Radioactive Waste Management

Dragon decommissioning ILW in 6m^3 concrete boxes

(Interim stage)

Summary of Assessment Report

Issue date of Assessment Report: 2 December 2013

Introduction

Research Sites Restoration Limited (RSRL) has sought interim stage endorsement of proposals for the packaging of Intermediate Level Wastes (ILW) produced from the decommissioning of the Dragon reactor into 6 cubic metre (6m^3) concrete boxes at Winfrith.

This Assessment Report provides the basis and findings of the interim stage disposability assessment by NDA Radioactive Waste Management Directorate (hereafter RWMD) for packages of Dragon decommissioning ILW. The assessment has 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 Disposability Assessment process is available elsewhere[1].

Background

The Dragon Reactor was a 20 MW high-temperature helium-cooled experimental reactor. It was the centrepiece of an Organisation of Economic Co-operation and Development (OECD) project to develop high temperature reactors (HTR) with helium coolant, and to develop the graphite coated U-Th fuel cycle technology for potential commercialisation. The reactor operated on the Winfrith site from June 1965 to September 1975.

The Dragon Reactor Building at Winfrith

Since shutdown the fuel has been removed from the reactor and transferred to RSRL Harwell. A dummy core has been inserted to maintain structural integrity and some other removable components (e.g. control rods) remain.

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

For the purposes of decommissioning the Dragon reactor, the Winfrith Closure Programme (WCP) has broadly adopted the Reactor Decommissioning Engineering Services (RDES) concept design and methodology that was developed for decommissioning of the Steam Generating Heavy Water Reactor (SGHWR) also located at Winfrith. The WCP outlines the methodology and equipment to be used to implement the Dragon reactor primary containment segmentation, waste assay and packaging for waste disposal. It also includes proposed waste basket packing plans that were designed during the SGHWR decommissioning RDES scheme work.

The agreed Final End State (FES) for the Winfrith site is a return to heath land by 2025, with the possibility of retaining some existing buildings on the Winfrith site for commercial use beyond this date. In order to achieve this FES objective, the ILW waste packages from Dragon decommissioning will require to be transported off-site soon after they are produced; as there are no plans to provide an interim storage building. Based on a Best Available Techniques (BAT) study for packaging SGHWR and Dragon decommissioning ILW, the WCP selected the Reinforced Concrete Box (RCB), referred to in this report as the $6m^3$ concrete box, as the preferred package for the Dragon reactor decommissioning ILW. The box is designed to be an IP2 transport package that will, depending on the packaged waste meeting the relevant criteria for packaging and transport, allow transport at the date required by RSRL, i.e. prior to 2025.

RSRL has previously (in 2006) presented a submission for a Conceptual Letter of Compliance (LoC) to RWMD for the packaging of ILW from the decommissioning of the Winfrith Dragon reactor into 2m boxes. RWMD carried out an assessment of RSRL's Conceptual LoC submission, and results were presented in a conceptual stage disposability assessment report. Based on this, a formal Conceptual Stage LoC was issued to RSRL for Winfrith Dragon reactor decommissioning wastes. The scope of this endorsement excluded components inconsistent with transport as LSA-II material in a 2m box. A number of action points to be addressed in a subsequent interim stage submission were identified in the conceptual stage assessment report. Where relevant (i.e. not specific to the discontinued proposal to use 2m boxes) these action points are considered in this interim stage assessment report where the information provided in the current submission has been assessed to judge whether the action point can be closed, or whether further information is still required.

