Radioactive Waste Management Directorate

Packaging of Magnox Care and Maintenance Preparation Wastes into Ductile Cast Iron Containers (Conceptual stage)

Summary of Assessment Report

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Background

EnergySolutions, acting as the Parent Body Organisation for the Magnox decommissioning station sites and in concert with the relevant Site Licence Company continues to seek innovative solutions for the management of radioactive wastes arising from preparations for care and maintenance of those sites. To this end, EnergySolutions has proposed adopting the German-designed and operated thick-walled Type II-15EI (MOSAIK flask) and Type VI-15 containers for the packaging and disposal of the Care and Maintenance Preparation Intermediate Level Wastes (CMP wastes) from the majority of the Magnox sites. This proposal, which does not involve encapsulation of the waste, represents a change to the current baseline for these wastes, which is currently based on cementation into thin-walled stainless steel containers of the types currently adopted for most ILW in the United Kingdom.

The proposed containers, hereafter known as the Type II and Type VI containers, are constructed from ductile cast iron (DCI). They are designed to be sufficiently robust to provide all safety functions required for transport and disposal in Germany without the need for the encapsulation of the waste or for additional shielding. These properties offer the potential to package wastes for disposal without encapsulation and to avoid the need for a shielded store for interim storage. It is understood that the realisation of this opportunity would offer significant reductions in the cost and timescale for clearing sites.

To progress these proposals, advice on the disposability of the proposed packages has been sought from the NDA Radioactive Waste Management Directorate (hereafter RWMD). In particular, EnergySolutions, on behalf of Magnox, has sought Conceptual stage endorsement for the storage, transport and disposal of Magnox CMP wastes from seven decommissioning sites, using Type II and Type VI containers.

This document summarises the results of the assessment carried out by RWMD in response to the submitted proposals. The assessment has been carried out under the Letter of Compliance (LoC) process, whereby RWMD examines the disposability of proposed waste packages by assessment against existing packaging standards, specifications and the reference design concept for the disposal of ILW in a Geological Disposal Facility (GDF).

RWMD Reference Basis for Assessment and Endorsement

This assessment has considered the compatibility of the proposed packages with the requirements for safe long-term management, including storage, transport, emplacement and potentially extended storage underground, and disposal. The current reference basis for this assessment of disposability is a conceptual design for a GDF derived from the Nirex Phased Geological Repository Concept (PGRC). This is shortly to be updated to the recently-

published generic Disposal System Safety Case (DSSC). Further information on the Letter of Compliance process is available elsewhere[1].

The general requirements placed on ILW packages for disposal in a GDF are embodied in the Generic Waste Package Specification (GWPS). The GWPS has been supplemented, following a change control process, by an 'addendum' that reflects the 'robust shielded container' approach and the associated requirements for disposal[2]. The proposed packages based on Type II and Type VI containers have been considered against these requirements.

Assessment at the Conceptual stage considers consistency with the general requirements for disposal in a GDF concept as expressed in the GWPS. Compatibility with the GWPS is the minimum level of consistency required to support issue of a Conceptual stage LoC. The assessment would also identify detailed technical issues to be resolved at the Interim stage.

Assessment at the Interim stage is based on consideration of specific requirements that directly reflect the detail of the current conceptual design(s) for a GDF. These specific requirements are expressed as a detailed Waste Package Specification for the particular package design employed. In the case of novel proposals, such as those for packages based on Type II and Type VI containers, the development of detailed Waste Package Specifications needs to be preceded by a formal process of Concept Change to introduce significant modifications to the conceptual design(s) for a GDF. Further endorsement of packages based on Type II and Type VI containers at Interim stage therefore requires such a Concept Change.

Scope of the Assessment

The preparation of Magnox sites for care and maintenance generates a diverse range of ILW. To identify the range of issues relevant to disposal of the packages, EnergySolutions has sought an assessment of all relevant wastes from the relevant sites. Consequently, this assessment considers the disposability of the 197 waste streams identified in the 2007 UK Radioactive Waste Inventory (UK RWI), which arise from CMP at Bradwell, Berkeley, Chapelcross, Dungeness A, Hinkley Point A, Oldbury A and Sizewell A.

