Radioactive Waste Management

Shaft and Silo at Dounreay

(Interim stage)

Summary of Assessment Report

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Introduction

Dounreay Site Restoration Limited (DSRL) has sought Interim stage endorsement of two separate proposals for the packaging of solid and sludge wastes from each of the Shaft and Silo facilities. It is proposed that solid wastes from both facilities would be packaged in 6m^3 concrete boxes and sludge wastes would be packaged in stainless steel TRU-Shield drums. DSRL has also requested assessment of a variant option where solid wastes would also be packaged in TRU-Shield drums.

This Assessment Report provides the basis and findings of both Interim stage disposability assessments by NDA Radioactive Waste Management Directorate (hereafter RWMD) for packages of solid and sludge wastes from the Shaft and Silo facilities. Due to the similarities of the wastes, waste treatment and packaging proposals, and in agreement with DSRL, the output of both assessments has been reported in a single assessment report. The assessments have been carried out through the Disposability Assessment process, whereby RWMD examines the disposability of proposed waste packages by assessment against relevant waste package standards and specifications and the illustrative geological disposal concepts for LLW/ILW. The illustrative geological disposal concepts for LLW/ILW have been developed as part of the programme to implement geological disposal for the UK's higher activity wastes. Further information on the Letter of Compliance process is available elsewhere[1].

For wastes packaged in 6m^3 concrete boxes, the relevant Waste Package Specification is WPS/360. Wastes packaged in TRU-Shield drums could not be assessed against a Waste Package Specification since this container is not currently part of the disposal system specification. Non-standard packages normally are assessed at the Conceptual stage against the generic specification for Waste Packages Containing Low Heat Generating Waste, as specified in RWMD's Disposability Assessment Aim and Principles. A Waste Package Specification for the TRU-Shield drum, which is a requirement for assessment and successful endorsement at Interim stage, does not exist at present. DSRL has requested that these submissions be assessed at Interim stage, without Conceptual stage endorsement. In order to carry out a quantitative Interim stage assessment, extensive use has therefore been made of WPS/300, the Waste Package Specification for 500 litre drums, where use of this dimensionally similar waste container surrogate is appropriate. Where an analogy to the 500 litre drum cannot be justified, the Generic Specification for Waste Packages Containing Low Heat Generating Waste has been used.

[1] NDA, Guide to the Letter of Compliance Process, NDA Document WPS/650, March 2008

Background

The Dounreay site has hosted three reactors: the Dounreay Materials Test Reactor (MTR), the Dounreay Fast Reactor (DFR) and the Prototype Fast Reactor (PFR). Operation of all three of these reactors and their support facilities at the Dounreay site resulted in the generation of a wide range of solid radioactive wastes. Wastes classified as ILW were consigned to the Shaft for disposal and subsequently to the Silo for interim storage.

The Shaft is approximately 65 m deep and has a nominal diameter of 4.6 m. Wastes were deposited into the Shaft during the period 1959 to 1977. The "wet" Silo is 9.1 m deep, 8.5 m wide and 10.4 m long. It was constructed as a replacement waste storage facility for the Shaft and accepted wastes during the period 1971 to 1998.

Since the closure of each facility, wastes have been stored under water. Many of them will have undergone significant degradation in the extended period between the original consignment to the Shaft and Silo and their eventual retrieval for packaging. The exact condition of the waste is not known although it is expected to comprise a mixture of intact or partly degraded solid items and a sludge phase comprising the products of that degradation.

DSRL has proposed packaging of the solid waste component in 6m^3 concrete boxes. These boxes were originally intended for the sea-disposal of reactor decommissioning wastes and have been used for decommissioning wastes from the Windscale Advanced Gas-cooled Reactor (WAGR) at Sellafield. The solid wastes from the Shaft and Silo contain fissile materials and to permit transport in the public domain would therefore require competent authority approval of the 6m^3 concrete box as a fissile package, or to comply with the fissile exception criteria under the International Atomic Energy Agency Transport Regulations, 2012 Edition. This is likely to be an onerous task, which carries a risk that such approval might not be obtained. To mitigate this risk, DSRL requested assessment of an alternative packaging option whereby the solid wastes would be packaged in TRU-Shield drums, in a similar arrangement to that proposed for packaging sludge wastes.

