Radioactive Waste Management

Packaging of Solid Intermediate Level Waste (ILW)
at the Sellafield Box Encapsulation Plant (BEP) (Interim Stage)

Summary of Assessment Report

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Background

EXECUTIVE SUMMARY

Radioactive Waste Management Limited (hereafter RWM) (formerly NDA Radioactive Waste Management Directorate) has undertaken an Interim stage Disposability Assessment for the proposals by Sellafield Ltd for packaging Miscellaneous Beta Gamma Waste (MBGW) at the Sellafield Box Encapsulation Plant (BEP). The assessment includes consideration of packages which will contain sludge arising from carryover with MBGW.

The objectives of this Interim stage assessment of proposals for packages of MBGW are to provide Sellafield with:

- An assessment of disposability in accordance with the Joint Regulators' Guidance to Industry.
- Supporting advice on disposability of MBGW to a Geological Disposal Facility (GDF) in the form of an Assessment Report.
- Where appropriate, endorsement of the proposals via issue of a Letter of Compliance (LoC).

Further information on the Disposability Assessment process is available elsewhere[1].

RWM Reference Basis for Assessment and Endorsement

The Disposability Assessment process considers the compatibility of the proposed packages with the requirements for safe long-term management, including interim storage at the site of arising, transport, emplacement and potentially extended storage underground, and disposal. The current reference basis for such an assessment is the documented disposal system concept and safety case for a Geological Disposal Facility (GDF) derived from the generic Disposal System Safety Case (DSSC).

The general requirements placed on waste packages for disposal in a GDF are embodied in the Generic Waste Package Specification (GWPS)[2]. Further requirements for particular types of waste package are embodied in the relevant Waste Package Specification (WPS). In the case of the MBGW packages, the relevant WPS is that for packages based on the corner-lifting variant of the $3m^3$ box.

Scope of the Assessment

[1] *An Overview of the RWM Disposability Assessment Process, WPS/650/03, April 2014.*
[2] NDA, *Generic Waste Package Specification*, NDA Report NDA/RWMD/067, March 2012.

The wastes being proposed are currently stored at the Sellafield site in a range of donor plants including the Magnox Swarf Storage Silos (MSSS) (excluding Compartment 11), First Generation Magnox Storage Pond (FGMSP), Pile Fuel Storage Pond (PFSP), Sellafield Waste Storage Cells (SWSC), and secondary (operational) wastes arising from the BEP, MSSS, Silo Maintenance Facility (SMF) and Silo Emptying Plants (SEP). The wastes comprise of 13 waste streams from the 2016 UK Radioactive Waste Inventory (UK RWI).

Packaging Process

All of the wastes to be packaged at the BEP are categorised as solid Intermediate Level Waste (ILW) predominantly consisting of Miscellaneous Beta Gamma Waste (MBGW). These packages will include a component of sludge carryover as a consequence of the origin of the wastes. In addition to the waste generated by the respective donor plants, there will be large maintenance/operational wastes generated by BEP itself.

Waste Processing and Packaging

Wastes would be transferred to the BEP from the various donor plants using either skips or $3m^3$ box liners, loaded in shielded flasks. Skips used to transfer waste from the MSSS would be reusable and would not form part of the waste package, noting that once the skips have been emptied they would be returned to MSSS. Pond skips from the PFSP and FGMSP would routinely be transferred without cover water in a transfer flask. The skips recovered from the ponds (including Zeolite skips) would be loaded into liners and would form part of the waste package.

Wastes would be emptied from the import container using robots. If wastes require treatment, they would be placed on a waste handling table. Alternatively, should waste items not require treatment then items would be loaded directly into a waste export liner. There are also a number of large bulky steel operational wastes which would be directly disposed in $3m^3$ boxes and would not require a liner.

During disruption or handling of wastes, liquor and sludge carryover could be collected on the waste handling table which would be diverted into a sludge settling liner where the sludge would be allowed to settle prior to decanting off the liquor. During Zeolite skip campaigns the liquor drained from the skip would be directed into a settling liner and a similar settlement and decant process adopted. The settling liner will contain a layer of settled sludge, up to a maximum sludge volume of 160 litres, with a more realistic maximum of 80 litres. This liner will then become the next waste liner. Solid waste items will be placed on top of the settled sludge bed prior to grouting. In the case of pond skips, the contents would be removed, undergo any necessary treatment or inventory assignment and then be reloaded back into the pond skip.