The waste types, as declared in the 2007 UK RWI, comprise (as raw waste) 5,545m^3 (4,484 tonnes), divided as follows:

- Fuel Element Debris (FED) Metals – 2,244m^3;
- FED Graphite – 862m^3;
- FED Nimonic – 2m^3;
- Ion Exchange (IE) Materials – 351m^3;
- Sludge – 479m^3;
- Miscellaneous Contaminated Items (MCI) – 1,056m^3;
- Miscellaneous Activated Components (MAC) – 100m^3;
- Gravel – 337m^3;
- Sand – 57m^3;
- Filters – 56m^3;
- Cartridges – 2m^3.

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

2 NDA, *Generic Specification for Robust Shielded Waste Packages*, Technical Note 13403461, November 2010.

The volume and activity of these wastes is moderate compared to the total inventory of ILW for disposal in the UK (approximately 2% of the total volume of ILW in the 2007 UK RWI). Nevertheless, the proposed packages represent a significant change to established practices. As discussed above, further endorsement of the proposals at Interim stage is anticipated to require consideration of a Concept Change to the design concepts for a GDF used as the reference basis for the LoC process.

To support the Conceptual stage assessment of disposability reported herein, and to inform a potential Concept Change, the assessment has been supplemented by a preliminary consideration of options for modifying the design concepts for a GDF to accommodate the proposed packages. The potential additional transport and disposal costs that might arise also have been analysed. In anticipation of the adoption of the generic DSSC as the reference basis for assessment, this consideration has taken account of some aspects of the generic DSSC, such as the inclusion of a wider range of illustrative example geologies.

The scope of this assessment is limited to transport and disposability issues, and does not include any analysis of the business case for adoption of these packages. Nevertheless, it is understood that the analyses produced by RWMD have been considered in the EnergySolutions business case for use of these waste packages.

Packaging Proposals

To benefit from existing package approvals from the German transport regulator, the proposals are based on the adoption of existing container designs, without modification.

The larger capacity[3], cuboidal, Type VI containers are approved as Industrial Package Type 2 (IP-2) transport packages under the IAEA Transport Regulations, which places constraints on the nature of the waste and total contents. The smaller capacity[4], cylindrical Type II containers are approved as both IP-2 and Type B transport containers (the latter requires use of impact limiters) for a defined group of waste types and radionuclide contents. This latter approval allows a wider range of wastes to be transported than the Type IP-2 approval. Consequently, the use of the larger Type VI containers is constrained by the nature and activity of any particular waste and, in practice, wastes with higher activity would be packaged using Type II containers. Type II containers can also be additionally shielded using lead inserts within the container.

The Type II and Type VI containers are sealed and un-vented, in contrast to the vented thin-walled stainless steel containers currently adopted for most UK ILW. The addendum to the GWPS covering robust shielded containers recognises this possibility and requires demonstration that any resulting pressurisation does not adversely affect performance[2].

Although the proposals are intended to reduce the processing of wastes prior to packaging as compared to established approaches, some processing will still be necessary. This would depend on the characteristics of the wastes, but may include sorting, segregation (it has been proposed that bulk fuel would be removed, and so bulk fuel has not been considered in this assessment), size reduction and characterisation.

As many of the wastes will contain quantities of water, with sludges and ion exchange materials being fluidised for transfer, the removal of water would be a processing step for most or all wastes. Proposals for dewatering remain to be fully developed, but EnergySolutions has indicated that existing methods applied in Germany would be adopted, including where appropriate, defining the residual water content after dewatering. The assessment has assumed that waste types would be dewatered to the extent claimed and consequential gas generation from radiolysis estimated. Further substantiation of this assumption would be sought at the Interim stage. Dewatering is likely to give rise to secondary wastes, which have not been considered in this assessment.

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[3] Nominal capacity of 2.83m^3.

[4] Nominal capacity ranging from 0.49 to 0.165m^3 (depending on the amount of lead shielding used).

