Radioactive Waste Management

WPS/220/01

Waste Package Specification and Guidance Documentation:

Specification for Waste Packages Containing Low Heat Generating Waste: Part C – Fundamental Requirements

March 2020

Conditions of publication

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Executive Summary

This document provides the reader with the envelope in which to create waste packages containing Low Heat Generating Waste which are intended to be suitable for long-term interim storage prior to disposal, or direct disposal in a Geological Disposal Facility (GDF). This specification has been developed to capture the fundamental requirements applicable to the transport of waste packages to a GDF and all subsequent phases associated with geological disposal, which are appropriate to this stage of the programme. This includes engineering aspects relevant to a waste package and, where applicable, the most restrictive constraints, based on current knowledge, arising from the range of potential geological environments in which a GDF could be sited. The requirements in this specification cannot yet be considered bounding. Work is continually being undertaken by RWM to reach a point where the bounding requirements for the disposal of waste packages, which are compatible with the final designs of a GDF, are determined.

The requirements in this document are derived from the generic Disposal System Safety Case (gDSSC) and flow from the Disposal System Specification (DSS) Part B: Technical Specification [1], which lists the generic requirements for a disposal system, in the absence of a site.

This document replaces NDA/RWMD/068, WPS/430/01, WPS/501/01/ WPS/400/03, WPS/410/03, WPS/420/01, WPS/620/03 as the most current specification for packaging Low Heat Generating Waste (LHGW).

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1. Introduction

1.1 Role of the Document

This specification defines the properties and performance requirements that every waste package containing Low Heat Generating Waste (LHGW) must meet for eventual disposal in a Geological Disposal Facility (GDF).

The requirements set out in this document have been written such that they provide the envelope in which to develop new types of waste packages which are compatible with the current illustrative concepts and generic safety case for a GDF.

This document acts as the link between the Disposal System Specification (DSS) Part B: Technical Specification [1] , which sets out the fundamental requirements for safely disposing of radioactive waste and the practical measures that need to be taken by waste packagers in order to meet them.

1.1.1 The Waste Covered by this Specification

For the purposes of developing disposal concepts, RWM has adopted a waste categorisation system based on the heat output characteristics of the waste [2].

This specification is intended to be used when the waste stream for disposal meets the following description of LHGW:

> *"Low heat generating wastes (LHGW): that is, Intermediate Level Waste (ILW) arising from the operation and decommissioning of reactors and other nuclear facilities, together with a small amount of Low Level Waste (LLW) unsuitable for near surface disposal, and stocks of depleted, natural and low-enriched uranium (DNLEU)." [1]*

At this stage, the requirements for packaging DNLEU have not been specifically considered in this specification and are considered separately in WPS/230 [3]. Further development of the requirements for the disposal of DNLEU forms a part of RWM's forward work programme.

More details regarding the categorisation of waste are given in the 'Waste Packages and the Assessment of their Disposability Report' (DSSC/441/01) [4].

If there is uncertainty with the waste's categorisation, the user is encouraged to contact RWM as early as possible to discuss matters in more detail.

1.1.2 Target Audiences

This document has two target audiences:

1) Waste packagers seeking to develop packaging solutions for LHGW.

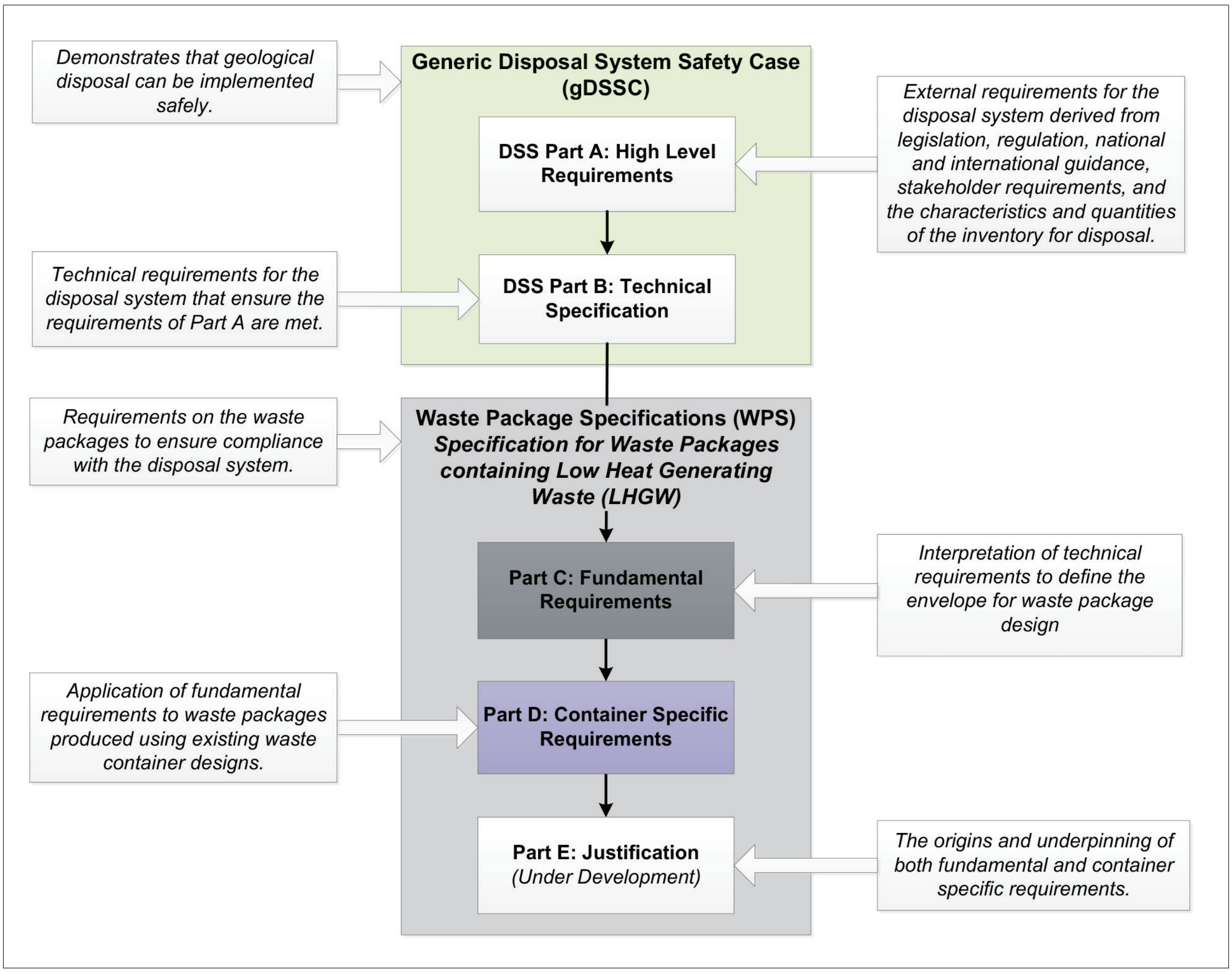
2) RWM, including waste management specialists who are involved in undertaking disposability assessments of waste packaging submissions, and those responsible for developing the disposal system.

1.2 Waste Package Specification and Guidance Documentation

This specification is referred to as 'Part C: Fundamental Requirements' and forms part of a suite of Waste Package Specifications and Guidance Documentation (WPSGD). It is designed to help inform the reader about how to package Low Heat Generating Waste in a form which will meet the anticipated needs of a GDF. Contained within this document, are the waste packaging requirements which form the envelope within which to package LHGW. All waste packages intending to contain this type of waste must fall within the boundaries of this envelope.

This document sits within a hierarchy of documents containing requirements as shown in Figure 1.

Figure 1: Document hierarchy, illustrating how the successive tiers of documents are organised and the requirements from the DSS and higher-level gDSSC link with those in the waste package specifications (WPS).

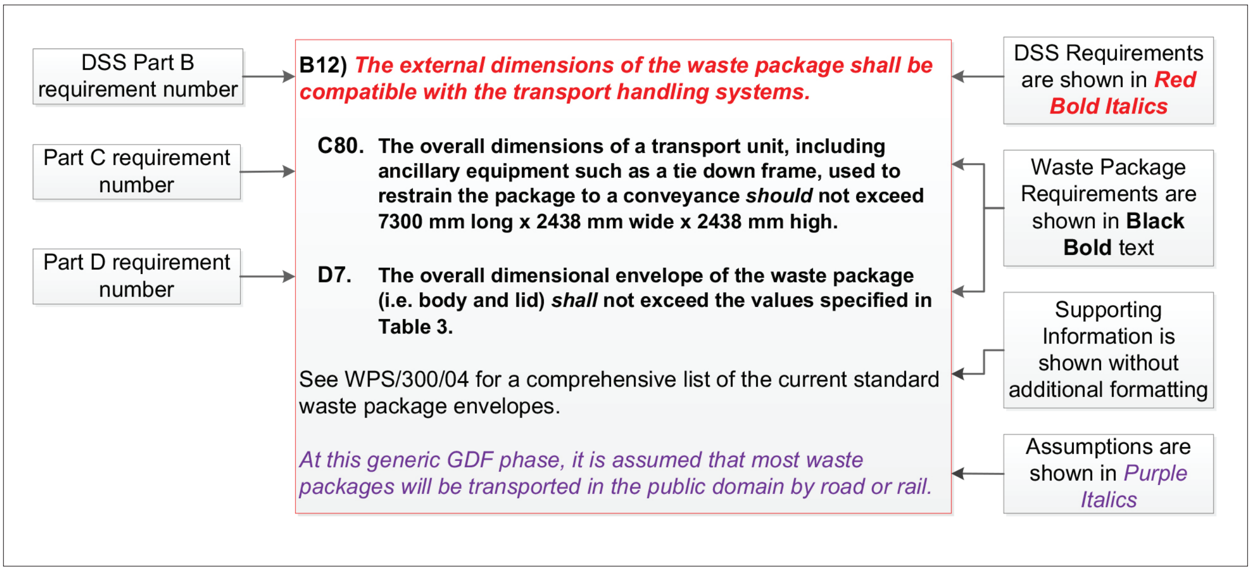


To support safe delivery of a fully operational GDF, RWM has developed the generic Disposal System Safety Case (gDSSC), which details the conceptual designs for a GDF and how this will ensure the safe disposal of radioactive waste. The gDSSC is comprised of 33 documents, including the Disposal System Specification Part A and Part B, which can be found at **rwm.nda.gov.uk/publications**. An overview of all documents within this suite is provided in DSSC/101/01.

Of key significance is the flow-down of requirements from the gDSSC suite of documentation into the waste package specifications.

The requirements within the hierarchy are formatted as shown in Figure 2.

Figure 2: An example of how the requirements are formatted within the Part C and Part D Waste Package Specifications.



Each tier within the hierarchy shown in Figure 2 broadly addresses the following:

- ***DSS Part A Requirements:*** Reflect stakeholder, regulator, and customer requirements. These form the highest level in the hierarchy and are not referred to explicitly within this Part C Specification.
- ***DSS Part B Requirements:*** These requirements outline what the disposal system needs to do to ensure compliance with the DSS Part A. Waste packages are an integral part to this system operating effectively. All relevant waste package requirements have been extracted from the DSS Part B and used as the top level requirements in this document. These requirements are numbered with the prefix 'B' to reflect their place in the hierarchy of requirements and their source i.e. DSS Part B.
- ***Part C: Fundamental Waste Package Requirements:*** The requirements in this document provide a translation of the relevant DSS Part B Requirements into more practical measures from a waste packaging perspective. They define the envelope within which to develop a waste package and, as such, can be considered to be the step below the ***DSS Part B Requirements;*** they have been assigned the prefix C. By meeting the 'C' level requirements listed in this Part C Specification, the requirements listed in the DSS Part B, will be appropriately satisfied.
- ***Part D: Container Specific Requirements:*** These container-specific requirements are derived from those set out in Part C and define the envelope for the existing range of container-specific solutions. The reader is directed to the Part D Specification: WPS/300/04 for waste packages which could be created using existing waste container designs. The existing container designs can be used as specified, or can be modified to suit the waste packager's needs, as long as the requirements set out in the Part C Specification are met.
- ***Part E: Justification:*** The Justification document supports the Part C and Part D specifications by detailing, where appropriate, the underpinning research, reasons and origins of the requirements detailed within.

- ***Supporting text and assumptions:*** This text is used to provide supporting material relevant to meeting the requirement listed above it. Assumptions are written in ***purple italicised text***.

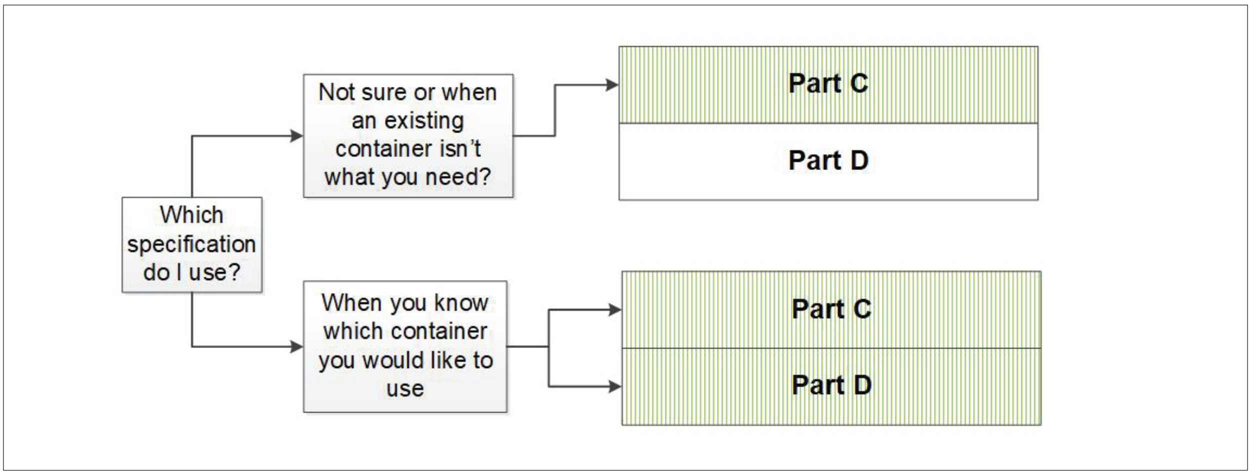
For a comprehensive list of the current WPSGD the reader is directed to the following website, where the latest documents are available for download:

https://www.gov.uk/government/organisations/radioactive-waste-management

1.2.1 How Part C and Part D Combine

To avoid repetition between the Part C and D LHGW specifications, requirements common to all waste packages, for example waste package records, are only found in the Part C specification. The Part C and Part D specifications are designed to be used together. The basic premise is shown in Figure 3. When the waste producer is seeking to develop a new type of waste package, for example, Part C must be used. However, if a waste producer is seeking to use an existing waste container design to package a particular waste stream, the Part D specification must, in all cases, be used in conjunction with Part C. Signposting is used throughout the documents to direct the user to the necessary detail.

Figure 3: Decision making diagram illustrating an example of when to use the Part C and Part D specifications, as indicated by green shading.



1.2.2 Should and Shall

Aligning with the recommendations of BS 7373-1:2001 [5], and maintaining consistency with that used in the DSS Part B, the waste package specifications use should and shall to denote targets and limits that each waste package is required to address:

- ***Shall*** denotes a hard limit.
- ***Should*** denotes a target.

Where ***shall*** is used, the limits cannot be exceeded. Where ***should*** is used, it denotes a target which can be exceeded if a suitable argument and justification can be made with the support of RWM through the disposability assessment process.

