Magnox Care and Maintenance Preparation Wastes in Ductile Cast Iron Containers (Conceptual stage)

Summary of Assessment Report

Issue date of Assessment Report: 19 May 2010

Background

EnergySolutions, acting as the Parent Body Organisation for the Magnox decommissioning station sites and in concert with the relevant Site Licence Companies (Magnox North and Magnox South), 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 (CMP) Intermediate Level Wastes (ILW) from the majority of the Magnox sites. This proposal, which does not involve encapsulation of the waste, would represent a change to the current baseline for these wastes, which is 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. 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. The realisation of this opportunity therefore may 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 North and South, has sought Conceptual stage endorsement for the storage, transport and disposal of Magnox North and South CMP ILW 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 process, whereby RWMD examines the disposability of proposed waste packages by assessment against existing packaging standards, specifications and underlying disposal concepts for ILW. There is not currently a Waste Package Specification for the type of packages proposed here. Compatibility has therefore been judged against the Generic Waste Package Specification (GWPS), and against certain criteria of other Waste Package Specifications that are anticipated to be analogous to a future WPS for these types of package. Further information on the Letter of Compliance process is available elsewhere[1].

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

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 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

The volume and activity of these wastes is moderate compared to the total inventory of ILW for disposal in the UK. Nevertheless, the proposed packages represent a significant change to established practices, and their designs are not currently recognised in the reference geological disposal concept used as the basis for the LoC process.

To facilitate the consideration of the proposals, the assessment of disposability reported herein has been supplemented by a separate, preliminary review of the implications for Geological Disposal Facility (GDF) design concepts, and of the potential additional transport and disposal costs that might arise.

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. However, some of the information generated by this assessment could have an effect on the business case.

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[2], 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[3], 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.

DCICs are sealed and un-vented, in contrast to the vented thin-walled stainless steel containers currently adopted for most UK ILW.

Although the proposals are intended to reduce the processing of wastes prior to packaging as compared to established approaches (mainly by proposing non-encapsulation), some processing is still 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 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 IE 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, and for some waste types has indicated claimed residual water content after dewatering. The submission indicates that dewatering proposals do not currently include the gravel waste type. The assessment has assumed that waste types would be dewatered to the extent claimed. The assessment reports detailed work on gas generation from radiolysis of water for the IE materials waste type, chosen for this analysis because it had the highest residual water content after dewatering of waste types for which a residual water content was claimed. It is noted that German operation of these containers includes additional dewatering of packages of IE material prior to transport. Dewatering is likely to give rise to secondary wastes, which have not been considered in this assessment.

All wastes would be packaged without encapsulation. Consequently, mobile wastes such as partially-dried sludges and IE materials would not be immobile 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. As noted above, shielding by the containers is proposed to obviate the need for a shielded store.

[2] Nominal capacity of 2.83m^3

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

Basis for Assessment

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 UK RWI. For 14 of the proposed waste streams, the inventory did not include any radionuclide data, and so these streams were excluded from the assessment.

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 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 2,097 Type VI and 2,338 Type II containers would be required. This is an increase of 557 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 6 of the 11 waste types were assigned to the Type VI container. Consequently, a total of 16 waste/container combinations were assessed, and some waste types were split between Type II and Type VI containers.

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 sought.

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

Containment of activity is provided by the closure of the containers: a lid bolted into place and sealed by an elastomer seal. The existing approvals for transport and for disposal in Germany are based on a case that this combination provides appropriate containment of activity under the conditions considered. In the UK, EnergySolutions proposes to replace the elastomer seals before transport. This is because the seals have a limited functional lifetime, of the order of 40 years. Seal failure could therefore occur prior to closure of a GDF.

The Type II and Type VI DCICs are designed as pressure vessels to a Maximum Normal Operating Pressure (MNOP) of 700kPa. Under normal conditions the containers initially would contain gases generated by, for example, corrosion reactions or radiolysis of residual water, resulting in increased internal pressure. One reference provided by the submission indicated that this MNOP could be exceeded for packages containing IE Materials, although another reference found that gas generation was unlikely to be significant in terms of pressurisation. Excessive pressurisation may influence the subsequent performance of packages under fault conditions. Furthermore, pressurisation ultimately may compromise the containment of activity, resulting in releases of radioactive gases or other mobile activity. Given the contradictory evidence in this area, significant work remains to be done to underpin and justify estimates of gas generation and the extent of subsequent pressurisation in DCICs containing Magnox CMP wastes.