Scottish Government Policy is that the long-term management of higher activity radioactive waste should be in near-surface facilities. Facilities should be located as near to the site where the waste is produced as possible. For the purposes of this assessment, near-site is interpreted not to preclude the potential transport of wastes through the public domain. The regulators' view is that packages conditioned in anticipation of geological disposal, and assessed under the disposability assessment process, would also be suitable for long-term storage in accordance with Scottish Government policy. Geological disposal has therefore been used as the assessment basis for the provision of advice on the potential transport and disposability aspects of the proposals.

Waste packaging proposal and scope of assessment

Total waste volumes of 739 m^3 and 480 m^3 are estimated to be in the Dounreay Shaft and Silo, respectively. Shaft wastes are represented in the UK Radioactive Waste Inventory by waste stream 5B25, known as ILW Shaft contents; Silo wastes are represented by waste stream 5B02, described as low alpha Remote Handled Intermediate Level Waste (RHILW).

Both the Shaft and the Silo contain a broad range of waste types, including: general waste and scrap from laboratory and plant operation, wastes from decommissioning and refurbishment activities, fuel element cladding, miscellaneous activated reactor components, sealed radioactive sources and effluent treatment sludge. "Fuel element wastes" were disposed of in the Shaft only and refer to components removed in

disassembly such as “tops and tails”. These are stainless steel from DFR elements or aluminium from MTR elements. Specific fuel and breeder material was also disposed to the Shaft. No fuel elements of any type were consigned intact to the Silo, although other reactor components of similar dimensions may be present.

It is proposed that the wastes would be retrieved from the Shaft and from Silo compartments using grabs, cutting equipment and buckets lowered by a crane. The retrieved waste would be placed on an irrigated screen (grid size 5 mm) to allow separation of particulate (sludge). Solid wastes would be inspected visually and using a gamma camera to identify and remove intact fuel or high dose items, to be packaged separately in TRU-Shield drums. DSRL has proposed to exclude these items from the assessment. However, since the proposals do not demonstrate whether or not all of these items can be removed reliably, the assessment is based on the actual inventories of the Shaft and Silo with these items included. After visual inspection, solid waste items would then be shredded into assay containers. After assay by gamma spectroscopy and neutron counting, the shredded waste would be tipped into baskets for grouting.

If the $6m^3$ concrete box option is pursued, two standard half height waste baskets (mild steel) would be used per $6m^3$ concrete box. An anti-flotation grid would be added above the upper half height waste basket to keep soft waste items below the top level of the grout for when the lid is cast. Wastes would be grouted in the $6m^3$ concrete boxes using a high density cementitious encapsulant. The high density encapsulant contains magnetite (iron oxide) aggregate, to provide greater shielding than standard density, cementitious encapsulant.

If the TRU-Shield drum option is pursued, solid waste would be encapsulated in a mild steel liner with a low density grout formulation of 3:1 Pulverised Fly Ash (PFA) to Ordinary Portland Cement (OPC), and following wasteform set, each liner would be loaded into a separate TRU-Shield container.

Particulate and sludge, separated using the irrigated screen, would be collected in bulk tanks and concentrated to target levels. After assay and characterisation, sludge wastes would be transferred to a mild steel liner and in-drum mixed with a 1:1 PFA:OPC grout formulation. Following wasteform set, each liner would each be loaded into a separate TRU-Shield container.

It is anticipated that 114 and 79 off $6m^3$ concrete boxes would be required to package solid wastes from the Shaft and Silo, respectively. Based on early trials with a high conditioning factor, if the solid wastes were to be packaged in TRU-Shield drums, it is anticipated that more than 7500 and 6000 would be required for the Shaft and Silo wastes, respectively.

Regardless of the solid waste packaging option, it is anticipated that 2060 and 934 off TRU-Shield drums would be required to package sludge wastes from the Shaft and Silo, respectively.

Many of the conclusions reached during these assessments are particular to the waste packaging option, rather than being specific to either Shaft or Silo wastes. Therefore the summaries presented below are similarly arranged.