1.3 Origin of the Waste Package Criteria

The appropriate packaging of radioactive waste is firmly recognised as part of the means to delivering a safe GDF. To create a waste package which will be suitable for disposal, it is helpful to understand which criteria are important to the overall performance of the waste package. Ultimately, it is required that:

B6) *Waste packages shall be compatible with safe transport to the GDF.*

B7) *Waste packages shall be compatible with safe handling in the GDF.*

B8) *Waste packages shall be compatible with safe disposal in the GDF.*

There are many factors that need to be understood and taken into account in order to satisfy these key waste package requirements. IAEA guidance on the properties of the waste containers [6], and of waste packages and their contents [7], have been used to derive the criteria for packaging radioactive waste to meet these requirements. From these packaging criteria, the requirements which are intended to make all waste packages compatible with the safe transport to, and disposal in, a GDF have been developed. All waste packages are intended to be:

- Passively safe and adequately physically robust so as to ensure containment and safe handling during all phases of the long-term management of the waste, including disposal at a GDF.
- Suitable for safe transport through the public domain in order to deliver them to a GDF safely, recognising that this could be as transport packages in their own right or as part of a transport package.
- Compatible with the safety cases for the Operational and Post-Closure phases of a GDF, therefore preventing harm to the public, workers and the environment.

These criteria are further embodied in the safety functions that all waste packages must be designed to fulfil, as shown in Figure 4.

Figure 4: Safety functions that a waste package must fulfil during respective Operational and Post-Closure phases of the GDF.

The waste packages are required to be able to provide the following five operational safety functions:

B9) The waste packages are required to be able to provide containment of radionuclides and other hazardous materials during normal operations and under accident conditions.
B10) The waste packages are required to be able to limit radiation dose to workers and members of the public.
B11) The waste packages are required to be able to preclude criticality.
B12) The waste packages are required to be able to provide the means of safe handling.
B13) The waste packages are required to be able to withstand internal and external loads.

The waste packages are required to be able to provide the following four post-closure safety functions:

B14) The waste packages are required to be able to provide containment of radionuclides and other hazardous materials.
B15) The waste packages are required to be able to contribute to the overall performance of the Engineered Barrier System.
B16) The waste packages are required to be able to contribute to ensuring that, following GDF closure, a criticality event is not a significant concern.
B17) The waste packages are required to be able to withstand internal and external loads.

1.3.1 Influences on the Waste Package Requirements

There are many interrelated factors that influence the Waste Package Requirements. Principally these are:

- The different stages in the lifecycle of a waste package of which RWM is currently responsible for specifying the requirements for the final three. This includes Transport (of waste to), Operations at, and the Post-Closure of a GDF.[1]
- An evolving safety case covering each of these three phases.
- Three potential geological environments in which a GDF could be constructed.
- Illustrative concepts of a GDF which inform the safety case.

Plans for the Transport, Operations and Post-Closure phases are currently under development and each one is at a differing degree of maturity, yet they all play a significant part in shaping the requirements for waste packages. This specification clearly defines the waste package requirements derived from these three final phases in the lifecycle of the waste package as they are currently understood at this stage of a GDF's development. Whilst considered to be a set of well underpinned requirements, influenced further by international experience, only when a GDF has been fully designed and the geological environment characterised can these requirements begin to be fixed and become fully bounding. This implies an element of risk which RWM monitor through different means, the primary instrument of which is the disposability assessment of packaging proposals.

The requirements in this specification will likely be refined further to find bounding requirements as the project progresses.

It is important to keep the full lifecycle of the waste package in mind when designing waste packages and to be aware of the requirements of each phase. This is because the degree of understanding and assumptions which underpin them influence waste packing requirements in subtly different ways whilst differing in complexity and certainty.

The range of geological environments in which the GDF could potentially be sited acts as an influence on the waste package requirements. The detailed design of a GDF cannot be developed and finalised until the siting process has been completed, i.e. a willing community identified, a suitable site selected and the associated subsurface environment characterised. Currently, ***RWM assumes that the eventual host rock for a GDF will be one of the following [8]:***

- ***A Higher Strength Rock (HSR).***
- ***A Lower Strength Sedimentary Rock (LSSR).***
- ***An Evaporite Rock (EVR).***

The host rock could have significant impacts on the detailed design of a GDF; consequently, it could also affect some of the requirements for packaging the waste. However, only a small number of requirements are dependent on geology. Of those that are, the illustrative design for higher strength rock is generally the most constraining. An example of a constraining requirement for higher strength rock is that of stacking and drop height, which have the strictest requirements in this geology. This is because the illustrative design has the largest underground openings, which in turn imposes the strictest requirements around stacking and potential drop heights (Generic Disposal Facility Design (GDFD) report, DSSC/412/01).

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[1] *Whilst RWM does not necessarily set the requirements for the earlier stages in the waste package lifecycle, it has a vested interest in these stages to ensure that waste packages created today will ultimately be disposable. This is broadly captured and recognised by the Assurance, Records and Management requirements in chapter 9.*

Where possible, this uncertainty has been accounted for by providing the most limiting parameters that the range of potential host rocks could impose on relevant waste package requirements.

This approach is in keeping with the principles outlined in the GDFD [8] and is intended to minimise the risk that waste packages will not be compatible with the requirements for geological disposal, and subsequently require repackaging at a later stage. RWM considers this an appropriate approach to the management of uncertainty. It aims to provide confidence that a waste package could be disposed of in any of the potential geological environments, without imposing inappropriate constraints on waste producers, which would result in significant additional cost and risk to operations.

Waste packages created within the resulting envelope will provide confidence in the future disposability (NB this includes transportation) of waste packages produced ahead of final Waste Acceptance Criteria being developed for a GDF. When a site is identified, and the designs and Safety Cases have been fully developed, it is anticipated that the initial WAC for the facility will be developed using the requirements in the WPS.

1.3.2 The Role of the Waste Package in the Disposal System

One of the key principles that underpins the safety of any disposal facility, and influences the approach that RWM is developing to dispose of radioactive waste, is that of a "multi-barrier system". The IAEA's Safety Standard 5 (SSR-5) [9], provides pertinent guidance to developers of disposal facilities with regards to the need for multiple safety functions and the role of engineered/natural barriers.

The multi-barrier system is discussed further below, and principally involves the combination of several engineered and natural barriers, to varying degrees, to isolate the waste, contain radionuclides and prevent them from reaching the biosphere in quantities that could cause harm. These barriers have multiple safety functions which are intended to work together and operate over different time scales. Ultimately it is the multiple barriers and safety functions working together that provides safety for the required timeframes and GDF as a whole. The engineered barriers are commonly referred to as the Engineered Barrier System (EBS).

The waste package is a core component of the EBS (as illustrated in Figure 5); it constitutes the first two layers of containment. These primary layers are the wasteform itself, and the container, which collectively form the waste package – as shown in Figure 6. The components of the waste package are intended to work together, harmoniously, so that the waste package will meet all of the requirements placed upon it for geological disposal.

Figure 5: Schematic representation of the barriers which comprise the multi-barrier approach to a GDF.

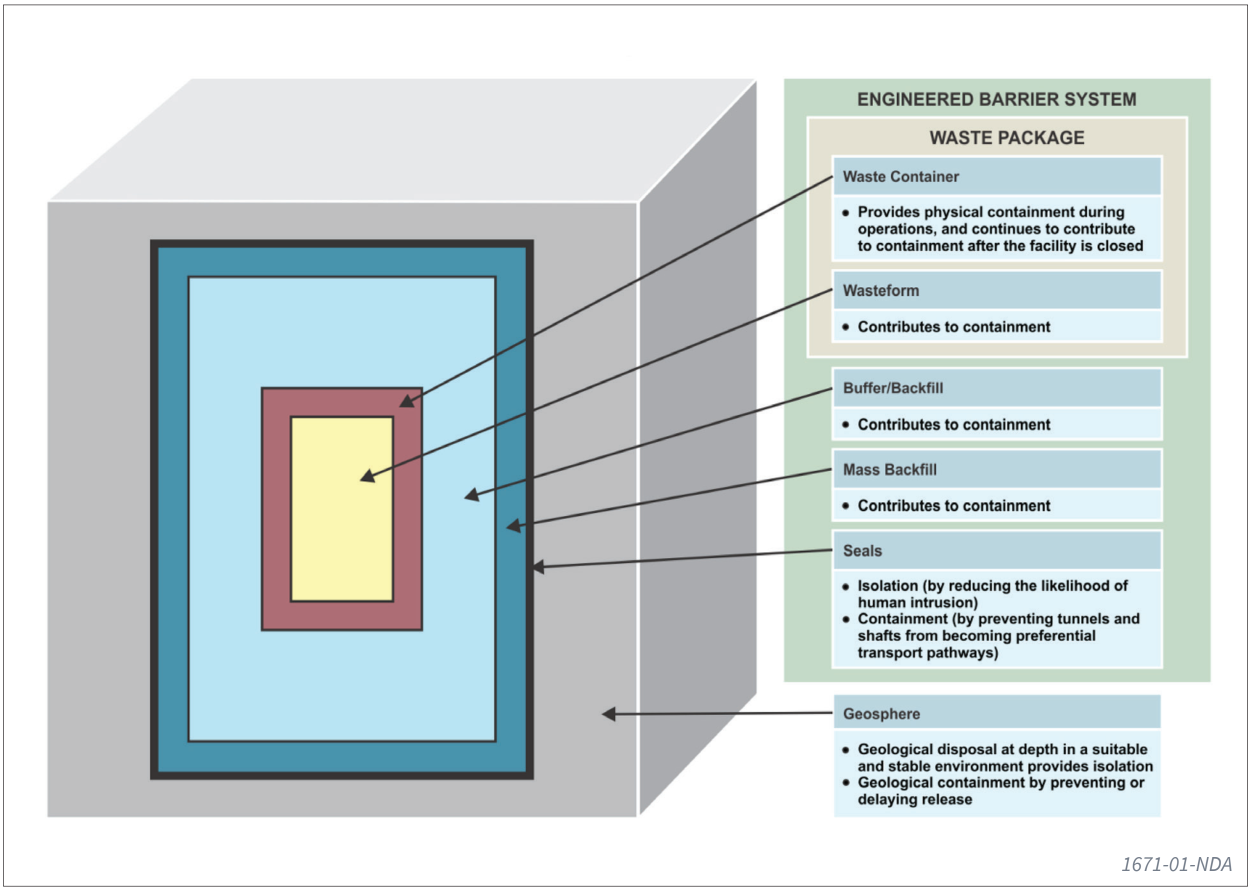
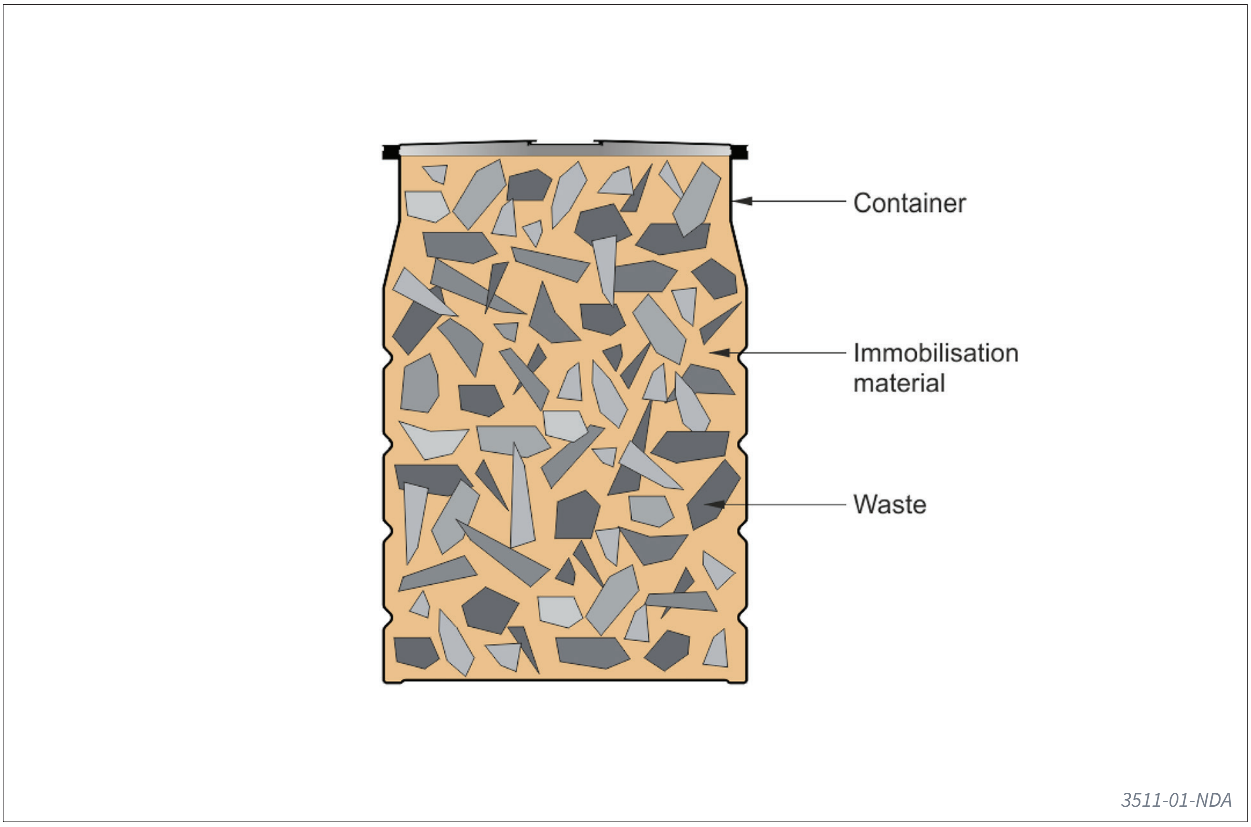


Figure 6: Schematic representation of a waste package in which an immobilisation material has been used. Together, the wasteform (consisting of the waste and immobilisation material) and the waste container, provide the primary layers of containment in the disposal system.



1.4 Contributions from the Waste Container and Wasteform to Waste Package Performance

A key requirement from the DSS Part B is:

B11) ***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.***

As defined in the DSS Part B, Section 3.1 [1], the overall performance of the waste package is the result of:

Waste Container Performance + **Wasteform Performance** = **Waste Package Performance**

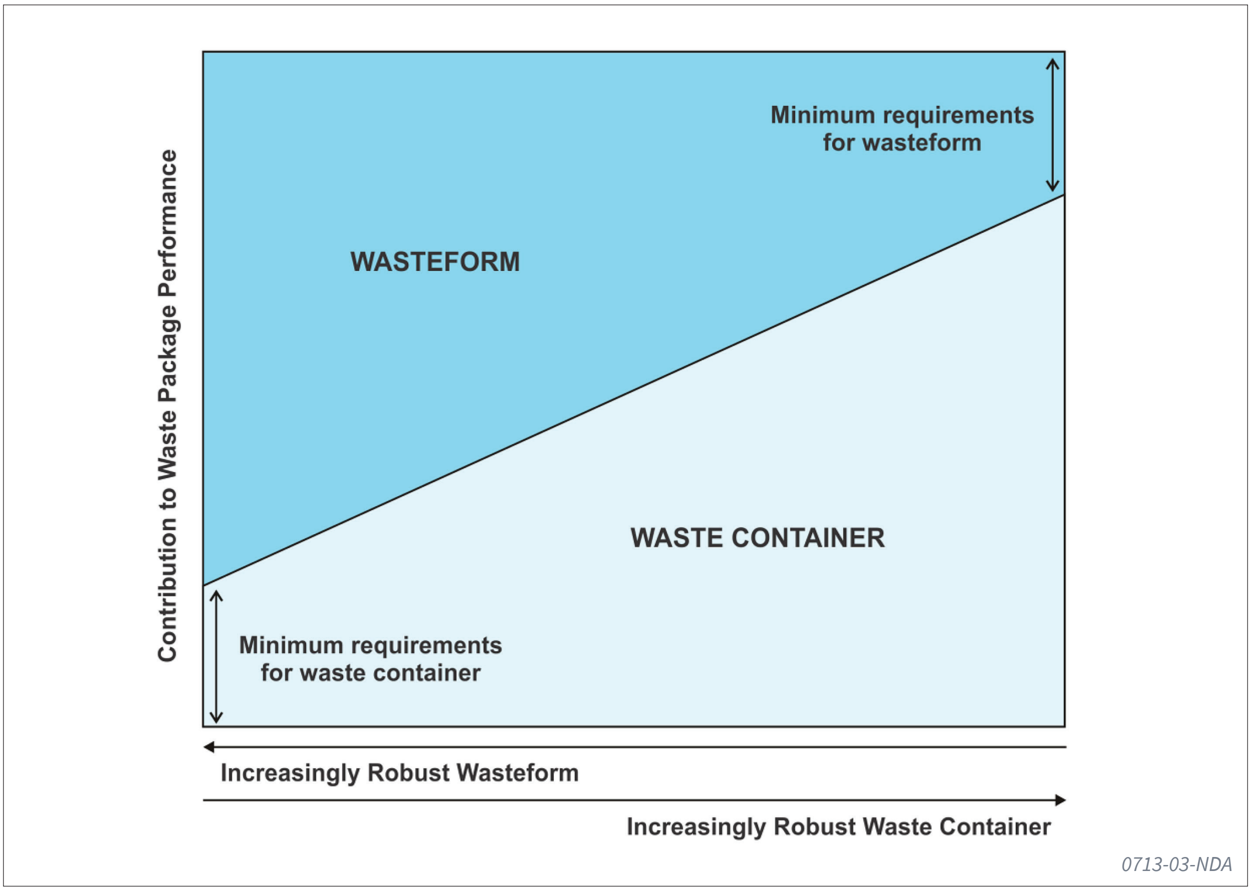
Once a waste package has been designed and produced, it must be recognised that it is not disposable without its associated information and assurance which allows RWM to demonstrate that a GDF is safe and will satisfy the scrutiny from stakeholders and regulators.