All wastes would be packaged without encapsulation or other conditioning. Consequently, mobile wastes such as partially-dried sludges and ion exchange materials would not be immobilised within the containers. It is anticipated that significant voidage would be present in many or all packages.

At this time, EnergySolutions has not provided proposals for the generation of the information required to produce waste package records, although a commitment is provided to do so.

The packages would be stored to await transport to a disposal facility. It is assumed that the cavity of the containers would be vented prior to transport and performance of the container seal confirmed to be compliant with the requirements of the Transport Certification. Furthermore, it is assumed that, should a container be noted to be non-compliant with the prescribed leak-tightness, remedial action will be taken to replace seals and return the package into a suitable condition, such that it is acceptable for transport. Seals would also be replaced if the period of interim storage exceeded the specified lifetime for a seal.

Basis for Assessment of Proposals

Assessment Inventories and Number of Packages

To assess the disposability of the proposed packages, it is necessary to define suitably conservative waste package inventories that capture the range and variability of the package contents. Furthermore, due to the large number and range of waste streams, for efficiency EnergySolutions has proposed that the wastes be grouped into 11 waste types. This approach has been adopted by RWMD and used as the basis for generating assessment inventories. The data used as the basis for this process are those reported in the 2007 UK RWI.

For 14 of the proposed waste streams, the inventory did not include any radionuclide data, and so these streams were not considered in the assessment. It was also indicated that one Magnox CMP waste stream from Chapelcross would be managed by a different route and this stream also was not considered. A further 24 waste streams were found to have insufficient compositional information to allow the assessment to be completed satisfactorily.

The selection of Type II or Type VI containers for a particular waste stream depends on the compatibility of the waste with the constraints applying to IP-2 packages (the Type VI containers). Those wastes not compatible with transport under IP-2 requirements are assumed to be packaged into Type II containers with an appropriate thickness of lead liner.

RWMD has reviewed the assignment of wastes to the containers proposed by EnergySolutions and has concluded that it does not take sufficient account of variability between waste package inventories within each waste stream. Considering this potential variability, RWMD has concluded that up to about 2,100 Type VI and 2,300 Type II containers would be required. This is an increase of 600 packages on the EnergySolutions estimate, due to the need for more of the smaller capacity Type II containers.

Based on the revised assignment, waste streams from 10 of the 11 waste types were assigned to the Type II container and waste streams from six of the 11 waste types were assigned to the Type VI container. Consequently, a total of 16 waste/container combinations were assessed, with some waste types split between Type II and Type VI containers. Any future changes to the assignment of wastes between container types potentially would further alter the expected numbers of packages.

Waste Package Properties and Performance

The assessment of disposability requires information on the properties and performance of the proposed waste packages. At the Conceptual stage this is commonly provided through analogy with similar proposals and reasoned argument. However, the current proposals are novel and as a consequence of this, more explicit evidence of the expected performance of the packages has been obtained.

As indicated above, options for handling and emplacement of these novel packages in a GDF have been developed as part of this Conceptual stage assessment. Preferred options for handling and emplacement of robust packages have been developed for each of the illustrative example geologies highlighted in the generic DSSC.

In the absence of conditioning or encapsulating material, the containment of mobile activity associated with the waste under normal and fault conditions depends on the performance of the container. Some waste items, such as larger steel components, may be relatively robust and thereby offer some additional protection against the dispersal of radionuclides.

Containment of activity is provided by the robust nature of the container and the lid closure is therefore an important component. The existing approvals for transport and for disposal in Germany are based on a case that the combination of bolted-lid and elastomeric seal provides appropriate containment of activity under the conditions considered. In the UK, EnergySolutions propose to confirm the containment performance and where necessary replace the elastomeric seals before transport. Information on seal performance indicates a functional lifetime of the order of 40 years.

Assessment of Disposability

Compatibility with Specifications

The addendum to the GWPS for packages based on robust shielded containers defines the general performance characteristics required for such waste packages[2]. In addition, the assessment of options for modifying a GDF concept to accommodate the proposed packages has concluded that the necessary changes should be feasible, and would be best implemented through the adoption of additional, dedicated vaults for these packages. It is understood that EnergySolutions has considered the potential cost implications of such changes in its business case for the use of robust containers.