Outcome of assessment for wastes packaged in 6m3 concrete boxes

The $6m^3$ concrete box proposals, containing solid wastes from the Shaft and the Silo, were assessed against the criteria in Waste Package Specification WPS/360. Several compliance gaps were identified, mainly due to the diverse nature of the wastes and the stringent requirements associated with classification of the $6m^3$ concrete box as an Industrial Package Type 2 (IP-2) for transport purposes. These are summarised in the sections below.

Compliance with Waste Package Specification

The maximum heat output estimated for a $6m^3$ concrete box containing Silo solid wastes was found to exceed the limit specified in WPS/360 for transport at 2040. At this time, the heat output is dominated by Co-60 (86% of the total heat output), which has a short half-life (5.27 years) and therefore decay-storage could be used to meet the heat output requirement for transport at a later date. The $6m^3$ concrete box does not have a competent authority certificate of approval for use as a fissile package, and the fissile content for these wastes were assessed to exceed the current fissile exception mass limit for Industrial Packages. The 2012 IAEA Transport Regulations, which have not yet been enacted in UK law, do allow provision for the production of a package-specific criticality safety assessment, demonstrating that sub-criticality could be maintained during routine, normal and accident conditions of transport. Such a criticality assessment has not been made to support these proposals at this time, although DSRL has stated an intention to do so. For endorsement as a disposable waste package by RWMD, the criticality safety assessment would be required to consider the operational and post-closure phases of a geological disposal facility also.

Compliance with transport criteria in the Waste Package Specification

The regulatory requirements for transport of industrial packages require the waste contents to be Low Specific Activity (LSA) or to consist of Surface Contaminated Objects (SCO). This places demands on the specific activity of the wastes, the distribution of the activity throughout the wasteform and on the dose rate from the bare wasteform, as part of limiting the quantity of radioactive material for transport in an Industrial Package. The category of LSA most appropriate to both wastes was judged to be LSA-II. The assessment concluded that the dose rate requirements for transport in an Industrial Package would not be met at the earliest assumed time of transport of 2040 for packages with the maximum radionuclide inventories, but would be met using the average radionuclide inventory. The average inventory is calculated based on the known inventories of wastes disposed to each facility from historical records. The maximum inventories are calculated based on the variability of the wastes to assess worst-case scenarios. Compliance with the dose rate criteria suggest that a proportion of wastes could be transported in Industrial Packages, provided the wastes can be segregated appropriately to comply with dose rate limits and be shown to be LSA.

To comply with the requirements of LSA it was concluded that, although the specific activity, when averaged across the whole waste package, met the requirements, demonstration that the activity would be distributed throughout the wasteform was unlikely to be met. An interpretation of the distribution of activity requirement for LSA wastes is provided in the IAEA Transport Regulations guidance to be that the activity in any tenth of the wasteform would vary in activity by no more than a factor of ten when compared with any other tenth of the wasteform. The assessment notes that approximately 30% of the wastes in the Shaft and Silo are described radiologically, in terms of inventories in the disposal records and that the proposals do not demonstrate adequately that the non-LSA items could be removed reliably from all wastes being retrieved. The demonstration that activity has been distributed throughout, would in part be dependent on the type of shredder used and its ability to homogenise the wastes. However, since the details of the shredder are also unknown at this time, the assessment concluded that the wastes would be unlikely to meet the LSA-II requirements.

The assessment also noted that the certificate of approval for transport of the $6m^3$ concrete box has lapsed and would need to be renewed before the package can be approved for transport or endorsed at Interim stage.

The assessment considered another potential solution of transporting fissile wastes in the $6m^3$ concrete box: namely packaging the $6m^3$ concrete box in a transport container to form a Type B arrangement. Without a design of the transport container, the feasibility of this option was assessed by mass and dimension, against transport criteria where the mode of transport included road or rail. For transport by rail, the mass and dimensions of a shielded transport container exceeded the limits defined for the W6A rail gauge, based on the UK rail transport network. For transport by road, the expected package masses would exclude a large number of routine transports. The assessment concluded that a Type B transport arrangement would therefore be unfeasible.