Compliant Waste Package + **Waste Package Records** = **Disposable Waste Package**

This specification clearly separates the contributions of the waste container or the wasteform from those which can be considered to be based on the waste package as a whole. Figure 7 outlines that no one feature of a waste container or wasteform can be considered in total isolation to meet the full performance requirements of the waste package. The more the container is relied upon to meet the requirements of the waste package, the less reliant the waste package could potentially be upon the wasteform to contribute towards achieving the total performance of the waste package. It is up to the waste packager to appropriately balance reliance on the container and wasteform to achieve the required overall performance of the waste package. This performance must be clearly reasoned, demonstrated and robustly justified, using evidence, which is assessed through the Disposability Assessment process, to show that all of the requirements detailed in this specification are adequately met for all phases of the waste package lifecycle.

The term 'appropriate' is widely used across the requirements. This represents an acknowledgement of the relative roles that the components of the waste package will play in providing the required waste package performance, as depicted graphically in Figure 7. The appropriateness of each component's contribution to the waste package performance will be assessed during the Disposability Assessment of the waste packaging proposal.

Figure 7: Relative contribution of the waste container and wasteform to waste package performance.



1.5 Disposability Assessment

Waste packaging proposals developed using the suite of WPSGD will ultimately be assessed by RWM through the Disposability Assessment process. Specific guidance on this process can be found on the RWM website (see section 1.2). However, the reader is directed to WPS/650 and WPS/908/05 for an overview of the process and guidance on the preparation of a submission for Disposability Assessment respectively.

Waste packagers are encouraged to contact RWM to discuss the intended waste packaging strategy at the earliest opportunity, especially where new proposals challenge the current requirements. Note that when challenging the requirements a compelling justification must be supplied for discussion and means of resolution within the Disposability Assessment process. From initial contact, and throughout the staged development of the waste packaging proposals, RWM will seek to guide waste packagers through the Disposability Assessment process, to minimise the risk that the conditioning and packaging of radioactive wastes results in packages incompatible with geological disposal. This early and sustained engagement also supports development of an optimised waste packaging solution, with appropriate application of best available techniques (BAT) / as low as reasonably practicable (ALARP) / as low as reasonably achievable (ALARA) across the whole lifecycle of the waste package.

The Waste Package Requirements

2 Key Considerations in the Development of a Waste Package

This section seeks to inform the reader of the key requirements that influence each aspect of creating an appropriate waste packaging proposal for assessment by RWM. These requirements, which are also reflected throughout the DSS, must be held at the centre of developing every waste package and evidenced clearly throughout.

All waste package developments must embody these principles. Demonstration of their application is required as part of the proposal to RWM, and is assessed during the Disposability Assessment Process.

C1. The design and manufacture of a waste package *shall* contribute to ensuring that:

a. risks to the health and safety of people, resulting from the operation and closure of a GDF, are as low as reasonably practicable (ALARP) [10, 11];

b. the best available techniques (BAT) can be used to minimise the generation of gaseous, aqueous and other radioactive wastes during the operation and closure of a GDF [12]; and

c. radiological risks to the public following the period of authorisation of a GDF are as low as reasonably achievable, economic and societal factors being taken into account (ALARA)[13].

3 Transport Phase

The majority of the requirements throughout this section are derived from the IAEA transport regulations but do not replicate them in their entirety. They are intended to make the transport regulations more accessible and relatable to developing a new waste package. Noting the inherent risk of mistranslation that this imposes, the reader is reminded that they must always consult the IAEA transport regulations [14] for the definitive set of requirements during transport. The requirements in this section are structured so that their IAEA source requirements, where applicable, are linked to them and can easily be found.

It is strongly advised that the developer of a new waste package seeks appropriate transport advice and consults RWM at the earliest stages of development to minimise the potential for transport related issues at a later date.

3.1 Introduction

The introduction to this specification details the importance of considering the needs of the Transport, Operations and Post-Closure phases of a GDF, when developing a waste package. The focus of this section is waste package transport, which is one of the major operations necessary for moving waste packages from the site at which they were created, or stored, to a GDF.

The fundamental principle applied to the transport of radioactive material, by any means, is that safety is to be ensured through the design of the transport packages and by controls and limits imposed on their contents. As a site for a GDF has not yet been identified, development of a transport system remains generic. Consequently, the DSS specifies:

B196) ***The transport system design shall take into account transport of radioactive waste and dangerous goods by inland waterway.***

B197) ***The transport system design shall take into account transport of radioactive waste and dangerous goods by sea.***

B198) ***The transport system design shall take into account transport of radioactive waste and dangerous goods by rail.***

B199) ***The transport system design shall take into account transport of radioactive waste and dangerous goods by road.***

At this generic GDF phase, it is assumed that most waste packages will be transported in the public domain by road or rail.

The Generic Transport System Design (GTSD) [15], describes the transport packages that can be used to safely transport radioactive waste to a GDF. The generic Transport Safety Case (TSC) [16], has been developed to provide confidence that the transport of waste packages to a GDF will be safe, without being specific to any potential GDF location. It also satisfies an important role in providing a basis against which waste packaging proposals, submitted by waste packagers, are assessed to determine whether the proposed packages are likely to be transportable in the future [17].

The IAEA Regulations for the Safe Transport of Radioactive Material (IAEA Transport Regulations) [14], are the international regulatory standards for the transport of radioactive materials. They specify criteria that must be met by each transport package during routine, normal and accident conditions of transport.

Within the UK, the transport of radioactive material through the public domain must be compliant with the Carriage of Dangerous Goods Regulations 2009 [18]. This regulation enacts the European Agreements concerning the International Carriage of Dangerous Goods by Road (ADR) [19], and the International Carriage of Dangerous Goods by Rail (RID) [20], into UK law. Both international agreements are based upon the IAEA Transport Regulations [14]; the relationship between these regulations is described and illustrated in the Transport Package Safety Report [21]. The Competent Authority for the transport of radioactive waste to a GDF in the UK is the Office for Nuclear Regulation (ONR).

This is encompassed within the DSS, which states:

B206) ***Radioactive materials and dangerous goods shall be transported in accordance with the safety requirements defined by the competent authority and all other applicable regulations.***

B208) ***Transport package designs shall be demonstrated to meet the requirements of the applicable regulations and consequently the IAEA's Regulations for the Safe Transport of Radioactive Material.***

C2. All transport packages transported to the GDF *shall* meet the requirements of the IAEA Transport Regulations as implemented in UK legislation at the time of transport.

The IAEA Transport Regulations apply a graded approach to the required performance standards of the transport package design; the greater the hazard of the contents, the greater the required integrity of the transport package.

The types of transport package can be split into two categories; those requiring Competent Authority approval, and those which do not require such approval, as specified in the IAEA Transport Regulations. Due to the nature and activity of their contents, the following transport packages do not require Competent Authority approval:

- Excepted.
- Industrial Package Type 1 (IP-1).
- Industrial Package Type 2 (IP-2).
- Industrial Package Type 3 (IP-3).
- Type A.

The following transport packages contain higher levels of radioactivity, and therefore require Competent Authority Approval for transport:

- Type B(U).
- Type B(M).
- Type C.

Section 4 of the IAEA Transport Regulations specifies the contents limits and requirements for each transport package type.

All of the transport package types listed above could be used as transport packages to a GDF. However, due to the volumes and activity of the material to be transported, it is anticipated that Type IP-2 and Type B transport packages will be most suitable. Therefore their requirements form the basis of this specification.

Type IP-2 transport packages have more constraining limits on their contents (**section 3.2**), whereas Type B transport packages can contain wastes with higher activities. Consequently, Type B transport packages have additional design requirements and must meet more strenuous testing requirements (**section 3.1.3**).

It must be recognised that the intended transport arrangements mean that the transport regulations do not always apply directly to the waste package. However, if licensing arguments rely on the waste package to remain intact under Normal Conditions of Transport (NCT) and/or Accident Conditions of Transport (ACT), see **section 3.1.3**, then the waste package contributes in some way to ensuring that it will be transportable via its intended transport route. Note that ***RWM assume that in a Type B transport arrangement all waste packages will not fail under NCT or ACT.***

This section relates specifically to transport packages recognising that in some instances the requirements do not directly relate to the waste package itself. It is this point that the reader must be cognisant of when deciding which requirements apply to a waste package and which do not. Every endeavour has been made to be clear about where a requirement relates to a waste package and where it relates to a transport package. It is the intended transport arrangements (Type IP-2/Type B) which will indicate whether a transport requirement relates directly to a waste package or not. This is discussed in more detail from section 3.1.1 onwards.

The rest of this chapter sets out the requirements for Type B and Type IP -2 transport packages.

3.1.1 Type B, Type IP-2 and Overpack Transport Configurations

B211) ***Except when waste packages are certified as transport packages, all radioactive waste shall be transported to a geological disposal facility in reusable transport containers.***

To understand the transport requirements and how they apply to the waste package, the role and function of items in the transport configuration must be determined. Examples showing some of the different types of transport configuration for waste packages are shown in **Figure 8**.

It is extremely important to recognise, when developing a waste package, that the transport arrangements of the waste packages will dictate a different set of requirements for the waste package itself. If a waste package cannot directly meet the safety requirements during transport then it must be packaged within a transport container that meets the IAEA transport regulations (**Figure 8** A); this is an example of a Type B transport arrangement. In some cases, the waste package can meet all of the safety requirements of the transport regulations. In this instance the waste package and transport package are identified as being the same thing and the waste package is commonly referred to being "a waste package that is a transport package in its own right". An example of this is shown in **Figure 8** B. In this example an IP-2 transport arrangement is shown.

C3. Waste packages *shall* be designed with the intention of transporting them either as transport packages in their own right or as part of a transport package.

3.1.1.1 Type B Transport Configuration

In a Type B transport arrangement the requirements set by the transport regulations do not necessarily apply directly to the waste package because they apply to the transport package; this is commonly a combination of the transport container with a waste package inside it (Figure 8 A). In this context the waste package is the contents of the transport package. It is stressed that the waste package still plays, although to a lesser extent than in a Type IP-2 arrangement, a part in ensuring that the transport regulations are met. E.g. by ensuring that the activity limits of the contents do not exceed those specified for a Type B transport package, see section 3.2.1. The waste package always has a part to play during transport, just to differing degrees depending on the transport arrangements.

When a transport container is used (such as a Standard Waste Transport Container (SWTC), illustrated in Figure 8 A), the waste package is expected to contribute to meeting the IAEA Transport Regulations, in specified circumstances:

C4. Where a transport container is used, the waste package *should* contribute towards the performance of the transport package.

3.1.1.2 Type IP-2 Transport Configuration

In a Type IP-2 transport arrangement, the waste package and transport package is usually the same thing, as illustrated in Figure 8 B. This type of waste package is often referred to as "a waste package that is a transport package in its own right". For a waste package that is a transport package in its own right, the IAEA Transport Regulations apply directly to the waste package.

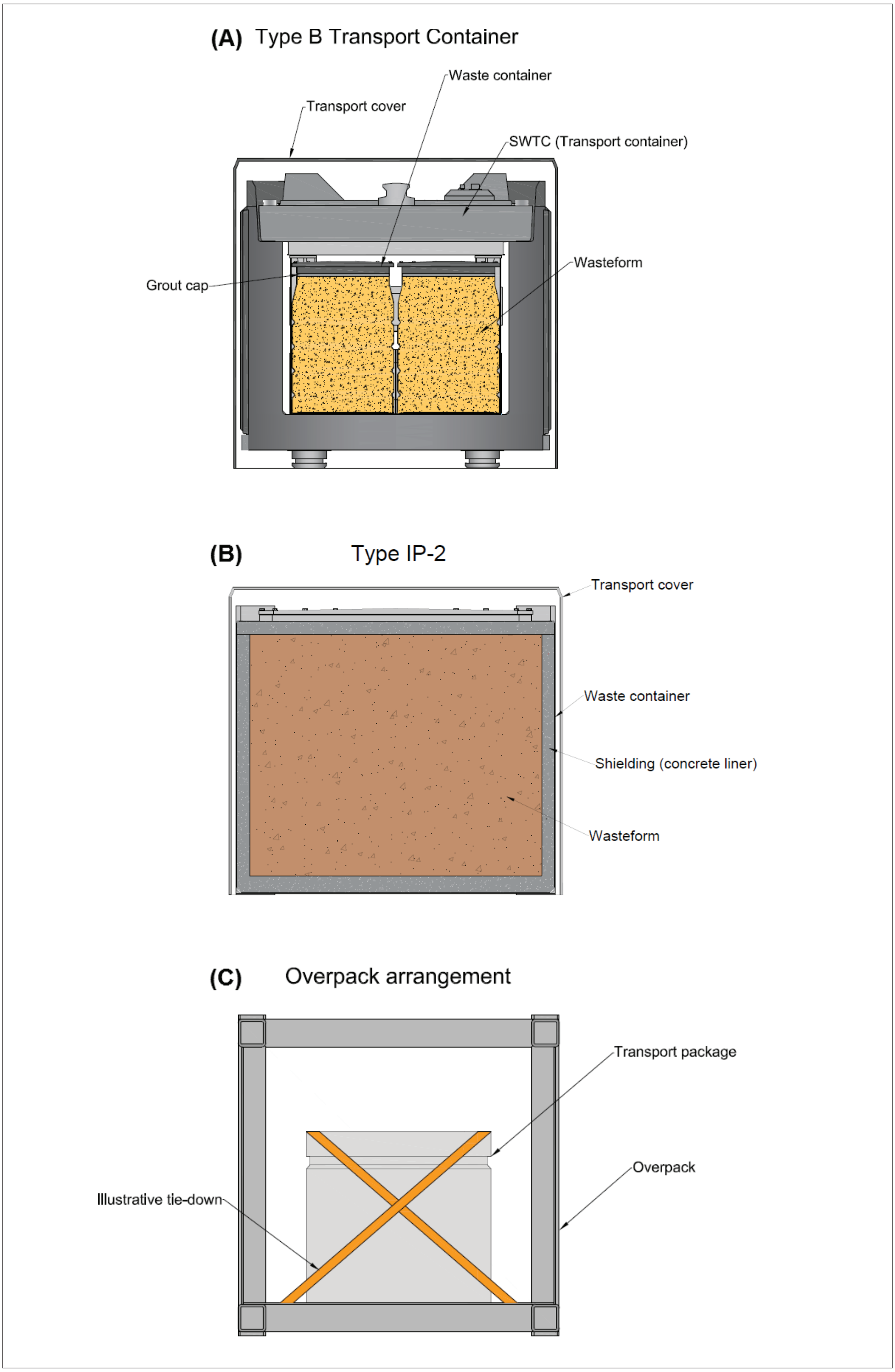
3.1.1.3 Overpacks Transport Configuration

As shown in Figure 8 C, an overpack can be used for transport. Overpacks are generally ISO freight containers that form one unit for convenience for the handling and stowage of the transport package(s). Therefore a transport package may be shipped inside an overpack. While some contamination, radiation level and criticality accumulation controls are placed upon an overpack, it is the transport package design and not the overpack, which must meet the transport package design requirements of the IAEA Transport Regulations.