For waste requiring treatment, operations would be performed using the in-cell robots. The primary purpose of the treatment processes is to allow egress of held-up liquors and sludge as well as facilitating the infiltration of grout during flood grouting. Such processes are also expected to improve packing efficiency and be advantageous in terms of handling and consignment.

Filled liners would have an anti-flotation plate fitted if required (Zeolite skips do not require an anti-flotation plate) before being moved to the grouting station.

Grout encapsulant (Ground Granulated Blast furnace Slag/CEM I) would be supplied to the liner through the cell wall grout pipe, noting that a number of grout fill approaches exist depending on the waste and liner configuration.

After grout curing, the encapsulated liner would be loaded into a $3m^3$ box. The box with liner would then be transferred to the Box Operations Cell import hatch. Here the $3m^3$ box would be placed onto the lidding station and a lid would be lifted into position on the box and bolted down using a robot.

The lidded box would be transferred to the swabbing station where it would be swabbed using a robot to confirm that loose contamination levels meet the Conditions for Acceptance for the BEP Product Store (BEPPS). Should any 'hot spots' be identified, the robot would re-swab the box to reduce the contamination. The box would then be exported to the BEPPS.

Waste package production is based upon common practice for the immobilisation of solid wastes, i.e. packaging in a $3m^3$ box and infiltration using a high fluidity cementitious grout. The proposed grout formulation has been developed to offer high infiltration into the solid waste items. Essentially, the BEP wasteform comprises cement encapsulated solid items and associated sludge carryover. In the BEP flood grout process, the layer of sludge and particulate is not intimately mixed with the grout. Depending on the sludge properties it may be (partially) mobilised and mixed, it may remain as a consolidated layer at the base of the liner, or it may (partially) float on the grout surface. Any sludge that floats to the surface will be further immobilised by the capping grout also noting that the anti-floatation plate will trap buoyant sludge.

The waste container is based on the generic $3m^3$ box which is considered by RWM to represent 'sound engineering' good practice and was designed to meet the requirements of the transport and GDF systems.

The packages would be stored at the BEPPS prior to transfer to a GDF. During this storage period the interspace between the liner and box would remain empty to ensure that any expansive corrosion that occurs in the liner does not impinge on the box walls. The BEP packages would commence package finishing ahead of export to a GDF.

The BEPPS is a modern store, designed to meet RWM requirements which would ensure a slow rate of container corrosion and limited wasteform evolution. It is noted that the corrosion rate of the liner/box under the interim storage conditions within the BEPPS would be consistent with the RWM requirements for package integrity of 150 years and should be consistent with the longer target period of 500 years.

Assessment Inventory and Number of Packages

Average and maximum inventory waste package datasheets have been derived for each of the individual waste streams to be packaged at the BEP. This enabled the closure of Action Point B13/012. These individual inventories were then used to construct a weighted average and a composite

maximum waste package assessment inventory at 2040. A weighted average radionuclide inventory at 2150 was also produced specifically to support the post-closure safety assessment.

The average and maximum assessment inventories derived for SWSC (excluding cell 6) MBGW were also considered separately to support the operational safety assessment. This is because the waste stream contains loose particulate materials, resulting in the application of higher accident Release Fraction (RF) values for these packages. However, the weighted average and composite maximum inventories bound the SWSC average and maximum package inventories.

Based on the current packaging proposals, 3,232 waste packages ($3m^3$ boxes) would be produced from the processing of MBGW through the BEP.

Assessment of Disposability

Waste Package Properties and Performance

RWM considers that the 'as manufactured' MBGW wasteforms are likely to perform adequately in the context of mechanical and physical properties, noting the existence of multiple containment barriers and that the waste will be encapsulated within a grout matrix. In addition, evolution of the wasteform is considered unlikely to have any significant detrimental effect on package properties or performance, noting that any waste corrosion expansion within a liner will be accommodated by the annulus between the liner and the outer $3m^3$ box, and will therefore not impact directly on the integrity of the outer box. As a result, seven wasteform related Action Points have been closed (B13/019; B13/024; B13/025; B16/001; B16/002; B16/003; B16/005). A number of these Action Points relate to the management of sludge and RWM have established that:

- an acceptable wasteform including sludge can be produced
- concerns over bleed water and water take-up from the sludge have been addressed through the assessment of the SL trials
- confidence in the wasteform is provided by the multi-barrier package and the presence of a clean layer of grout in the annulus / cap

In order to assess the challenge from the sludge content within the package an RF has been derived assuming that the sludge layer is close to the impact site, in this case a lid edge impact, with the sludge layer at the top. On this basis, the challenge from the sludge has been incorporated into the RF for this assessment. A separate RF value was also derived for packages containing loose particulates which are considered to have greater potential for release in an impact scenario. The RF values defined for these package types are considered to be appropriately conservative for use in this current assessment. On the basis of the RFs derived for this assessment, Action Point B16/004 can be closed.
Fire RFs have also been calculated assuming a compound wasteform of encapsulated sludge and MBGW using a conservative approach.