Compliance with concepts for a Geological Disposal Facility

Solid wastes packaged in $6m^3$ concrete boxes were assessed against the illustrative geological disposal concepts for LLW/ILW, recognising that the illustrative concept in the higher strength rock geology is considered in the 2010 generic Disposal System Safety Case to be suitably bounding of other geologies for operational and longer-term faults/scenarios.

Assessment of operational fault conditions at this stage of the Geological Disposal Facility design can only be reliably undertaken using the Design Basis Accident approach, which is intentionally conservative, as defined by the Office of Nuclear Regulation in the Safety Assessment Principles of 2006. Under these conditions, the packaging proposals for Shaft and Silo solid wastes in $6m^3$ concrete boxes were shown to result in unacceptably high doses to operators and members of the public, significantly above the Basic Safety Levels, as adopted in RWMD's Radiation Protection Policy Manual. Under normal operating conditions, the same packaging proposals were also shown to exceed the GDF design target of 1 mSv/yr to workers.

Package-specific criticality safety assessments, as justified above for transport, are similarly required for the operational and post-closure phases of a Geological Disposal Facility. Different package arrangements and scenarios are adopted to understand which phase is limiting (compliance against criticality safety cannot be given unless the package complies with all three phases). These will need to be provided by DSRL to RWMD in a future submission for assessment.

Outcome of assessment for wastes packaged in TRU-Shield drums

Compliance with Waste Package Specification

The TRU-Shield containers have been assessed previously by RWMD at the Conceptual stage but have not been adopted into the disposal system specification. A disposal system change control request has been initiated to include the use of TRU-Shield drums, but this assessment has not concluded due to ongoing TRU-Shield drum design changes led by DSRL. Consequently, specific assessment tools have not been developed for TRU-Shield drums, and will not be developed until these are approved as standard waste containers under the disposal concept. It is unusual therefore to assess such a packaging proposal at Interim stage under these conditions, and indeed endorsement cannot be given without specific, quantitative assessment against an appropriate Waste Package Specification. Without this specification, compliance was tested against WPS/300, the closest standard waste container analogue (the 500 litre drum), where appropriate, to give an indication of how likely the waste package would be to meet future requirements when defined. Where the use of WPS/300 was not considered appropriate, the Generic Specification for Low Heat Generating Waste was used instead. Potential compliance gaps that were identified in the safety assessments are summarised in the following sections below.

Compliance with transport criteria in the Waste Package Specification

The TRU-Shield containers are expected to be transported in a Type B configuration using an RWMD Standard Waste Transport Container (SWTC). The height of the TRU-Shield container as currently defined are such that a loaded stillage of four TRU-Shield drums could be transported only in the SWTC-150 (incorporating 150 mm of shielding), which has a larger internal cavity height. The TRU-Shield drums, as assessed for these packaging proposals, also have a greater mass than the mass limit for wastes packaged in 500 litre drums, as specified in WPS/300. Such a transport package may not comply with the 12 t payload mass limit, based on current designs of stillage (the TRU-Shield drums are taller and heavier than the 500 litre drums and therefore a bespoke stillage would be required for stacking and handling).

The external dose rates do not comply with the dose rate limits in the Transport Regulations, when assessed using the standard RWMD assessment tools and assuming the TRU-Shield drums can be modelled as the closest standard waste container analogue (the 500 litre drum). It would be considered feasible at the Conceptual stage that the dose rate limits would be met if the additional shielding present in the proposed transport package was modelled explicitly. Heat output was assessed to be compliant against the criterion in WPS/300. The build-up of flammable hydrogen gas within the transport package was assessed to exceed the limit on hydrogen gas generation, in terms of volume of gas produced per day, defined in WPS/300 based upon a lower limit of flammability of hydrogen in air of 4 % concentration by volume. This limit was exceeded for Shaft solid wastes and for both Shaft and Silo sludge wastes packaged in TRU-Shield drums. To be able to transport these packages safety, it would be necessary to employ a purge and inert process to remove oxygen from within the transport package prior to transport.

