Radioactive Waste Management

WPSGD no. WPS/705/01

Geological Disposal:

Guidance on the application of the specification for stillages for use in the transport and disposal of 500 litre drum waste packages

October 2015

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Conditions of Publication

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WASTE PACKAGE SPECIFICATION AND GUIDANCE DOCUMENTATION

WPS/705 GUIDANCE ON THE APPLICATION OF THE SPECIFICATION FOR STILLAGES FOR USE IN THE TRANSPORT AND DISPOSAL OF 500 LITRE DRUM WASTE PACKAGES

Executive Summary

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

Key documents in the WPSGD are the *Waste Package Specifications* (WPS) which define the requirements for the transport and geological disposal of waste packages manufactured using standardised designs of waste container. The WPS are based on the high level requirements for all waste packages as defined by the *Generic 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 guidance on the application of WPS/605 *Specification for stillage for the transport and disposal of 500 litre drum waste packages.* It provides an explanation of the rationale behind the definition of the requirements that make up that Specification, together with information that is intended to assist designers in the development of stillage designs in which those requirements will be achieved.

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

WPSGD DOCUMENT NUMBER WPS/705 - VERSION HISTORY		
VERSION	**DATE**	**COMMENTS**
WPS/705/01	October 2015	Issued for trial use by waste producers.

This document has been compiled on the basis of information obtained by RWM. It has been verified in accordance with arrangements established by RWM that meet the requirements of ISO 9001. The document has been fully verified and approved for publication by RWM.

List of Contents

1	**Introduction**	**1**
2	**The use of stillages for the handling of 500 litre drum waste packages**	**3**
3	**Guidance on the requirements for stillages**	**5**
3.1	General requirement for the stillage	5
3.2	General properties of the stillage	7
3.3	External dimensions	7
3.4	Handling feature	8
3.5	Stackability	9
3.6	Identification	9
3.7	Durability of integrity	11
3.8	Maximum gross mass	13
3.9	Criticality safety	14
3.10	Accident performance	15
References		**16**

1 Introduction

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 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* [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 Generic Waste Package Specification 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 RWM packaging specifications 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 via the RWM website.

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 role and extent of the WPSGD, reference should be made to [2].

The 500 litre drum is a standardised design of waste container that has been shown to be suitable for the packaging of low heat generating waste[1] (LHGW) for geological disposal. It is assumed that the waste packages that are produced using this waste container will be transported to the GDF in a stillage, each holding a 2 x 2 array of waste packages. This forms a disposal unit that can be handled during transport and disposal as a single unit.

Waste producers will be responsible for the design and fabrication of any stillages which are to be used for the transport and disposal of 500 litre drum waste packages which they manufactured. Such stillages must be produced to comply with the RWM specification [3] which defines the standards features and performance requirements for stillages that are to be used for those purposes. The suitability of specific designs of stillage to satisfy the requirements defined would generally be assessed by way of the RWM Disposability Assessment process [4]. Such designs could be endorsed by the issue of a Letter of Compliance to indicate that they are compliant with RWM's plans for geological disposal of low heat generating waste, and with the safety cases for the transport and geological disposal of such waste. Stillage designers, manufacturers and users are therefore urged to contact RWM at an early stage in order that their designs can be assessed.

The purpose of this document is to give guidance to stillage designers and manufacturers, in order to ensure that any proposed stillage design is capable of being endorsed by RWM by way of the Disposability Assessment process.

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1 This category of waste includes ILW, LLW and wastes with similar radionuclide inventories.

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

- Section 2 provides a brief summary of the properties of 500 litre drum waste packages and the manner in which they are handled during transport to and disposal in a GDF.
- Section 3 explains the rationale behind the definition of the requirements in the Specification for stillages and provides providing guidance as to how those requirements can be achieved.

2 The use of stillages for the handling of 500 litre drum waste packages

The 500 litre drum (Figure 1) is a standardised design of waste container that has been shown to be suitable for the packaging of a wide range of low heat generating waste for geological disposal. The WPS for 500 litre drum waste packages defines the standard features (as illustrated in Figure 2) together with the performance requirements for such waste packages [5].