SL has provided the drawings relating to the container design which has resulted in the closure of Action Point B13/030. However, to meet Final stage requirements SL will need to provide detailed finalised drawings of the waste

container. SL also needs to confirm the surface finishing details in the Manufacturing Specification and provide evidence of the testing of the twistlocks. On this basis, a new Final stage Action Point has been raised:

- **Action Point B18/001**: "Provide a Manufacturing specification / purchasing specification of the 3m^3 box, which includes details such as the surface finish, delivery, packaging and storage prior to use. (Final)"

Compliance with the Transport System Design and Safety Case

The transport safety assessment was based on a corner-lifting 3m³ box being transported in a shielded Standard Waste Transport Container (SWTC-285). The average and maximum waste package inventories at 2040 are expected to meet the dose rate criterion for transport in a SWTC-285. The waste packages are therefore consistent with IAEA Transport Regulation dose rate requirements for transport as a Type B package at 2040. Performance under normal and accident conditions of transport was also considered to meet regulatory requirements. However it is noted that the hydrogen generation rate during the period of transport operations is estimated to be just over the RWM limit, therefore, the transport container would need to be purged with nitrogen prior to transport.

Overall, RWM considers that the assessment of transport safety shows that the BEP waste packages containing MBGW transported in a SWTC-285 transport container are consistent with meeting transport system design and safety requirements as currently foreseen.

Compliance with Engineering Design and the Operational Safety Case

The BEP waste package is considered to be compliant with the system design for a 3m^3 box and meets the requirements of the RWM W*aste Package Specification for corner lifting variant of 3 cubic metre Box Waste Package* (WPS/315) with respect to mass, dimension, activity content, heat output, and lifting and handling features.

The assessed gaseous off-site releases under normal operations (ground level and 15m stack release) are considered to be acceptable for H-3, Rn-222 and C-14.

In addition to the radioactive content, the wastes to be packaged at the BEP are expected to contain various hazardous materials including uranium metal, uranium dioxide, lead, cobalt and lithium/magnesium. The nature of the packaging proposal using a cement based encapsulant is considered to provide sufficient chemical containment of these materials hence it is expected that no significant release of respirable particulate would occur in the event of a breach of containment.

Material release from a package is expected only in the event of the most severe accidents involving a breach of package containment and most accidents would result in negligible on- and off-site doses.

Noting that the current assessment was performed on a bounding package containing loose particulates from SWSC and it was considered that this package would be disposable, it was also concluded that the Qualification of Endorsement, QFN/B/019 (Particulate wastes from historic MBGW storage if

processed at the Solid Waste Storage Cells are excluded) can be removed for the Interim stage LoC.

It is considered that most of the packages produced at the BEP will meet the requirements of the current 2010 generic Operational Safety Case (gOSC), although for a number of accident fault scenarios the dose to workers do exceed the Basic Safety Level (BSL). However, it is recognised that there are a number of conservatisms associated with the calculation of these doses for which mitigating arguments can be made, these include:

- pessimisms within the 2010 gOSC with respect to fault scenarios:
    - The exposure of the operator in the crane maintenance area for impact and fire accident fault scenarios during stack collapse is pessimistic as there will be no operator access to the vault and the packages will be remotely emplaced by crane
    - The exposure time to an operator is 30 minutes for a stack fall which is conservative considering on stack fall an operator would immediately evacuate the event
    - Further the ROSA toolkit assumes that during a multiple stack collapse, 42 packages (one face of the stack) would be affected and applies the same impact RF and maximum inventory to every affected package. This is very pessimistic as the majority of the packages will be dropped from a lower height and there will be a smothering effect of packages on top of packages, therefore a smaller amount of the package inventory would likely be released
- the pessimism associated with the construction of the overall composite maximum package inventory used for the safety assessments
- Decontamination Factors (DF's) values were not used in the derivation of the RF values for this assessment noting that the DF's provided by SL based on the physical barriers present were considered by RWM to require additional experimental evidence.