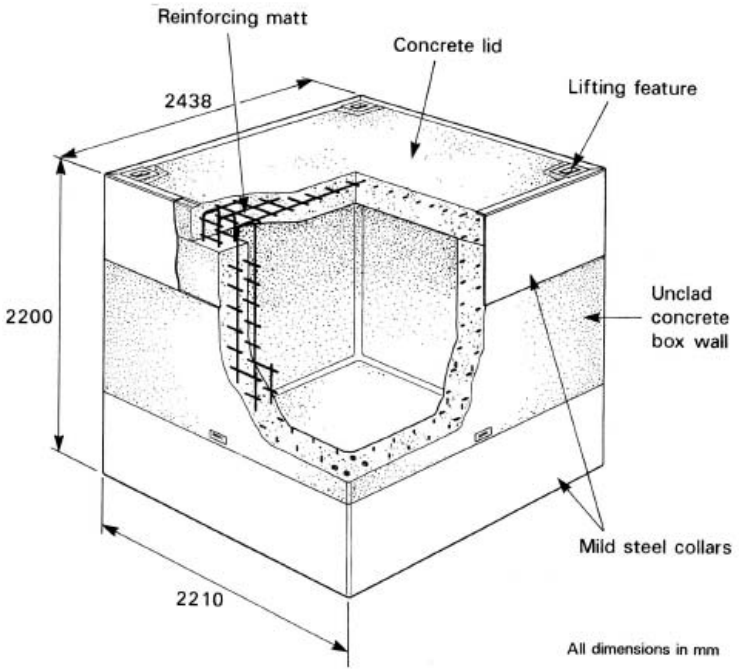
Waste packaging proposal and scope of assessment

Dismantling of the Dragon reactor pressure vessel will be broken down into 10 campaigns. The dismantling campaigns will be arranged to match the segmentation process to reflect the order in which materials are to be removed and packaged.

The wastes included in the RSRL submission constitute stream 5G304 in the 2010 UK Radioactive Waste Inventory (UKRWI). The total volume of raw waste material is given in the UKRWI (2010) as 79.8 m^3.

The wastes to be packaged are predominantly steel and graphite. The total mass has been assessed as 77t including 45.5t mild steel, 28t graphite and 2t stainless steel. In addition there are smaller quantities of Nimonic (1.1t), Monel-400 (0.1t) and Boron Carbide (0.1t).

RSRL anticipate producing 25 off 6m^3 concrete boxes, each containing a 3.25 m^3 basket containing the grouted waste, giving a total package volume of 296 m^3.



Schematic of 6m^3 concrete box

The design of the 6m^3 concrete box is intended for use in packaging activated metals, for transport and disposal of Low Specific Activity wastes as Industrial Packages. The 6m^3 concrete box has dimensions 2438mm by 2210mm on plan, by 2200mm height. It comprises a reinforced concrete box with 8mm thick mild steel collars top and bottom. The collars provide additional protection to the corners and the twistlock lifting features. The lid is cast after grouting the contents in place so as to present an essentially monolithic structure.

The package has 240mm thick walls for shielding, a mass limit of 50t and a payload volume of 5.76m^3. Two variant options are available: normal density or high density, where the density option applies to both the type of concrete container and the waste encapsulating grout. The high density option is presently proposed for packaging these solid wastes, although RSRL will use standard density boxes if the dose rate from the waste is found to be low enough following improved assay.

RSRL concede that the inventory information presented within the current submission may be subject to change, pending the outcome of a proposed sampling campaign.

As stated above, the wastes predominantly consist of metallic and graphite items, most of which would be size-reduced for removal and packaging. In summary:

- The main part of the enabling works will involve a sampling campaign to confirm whether the inventory is low enough to enable the waste to be packaged into normal density 6m^3 concrete boxes (the current plan allows for the use of high density concrete boxes). This sampling campaign is programmed to take place in 2014.
- The size-reduced Dragon ILW arisings from each campaign will be loaded into perforated steel waste baskets. Higher-activity components would be placed within an inner steel basket placed inside the perforated baskets to allow them to be centrally located and provide a degree of shielding. In addition, the perforated waste baskets would contain other furniture designed to ensure good grout infiltration: ‘milk crates’ to keep pipework upright and ‘toast racks’ for planar or nearly planar items.
- The packaged waste baskets would be transferred to the Winfrith ILW grouting facility. In the grout facility the basket will be subjected to dose rate assay to check it is within the waste product specification inventory envelope before being lowered into the 6m^3 concrete box. Once filled, the 6m^3 concrete box would be transferred to the grouting station. Grouting occurs in two stages;

stage one involving filling the box with grout, stage two being grouting of the lid on the box. The completed box would be radiologically surveyed prior to transfer off-site.

