and centrifuges. Natural uranium has been enriched to up to ~5% uranium-235 for civil reactor fuels and to over 90% uranium-235 (i.e. HEU) for the manufacture of nuclear weapons and fuel for research and submarine reactors. The depleted uranium 'tails' produced as a by-product of these enrichment processes have been stored since their production, at Capenhurst, in the form of UF_6.

This material generally comprises tails from the enrichment of 'fresh' uranium and contains only naturally occurring isotopes of uranium (i.e. uranium-234, uranium-235 and uranium-238) together with traces of naturally occurring uranium daughter products.

Some of the uranium recovered during the reprocessing of Magnox fuel at Sellafield (i.e. MDU, see below) was 're-enriched' in the Capenhurst Diffusion Plant and the tails arising from this processing are also stored at Capenhurst. Such tails are contaminated with trace quantities of fission products (notably technetium-99), uranium-236 and various transuranics (notably various isotopes of plutonium and neptunium-237).

Current plans are for the entire stocks of civil UF_6 tails that are held at Capenhurst, together with future arisings from ongoing enrichment operations, to be 'deconverted' to U_3O_8, a stable non-hygroscopic free flowing powder that is expected to retain its properties during interim storage[16]. The U_3O_8 product will be stored in mild steel DV70 containers, which have a capacity of ~3 m^3, and can contain up to ~12 t of product.

4.3.2 Magnox depleted uranium

MDU is one of the major products from the reprocessing of Magnox fuel. MDU is contaminated with trace quantities of fission products, uranium-233 and uranium-236, and some transuranics. Most of the product of over 50 years of Magnox reprocessing at Sellafield is currently held at Capenhurst in the form of UO_3, originally as a free flowing powder. As it is hygroscopic, it absorbs water from the atmosphere, which can result in the formation of agglomerates with time.

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15 Note that some TPU can have a uranium-235 content of up to ~1.6% (see Section 4.3.3).

16 Currently assumed to extend to ~100 years.

MDU has historically been stored in 200 litre mild steel drums each containing up to ~700 kg[17] of product. Deterioration of these containers has led to a campaign of overpacking in larger (i.e. ~500 litre) stainless steel drums. The overpacking of historic MDU is known to have included the use of bags made from organic materials.

4.3.3 THORP product uranium

Fuel from the UK's fleet of AGRs has been reprocessed in THORP at Sellafield. The uranium recovered from such reprocessing (i.e. TPU) is contaminated with trace quantities of fission products (notably technetium-99, ruthenium-106, caesium-134, caesium-137, and cerium-144), uranium-233 and uranium-236, and transuranics (e.g. isotopes of plutonium and neptunium-237). TPU is stored in the form of UO_3 in ~50 litre stainless steel drums, each containing ~150 kg of product.

It is noted that the reprocessing of enriched uranium fuels from AGR stations can result in a uranium product with uranium-235 enrichments of up to ~1.6%. Whilst this Generic Specification is only intended to apply to DNLEU with uranium-235 enrichments of up to 1%, it can also be used to consider the issues that would arise from the transport and disposal of waste packages containing DNLEU with a uranium-235 content of slightly higher than 1%.

4.3.4 Other 'miscellaneous' DNLEU

Relatively small quantities of DNLEU with a range of uranium-235 enrichments, arising from a variety of fuel manufacturing processes, and therefore in a number of different physico-chemical forms, at various sites across the UK, including Aldermaston, Capenhurst, Sellafield and Springfields. Some of this material may be suitable for disposal as DNLEU, whilst other components may be more suitable for disposal as LHGW.

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[17] The actual quantities of product in such containers are known to vary widely, values of between 100kg and 800kg have been recorded.

5 Basis for the definition of the packaging requirements

5.1 The role of the waste container and wasteform in achieving waste package performance

The fundamental aims for the packaging of waste are to ensure that the resulting waste packages are:

- Passively safe and suitably robust physically, so as to ensure containment and safe handling during all ensuing periods of the long-term management of the waste;
- Suitable for safe transport through the public domain in compliance with the relevant regulations; and
- Compatible with the safety cases for the operational and post-closure periods of a GDF.

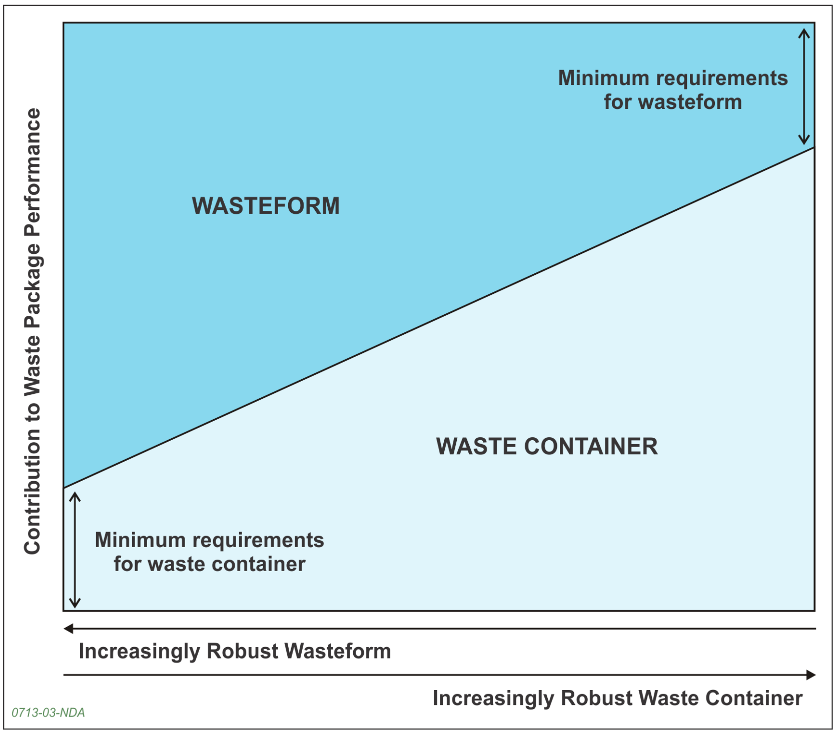
The waste package provides the most immediate barrier to the release of radionuclides and other hazardous materials from the waste it contains, during interim storage, transport and within a multiple barrier geological disposal system. It may also play a role in protecting individuals from the radiation emitted by the radionuclides it contains during interim storage, transport and the GDF operational period.

The barrier provided by a waste package can be considered to comprise two components, each of which can act as a barrier in its own right:

- The waste container; which provides a physical barrier and also enables the waste to be handled safely during and following waste package manufacture. Waste containers can be manufactured from a range of materials with designs selected to suit the requirements for the packaging, interim storage, transport, and disposal of the wastes they contain.
- The wasteform; which can be designed to provide a significant degree of physical and/or chemical containment of the radionuclides and other hazardous materials associated with the waste. The wasteform may comprise waste in which the radionuclides have been 'immobilised' (e.g. by mixing with an encapsulating material), or which may have received more limited pre-treatment prior to packaging (e.g. size reduction and/or drying). In the case of the DNLEU considered in this Generic Specification, it is likely that the wasteform will generally be well defined, in the form of uranium oxide (see Section 4) which may or may not have been encapsulated.

Both the waste container and the wasteform contribute to achieving the required performance of the waste package, the relative importance of each generally depending on the robustness of the former. This is illustrated in Figure 3 which shows, in stylised form, how the use of a more robust waste container can reduce the required contribution of the wasteform to overall waste package performance. Figure 3 also shows that for all waste packages both the waste container and the wasteform will always be required to play some role in the achievement of the required performance of the waste package. It should be noted that it is the overall performance of the waste package as a whole, rather than that of its components, that is the governing factor in judging its disposability.

Figure 3 Relative contribution of the waste container and wasteform to waste package performance



5.2 The transport of waste packages to a GDF

In the absence of a geographical location for a GDF, the TSC currently assumes that all waste packages destined for geological disposal will have to be transported, through the public domain to a GDF, from the site of their arising, packaging and/or interim storage.

The transport of radioactive materials through the public domain is subject to a range of requirements implemented into UK law[18], notably the IAEA *Regulations for the Safe Transport of Radioactive Material*[19] [24]. The IAEA Transport Regulations, which are supported by extensive guidance [25], define general requirements and, in some cases, quantified limits for a range of properties of radioactive materials which are to be transported through the public domain and these are, where relevant, incorporated into this Generic Specification.

The distinction between a 'waste package' and a 'transport package' is important as it influences the manner by which the requirements of the IAEA Transport Regulations are applied in this Generic Specification:

- A waste package will, in general, comprise a container in which waste is placed and which is suitable for disposal without further treatment.
- A transport package is an assembly which is suitable for transport, and which may or may not require additional protection for that purpose.

Some waste packages will be capable of satisfying the requirements of the IAEA Transport Regulations, without additional protection, and are described as 'transport packages in their own right'. The requirements of the IAEA Transport Regulations are therefore applied

[18] The Radioactive Materials Transport Team of the Office for Nuclear Regulation (ONR) has regulatory responsibility for the transportation of radioactive material in Great Britain.

[19] These regulations are referred to as the 'IAEA Transport Regulations' in the remainder of this document.

directly to such waste packages. However, some designs of waste package will not be suitable for transport without additional protection which can be provided, for example, by a ‘transport container’. A transport container might be required to provide radiation shielding and/or additional physical containment of the contents of the waste package. In such cases a transport package would comprise a reusable transport container into which one or more waste packages are placed. On receipt at a GDF, the waste packages would normally be removed from the transport container prior to disposal. For such waste packages, significant benefit can be claimed for the protection that is provided by the transport container as the requirements of the IAEA Transport Regulations are applied to the transport package as a whole, i.e. the transport container and the waste package(s) it contains.

The constraints of the transport system and the regulations which apply to the transport of waste packages through the public domain are, in many cases, the most bounding in the definition of the packaging requirements that make up this Generic Specification. It is therefore important that the assumptions regarding the transport of waste packages are clearly defined. At the highest level this includes an assumption that all waste packages will be transported using the systems and operational procedures defined by the GTSD [7].

The IAEA Transport Regulations define a number of categories of transport package, two of which are of relevance to the transport of DNLEU, and therefore to this Generic Specification:

- Industrial Packages (Type IP); for the transport of materials with limited specific activity and for which protection, notably under accident conditions, is mainly vested in controls placed on the form and specific activity of the contents of the transport package; and

- Industrial Packages for fissile material (Type IF); for the transport of materials with limited specific activity but which for which the nature (i.e. quantity, concentration and/or enrichment) of any fissile material they contain would mean that they would require Competent Authority approval for their transport. In general, uranium with a uranium-235 content of greater than 1%[20] will need to be transported in a Type IF transport package (see Section 6.3.7).

The use of Type IP or Type IF transport packages require that the radionuclide inventory of their contents is limited to that defined by the IAEA Transport Regulations for low specific activity (LSA) material or surface contaminated objects (SCOs), as discussed in Section 6.3.1.