C5. Where a transport container or an overpack is used, the waste package *shall* be compatible with the requirements of the transport container or overpack.

Where no transport container or overpack is used, the waste package is considered a transport handling unit in its own right. Therefore, the transport system handling, i.e. the collective, lifting, tie down, dimensions and gross mass requirements apply directly to the waste package.

Figure 8: Illustrations of three possible transport package arrangements;
(A) Type B transport package arrangement where the waste package and transport container, in this case a Standard Waste Transport Container (SWTC), form the transport package.
(B) IP-2 transport package, where the waste package is the transport package.
(C) Transport package being transported within an overpack.



3.1.2 General Requirements During Transport

The following requirement is derived from IAEA Transport Regulations Section 6 General requirements for all Packages and Packagings:

C6. Transport packages *shall* comply with the general requirements stated in paragraphs 607 to 618 in the IAEA Transport Regulations.

Section 6 of the IAEA Transport Regulations, Paras 607 to 618, provides the general requirements that all transport packages must meet. These general requirements cover the following and are discussed in greater detail throughout this document:

- Tie down.
- Handling features.
- Transport package finish.
- Physical and chemical compatibility.
- Containment under vibration.
- Ambient temperatures and pressures.
- Other dangerous goods properties.

For information regarding criticality, please refer to section 8.13.

3.1.3 Normal and Accident Conditions of Transport

3.1.3.1 Test Requirements in the IAEA Transport Regulations

B46) ***The impact and fire accident performance of the waste package shall comply with the assumptions that underpin the safety cases for transport.***

A graded approach is applied when specifying the performance standards for different transport package types, which fall into one of three different conditions. These conditions are; Routine Conditions of Transport (RCT), Normal Conditions of Transport (NCT), and Accident Conditions of Transport (ACT).

These transport regulations require that protection during the applicable transport tests is provided by:

- Containment of the radioactive contents.
- Control of the external radiation levels.
- Prevention of Criticality.
- Prevention of damage caused by heat.

The following requirement is derived from the IAEA Transport Regulations Section 6 Requirements for radioactive material and for packagings and packages.

C7. All transport packages *shall* meet the requirements for RCT, as specified in the IAEA Transport Regulations.

C8. All transport packages *shall* meet the applicable requirements for NCT, as specified in the IAEA Transport Regulations.

C9. Where applicable, transport packages *shall* meet the requirements for ACT, as specified in the IAEA Transport Regulations.

C10. Type IP-2 and Type B transport packages *shall* meet the test requirements for NCT and ACT conditions, as specified in Table 1.

Where a transport container is used, the ability of the transport package to meet the containment and shielding requirements if the waste package were to lose containment under NCT or ACT must be considered.

3.1.3.2 Alternative Test Requirements

For Type IP transport packages, alternative test requirements may be used. The alternative test conditions and pass criteria are provided in paragraphs 626 to 630 of the IAEA transport regulations.

Table 1: Testing and Performance Requirements for NCT and ACT for both Type IP-2 and Type B transport packages, where Para refers to the applicable paragraph within the IAEA Transport Regulations from which the statement is derived [14].

<table>
<tr><th rowspan="2">Test Conditions</th><th colspan="2">Type IP-2</th><th colspan="2">Type B</th></tr>
<tr><th>Test Para</th><th>Measure of Performance</th><th>Test Para</th><th>Measure of Performance</th></tr>
<tr><td colspan="5">Normal Conditions of Transport (NCT)</td></tr>
<tr><td>Water Spray Test</td><td>N/A</td><td rowspan="4">• Para 624 (a): Prevent loss or dispersal of the radioactive contents.
• Para 624 (b): Prevent more than 20%[1] increase in the maximum radiation level at any external surface of the transport package.</td><td>721</td><td rowspan="4">• Para 648 (b): Prevent more than 20%[1] increase in the maximum radiation level at any external surface of the transport package.
• Para 659 (b): Restrict the loss of radioactive contents to not more than 10^{-6} A_2 per hour.</td></tr>
<tr><td>Free Drop Test</td><td>722</td><td>722</td></tr>
<tr><td>Stacking Test</td><td>723</td><td>723</td></tr>
<tr><td>Penetration Test from 1 m</td><td>N/A</td><td>724</td></tr>
<tr><td colspan="5">Accident Conditions of Transport (ACT)</td></tr>
<tr><td>Drop Test 9 m</td><td colspan="2" rowspan="6">N/A</td><td>727 (a)</td><td rowspan="5">• Para 659 (b)(i): Retain sufficient shielding to ensure that the radiation level 1 m from the surface of the package would not exceed 10 mSv/hr with the maximum radioactive contents that the transport package is designed to contain.
• Para 659 (b)(ii): Restrict the accumulated loss of radioactive contents in a period of one week to not more than 10 A_2 for ^{85}Kr and not more than an A_2 for all other radionuclides.</td></tr>
<tr><td>Penetration Test from 1 m</td><td>727 (b)</td></tr>
<tr><td>Crush Test 9 m</td><td>727 (c) Lightweight/ low density packages</td></tr>
<tr><td>Thermal Test 800°C for 30 mins</td><td>728 (a) and (b)</td></tr>
<tr><td>Water Immersion 15 m</td><td>729</td></tr>
<tr><td>Enhanced Water Immersion 200 m</td><td>730 When contents > 10^5 A_2</td><td>• Para 660: No rupture of containment system.</td></tr>
</table>

[1] The 20% increase takes into account damage to the external package and any internal movement of the contents due to NCT including movement within the wasteform. The contents are assumed to be in the routine shipment configuration and all potential movement shall be taken into account to determine the maximum radiation level due to NCT.

3.1.4 External Dose Rate Requirements Under Routine Conditions of Transport

B29) ***The external dose rate from the waste package shall comply with regulatory limits for transport.***

By the contents of the waste packages complying with the contents specification, and ultimately the Package Design Safety Report (PDSR), for its intended transport arrangements, the waste package ensures compliance with the external dose rate limits set during transport. These external dose rate limits are set out below.

B27) ***The external dose rate from the waste package shall enable safe handling of the waste package during transport.***

All package types will be transported under either the conditions of exclusive use, or non-exclusive use. Under Exclusive use means that the consignor will have sole use of a conveyance or of a large freight container. If shipping under exclusive use several limits are relaxed regarding dose rates, package surface temperature limits and fissile limits. Both the GTSD [15], and generic Transport Safety Case (gTSC) [16], allow transport under either condition, the requirements for the control of external radiation levels under both are included in this section.

The following requirement is derived from Para 617 of the IAEA Transport Regulations:

C11. Dose rate calculations under routine conditions of transport *shall* take the maximum inventory to demonstrate compliance with the dose rate limits.

3.1.4.1 Dose Rate Requirements of Non-Exclusive Use

For transport under the conditions of non-exclusive use, transport packages are required to meet the following, as derived from Para 527, 567 and Para 566 (b) respectively, of the IAEA Transport Regulations [14]:

C12. The maximum radiation level at any point on the external surface of a transport package or overpack *shall* not exceed 2 mSv/hr.

C13. The radiation level at 1 m from the external surfaces of the transport package or overpack *shall* not exceed 0.1 mSv/hr.

C14. The radiation level at 2 m from the external surface of the vehicle *shall* not exceed 0.1 mSv/hr.

It is anticipated that the transport packages or overpacks will be marginally smaller than the road and rail vehicles (as described in the GTSD [15]), therefore, RWM have taken the value of 0.1 mSv/hr at 2 m as a requirement from the surface of the transport package or overpack.

3.1.4.2 Dose Rate Requirements of Exclusive Use

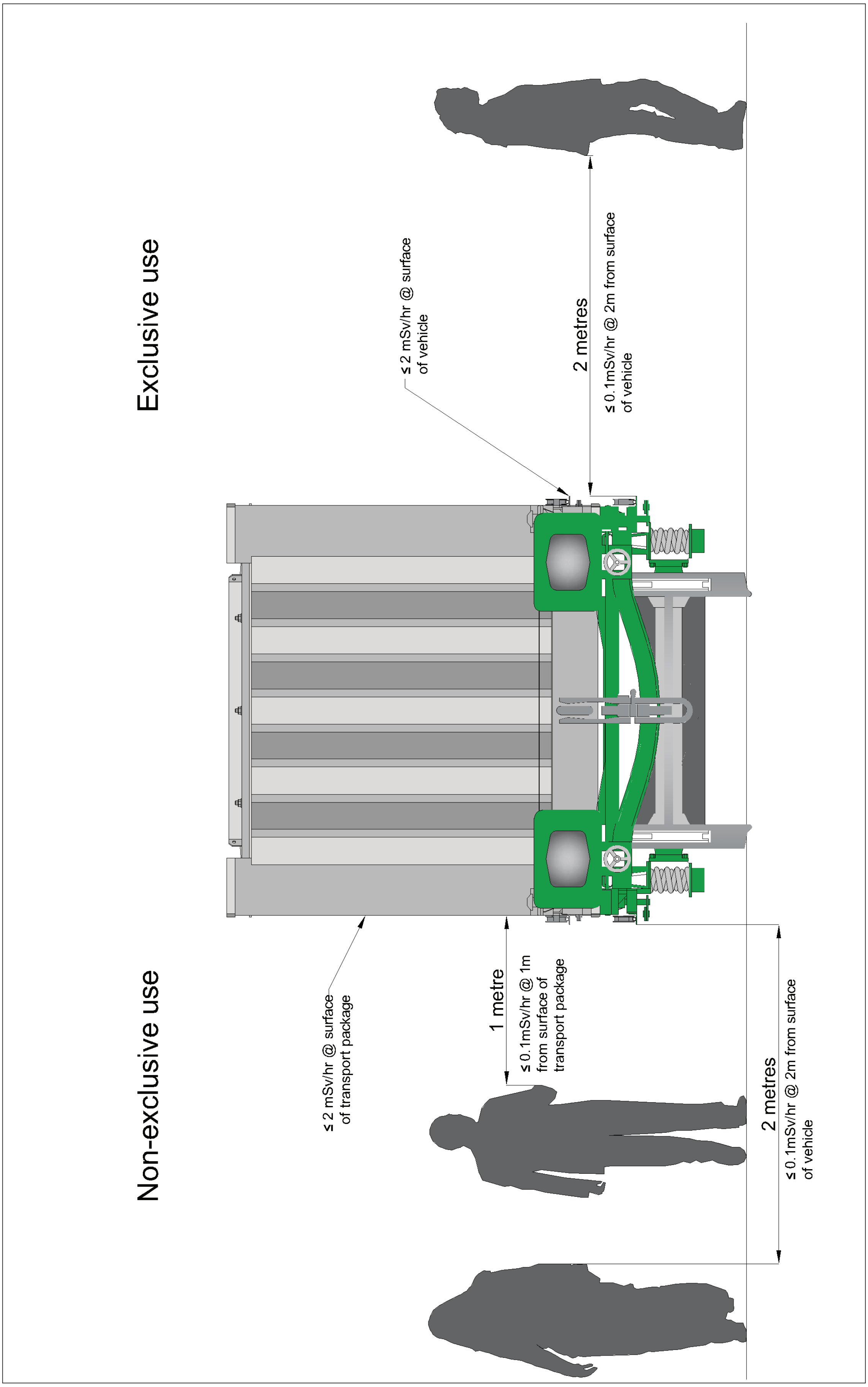
For transport under the conditions of exclusive use, transport packages are required to meet the following, as derived from Para 528, 573 (b) and 573 (c) respectively, of the IAEA Transport Regulations:

C15. The maximum radiation level at any point on the external surface of a transport package or overpack under exclusive use *shall* not exceed 10 mSv/hr.

C16. The maximum radiation level *shall* not exceed 2 mSv/hr at any point on the outer surfaces of the vehicle, including the upper and lower surfaces, or, in the case of an open *vehicle*, at any point on the vertical planes projected from the outer edges of the *vehicle*, on the upper surface of the load, and on the lower external surface of the *vehicle*.

C17. The maximum radiation level *shall* not exceed 0.1 mSv/hr at any point 2 m from the vertical planes represented by the outer lateral surfaces of the *vehicle*, or, if the load is transported in an open vehicle, at any point 2 m from the vertical planes projected from the outer edges of the *vehicle*.

Figure 9: A schematic illustrating the dose limits for Transport under conditions of non-exclusive use (left), and exclusive use (right).



3.1.5 Transport Package Temperature Limits

B32) *The heat generated by the waste package shall be controlled to ensure that regulatory limits on the surface temperature of transport packages are not exceeded.*

3.1.5.1 Type IP-2 Transport Packages

There are no limits placed on the heat generation of contents in Type IP transport packages in the IAEA Transport Regulations. However, section 8.7 of this specification must be consulted for more information on heat output requirements from waste packages in relation to the other GDF phases a waste package will have to go through.

3.1.5.2 Type B Transport Packages

The following requirement is derived from Para 666 and 667 respectively, of the IAEA Transport Regulations:

C18. A Type B transport package *shall* be designed for an ambient temperature range of:

a. -40°C to +38°C for a Type B(U) transport package.

b. Where C18 (a) cannot be met, ambient conditions other than those for Type B(U) packages may be assumed with the approval of the competent authority for the UK.

A reduced ambient temperature range may be used by Type B(M) packages, noting that any reduction in the ambient temperature range will incur a restriction upon shipment.

The following requirement is derived from the IAEA Transport Regulations Para 616:

C19. The range of ambient temperatures the transport package could be exposed to *shall* be limited during shipment to only those temperatures claimed in the Package Design Safety Report (PDSR).

An ambient temperature range can be specified to prohibit shipment at temperatures where the package material properties are outside of their intended specification.

In addition, as derived from Para 667 and 653 respectively of the IAEA Transport Regulations:

C20. Type B(M) transport packages *shall* be designed so that, under ambient conditions (approved by the competent authority for the UK), heat generated within the package under NCT will not affect the transport package, such that it would fail to meet the applicable requirements for containment and shielding as provided in Table 2 if left unattended for a period of one week.

C21. Type B(U) transport packages *should* be designed so that, under ambient conditions (38°C and insolation conditions), heat generated within the package under NCT will not affect the transport package, such that it would fail to meet the applicable requirements for containment and shielding as provided in table 2 if left unattended for a period of one week.

As derived from Para 654 of the IAEA Transport Regulations, for packages transported under non-exclusive use (section 3.1.4):

C22. A Type B(M) transport package *shall* be designed so that the temperature of the accessible surfaces of the package do not exceed 50°C, when transported under non-exclusive use.

C23. A Type B(U) transport package *should* be designed so that, at 38°C and in the absence of insolation, the temperature of the accessible surfaces of the package do not exceed 50°C, when transported under non-exclusive use.

