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Bibliography

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**WASTE PACKAGE SPECIFICATION AND GUIDANCE DOCUMENTATION
GUIDANCE ON THE STRUCTURE AND FORMAT OF WASTE PRODUCT
SPECIFICATIONS**

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

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

This document has been produced to assist waste packagers in the production of Waste Product Specifications that are suitable to form part of a submission for the disposability assessment of proposals to package waste for geological disposal.

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

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WPS/620/01	March 2006	Aligns with GWPS (Nirex Report N/104) as published 2005
WPS/620/02	March 2008	Responsibility for the WPSGD passed to the NDA RWMD. Aligns with Issue 2 of GWPS (Nirex Report N/104) as published 2007.
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1 Introduction

The Nuclear Decommissioning Authority (NDA), through Radioactive Waste Management Ltd (RWM), is responsible for implementing UK Government policy for the long-term management of higher activity radioactive wastes, as set out in the *Implementing Geological Disposal White Paper* [1]. The White Paper outlines a framework for managing higher activity radioactive waste in the long term through geological disposal, which will be implemented alongside the ongoing interim storage of waste packages and supporting research.

RWM produces 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 RWM assists 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 Disposal System Specification (DSS) [2] 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 DSS 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.

The WPS, together with a wide range of explanatory material and guidance that users will find helpful in the development of proposals to package waste, make up a suite of documentation known as the *Waste Package Specification and Guidance Documentation* (WPSGD). For further information on the extent and the role of the WPSGD, all of which can be accessed via the RWM website, reference should be made to the *Introduction to the RWM Waste Package Specification and Guidance Documentation* [3].

The purpose of this document is to provide waste packagers with guidance on the preparation of a *Waste Product Specification* (WPrS), a key controlling document that plays a vital role in the manufacture of waste packages.

This document is structured as follows:

- Section 2 provides background information on the geological disposal of radioactive waste and the role that waste packages play in ensuring the safety of such disposal. This Section also summarises what the WPrS is and the role that it plays during the manufacture of waste packages.
- Section 3 provides more detail on the role that the WPrS is expected to play during the manufacture and disposal of waste package.
- Section 4 outlines the requirements for and the contents of a WPrS.
- A glossary of important terms and phrases is presented at the end of the document.

2 Background

2.1 The concept of geological disposal

The 2014 White Paper sets out the UK Government's framework for managing higher activity radioactive waste in the long term through geological disposal [1]. Whilst the precise manner in which geological disposal would be implemented in the UK is not yet defined, RWM envisages that any approach to long-term management of waste (including disposal) would comprise a number of distinct stages which could include:

- the manufacture of passively safe and disposable waste packages;
- a period of interim surface storage, usually at the site of waste arising or packaging;
- transport of the waste packages to a GDF;
- transfer of waste packages underground and emplacement in the disposal facility;
- back-filling of the disposal areas; and
- eventual sealing and closure of the facility.

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

2.2 The role of the waste package in geological disposal

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

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

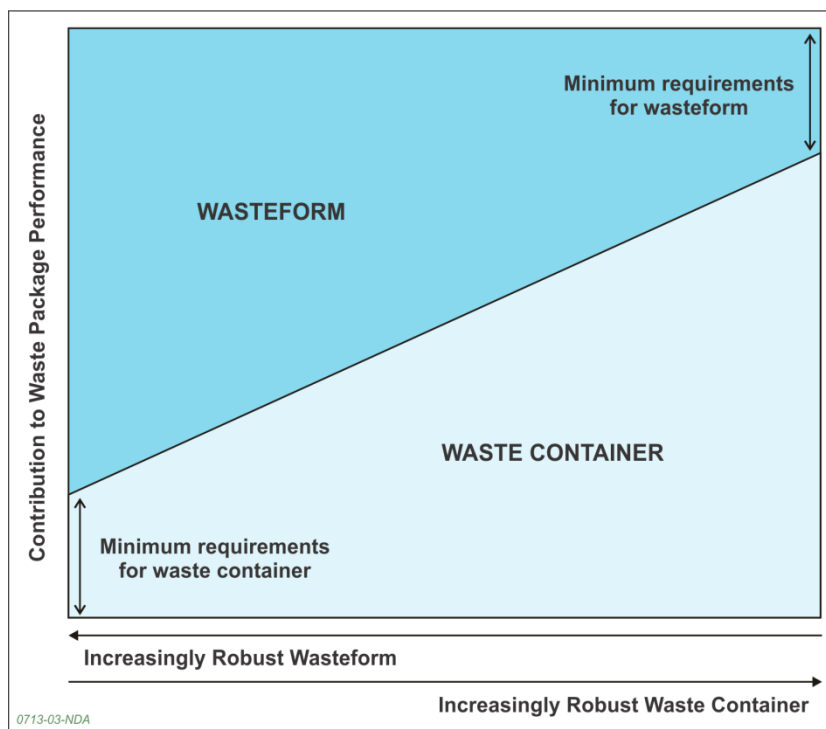
- The waste container, which provides a physical barrier and also enables the waste to be handled safely during and following waste package manufacture. Containers can be manufactured from a range of materials with designs selected to suit the requirements for the packaging, transport and disposal of the wastes they contain.
- The wasteform, which can be designed to provide a significant degree of physical and/or chemical containment of the radionuclides and other hazardous materials associated with the waste. The wasteform may comprise waste 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).