The TSC assumes that waste packages containing LHGW that are transported as Type IP transport packages in their own right will be subject to the specific controls defined for Type IP-2[21] transport packages. This may also be the case for waste packages containing DNLEU, although it may be possible to apply the less onerous requirements for Type IP-1 transport packages to waste packages containing unirradiated DU.

The IAEA Transport Regulations define two regimes under which transport packages can be carried, these being under the conditions defined as ‘exclusive use’[22] and ‘non-exclusive

[20] As specified by Paragraph 417(a) of the IAEA Transport Regulations.

[21] The difference between these two classes of transport package is that whilst Type IP-1 packages are only required to be able to satisfy the general requirements for all transport packages (Paragraph 607-618), Type IP-2 transport packages are also required to be able to withstand a free drop test (Paragraph 722) and a stacking test (Paragraph 723), without suffering any loss or dispersal of radioactive contents or reduction in shielding.

[22] Paragraph 221 defines ‘exclusive use’ as: *‘…the sole use, by a single consignor, of a conveyance or of a large freight container, in respect of which all initial, intermediate and final loading and unloading is carried out in accordance with the directions of the consignor or consignee’*.

use'. The packaging requirements that make up this Generic Specification are based on an assumption that the transport of waste packages containing DNLEU will take place under the conditions of exclusive use.

5.3 Geological disposal concepts for DNLEU

For a waste package to be deemed 'disposable' it must be both physically compatible with the systems defined for transport and a GDF, and with the assumptions that underpin the safety cases for transport and the operational and post-closure periods of the GDF. The design of a GDF, which will be strongly influenced by the geological environment in which it is constructed, will therefore place constraints on the required properties and performance of waste packages.

A wide range of geological environments that could be suitable for hosting a GDF for higher-activity radioactive wastes exist in the UK. However, at this point in time, no site for a GDF has been selected and so only illustrative designs for a GDF have been defined. RWM has identified three geological environments that exist in the UK and that could host a GDF, these are described by the generic nature of the host rock they comprise and are; higher strength rock (HSR), lower strength sedimentary rock (LSSR) and evaporite rock (EVR). By drawing on work to investigate geological disposal concepts that have been planned or implemented worldwide [26], RWM has identified 'illustrative' concepts for the geological disposal of LHGW which could be implemented in each of the three generic host rock types [27], these are listed in Table 4.

Table 4 Illustrative geological disposal concepts for LHGW

Host rock	Generic concept	Illustrative concept
HSR	Wastes packages stacked in vaults with cement[23] backfill	UK ILW/LLW Concept (NDA)
LSSR	Waste packages stacked in vaults with structural cement backfill	Opalinus Clay Concept (NAGRA, Switzerland)
EVR	Waste package emplaced in 'rooms' without backfill, or with crushed evaporite backfill if host formation is thin	WIPP bedded salt concept (US DOE)

RWM is using these illustrative concepts to further develop an understanding of the requirements of the geological disposal system for LHGW, and to aid in the development of packaging specifications. No such illustrative concepts have yet been identified for DNLEU, as few countries have considered the disposal of such materials in any great detail. A major aspect of the ongoing work for the Uranium Integrated Project Team (U-IPT) RWM has been to identify potential disposal concepts for DNLEU [28]. In the meantime this Generic Specification has been developed on the assumption that the illustrative concepts identified for the geological disposal of LHGW (Table 4) will also apply to DNLEU. Accordingly, the packaging requirements defined by this Generic Specification will reflect the general constraints imposed by the transport and GDF systems for waste packages containing LHGW.

[23] Nirex Reference Vault Backfill.

5.4 Packaging, transport and disposal of DNLEU

The aim of a Generic Specification is to define the packaging requirement for any design of waste package containing a specific type of waste which could be disposed of in accordance with a particular geological disposal concept (or range of concepts). As discussed in Section 4.3, most of the DNLEU that could come forward for geological disposal is already packaged in some manner, although the designs of those packages may not be suitable for disposal, without additional processing. By way of the U-IPT RWM has considered options for the packaging of existing and anticipated stocks of DNLEU in a form suitable for transport and disposal [29]. Whilst no single option has been selected as the optimum approach, two are considered adequately viable to have been considered as part of the development of this Generic Specification. These comprise:

- 'Repackaging' of uranium oxide by mixing it with a cementitious grout within thin walled stainless steel containers[24]. The waste packages would be handled using stillages (Figure 4) and transported to a GDF in a reusable transport container[25]. On receipt at a GDF the waste packages would be removed from the transport container and transferred using remote handling techniques to a disposal vault where they would be using an overhead crane (Figure 5).
- 'Overpacking' of the as-stored packages of DNLEU (see Section 4.3) within stainless steel 'transport and disposal containers' (TDC - Figure 6). The waste packages26 would be transported to a GDF, without additional protection, and emplaced in the disposal vaults using a stacker truck (Figure 7).

For both of these packaging approaches it is anticipated that the disposal vaults would be backfilled at some point after emplacement of the waste packages, mainly as a means of reducing voidage within the vaults.

It should be noted that other approaches to the packaging of the current and anticipated stocks of DNLEU have been considered by the U-IPT (e.g. direct disposal of the products described in Section 4.3). Whilst these approaches are not explicitly considered in this Generic Specification, the disposability of the resulting waste packages can be assessed against the requirements defined herein.

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[24] Such waste packages, when containing ILW, are referred to as 'unshielded' waste packages.

[25] It is currently assumed that 500 litre drum waste packages containing ILW would be a transported to a GDF within one of three variants of the standard waste transport container (SWTC), as Type B waste packages. Such an approach could be adopted for 500 litre drum waste packages containing DNLEU, although a bespoke reusable transport container, such as a design based upon that of an ISO freight container for use as part of an Industrial Package, may be a more optimal approach.

[26] This being the combination of the as-stored packages and a TDC.

Figure 4 500 litre drum waste packages

Figure 5 Disposal of repackaged DNLEU

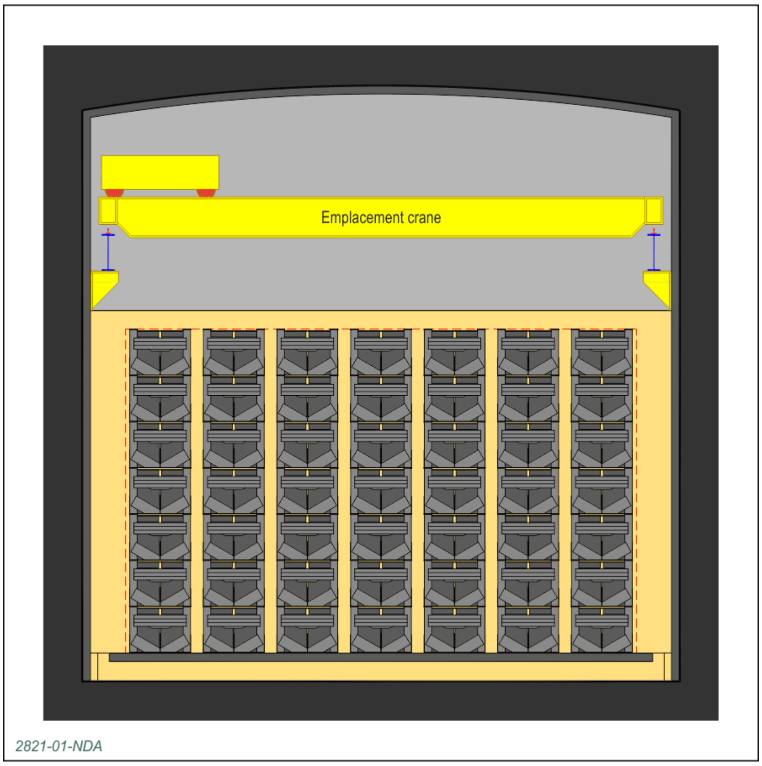


Figure 6 Typical TDCs containing as-stored packages of DNLEU

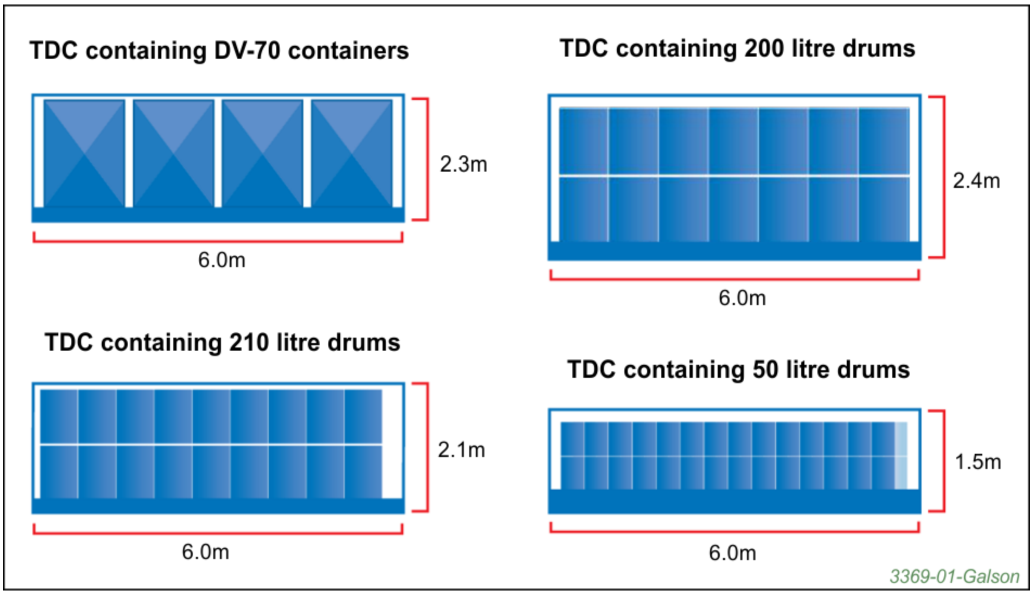
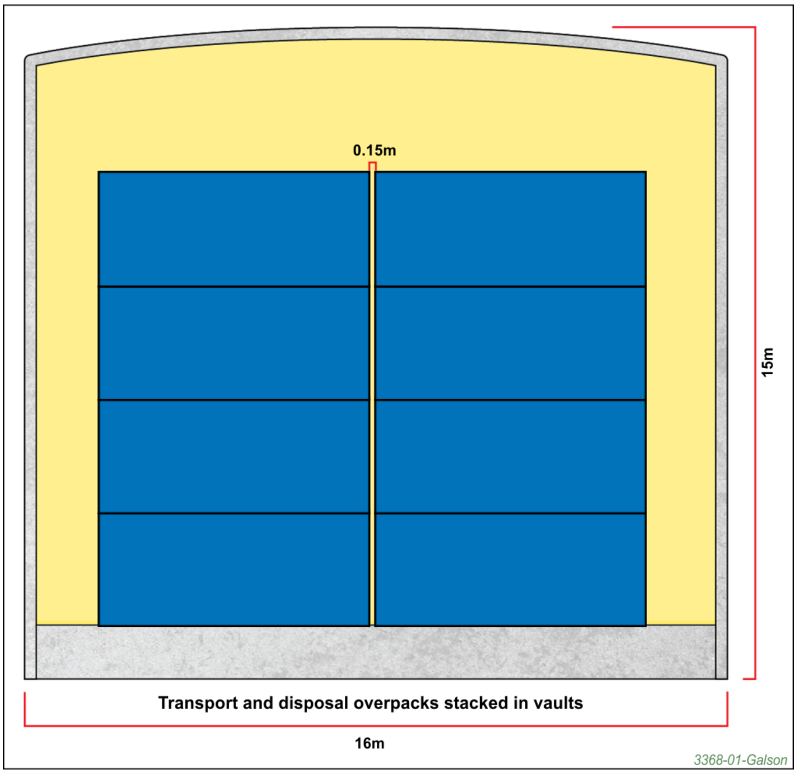


Figure 7 Disposal of DNLEU overpacked using TDCs



6 Requirements for waste packages containing DNLEU

This Generic Specification is founded on the requirements for the geological disposal of DNLEU, as defined by the DSS. Waste packages containing DNLEU should be capable of being safely transported to a GDF in accordance with the systems defined by the GTSD [7] and, following receipt at a GDF, of being safely handled by way of the processes and equipment defined in a GDFD [6]. Also included is a consideration of the required performance of waste packages in the GDF post-closure period, as defined by the DSS in the form of a series of environmental safety functions.

