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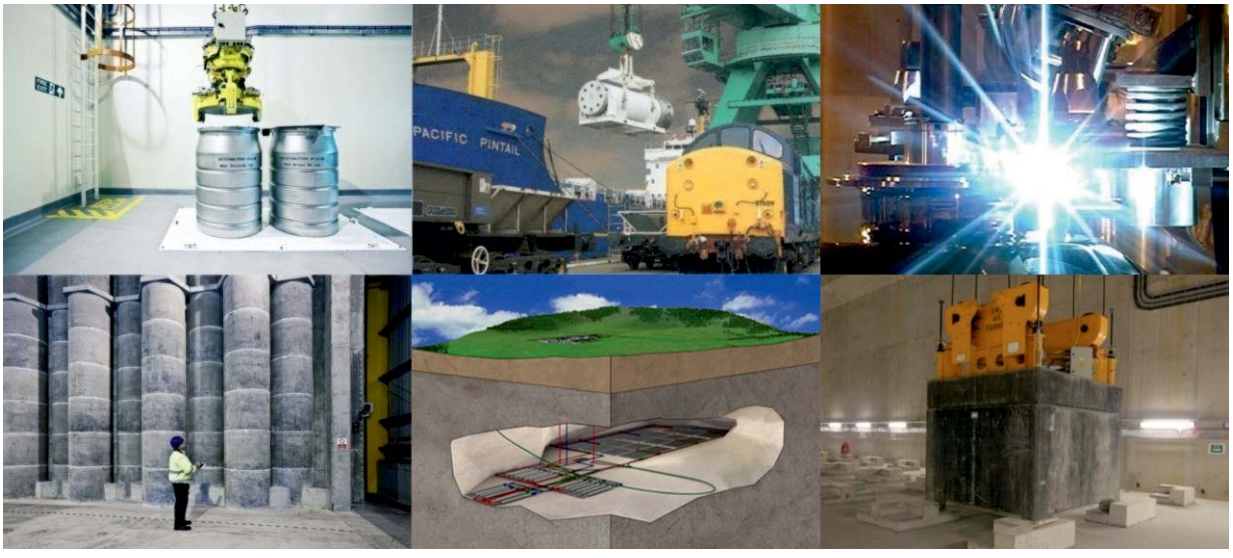
WPSGD No. WPS/501/01

Geological Disposal

Wasteform Specification for waste packages containing low heat generating waste

April 2013



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WASTE PACKAGE SPECIFICATION AND GUIDANCE DOCUMENTATION

WASTEFORM SPECIFICATION FOR WASTE PACKAGES CONTAINING LOW HEAT GENERATING WASTE

Executive Summary

This document forms part of the *Waste Package Specification and Guidance Documentation* (WPSGD), a suite of documents prepared and issued by the Radioactive Waste Management Directorate (RWMD) of the Nuclear Decommissioning Authority (NDA). The WPSGD are intended to provide a 'user-level' interpretation of the RWMD packaging specifications, and other aspects of geological disposal, to assist UK waste producers in the development of plans for the packaging of higher activity waste in a manner suitable for geological disposal.

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

This document provides a specification for the wasteforms contained by waste packages that result from the conditioning of low heat generating waste for transport to and disposal in a geological disposal facility.

The documents that make up the WPSGD will be subject to periodic revision which may lead to significant changes in packaging requirements. Users are therefore advised to contact RWMD, or refer to the NDA Bibliography at www.nda.gov.uk, to confirm that they are in possession of the latest version of any documentation used.

WPSGD DOCUMENT NUMBER WPS/501 - VERSION HISTORY		
VERSION	**DATE**	**COMMENTS**
WPS/501/01	April 2012	Aligns with Generic Specification for waste packages containing low heat generating waste (NDA/RWMD/068) as published August 2012. Replaces WPS/500, WPS/510 and WPS/520

1 Introduction

RWMD produce packaging specifications as a means of providing a baseline against which the suitability of plans to package higher activity waste for geological disposal can be assessed. In this way we assist the holders of radioactive waste in the development and implementation of such plans, by defining the requirements for waste packages which would be compatible with the anticipated needs for transport to and disposal in a geological disposal facility (GDF).