Package-specific criticality safety assessments based on quantitative modelling were not produced by DSRL to support the proposals for sludge wastes and where solid wastes are packaged alternatively in TRU-Shield drums. For sludge wastes DSRL has proposed to use a package fissile content limit equivalent to the upper screening level in a generic criticality safety assessment (CSA) for High Enriched Uranium packaged in 500 litre drums. The criticality arguments are not sufficiently developed to permit assessment of whether or not the Safe Fissile Mass, which would include uncertainties in measurement and measurement error, would be higher than the fissile content limit or whether such uncertainties have been included already and would form the basis of the Safe Fissile Mass argument. The assessment concluded that use of the generic CSA was not justified because the underlying assumptions made in this safety case were not demonstrated to be applicable to these wastes packaged in TRU-Shield drums. The use of the upper screening level was also not supported without an appropriate ALARP case regarding the fissile content. The fissile content limit for both Shaft and Silo solid wastes is higher than the upper screening level for the generic CSA and could also not be justified. The lack of package-specific CSAs prevented endorsement of these wastes previously at Conceptual stage and would be required for assessment before endorsement at any stage can be considered.

Compliance with concepts for a Geological Disposal Facility

The design of the TRU-Shield drum was assessed against the illustrative geological disposal concepts for LLW/ILW. It was found not to be compatible with the planned handling, storage, monitoring and disposal system of the illustrative geological disposal concepts. Doses calculated in response to operational fault conditions were found to exceed the Basic Safety Levels for workers, but were approximately an order of magnitude lower than the doses calculated for the equivalent wastes packaged in 6m^3 concrete boxes.

The generic Disposal System Safety Case identified bounding waste streams to support Design Basis Accident analyses for the geological disposal facility and the doses calculated for those streams bound the dose consequences for the wastes packaged in TRU-Shield drums. Improvements to both the geological disposal facility design and to the assessment methodologies and data are expected to reduce the bounding doses to below the Basic Safety Levels. Doses from wastes packaged in TRU-Shield drums are expected proportionately to be reduced to below these Levels. It is therefore judged by RWMD that the dose consequences calculated for accidental fault conditions would comply with the illustrative geological disposal concepts for wastes packaged in TRU-Shield drums only.

Radium wastes decay to radon gas. The sources of radium in the Shaft are expected to be transferred into the sludge waste stream at the point where the wastes are shredded. Shaft sludge wastes were found not to comply with off-site dose limits due to discharges of radon from the packages. The assessment used conservative estimates of the radium inventory, as supplied by DSRL. Improvements in understanding the provenance of these wastes and therefore better estimating the inventory may reduce assessed doses to acceptable levels. Where this is not possible, DSRL would be required to develop suitable mitigation measures to ensure discharges of radon are controlled. Silo wastes containing radium were reported to be ill-defined but lower than the quantities found in the Shaft. Since the doses from Silo radon discharges cannot be assessed, and are bounded by Shaft discharges, the assessment has considered that Silo radon discharges would only be acceptable when those from the Shaft are, and that any mitigation measures required in the treatment of Shaft wastes, would also apply to the treatment of Silo wastes.

Outcome of assessment – package independent compliance gaps

Two package independent compliance gaps were also identified. While it is expected that DSRL does operate a suitable quality management system, and are noted to work to British Standards including ISO:9001, this was not demonstrated sufficiently in the proposals against RWMD criteria for assessment. It is considered that this compliance gap can be remedied relatively easily by DSRL. The proposals put forward regarding waste package data and information recording were also not sufficiently developed for assessment at the Interim stage and did not comply with the specifications. It is expected that these proposals would be developed as the waste treatment processes evolve.

Statement of disposability

The assessments identified 39 Action Points including 4 Action Points that are still to be closed at the Conceptual stage from previous assessments. Action Points for resolution at the Final assessment stage are not included in this assessment report; these will be included in response to future submissions when the proposals have been developed further. Compliance gaps were identified against the relevant Waste Package Specifications and against the concepts for a Geological Disposal Facility and are applicable to both solid and sludge wastes from both the Shaft and the Silo. It is recognised that the treatment and packaging of Shaft and Silo wastes is extremely challenging and good progress has been made in a number of the assessment areas. At this time, however, neither Interim nor Conceptual stage endorsement can be given.