No explicit consideration of the needs of interim storage has been included in the definition of the packaging requirements that make up this Generic Specification. It is assumed that such facilities will be designed to ensure that waste packages will remain suitable for transport and disposal following the anticipated period of storage.

This Section defines the requirements, for each of the packaging criteria listed in Table 1, for waste packages containing wastes that fall into the category of DNLEU. In general, the packaging requirements specified below are defined for the complete waste package, but in practice the manner in which they are achieved will depend on a number of factors including:

- the nature of the waste container;
- the physical, chemical and radiological properties of the waste; and
- the means by which the waste is conditioned for disposal.

Accordingly, the packaging requirements are grouped in a manner to reflect those which are most directly related to the waste container, the wasteform, and the waste package as a whole. In addition, a number of requirements are defined for the controls that will need to be applied during the manufacture and storage of waste packages.

The format of this Section is to define each packaging requirement in terms of that defined by the GWPS (shown in ***bold italic type***) together with any additional requirements for waste packages containing DNLEU (shown in **bold type**). The requirements in this Section are defined in a manner that could be applied to any design of waste package containing DNLEU in order that it could be accommodated by the generic transport and GDF designs and safety cases. This is followed, where relevant, by a discussion of how the requirement would apply to waste packages manufactured in accordance with the two approaches to the packaging of DNLEU identified in Section 5.4 (i.e. repackaging or overpacking).

It should be noted that, where the words ‘shall’ and ‘should’ are used in the packaging requirements, their use is consistent with the recommendations of BS 7373:1998 [30] in that they have the following meaning:

- ‘shall’ denotes a limit which is derived from consideration of a regulatory requirement and/or from a fundamental assumption regarding the current designs of the transport or disposal facility systems;
- ‘should’ denotes a target from which relaxations may be possible if they can be shown[27] not to result in any significant reduction in the overall safety of the geological disposal system.

[27] This would generally be by way of the Disposability Assessment process.

6.1 Requirements for waste containers

The properties of the waste container shall be such that, in conjunction with those of the wasteform, it satisfies all of the requirements for the waste package.

In Section 5 the contribution that the waste container can make to the overall properties and performance of a waste package was discussed. For some of the required waste package properties (e.g. external dimensions, lifting features, and identification) the waste container alone will generally be expected to satisfy the requirement, whereas for others (e.g. external dose rate, accident performance) it may only play a partial role. The extent of the role played by the waste container in meeting any of the waste package properties listed below will depend on its robustness, as illustrated by Figure 3. It should be noted that, whilst some designs of waste container may be able to provide most aspects of required waste package performance, this will not preclude the need for the wasteform to satisfy the requirements defined in Section 6.2.

The generic requirements for waste containers, not all of which will apply to some disposal concepts, are that they should provide the waste package with adequate:

- Mechanical strength; to:
    - withstand stacking forces;
    - resist damage due to pressurisation by any internally generated gases;
    - ensure that the specified impact accident performance can be achieved; and
    - withstand any other loads that may be applied during the long-term management of the waste package, as required by the ESC.
- Radiation shielding[28]; to ensure that the external dose rate is minimised and that specified limits are not exceeded;
- Thermal properties; to ensure that the required fire accident performance and other thermal requirements of the waste package will be achieved; and
- Resistance to degradation; to ensure that the integrity of the waste container is maintained for an extended period, thereby:
    - maintaining the contents of the waste in a sub-critical condition during transport and the GDF operational period, including providing physical location of the fissile material and preventing the entry of water into the waste package; and
    - preventing the early accumulation of fissile material from more than a single waste package during the post-closure period.

These generic requirements are addressed in the relevant packaging requirements for waste containers and waste packages defined below.

[28] It should be noted that some designs of waste container will not provide sufficient radiation shielding to satisfy the requirements of transport and that this would be provided by the use of a transport container or other device.

6.1.1 External dimensions

The external dimensions of the waste package shall be compatible with the transport and GDF handling systems.

The overall dimensions of a transport package should not exceed 6.058 m x 2.438 m plan x 2.591 m high.

The dimensions of a transport package carried by rail shall not exceed 2.67 m wide or 2.40 m high.

The external dimensions of waste packages (and transport packages) are limited by the handling systems used during transport and following receipt at a GDF.

The current GDF handling systems are based on transport packages having dimensions that lie within the envelope defined for Series 1 freight containers as specified in ISO668 [31], and the first set of dimensions given above are those for an ‘ISO 20-foot standard container’.

Waste packages are assumed to be transported to a GDF by road, rail, sea or inland waterway, or by a combination of these means. In general, transport by rail is the most restrictive from the point of view of the external dimensions of waste packages. The maximum overall dimensions of a transport package must be compatible with the dimensions envelope defined by Standard W6A Rail Gauge [32]. This leads to a maximum transport package width of 2.67 m[29] and a maximum height of 2.40 m [33]. Transport by rail will also impose limits on the length of transport packages although these will be generally less restrictive than that imposed by the GDF systems (i.e. ~6 m). Less restrictive rail gauges exist although this could limit which parts of the network could be used. Larger waste packages could be transported by road; although the transport of larger waste packages in this manner may ultimately be limited by restrictions on their gross mass.

The limiting dimensions stated above apply directly to waste packages such as those manufactured using TDCs, which are transport packages in their own right.

For waste packages requiring additional protection during transport the limiting dimensions will apply to the external dimensions of the transport container and a reduced envelope will apply to the waste package. Three variants of the SWTC are currently under development by RWM, all of which are suitable for the transport of 500 litre drum waste packages in stillages. The SWTC-150[30] has the largest cavity size and can accommodate cuboidal waste packages with maximum external dimensions of 1.85 m x 1.85 m by 1.37 m high. The use of a transport container with a design based upon that of an ISO freight container with external dimensions bound by the values above could provide a larger cavity than the SWTC, and could accommodate more than one waste package[31].

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[29] These values represent the total envelope permitted by the W6A rail gauge and therefore the effects of any peripheral equipment (e.g. weatherproofing covers, impact limiters etc.) used during transport would have to be taken into account.

[30] The numeric part of the identifier indicates the nominal thickness of stainless steel shielding provided by the transport container.

[31] Or stillage of waste packages in the case of the 500 litre drum.

6.1.2 Handling feature

The waste package shall enable safe handling by way of the transport and GDF handling systems.

The waste package shall incorporate handling features to enable lifting under a load equivalent to twice the maximum specified gross mass without any effect that would render it non-compliant with any of the requirements defined in this Specification.

Where tie down within a conveyance is necessary for their safe transport, waste packages shall incorporate tie-down features suitable for their maximum specified gross mass.

The design of the waste package should enable remote handling.

To permit their safe and efficient handling, waste packages should incorporate standardised designs of handling feature designed in such a manner as to be compatible with the handling systems that are assumed for use during transport and following receipt at a GDF.

These handling features must be able to withstand the full range of forces which could be applied during all normal waste package handling operations. This includes a requirement for them to be able to withstand the loads that would result from the lifting of a waste package with twice the specified maximum gross mass, to take into account the so-called 'snatch factor' [34].

Waste packages which are transport packages in their own right, such as those manufactured using a TDC, will need to be restrained during transport and this can be achieved by the inclusion of 'tie-down' features in the waste container design. This is an explicit requirement for waste containers which are classed as ISO freight containers, and which have followed that route for their approval for the transport of radioactive material.

In order to retain flexibility in the definition of operational procedures at a GDF (and during transport), and to help ensure that operator doses will be as low as reasonably practicable (ALARP), the option for their use with remote handling equipment should be retained in the design of the handling features of all waste packages.

For some waste package designs the handling feature will also play a significant role in their safe stacking (Section 6.1.3).

6.1.3 Stackability

Where required by the transport or disposal system, the waste package shall enable safe stacking.

Waste packages which rely on their design to withstand stacking loads should be capable of being stacked with other waste packages of the same design, each with their maximum specified gross mass, to the maximum height defined by the disposal system. This loading shall not result in any effect that could render the waste package non-compliant with any of the requirements defined in this Specification.

Waste packages which are transport packages in their own right shall comply with the stacking requirements defined by the IAEA Transport Regulations.

Waste packages which are to be stacked should be able to do so without suffering any effects that could threaten their safe onward management. This will require them to be able to maintain their dimensional envelope and shape, notably that of the handling feature, until the end of the GDF operational period.

The IAEA Transport Regulations (Paragraph 723[32]) specify a 'stacking test' as part of the process for demonstrating the ability of transport packages[33] to withstand 'normal conditions of transport' (NCT). This requires transport packages to be capable of withstanding a compressive vertical load equal to five times their maximum weight, following which it must be capable of preventing the loss or dispersal of its contents or of its shielding integrity (Paragraph 622). This requirement applies to all waste packages which are transport packages in their own right, such as those manufactured using TDCs.

The GDFD defines a maximum disposal vault height of 15 m for a GDF constructed in a higher strength host rock[34] [6]. The Generic Specification for waste packages containing LHGW [20] defines maximum stack heights of 11 m for such waste packages emplaced using a stacker truck and 8.7 m if an overhead crane is used. The former would apply to waste packages manufactured using TDCs and the latter to waste packages containing repackaged DNLEU, if they rely on their design to withstand stacking loads[35].

6.1.4 Identification

The waste package shall enable unique identification until the end of a GDF operational period.

The waste package shall be marked at multiple defined locations with a unique alpha-numeric identifier.

The waste package shall remain identifiable by automated systems for a minimum period of 150 years following manufacture.

The application of a unique identifier enables the identification and tracking of every waste package throughout the different stages of its long-term management, and helps to ensure the permanent assignment of the appropriate data record to that waste package.