Figure 1 500 litre drum and stillage for waste packages

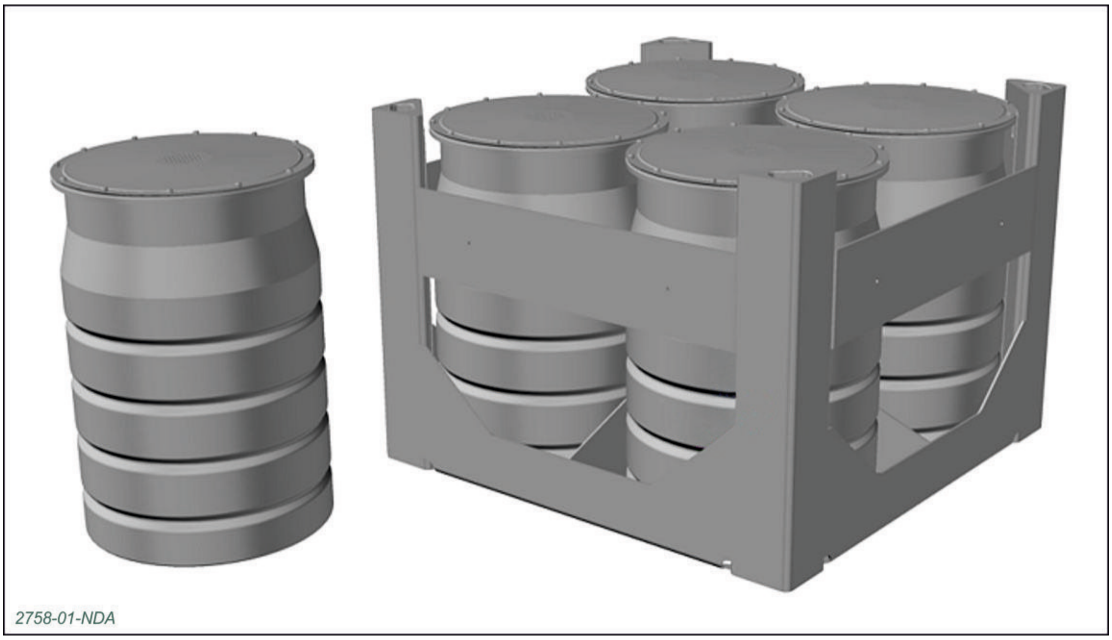
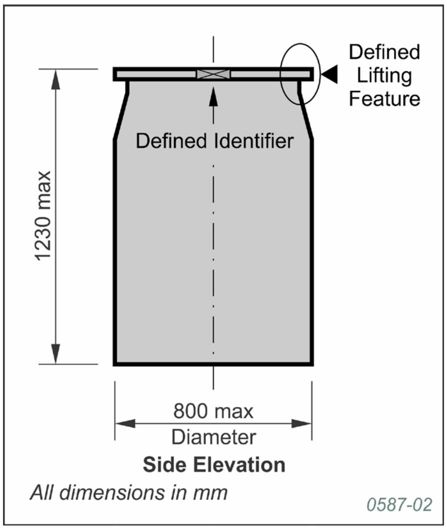


Figure 2 Standard features of the 500 litre drum

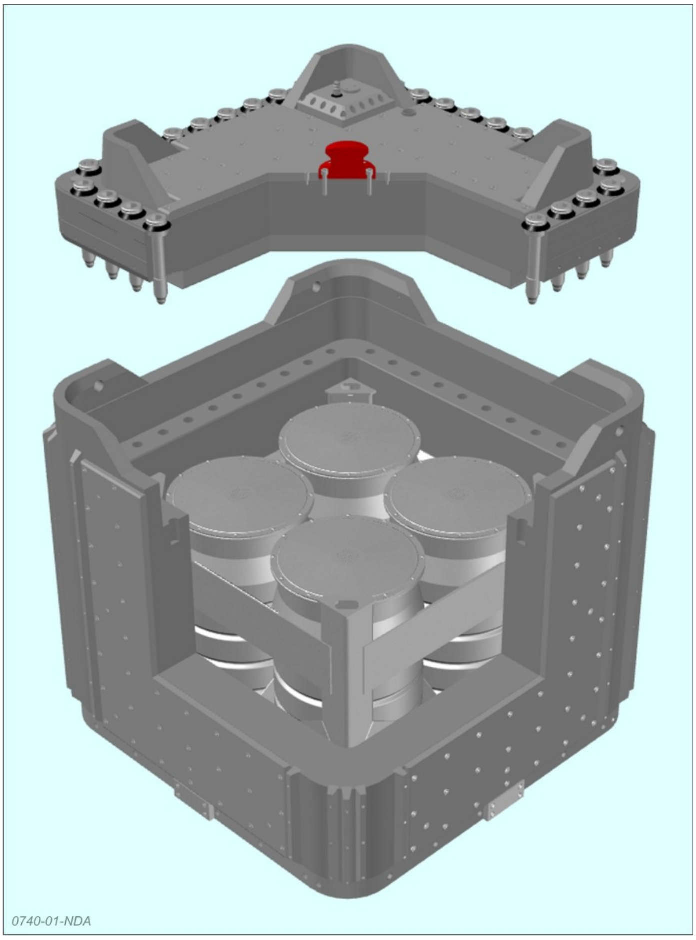


The generic Disposal System Technical Specification [6], together with the supporting generic systems designs [7, 8], assume that, for both transport to and disposal in a GDF, 500 litre drum waste packages will be handled in a 2x2 array within a stillage. To date a number of stillage designs have been developed, each design reflecting the specific needs of individual waste packagers, primarily for the interim storage of waste packages prior to their export to a GDF. Figure 1 shows a group of four 500 litre drum waste packages in a typical design of stillage, the 'compact stillage' developed by Sellafield Ltd and used extensively at that site.

