Radioactive Waste Management Directorate

Packaging of Spent ILW Ion Exchange Resins at Sizewell B using MOSAIK Casks

(Interim Stage)

Summary of Assessment Report

Issue date of Assessment Report: 23 March 2012

Background

EdF Energy Nuclear Generation Ltd (NGL) has proposed adopting the German-designed and operated thick-walled Type II-15EI (MOSAIK cask) container for the packaging of current stocks and future arisings of spent ILW ion exchange (IEX) resins at Sizewell B power station. This proposal represents a change to previous proposals for these wastes, which were based on cementation into thin-walled stainless steel containers of the types currently adopted for most ILW in the United Kingdom.

The proposed container, hereafter the MOSAIK cask, is constructed from Ductile Cast Iron (DCI). It is designed to be sufficiently robust to provide all safety functions required for transport and disposal of appropriate waste in Germany without the need for the encapsulation of the waste or for additional external shielding. These properties offer the potential to package wastes for disposal at short notice without encapsulation. It is understood that realising this opportunity would offer essential benefits in managing the accumulation of IEX resins at Sizewell B.

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, NGL has sought Interim stage endorsement for the transport and disposal of Sizewell B IEX resins using MOSAIK casks.

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 the conceptual designs for a Geological Disposal Facility (GDF) derived from 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 for Sizewell B IEX resins based on Type II (MOSAIK cask) and Type VI containers have been assessed previously at the Conceptual stage, but endorsement was not provided at that stage as the necessary addendum to the GWPS had not been published at that time.

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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.

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 a particular package design. In the case of novel proposals that may require significant modifications to the conceptual design(s) for a GDF, as is the case for packages based on MOSAIK casks, the development of detailed Waste Package Specifications is preceded by a formal process of concept change. RWMD is currently implementing the necessary change and will develop the detailed Waste Package Specification for packages based on the MOSAIK cask. Until this specification is published, the current proposals will not be endorsed formally through the issue of an Interim stage Letter of Compliance.

Scope of the Assessment

The assessment has considered the proposed packages containing Sizewell B IEX resins, which correspond to waste stream 3S12 in the 2010 Radioactive Waste Inventory.

Sizewell B IEX resins have been the subject of previous assessments based on different packaging approaches. Although these proposals are now superseded, the relevant Action Points raised at that time have been reviewed. The proposed packages have also been reviewed against the Interim stage Action Points applying to the proposed packages based on MOSAIK casks containing Magnox Care and Maintenance Preparation (CMP) wastes to provide a consistency of approach in the assessment of these relatively novel packages.

A detailed Assessment of Disposability has been undertaken and is reported. The assessment has used the draft detailed Waste Package Specification that ultimately would cover these packages as the basis for analysis. The draft nature of this specification means that consistency with the published requirements cannot be confirmed at this time.

Packaging Proposals

Nature of the waste

NGL has prepared proposals for the packaging of IEX resins at Sizewell B in three campaigns, covering both current stocks and future arisings. Due to the higher inventory expected in the third campaign, it would make use of different containers (as discussed below). Consequently, the current assessment covers the packages to be produced in Campaigns 1 and 2, although comments are provided on Campaign 3 as appropriate.

The currently stored resins (to be packaged in Campaign 1) consist of a variety of spent organic ion exchange resin products comprising mixed anion and cation bead resins. All resins are based on styrene divinylbenzene (DVB) co-polymer. It is anticipated that future arising of resins (to be packaged in campaigns 2 and 3) would not be significantly different to those in storage. Currently, approximately 25m^3 of spent resins are stored on the Sizewell B site in three dedicated storage tanks. This volume will be packaged in Campaign 1. Campaign 2 is expected to comprise a similar volume of resins and Campaign 3 is currently estimated to give rise to about 20m^3 of resins.

The total volume of resins might increase in the event of a lifetime extension for Sizewell B. Any such additional resins would fall under Campaign 3 or a subsequent campaign and are not considered further.