The use of a waste package identification system based on alpha-numeric identifiers ensures the maximum flexibility and capacity of a system which will need to be capable of ensuring that large numbers of waste packages, arising from multiple sites and packaging plants, will be handled safely and efficiently following receipt at a GDF.

For automated reading systems to operate effectively, multiple standardised locations are specified for identifiers. This will aid in the ease of reading by reducing the need for the waste package to be moved to facilitate identification of identifiers being obscured by handling equipment. It also provides redundancy in the event of damage to individual identifiers (for example that caused by corrosion) and will reduce the risk of waste packages becoming unidentifiable. Identifier locations are selected to ensure that the application of the identifiers does not compromise the durability of the integrity of the waste container (Section 6.1.5). This latter aspect is also a consideration when the method of applying identifiers is selected.

Making the identifier 'machine-readable' and the use of a format containing check digits allows the waste package to be identified remotely by automated systems and the veracity of its identifier confirmed. The use of a standard character set, such as OCR-A characters [35], of a specified size, permits waste package identification by either automated or direct visual (i.e. by human operators) means. The location of identifiers on a waste package should be such as to permit easy access by reading equipment at all stages during the handling of the waste package at a GDF.

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32 'Paragraphs' referred to in this way are direct references to the 2012 IAEA Transport Regulations.

33 This requirement applies to all transport packages unless their shape *'effectively prevents stacking'*.

34 This being the highest value, and thereby the most bounding case from the point of view of waste package stacking, for GDFs constructed in each of the generic host rock types considered by the GDFD.

35 The use of stillages for the stacking 500 litre drum waste packages obviates any stackability requirement.

Waste packages should remain identifiable at least until the time at which it is no longer readily available for inspection and identification, which could be the time at which it is surrounded by the backfill material or when the disposal area or the GDF as a whole has been closed. On the basis of current planning assumptions regarding when a GDF would be available to receive waste packages containing DNLEU for disposal (i.e. ~2100) and the anticipated closure of the GDF (assumed to commence in ~2190) [6], a minimum period of 150 years following their manufacture is defined as that for which waste package identification by way of its identifiers should be maintained. This period allows flexibility in the timing of waste package manufacture and disposal, and GDF closure.

Waste packages which are transport packages in their own right, such as those manufactured using TDCs, will also be required to bear identifiers (i.e. 'placarding') in accordance with the regulatory requirements for their transport.

6.1.5 Durability of waste container integrity

The waste package shall enable safe handling by way of its handling feature until the end of a GDF operational period.

The waste container shall maintain containment for as long as is required by a GDF safety case.

Integrity is defined as the ability of a waste container to provide containment of its contents and of a waste package to be safely handled and stacked. Two of the five operational safety functions defined for waste packages in the DSS are the need for containment and safe handling. These both rely heavily on the maintenance of waste container integrity for an appropriate period. Other safety functions, notably the ability of the waste package to withstand internal and external loads, will also rely at least in part on such integrity. The requirement for the durability of waste container integrity is therefore defined in terms of the period for which the waste container needs to maintain containment, the surety of its handling features, and its ability to withstand all anticipated loads, notably those resulting from stacking. The DSS also defines a number of environmental safety functions for the waste container (and in this case, the wasteform) in the post-closure period. These include containment of the waste and limiting the access of groundwater to the wasteform, which is identified as a means of delaying the release of radionuclides into the other components of the EBS.

Regulatory guidance on the conditioning and disposability of higher activity waste states that *'A minimum package lifetime of 150 years should be set for design purposes'* [36]. This period has been defined with the uncertainty of the date of the availability of a GDF in mind and to ensure that waste packages maintain their integrity during an extended period of on-site interim storage. The potential for retrieval of waste packages from a GDF for a period beyond the anticipated end of the operational period must be taken into account when defining the period over which the integrity of the waste container is required to be maintained. The DSS further requires that activities concerned with the development and implementation of geological disposal should be carried out in such a way that the option of retrievability is not foreclosed.

Whilst indefinite retention of all radionuclides is not the aim, the waste container should provide an effective barrier for a period that would permit short-lived radionuclides to decay to relatively insignificant levels before their release. The Generic Specification for LHGW requires that *'the integrity of the waste container should be maintained for a period of 500 years…'* partly to allow for the decay of water soluble radionuclides such strontium-90 and caesium-137 which are present in significant quantities in some ILW [20]. In the case of waste packages containing DNLEU, which predominantly contains relatively insoluble radionuclides with very long half-lives, retention until significant decay has occurred is not realistic. The quantities of short-lived radionuclides in DNLEU are very small and the benefit of their retention for a period running into a few centuries for post-closure safety would be limited.

The GDFD currently assumes that waste packages containing DNLEU will be emplaced during two 30 year periods commencing in 2110 and 2160, with the GDF entering the closure phase in ~2190 [6]. Accordingly waste packages manufactured in the period shortly before disposal, and using waste containers designed to retain integrity for a period of 150 years, would remain intact at least until the end of the GDF operational period. It should also be noted that work to consider the likely durability of stainless steel waste containers under GDF conditions concluded that containers designed to meet the durability requirement identified by regulatory guidance (i.e. 150 years), would be expected to maintain an appropriate level of integrity for at least 500 years [37].

6.2 Requirements for wasteforms

The properties of the wasteform shall be such that, in conjunction with those of the waste container, it satisfies all of the requirements for the waste package.

The properties of the wasteform shall comply with the requirements for containment within the geological disposal concept, as defined by a GDF safety case.

The physical, chemical, biological and radiological properties of the wasteform shall:

- **make an appropriate contribution to the overall performance of the waste package; and**
- **have no significant deleterious effect on the performance of the waste container.**

The wasteform should provide a stable, low-solubility matrix that limits the rate of release of the majority of radionuclides by dissolution in groundwater that may come into contact with the wasteform

Evolution of the wasteform shall not have a deleterious effect on the waste package properties that are necessary for safe transport and operations at a GDF.

Evolution of the wasteform shall not affect the ability of the waste package to maintain its environmental safety functions as specified in the DSS and drawn upon for post-closure performance, as set out in the ESC.

As discussed in Section 5.1, the required performance of a waste package will be provided by a combination of the properties of the waste container and the wasteform it contains. Waste packages manufactured using thin-walled waste containers may rely to a significant degree on the properties of the wasteform if they are to achieve the required performance. By contrast, when a more robust waste container is used, the wasteform will play a lesser role although this will not completely preclude the need for it to possess the properties required to ensure appropriate waste package performance.

The properties of the wasteform will play a key part in ensuring the passive safety of a waste package, irrespective of the nature of the waste container. Wastes should therefore normally be conditioned to reduce chemical reactivity and to satisfy some basic requirements as to their physical and biological properties. This should extend to ensuring the compatibility of the wasteform and the material from which the waste container is fabricated.

The two packaging options for DNLEU discussed in Section 5.4 (i.e. repackaging or overpacking) will result in two fundamentally different wasteforms in that for one the waste would be 'encapsulated' and for the other it would be 'non-encapsulated'. RWM has produced a specification for the properties of the wasteforms in waste packages containing LHGW [38], which is supported by guidance on the production of encapsulated and non-encapsulated wasteforms [39, 40]. Whilst this specification and guidance was not produced with DNLEU wasteforms in mind, the principles it contains are applicable to them. This notably includes the appropriate control of the quantities of some types of material, or of wasteform properties, that could affect the overall performance of the waste package or the other barriers that make up the geological disposal system. These comprise[36]:

- (Free liquids);
- Activity or hazardous materials in particulate form;
- Voidage;
- (In-homogeneity);
- (Reactive materials);
- Other hazardous materials[37]; and
- Materials that could have a deleterious effect on the other barriers that make up the geological disposal system.

The extent of the controls on these properties will be very dependent on the robustness of the waste container and the consequences of the presence of these materials and wasteform properties for waste package performance during transport and the GDF operational period. This would normally be assessed as part of the disposability assessment of a proposed waste package design. The issues that could arise for encapsulated and non-encapsulated DNLEU wasteforms are discussed below.

Activity or hazardous materials in particulate form

As discussed in Section 4.3 DNLEU currently exists as uranium oxide in a powder or granular form. Such materials would be expected to comprise a wide range of particle sizes, including some which would fall into the category of ‘activity in particulate form’. Historically it has been assumed that this should include all particles with sizes of up to 100μm, notably in connection with the performance of waste packages under impact accidents conditions. It was however acknowledged by RWM that this size range may be over conservative, especially when the conclusions of an International Commission on Radiological Protection study into the matter are considered [41]. As a means of justifying a reduction in this conservatism RWM has recently commissioned work to determine what constitutes a ‘respirable particle’ in the context of a GDF [42, 43] and this has led to a reduction in the maximum size of particles that need to be considered in GDF accidents to 10μm.

The issues arising from the presence of activity in particulate form are clearly more significant for a non-encapsulated wasteform and it would be expected that the use of a suitably formulated encapsulant would significantly reduce such issues. Notwithstanding the approach to the conditioning of ‘raw’ DNLEU, it will be necessary to demonstrate that the presence of particulates in the resulting wasteform does not result in unacceptable consequences for operational safety, notably following an impact or fire accident.

Voidage

Voidage within wasteforms can have a number of potential adverse effects for waste package performance, of which the following could be issues for waste packages containing DNLEU:

- Enhanced local corrosion of the waste container material and potential loss of container integrity;

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[36] The three properties shown in parentheses are not expected to associated with DNLEU in the form covered by this Generic Specifications (i.e. uranium oxide in powder form).

[37] Hazardous materials include flammable, explosive, pyrophoric, chemically toxic and oxidising materials.

- Reduction in wasteform and waste package strength;
- Reduced confidence in the predictability of waste package performance under accident conditions; and
- Long-term slumping/subsidence of waste packages in the GDF post-closure period.

Voidage can take one or both of two main forms, as porosity resulting from the physical form of a wasteform or 'open' voidage resulting from discrete unfilled spaces within the waste package.

For a non-encapsulated DNLEU wasteform, the volume of porosity or 'micro-voidage' could be significant, its extent depending largely on the morphology of the uranium oxide particles. For encapsulated DNLEU, a suitably formulated and manufactured wasteform will significantly reduce such voidage and this would be limited to the porosity of the resulting wasteform.

The use of a conditioning process involving the repackaging of DNLEU (e.g. mixing the uranium oxide with a cementitious grout) would also have the effect of significantly reducing open voidage when compared with that which is assumed to be present in the DNLEU as currently packaged for storage. Overpacking of the existing or planned storage packages in a TDC (e.g. Figure 6) would result in the creation of additional voidage within the waste packages, unless the TDC was to be back-filled in some way.

Quantitative limits for acceptable voidage have not yet been adopted by RWM and it is likely that all accessible voids in waste packages destined for disposal in a GDF constructed in HSR, or some LSSR, will have to be filled with a suitable material.

Other hazardous materials

No significant quantities of 'other' hazardous materials (i.e. apart from uranium) are expected to be present in DNLEU from the anticipated sources, although limited quantities of process residues such as HF, UO_2F_2, may be present in DNLEU arising from the de-conversion of UF_6.