The 500 litre drum waste container is used to manufacture 'unshielded waste packages', which signifies that the container is typically fabricated from relatively thin section stainless steel. As such the waste container provides little radiation shielding of the waste package radionuclide contents and, as a consequence, remote techniques are generally utilised for their handling. For this reason, it is intended to transport 500 litre drum waste packages through the public domain inside protective transport containers. Figure 3 illustrates the standard waste transport container (SWTC) which it is anticipated will be used to transport stillages containing four 500 litre drum waste packages. Three designs of SWTC are currently envisaged, providing nominal shielding thicknesses of 70mm, 150mm and 280mm of steel with a density of 7700kg m^{-3}.

The transport packages that result from the combination of 500 litre drum waste packages and a SWTC will form a Type B transport package, as defined by the IAEA *Regulations for the Safe Transport of Radioactive Material* [9].

Figure 3 Typical transport configuration for 500 litre drum waste packages



3 Guidance on the requirements for stillages

This Section identifies and discusses the requirements for stillages which are defined in the Specification [3] **(given in bold script)**, explains the basis for the definition of those requirements and, where relevant, discuss the factors that influence their means of achievement.

It should be noted that, where the words *shall* and *should* are used in defining the requirements which make up the Specification, their use is consistent with the recommendations of BS 7373:1998 [10] and that they have the following meaning:

- '*shall*' denotes a limit which is derived from consideration of a regulatory requirement and/or from a fundamental assumption regarding the current designs of the transport or disposal facility systems;

- '*should*' denotes a target from which relaxations may be possible if they can be shown[2] not to result in any significant reduction in the overall safety of the geological disposal system.

3.1 General requirement for the stillage

The stillage *shall* be capable of being used for the handling of four 500 litre drum waste packages manufactured in compliance with the WPS for such packages [5].

It is currently assumed that all 500 litre drum waste packages will be manufactured to comply with the relevant WPS and will be transported to and emplaced in a GDF in stillages containing a 2x2 array of such waste packages.

The stillage *shall* be capable of being used with fewer than four 500 litre drum waste packages.

It shall be possible to handle the stillage, using standard equipment and techniques, irrespective of loading condition.

The stillage *shall* provide adequate restraint and location of waste packages during all routine handling during transport to and emplacement in a GDF.

Waste packages shall be adequately restrained to prevent damage to either themselves or the stillage, and to ensure that the external radiation dose rate of the transport package does not increase during the transport operation.

The stillage *shall* be designed so as to permit the simple and efficient loading and unloading of 500 litre drum waste packages by means of a standard design of lifting grab, using a recessed flange handling feature specified for the waste package.

The design of all 500 litre drum waste packages will include a lifting feature (Figure 4), such as they can be handled using a common design of lifting grab [11]. The design of the stillage shall be such that the ability to handle the waste packages in this manner is not compromised.

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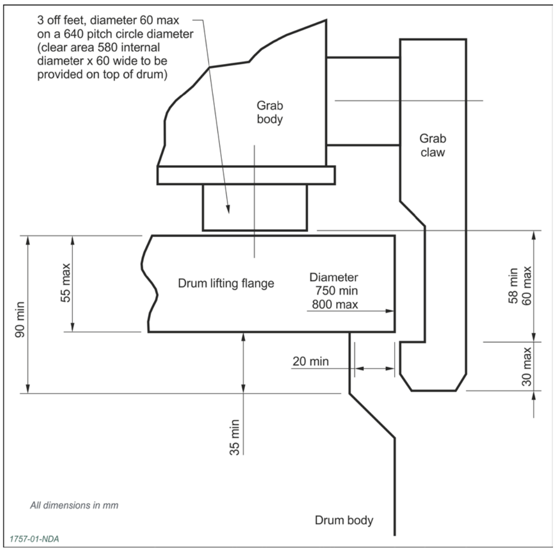
[2] This would generally be by way of the Disposability Assessment process.

Figure 4 Lifting feature of the 500 litre drum



The loaded stillage *shall* be capable of simple and efficient insertion into and removal from a SWTC.

It is assumed that the transport container used for movement of the stillage will be one of the three anticipated variants of the SWTC (i.e. SWTC-70, SWTC-150 and SWTC-285). The SWTC variant used for particular 500 litre drum waste packages will mainly depend on their external radiation dose rate and the degree of shielding required to satisfy the external dose rate requirements for the transport package.

The stillage *shall* be designed for ease of decontamination.

During handling operations at the site of arising, preparation for transport and upon arrival at a GDF, all waste packages and stillages will be monitored to ensure that any surface contamination is within the limits specified by the GDF waste acceptance criteria (WAC). Remedial action (i.e. decontamination) may be necessary for waste packages or stillages that exceed these limits and both must be designed in order to facilitate such action.

The stillage *shall* be designed to facilitate complete encapsulation and the minimisation of voids during the backfilling of the GDF disposal vaults.