The assessment of the Type II and Type VI containers against the specification for robust shielded waste packages has determined that the proposed packages are expected to be compliant with the specification. Consistency with this general specification is a necessary precursor to endorsement at the Conceptual stage.

Transport Safety

The proposed containers have been granted approval for the transport of certain radioactive wastes by the relevant German regulator. Consequently, these containers also may be used for the transport of wastes in the UK without any further approval, subject to compliance with the constraints embodied in the existing approvals. Compliance with the approvals would ensure that the performance of the packages under normal and accident conditions of transport would be acceptable.

Both the Type II and VI containers have been approved as IP-2 transport packages. These approvals are associated with a contents specification and the wastes must comply with the requirements for either Low Specific Activity (LSA) materials or Surface Contaminated Objects (SCO). Detained examination of the proposed package contents for the particular Magnox CMP waste streams proposed for Type IP-2 transport arrangements would meet the relevant requirements will be required at Interim stage.

The Type II container also has been approved as a Type B(U)[5] transport package, when used with impact and thermal protection. This is also associated with a contents specification and criteria related to waste loading. Detailed examination of the proposed package contents for the particular Magnox CMP waste streams proposed for Type B transport arrangements would meet the relevant requirements will be required at Interim stage.

[5] As defined within IAEA Regulations for the Safe Transport of Radioactive Materials

The Type B approvals are currently limited to 'compacted' activated and/or contaminated components and parts, with associated defined radionuclides. This description, and the range of radionuclides included, apparently does not cover all the Magnox CMP wastes. EnergySolutions is currently investigating whether the existing approvals could be extended in Germany to encompass the necessary range of wastes. Evidence to this effect would be sought at Interim stage. Should this not prove to be possible, a separate approval from the UK regulator would be required to cover the excluded wastes.

The realisation of the performance assumed in the approvals requires that the container lid closure, and in particular the seal, performs as anticipated. Due to uncertainties in the endurance of the seals during storage, EnergySolutions has stated that the packages would be de-pressurised and performance of the seals would be confirmed immediately prior to transport. This would give assurance of compliance with the transport containment case. Further justification regarding the practicality of seal changes will be required at Interim stage to confirm that this condition would be delivered in practice.

Overall, the existing approvals give confidence that many of the proposed waste / container combinations could be safely transported. Nevertheless, some combinations may present a challenge to the existing criteria and additional work is required to demonstrate that they could be safely transported. Such a demonstration would be required before the packaging of the relevant wastes could be endorsed at the Interim stage. It is also noted that the differing handling requirements for the proposed packages, as compared to the established waste package types, would introduce additional complexity into the transport system. It is understood that the cost implications of increased complexity have been considered in the EnergySolutions' business case for use of these waste packages.

Operational Safety

The operational safety assessment has been based on the reference GDF concept as described above, supplemented by consideration of the options to modify the design of a GDF to accommodate the proposed packages. Initial work generated a supplementary fault and hazard schedule specific to the arrangements required for the handling and emplacement of the Type II and VI containers. This has enabled a qualitative case to be made for the operational safety of the handling and emplacement of the Type II and VI containers.

As the basis for developing the operational safety arguments, it was assumed that Type II containers would be transported as Type B packages, impact and thermal protection would be removed through a remote operation and packages emplaced in a dedicated ILW vault. For Type VI containers it was assumed that these would be transported as Type IP-2 packages and emplaced within the same dedicated vault. The qualitative operational safety case has confirmed that these arrangements would be necessary and the changes would result in additional complexity into the disposal system. It is understood that the cost implications of these changes have been considered in EnergySolutions' business case for use of these waste packages.