Materials that could have a deleterious effect on the other barriers that make up the geological disposal system.

A number of materials, notably organics, if present in a wasteform could have a significant effect on the post-closure migration of radionuclides from a GDF. The degradation of materials such as PVC and cellulose has been shown to produce chemical species that act as complexants, which can increase the solubility of some radionuclides and reduce the sorption capacity of the backfill and the geological barrier.

It would be impractical to eliminate all organic materials from a GDF, but wherever possible the quantity of organic materials in waste should be minimised to restrict the potential for the generation of complexants and other chemicals that could threaten the long-term performance of the disposal system. It is known that some DNLEU products will contain polymeric materials in the form of bags and their presence will have to be addressed if these products are to be overpacked.

Wasteform evolution

Evolution of the wasteform, resulting from chemical, biological and/or radiation-induced processes will change the properties of the wasteform with time. It is important that such evolution does not result in changes that render the waste package incompatible with the needs of transport or the requirements for safety in the GDF operational period.

In the post-closure period the wasteform may continue to play a role in the overall safety of a GDF. The DSS defines a single environmental safety function for wasteforms requiring them to '*provide a stable, low-solubility matrix that limits the rate of release of the majority of radionuclides by dissolution in groundwater that comes into contact with the wasteform'.*

Accordingly, the consequences of evolution should be such that the wasteform will continue to make an appropriate contribution to the overall performance of the waste package, and to the geological disposal system as a whole. It is noted that the solubility of uranium oxides in neutral to alkaline groundwater (i.e. pH in the range 7 to 12) is low and whilst the high surface area of oxide in powder form will tend to maximise dissolution, the release of uranium from waste packages will ultimately be controlled by its solubility in groundwater.

In relation to the performance of the waste container, consideration should be given to the potential for chemical reactions between the wasteform and the inner surfaces of the waste container and/or expansive corrosion of components of the waste that could result in forces being exerted on the waste container. The two main chemical forms of DNLEU (i.e. U_3O_8 and UO_3) are expected to be benign in this respect, although their long-term evolution, and the possible effects of this for the EBS, is yet to be fully understood.

6.3 Requirements for waste packages

6.3.1 Activity content

The activity content of the waste package shall be controlled to comply with the radionuclide related assumptions that underpin the safety cases for transport and a GDF operational period.

The contents of waste packages shall be capable of being categorised as low specific activity (LSA) material or as surface contaminated objects (SCO).

The allowable activity content of waste packages may be limited by one or more of a number of radionuclide-related parameters which are dealt with separately in this Generic Specification. These comprise:

- External dose rate (Section 6.3.3)
- Heat output (Section 6.3.4)
- Release of activity in gaseous form (Section 6.3.6)
- Criticality safety (Section 6.3.7)
- Accident performance (Section 6.3.8)

The IAEA Transport Regulations define explicit limits for the activity contents of different types of transport package.

The contents of Industrial Packages must comply with the activity limits and other requirements defined for LSA material and SCOs. Paragraph 409 defines the various requirements for the physical properties and activity concentrations of three categories of LSA material. Of particular relevance to the transport of DNLEU is LSA-I which includes unirradiated natural uranium and depleted uranium and other materials with very limited specific activity. Materials with higher specific activity (i.e. up to $2 \times 10^{-3}\ A_2g^{-1}$) can be transported as LSA materials provided that additional requirement on their physical form and the homogeneity of the activity they contain can be satisfied.

It is important to note that whilst the two predominant isotopes of uranium (i.e. uranium-235 and uranium-238) have ‘unlimited’ A_2 values, and would therefore not be included in the determination of the activity content of material that could be defined as LSA material, others radionuclides (notably uranium-236 and other trace contaminants[38] that could be

[38] Such as fission products and transuranics - see Section 4.3.

present in DNLEU) have finite A_2 values and this may affect the ability of some types of DNLEU (i.e. MDU and TPU) to satisfy the definition of LSA material[39].

The radiological properties of DNLEU are such that it is likely that it can satisfy the requirement for LSA material (see below) and that all waste packages containing DNLEU will be capable of being transported as Industrial Packages (i.e. Type IP or Type IF, see Section 5.2).

Paragraph 241 defines a SCO as *'a solid object which is not itself radioactive but which has radioactive material distributed on its surfaces'*. Bulk DNLEU in the forms described in Section 4.3 would therefore not qualify as a SCO.

6.3.2 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.

The gross mass of a transport package should not exceed 65 t.

The maximum gross mass of waste packages must be such that will permit them to be safely and efficiently handled using the systems defined for transport to, and emplacement in, a GDF. The gross masses of transport packages must also be compatible with the UK transport infrastructure such that no undue limits are placed on the mode of transport that can be used (i.e. by road, rail, sea or inland waterway).

The GDFD [6] currently includes a number of assumptions regarding the safe working loads for a GDF lifting and handling equipment. This includes a capability to transfer underground and subsequently handle transport packages with gross masses (including any handling equipment such as lifting frames) of up to 80 t.

For waste packages which are transport packages in their own right, emplacement is assumed to be by the use of a stacker truck with a safe working load of 65 t. For waste packages transported within transport containers the lifting and handling equipment used to remove waste packages from the transport container and emplace them may place a more onerous limit on gross mass.

The GTSD [7] currently assumes the use of a four-axle rail wagon (which could be used on a large proportion of the UK rail network) for transport packages, which would limit the gross mass of transport packages to ~65 t[40]. The possibility does exist for the use of eight-axle rail wagons capable of carrying greater loads but these may only be suitable for use on a reduced proportion of the rail network.

For transport by road, the maximum permitted laden mass of an ordinary heavy goods vehicle (HGV) is 44 t which, when an allowance is made for the mass of the vehicle itself, sets a limit of ~30 t for the load. Transport packages with gross masses of greater than 30t will require special transport arrangements and there may therefore be operational benefits in maintaining transport package masses below this value.

The above limits apply directly to waste packages which are transport packages in their own right, such as those manufactured using a TDC. For waste packages transported within a reusable transport container, the mass of such a container will have to be deducted from the 65 t transport package limit. Of the three variants of the SWTC currently under development by RWM, the SWTC-70[30] has the smallest tare mass (18 t) and is

[39] All of the MDU and TPU produced to date is capable of satisfying the requirements for LSA-II material.

[40] This value is equal to the maximum permitted gross mass of such a wagon (90 t) less the estimated mass of the unladen 4-axle rail wagon (~25 t).

designed to carry payloads of up to 12t. The maximum gross mass of such a transport package would permit transport by road using an ordinary HGV.

6.3.3 External dose rate

The external dose rate from the waste package shall enable safe handling of the waste package during transport and a GDF operational period, and shall comply with regulatory limits for transport.

The external dose rate of the waste package shall be compatible with the dose rate at 2 metres from any external surface of a transport package, under routine conditions of transport, not exceeding 0.1 mSvh^{-1} and the dose rate on its external surface not exceeding 10 mSvh^{-1}.

The IAEA Transport Regulations (Paragraph 573) define limits for the external dose rate from transport packages carried under the conditions of exclusive use. These require that the external dose rates of transport packages[41] shall not exceed:

- 10 mSvh^{-1} on the external surface; and
- 0.1 mSvh^{-1} at 2 m from the external surface.

These limits are applied directly to all waste packages transported without additional radiation shielding and indirectly to waste packages carried in transport containers, in which case they apply to the external surfaces of the transport package. The radiological properties of most DNLEU (i.e. most uranium isotopes being predominantly alpha-emitters and the quantities of beta/gamma emitters in DNLEU are expected to be small) are such that these limits are unlikely to be exceeded in practice.

Radiation exposure of workers can also occur at other stages during the long-term management of DNLEU. This notably includes operations at the site of arising of the material (i.e. storage and packaging), and at a GDF (i.e. emplacement and other operations prior to disposal vault closure), both of which take place over a significantly longer period of time than transport. Accordingly ALARP arguments will have to be made regarding radiation dose over the full period of the long-term management of DNLEU.

6.3.4 Heat output

The heat generated by the waste package shall be controlled to ensure that:

- ***thermal effects result in no significant deterioration in the properties of the wasteform, the performance of the waste package, or of the disposal system as a whole; and***
- ***regulatory limits on the surface temperature of transport packages are not exceeded.***

Excessive heat generation by waste packages has the potential to result in damage to the waste package and could affect the performance of the geological disposal system as a whole by causing damage to other barriers.

Damage to waste packages, notably as a result of heat-accelerated corrosion of either the waste container or components of the wasteform, could result in an unacceptable degradation of the performance of waste packages.

41 The limits actually apply to the external surfaces of the vehicle transporting the packages. In the absence of knowledge regarding the design of any such vehicle, the values are conservatively applied directly to the transport packages.

No limits on heat output or external surface temperature are defined for Industrial Packages by the IAEA Transport Regulations although there are additional operational controls for the stowage and storage of transport packages that have an average surface heat flux of greater than 15 Wm^{-2} (Paragraph 565).

The heat output limits for waste packages will depend on the disposal concept. As an example the DSS defines a target of 80°C for the maximum temperature within ILW disposal vaults during the operational period and uses the same temperature as a target for the peak value for limiting damage to the EBS in the post-closure period. Thermal modelling of a range of possible disposal vault designs has shown that the temperature targets for both the operational and post-backfilling periods would not be threatened by average heat output (i.e. for all of the waste packages in a vault) of 6 Wm^{-3} [44].

The heat output from waste packages containing DNLEU will generally be small (the radiogenic heat output of natural uranium is ~0.01 Wte^{-1}). Accordingly neither the regulatory limits specified for transport, nor the 6 Wm^{-3} screening level defined for the GDF post-closure period are likely to be challenged by waste packages containing DNLEU.

6.3.5 Surface contamination

The non-fixed[42] surface contamination of the waste package shall be as low as reasonably practicable and shall comply with regulatory limits for transport.

For waste packages which are transport packages in their own right the non-fixed surface contamination, when averaged over an area of 300 cm^2 of any part of the surface of the waste package, shall not exceed:

- **4.0 $Bqcm^{-2}$ for beta, gamma and low toxicity alpha emitters[43]; and**
- **0.4 $Bqcm^{-2}$ for all other alpha emitters.**

For waste packages transported inside transport containers the non-fixed surface contamination, when averaged over an area of 300 cm^2 of any part of the surface of the waste package, should not exceed:

- **4.0 $Bqcm^{-2}$ for beta, gamma and low toxicity alpha emitters; and**
- **0.4 $Bqcm^{-2}$ for all other alpha emitters.**

Limits on the non-fixed surface contamination of waste packages are specified to ensure that:

- Regulatory limits are achieved for waste packages which are transported without additional protection;
- Contamination of transport and GDF systems can be maintained at appropriate levels; and
- Routine doses to workers and the members of the public will be ALARP and in accordance with good industry practice.

The limits specified are those defined in Paragraph 507 for the non-fixed surface contamination of transport packages and therefore are applied directly to all waste packages transported without additional protection.