As derived from Para 655 of the IAEA Transport Regulations, for packages transported under exclusive use (section 3.1.4):

C24. A Type B(M) transport package *shall* be designed so that, the temperature of the accessible surfaces of the package do not exceed 85°C, when transported under exclusive use.

C25. A Type B(U) transport package *should* be designed so that, at 38°C and in the absence of insolation, the temperature of the accessible surfaces of the package do not exceed 85°C, when transported under exclusive use.

3.1.6 Gas Generation in Transport Packages

To ensure containment is met (see Table 1), RWM require the following information:

C26. Gas and aerosol generation by any mechanism *shall* be calculated and its subsequent leakage from the transport package predicted to ensure it meets the containment requirement during both NCT and ACT.

3.1.7 Pressurisation

B35) *The generation of bulk, radioactive and toxic gases by the waste package shall comply with the requirements for safe transport.*

More information on the requirements on gas generation for the waste package are given in section 8.10.

The following requirement is derived from the IAEA Transport Regulations Para 664 and 616 respectively, and applies to Type B Transport Packages:

C27. The maximum normal operating pressure of a transport package *shall* not exceed a gauge pressure of 700 kPa for Type B(U) transport packages.

C28. For Type IP-2 transport packages, the package designer *shall* demonstrate that the package will not fail under the maximum pressure they are calculated to operate in during RCT.

Therefore, under the maximum ambient temperature, with the maximum contents heat generation, insolation and gas generation, a Type B(U) transport package cannot exceed 700 kPa gauge pressure.

C29. If a waste package is transported within a Type B transport package, the waste package designer *should* calculate the pressure and demonstrate the transport package can meet the regulatory requirements.

3.2 Contents Specifications

3.2.1 Type B and Type IP-2 Activity Limits

3.2.1.1 Type B Transport Packages

The following requirement is derived from the IAEA Transport Regulations Para 660:

C30. For Type B transport packages that are not designed to meet the enhanced immersion test, the total activity content of the transport package *shall* not exceed 10^5 A_2.

See **section 3.1.3** for more details on the enhanced immersion test.

3.2.1.2 Type IP-2 Transport Packages

The following requirements are derived from the IAEA Transport Regulations Para 521 and 517 respectively.

C31. The contents of waste packages transported as part of a Type IP transport package, or as Type IP transport packages in their own right, *shall* be capable of being categorised as low specific activity (LSA) material or as surface contaminated objects (SCO).

C32. The quantity of LSA material or SCO in the transport package *shall* be restricted such that the external radiation level at 3 m from the unshielded waste does not exceed 10 mSv/hr.

For more detailed information on LSA and SCO Table 2 can be used as a guide to direct the reader to more specific information in the IAEA Transport Regulations. RAMTUC guidance on how to interpret the activity distribution requirements for some LSA materials can be found in RAMTUC(16)GN14 [22].

Table 2: Applicable Paragraphs for addressing both LSA and SCO in the IAEA Transport Regulations [14].

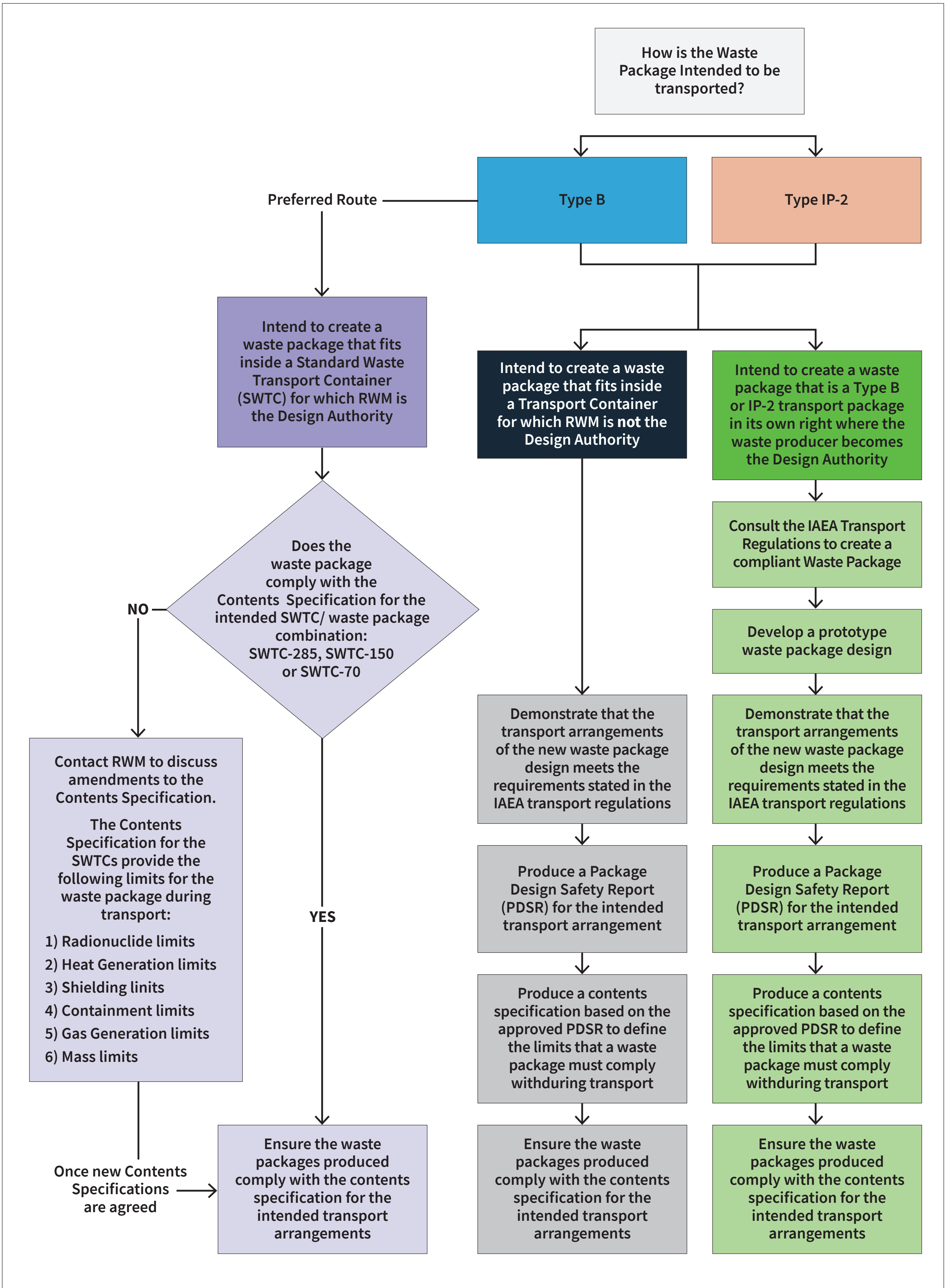
Topic	Paragraph Number
Definition of LSA Material	226
Definition of SCO	241
LSA Classification and Activity Limits	408-411
SCO Classification and Activity Limits	412-414
Radiation Level of Unshielded LSA and SCO	517
Packaging and conditions of use for LSA and SCO material	521
Conveyance activity limits for LSA and SCO material	522
LSA-III Material	601
LSA-III Material Leaching Test	703

All transport packages have to be able to demonstrate that they meet the design requirements provided in the IAEA transport regulations and distilled out in this document. These are ultimately met through a transport package design safety report which defines the allowable contents of a transport package. The permitted contents may be specified in a contents specification. A significant proportion of the limits placed on existing waste package designs which will be transported in an SWTC, as specified in the Part D specification for LHGW, are derived from the contents specifications for their intended transport arrangements. However, the development of a new type of waste package will necessitate the creation of a package design safety report which may require a contents specification for waste packages in their intended transport arrangements.

C33. A Contents Specification Document *should* be developed to define the contents limits for a transport package.

A basic summary of the transport options detailed in this chapter is shown in the Figure 10.

Figure 10: A transport option decision tree summarising the basic steps involved with each option.



4 Operational Phase

4.1 Background

The generic Operational Safety Case (gOSC) [23], is a safety focused feasibility study for the generic stage of the GDF programme that forms part of the gDSSC [24]. It makes no assumptions about the geological environment or the design detail, and purely considers the safety of workers and the public during the construction and operation of the disposal facility.

The gOSC presents arguments in four strands, each presented by an underpinning volume:

- Vol. 1 [25]: Construction and Non-Radiological Safety Assessment.
- Vol. 2 [26]: Normal Operations Safety Assessment.
- Vol. 3 [27]: Accident Safety Assessment.
- Vol. 4 [28]: Criticality Safety Assessment.

The gOSC has been written to reflect the current stage of the GDF programme. Therefore, it is not a safety case as would be expected to ensure compliance with the requirements of a Nuclear Site Licence (NSL). The production of safety case documents to meet the requirements for a NSL will occur when a specific site has been identified and will be supported with the commensurate level of design and substantiation.

To undertake quantitative analysis of the performance of the waste package under fault scenarios, quantitative data for the waste package are required for input into computational modelling [29]. The fault scenarios that a waste package will be assessed against are discussed in Section 4.4.

The assessment of Criticality Safety (Volume 4) is not included here, as criticality is subject to the requirements described in Section 8.12 which covers Transport, Operations and Post-Closure in a holistic approach.

For a greater understanding of the information that is required from a waste package to feed into the operational safety assessment the reader is directed to WPS/650 and WPS/908.

4.2 Relationship with the Waste Package

The gOSC is applicable following receipt of the waste package within the licenced site's boundary. Therefore, the operational phase places requirements on the waste package in both the transport and disposal configuration.

A proposed waste package is evaluated to determine its radionuclide loading (inventory) and likely performance if subjected to the fault scenarios identified in the gOSC [23]. Likewise, comparisons will be made regarding the external dose and criticality hazard.

The DSS identifies a range of functions that a waste package is intended to fulfil during the transport and operational phases. The requirements within this chapter are intended to contribute to safe operations. However, a number of additional waste package attributes have been identified which are of particular importance to the operational safety of the facility. A list of these waste package attributes is presented below, which need to be understood and controlled until the anticipated end of the operational period, see durability section. Associated with each feature is the applicable section within this specification where the requirements are further discussed:

- Stacking (section 8.3)
- Handling features (section 8.5)
- Durability (section 8.6)
- Surface contamination (section 8.8)
- The generation of radiological and non-radiological gas (section 8.10)
- Criticality (section 8.12)

4.3 External Dose Rate from a Waste Package

B28) ***The external dose rate from the waste package shall enable safe handling of the waste package during the GDF operational period.***

Currently, it is assumed that the GDF operational processes and supporting systems will be designed to be able to handle waste packages that meet the dose rate limits when in transport configuration [25]. I.e. if the waste package in its transport configuration meets the dose rate limits set for transport, it is assumed that the GDF will be designed to be able to handle the waste packages when not in transport configuration. See section 3 for the dose rate limits set during transport.

4.4 Waste Package Performance Under Normal and Accident Conditions

B22) ***The activity content of the waste package shall be controlled to comply with the radionuclide related assumptions that underpin the safety case for the GDF operational period.***

C34. The waste package design *shall* be appropriate to the hazard being controlled.

C35. The contribution of the waste package to safety during normal operations *shall* be verifiable.

Please refer to gOSC Vol. 2: Normal Operations Safety Assessment [26], for more details.

C36. The performance of the waste package, when subjected to reference accident scenarios *shall* be verifiable.

See Table 3 for the reference accident scenarios against which a waste package's accident performance is assessed. It is a requirement of REPPIR 19 [30], and the associated Approved Code of Practice (ACOP), that all accident scenarios regardless of probability of occurrence are evaluated and adequately considered. For the purposes of complying with this regulatory requirement RWM has determined that the most onerous events are: fire impinging on, and the dropping of waste packages. See below for more details.

B43) ***Under all credible accident scenarios the release of radionuclides and other hazardous materials from the waste package shall be low.***

B44) ***Under all credible accident scenarios the release of radionuclides and other hazardous materials from the waste package shall be predictable.***

B45) ***The waste package should exhibit progressive release behaviour within the range of all credible accident scenarios.***

B47 ***The impact and fire accident performance of the waste package shall comply with the assumptions that underpin the safety cases for the GDF operational period.***

B48) ***The accident performance of the waste package shall ensure that, in the event of any credible accident during the GDF operational period, the on- and off-site doses resulting from the release of radionuclides from the waste package shall be as low as reasonably practicable (ALARP).***

B49 ***The accident performance of the waste package shall ensure that, in the event of any credible accident during the GDF operational period, the on- and off-site doses resulting from the release of radionuclides from the waste package should be consistent with meeting the relevant Basic Safety Levels.***

C37. A waste package *shall* minimise the loss of containment in the event of a reference accident scenario.

C38. A waste package *should* be designed to minimise the loss of integral shielding in the event of a reference accident scenario.

C39. The low, predictable and progressive release behaviour of the waste package under all reference accident scenarios *shall* be underpinned.

C40. The waste container and wasteform *should* contribute to the overall performance of the waste package under each reference accident scenario.

Table 3: The reference accident scenarios for which waste package accident performance must be verified.

Reference Accident Scenario	Package type	Conditions properties are measured against	Source
Fire (°C and minutes)	Unshielded	1000 ˚C in a fully engulfing fire for a duration of 30 minutes.	[31]
	Shielded	1000 ˚C in a fully engulfing fire for a duration of 60 minutes.	
	Robust shielded	1000 ˚C in a fully engulfing fire for a duration of 60 minutes.	
Drop height (metres)	Unshielded	11 m onto a flat unyielding target. 10 m onto an aggressive target (e.g. another waste package).	[32]
	Shielded	10 m onto a flat unyielding target. No limit has currently been defined for an aggressive feature.	
	Robust shielded	7.5 m onto a flat unyielding target. 6 m onto an aggressive feature.	

The categorisation of a waste package as an unshielded, shielded and robust shielded waste package is dependent on a number of attributes of the waste package. The attributes of each waste package type are clearly defined in Section 2 of the Part D specification for Low Heat Generating Waste. When developing a proposal for a new type of waste package these attributes must be considered and the proposed waste package categorised accordingly. This is so that accident performance of the waste package can be assessed against the appropriate scenario detailed in Table 3.

5 Post-Closure Phase

Post-emplacement of waste packages and closure of the GDF is the longest and final phase in the lifecycle of a waste package and is referred to as Post-Closure. The requirements of this phase are derived from the fundamental principles of isolate and contain (as described in section 1.3.2).

These principles are set out in the generic Environmental Safety Case (gESC) main report [33], and are applicable to the different potential geological environments within which a GDF could be built. Furthermore, such principles have been developed following the experience that has been gained from the international community. This knowledge has resulted in the derivation of safety functions for each component of the Engineered Barrier System (EBS).

The gESC recognises the importance of the waste package in contributing to the performance of the EBS through the safety functions shown in Table 4. How the waste package, in conjunction with the barriers of a GDF, will contribute to the environmental safety functions that support the isolation and containment of radionuclides, in addition to other hazardous materials, is particularly important and subsequently discussed.

C41. The waste package *should* not adversely affect the environmental safety functions listed in Table 4.

The environmental safety functions are fully detailed in **Table 6** of the gESC. The reader is directed to **section 1.4** for a description of the balance that must be struck between contributions from the wasteform and waste container in order to demonstrate waste package performance.

Table 4: General Environmental Safety Functions as identified in Table 6 of the gESC [33], that waste packaging strategies must contribute towards so far as reasonable practicable.

Barrier component	General Environmental Safety Function
Wasteform	Limit the release of contaminants (radionuclides and hazardous substances).
	Stabilise the structure and geometry of the engineered barriers.
	Protect the internal surface of the waste container.
	Limit the potential for nuclear criticality.
Container	Prevent or Limit the release of contaminants (radionuclides and hazardous substances).
	Prevent disruption by over-pressurisation from gas generation.
	Stabilise the structure and geometry of the engineered barriers.
	Limit the potential for nuclear criticality.