Waste processing and packaging

Based on the assumed radionuclide inventories and the period available for decay, NGL has determined that the resins packaged in Campaigns 1 and 2 would be compatible with the requirements for low specific activity (LSA) and therefore could be transported under IP-2 arrangements. It is currently anticipated that the radionuclides associated with the Campaign 3 resins would have insufficient time to decay to levels consistent with LSA and therefore the packages arising from Campaign 3 would be transported under Type B arrangements.

The resin would be retrieved from the current storage tanks using existing site infrastructure and transferred into MOSAIK casks using the German FAFNIR V processing plant. Subsequently, the resins would be further dewatered using the NEWA processing plant. This process would reduce the 'free water' content to a target of less than 1% by volume, or about 5 litres per package. The currently proposed process would not seek to remove 'bound water' directly associated with the resin beads. The quantity of 'bound water' would be considerably greater than that of 'free water'.

The waste package would then be sealed and placed in an interim store until the currently assumed date of transport to a GDF, namely 2040. The performance of the container seal would be confirmed to be compliant with the requirements of the Transport Certification immediately before transport.

Parameters for Assessment of Disposability

Assessment Inventories and Number of Packages

To assess the disposability of the proposed packages, it is necessary to define waste package inventories that capture the range and variability of the package contents.

The basis of the assessment inventory is the characterisation of resin stocks sampled in 2008, supplemented by information from the Station Safety Report (SSR) for the additions to the stocks made subsequently. It is assumed that the nature and activity of each campaign at the time of packaging is the same as for these stocks. The average assessment inventories for Campaigns 1 and 2 are derived by applying different decay periods corresponding to differing elapsed time between packaging and transport.

The variability between individual packages will reflect variations between batches of homogenised resins. This variability is expected to be small but cannot be characterised at the current time. Consequently, a conservative maximum package inventory has been derived by scaling the average inventories to give a dose-rate conforming to the dose-rate limit for transport, namely 0.1 mSv/hr at 1 metre, at 2040. It will be required that equivalent controls are implemented during packaging to ensure compliance with this position.

It is assumed that the containers would be loaded to 95% of capacity (this is a conservative value and actual loadings are likely to be of the order of 90%). This results in an assumed waste loading of 0.466m^3 of resin per package, with an estimated mass of 340 kg in the drained condition. Based on the assumed loading and the volume of waste, it is expected that 55 packages would be produced in each of campaigns 1 and 2.

Gas Generation and Pressurisation

As the proposed packages would be sealed and un-vented, the generation of gas is potentially a significant challenge. The principal sources of gas production from the resins are the radiolysis of the residual free water, the bound water associated with the resins and the organic resins themselves, and corrosion of the container inner surface if the paint coating was damaged. Over time the rate of radiolytic gas generation will be reduced to a negligible level through decay of the principal radionuclides, in particular caesium-137 and, initially, cobalt-60.

NGL has modelled the rise in pressure within a MOSAIK cask as a function of time after receipt at a GDF. The modelling is based on leakage through the container closure controlled by permeation of hydrogen through the elastomer seal, assuming that the pressure in the package on receipt at a GDF is atmospheric pressure. This modelling shows the pressure rising initially as gas builds-up, but then peaking and decaying away due to the combined effects of leakage and reducing radiolysis due to radioactive decay. For the average assessment inventories, the illustrative peak container (absolute) pressure would be less than 130 kPa after about 100 years. For the maximum assessment inventories, the illustrative peak container (absolute) pressure due to radiolysis would be less than 220 kPa,

again after about 100 years. This modelling does not include corrosion as it was assumed that the protective paint coating remained intact.

RWMD will require that the leakage behaviour of the actual packages would be further substantiated during manufacture and prior to transport.

As an illustration of the margin of safety with respect to pressurisation, a bounding (absolute) pressure also has been estimated, based on no allowance for leakage and assuming complete decay of the principal radionuclides and a contribution from corrosion. This estimate is intentionally conservative and is not a prediction of expected behaviour as it assumes physically unrealistic perfect sealing. This bounding quantity of gas for a period of a few hundred years was estimated to be about 0.7 m^3. The bounding (absolute) pressure, based on a conservative voidage of 50 litres, would be less than 1.4 MPa (14 atm) for a period of 300 years.