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42 Non-fixed contamination is defined by the IAEA Transport Regulations (Paragraph 215) as '…*contamination that can be removed from a surface during routine conditions of transport*'.

43 Low toxicity alpha emitters are defined by the IAEA Transport Regulations (Paragraph 227) as *'…natural uranium; depleted uranium; natural thorium; uranium-235 or uranium-238; thorium-232; thorium 228 and thorium-230 when contained in ores or physical and chemical concentrates; or alpha emitters with a half-life of less than 10 days'.*

The same limits are also used as targets for the non-fixed contamination of all waste packages on the basis that they represent realistic and achievable levels and will reduce any potential requirement for the decontamination of the internal surfaces of transport containers and the areas of a GDF where 'bare' waste package are handled.

Most of the material described as DNLEU will be classed as containing 'low toxicity alpha emitters' and therefore the higher surface contamination limits will apply (i.e. 4.0 $Bqcm^{-2}$). Such levels should be readily achievable during waste package manufacture and maintained during interim storage. In view of the large numbers of waste packages containing DNLEU that could require disposal, possible issues arising from the chemotoxic effects of the surface contamination of waste packages will need to be considered, particularly during the GDF operational period. This issue has the potential to require lower surface contamination limits, defined in terms of mass per unit area rather than activity per unit area as defined above and in the Transport Regulations.

6.3.6 Gas generation

The generation of bulk, radioactive and toxic gases by the waste package shall comply with the requirements for safe transport and disposal.

The release of radionuclides in gaseous form from the waste package shall comply with the assumptions that underpin the safety cases for transport and a GDF operational period.

Gases generated by waste packages should not result in the release of radionuclides, in gaseous or particulate form, from the transport package under normal conditions of transport exceeding 10^{-6} A_2 per hour.

The generation of gases by the contents of waste packages can give rise to a range of potential effects that may have an influence on all periods of the long-term management of waste packages. In the early stages of their management (i.e. during transport and the GDF operational period) , these potential effects include pressurisation and damage to waste containers and wasteforms, pressurisation of sealed transport containers, and the release of radioactive, toxic and flammable gases from waste packages and transport packages. After closure of a GDF, gas generation has the potential to cause pressurisation and damage to the EBS and host rocks leading to the potential modification of groundwater flow patterns, and the rate of re-saturation of disposal vaults and/or mineralogical changes to backfill material.

Sealed waste packages, or sealed containers within a waste package, that have attained, or are likely to attain, an internal pressure of 0.5 bar (50 kPa) greater than atmospheric pressure will be subject to the Pressure Systems Safety Regulations (PSSR) [45].

The IAEA Transport Regulations (Paragraph 624) require Type IP-2 transport packages to be sufficiently robust to withstand NCT without suffering a *'loss or dispersal of the radioactive contents*[44]*'*. The magnitude of such a loss is not quantified and RWM has conservatively decided to apply the limit of $10^{-6}A_2$ per hour for the loss of radioactive contents from Type B transport packages under NCT (Paragraph 659) to Type IP transport packages.

This limit would equally apply to transport packages comprising of repackaged or overpacked DNLEU although it is unlikely to be approached in either case due to the low potential for gas generation by uranium oxide and the very small A_2 content of the waste packages.

[44] The 'radioactive contents' includes both radioactive gases and activity in particulate form which may be entrained in non-radioactive gases).

During the operational period of a GDF the ventilation system will prevent unsafe accumulations of toxic, asphyxiating, radioactive, flammable or explosive gases within the disposal vaults and associated facilities by managing them to safe concentrations and discharging them to the atmosphere. However, the potential for the accumulation of flammable and/or explosive mixtures within waste packages will need to be considered.

In the post-closure period the migration of gases from the disposal vaults is one of the main potential pathways by which radionuclides might be released to the accessible environment. Gases produced by waste packages in this period could thus affect post-closure safety, if the potential for their generation is not managed appropriately at the packaging stage.

The release of activity in gaseous form from waste packages has the potential to cause on-site and off-site dose during both the GDF operational and post-closure periods. The ESC [11] identifies hydrogen-3, carbon-14 and radon-222 as the three most significant radionuclides that could be released from waste packages in gaseous form in such a manner that could lead to off-site dose. The generic Operational Environmental Safety Assessment [46] uses a value of 0.01 mSv/year (derived from the 2009 Statutory Guidance to the Environment Agency [47]) as a target for the maximum dose to the most exposed group of members of the public due to routine discharges from a GDF during the operational period; this is a factor of 15 times lower than the dose limit established by the environment agencies in the Guidance on Requirements for Authorisation [48].

Gases can be generated by wasteforms by a number of different mechanisms including radioactive decay, radiolysis, corrosion and processes that result in the release of entrained radioactive gases from waste. The physical, chemical, biological and radiological properties of the wastes covered by this Generic Specification are such that the potential for gas generation by waste packages is small, and there are only a limited number of gas generation mechanisms that need to be considered:

- The generation of radon-222[45], produced by the radioactive decay of radium-226, a daughter product of uranium-238 (and uranium-234). The purification of uranium ore following mining will remove the naturally occurring radium-226 and the creation of 'new' radium-226 is a very slow process. As a consequence, the release of radon-222 from waste packages containing DNLEU will not constitute a safety issue for transport or the GDF operational period. For the post-closure period, the potential impacts of radon-222 generated in the biosphere from the decay of radium-226 will need to be considered.
- The production of inactive hydrogen from the corrosion of ferrous materials, notably used in the fabrication of waste containers, which could constitute a fire or explosion hazard. The production of hydrogen from waste container corrosion is an issue already considered as part of the disposability assessment of packaging proposals for ILW, and a simple model[46] exists to quantify the extent of such generation.

[45] Other isotopes of radon will also be generated by DNLEU (i.e. radon-219 from uranium-235 and radon-220 from uranium-236) but their rates of generation will be very small and the half lives so short that they will not constitute a safety issue during the transport or disposal of DNLEU.

[46] The *Simplified Model of Gas Generation* (SMoGG).

6.3.7 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; and***
- ***in a GDF post-closure period both the likelihood and the consequences of a criticality are low.***

The uranium-235 content of the uranium in the waste should not exceed 1%.

The quantities of fissile material, neutron moderators and reflectors in the waste package shall be controlled to ensure that the transport package satisfies the criticality safety requirements of the IAEA Transport Regulations.

The passive criticality safety of waste packages is generally achieved by controlling the quantities of fissile material and of neutron moderating and reflecting materials[47] they contain, such that criticality cannot occur under all credible conditions during their long-term management. This relies on determining the limiting quantities of fissile materials in a waste package that will satisfy the criticality safety requirements for transport, and the operational and post-closure periods of a GDF, and ensuring that this quantity is not exceeded during waste package manufacture.

Due to the relatively low concentrations of fissile radionuclides (i.e. uranium-235), and the presence of large quantities of neutron poisons (i.e. uranium-238), criticality safety is not an issue for the transport and disposal of waste packages covered by this Generic Specification.

With specific regard to transport, all packages containing natural or depleted uranium that is either unirradiated or irradiated in a thermal reactor (i.e. such as a Magnox power station) will be capable of being excepted from the IAEA Transport Regulations requirements for packages containing fissile material on the basis that such materials are not classed as 'fissile material' (Paragraph 222). RWM has produced detailed guidance on the manner in which the fissile exceptions can be applied to waste packages containing limited quantities of fissile nuclides [49].

Uranium with a uranium-235 content of up to 1% can be excepted provided that the mass of uranium-233 and plutonium is less than 1% that of uranium-235 and that the fissile nuclides are *'distributed essentially homogeneously throughout the material'* (Paragraph 417(a)). For uranium with higher uranium-235 contents exception can be achieved for packages containing limited quantities of such material without Competent Authority approval (Paragraphs 674 and 675).

For packages that cannot be so excepted, and therefore not capable of being transported as Type IP transport packages, the requirements of Paragraph 673 apply. This allows for a criticality safety case to be made for waste packages transported as Type IF transport packages.

Limits on the fissile material contents of waste packages will also be dependent on the disposal concept (notably the design of the waste package) and the nature of the fissile material (e.g. the proportions of different fissile nuclides present). The screening level methodology developed for waste packages containing ILW could be applied to those containing DNLEU and, on the basis that the wastes would be well characterised, could be

[47] In general, the materials of interest are water, graphite, deuterated compounds and beryllium.

used to define fissile material limits which satisfy the requirements for criticality safety during the GDF operational and post closure periods, without being over-restrictive.

During the development of proposals to package DNLEU, waste packagers will be required to demonstrate that the requirement for the criticality safety of the proposed waste packages will be satisfied in practice. To this end, and as part of a submission for the disposability assessment of the proposed waste packages, the waste packager will need to produce *Criticality Compliance Assurance Documentation* (CCAD). The CCAD will need to consider the quantity and form of the fissile materials in a waste stream, identify and justify a suitable safe fissile mass and define the procedural controls that will be put in place to ensure that the relevant limits on fissile material, and neutron moderators and reflectors, will not be exceeded during the packaging of the waste. Guidance is available on the requirements for and preferred format of CCAD [50].

6.3.8 Accident performance

Under all credible accident scenarios the release of radionuclides and other hazardous materials from the waste package shall be low and predictable.

The waste package should exhibit progressive release behaviour within the range of all credible accident scenarios.

The impact and fire accident performance of the waste package shall comply with the assumptions that underpin the safety cases for transport and a GDF operational period.

The accident performance of the waste package shall ensure that, in the event of any credible accident during a GDF operational period, the on-site and off-site doses resulting from the release of radionuclides from the waste package shall be as low as reasonably practicable and should be consistent with meeting the relevant Basic Safety Levels.

Waste packages may be subject to a range of accident conditions during their long-term management, up until the end of the GDF operational period. Such accidents, which notably include impacts and fires, are a potential mechanism for the release of radionuclides from waste packages into the environment. Waste packages must be capable of complying with the assumptions that are made in the safety cases for transport and the GDF operational period regarding their performance in response to specified accident scenarios. Additionally the impacts on workers and members of the public resulting from the release of radionuclides and other hazardous materials from waste packages as a consequence of accidents must be ALARP and less than the relevant regulatory limits.

The magnitude of the mechanical, thermal and other challenges that could result from accidents at a GDF will vary depending on the design of the facilities, and the manner in which the facility is operated. The response of waste packages to the full range of such challenges should be 'progressive' in that there should be no significant 'cliff-edge' effects where a small increase in the magnitude of the challenge would produce a large deterioration in waste package performance.

The IAEA Transport Regulations define 'accident conditions of transport' (ACT) as the basis for demonstrating the ability of transport packages to withstand impact and fire accidents during transport without causing excessive exposure of transport workers or members of the public to radionuclides released during such accidents.

The IAEA Transport Regulations do not define ACT for Type IP transport packages, safety under accident conditions being conferred on such transport package by the controls on the form, activity and fissile material content of the contents of the package. For waste packages transported as Type IF transport packages, there will be a requirement for the required degree of criticality safety to be maintained under defined ACT.