Packaging specifications are designed to address the performance of the barrier(s) provided by the waste package. They do this by defining requirements for waste packages that have been derived from the needs relating to their long-term management.

Both the waste container and the wasteform can contribute to achieving the required performance of a waste package, 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.

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



2.3 The assessment of packaging proposals

RWM has established the Disposability Assessment process to support waste producers in the development of plans to package higher activity wastes. Specifically, the Disposability Assessment process is used by RWM to demonstrate that proposals to package waste would, if implemented, be likely to result in 'disposable' waste packages. In this context a disposable waste package is one that is compliant with all of the relevant regulations and safety cases for transport to and disposal in a GDF, and in line with regulatory expectations for the long term management of the waste [4].

The Disposability Assessment process also plays an important role in underpinning the generic *Disposal System Safety Case* (DSSC) [5] by providing confidence that the safety cases for the transport and disposal of waste, which are based on generic assumptions regarding the wastes that are anticipated to be accommodated by a GDF, are compatible with the 'real' waste packages that are being manufactured. The performance of disposability assessments also helps to show that the disposal concepts considered within the generic DSSC will be appropriate for the wastes they will be expected to cover, as well as identifying wastes that could challenge current disposal concepts and allow early consideration of the changes that may be required to these concepts to permit these wastes to be accommodated.

Disposability assessment can be performed at a number of stages during the development of proposals to package waste:

- At the *Pre-conceptual stage*, to assist waste packagers in the consideration of potential packaging options for a waste;
- At the *Conceptual stage*, to establishing the general feasibility of an approach to packaging of a waste;
- At the *Interim stage*, to determining whether sufficient evidence exists that implementation of the proposed approach will result in the manufacture of disposable waste packages; and.
- At the *Final stage*, to confirm that the as-built packaging plant will be capable of manufacturing disposable waste packages.

A full description of the Disposability Assessment process can be found in [6], and guidance on the manner by which waste packagers should prepare submissions for the assessment of packaging proposals can be found in [7].

2.4 The Waste Product Specification

The WPrS is the document produced by the waste packager that describes the waste package that is to be manufactured by the processes proposed for the packaging of a specific waste.

The WPrS is also an important component of the waste package records that will follow a waste package through all subsequent stages of waste management and that will play a role in demonstrating the suitability of the waste package for acceptance into each stage of its future managements, notably transport to and disposal in a GDF.

The suitability of the WPrS produced by a waste packager is evaluated as part of the disposability assessment of a packaging proposal. This is discussed in Section 4.3.

3 The role of the Waste Product Specification

The WPrS defines the waste package that is to be manufactured by stating the limits and controls on the waste package production process. This key document will eventually be used, together with further records to show compliance with the requirements stated in the WPrS, to demonstrate that waste packages meet the criteria for acceptance at a GDF and are compatible with all future stages of waste management. The WPrS can also be used by an auditor to seek confirmation that the packaging process and resultant waste packages conform to that endorsed by the assessment.

Following manufacture it will usually not be practical to use direct measurement and testing to describe a waste package. It is therefore the purpose of the WPrS to provide a link to underpinning development work and demonstrations of expected performance by define and controlling what is being made. This is achieved by specifying, in sufficient detail, all of the component parts, manufacturing processes and parameters and storage regimes that affect the properties and performance of the waste package.

Specifically the role of the WPrS is to:

- define the waste package that the waste packager is setting out to manufacture;
- provide a summary of the key characteristics of the packaging process, including any limits on quantities, that will influence product quality and the performance of the waste package during interim storage, transport and the operational and post-closure periods of a GDF;
- point to the relevant Criticality Compliance Assurance Documentation (CCAD), that ensures that the requirements for criticality safety, during the onward management of the waste, will be assured at the time of packaging;
- record the packaging process that has been endorsed by RWM as being compliant with the relevant WPS, and thereby provide the basis for determining that the waste packages conform with the disposability assessment;
- act as a controlling document for the waste package product, such as is embodied as a Quality Plan;
- provide, as a component of the waste package records, a possible means for recording general information on the waste, the packaging process and references for key waste package development work.