In order to ensure suitable chemical conditions within the GDF during the post-closure period, the disposal vaults may be back-filled with a suitable material at some time following the emplacement of the waste packages. This will be carried out in such a manner such as to ensure a specified ratio between the amount of radioactive waste in the vault and the vault backfill material. In order to achieve this, voidage must be known and access should be assisted by the stillage being designed to facilitate the flow of backfill around the waste packages it contains.

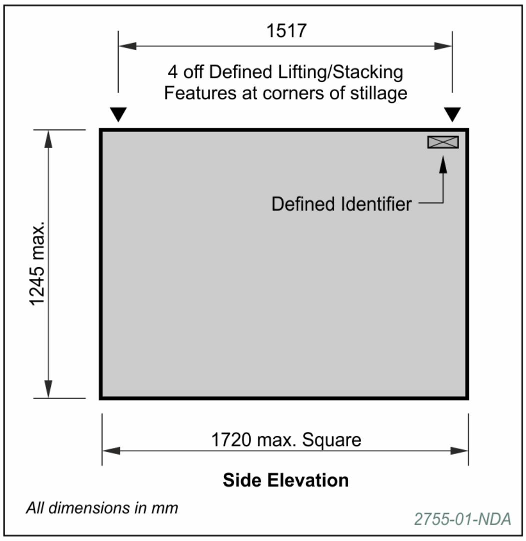
The design of the stillage *shall* facilitate inspection of the external surfaces of the waste packages without the need to remove them from the stillage.

Waste packages will need to be identified and/or inspected at a number of points during their long-term management, notably prior to export from the site of manufacture and following receipt at a GDF. In the latter case such identification and inspection will form part of the process of demonstrating the compliance of the waste packages with the GDF WAC. In order to facilitate the periodic identification and/or inspection of the waste packages, the design of the stillage should permit the use of remotely operated equipment (e.g. video cameras) to read at least one of the four waste package identifiers (Figure 2) and to examine as large a fraction of the external surfaces of the waste packages and the stillage as is reasonably possible.

3.2 General properties of the stillage

The properties of the stillage, the standard features of which are shown in Figure 5, *shall* be such that it will satisfy the design requirements outlined above whilst having no significant deleterious effects on any aspect of the performance of the waste packages it contains.

Figure 5 Standard features of the stillage for 500 litre drum waste packages



In order to facilitate handling using the anticipated transport and GDF systems, use of the SWTC for transport, identification and stacking, all stillages must comply with the standard features shown in Figure 5.

It will be the case that many 500 litre drum waste packages will need to be transferred from the current stores and stillages into stillages suitable for disposal. This transfer should take place at the site of arising, prior to loading into a suitable transport container. It is possible that, following emplacement in a GDF, a number of waste packages will need to be retrieved from the disposal stillage in order to comply with the GDF's inspection and maintenance regime. Since 500 litre drum waste packages are unshielded waste packages, all these operations, and all other handling of the stillages, must be done remotely. Any stillage must therefore be designed to facilitate such handling.

3.3 External dimensions

The stillage *shall* be square in plan and the overall plan dimension *shall* not exceed 1720mm.

The overall height of the stillage *shall* not exceed 1245mm.

The external dimensions are consistent with the cavity dimensions of all variants of the SWTC and are the same as the maximum values specified for both variants of the 3 cubic metre box [12, 13] and the 3 cubic metre drum [14].

3.4 Handling feature

The stillage *shall* incorporate four lifting points, in the form of twistlock apertures with dimensions and geometry as defined in Figure 6, located as shown in Figure 7.

The stillage *shall* be capable of being lifted with a force of 180kN using two diagonally opposite twistlock apertures, without exhibiting any permanent deformation of the stillage itself, or damage to any of the waste packages that it contains.

It should be noted that the dimensions, shape and layout of the handling feature are specified to be identical to that of the corner-lifting variant of the 3 cubic metre box [13], in order to facilitate the use of common handling equipment.

All twistlock aperture dimensions and features are consistent with the Sellafield Design Standard for twistlocks [15]. The twistlock aperture dimensions as specified in that standard are known to differ from those within the relevant British Standard [16] but independent assessment of the twistlocks by Bureau Veritas [17] has established that their structural integrity is consistent with that standard. The report also noted that, as was intended by Sellafield, the slightly larger dimensions of their twistlock design are consistent with ease of use with remote handling equipment and that '*The larger aperture of the 'non-conforming' SL design is likely to lead to improved quality of operations…*'