During the GDF operational period, the potential exists for a range of accidents which could result in damage to waste packages, the release of radionuclides and radiation dose to workers on-site and/or members of the public off-site. As well as requiring that the doses resulting from accidents in which radionuclides are released are ALARP, the ONR *Safety Assessment Principles* (SAPs) [51] define Basic Safety Objectives (BSOs) for the cumulative annual on-site and off-site doses due to accidents on nuclear sites. The SAPs also define Basic Safety Levels (BSLs) as targets for the maximum on-site and off-site dose that could result from release of radionuclides as a result of design basis accidents, on the basis of the expected frequency of the initiating event that would result in such an accident.

The assessment of operational safety in the generic OSC includes both deterministic, design basis analysis (DBA), and probabilistic elements [10]. The purpose of DBA is to provide a robust demonstration of the fault tolerance of the engineering design and the effectiveness of the safety measures. DBA should be carried out as part of the engineering design and performed on a conservative basis. DBA should demonstrate, as far as is reasonably practicable, that:

- None of the physical barriers to prevent the escape or relocation of a significant quantity of radioactivity is breached or, if any are, then at least one barrier remains intact and without a threat to its integrity;
- There is no release of radioactivity; and
- No person receives a significant dose of radiation.

Below the BSL, doses (or risks) are tolerable only if they have been reduced to levels which are ALARP. However, in meeting the BSLs doses or risks may not necessarily be ALARP, so the ALARP principle needs to be applied throughout the development of the GDF design to identify reasonably practicable means of reducing doses (or risks) still further.

As in the case of surface contamination, the chemotoxicity of uranium, and any other toxic materials that may be present (e.g. fluorine compounds[48]), needs to be considered in the analysis of the consequences of accidents resulting in the release of the contents of waste packages containing DNLEU.

6.4 Requirements for the manufacture and storage of waste packages

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.

6.4.1 Quality management

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.

All activities relevant to the licensing and permitting of a GDF will be conducted in accordance with appropriate quality management arrangements. The objective in establishing and operating a quality management system is to provide an integral

[48] Such as HF and UO_2F_2 resulting from the de-conversion of UF_6.

framework of procedures that ensure that the work is adequately controlled, documented and recorded. It is the responsibility of the waste packager to develop, operate and maintain appropriate quality management arrangements for all aspects of the retrieval and packaging of waste and the interim storage of waste packages. As a minimum, all quality management systems shall comply with BS EN ISO9001 [52] and should comply with the relevant RWM specification [53] and its supporting guidance [54].

6.4.2 Waste package data and information recording

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.

Information shall be recorded regarding the quantity of all radionuclides of relevance to the safe transport and disposal of the waste package.

Compliance with the various regulations that apply to the transport and disposal of radioactive waste will rely in part on the existence of appropriate records regarding all relevant aspects of waste package manufacture, notably information regarding their radionuclide inventory. The recording of such data and information should be carried out in accordance with the RWM specification [55].

Not all of the radionuclides that could be present in the wastes to which this Generic Specification applies will have relevance to the safety of long-term management of those wastes. A methodology has been developed for the identification of those radionuclides which have relevance to the safety of the geological disposal of ILW [56]. Whilst this methodology was not developed with DNLEU in mind, the principles it enshrines are broadly applicable to the disposal of DNLEU.

Waste packagers will be required to identify which of those radionuclides will be present in the waste to be packaged at levels which will require their quantities to be determined and recorded during waste package manufacture.

6.4.3 Requirements for waste packages containing nuclear material

The management of waste packages containing nuclear material shall comply with all relevant international safeguards obligations and security requirements for their transport and disposal.

All of the wastes to which this Generic Specification applies will contain radionuclides that are described as 'nuclear materials' (NM)[49]. All operations involving NM are subject to regulatory control and, from the viewpoint of the long-term management of wastes containing NM, this will include retrieval from storage, packaging, and the interim storage, transport and disposal of waste packages. Waste packagers will be required to address all of the requirements for NM accountancy and the security of NM up to the point of their receipt at the GDF site and also will need to ensure that appropriate records are available to permit RWM to assume responsibility for the NM in waste packages from that point.

International safeguards

The safeguards status of any nuclear material contained within the waste package shall be ascertained and recorded.

Packaged wastes that contain NM derived from the UK civil nuclear programme may be subject to controls known as 'safeguards' allowing independent verification by international

[49] NM is generally defined as material containing plutonium, uranium, neptunium, americium, and thorium.

nuclear safeguards inspectorates (i.e. Euratom and the IAEA) to confirm that nuclear material has not been diverted from peaceful use.

In order that the contents of waste packages that contain safeguarded materials can be fully verified, Site License Companies are required to provide sufficient information on the quantity, nature and status of all safeguarded material that will be incorporated into proposed waste packages.

The IAEA has published an overview of the techniques and equipment underlying the implementation of IAEA safeguards, including those used for NM accountancy, containment and surveillance measures, environmental sampling, and data security [57]. The HSE has also produced guidance on good practice for NM accountancy and safeguards on nuclear licensed sites [58].

From the point of view of safeguards, DNLEU with a uranium-235 of less than natural uranium is *'source material'* and that with a higher uranium-235 concentration is *'special fissile/fissionable material'*. DNLEU arising from processes involving the civil use of uranium will be subject to safeguards, whereas that arising from military uses may not be. It is expected that DNLEU will remain 'on inventory' at the site of storage until it is transported to a GDF, at which time it will be transferred to the GDF site inventory.

Physical protection nuclear security

The quantity of nuclear material contained within the waste package shall be controlled such that the waste package can be transported subject to standards of physical protection no higher than those defined for the transport system.

The Nuclear Industries Security Regulations 2003 (NISR) lay down the requirements for security of nuclear premises, security of transport of NM and security of sensitive nuclear information. The ONR has issued National Objectives, Requirements and Model Standards (NORMS) for the protective security of civil licensed nuclear sites, other nuclear premises and NM in transit [59] to support implementation of the NISR.

The security standards in NORMS are offered as a benchmark (i.e. Model Standard) to reflect internationally agreed recommendations on the physical protection of NM published by the IAEA [60]. IAEA guidance on the physical protection of NM [61], which accords with NISR in this regard, specifies mass limits for the quantities of NM that can be transported with four 'categories' of physical protection (Categories I to IV, Category I being the most restrictive).

The transport of waste packages containing DNLEU will be subject to the NISR. For DNLEU with a uranium-235 content of no more than 0.711% (i.e. natural uranium) Category IV standard of protection will be required. This will rise to Category III for DNLEU with a uranium-235 content of greater than 0.711%.

7 Summary

This Generic Specification defines requirements for waste packages containing DNLEU that will be the subject of geological disposal. These requirements derive directly from the application of the high-level requirements defined by the GWPS to the waste packages containing such wastes.

The form of this Generic Specification is to define bounding requirements for waste packages such that it can be used as the basis for the development of proposals to package DNLEU using a limited range of waste containers and approaches to packaging. To assist in the development of such proposals users are referred to the WPSGD, specifically to the guidance which explains the basis for the derivation of the packaging requirements and the manner in which they can be achieved for practical packaging projects.

This Generic Specification provides a baseline for the conduct of Conceptual stage disposability assessments of proposals to package DNLEU for geological disposal.

This Generic Specification also provides the basis for the definition of the WPS which define the requirements for waste packages manufactured using a standardised design of waste container and containing DNLEU.

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Appendix A Glossary of terms used in this document

activity

The number of atoms of a radioactive substance which decay by nuclear disintegration each second. The SI unit of activity is the becquerel (Bq) equal to one radioactive decay per second.

The IAEA Transport Regulations define a unit of activity, the A_2, as a means of standardising the dose consequences of different radionuclides on the basis of the different possible exposure pathways that could occur following the release of radionuclides from a transport package. A_2 values (in TBq) for a wide range of radionuclides are listed in Table 2 of the IAEA Transport Regulations [24].

alpha activity

Alpha activity takes the form of particles (helium nuclei) ejected from a decaying (radioactive) atom. Alpha particles cause ionisation in biological tissue which may lead to damage. The particles have a very short range in air (typically about 5cm) and alpha particles present in materials that are outside of the body are prevented from doing biological damage by the superficial dead skin cells, but become significant if inhaled or swallowed.

backfill

A material used to fill voids in a GDF. Three types of backfill are recognised:

- local backfill, which is emplaced to fill the free space between and around waste packages;
- peripheral backfill, which is emplaced in disposal modules between waste and local backfill, and the near-field rock or access ways; and
- mass backfill, which is the bulk material used to backfill the excavated volume apart from the disposal areas.

backfilling

The refilling of the excavated portions of a disposal facility after emplacement of the waste.

barrier

A physical or chemical means of preventing or inhibiting the movement of radionuclides.

beta activity

Beta activity takes the form of particles (electrons) emitted during radioactive decay from the nucleus of an atom. Beta particles cause ionisation in biological tissue which may lead to damage. Most beta particles can pass through the skin and penetrate the body, but a few millimetres of light materials, such as aluminium, will generally shield against them.

buffer

An engineered barrier that protects the waste package and limits the migration of radionuclides following their release from a waste package.

conditioning

Treatment of a radioactive waste material to create, or assist in the creation of, a wasteform that has passive safety *containment*

The engineered barriers, including the waste form and packaging, shall be so designed, and a host geological formation shall so be selected, as to provide containment of the waste during the period when waste produces heat energy in amounts that could adversely affect the containment, and when radioactive decay has not yet significantly reduced the hazard posed by the waste

criticality

A state in which a quantity of fissile material can maintain a self-sustaining neutron chain reaction. Criticality requires that a sufficiently large quantity of fissile material (a critical mass) be assembled into a geometry that can sustain a chain reaction; unless both of these requirements are met, no chain reaction can take place and the system is said to be sub-critical.

criticality safety

A methodology used to define the conditions required to ensure the continued sub-criticality of waste containing fissile material.

disposability

The ability of a waste package to satisfy the defined requirement for disposal.

disposability assessment

The process by which the disposability of proposed waste packages is assessed. The outcome of a disposability assessment may be a Letter of Compliance endorsing the disposability of the proposed waste packages.

disposal

In the context of solid waste, disposal is the emplacement of waste in a suitable facility without intent to retrieve it at a later date; retrieval may be possible but, if intended, the appropriate term is storage.

disposal facility (for solid radioactive waste)

An engineered facility for the disposal of solid radioactive wastes.

disposal system

All the aspects of the waste, the disposal facility and its surroundings that affect the radiological impact.

dose

A measure of the energy deposited by radiation in a target.

dose rate

The effective dose equivalent per unit time. Typical units of effective dose are sievert/hour (Svh^{-1}), millisieverts/hour ($mSvh^{-1}$) and sievert/year (Svy^{-1}).

emplacement (of waste in a disposal facility)

The placement of a waste package in a designated location for disposal.