The packaging specifications form a hierarchy which comprises three levels:

- The *Generic Waste Package Specification* (GWPS) [1]; which defines the requirements for all waste packages which are destined for geological disposal;
- *Generic Specifications;* which apply the high-level packaging requirements defined by the GWPS to waste packages containing a specific type of waste; and
- *Waste Package Specifications* (WPS); which apply the general requirements defined by a Generic Specification to waste packages manufactured using standardised designs of waste container.

As a means of making the full range of RWMD packaging specifications readily available to waste producers and other stakeholders, a suite of documentation known as the *Waste Package Specification and Guidance Documentation* (WPSGD) is published and maintained for ready access (i.e. via the NDA website at www.nda.gov.uk). The WPSGD includes a range of WPS for different waste package types together with explanatory material and guidance that users will find helpful when it comes to application of the WPS to practical packaging projects. For further information on the extent and the role of the WPSGD, reference should be made to the *Introduction to the RWMD Waste Package Specification and Guidance Documentation* [2].

This document is a specification for the required properties of the wasteforms that form a key component of waste packages containing intermediate level waste (ILW) and other wastes with similar radiological properties. The requirements specified herein are based on the high-level wasteform requirements specified in the *Generic Specification for waste packages containing low heat generating waste* [3]. This specification is supported by a number of other documents from the WPSGD, notably guidance on the achievement of the requirements for encapsulated and non-encapsulated wasteforms [4, 5].

The suitability of proposed approaches to the conditioning particular waste, and the ability of the resulting wasteform to satisfy the requirements laid down by this Specification is assessed as part of the RWMD *Disposability Assessment Process* [6]. Waste packagers intending to submit waste packaging proposals for such assessment by RWMD are referred to *Guidance on the preparation of submissions for the Disposability Assessment of waste packages* [7].

2 The packaging of low heat generating waste for geological disposal

The description 'low heat generating waste' encompasses radioactive wastes with radiological properties similar to that of ILW, as defined in the Generic Specification for such wastes [3]. Over the past two decades, the UK waste producers have developed plans for the packaging of a range of such wastes and, in some cases, have implemented those plans by manufacturing waste packages with the properties that are compatible with our plans for the geological disposal of the waste.

To aid in the development of those plans RWMD has established the Disposability Assessment Process [6], the purpose of which is to demonstrate that the manufactured waste packages will be passively safe and disposable, and aligned with regulatory expectations for the long term management of the waste they contain [8]. This will also demonstrate that waste packages will be capable of providing an appropriate barrier to the release of radionuclides and other hazardous materials that is required of them as part of a multiple barrier geological disposal system. If a Disposability Assessment concludes that the proposed waste packages would have the appropriate properties to satisfy these requirements, a *Letter of Compliance* (LoC) can be issued to endorse the plans for the packaging of the waste.

The development of plans for the packaging of low heat generating waste has resulted in the identification of a number of generic approaches to such packaging. This has included the definition of designs of waste container and the development of processes by which waste can be 'conditioned' to produce a wasteform possessing such properties that will ensure the disposability of waste packages.

To date a number of generic types of waste container have been used, or are proposed to be used, for the packaging of low heat generating waste:

- Thin walled (i.e. a few mm) metal containers, typically made of stainless steel, and which may include internal shielding;
- Thick-walled (i.e. up to a few 100mm) cast iron containers; and
- Thick walled (typically a few 100mm) reinforced concrete containers.

This has also resulted in the definition of a number of standardised designs of waste container, which are identified in the generic *Disposal System Technical Specification* (DSTS) [9], and for which WPS have been produced.

A range of approaches to the 'conditioning' of different waste types have also been developed, these include:

- mixing of the waste with an encapsulating medium (e.g. cement or polymer) to form a monolithic 'encapsulated' wasteform;
- compaction of the waste in a sacrificial container and packaging the resulting product in a waste container by surrounding it with a suitable material to form an 'annular grouted' wasteform;
- high temperature processing of the waste to form a monolithic 'vitrified' wasteform; and
- the use of more simple processes, such as size reduction and/or drying, to produce a 'non-encapsulated' wasteform.