A number of factors have been identified which could, potentially, have an impact on the safety functions of the multiple barriers of the GDF. A list of these factors, that need to be understood and controlled, is presented below alongside the applicable sections of this specification which addresses them:

- Evolution of the waste packages (section 7.2)
- Organics and Complexants (section 7.2.2.1)
- Non Aqueous Phase Liquids (section 7.2.2.1)
- Free Liquids (section 7.2.2.1)
- Oxidants (section 7.2.2.1)
- Mass transport properties (section 7.2.2.1)
- Heat output (section 8.7)
- Voidage (section 8.9)
- The generation of radiological and non-radiological gas (section 8.10)
- Radiological hazardous materials (section 8.11)
- Non-radiological hazardous materials (section 8.11)
- Non-hazardous pollutants (section 8.11)
- Criticality (sections 8.12)

6 The Container

This section covers the minimum properties and functions that a waste container contributes to the overall performance of the waste package and the requirements placed upon them.

6.1 Surface Contamination

C42. The design of the waste container (i.e. geometric features, material of construction, and surface finish) *should* be such that it facilitates decontamination of the waste package following manufacture.

The detailed requirements applicable to surface contamination of a waste package are listed in section 8.8.

6.2 Stacking

The principles detailed graphically in Figure 7 are particularly important here.

C43. The waste container *shall* contribute to the stacking performance of the waste package.

If the waste container is unable to contribute much to the stacking performance of the completed waste package, then a solution must be found. See disposal stillages for the transport and handling of 500 L Drums WPS/605/01 as an example.

7 Requirements on the Wasteform

This section defines the functions, properties and material considerations required of the wasteform which, when combined, contribute to the overall integrity and performance of the waste package.

7.1 Role of the Wasteform in the Disposal System

The wasteform is the waste in the physical and chemical form in which it will be disposed of, including any conditioning media and container furniture, but not including the waste container itself.

B21) ***The properties of the wasteform shall comply with the requirements for containment within the geological disposal concept, as defined by the GDF safety case.***

The wasteform can contribute towards the containment function in its own right, but must also be compatible with the other features of the EBS. The containment function is described in the safety cases for each of the three phases of the GDF.

To ensure containment:

C44. All reasonable measures *shall* be taken to ensure that radionuclides are immobile.

C45. All reasonable measures *shall* be taken to ensure that hazardous substances are immobile.

C46. All reasonable measures *shall* be taken to ensure that the input of non-hazardous pollutants from the waste package to groundwater is limited.

C47. The wasteform *should* provide a stable, low-solubility matrix that limits the release of contaminants.

For the list of Hazardous Substances and Non-Hazardous Pollutants which research has identified as being of most significant, please refer to [34].

7.2 Properties and Evolution of the Wasteform

The requirements placed on the properties of the wasteform (section 7.2.1), and the evolution of the wasteform (section 7.2.2), outline how the wasteform can contribute to the performance of the waste package.

7.2.1 Properties of the Wasteform

The properties of the wasteform can contribute to the performance of the waste package and help ensure that the waste package meets the required safety functions for all phases of the GDF.

C48. The physical, chemical, biological and radiological properties of the wasteform *shall*:

a. Make an appropriate contribution to the overall performance of the waste package.

b. Have no significant deleterious effect on the performance of the waste package.

7.2.2 Evolution of the Wasteform

C49. Evolution of the wasteform *shall* not compromise the properties that are necessary for safe transport and operations at the GDF.

It is recognised that some waste packages will be (and in other instances, have been) stored for significant periods of time prior to transport and emplacement within a GDF. Evolution of the wasteform can change the properties of the waste package, which may compromise the ability for the waste package to meet the eventual safety case for the GDF. A period of 150 years is currently considered as the minimum duration that waste packages will have to be shown to have maintained adequate integrity (see section 8.6).

C50. Evolution of the wasteform *shall* not compromise the environmental safety functions of the waste package.

The ability of the wasteform to meet its environmental safety functions is an integral part of the Post-Closure safety assessment [35]. The environmental safety functions are listed in Section 5 (Table 4) and derived from the gESC [33].

7.2.2.1 Controls on the Wasteform

To meet the high level requirements placed on the properties and evolution of the wasteform, controls on the inclusion of substances and certain material types, are enforced on the wasteform so far is reasonably practicable - as shown in Table 5.

C51. The properties and characteristics in Table 5 *shall* apply to all package contents and any degradation products thereof.

Table 5: Summary of requirements placed upon the wasteform.

Property Type	Property/characteristic	Requirements
Physical	Free Liquids	**C52. Free liquids *shall* be minimised.** **C53. Free liquids *should* be excluded.**
	Loose Particulate	**C54. The release of respirable particles <10 µm from a reference accident scenario *should* be minimised.**
	Mechanical Strength	**C55. The wasteform *should* contribute towards the mechanical performance of the waste package.**
	Combustion	**C56. The wasteform *should* not burn or support combustion.**
	Homogeneity	**C57. The presence of local concentrations of materials within the wasteform, or lack of homogeneity, that may be detrimental to the performance of the waste package under normal and accident conditions *should* be minimised.**
	Thermal Conductivity	**C58. The Thermal conductivity of the wasteform *shall* be sufficient to dissipate heat generated within the waste package preventing unacceptable temperature rises.** **C59. The thermal conductivity of the wasteforms should be between 0.5 - 10 $Wm^{-1}K^{-1}$.**
	Mass Transport Properties	**C60. The mass transport properties of the wasteform *should* not compromise the environmental safety functions of the waste package.**
Chemical	Acids and materials which could degrade to generate acids	**C61. Acids and materials which could degrade to generate acids *should* be minimised.**
	Organic Materials	**C62. Organic materials *should* be minimised, as far as reasonably practicable.** **C63. Organic materials *should* be immobilised within a suitable matrix.**
	Complexants, Chelating Agents, and materials which could degrade to generate such compounds	**C64. Complexants, Chelating Agents, and materials which could degrade to generate such compounds *should* be minimised.** **C65. Complexants, Chelating Agents, and materials which could degrade to generate such compounds *should* be immobilised within a suitable matrix.**
	Non-Aqueous Phase Liquids (NAPLs), and materials which could degrade to generate such compounds	**C66. Non-Aqueous Phase Liquids (NAPLs) *should* be minimised.** **C67. Non-Aqueous Phase Liquids *should* be immobilised within a suitable matrix.**

Table 5: Continued

Property Type	Property/characteristic	Requirements
Chemical	Reactive Materials	**C68. Reactive metals *should* be immobilised.** **C69. Reactive materials *should* be made passively safe.**
	Oxidising Materials	**C70. Oxidising materials *should* be controlled.** **C71. Oxidising materials *should* be made passively safe.**
	Organic Materials	**C72. *Should* be minimised.** **C73. *Should* be immobilised within a suitable matrix.**
	Non-hazardous pollutants	This topic is covered in greater detail in section 8.11. Specific cases are further detailed below.
	Hazardous substances	This topic is covered in greater detail in section 8.11. Specific cases are further detailed below.
	Flammable and Pyrophoric Materials	**C74. Flammable and pyrophoric materials in the waste package *should* be minimised.**
	Sealed Containers	**C75. Sealed containers *should* be excluded.**
	Pressurised Containers	**C76. Pressurised containers *should* be excluded.**
	Waste items containing stored energy	**C77. Waste items containing stored energy *shall* be made safe.**
	Explosive Materials	**C78. Explosive materials *shall* be made safe.**
Radiological	Activity	See sections 3.2.1 and 4.3

Guidance on how to meet and demonstrate compliance with the requirements within this section is discussed in the following documentation:

- Guidance on the production of encapsulated wasteforms (WPS/502).
- Guidance on the production of non-encapsulated wasteforms (WPS/503).

8 The Waste Package

In addition to the properties and functions unique to the waste container and wasteform described in sections 6 and 7, there are also requirements which can be considered to relate to the performance of the waste package as a whole. This section details the requirements that the waste package must fulfil.

8.1 External dimensions

B12) ***The external dimensions of the waste package shall be compatible with the transport handling systems.***

B13) ***The external dimensions of the waste package shall be compatible with the GDF handling systems.***

C79. Transport units, including any ancillary equipment such as tie down frame *shall* be compatible with the dimensional restrictions for transport by road, rail and transfer at the GDF by drift and shaft.

C80. The overall dimensions of a transport unit, including ancillary equipment such as a tie down frame, used to restrain the package to a conveyance *should* not exceed 7300 mm long x 2438 mm wide x 2438 mm high.

These dimensions are inclusive of transport and GDF operations.

The Part D specification for LHGW provides a comprehensive list of the current standard waste package envelopes.

C81. The external dimensions of the waste package *shall* be compatible with the intended transport arrangements.

C82. To be compatible with transport within one of RWM's Standard Waste Transport Containers (SWTC), the overall dimensions of a waste package, and any associated furniture e.g. a stillage, *shall* be compatible with the cavity dimensions listed in Table 6.

C83. The external dimensions of a waste package *should* conform with the dimensional envelope as specified for a standard waste package.

Table 6: Cavity dimensions of Standard Waste Transport Container (SWTC) variants developed by RWM [36-38].

SWTC variant	Maximum cavity dimensions		
	Length / m	Width / m	Height / m
70	1.72	1.72	1.245
150	1.85	1.85	1.37
285	1.72	1.72	1.245

8.2 Gross mass

B24) *The gross mass of the waste package shall be compatible with the transport system.*

C84. The overall mass of a waste package in its transport configuration *shall* not exceed 120,000 kg.

C85. The overall mass of a waste package in its transport configuration *should* not exceed 65,000 kg.

C86. For waste packages which are intended to be transported within an SWTC, the mass of the disposal unit *should* not exceed 12,000 kg.

The different designs of SWTC can accommodate different payloads [36-38]. For the SWTC 285 design (the heaviest of the transport containers) the maximum payload is 12,000 kg.

B26) *The gross mass of the waste package shall be compatible with the GDF handling systems.*

It is assumed that the GDF handling systems, including lifting systems, drift or transfer systems, will have sufficient load capacity to handle a waste package in its transport configuration [8].

Compliance of a waste package with the mass limits set by the transport system will consequently enable subsequent compliance with the GDF handling systems.

B25) *The gross mass of the waste package shall be compatible with the requirements for the waste package to be safely stacked.*

Where a waste package is designed to be handled in conjunction with a number of other waste packages, e.g. in a stillage as part of 4 x 500 L Drums the total mass of the disposal unit and any other accompanying equipment must be included in the calculations:

The sum mass of the four 500 L drums + Mass of the stillage = The gross mass of the disposal unit

8.3 Stacking

B16) *Where required by the transport or disposal system, the waste package shall enable safe stacking.*

C87. Disposal units *shall* be capable of being stacked with other disposal units of the same type, each with their maximum specified gross mass, not resulting in any permanent deformation or abnormality that would render them non-complaint with any other performance requirements defined within this specification, to a maximum height of:

a. 8.8 m for waste packages handled using overhead cranes.

b. 11 m for waste packages handled using top loading stacker trucks.

C88. Waste packages *should* be stackable without the need for, or reliance on, interlocks or restraints.

It is important to note that these stacking heights may not be the only stacking requirements placed upon a waste package. For the stacking requirements of transport packages, the reader is directed to section 3, to ensure that all waste packages also comply with stacking requirements during transport. The most limiting values in either case must always be used.

C89. Each disposal unit *shall* be capable of being safely stacked when allowing for an offset of 25 mm in each orthogonal direction for cuboidal packages or a 25 mm radial offset for cylindrical packages from the disposal units above and below.

See section 8.6 for the requirements which dictate how long a stacked column of waste packages must be stable for.

8.4 Waste Package Identification

The structure and format of the waste package identifier, the manner of its marking on waste packages, and their use by the waste packager is specified below. Further guidance can be found in WPS/860/03.

The allocation and use of waste package identifiers is subject to the quality requirements as specified in section 9.2.

B17) *The waste package shall enable unique identification until the end of the GDF operational period.*

C90. The waste package *shall* be marked with a unique RWM identifier.

C91. Each identifier *shall* be at four defined locations to be agreed by RWM.

This requirement refers to the location of identifiers for new waste package designs, rather than each waste stream. When using an existing waste container design to create a waste package, see the Part D specification covering LHGW containers for the specific locations of identifiers.

C92. A waste package and its identifier *shall* remain identifiable by automated systems for a minimum period of 150 years following manufacture.

C93. Waste package identifiers *shall* display adequate contrast with the substrate to which they are attached.

C94. The format of the RWM identifier *shall* be ten alpha-numeric characters arranged in a horizontal sequence from left to right with no intermediate spaces or other markings.

The identifier format is shown in Figure 11.

C95. The characters *shall* be of the Optical Character Recognition A form (OCR-A), as specified by BS 5464: Part 1, each with a height of between 6 and 10 mm.

The format of OCR-A is shown in Figure 12 [39].

C96. The waste package identifier *shall* comprise three Data Fields which are contained within the ten alpha-numeric character sequence (Figure 11).

Figure 11: Format of RWM alpha-numeric waste package identifier.

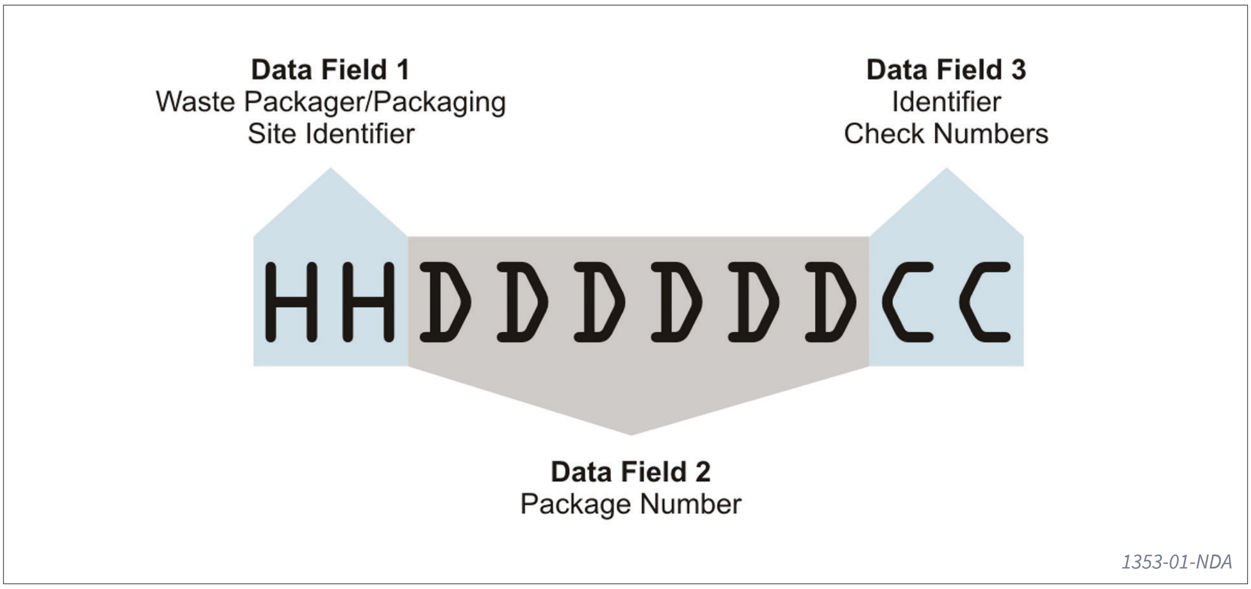


Figure 12: Permissible OCR-A characters that are to be used in the production of a waste package identifier.

8.4.1 Data Field 1

C97. Data Field 1 identifiers *shall* be allocated by RWM.

C98. Data Field 1 *shall* identify the original source of the waste package (i.e. the packaging site or plant).