Environment Agency (EA)

The environmental regulator for England and Wales. The Agency's role is the enforcement of specified laws and regulations aimed at protecting the environment, in the context of sustainable development, predominantly by authorising and controlling radioactive discharges and waste disposal to air, water (surface water, groundwater) and land. The Environment Agency also regulates nuclear sites under the Environmental Permitting Regulations and issues consents for non-radioactive discharges.

environmental safety case

The collection of arguments, provided by the developer or operator of a disposal facility, that seeks to demonstrate that the required standard of environmental safety is achieved.

fertile material

Fertile material is that which is not naturally fissionable but which, following neutron irradiation, can be converted into fissile material. The most significant fertile materials are uranium-238 which can be converted into plutonium-239 and thorium-232 which can be converted into uranium-233.

fissile material

Fissile material is that which undergoes fission under neutron irradiation. For regulatory purposes material containing any of the following nuclides is considered to be 'fissile': uranium-233, urainium-235, plutonium-239 and plutonium-241.

fission

The splitting of a heavy nucleus into two lighter nuclei, accompanied by the release of energy and, generally, a number of neutrons. Fission can occur spontaneously but is usually caused by the absorption of a neutron by the fissioning nucleus.

gamma activity

An electromagnetic radiation similar in some respects to visible light, but with higher energy. Gamma rays cause ionisations in biological tissue which may lead to damage. Gamma rays are very penetrating and are attenuated only by shields of dense metal or concrete, perhaps some metres thick, depending on their energy. Their emission during radioactive decay is usually accompanied by particle emission (beta or alpha activity).

geological disposal

A long term management option involving the emplacement of radioactive waste in an engineered underground geological disposal facility or repository, where the geology (rock structure) provides a barrier against the escape of radioactivity and there is no intention to retrieve the waste once the facility is closed.

geological disposal facility (GDF)

An engineered underground facility for the disposal of solid radioactive wastes.

half-life

The time taken for the activity of a given amount of a radioactive substance to decay to half of its initial value. Each radionuclide has a unique half-life.

hazardous materials

Materials that can endanger human health if improperly handled. As defined by the Control of Substances Hazardous to Health Regulations, 2002.

Health and Safety Executive (HSE)

The HSE is a statutory body whose role is the enforcement of work-related health and safety law. HSE is formally the licensing authority for nuclear installations in Great Britain, although the licensing function is administered on HSE's behalf by its executive agency the ONR.

higher activity radioactive waste

Generally used to include the following categories of radioactive waste: low level waste not suitable for near surface disposal, intermediate level waste and high level waste.

high level waste (HLW)

Radioactive wastes in which the temperature may rise significantly as a result of their radioactivity, so this factor has to be taken into account in the design of storage or disposal facilities.

immobilisation

A process by which the potential for the migration or dispersion of the radioactivity present in a material is reduced. This is often achieved by converting the material to a monolithic form that confers passive safety to the material.

intermediate level waste (ILW)

Radioactive wastes exceeding the upper activity boundaries for LLW but which do not need heat to be taken into account in the design of storage or disposal facilities.

International Atomic Energy Agency (IAEA)

The IAEA is the world's centre of cooperation in the nuclear field. It was set up as the world's "Atoms for Peace" organization in 1957 within the United Nations family. The Agency works with its Member States and multiple partners worldwide to promote safe, secure and peaceful nuclear technologies.

Letter of Compliance (LoC)

A document, prepared by RWM, that indicates to a waste packager that a proposed approach to the packaging of waste would result in waste packages that are compliant with the requirements defined by relevant packaging specifications, and the safety assessments for transport to and disposal in a GDF, and are therefore deemed 'disposable'.

low level waste (LLW)

Radioactive waste having a radioactive content not exceeding 4 gigabecquerels per tonne (GBq/t) of alpha or 12 GBq/t of beta/gamma activity.

Nirex (United Kingdom Nirex Limited)

An organisation previously owned jointly by Department for the Environment, Food and Rural Affairs and the Department for Trade and Industry. Its objectives were, in support of Government policy, to develop and advise on safe, environmentally sound and publicly acceptable options for the long-term management of radioactive materials in the United Kingdom. The Government's response to Committee on Radioactive Waste Management in October 2006 initiated the incorporation of Nirex functions into the NDA, a process which was completed in March 2007.

Nuclear Decommissioning Authority (NDA)

The NDA is the implementing organisation, responsible for planning and delivering a GDF. The NDA was set up on 1 April 2005, under the Energy Act 2004. It is a non-departmental public body with designated responsibility for managing the liabilities at specific sites. These sites are operated under contract by site licensee companies (initially British Nuclear Group Sellafield Limited, Magnox Electric Limited, Springfields Fuels Limited and UK Atomic Energy Authority). The NDA has a statutory requirement under the Energy Act 2004, to publish and consult on its Strategy and Annual Plans, which have to be agreed by the Secretary of State (currently the Secretary of State for Trade and Industry) and Scottish Ministers.

Nuclear Installations Act 1965 (NIA65)

UK legislation which provides for the operation and regulation of nuclear installations within the UK.

nuclear material (NM)

Fissile material or material that can be used to produce fissile material (i.e. source material). This includes all isotopes of uranium, plutonium and thorium, together with certain isotopes of neptunium and americium.

Office for Nuclear Regulation (ONR)

The HSE's executive agency ONR is responsible for regulating the nuclear, radiological and industrial safety of nuclear installations and the transport of radioactive materials in Great Britain under the Nuclear Installations Act 1965 (NIA 65) and the Carriage of Dangerous Good Regulations.

The Government intends to bring forward legislation to establish ONR as a new independent statutory body outside of the HSE to regulate the nuclear power industry, formally responsible in law for delivering regulatory functions. The creation of the ONR as a statutory body will consolidate the regulation of civil nuclear and radioactive transport safety and security regulation through one organisation. Pending the legislation, and in the interim, the HSE has established the ONR as a non-statutory body. The Government will review the functions and processes of the interim body in order to inform its planned legislation.

operational period (of a disposal facility)

The period during which a disposal facility is used for its intended purpose, up until closure.

passive safety

Not placing reliance on active safety systems and human intervention to ensure safety.

plutonium (Pu)

A radioactive element occurring in very small quantities in uranium ores but mainly produced artificially, including for use in nuclear fuel, by neutron bombardment of uranium.

post-closure period (of a disposal facility)

The period following sealing and closure of a facility and the removal of active institutional controls.

quality management

The system by which an organisation determines, implements and ensures quality in its activities.

radioactive decay

The process by which radioactive material loses activity, e.g. alpha activity naturally. The rate at which atoms disintegrate is measured in becquerels.

radioactive material

Material designated in national law or by a regulatory body as being subject to regulatory control because of its radioactivity.

radioactive waste

Any material contaminated by or incorporating radioactivity above certain thresholds defined in legislation, and for which no further use is envisaged, is known as radioactive waste.

Radioactive Waste Management Ltd (RWM)

A wholly owned subsidiary of the NDA, established to design and build an effective delivery organisation to implement a safe, sustainable, publicly acceptable geological disposal programme. Ultimately, it will evolve under the NDA into the organisation responsible for the delivery of a GDF. Ownership of this organisation can then be opened up to competition, in due course, in line with other NDA sites.

radioactivity

Atoms undergoing spontaneous random disintegration, usually accompanied by the emission of radiation.

radionuclide

A radioactive form of an element, for example carbon-14 or caesium-137.

retrievability

A feature of the design of a GDF that enables the waste to be withdrawn, even after the disposal vaults have been backfilled

safeguards

Measures used to verify that nation states comply with their international obligations not to use nuclear materials (plutonium, uranium and thorium) for nuclear explosives purposes. Global recognition of the need for such verification is reflected in the requirements of the Treaty on the Non-Proliferation of Nuclear Weapons (NPT) for the application of safeguards by the International Atomic Energy Agency. Also, the Treaty Establishing the European Atomic Energy Community (the Euratom Treaty) includes requirements for the application of safeguards by the European Community.

safety case

A ‘safety case’ is the written documentation demonstrating that risks associated with a site, a plant, part of a plant or a plant modification are as low as reasonably practicable and that the relevant standards have been met. Safety cases for licensable activities at nuclear sites are required as license conditions under NIA65.

safety function

A specific purpose that must be accomplished for safety.

shielding

Shielding is the protective use of materials to reduce the dose rate outside of the shielding material. The amount of shielding required to ensure that the dose rate is as low as reasonably practicable (ALARP) will therefore depend on the type of radiation, the activity of the source, and on the dose rate that is acceptable outside the shielding material.

spent nuclear fuel

Nuclear fuel removed from a reactor following irradiation that is no longer usable in its present form because of depletion of fissile material, poison build-up or radiation damage.

transport container

A reusable container into which waste packages are placed for transport, the whole assembly then being referred to as a transport package.

transport package

The complete assembly of the radioactive material and its outer packaging, as presented for transport.

Transport Regulations

The IAEA Regulations for the Safe Transport of Radioactive Material and/or those regulations as transposed into an EU Directive, and in turn into regulations that apply within the UK. The generic term ‘Transport Regulations’ can refer to any or all of these, since the essential wording is identical in all cases.

transport system

The transport system covers the transport modes, infrastructure, design and operations. It can be divided in two main areas– the transport of construction materials, spoil and personnel associated with building a GDF and the more specialised transport of the radioactive waste to a GDF by inland waterway, sea, rail and/or road.

uranium (U)

A heavy, naturally occurring and weakly radioactive element, commercially extracted from uranium ores. By nuclear fission (the nucleus splitting into two or more nuclei and releasing energy) it is used as a fuel in nuclear reactors to generate heat.

Uranium is often categorised by way of the proportion of the radionuclide uranium-235 it contains:

- natural uranium; with a uranium-235 content of ~0.7%;
- depleted uranium; with a uranium-235 content less than ~0.7%;
- low enriched uranium; with a uranium-235 content of between ~0.7% and ~20%[50]; and
- highly enriched uranium; with a uranium uranium-235 content of greater than ~20%.

waste acceptance criteria (WAC)

Quantitative and/or qualitative criteria, specified by the operator of a disposal facility and approved by the regulator, for solid radioactive waste to be accepted for disposal.

Quantitative or qualitative criteria specified by the regulatory body, or specified by an operator and approved by the regulatory body, for radioactive waste to be accepted by the operator of a repository for disposal, or by the operator of a storage facility for storage.

waste container

The vessel into which a wasteform is placed to form a waste package suitable for handling, transport, storage and disposal.

wasteform

The waste in the physical and chemical form in which it will be disposed of, including any conditioning media and container furniture (i.e. in-drum mixing devices, dewatering tubes etc.) but not including the waste container itself.

waste package

The product of conditioning that includes the wasteform and any container(s) and internal barriers (e.g. absorbing materials and liner), as prepared in accordance with requirements for handling, transport, storage and/or disposal.

waste packager

An organisation responsible for the packaging of radioactive waste in a form suitable for transport and disposal.

[50] It should be noted that, in this document, the description "DNLEU' only covers uranium with uranium-235 contents of up to 1% (see Section 4.2).

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