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3 General requirements for wasteforms

Whichever type of waste container and approach to waste conditioning is adopted for the treatment of a particular waste it will be the performance of the resulting waste package as a whole that will be used to judge its disposability. The fundamental aims for the packaging of waste are to ensure that the resulting waste packages are:

- passively safe and adequately physically robust, so as to ensure containment and safe handling during all ensuring phases of the long-term management of the waste including disposal at a GDF;
- suitable for safe transport through the public domain in compliance with the relevant regulations for such transport; and
- compatible with the safety cases for the operational and post-closure periods of a GDF.

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

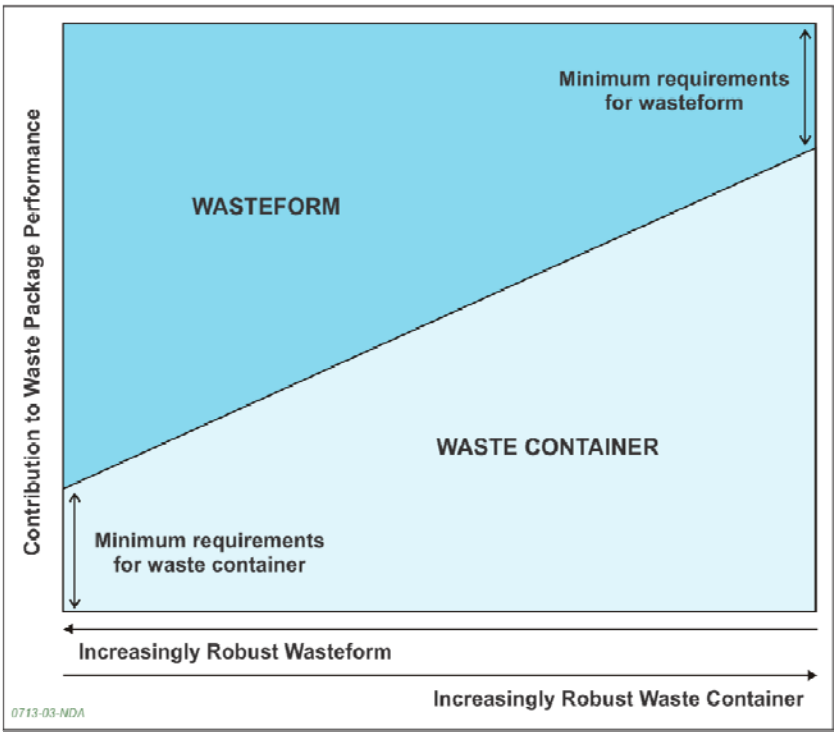
The barrier provided by a waste package can be considered to comprise two distinct components, each of which can act as a barrier in its own right:

- The waste container, which provides a physical barrier and also enables the waste to be handled safely during and following waste package manufacture. Containers can be manufactured from a range of materials with designs selected to suit the requirements for the packaging, transport and disposal of the wastes they contain.
- The wasteform, which can also provide a significant degree of physical and/or chemical containment of the radionuclides and other hazardous materials associated with the waste. The wasteform may comprise waste which has been 'immobilised' (e.g. by the use of an encapsulating medium such as cement) or that which may have received more limited pre-treatment prior to packaging (e.g. size reduction and/or drying).

Therefore, both the waste container and the wasteform contribute to the achievement of the required performance of the waste packages, with the relative importance of each generally depending on the robustness of the former. This is illustrated in Figure 1 which shows in stylised form how the use of a more robust waste container can reduce the required contribution of the wasteform to overall waste package performance.

Figure 1 also shows that for all waste packages both the waste container and the wasteform will be required to play some role. It should also be noted that it is the overall performance of the waste package, rather than that of its two components, that is the governing factor in judging its disposability. When defining the requirements for wasteforms, it is the overall performance of the waste package that should be the basis for such definition rather than that of the wasteform in isolation.