It is noted that the update to the generic DSSC which was published in August 2017, now considers three factors for the waste package including 1) inherent nature of the wasteform, 2) the material hold-up by the container during accident scenarios i.e. use of DFs, and 3) the respirable particle size of released material during accident scenarios, although the updates have not yet been implemented in the disposability assessment process. Once the disposability assessment process methodologies are updated to reflect these updates to the DSSC, the assessed doses for BEP packages are expected to reduce considerably.

RWM acknowledges that if DFs could be successfully shown to apply to these packages, the required impact fault risk reduction factors would be achieved. RWM is committed to undertaking generic work on DFs, recognising that the contribution from multiple barriers in a packaging concept and the probable impact fault risk reduction could significantly reduce the challenge to the plans for GDF design and operation.

Overall, the BEP waste packages are considered to be consistent with the current concept for package receipt, and emplacement for disposal in the Unshielded Intermediate Level Waste (UILW) vaults. Therefore, it is concluded that based on this assessment it will be possible for the BEP packages to be safely handled within a GDF.

Compliance with the Post-closure Safety Case

The post-closure gas generation rate for this package is significantly below the proposed screening level and considered acceptable.

With respect to the groundwater pathway, inventory screening highlighted five radionuclides (Ni-59, Se-79, Rb-87, Th-230 and U-234), that have activities more than 1% of the activities of those radionuclides in all UILW at 2150. However, the risks associated with these radionuclides are considered not to be significant in terms of their overall impact on the Post-closure Safety Assessment. In summary, RWM considers the BEP packages to be compliant with the environmental safety case as currently foreseen.

Criticality compliance

SL has produced a package-specific CSA for transport and provided justification to demonstrate that this covers the operational and post-closure phases of a GDF. RWM has evaluated this and concluded that sufficient information has been provided to support the derivation of the limiting SFM and Action Point B13/034 can be closed.

RWM has concluded that the adoption of a post-closure fissile limit based on the low-likelihood package envelope analysis carried out by SL is appropriate for BEP packages.

Status of Management System and Data Recording

The evidence submitted by SL has provided demonstration that the arrangements for development of the management system is at sufficient maturity for this stage of assessment. However, there remain a number of issues to be resolved at the Final stage. To address these issues, the following evidence will need to be provided by SL:

- final approved versions of the Quality Plans and Work Instructions for BEP operations (which will need to be referenced in the Waste Product Specification);
- details of the arrangements for the commissioning of the plant pertinent to waste treatment and packaging, including test criteria;
- approved, final versions of the Waste Product Specification, Criticality Compliance Assurance Documentation and Conditions for Acceptance;
- a finalised procedure for the identification, assessment and disposition of non-conforming products.

With respect to the package storage conditions and monitoring regime it is noted that there is an outstanding Action Point relating to the development of the Condition Monitoring and Inspection strategy, which will need to be addressed at the Final stage.

SL proposals for data recording and production of a waste package records at the BEP are considered sufficiently advanced to meet RWM's requirements at

the Interim stage. This includes the methodology for producing the physical/chemical inventories and the radionuclide inventories as described in a draft Data Recording Methodology. It is also considered that the draft Disposability Records Specification produced for BEP is at an appropriate stage of maturity to support Interim stage endorsement.

Due the wide range of wastes to be processed at the BEP and the complexity of the database system a 'surveillance' audit of the data recording system by RWM will be undertaken as part of the Final stage assessment.

Conclusions

RWM has performed an Interim stage Disposability Assessment of SL's proposal to produce waste packages containing MBGW, with sludge carryover, at the BEP against the requirements for geological disposal. The proposal includes a description of the waste, transfer to and processing at BEP, and storage at the BEPPS prior to final package finishing (as required), before disposal at the GDF.

It is concluded that SL has provided sufficient evidence at Interim stage to demonstrate that disposable waste packages can be produced at the BEP and that they will be compliant with the requirements of the transport, operational and post-closure phases of a GDF. On this basis all remaining Interim stage Action Points have been closed. In addition the LoC exclusion, QFN/B/019, concerning particulate wastes from the Solid Waste Storage Cells, can be removed from the Interim stage LoC.

The requirement to address a number of specific issues relating to the finalised box design has resulted in a new Final stage Action Point being raised in this Assessment Report, this is in addition to the five Final stage Action Points previously raised by RWM through previous interactions. In addition RWM has provided advice on specific areas for SL to consider in the preparation of their Final stage submission.

Overall, it is concluded that RWM can endorse the proposals to package MBGW through the BEP and issue an Interim stage Letter of Compliance. This LoC is subject to a number of existing qualifications, namely three exclusions and one condition.