C99. Data Field 1 *shall* consist of two sequential hexadecimal characters (HH in Figure 11).

C100. The following characters *shall* be used:

0 1 2 3 4 5 6 7 8 9 A B C D E F

8.4.2 Data Field 2

C101. Data Field 2 identifiers *shall* be allocated by the Waste Packager.

C102. Data Field 2 *shall* identify the package number from a particular waste packaging site or plant.

C103. Data field 2 *shall* consist of six package sequential decimal characters (DDDDDD in Figure 11).

C104. The following characters *shall* be used:

0 1 2 3 4 5 6 7 8 9

C105. Waste Packagers *should* sub allocate the Data Field 2 identifiers issued to a site or packaging plant, in blocks to differentiate between packaging plants, waste package types and waste streams.

C106. Each sub-block of Data field 2 identifiers *shall* only be used for the intended waste package type and/or waste stream.

C107. The number 000000 *shall* not be used as a Data Field 2 identifier.

8.4.3 Data Field 3

C108. Data field 3 *shall* consist of a check number.

C109. The Check Number *shall* consist of two sequential decimal characters (CC in Figure 11) from the following list:

0 1 2 3 4 5 6 7 8 9

C110. The Check Number for an identifier *shall* be derived using the following algorithm:

$$CC = 97 - R$$

$$R = \{(HHDDDDDD) \times 100\} \bmod 97$$

Where HHDDDDDD is a real number and ‘mod’ represents the modulo function nmodm, which returns the remainder when n is divided by m.

C111. The Check Number *shall* be prefaced by zero if the result of applying the algorithm is less than ten.

C112. Calculation of the Check Numbers *shall* be suitably verified.

8.5 Handling Features

B14) *The waste package shall enable safe handling by way of the transport handling systems.*

C113. The transport unit *should* demonstrate compatibility with:

a. Overhead lifting.

b. Restraint on a rail wagon and a road trailer.

C114. The use of automated handling for lifting and tie down operations *shall* be factored into the waste package design.

C115. Consideration *should* be given to the use of conventional lifting features and the application of a suitable design code when designing waste package handling arrangements.

B15) *The waste package shall enable safe handling by way of the GDF handling systems.*

C116. The waste package *should* have overhead accessible lifting features.

C117. The waste package and/or disposal unit *should* have overhead accessible lifting features.

Below is a description of some of the possible ways in which the waste packager may wish to demonstrate adequacy of the waste package handling arrangements. Waste container lifting features must have adequate strength to allow safe lifting taking account of the static load and dynamic effects. An approach to achieving this would be to qualify the package against a design load that takes into account these effects. A conservative design load of twice the weight of the waste package can be applied, equivalent to a conservative impact factor of 2 as per Table 4 of the crane standard, BS 2573, [40] and consistent with the test standard for freight containers, BS 1496, [41]. Alternatively the lifting points can be designed in accordance with an appropriate standard or code such as BS EN 13001-1:2015 [42] or TCSC 1079 [43]. Consideration needs to be given to the maximum offset of the lifting point and lifting equipment engagement and to the maximum offset of the waste package centre of gravity.

C118. The waste package and/or disposal unit *shall* incorporate lifting features which have adequate strength so that:

a. The waste package and/or disposal unit can be handled without exhibiting any permanent deformation that would render it incompatible with the requirements of this specification following application of the design load during handling.

b. The waste package and/or disposal unit can be safely lifted using any two diagonally opposing lifting features if the disposal unit consists of more than three lifting points.

Tolerances in lifting equipment and waste container design can result in unequal loading of lifting points when there are more than three lifting points. In the extreme case, this can result in the entire load being borne by a minimum of two diagonally opposite lifting features. If requirement C118 is unduly constraining, consideration may be given to lifting equipment that has a means of reducing the imbalance across the lifting point loads. This would be determined as part of the disposability assessment process.

C119. The design of the waste package *shall* enable remote handling of the waste package.

B18) *The waste package shall enable safe handling by way of its handling feature until the end of the GDF operational period.*

DSS requirement B18 is directly linked to the requirements on durability of the waste package. The requirements relating to durability, detailed in section 8.6, must be consulted and applied directly to the handling features, amongst other criteria detailed in this specification, to ensure that waste packages can be safely handled until the anticipated end of GDF operations.

8.6 Durability

B19) *The waste package shall maintain containment for as long as is required by the GDF safety case.*

C120. The integrity of the waste container, wasteform, and waste package, as a whole, *shall* be maintained for a period of 150 years following manufacture of the waste package.

C121. The integrity of the waste container, wasteform and waste package as a whole, *should* be maintained for a period of 500 years following manufacture of the waste package.

There are several areas where these requirements are of particular importance. In these key areas, the durability requirements must be recognised and compliance demonstrated within waste package designs. These key areas are:

- Containment (**sections 3** and **4**)
- Shielding (**section 3.1.4** and **4.3**)
- Handling (**section 8.5**)
- Stacking (**section 6.2** and **8.3**)
- Identification (**section 8.4**)
- Venting (**section 8.10**)

The term "maintenance" can be met in differing ways. The three main interpretations can be either:

1. The physical actions of maintenance – e.g. maintaining the painted surface of the waste package (if it has been designed to be painted).
2. Maintenance through the intrinsic properties of the materials selected to construct the waste package. The performance of the waste package can be maintained through the appropriate quality control and selection of the materials used in the construction of the waste package, with the inclusion of appropriate margins.
3. Appropriate storage arrangements prior to transport to a GDF, see **section 9.3** for more details.

8.7 Heat Output

B30) *The heat generated by the waste package shall be controlled to ensure that thermal effects result in no significant deterioration in the performance of the waste package.*

C122. The heat output of the waste package at time of disposal vault closure *should* not exceed 6 W/m^3 of conditioned waste.

B31) *The heat generated by the waste package shall be controlled to ensure that thermal effects result in no significant deterioration in the performance of the disposal system as a whole.*

Any potential factors which could cause heat excursions above 6 W/m^3 throughout the lifetime of a waste package must be considered and acknowledged.

8.8 Surface Contamination

B33) *The non-fixed surface contamination of the waste package shall be as low as reasonably practicable (ALARP).*

B34) *The non-fixed surface contamination of the waste package shall comply with regulatory limits during transport.*

C123. For 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:

a. 4.0 Bq cm^{-2} for beta, gamma and low toxicity alpha emitters.

b. 0.4 Bq cm^{-2} for all other alpha emitters.

C124. 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:

a. 4.0 Bq cm^{-2} for beta, gamma and low toxicity alpha emitters.

b. 0.4 Bq cm^{-2} for all other alpha emitters.

8.9 Voidage

C125. The development and production of the waste package *shall* ensure that the volume of voidage within the waste package is minimised.

8.10 Gas Generation

B35) *The generation of bulk, radioactive, and toxic gases by the waste package shall comply with the requirements for safe transport.*

The reader is directed to section 3 (Transport) for the applicable gas generation requirements.

B36) *The generation of bulk, radioactive, and toxic gases by the waste package shall comply with the requirements for disposal.*

Careful consideration must be given to the role that both the waste container and wasteform can play in regulating the generation and handling of gases within waste packages.

There are two primary methods for achieving pressure regulation:

- Where relevant, include vents in the container to release internally generated gases but retain activity in particulate form.
- Control the production and release of gas by considering the contents and conditioning media used when producing the waste package. This is particularly important in the case of ^{222}Rn gas where more information on this topic can be found in WPS/902.

C126. The waste packaging strategy *should* manage the potential for active gas release in the different phases:

a. Storage.

b. Transport.

c. Operations.

d. Post Closure.

C127. The waste packaging strategy *should* manage the potential for non-active gas release in the different phases:

a. Storage.

b. Transport.

c. Operations.

d. Post Closure.

B118) *The airborne discharge shall conform to the relevant regulatory requirements.*

B38) *The release of radionuclides in gaseous form from the waste package shall comply with the assumptions that underpin the safety cases for the GDF operational period.*

8.10.1 Contributions to Gas Management by the Waste Container

C128. Any vents incorporated into the design of a waste container *shall*:

a. Minimise the release of particulate materials.

b. Allow the controlled release of gas to ensure compliance with the Pressure Systems Safety Regulations (PSSR).

c. Be situated so that they do not become blocked when packages are handled or stored.

8.10.2 Contributions to Gas Management by the Wasteform

C129. The wasteform *shall* be sufficiently permeable to allow gases generated within the wasteform to be released.

B37) ***The release of radionuclides in gaseous form from the waste package shall comply with the assumptions that underpin the safety case for transport.***

The reader is directed to section 3 (Transport) for applicable gas generation requirements.

8.11 Groundwater Protection

B93) ***In accordance with the groundwater protection provisions of the Environmental Permitting (England and Wales) Regulations 2010,[2] it shall be demonstrated that all necessary technical precautions will be taken to prevent the input of hazardous substances to groundwater.***

B94) ***In accordance with the groundwater protection provisions of the Environmental Permitting (England and Wales) Regulations 2010, it shall be demonstrated that all necessary technical precautions will be taken to limit the input of non-hazardous pollutants to groundwater so as to ensure that such inputs do not cause pollution of groundwater.***

RWM is currently developing waste package requirements to address the groundwater protection requirements listed above.

To date, the established position which has been endorsed through the disposability assessment process is reflected in the following requirement:

C130. Where it is not already a component of the waste, lead *shall* not be deliberately added to a waste package.

For the list of Hazardous Substances and Non-Hazardous Pollutants which underpinning research has identified as being of most significance, please refer to [34].

Waste Packagers are urged to contact RWM at the earliest possible opportunity during the development of a packaging proposal for advice on this topic.

[2] Equivalent protections are provided for in Northern Ireland by the Groundwater Regulations (Northern Ireland) 2009 and in Scotland by the Water Environment (Controlled Activities) (Scotland) Regulations 2011.

8.12 Criticality Safety

B39) *The presence of fissile material, neutron moderators and reflectors in the waste package shall be controlled to ensure that criticality during transport is prevented.*

B40) *The presence of fissile material, neutron moderators and reflectors in the waste package shall be controlled to ensure that the risk of criticality during the GDF operational period is tolerable.*

B41) *The presence of fissile material, neutron moderators and reflectors in the waste package shall be controlled to ensure that the risk of criticality during the GDF operational period is as low as reasonably practicable (ALARP).*

B42) *The presence of fissile material, neutron moderators and reflectors in the waste package shall be controlled to ensure that in the GDF post-closure period both the likelihood and the consequences of criticality are low.*

It is important that the approach to criticality safety is proportionate to the potential criticality risk. Therefore, it is necessary first to consider the composition of the fissile material in the waste stream and the proposed waste package to determine an appropriate and proportionate approach to demonstrating criticality safety, before undertaking a detailed analysis.

C131. A safe fissile mass (SFM) for the waste package *shall* be derived and presented in Criticality Safety Assessments for the Transport, Operations and Post Closure phases of a GDF.

C132. The most restrictive safe fissile mass derived from the three phases *shall* set the package fissile material limit.

The following requirement is derived from the IAEA transport Regulations paragraphs 222, 417 and 674, and 673 respectively:

C133. A criticality safety demonstration *shall* be made for waste package transport that satisfies the IAEA Transport Regulations [14] in one of the following ways:

a. A non-fissile case *shall* be made under Para 222.

b. A fissile exception case *shall* be made under Para 417, or Para 674.

c. For fissile waste material a criticality safety case *shall* be provided according to Para 673.

Definitions for these categories can be found in the IAEA Transport Regulations for the Safe Transport of Radioactive Materials [14]. Further guidance on the Application of the Criticality Safety Requirements of the IAEA Transport Regulations for Waste Packages that Contain Small Quantities or Concentrations of Fissile Material is provided in the latest version of WPS/911 [44].

Waste packagers are encouraged to use the generic fissile mass limits derived by RWM, summarised in the latest version of the criticality guidance WPS/916 [45] (detailed fully in [46-50] if applicable) for the proposed waste package. See below.

A hierarchy of fissile material limits for LHGW is used, with increasing knowledge of the specific waste stream required as one moves through the hierarchy. More information relating to this process can be found in WPS/916.

C134. The General Criticality Safety Assessment or generic Criticality Safety Assessments *should* be used to derive the safe fissile mass of the proposed waste package.

The General Criticality Safety Assessment (GCSA) and the five generic Criticality Safety Assessments (gCSAs) derived by RWM, represent the first two levels of the criticality safety assessment hierarchy. If waste packagers can demonstrate that their package is compliant with the assumptions and characteristics that underpin the GCSA or one of the five generic cases, then the specified fissile material controls for that CSA can be applied to the proposed waste package.

If the waste stream or proposed conditioning and packaging strategy is substantially different from any of the gCSAs, or the waste packager wishes to package waste with a higher fissile content, then they cannot be used.

C135. If a GCSA or gCSA cannot be used directly or modified, a package specific CSA *shall* be developed in order to derive a safe fissile mass and the associated constraints.

It is of particular importance to consult the appropriate guidance within WPS/916, as the amount of work required to create a package specific CSA is highly variable [45]. This variability is dependent upon how similar the proposed package is to other packages for which a package specific CSA has already been developed. It takes a greater degree of effort and engagement with RWM to develop a package specific CSA, rather than utilising the aforementioned generic cases.

In all cases, contact should be made with RWM at the earliest possible opportunity to discuss criticality safety compliance in addition to wider disposal plans.

A criticality compliance assurance document (CCAD) is required from the waste packager as part of the Disposability Assessment process. The CCAD is required to detail the processes that a waste packager will adopt to ensure compliance with a stated fissile material limit (or any other criticality safety control). The reader is directed to section 9.6.3 for further details.

Guidance on CCAD can be found in WPS/916.

9 Assurance, Records and Management (ARM)

9.1 Introduction

The purpose of the Assurance, Records and Management (ARM) requirements is to ensure that manufactured waste packages can be demonstrated to be disposable to the future disposal system operator, stakeholders and regulators. To fulfil these requirements, it is imperative that waste packages are designed, manufactured and stored under an appropriate Management System. Of equal importance are the associated waste package records which play the vital role of bridging what has been done today with what RWM anticipate concerned parties will want to see in future. Therefore, the role of the waste package record is to provide assurance, to future generations, that waste packages were manufactured and stored in such a manner that they will ultimately be disposable. To these ends, ARM requirements are identified in the following areas:

- Management System arrangements for the design and manufacture of waste packages.
- Arrangements for the Interim Storage of waste packages, as far as these may influence disposability.
- Nuclear Safeguards.
- Nuclear Security.
- Production of Waste Package Records, including provision of key documentation or equivalent arrangements as follows:
  - Package Records Specification (PRS).
  - Waste Product Specification (WPrS).
  - Criticality Compliance Assurance Documentation (CCAD).
  - Transport Package Design Safety Documentation.

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

It is crucial that the requirements for these areas are fulfilled for each defined set of waste packages. Details of the requirements concerning these themes are provided below.

9.2 Management Systems

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

C136. Management system arrangements *shall* be in place during all lifecycle stages of a waste package, to control any activities that might affect the disposability of a waste package, including:

a. Design and development of waste packages.

b. Waste processing and packaging.

c. Interim Storage.

d. Continuous activities that might apply throughout all lifecycle stages including production of Waste Package Records.

C137. Objective evidence *shall* be provided to demonstrate that management system arrangements:

a. Apply to all lifecycle stages of a waste package.

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

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

C138. The management system arrangements *shall*:

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

The reader is directed to sections 9.6.1, 9.6.2, 9.6.3, and 9.6.4 for PRS, WPrS, CCAD, and Transport Package Design Safety Documentation requirements, respectively.

b. Include basic controlling documents for the activities recognised in Requirements C137-C140.

c. Define the tests, measurements or inspection regimes that will be undertaken to confirm compliance with delivering a disposable product.