Figure 1 Relative contribution of the waste container and wasteform to waste package performance



The properties of the wasteform will play a key part to ensure the passive safety of a waste package, irrespective of the nature of the waste container. Wastes should therefore be conditioned to minimise chemical reactivity and to satisfy some basic requirements as to their physical and biological properties. This should extend to ensuring the compatibility of the wasteform and the material from which the waste container is fabricated. These general requirements for wasteforms can be achieved by sorting, segregation and/or a range of pre-treatment processes to ensure the appropriate control of the quantities of some types of material, or of wasteform properties, that could affect the overall performance of the waste package or the other barriers that make up the geological disposal system. Typically this could include controls on the presence of:

- free liquids;
- activity or hazardous materials in particulate form;
- voidage;
- in-homogeneity;
- reactive materials;
- other hazardous materials; and
- materials that could have a deleterious effect on the other barriers that make up the geological disposal system.

The extent of such controls will be very dependent on the robustness of the waste container and the consequences of the presence of these materials and wasteform properties for waste package and disposal system performance. This would normally be assessed as part of the disposability assessment of a proposed waste package design.

In relation to the performance of the waste container consideration should be given to the potential for chemical reactions between the wasteform and the inner surfaces of the waste

container or expansive corrosion of components of the waste that could result in forces being exerted on the waste container.

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

In the post-closure period the wasteform may continue to play a role in the overall safety of a GDF. The DSTS [9] defines a single post-closure safety function for wasteforms requiring them to '*provide a stable, low-solubility matrix that limits the rate of release of the majority of radionuclides by dissolution in groundwater that comes into contact with the wasteform'.* Accordingly the consequences of evolution should be such that this requirement is satisfied and that the wasteform will continue to make an appropriate contribution to the overall performance of the waste package, and to the geological disposal system as a whole.

As noted above, the RWMD packaging specifications form a hierarchy of documents which are increasingly specific to waste type and waste package design. With regards to wasteforms the GWPS [1] states that:

> *The properties of the wasteform shall be such that, in conjunction with those of the waste container, it satisfies all of the requirements for the waste package.*
>
> *The properties of the wasteform shall comply with the requirements for containment within the geological disposal concept, as defined by the GDF safety case.*

For wastes such as ILW this requirement is expanded in the Generic Specification for waste packages containing low heat generating waste [3] by the addition of:

> *The physical, chemical, biological and radiological properties of the wasteform shall:*
>
> - *make an appropriate contribution to the overall performance of the waste package; and*
> - *have no significant deleterious effect on the performance of the waste container.*
>
> *Evolution of the wasteform shall ensure maintenance of the waste package properties that are necessary for safe transport and operations at a GDF.*
>
> *Evolution of the wasteform shall ensure maintenance of the required safety functions for post-closure performance as set out in the Environmental Safety Case.*

Section 4 identifies and defines requirements for a range of specific wasteform properties which will have an influence of the achievement of the overall performance of a wasteform.

4 Specification for wasteform properties

The production of the wasteform is the means by which the original 'raw' waste is rendered passively safe, so its design can have a significant influence on waste package performance under normal and accident conditions during interim storage, transport and following disposal. The parameters that could affect the quality of the wasteform, and thus its ability to meet any aspect of this Specification and control limits, should be identified and established. This Section lists the requirements that are required of all wasteforms resulting from the conditioning of ILW, and any other wastes with similar radiological characteristics.

The wasteform requirements are grouped under six headings:

- physical immobilisation;
- mechanical and physical properties;
- chemical containment;
- hazardous materials;
- gas generation; and
- wasteform evolution.

In the requirements specified below the word 'appropriate' is widely used, in acknowledgement of the relative roles that the wasteform and the waste container will play in providing the required waste package performance. Whether a particular wasteform will be capable of delivering the appropriate contribution to waste package performance will ultimately be judged during the disposability assessment of a proposal to package wastes.

4.1 Physical immobilisation

The wasteform shall be designed to immobilise radionuclides and other hazardous materials so as to make an appropriate contribution to waste package performance during all stages of long-term management.