4 Requirements for and contents of a Waste Product Specification

4.1 Requirements for a WPrS

As discussed in Section 3, to provide RWM with the required level of assurance that waste is being packaged in a manner commensurate with all the requirements for safe long-term management including disposal, the WPrS should identify all key parameters that affect product quality. It should therefore be developed from consideration of the package properties and composition that are relevant to each of the stages of the management of the waste.

A WPrS will apply to a distinct waste package type and, in some cases; more than one WPrS may be required for a single waste stream. Significant changes to any feature of waste package production (e.g. variations in the nature of the waste within a waste stream, changes in the specification of conditioning materials) would require a separate WPrS which would require assessment and endorsement by RWM. A single waste packaging plant may therefore require several different WPrSs to cover the range of wastes being packaged.

In order to provide an adequate definition of a waste package as produced, and as evolved during storage, the WPrS should identify:

- Waste origin and composition;
- Waste container;
- Inactive waste conditioning materials;
- Formulation envelope;
- Process conditions;
- Waste product storage conditions;
- Supporting R&D.

4.2 Items for inclusion in a WPrS

The WPrS should normally be a concise document, with reference to supporting documents being clearly defined. The following represents the minimum information required in a WPrS.

4.2.1 Waste origin and composition

The WPrS should identify the origin of the waste to be packaged in order that the wastes covered by the particular WPrS are clearly defined. This should comprise the relevant UK Radioactive Waste Inventory Waste Stream Identifier(s) and a full description of the physical, chemical and radiological properties of the waste. It should also include such information about the processes that gave rise to the waste so that the ranges of quantities of the key components in the waste and the limits on the significant parameters can be adequately defined. The use of 'generic' descriptions (e.g. 'PCM'), without details on the actual composition of the waste, is discouraged as such descriptions often apply to a very wide range of wastes.

Typical factors that may need to be considered include ranges for:

- solids and/or liquids content;
- physical size and/or shape of solids;
- chemical composition of waste;
- heat output;

- radionuclide inventory;
- fissile material, including neutron moderators and reflectors;
- reactive metals;
- excluded materials.

4.2.2 Waste container

The WPrS should identify technical information on the waste container and identify/list associated items of internal furniture e.g. paddles, anti-flotation plates, liners, etc. The WPrS should make reference to the manufacturing specification for the waste container, including details of manufacturing quality system, design drawings, materials specification, material control, non-conformance control, welding, testing, inspection reports and manufacturing records.

The methods of control of the container storage environment, including any limits on temperature and relative humidity, and the handling regime of the waste container following manufacture and prior to use should also be included.

4.2.3 Inactive waste conditioning materials

Where appropriate, the WPrS should make reference to the material controls and define limits on the physical and chemical composition of any conditioning materials the intended encapsulation materials or conditioning agents insofar as they affect the product. This should include any relevant standards (i.e. British Standards) and specifications for such materials and, if available, list(s) of the supplier(s) who are approved to supply materials to these standards and specifications.

Storage conditions of encapsulation materials or conditioning agents should also be specified where deterioration during storage might adversely affect the product.

4.2.4 Formulation envelope

In cases where an encapsulating medium is to be used the WPrS should define the limits on the ratios of the waste to the encapsulant materials and any other conditioning materials that may be used. This should include limits on the ratios of different encapsulation materials if blends are used and should also address variations in waste composition. The WPrS may also make reference to underlying research and development studies undertaken to derive the formulation, should this not be recorded elsewhere.

4.2.5 Process conditions

The WPrS should contain limits on the key process parameters that influence product quality and provide references to the quality plans used to control the process. This could take the form of the operating instructions which control the process conditions.

Depending on the method of waste conditioning (e.g. encapsulation with cementitious or polymer grout, or non-encapsulation) this could include:

- For encapsulated wasteforms:
 - waste/encapsulant mixer design, speed and mixing time;
 - encapsulant and/or conditioning agent addition rate;
 - fluidity of encapsulant;
 - temperature of ingredients and process environment;
 - encapsulant cure time.
- For non-encapsulated wasteforms:

- Criteria for the pre-treatment of waste (e.g. sorting, size reduction);
- Process description, conditions and end point for waste draining or drying.

4.2.6 Waste package storage conditions

The WPrS should define the limits on handling of packages and storage conditions insofar as they affect the waste packages and as defined through the development of storage, monitoring and inspection strategy for the packages. These should include limits on:

- temperature;
- relative humidity;
- atmospheric pollution (i.e. chloride) levels;
- ambient light levels;
- stacking conditions;
- monitoring regime.