Figure 6 Stillage twistlock aperture geometry and dimensions

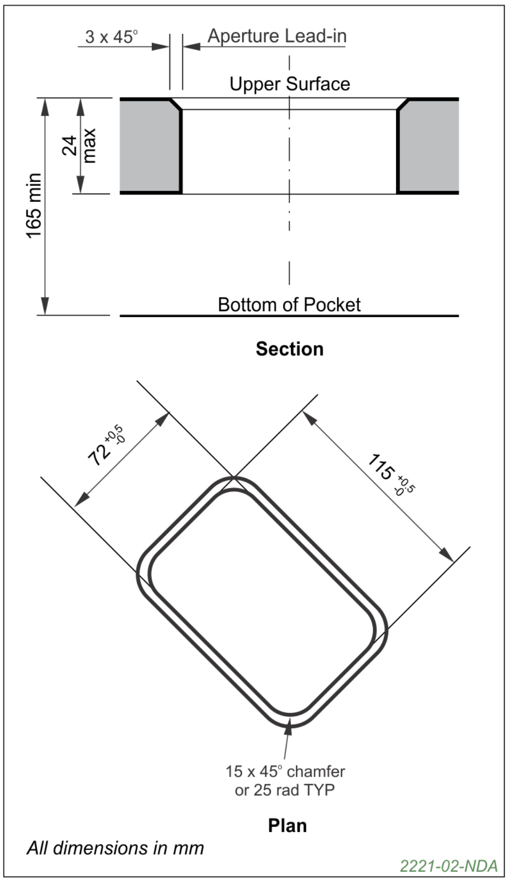
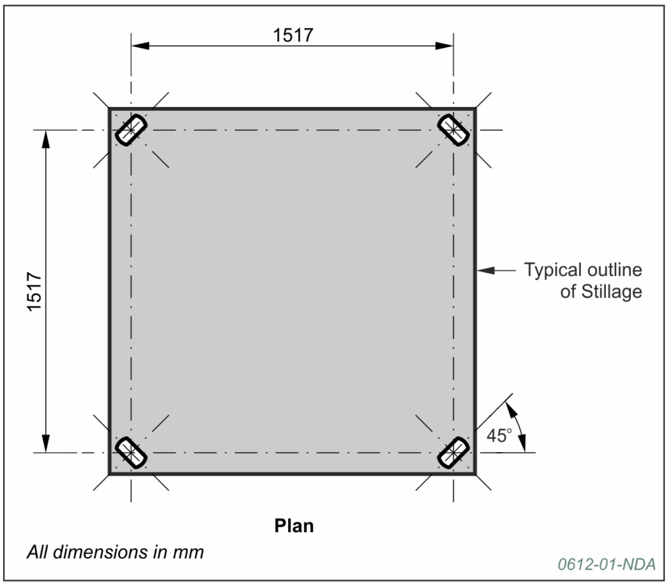


Figure 7 Layout of lifting features for stillage



3.5 Stackability

The stillage *shall* be capable of withstanding a compressive load of 540kN applied evenly along its vertical axis of its corner posts. Under these load conditions, the stillage *shall* not exhibit any permanent deformation or abnormality that would render neither it, nor the waste packages that it contains, incompatible with any of the requirements for safe transport and disposal.

The Generic Specification for waste packages containing LHGW [18] defines a maximum stack height of 9m for waste package emplaced using an overhead crane. Such a height applies to unshielded waste packages and would result in stillages containing 500 litres drums being stacked 7-high.

The maximum gross mass specified for 500 litre drum waste packages is 2000 kg and, assuming a gross mass of 1000 kg for the stillage, this would result in a maximum total compressive load of 540kN on a stillage at the bottom of such a stack.

3.6 Identification

The stillage *shall* be marked with a unique identifier, comprising ten alpha-numeric characters each with a height of between 6mm and 10mm, and in a form that complies with the relevant RWMD specification (Figure 8).

The identifier *shall* be marked on the vertical face of the twistlock plate of each right hand pillar (Figure 5).

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

The application of a unique identifier enables the identification and tracking of a stillage, and the waste packages that it contains, throughout the different stages of its long-term management[3], and permits the permanent assignment of the appropriate data records to the stillage and its contents.

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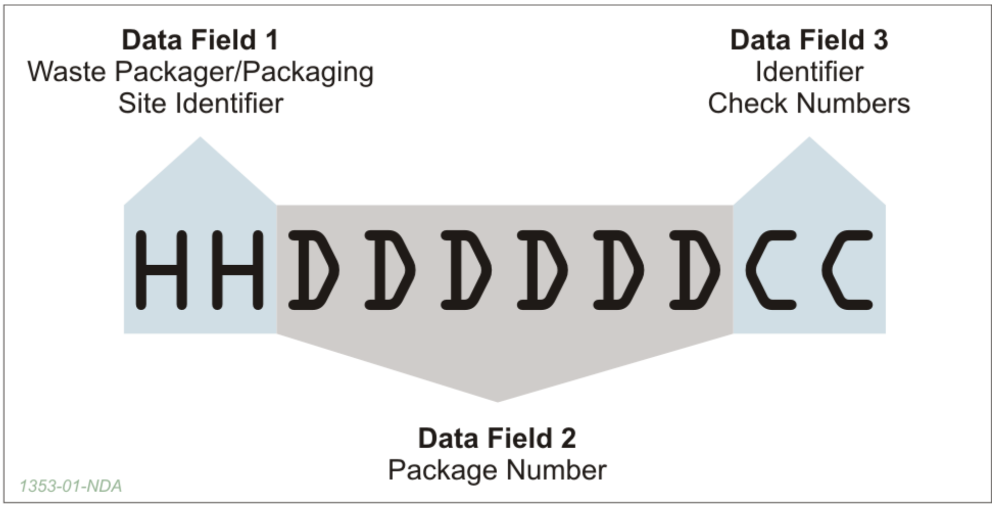
3 In practice this requirement would only need to extend up to the end of the GDF operational period as after backfilling of the disposal vault the requirement to identify stillages would be expected to cease.