4.1.1 Immobilisation of radionuclides and particulates

All reasonable measures shall be taken to ensure that radionuclides and other hazardous materials in the waste are immobilised and that loose particulate material is minimised.

4.1.2 Response to an impact accident

All reasonable measures shall be taken to ensure that, in the event of an impact accident, the quantity of potentially mobile radionuclides present within the waste package, including those generated as a result of the impact accident, is commensurate with the waste package meeting the impact accident performance requirements defined by the relevant WPS.

4.1.3 Response to a fire accident

All reasonable measures shall be taken to ensure that, in the event of a fire accident, the quantity of potentially mobile radionuclides present within the waste package, including those generated as a result of the fire accident, is commensurate with the waste package meeting the fire accident performance requirements defined by the relevant WPS.

The wasteform should not readily burn or otherwise support combustion.

4.1.4 Free liquids

All reasonable measures shall be taken to exclude free liquids, and materials that may degrade to generate liquids, from the wasteform. Free liquids not removed from wastes prior to waste packaging should be immobilised by a suitable waste conditioning process.

4.2 Mechanical and physical properties

The wasteform shall be designed to provide the mechanical and physical properties necessary to ensure appropriate performance of the waste package during all stages of long-term management.

4.2.1 Mechanical strength

The wasteform shall provide adequate mechanical strength to allow the waste package to be transported and handled without affecting the ability of the waste package to meet all the requirements of the relevant WPS.

4.2.2 Voidage

The development and production of the wasteform should ensure that the volume of voidage within the waste package is appropriately minimised.

4.2.3 Mass-transport properties

The wasteform shall be sufficiently permeable to allow gases generated within the wasteform to be released without compromising the ability of the waste package to meet any aspect of the relevant WPS.

The mass transport properties of the wasteform (e.g. diffusivity and permeability) shall provide best practicable means for the containment of water-soluble radionuclides within the waste package.

4.2.4 Homogeneity

Local concentrations of materials within the wasteform that may compromise the ability of the waste package to meet any aspect of the relevant WPS should be minimised.

4.2.5 Thermal conductivity

The thermal conductivity of the wasteform shall be sufficient to dissipate any heat generated within the waste package, when emplaced in a GDF, without unacceptable temperature rise.

4.3 Chemical containment

The wasteform shall not be incompatible with the chemical containment of radionuclides and hazardous materials as embodied in the requirements of a GDF.

Where they may affect chemical containment, the presence of following items in waste should be minimised, neither should they be introduced through waste conditioning or packaging, wherever practicable:

- oxidising agents;
- acids and/or materials that degrade to generate acids;
- cellulose and other organic materials;
- complexants and chelating agents, and/or materials that degrade to generate such compounds;
- non aqueous phase liquids and/or materials that degrade to generate them;
- any other materials that could detrimentally affect chemical containment.

4.4 Hazardous materials

The wasteform shall not contain hazardous[1] materials, or have the potential to generate such materials, unless the treatment and packaging of such materials or items makes them safe. The means by which any of these materials is made safe shall be demonstrable for all relevant periods of long-term management.

4.5 Gas generation

Gases generated by the wasteform shall not compromise the ability of the waste package to meet any aspect of the relevant WPS.

4.6 Wasteform evolution

Changes in the characteristics of the wasteform as it evolves shall not result in degradation that will compromise the ability of the waste package to meet any aspect of the relevant WPS.

The deleterious effects of the following processes should be considered:

- dimensional changes, e.g. shrinkage;
- corrosion including, but not limited to, the production of gases and particulate material, and wasteform expansion resulting from the formation of lower density solid corrosion products;
- microbial activity;
- self-irradiation and irradiation by surrounding waste packages;
- heat generation by the wasteform and its surroundings including, but not limited to, localised heat sources within the wasteform, the effects on the curing of the encapsulant material and the consequential effects on longer-term performance.

[1] Including flammable, explosive, pyrophoric, chemo-toxic and oxidising materials; sealed and/or pressurised containers; and/or mechanical devices containing stored energy.

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