C139. Management system arrangements *shall*, if applicable, be in place during the design and development stage to control the following activities:

a. Container design.

b. Wasteform development.

c. Packaging process development.

d. Plant specification and design.

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

f. Any other activities that may be carried out that affect waste package design and development.

C140. Management system arrangements *shall*, if applicable, be in place during the waste processing and packaging stage to control the following activities:

a. Waste characterisation and inventory derivation.

b. Waste retrieval and loading.

c. Container manufacture.

d. Plant commissioning.

e. Plant operations including raw materials storage.

f. Management of non-conforming waste packages.

g. Any other activities that may be carried out that affect waste processing and packaging.

C141. Management system arrangements *shall*, if applicable, be in place during the interim storage stage to control the following, under asset management principles:

a. Environmental conditions in the store.

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

c. Monitoring and inspections of the waste packages in storage.

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

The reader is directed to section 9.3 for further details.

C142. Management system arrangements *shall*, if applicable, be in place throughout all lifecycle stages of a waste package to control the following continuous activities:

a. Change control and continuous improvement.

b. Production and management of waste package records.

c. Long-term retention and management of waste package records.

d. Risk management.

e. Any other activities that may be carried out that affect the waste package lifecycle.

C143. RWM *shall* be granted access to conduct Technical Audits of any activities during the lifecycle of a waste package.

In order to demonstrate that appropriate controls were applied during packaging, to produce a compliant waste package, relevant parts of the management system need to be included in the Waste Package Record. Further details of which are provided in section 9.6.

9.3 Interim Storage

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

For a full description of "adequate" the applicable NDA Stores Guidance on the interim storage of waste packages [51] can be consulted. Some primary considerations are:

- To avoid cycling of wetting and drying of the waste packages.
- Maintaining low operating temperatures of the store to slow corrosion processes.
- Prevent the presence of corrosion promoting species, such as chloride.

Further RWM guidance on storage can be found in WPS/630/02 and WPS/640/02.

C144. A strategy and implementation plan for the monitoring and inspection regime of the storage system *shall* be provided.

C145. Atmospheric conditions and contaminants, which could affect the long-term properties and performance of the waste package during interim storage, *shall* be:

a. Controlled.

b. Monitored.

Please refer to NDA Industry Stores Guidance [51], for the recommended operational limits.

Failure to adequately maintain waste packages whilst in storage risks the waste package not meeting the eventual Waste Acceptance Criteria (WAC), of the GDF.

C146. Steps to mitigate the consequences of storage conditions moving outside of the recommended ranges for prolonged periods of time *shall* be defined.

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

The reader is directed to section 9.6 for more details of the requirements for waste package records.

9.4 Nuclear Safeguards

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

B1018) *The reporting requirements of Commission Regulation (Euratom) 302/2005 shall be met in accord with the safeguards approach.*

C147. Where subjected to safeguard obligations, the handling and management of waste packages containing 'nuclear materials' *shall* be compliant with relevant safeguards controls.

The term 'nuclear materials' is defined in Article 2.4 of EC Regulation (Euratom) 302/2005 as [52]:

"Nuclear materials" means ores, source material or special fissile material as defined in Article 197 of the Euratom Treaty.

In summary, Article 197 defines these materials as:

'Special fissile materials':	^{239}Pu, ^{233}U, uranium enriched[3] in ^{235}U or ^{233}U.
'Source materials':	Natural uranium, depleted uranium, thorium.
'Ores':	Materials from which source materials can be extracted by chemical or physical processing.

Article 18.2(b) of the Regulation further specifies six categories of nuclear material for which Nuclear Materials Accounting (NMA) reporting is required, these are:

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

C148. The safeguards status, when applicable, of each waste package at time of dispatch to the GDF *shall* be determined in accordance with extant safeguards authority regulations.

C149. When applicable, waste packages containing nuclear materials below the threshold for Terminated status *should* be identified and where possible the safeguards status of waste packages Terminated.

C150. The safeguard status, when applicable, of the waste package *shall* be recorded as part of the Waste Package Record including evidence of agreement from the relevant authority.

The reader is directed to **section 9.6** for more details on the requirements of waste package records.

The reader is further directed to **WPS/923/01** for RWM guidance on this topic.

[3] In this context 'enriched' uranium is that in which the abundance ratio of the sum of ^{233}U and ^{235}U to ^{238}U is greater than the ratio of ^{235}U to ^{238}U in natural uranium (i.e. 0.7 %w/w).

9.5 Nuclear Security

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

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

C151. The security categorisation of the waste package *shall* be determined.

C152. The waste package record *shall* contain the information necessary to determine the security categorisation of the waste package under relevant controlling arrangements.

The reader is directed to section 9.6 for more details of the requirements of waste package records.

9.6 Production of Waste Package Records

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

C153. Each waste package *shall* have a record.

C154. A methodology *shall* be in place for acquiring, recording and managing the data, information and documentation required for a waste package record.

C155. The Waste Package Record *shall* be produced and managed to meet the requirements of IMP06: Managing NDA Information requirements.

a. Waste Package Records *shall* be designated as vital records.

b. All Waste Package Records *shall* be transferred to the Nucleus archive for long-term storage.

IMP06: Managing NDA Information requirements [53].

C156. The contents of each Waste Package Record *shall* be organised into three classes to cover the full lifecycle of the waste package:

a. Class A: Underpinning and Justification documentation.

b. Class B: Compliance definition and control documentation.

c. Class C: Compliance demonstration documentation.

Class A: This class contains evidence sufficient to demonstrate that the waste package, when manufactured, fulfils the requirements in the Part C and Part D specifications.

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

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

The requirements for each record Class are listed in Table 7. For further guidance the user is directed to the WPS/850/03.

Table 7: Waste Package Records requirements for Classes A, B and C.

Class	Requirement	Designated Category	Definition
Class A	**C157. The Class A record *shall* be comprised of documentation that fulfils the requirements for a record of:**		
	a. Background, nature and origin of the waste.	A1	As necessary to provide an unambiguous definition of the waste that has been packaged.
	b. The development and performance of the waste package.	A2	As necessary to provide evidence of process and wasteform development, including limits and exclusions, and expected performance of the waste package.
	c. The design and development of the waste container.	A3	To include container design drawings and manufacturing specification.
	d. The arrangements for producing package records, including deriving the data and information.	A4	To include methods and any fingerprints used to generate waste composition and radionuclide inventories.
	e. Arrangements for interim storage, monitoring and inspection of manufactured waste packages.	A5	As necessary to provide evidence of the application of appropriate controls during the interim storage of waste packages. See **section 9.3** for further requirements.
	f. Management system arrangements.	A6	As necessary to provide evidence of the application of appropriate controls in waste processing. See **section 9.2** for further requirements.
Class B	**C158. The Class B record *shall* be comprised of documentation that fulfils the requirements for a record of:**		
	a. The Package Record Specification (PRS).	B1	See **section 9.6.1** for further requirements.
	b. The Waste Product Specification (WPrS).	B2	See **section 9.6.2** for further requirements.
	c. The Criticality Compliance Assurance Documentation (CCAD).	B3	See **section 9.6.3** for further requirements.
	d. The measures necessary to demonstrate compliance with the contents specification of the transport package safety document.	B4	See **section 9.6.4** for further requirements.

Table 7: Continued

Class	Requirement	Designated Category	Definition
Class C	**C159. A Class C record *shall* be comprised of evidence to demonstrate that the requirements have been met to provide a record of:**		
	a. Waste package identifier.	C1	A statement of the waste package identification number (see **section 8.4**).
	b. Statement of compliance with Class B records.	C2	A statement that identifies the version of the controlling documents (Class B) against which the particular waste package has been manufactured and whether it is compliant.
	c. Compliance of the container.	C3	Evidence to demonstrate that the container used to produce the particular waste package complies with the relevant requirements of the Class B documents.
	d. Compliance of the waste.	C4	Evidence to demonstrate that the waste complies with the relevant limits or constraints placed on the waste in the Class B documents. This includes providing the radionuclide inventory and composition for the particular waste package.
	e. Compliance with processing.	C5	Evidence to demonstrate that the waste packaging process has been applied as specified in the Class B documents.
	f. Compliance of the waste package.	C6	Evidence to demonstrate compliance with any requirements and limits placed on the completed waste package in the Class B documents.
	g. Waste package management.	C7	Evidence to demonstrate that the waste package has been managed and stored since manufacture in compliance with the arrangements detailed under Category A6 (see **section 9.2**).
	h. Resolution of non-compliance.	C8	Identification of any non-compliances for the particular waste package and evidence of resolution.
	i. Other necessary package-scale information.	C9	Other pertinent information relating to an individual waste package to support the aims and principles of the waste package record. This includes Safeguards status and security-related information (see **sections 9.4** and **9.5**).

Additional guidance for the management of packaging records can be found in WPS/870/03.

9.6.1 Package Records Specification

C160. To demonstrate that the requirements of the Waste Package Record are fulfilled and to facilitate their future use, the contents of a Waste Package Record *shall*:

a. Be clearly recorded in an index which lists the original documents containing required data and information that are included in the Waste Package Record for a defined set of waste packages.

b. Provide an explanation of how to use the Waste Package Record for a defined set of waste packages.

RWM refer to the arrangements that fulfil this requirement as the Package Records Specification (PRS).

C161. All relevant versions/issues of the documents that form the Waste Package Records *shall* be listed in the index.

9.6.2 Waste Product Specification (WPrS)

C162. Each waste package *shall* be produced in compliance with an agreed Waste Product Specification.

C163. Supporting documents referenced within the Waste Product Specification *shall* be included in the Package Record Specification.

The reader is directed to section 9.6.1 for further details.

C164. Each iteration of the Waste Product Specification against which waste packages were made *shall* be included in the Package Record Specification.

C165. The Waste Product Specification *shall*:

a. Define the waste package that is to be produced.

b. Define the processes which will be used to create the waste packages.

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

d. Identify the limits and controls required during the production of a waste package.

e. Identify the waste product storage arrangements.

C166. The Waste Product Specification *shall* state the limitations and manufacturing specifications for the following factors:

a. Constraints on the waste to be packaged.

b. The waste container.

c. The inactive waste conditioning materials and any formulation envelope used.

d. Process requirements and controls.

C167. The Waste Product Specification *should* provide references to supporting Research and Development to justify the limits and specifications cited therein.

9.6.3 Criticality Compliance Assurance Documentation (CCAD)

C168. Assurance *shall* be provided that the fissile content, and other constraints, of each waste package to be produced, is within the limits prescribed in the associated CSA.

C169. Supporting documents referenced within the justification for criticality compliance assurance arguments *shall* be included in the Package Record Specification.

C170. Each iteration of the Criticality Compliance Assurance Documentation, against which waste packages were made *shall* be retained and recorded in the CCAD section of the Package Records Specification.

C171. Assurance of criticality compliance *shall* be described in a manner that is easily identifiable as the Criticality Compliance Assurance Documentation.

C172. The description of criticality compliance assurance *shall*:

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

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

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

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

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

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

C173. The description of assurance arrangements *shall* be approved by an individual with sufficient knowledge of the operation of the packaging plant.

Through this requirement, RWM seeks confirmation from an individual with sufficient understanding of how the packaging plant operates, and its associated procedures, that the CSA will be adhered to. This is necessary to ensure that the CSA is implemented correctly.

9.6.4 Transport Package Design Safety Documentation

The following requirements apply only when the waste package is the transport package. For further details, the reader is directed to section 3 (Transport).

C174. The Class C record *shall* provide the information to demonstrate compliance with the contents specification.

Abbreviations

ACT	Accident Conditions of Transport
ADR	International Carriage of Dangerous Goods by Road
ALARA	As Low as Reasonably Achievable
ALARP	As Low as Reasonably Practicable
BAT	Best Available Technique
CCAD	Criticality Compliance Assurance Document
DNLEU	Depleted Natural and Low Enriched Uranium
DSS	Disposal System Specification
EBS	Engineered Barrier System
EVR	Evaporite Rock
gCSA	generic Criticality Safety Assessment
GCSA	General Criticality Safety Assessment
GDF	Geological Disposal Facility
GDFD	Geological Disposal Facility Design
gDSSC	generic Disposal System Safety Case
gESC	generic Environmental Safety Case
gOSC	generic Operational Safety Case
gTSC	generic Transport Safety Case
gTSD	generic Transport System Design
HAW	Higher Activity Waste
HSR	Higher Strength Rock
IAEA	International Atomic Energy Agency
ILW	Intermediate Level Waste
ISO	International Standards Organisation
LHGW	Low Heat Generating Waste
LLW	Low Level Waste
LSA	Low Specific Activity
LSSR	Lower Strength Sedimentary Rock
MNOP	Maximum Normal Operating Pressure
NAPLS	Non Aqueous Phase Liquids
NCT	Normal Conditions of Transport

NDA	Nuclear Decommissioning Authority
NSL	Nuclear Site Licence
ONR	Office for Nuclear Regulation
gOSC	Generic Operational Safety Case
REPPIR	Radiation (Emergency Preparedness and Public Information) Regulations
RID	International Carriage of Dangerous Goods by Rail
RWM	Radioactive Waste Management Limited
SCO	Surface Contaminated Object
SFM	Safe Fissile Mass
SLC	Site Licence Company
SWTC	Standard Waste Transport Container
TCSC	Transport Container Standardisation Committee
TSC	Transport Safety Case
WAC	Waste Acceptance Criteria
WPS	Waste Package Specification
WPSGD	Waste Package Specification and Guidance Documents

Glossary and terminology

A2	A unit of activity as defined by the IAEA Transport Regulations (Para 201). The A_2 is a measure of radiological significance of a specific nuclide to transport safety and is linked to possible exposure pathways to humans by the radiation emitted by that radionuclide.
Backfill	A material used to fill free space voids in a GDF.
Conditioning	Treatment of a radioactive waste material to create, or assist in the creation of, a wasteform that has passive safety.
Exclusive Use	As defined by the IAEA Transport Regulations (Para 221).
Fissile Material	Defined by the IAEA Transport Regulations (Para 222). A fissile material is one containing any of the following fissile nuclides; ^{233}U, ^{235}U, ^{239}Pu and ^{241}Pu.
Immobilisation	A process by which the potential for the migration or dispersion of the radioactivity present in a material is reduced. This is typically achieved through conversion of the material into a monolithic form that confers passive safety to the material.
Low Specific Activity (LSA)	As defined by the IAEA Transport Regulations (Para 226). LSA material refers to radioactive material that has a limited activity. There are three categories of LSA material (LSA-I, LSA-II and LSA-III).
Low Toxicity Alpha Emitters	As defined by the IAEA Transport Regulations (Para 227). These are identified as natural uranium, depleted uranium, natural thorium, ^{235}U or ^{238}U; ^{232}Th, ^{228}Th and ^{230}Th when contained in ores or physical and chemical concentrates; or alpha emitters with a half-life of less than 10 days.
Nuclear Material	Ores, source material or special fissile material as defined in Article 197 of the Euratom Treaty.
Overpack	As defined by the IAEA Transport Regulations (Para 230). An enclosure used by a single consignor to contain one or more packages to form one unit for handling and storage during transport.
Safe Fissile Mass (SFM)	The quantity of fissile material that can be safely accommodated within a waste package, taking into account the nature of the fissile material, the presence of other materials of significance to criticality safety and the degree of characterisation of the waste package contents.
Specific Activity	As defined by the IAEA Transport Regulations (Para 240). The activity per unit mass of that radionuclide.
Surface Contaminated Objects (SCO)	As defined by the IAEA Transport Regulations (Para 241). A solid object that is not itself radioactive but which has radioactive material distributed on its surface.

Transport Package	As defined by the IAEA Transport Regulations (Para 231). The complete product of the packing operation, consisting of the packaging and its contents prepared for transport.
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 Container	Any vessel used to contain a wasteform for disposal.
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.

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