Conclusions

Two packaging proposals for wastes from the Dounreay Shaft and Silo were submitted for assessment. The wastes for each are expected to contain solid and sludge waste components. The solid wastes from each submission would be packaged in 6m^3 concrete boxes; the sludge wastes would be packaged in TRU-Shield drums. An alternative option was also assessed whereby solid wastes would be packaged in TRU-Shield drums also, to minimise risks associated with obtaining a competent authority certificate of approval for use of the 6m^3 concrete box as a fissile transport package.

A number of compliance gaps were identified for all proposals. Principal barriers to endorsement are in the following areas:

- The 6m^3 concrete box has been approved and used previously as an Industrial Package, for transporting Low Specific Activity wastes. The certificate of approval for transport of the 6m^3 concrete box as a non-fissile package has lapsed and would need to be renewed before the package can be approved for transport or endorsed at Interim stage.
- Assessment of the DSRL wastes against the criteria for LSA highlighted that the full range of wastes would not be considered to be LSA. DSRL has not demonstrated if or how non-LSA items could be identified and removed reliably and consistently from the wastes being packaged in the 6m^3 concrete boxes. If this could be demonstrated, then assessment of dose rates against the requirements for wastes packaged in Industrial Packages suggest that a proportion of wastes could be packaged in 6m^3 concrete boxes.
- The 6m^3 concrete box does not have a competent authority certificate of approval for use as a fissile package but is proposed to contain wastes with potentially significant fissile content. The likelihood of success of competent authority approval of the 6m^3 concrete box for use as a fissile transport package was not considered in these assessments, but a package-specific criticality safety assessment would be necessary to obtain the certificate of approval. For endorsement as a disposable waste package by RWMD, the criticality safety assessment would be required to consider the operational and post-closure phases of a geological disposal facility also
- Doses from fault conditions at a Geological Disposal Facility for wastes packaged in 6m^3 concrete boxes were assessed to be significantly above the Basic Safety Levels for workers and members of the public. These dose consequences cannot be reduced to tolerable levels through improvements in the facility design and operational safety assessment methodologies alone.
- The TRU-Shield drum is not currently adopted in the disposal system specification and therefore cannot be endorsed at the Interim stage until it has successfully completed the disposal system change control process. This process has been initiated, separate to these assessments, but cannot be concluded until the design is finalised.
- The generic criticality safety assessment for High Enriched Uranium packaged in the 500 litre drum was not shown to be applicable to wastes packaged in TRU-Shield drums. RWMD considers that the generic criticality safety assessment does not apply and therefore a package-specific criticality safety assessment, based on quantitative modelling for these packaging proposals to derive specific Safe Fissile Masses, is required. Criticality safety assessments would be required for solid and sludge wastes, covering transport to and disposal at a Geological Disposal Facility.

- Radon discharges from the Shaft sludge waste packages are calculated to give off-site normal doses significantly above the environmental dose limit, as defined by the Scottish Environment Protection Agency. Suitable mitigation, possibly based on refinement of the inventory, would therefore be required.
- The waste package data and information recording proposals are currently at an insufficient stage of development. This in turn appears to highlight uncertainties in the waste treatment and capabilities of the assay equipment for the range of wastes expected. These uncertainties need to be resolved at the Interim stage.

It is RWMD's view that a combination of both waste containers could be used for packaging solid wastes, provided DSRL can define and enforce appropriate limits on the wastes being packaged in each package type. In particular, compliance with the requirements for transport of waste as LSA are expected to be challenging. DSRL would need to demonstrate how non-LSA items could be identified and removed reliably and consistently from the wastes being packaged in the $6m^3$ concrete boxes. This approach would be in keeping with the segregation philosophy set out in RWMD's Disposability Assessment Aim and Principles. This combination has not been assessed because the submissions do not define what cross-over limits (from one packaging option to the other) would be used and how they would be implemented consistently and practically, in terms of both detection and segregation equipment. Future submissions may wish to explore the viability of a combined packaging approach in greater detail.

For the proposals submitted, and given that the disposal system change control process for the TRU-Shield drum has not been completed, neither Interim nor Conceptual stage endorsement can be given.