RWMD has analysed the significance of the static loads induced by pressurisation of MOSAIK casks. It has been determined that a pressure of about 30 MPa (300 atm) would be required to cause failure. The pressures necessary to cause such failures are considerably greater than the bounding pressure for the Sizewell B resins packages, demonstrating that there is a considerable margin of safety.

Based on these arguments, RWMD has concluded that static pressurisation does not represent a significant direct threat to the performance of the proposed packages and would not be expected to cause mechanical damage. This conclusion is based on the nature and inventory of this waste, and in this case is not dependent on achieving a specific degree of dryness. The potential effect of prior pressurisation on performance under accident conditions is considered below.

Waste Package Properties and Performance

In the absence of conditioning material, the containment of mobile activity associated with the waste under both normal and fault conditions depends significantly on the performance of the MOSAIK cask. The expected performance of the containers in the relevant design basis accidents has not yet been demonstrated satisfactorily. Consequently, RWMD has adopted simple, conservative models of the potential releases of activity from packages in accidents, based on the properties of the waste itself and taking no credit for the container.

The potential releases have been quantified as release fractions. In the case of an impact accident, suspendible particles are assumed to be entrained in gases vented from the package as pressure is relieved through an opening caused by the impact. Due to the low fraction of sufficiently small particles in the Sizewell B IEX resins, releases in impacts are expected to be small. Confirmation of the particle size distribution will be required during the retrieval of the waste. In the case of a fire accident, volatile and gaseous species are assumed to be released after degradation of the container seals, giving relatively higher expected releases.

As noted, prior pressurisation is considered as one of the driving forces causing releases under accident conditions, together with steam generation in fire accidents, and the effect has been encompassed by the RF values. The significance of the potential releases is discussed in the Assessment of Disposability.

Compatibility with Specifications

At the Interim stage it is necessary to demonstrate the compliance of the proposed packages with an appropriate detailed Waste Package Specification. As discussed above, the necessary specification has not yet been published. In advance of this publication, a comparison with an initial draft of such a specification suggests that the proposed packages would be compliant. Nevertheless, a formal assessment and demonstration of compliance would be required before the packages could be endorsed at the Interim stage.

The Regulatory Joint Guidance on the Management of Higher Activity Wastes (Part 3b) highlights an expectation that packages would be passively safe and identifies 'non-pressurisation' as a key safety function of waste packages. Similarly, the GWPS requires that pressurisation should not compromise the safety functions of packages. Arguments to this effect have been presented above and the significance of pressure-driven releases in accidents is assessed in the Assessment of Disposability. RWMD believes that these arguments provide confidence that pressurised MOSAIK casks containing Sizewell B IEX resins can be judged to be safe in a GDF and that intervention would not be necessary to maintain safety.

Assessment of Disposability

Transport Safety Assessment

The MOSAIK cask has received unilateral approval for transport under IP-2 arrangements. Consequently, the acceptability of the proposed packages for transport would be determined through demonstrated compliance with the requirements of the existing approval. To this end, RWMD has reviewed the packages against its understanding of these requirements.

At the time of transport to a GDF, the consignor (potentially Magnox or a successor organisation) would need to demonstrate compliance with an extant Approval Certificate. This would require both the continuous maintenance of the certificate by the approving authority until the date of transport, and the production and retention of all relevant information and records need to demonstrate compliance by the consignor. The conclusions of the current assessment recognise that these requirements could be fulfilled, but it is noted that ensuring this in practice could present significant challenges.

It is recognised that the Sizewell B resins correspond directly to wastes for which the containers were originally designed and approved, namely IEX resins arising from the operation of a Pressurised Water Reactor (PWR) such as Sizewell B. It is therefore readily deduced that, at the present time, the proposed packages should be acceptable for transport under the existing certificate. This position has been confirmed through review by RWMD.