RWMD has reviewed the supplied evidence of impact and fire performance. For impacts, the containment function of the DCIC body has been shown for relevant impact scenarios, although further evidence of the response of the lid closure in impacts is required. It has therefore been necessary to define release fraction (RF) values for use in the assessment. Bounding impact RFs have been selected to represent the uncertainty in lid closure performance. For relevant fire scenarios, the performance of the seals has not been sufficiently demonstrated, and so release fractions have been selected on the basis of available data for vented packages.

Assessment of Disposability

Compatibility with Specifications

There is not currently a Waste Package Specification for the DCIC type of container, i.e. a robust, thick-walled container without a vent. Compatibility with specifications has therefore been judged against the Generic Waste Package Specification (GWPS), and against Waste Package Specifications that are anticipated to be analogous to a future DCIC type WPS for certain criteria.

This means that the existing reference GDF design has been used as the basis for the assessment reported herein. This allows significant issues to be identified and provides a basis for understanding the implications of the changes necessary to accommodate the proposed packages.

The review has found that DCICs could be compatible with relevant specifications. Although the GWPS includes requirements that the DCIC concept would not be able to meet, such as for package venting and properties of the waste form, it is anticipated that a comparison of DCICs against the safety functions these measures are designed to provide could prove favourable, subject to further work, for example around pressurisation of packages.

A further, separate assessment has investigated alternative GDF designs that could accommodate the packages, as well as the cost implications. This 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 recommended that EnergySolutions consider these potential cost implications in its business case for DCICs.

A formal endorsement of packages based on the Type II and Type VI containers can only be provided against a Waste Package Specification under the GWPS. The current assessment of the packages has identified most of the necessary elements of such a specification, although, as discussed herein, some issues remain to be resolved. Furthermore, a change to the reference concept design would be required

to provide the underpinning for the specification. RWMD will pursue this via Concept Change Control.

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). It has not yet been demonstrated that all wastes currently proposed for Type IP-2 transport arrangements could meet these requirements.

The Type II container also has been approved as a Type B(U) transport package, when used with an impact limiter. This is associated with a contents specification and criteria related to waste loading. The Type B approvals are currently limited to 'compacted' activated and/or contaminated components and parts, with a set of associated radionuclides. This description, and the range of radionuclides included, 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. 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 closures, and in particular the seals, perform as anticipated. Due to uncertainties in the endurance of the seals during storage, EnergySolutions has stated that the seals would be changed immediately prior to transport. This would give assurance that the transport containment case would be complied with and would deal with the pressurisation issue during the transport phase. Further justification that it is practical to change seals will be required.

Overall, the existing approvals give confidence that some of the proposed waste / container combinations could be safely transported. Nevertheless, other proposed waste packages present a challenge to the existing criteria and additional work is required to demonstrate that they could be safely transported. It is also noted that the differing handling requirements for the proposed packages would introduce additional complexity into the transport system. The cost implications of increased complexity could have an effect on the EnergySolutions business case for DCICs.

Operational Safety

As indicated above, the reported assessment has been based on the reference GDF concept. To gain insight into the issues raised, it was assumed that Type II containers would be transported as Type B packages and emplaced in Unshielded ILW (UILW) vaults; and that Type VI containers would be transported as Type IP-2 packages and emplaced in Shielded ILW (SILW) vaults. It is recognised that these assumptions are not likely to be implemented in practice, and that the adoption of dedicated vaults for such packages has been recommended. It is noted that this would introduce additional complexity into the disposal system, and that this could have cost implications that could in turn affect EnergySolutions' business case for DCICs.

An analysis of the faults and hazards associated with these packages and associated emplacement systems is required at a future assessment stage. One notable difference is the potential for pressurised packages, which could represent an additional hazard, as well as having implications for the hazards associated with existing faults, such as impact and fire.

The adoption of conservative RF values to represent uncertainty in the performance of the packages and the conservative assessment inventories result in the operational safety assessment toolkit predicting relatively high doses. The highest assessed doses exceed the relevant Basic Safety Levels (BSLs), as defined in the NII Safety Assessment Principles (SAPs), suggesting that the proposed packages are not optimal.

These initial results highlight the importance of demonstrating that the proposed packages would, in practice, provide complete containment of activity under the relevant accident conditions. In the absence of this demonstration, a conservative treatment of potential releases from the packages is not yet sufficient to justify the adoption of the proposals.

It is recognised that the grouping of the wastes results in additional conservatism and may obscure the acceptability of some lower activity wastes when packaged as proposed. Consequently, it is recommended that future submissions should be focused on specific waste type / waste container combinations, thereby minimising this source of conservatism.