Figure 8 Form of stillage identifier



RWM has produced a specification for waste package identification [19] together with supporting guidance [20]. All waste package identifiers are required to have a standard form, consisting of ten alpha-numeric characters (Figure 8). Each identifier comprises a 2 digit code for the site at which the waste package was manufactured, a unique 6 digit package number and a 2 digit 'check number', to minimise the possibility of misreading of the identifier. The same form of identifier will be used for stillages, as this forms the disposal unit for 500 litre drum waste packages.

The use of a standard character set (i.e. OCR-A characters, Figure 9, [21]), of a specified size (i.e. 6-10mm high) will permit either direct visual checking by human operators or the use of automated reading equipment. Making the identifier machine-readable and the use of a format containing check digits allows the stillage to be identified remotely and its number verified by an automatic computer check. Stillage identifiers will need to remain machine readable for a period that permits identification of the stillage at least until the time at which it is surrounded by the backfill material. In defining a durability timescale for identifiers RWM applies the same arguments as those used to justify the required durability of waste container integrity. These lead to a minimum period of 150 years following manufacture during which the waste package shall remain capable of being identified.

Figure 9 Character set for stillage identifiers

For automated reading systems to operate effectively, standard locations must be specified for identifiers on waste packages and stillages. Multiple locations will aid in the ease of reading by reducing the need for the waste package to be moved during identification as well as providing redundancy in the event of damage (for example that caused by corrosion) and will reduce the risk of waste packages becoming unidentifiable. The specified locations for identifiers on the stillage are shown in Figure 5.

The locations specified for identifiers on the stillages have been selected in such a manner as to reduce the need for the stillage to be moved in order for it to be identified and also minimise the possibility of the identifier being obscured by handling equipment. The locations have also been selected such that they are on thicker sections of stillage, to reduce any deleterious effect on the durability of the stillage.

The recommended method of inscribing the identifier is to laser-etch the characters, which in the case of stainless steel surfaces is expected to satisfy the requirement specified for the longevity of the marking.

In-house markings and additional labels may be applied to stillages by the waste packager if required for its own purposes, provided that they do not affect stillage performance. In particular, any additional identification, whether temporary or permanent, must not compromise the integrity of the stillage. This should include a consideration of the materials used for such markings, guidance on which can be found in [22].

3.7 Durability of integrity

The integrity of the stillage *shall* be such that it is capable, when fully loaded, of being handled safely and efficiently, as required during transport and the operational period of a GDF.

The integrity of the stillage *shall* be maintained for a period of 150 years and *should* be maintained for a period of 500 years following manufacture.

The two main safety functions of a stillage are safe handling and stacking, both of which will need to be maintained for specified times. The requirement for the durability of stillage integrity is therefore defined in terms of the period for which the stillage needs to maintain the surety of its handling features and its ability to withstand all anticipated external loads, notably those resulting from stacking.

Regulatory guidance on the conditioning and disposability of higher activity waste states that *'A minimum package lifetime of 150 years should be set for design purposes'* [23]. Whilst this applies to waste packages it also applies indirectly to the stillages for 500 litre drum waste packages in that they may rely on the ability of the stillage to provide safe handling and, any loss of stacking function could threaten the integrity of the waste package (i.e. were a stack to collapse). A 150 year period also broadly aligns with current planning assumptions regarding when a GDF would be available to receive stillages for disposal (i.e. 2040) and the anticipated length of the GDF operational period for waste packages containing ILW (assumed in the Generic Disposal Facility Designs report to be ~100 years).

The potential for the retrieval of stillages from the disposal vaults also needs to be considered when defining the period over which the integrity of the stillage is required to be maintained. RWM's current position on retrievability is that activities concerned with the development and implementation of a GDF will be carried out in such a way that the option of retrievability is not excluded [24]. The UK Government's policy regarding retrievability is outlined in the 2014 White Paper [25] which states that waste packages could be retrieved during the GDF operational period *'if there was a compelling reason to do so'*, whilst acknowledging that a GDF '*could be open for construction and waste placement for around one hundred years, to accommodate the current volume of legacy waste*'. The White Paper also notes that retrieving emplaced waste packages '*would tend to become more difficult with time, particularly after the end of its operational stage (that is, once a GDF has been closed permanently)*'.