The qualitative assessment has by necessity utilised a number of simplifying assumptions and RWMD has ensured that these are suitably conservative and bounding. The adoption of bounding estimates for activity release fractions under fault conditions, the grouping of waste streams and assessment of 'group' radionuclide inventories, and the estimate of the performance of a package when pressurised, have all contributed pessimisms which challenge design targets. Such pessimisms should be reduced in future by the provision of further waste package specific information. Notwithstanding the inherently pessimistic approach, the qualitative assessment gives confidence that doses to operators and members of the public from operations involving the proposed packages are likely to be acceptable.

This analysis will be followed by a quantitative analysis of the faults and hazards associated with these packages and associated emplacement systems at the Interim stage. One notable difference introduced by these packages is the potential for waste packages to be pressurised and further consideration of the impact of this during the operational phase would be required at the Interim stage.

The formal adoption of GDF concept designs more explicitly adapted to packages based on Type II and Type VI containers (through Change Control) potentially offers the opportunity to reduce conservatisms through more detailed design developments. Nevertheless, it would remain the case that the differing handling requirements of the proposed packages would continue to require specific faults and hazards to be considered.

In summary, the safety significance of these packages during GDF operations has been assessed. It has been determined using bounding assumptions that although some proposed packages apparently challenge existing criteria, it is likely that, following the provision of further information, an acceptable operational safety case can be constructed. Nevertheless, further work is required at the Interim stage to demonstrate that the proposed packages remain safe following extended periods of storage. The extent of the challenges presented depends on the nature of the waste and satisfactory resolution of such challenges may be more difficult for some wastes. The potential risk from pressurisation of some packages is noted as a particular issue requiring explicit examination at the Interim stage.

Post-closure Performance

The initial post-closure safety assessment has not revealed any issues that would preclude endorsement of the proposed packages. This reflects the relatively moderate radionuclide inventory of the wastes and its relatively homogeneous distribution across a significant volume.

The significance of the relatively large voidage associated with the un-encapsulated wastes remains to be confirmed. Although the significance of voidage is to some extent a GDF site-specific issue, RWMD will seek to use developing generic assessments to consider this issue further. If it is found that the voidage proposed here will be significant in terms of post-closure performance, it may be necessary for the site operator to introduce an inert void filler prior to despatch of the waste packages to a GDF.

The use of thick-walled cast iron containers, rather than the stainless steel containers assumed in the baseline, would significantly increase the volume of iron in a GDF. This would increase both the rate of gas generation from the anaerobic corrosion of the containers and the total volume of gas produced compared with the baseline assumptions about packaging of the relevant wastes. The Conceptual stage assessment has determined these increases not to be significant.

Summary of Assessment of Disposability

The existing approvals for the Type II and VI containers provide confidence that many of the proposed packages could be transported safely and supports endorsement at the Conceptual stage. Confirmation of this position for each waste stream would be sought at Interim stage on a case-by-case basis. It is anticipated that further work by EnergySolutions would be required to confirm this for the full range of wastes being considered.

An initial fault and hazard schedule for the handling of the packages and a generally conservative treatment of package performance in operations has been used to undertake a qualitative operational safety assessment. This provides the basis for endorsement at the Conceptual stage. It is recognised that this treatment does not fully represent the likely performance of the packages and it therefore highlights the need for further substantiation of the actual performance to confirm that the proposals are optimal. Further evidence will be sought at Interim stage to demonstrate understanding of the potential for, and significance of, package pressurisation during storage at a GDF.

The post-closure performance of the proposed packages is judged to be acceptable and consistent with endorsement at Conceptual stage. Nevertheless, RWMD expects to continue to consider the implications of voidage in and gas generation from such packages to provide support for further endorsement at later stages.

Requirements for Future Development Work

It was found that the radionuclide inventory data or compositional information for 38 waste streams was not sufficient to support endorsement at this time. Further information on these streams would be required before they could be considered for endorsement. One waste stream has been excluded from the assessment as it was subsequently stated that an alternative management route would be adopted for this waste.

RWMD considers that a submission for the full range of Magnox CMP wastes has been an appropriate basis for considering the proposals and identifying continuing issues on a generic basis at Conceptual stage. However, the satisfactory resolution of many issues will need to be approached on a waste stream specific (case-by-case) basis. It is therefore recommended that Interim stage submissions should be based on individual waste streams, groups of waste streams or specific waste types.