4.2.7 Supporting research and development

The WPrS may be an appropriate means to reference key supporting research and development reports insofar as the issues addressed affect product quality. There is no requirement to include R&D results in the WPrS itself, but the following issues are typical factors that may need to be referenced, depending on the nature of the waste conditioning process(es):

- Waste simulant design and testing;
- Waste grouting trials, including wasteform product quality indicators;
- Waste drying trials;
- Timed-based trends to indicate wasteform evolution;
- Inactive commissioning trials;
- Active waste analyses;
- Active commissioning trials.

Care should be exercised to understand whether the references cited in a WPrS are intended to provide a comprehensive record of the supporting development work. This should be examined separately in the specification of the waste package records.

4.3 Evolution of the WPrS

A WPrS should be provided to RWM for assessment as part of the submission for a relevant stage of a disposability assessment, but its form and degree of development will depend on the stage of the assessment. It is expected that the WPrS will be developed in an iterative fashion throughout the complete disposability assessment process (see Section 2.3) and that it will draw on results from historic and ongoing research and development work and inactive and active packaging plant commissioning as appropriate.

The definition of the WPrS is expected to evolve during successive packaging submissions as follows:

- At the Conceptual stage: there is no formal requirement for a WPrS at this stage although the waste packager may choose to produce a draft, in outline

form, for RWM's comment. This could describe the anticipated waste package type, waste and encapsulant, waste packaging process and storage arrangements. The production of such a draft may prove useful in identifying areas of R&D work that will be necessary to support the packaging proposal going forward

- At the Interim stage the WPrS should be sufficiently developed to have allowed the parameters of importance to product quality to be defined and limits and/or ranges identified, as appropriate. Where relevant the wasteform formulation envelope and process conditions should have been defined, including the identification of those which are fixed and those which are to be controlled.
- At the Final stage an approved version of the WPrS, which fully describes the proposed waste packages, should be available. It should provide a clear description of the formulation envelope and process, the storage conditions which will be applicable to the final product and the relevant supporting research and development reports.

4.4 Making changes to a WPrS

It is important that the WPrS is reviewed and, where necessary, revised to ensure that it continues to define the characteristics of the waste package product, following any change in:

- waste composition;
- container design;
- inactive waste conditioning material;
- formulation envelope;
- process conditions, or;
- product storage conditions.

It should be noted that this does not mean that a WPrS can be modified retrospectively to acknowledge any of these changes but rather that the consequences of anticipated changes can be assessed and, if considered to be within the bounds of the original LoC, the production of further waste packages against a new WPrS can be endorsed.

References

- 1 Department of Energy and Climate Change, *Implementing Geological Disposal, A Framework for the long-term management of higher activity radioactive waste*, URN 14D/235, 2014.
- 2 RWM, *Geological Disposal: Generic Disposal System Specification. Part A: High Level Requirements*, DSSC/401/01, 2016.
- 3 NDA, *Geological Disposal: Introduction to the RWM Waste Package Specification and Guidance Documentation*, WPS/100/04, 2015.
- 4 HSE/EA/SEPA, *The management of higher activity radioactive waste on nuclear licensed sites. Joint guidance from the Health and Safety Executive, the Environment Agency and the Scottish Environment Protection Agency to nuclear licensees*, Revision 2, 2015.
- 5 RWM, *Geological Disposal: Overview of the generic Disposal System Safety Case*, DSSC/101/01, 2016.
- 6 NDA, *Geological Disposal: An overview of the RWM Disposability Assessment process*, WPS/650/03, 2014.
- 7 NDA, *Geological Disposal: Guidance on the preparation of submissions for the disposability assessment of waste packages*, WPS/908/04, 2014.

Glossary of terms used in this document

conditioning

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

containment

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

disposability

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

disposability assessment

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

disposal

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

disposal system

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

fissile material

Material comprising of or containing the fissile radionuclides uranium-233, uranium-235, plutonium-239 and/or plutonium-241.

geological disposal

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

geological disposal facility (GDF)

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

higher activity waste

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

immobilisation

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

Letter of Compliance (LoC)

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

Nuclear Decommissioning Authority (NDA)

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

operational period (of a disposal facility)

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

passive safety

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

post-closure period (of a disposal facility)

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

Radioactive Waste Management Limited (RWM)

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

safety case

A 'safety case' is the written documentation demonstrating that risks associated with a site, a plant, part of a plant or a plant modification are as low as reasonably practicable and that the relevant standards have been met.

waste container

Any vessel used to contain a wasteform for disposal.

wasteform

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

waste package

The product of conditioning that includes the wasteform and any container(s) and internal barriers (e.g. absorbing materials and/or liner).

waste packager

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