In order to satisfy the potential requirements of both the operational and early post-closure periods, the need to maintain stillage integrity for 500 years, as specified for waste packages in the Generic Specification [18] is also applied to stillages. RWM has carried out work which shows that current designs of waste container, designed to meet the durability requirement identified by regulatory guidance (i.e. 150 years), would also be expected to maintain an appropriate level of integrity for at least 500 years [26]. This would also be expected to apply to stillages fabricated using similar materials (i.e. stainless steel). Notwithstanding this assumption RWM acknowledges that after 150 years stillages may need to be handled by means which do not involve the use of the specified handling feature.

The ability of a stillage to maintain its integrity over a specified period is controlled by a number of key factors:

- the design of the stillage, including the materials and manufacturing processes;
- the nature of stillage material degradation mechanisms;
- the nature of any interactions between the stillage and the waste packages it contains; and
- the environment of storage and disposal facilities.

Chemical corrosion is the major potential threat to the ability of a stillage to maintain an adequate level of integrity for the required timescale. Other mechanisms of degradation can include the effects of heat, biodegradation, abrasion, radiolysis and chemical reactions between waste container components.

When selecting a material for the fabrication of stillages, designers will need to understand both the internal and external environments that a stillage will be subjected to, and determine which degradation mechanisms can take place in those environments. The response of waste packagers to the same requirement for waste containers has generally been to use austenitic stainless steel to grade 316L (EN 1.4404 [27]) or its equivalent. The corrosion performance and mechanical properties of this material are generally regarded as optimum for the packaging and disposal of radioactive waste, and this performance has been demonstrated by experience and research [28]. 'Duplex' stainless steel (notably grade EN 1.4462) has been identified as an alternative material due to its superior mechanical properties and resistance to stress corrosion cracking, making it particularly suited to longer term use.

Although the use of such materials is not a requirement in itself, stillage designers and manufacturers are encouraged to consider the use of these materials in their designs. It is particularly desirable that the corrosion performance of the stillage should at least match that of the waste containers which it contains. Whichever material is selected it should be noted that quality control of the material, the stillage manufacturing process and the control of surface finish of the material will also play key roles in maintaining the integrity of the stillage.

A variety of corrosion mechanisms can threaten the integrity of a stillage manufactured from stainless steel, the most significant of which are; general atmospheric corrosion, pitting or crevice corrosion and stress corrosion cracking.

The rate of general atmospheric corrosion performance of stainless steel are widely reported [29] and corrosion rates from $<0.2\mu my^{-1}$ ($>5,000ymm^{-1}$) to $3\mu my^{-1}$ ($300ymm^{-1}$) have been observed in industrial/urban and marine environments. Initial measurements from longer-term testing suggest corrosion rates of $\sim0.01\mu my^{-1}$ ($100,000ymm^{-1}$) are more typical for a GDF environment which, when applied to waste container sections of a few mm, would suggest that such a mechanism is not a significant threat to integrity.

Localised corrosion mechanisms such as pitting or crevice corrosion, tend to be considered a greater threat to stainless steel waste containers than general corrosion. Nevertheless, data extrapolated from tests [30, 31] have shown that the time for a pit to penetrate 1mm into 316L stainless steel is many centuries. Crevices formed between the components that make up a stillage, such as between the corner posts and side plates, should be avoided, as should any design feature that acts as a stress raiser. Localised corrosion mechanisms are also dependent upon the presence of surface contaminants, in particular, chlorides. Work has been carried out to investigate these effects for waste containers and to specify requirements for, amongst other factors, the surface finish of stainless steel used [32]. This work would be equally relevant to stillages.

The incidence of atmospheric stress corrosion cracking is dependent on the presence and concentration of soluble chloride deposits, the chemical form of the chloride, temperature, relative humidity and the metallurgical state of the stainless steel [29]. Such corrosion of stainless steel can be accelerated at temperatures above 60°C but may also be significant at lower temperatures. A pre-requisite for this type of localised corrosion is access by oxygen to the surface of the container material. Accordingly the elimination or reduction of gaps and crevices in the stillage design is of benefit.

Intergranular corrosion or ‘weld decay’ can occur in austenitic stainless steel that has been ‘sensitised’ by the high temperatures experienced during welding. The risk of sensitisation is minimised by use of low carbon or stabilised grades of stainless steel. Nevertheless, excessively high heat inputs should be avoided, as should contamination of the weld by materials containing carbon or nitrogen.

The following matters should be taken into account during the design of a stillage:

- A high pH environment is generally considered to be beneficial in reducing corrosion rates;
- The presence of microbes, together with the right conditions of nutrient and water supply on a surface, could lead to the microbially induced corrosive degradation of the material.
- Stored waste packages will emit and be exposed to gamma radiation from within and from surrounding packages. A consequence of such exposure is to produce nitric acid from atmospheric nitrogen, oxygen and water. Minimisation of the presence of free water, or water readily available in the vapour phase, will reduce the quantity of nitric acid that could be produced.
- Radiolysis of waste package contents can result in the production of aggressive chemicals (e.g. hydrochloric acid from the radiolysis of polyvinyl chloride) that accelerate degradation processes.