The suggested approach to making Interim stage submissions may require further work to develop arguments specific to each waste type, building on the more generic evidence provided at the Conceptual stage. The following issues should be addressed in future submissions and would be required before Interim stage LoC endorsement:

- substantiated and justified information on the nature and inventory of the waste(s), including addressing identified deficiencies;
- demonstration the viability of extending the existing transport approvals for the packages to cover the particular waste(s);
- proposals for the processing of the particular waste(s) (including management of water content) and evidence that the necessary condition of the waste(s) would be achieved;
- full descriptions of container designs with the functionality of key features understood and proven;
- provision of evidence on a waste stream specific (case-by-case) basis to substantiate the anticipated performance of the packages in accidents for handling and emplacement in dedicated vaults, including;
  - application of a more sophisticated bolt model in impact modelling of the packages;
  - develop, on a waste stream specific (case-by-case) basis, and by a variety of arguments, impact release fractions for packages, taking account of the evolution of the seals;
  - develop relevant container-on-container impact scenarios and provide relevant and justifiable impact release fractions for these scenarios, taking account of the evolution of the seals;
  - provide details of anticipated gas generation and, where necessary, a strategy to avoid unacceptable container pressurisation for problematic waste(s), based on a consideration of waste properties and the proposed drying process;
- compliance of the proposed packages with a Waste Package Specification specific to packages based on Type II and Type VI containers;
- detailed proposals for the acquisition and retention of all necessary package data.

RWMD has indicated that the Conceptual stage assessment has been necessarily based on conservative treatments of some issues, due to the large number of waste streams to be considered. EnergySolutions is advised that to avoid unnecessary conservatism, and any difficulties in demonstrating disposability that may arise from this, future submissions should be based on smaller numbers of waste streams.

Sustainability

The proposed waste packages based on Type II and VI containers results in an increased disposal volume for Magnox CMP wastes compared with the current baseline, and hence an increased GDF footprint. There are also additional costs for the transport system and a GDF itself in accommodating these packages. The disposal of a large mass of cast iron as shielding also represents a significant consumption of resources, as compared to the current baseline.

RWMD recognises that these negative impacts may be countered by significant advantages when considering the whole life-cycle of waste retrieval, packaging, interim storage, transport and disposal, and accepts that overall acceptability should be based on a balance of factors across the waste management chain.

Conclusions

RWMD has determined that the evidence submitted by EnergySolutions for the packaging of Magnox CMP wastes in Type II and Type VI containers is sufficient to conclude that a successful assessment of disposability eventually could be produced. This is a necessary condition of endorsement at the Conceptual stage.

Although it is likely that some or all of the proposed packages eventually could be shown to be disposable, the adoption of Type II and VI containers for the disposal of Magnox CMP wastes would have a significant impact on a GDF. The dimensions of the containers, adoption of dedicated vaults and handling requirements would increase the excavated volume and ultimately the cost of the GDF. It is understood that these matters have been considered in EnergySolutions' business case for use of these waste packages and it has been concluded that there is an overall net benefit to the NDA.

The conclusion that an assessment of disposability could be produced and the understanding that the adoption of the Type II and Type VI containers would have an overall net benefit is sufficient to support the endorsement of the packaging of Magnox CMP wastes in such containers at the Conceptual stage. This endorsement is limited to 158 of the 197 wastes streams for which sufficient information has been submitted.

RWMD will pursue the changes necessary to accommodate these waste packages into the reference geological disposal concepts *via* Concept Change and, subject to the approval of the necessary changes, would develop a Waste Package Specification applicable to these types of waste packages. This specification will provide detailed criteria defining the performance requirements for waste packages based on Type II and Type VI containers. Formal compliance with these criteria would need to be demonstrated in order to achieve endorsement at the Interim stage. In support of further endorsement, RWMD has also identified specific Action Points that would need to be addressed at Interim stage on a case-by-case basis.