It is intended to mix ILW arisings from different campaigns (three $6m^3$ boxes can be accommodated in the waste packaging area). Waste shown by assay not to fit within the radionuclide inventory envelope allowed by the Waste Product Specification for Dragon decommissioning waste in $6m^3$ concrete boxes would be diverted for packaging and disposal via an alternative route, involving flasking of the waste items to Harwell.

The grout formulation and envelope to be used for encapsulation of the Dragon decommissioning ILW is yet to be defined, but RWMD expects that a suitable grout can be developed, subject to a suitable superplasticiser being specified (see later in this summary).

Parameters for Assessment of Disposability

Assessment Inventories

Assessment inventories for the proposed packages have been generated based on the information provided in the submission. There is some uncertainty regarding the nature and quantity of the wastes (differences have been noted by RWMD between the quantities quoted in the UKRWI and the submission and, secondly, the presence and level of fissile contamination in a limited number of components is not known). This can be resolved during the packaging process, leading to requirements on the assay system and quality management system to identify wastes to be diverted to an alternative waste packaging route (see previous comment on flasking of such items for transport to Harwell), which is not part of this assessment.

Waste Package Properties and Performance

The $6m^3$ concrete box design is considered likely to meet RWMD requirements, but there is some uncertainty regarding the details of the design and manufacture. After lapsing for some years, Design Authority for the package has been assigned to Dounreay Site Restoration Limited (DSRL) in September 2013. Future applications of the $6m^3$ box are expected to include design refinements. A full assessment of the developed package has therefore not been possible, given the absence of some container details.

Compatibility with Specifications

The current packaging proposal meets or could be shown to be compatible with many areas of the RWMD specifications. However, further information is needed on a number of these, in particular: external dose rate; surface contamination; lifting features; package integrity; criticality safety; stackability; quality management; and waste package data and information recording.

All of these areas are discussed further in the key issues section below.

Assessment of Disposability

Transport Safety Assessment

There is insufficient information to conclude that use of the $6m^3$ concrete box for Dragon decommissioning ILW is consistent with meeting the transport system design and safety requirements as currently foreseen by RWMD.

At 2040, the assumed earliest date of transport to the GDF, five issues have been noted that currently would prevent endorsement:

- Some individual waste items could exceed LSA-II specific activity limits.
- A collection of individual waste items could exceed the bare dose rate limit at 3m from the waste.
- Some packages may exceed surface contamination limits because of migration of mobile radionuclides through the walls of the concrete box.
- The $6m^3$ concrete box has not been shown to comply with transport stacking requirements.
- The proposed package has not been shown to be fissile excepted (low levels of fissile contamination of some of the wastes cannot be ruled out at the current time).

In addition, as noted above, there was no Design Authority for the $6m^3$ concrete box until September 2013, therefore it will be some time before a number of the container related issues can be satisfactorily resolved.

Operational Safety Assessment

The impact, fire and contamination accident performance of this waste/container combination is acceptable based on RFs that are derived from an assumption that the packing of metal waste would be controlled to avoid expansive corrosion threatening the integrity of the package. Although the Basic Safety Levels (BSL) are exceeded for certain fire and impact faults, the dose consequences are below the equivalent doses calculated for the bounding waste streams in the Disposal System Safety Case (DSSC). It is expected that addressing the conservatisms in the current calculation methodology would bring all of these doses to below the BSL. Doses calculated under operational conditions are expected to be below the Geological Disposal Facility (GDF) BSO design target. Based on the inventory and gas modelling, radioactive gas generation (tritium and C-14 in methane and carbon dioxide) is not expected to be significant and there are no chemotoxicity issues associated with the waste.

Post-closure Safety Assessment

The potential significance of the proposed packages has been assessed by comparison with the baseline total inventory of waste to be disposed of as Shielded ILW. It is concluded that the use of the $6m^3$ concrete box for Dragon decommissioning ILW would be consistent with meeting the GDF post-closure requirements as currently foreseen by RWMD. It is noted that, due to their potential to affect radionuclide migration in the disposal environment, RSRL need to work with the Design Authority (DSRL) and RWMD to agree the requirements for the superplasticiser(s) to be used in the concrete for fabricating the $6m^3$ boxes and in the grout for encapsulating the wastes.