To assist waste packagers in these areas, guidance has been produced on the general corrosion properties of stainless steel [28], the requirements for surface finish [24] and on welding techniques used during the manufacture of stainless steel containers which will also have relevance to the fabrication of stillages [33].

3.8 Maximum gross mass

The gross mass of the stillage *should* not exceed 1,000kg.

The Generic Specification for waste packages containing LHGW [18] defines a maximum gross mass of 12t for unshielded waste packages on the basis that this is the maximum payload mass which the SWTC-285 could carry if the total mass of the transport package would not exceed 64t[4]. Accordingly all three variants of the SWTC have been designed to carry payloads with gross masses of up to 12t.

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[4] For transport by rail, the GTSD [Ref] currently assumes the use of a four-axle wagon, which would allow transport packages with gross masses of up to ~64t to be carried on a large proportion of the UK rail network.

In principle this value could be applied to a stillage containing four 500 litre drum waste packages, which would leave an 'allowance' of up to 4t for the gross mass of the stillage. However, as a means of limiting stacking loads a maximum gross mass of 1t is specified for all stillages. RWM has recently carried out design and manufacturing development work for an exemplar prototype stillage, in order to inform the development and maintenance of the stillage specification and guidance. [34] The gross mass of that design is significantly less than this limit which therefore should not unduly restrict stillage design.

3.9 Criticality safety

The design of the stillage *should* not include any feature that could deleteriously contribute to the criticality safety of the waste packages contained within it.

With regard to criticality safety of waste packages the Generic Specification for waste packages containing LHGW [18] requires that:

'The presence of fissile material, neutron moderators and reflectors in the waste package shall be controlled to ensure that:

- *criticality during transport is prevented;*
- *the risk of criticality during the GDF operational period is tolerable and as low as reasonably practicable; and*
- *in the GDF post-closure period both the likelihood and the consequences of a criticality are low.'*

In general these requirements are met by limiting the amount of fissile material contained in waste packages to quantities derived from a criticality safety assessment (CSA) of the package design. CSAs are inherently pessimistic exercises and generally assume the worst case geometry of waste packages as regard to the likelihood of accidental criticality during any of the periods of the long-term management of the waste packages. In the case of 500 litre drum waste packages carried in stillages this includes assuming that the waste packages are placed as close together as physically possible (i.e. that they are touching). As a consequence, the design of the stillage need have no requirement to maintain the position of the waste packages from the criticality safety point of view. The CSAs for 500 litre drum waste packages also assume that the stillages will be made from stainless steel. Accordingly the materials for the manufacture of stillages should be such as to not be significantly different to stainless steel in terms of neutron reflection or moderation.

Criticality safety during the GDF post-closure phase is assessed against four scenarios which are as follows;

(i) During the period following backfilling before any significant evolution of the waste package or its contents has occurred;

(ii) *Package-scale scenarios,* in which evolution of the waste package contents has occurred such that the redistribution of the fissile material can occur within an effectively intact waste container;

(iii) *Stack-scale scenarios,* in which there is localised degradation (on the scale of a stack of waste packages) and the failure of the waste container such that the accumulation of the fissile material from a limited number of waste packages can occur; and

(iv) *Vault-scale scenarios,* in which waste package failures are such that the accumulation of the fissile material from a larger number of waste packages can occur.

Of these scenarios only the last two are influenced by the stillage, in that premature loss of integrity of the stillage could be a casual factor in either of these scenarios. Such a possibility re-emphasises the need for the stillage to be manufactured from materials whose long-term performance equals that of the materials used in the manufacture of the 500 litre drum waste containers.

More extensive guidance on criticality safety, if required, can be found in [35].

3.10 Accident performance

The stillage *should* be designed such that under all credible accident scenarios it will not affect the ability of the waste packages it contains to satisfy the impact performance requirements of the WPS for those waste packages [5].

The Generic Specification for waste packages containing LHGW [18] defines the following requirements for the impact and fire accident performance of waste packages:

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

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

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

Stillages containing 500 litre drum waste packages may be subject to a range of accident conditions during their long-term management, up until the end of the GDF operational period. Specifically these include minor impacts during normal handling and more severe accidents involving impacts and/or fires during transport or the GDF operational period. All such accidents are a potential mechanism for the release of radionuclides from the waste packages into the environment in an uncontrolled manner and/or the exposure of workers and members of the public to radiation.

The adequacy of the accident performance of the waste packages that would result from the implementation of proposals to package waste will be evaluated as part of the disposability assessment of those proposals. In the case of 500 litre drum waste packages it will be important that their accident performance is not deleteriously affect by them being handled in stillages. This is particularly important in the case of accidents involving impacts where the stillage design should not include any aggressive features, such as sharp corners, which could cause damage to the waste packages in the event of such an impact.

RWM has produced extensive guidance on the manner by which the required accident performance of waste packages containing LHGW can be achieved [36], this guidance also has relevance to the design of stillages.

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