The existing approval requires that the pressure within the packages must be less than the Maximum Normal Operating Pressure (MNOP) of 700 kPa above atmospheric pressure at all times during transport. It is anticipated that the potential pressure rise during on-site interim storage, prior to transport, could give unacceptable pressures at the time of transport. It is therefore required that NGL recognises that the packages must be de-pressurised prior to transport to ensure compliance with the MNOP.

Operational Safety Assessment

The acceptability of the proposed packages has been assessed using the recently-developed extended operational safety toolkit that encompasses the handling and emplacement of DCI container packages (including MOSAIK casks).

It has been determined that the assessed doses for faults based on impacts are acceptably close to or less than the Basic Safety Objective (BSO) for both on-site and off-site doses (0.1 and 0.01 mSv respectively). This reflects the relatively low Release Fraction (RF) value attributed to impact accidents. Optimisation of the design of a GDF would be expected to further reduce the assessed doses and it is recognised that the derivation of the impact RF values uses a conservative treatment of the effect of pressurisation.

In contrast, several faults based on fires give assessed doses that exceed the highest Basic Safety Level (BSL) for both on-site and off-site doses. This reflects the high RF value attributed to fire accidents. Of particular note are the doses from a fire at the surface receipt area, which results in a large assessed dose to both public and workers, and in the drift and underground receipt area, which result in large assessed doses to workers.

RWMD recognises that there are significant conservatisms in the current methodology that have influenced these assessed doses. Further consideration of the following factors could result in potentially significant reductions in the assessed doses.

- modifying the assumed severe fire conditions (namely a 1000ºC fire of one hour duration) to better represent expected conditions;
- representing more than one fire condition to better represent the potential conditions in the relevant parts of a GDF;
- optimising the assumed design for the DCI container vault, removing pathways and/or introducing protection for exposure to releases from fire accidents (note that currently very little protection is assumed for worker doses in such cases);
- review of dose-release ratios (DRRs) to take account of the temperature of the situation ('hot' releases would be expected to be more widely dispersed).

Work is underway to challenge such conservatisms, particularly for that sub-set of fire faults that occur during and after emplacement of the packages into the disposal vault. Preliminary conclusions are that significant reductions in the assessed doses would be achieved by introducing additional, more specific features into the assumed generic vault design. The preliminary conclusions are that the reductions would be sufficient to reduce the assessed doses to clearly acceptable levels.

The current assessment has observed that the adverse effects of that sub-set of fire faults occurring during the receipt and transfer of the packages underground can be further mitigated by adding thermal protection to the packages, thereby reducing the temperature experienced by the waste. RWMD has identified the 'shock absorbers' required for the transport of MOSAIK casks under Type B transport arrangements (also known as impact limiters) as a means of providing the necessary thermal protection.

In light of the above, RWMD concludes that significant reductions in the assessed doses from all fire faults may be anticipated in time. It is determined that Interim stage endorsement could be provided on this basis. Since adding thermal protection provides and important and substantial reduction in the highest assessed doses, namely those in receipt and transfer, it would be further required that any Interim stage endorsement should be conditional on the use of thermal protection as described above.

The assessment also considered potential challenges arising from gas generation under normal conditions, with the resulting expectation of hydrogen leakage. Typically this leakage would effectively mimic the behaviour of vented packages, releasing hydrogen at the rate of generation. The eventual failure of the seals might cause a temporary increase in leakage from an individual package as excess pressure was vented, although the rate would then return to match the generation rate. Such increased leakage would be small relative to the total gas burden in a vault and does not present a significant additional challenge. Mechanical failure due to static loads arising from pressurisation is not expected as the predicted pressures are insufficient. On these grounds, the assessment has concluded that pressurisation alone is not a significant additional hazard under normal conditions.

Based on the arguments considered under Operational Safety, it is concluded that pressurisation would not present a significant additional hazard under normal conditions and the influence of pressure on accident performance has been considered through the RF values used in the assessment. It therefore judged that a good basis exists for demonstrating that the expected pressurisation of the proposed packages does not present an unacceptable challenge to the disposability of the proposed packages.