The adoption of GDF concept designs more explicitly adapted to packages based on Type II and Type VI containers potentially offers another opportunity to reduce conservatisms. However, the differing handling requirements of the packages may introduce different, additional DBA to be considered as part of the necessary concept change.

As highlighted previously, the packages potentially introduce additional routes for releases during storage at a GDF, due to significant pressurisation and/or the ageing of the seals. Such risks have not been assessed at this time and further information on the evolution of the containment and/or the efficacy of measures to avoid pressurisation is required.

In summary, the safety of the packages during operations at a GDF has not yet been demonstrated satisfactorily. Nevertheless, reductions in conservatisms and the anticipation that complete containment may be justifiable gives some confidence that, subject to further evidence, satisfactory performance could be demonstrated for some or all of the waste / container combinations.

Post-closure Performance

The initial post-closure safety assessment has not revealed any issues that would preclude endorsement. This reflects the relatively small or 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 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 to minimise voidage by use of inert filler.

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, although these increases have not been found 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, although further work is required from EnergySolutions to confirm this for the full range of wastes considered. Similarly, the post-closure performance of the packages is judged to be acceptable, although ultimately RWMD may need to undertake further work on the implications of voidage and gas generation.

The absence of sufficient justification for complete containment of activity under the current DBA has necessitated a conservative treatment of operational safety. While it is recognised that this does not fully represent the likely performance of the packages, it highlights the need for further substantiation of the actual performance to confirm that the proposals are optimal. Further work is also required to understand the potential for, and significance of, pressurisation during storage at a GDF.

Based on the above, and mindful of the novelty and significance of the proposals, RWMD judges that, while there are grounds for believing that ultimately some or all of the proposed packages could be shown to be disposable, insufficient evidence is available at this time to support endorsement of the proposals at the Conceptual stage.

Requirements for Further Development Work

Further work is required to provide the evidence needed to support endorsement at the Conceptual stage via an LoC, the most significant requirements being as follows:

- substantiate the performance of the packages under the accident scenarios for GDF operations, either demonstration of complete containment or provide refined RF values;
- understand the constraints on the water content of the waste and any associated risks due to pressurisation of the containers;
- provide confidence that the functionality of the lid bolts can be maintained during storage prior to transport, allowing the seals to be changed as necessary; and
- demonstrate that the requirements for Data Recording and Management Systems are understood.

Fourteen streams have been excluded from the assessment due to insufficient information. Further information on these streams would be required before all they could be considered for endorsement.

Interim stage submissions will require further work to develop the arguments and the limited evidence provided at the Conceptual stage. The following are required as inputs to a future Interim stage submission, and would be required before Interim stage endorsement via an LoC:

- well-evidenced information on the nature and inventory of the wastes;
- demonstration that extending the existing approvals for the transport of the packages to cover all of the expected wastes is viable;

- proposals for the processing of all wastes (including management of water content) and evidence that the necessary condition of the waste would be achieved;
- full descriptions of container designs with the functionality of key features understood and proven;
- evidence to substantiate the performance of the packages under the DBA for handling and emplacement in dedicated vaults;
- compliance of the proposed packages with a Waste Package Specification specific to packages based on Type II and Type VI containers should be demonstrated; and
- detailed proposals for the acquisition 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 DCIC concept results in a requirement for increased disposal volume for Magnox CMP wastes, 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 shielding would also need to be justified in terms of resource use. RWMD recognises that these negative impacts may be counteracted by significant advantages when considering the whole life-cycle of retrievals, 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 is not yet sufficient to conclude that a successful assessment of disposability eventually could be produced. This is a necessary condition of endorsement at the Conceptual stage. Nevertheless, it is judged that with some further work the necessary evidence is likely to be available.

Irrespective of the conclusions of the assessment of disposability, formal endorsement at the Conceptual stage also would require a change to the reference GDF concept to provide the basis for a Waste Package Specification covering the proposed packages. At this time, the necessary components of such a specification have been identified but the noted change is also required to formalise the position and to derive numerical criteria.

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.

Although the proposed packages may be disposable, a significant fraction of streams considered here are considered to be endorsable via LoCs under the baseline proposals. Furthermore, adoption of the Type II and Type VI containers increases the complexity of the handling requirements and introduces additional uncertainty through issues such as pressurisation and the post-closure effects of voidage.

As noted above, further evidence is required to support endorsement via a Conceptual stage LoC. RWMD will pursue the changes necessary to accept DCICs into the reference geological disposal concept via Concept Change Control, and will develop a Waste Package Specification applicable to these types of packages.