Key issues

Expansive corrosion of waste

Based on work carried out for the WAGR 6m^3 box, RWMD understands that modelling shows there is a limit of 0.078% on wasteform expansion before the rebar in the concrete box would start to deform. This is anticipated to be followed by spalling of concrete from the walls of the 6m^3 concrete box, and should be avoided during the period whilst boxes may need to be stored and handled. RSRL should define and justify the waste metals loadings and corrosion related expansion limits to ensure box integrity is maintained for the period required in the WPS.

Transport requirements

Further information is required to show that individual waste items would not exceed LSA specific activity and bare dose rate limits at 2040.

Based on a conservative interpretation of the IAEA transport regulations, the transport assessment was based on the following assumptions:

1. each solid item needs to be LSA II (or LSA-III, if it meets leach test requirements) based on its individual A_2/g value. RWMD notes that there is an opportunity for RSRL to challenge this interpretation of the guidance with ONR.
2. An appropriate collection of unshielded solid items must have a total dose rate of less than 10mSv/h at 3m. RWMD notes that there may be scope to interpret this requirement in different ways e.g. dose rate at 3m from the edge of the collection of objects, rather than at 3m from each individual item. The latter would potentially allow higher dose items to be placed in the centre of a collection.

The RWMD generic specification and IAEA Transport Regulations for low heat generating waste require that for waste packages transported as a Type IP transport package, the quantities of fissile material, neutron moderators and reflectors in the waste package should be controlled to ensure that the transport package can be excepted from the requirements of the IAEA Transport Regulations for packages containing fissile material. The most recent revision of the IAEA Transport Regulations has made significant changes to the definition of fissile exceptions. RSRL's submission is based on the IAEA 2009 Transport Regulations. These cannot be applied to packages made after 2014 as 'grandfathering' of the earlier regulations ceases to apply after this date. As the Dragon decommissioning waste packages are to be made after this time, RSRL will need to take into account the revised fissile exception transport regulations and their consequences for fissile exception of the Dragon decommissioning packages.

The currently proposed gamma spectroscopy assay method of determining fissile content for packaging may be inappropriate due to the high levels of Co-60 in the waste. Compton scattering would obscure the Cs-137 peak, resulting in a high limit of detection value for Cs-137. If the limit of detection is recorded as the value for Cs-137, then the amount of fissile material present may be significantly overestimated, potentially leading to problems with meeting the fissile mass limit set in the IAEA transport regulations. RWMD recommends that RSRL should reconsider the method for assigning a 'fuel contamination' inventory to the waste. RWMD believes that meeting the revised fissile exception regulations for IP-2 non-fissile packages will not be straightforward and therefore RSRL is advised to consult further with RWMD and ONR-RMTT.

Transport Regulations require that the waste package must be capable of being stacked six high. This leads to a requirement that the waste package must be capable of withstanding a compressive load of 2.0MN applied along the vertical axis of the waste package. Further evidence is required to show that the proposed packages is capable of being stacked 6 high.

The non-fixed surface contamination of a waste package is limited by the transport regulations. As the 6m^3 concrete box is a self venting container, there is the potential for more mobile radionuclides (e.g. caesium, tritium) to move through the concrete and reach the outer surface. RSRL will need to demonstrate that this will not be an issue for the Dragon decommissioning wastes.

Number of packages

Meeting the required dose rate at 3m from the bare waste in order to allow transport from Winfrith to the store at Harwell in ~2020 could, because of reduced waste loadings, increase the number of packages required (although this is less likely for Dragon wastes than the similarly packaged but generally greater radionuclide inventory SGHWR wastes). This would not be consistent with RWMD's Disposability Principle 3, which states that proposed waste packages should not unnecessarily or disproportionately consume the resources for geological disposal or disposal system capacity. RSRL should confirm the number of packages that would be manufactured, consistent with meeting RWMD's principles.