Post-closure Safety Assessment

The Sizewell B resins represent a relatively small volume of waste dominated by shorter-lived radionuclides. Consequently, it has been determined that these wastes do not present a significant radiological risk in following closure of a GDF. The introduction of a moderate quantity of additional organic materials into a GDF, namely the IEX resins, has been assessed as having no significant impact on the existing arguments relating to the complexation of radionuclides and criticality safety.

The proposed packages potentially introduce additional voidage into a GDF. RWMD is currently investigating the acceptable level of voidage and is not yet able to determine whether the voidage associated with the Sizewell B IEX resins would be acceptable. Consequently, NGL is advised that the option to require filling of residual voidage is retained.

Although the corrosion of the cast iron associated with DCIC-based packages potentially represents an increased total source term for gas, this would be produced at a rate similar to that expected from thin-walled containers. Assessments for such packages have demonstrated that this modified gas source term would not have a detrimental effect on the post-closure performance of a GDF.

Review of Technical Issues and Action Points

A number of technical issues applicable to the current proposals were identified through a Conceptual stage assessment for two waste packaging options using MOSAIK casks, based on either dewatering or binding the waste with a polymer matrix. Of the 15 Interim stage Action Points, nine have been judged relevant to the current assessment.

In addition to the consideration of proposals for the packaging of Sizewell B IEX resins, RWMD also has considered proposals for the packaging of a range of CMP wastes from Magnox sites using MOSAIK casks. The Conceptual stage assessment of these proposals raised a number of generic Interim stage Action Points. To provide consistency in the assessment of packages based on MOSAIK casks, these Interim stage Action Points also have been considered. Of the 21 Interim stage Action Points, 16 were considered potentially relevant to the current assessment.

The assessment has concluded that all 25 Interim stage Action Points identified above may be considered to be closed or no longer applicable for the proposed packages containing Sizewell B IEX resins. Through this analysis, a further 13 Final stage Action Points have been placed, seeking resolution of issues relating to commissioning of the packaging plant, and Management System and Data Recording arrangements. Particular requirements of note include the need to confirm and codify at the Final stage suitable success criteria for the dewatering process, seal testing and detailed criteria to be applied to the monitoring of package during interim storage, building on the outline and/or draft proposals considered and accepted at the Interim stage.

RWMD has analysed the evidence regarding the passive safety of the proposed packages, including consideration of the significance of pressurisation. It is judged that this evidence is sufficient to fulfil regulatory expectations as expressed in the Regulatory Joint Guidance on the Management of Higher Activity Wastes (Part 3b). Nevertheless, it is recommended that confirmation of this position is sought from regulators at an early opportunity.

Conclusions

An Interim stage assessment has been undertaken for the proposed packages containing Sizewell B IEX resins, based on the use of Type II Ductile Cast Iron Containers (MOSAIK casks) compliant with the requirements for transport under IP-2 arrangements. An Assessment of Disposability has been reported and the compliance of the proposed packages with all the requirements for transport, handling and disposal at a Geological Disposal Facility has been formally assessed.

Based on the conclusions of the Assessment of Disposability, it has been concluded that the proposed packages should be endorsed at the Interim stage through the issue of a Letter of Compliance. However, such an endorsement will be delayed until the relevant detailed Waste Package Specification has been published and compliance with its requirements has been explicitly assessed and demonstrated. Any such endorsement will be conditional on the de-pressurisation of packages before transport and on the use of Type B shock absorbers for the transport of the package to provide mitigation of significant assessed doses arising from fire faults in GDF operations. RWMD would place a condition that filling of residual voidage in the packages might be required. At this time, the endorsement would be limited to the packages to be produced under Campaigns 1 and 2.

The assessment has identified 13 Final stage Action Points that need to be resolved to progress the endorsement of packages to be produced under Campaigns 1 and 2 to completion at the Final stage.

The conclusions of the current assessment have been based on a number of key features of the wastes, in particular the assumed particle size distribution of the IEX materials and the successful draining of the waste to a defined residual water content.