Box design and manufacture

RSRL has created a specification for the manufacture of a prototype 6m^3 concrete box. RWMD supports the need to show that a 6m^3 concrete box with suitable characteristics can be manufactured and emphasizes that RSRL should evaluate the performance of the prototype (for example, uniform shielding requirements, no stress-induced cracking, adequate concrete strength). This will require close collaboration with the box Design Authority at DSRL.

The following issues have been identified for specific development:

- There is a possibility that superplasticisers may degrade to form chelating agents which could lead to the increased solubility and unacceptable mobility of radionuclides at a GDF in the post-closure phase. RSRL is recommended to liaise with the box Design Authority, DSRL, and RWMD on the issue of superplasticisers, to confirm that the performance of the superplasticiser used in the prototype box manufacture and waste encapsulating grout is consistent with current RWMD plans. RWMD is currently working with industry to develop a range of generic plasticisers, which are chemically defined and not subject to formulation change.
- Revised box drawings have not yet been prepared. RSRL should provide detailed design drawings and full manufacturing specifications of the 6m^3 concrete box, defining the concrete formulation to be used for the standard density and high density concrete box. The precise concrete formulation to be used for the standard density and high density concrete will also need to be defined. In addition, the surface finish for the cold joint between the previously manufactured box shell and the lid, which is cast into the box after grouting of the waste, should be specified to ensure the box to lid concrete-to-concrete joint has a suitably low permeability.
- Higher strength twistlocks may be required for the 6m^3 concrete box, as standard twistlock equipment is specified to lift up to 32.5 tonnes. RSRL will need to confirm that the twistlocks will hold under a suitable snatch factor.

Performance of the base twistlocks should also be confirmed. RWMD notes that the original design of twistlock on the WAGR (Windscale Advanced Gas Reactor) box (the container on which the RSRL 6m^3 box is based) did not allow for drainage. RSRL should provide protection during transport to ensure that the twistlocks do not fill up with water, alternatively, a drain hole could be added to the twistlock and container design.

Quality Management System

The quality management system being applied to research and development activities is not clearly defined. Once RSRL has confirmed the system under which the Dragon decommissioning project is being managed, RWMD will make arrangements to perform an audit of how these arrangements are being implemented.

Package Records

RSRL needs to ensure realistic and justifiable package inventories are produced, particularly for the primary circuit components including the fuel spikes, coolant ducts and heat exchangers, which are expected to have a small contamination-related waste inventory as well as the activation product inventory. This is particularly important in showing waste components will comply with LSA-II and fissile material limits. The retention of information relating to these components is best ensured through a methodology statement. The methodology should provide information on assay methods, uncertainties and their justification.

Conclusions

The proposed encapsulation of Dragon decommissioning ILW within 6m^3 concrete boxes has been assessed. This assessment report has concluded that packages containing Dragon decommissioning ILW are currently not fully compatible with the requirements defined by RWMD in its geological disposal concept. Further evidence is required to support an Interim stage LoC.

The key areas preventing interim stage endorsement are:

- Additional information is needed on the specific activity and dose rate from individual items of waste at 2040 to show that IP-2 package transport requirements can be met.
- The fissile exceptions for the wastes need to be reviewed and the ability to comply assessed in the light of the revised definitions of fissile exceptions in the 2012 IAEA Transport Regulations.
- Uncertainties about the box design, materials and the absence of manufacturing drawings.
- Evidence is required that a management system is being applied to research and development activities and is in place for waste package manufacture.
- Evidence is required that limits have been defined for expansive corrosion of waste that will avoid package degradation over the required lifetime.
- Further evidence is required to show that the package can be stacked 6 high.

This assessment report has been prepared by RWMD to highlight the additional information required in a future submission from RSRL for the packaging of Dragon decommissioning ILW.

Six interim stage Action Points, which remain relevant following the change from a 2m box to a $6m^3$ concrete box, are outstanding from the previous Dragon reactor decommissioning conceptual stage assessment. Fourteen further Action Points have been raised based on this interim stage disposability assessment, nine of which are to be resolved prior to interim stage endorsement and a further five for resolution prior to final stage endorsement.