Nuclear Decommissioning Authority

Radioactive Waste Management Directorate

Accident Performance Assessment of AWE Legacy Hydrodynamic Vessel Packages

(Pre-Interim stage)

Summary of Assessment Report

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Background

For nearly fifty years, the Atomic Weapons Establishment (AWE) has carried out hydrodynamic (HD) experiments to test the performance of materials under explosive force. These tests are performed using high integrity carbon steel pressure vessels which become contaminated with radioactive material as a consequence of the experiment. Since it is not possible to re-use the vessels, each experiment generates a vessel that is classified as Intermediate Level Waste (ILW).

To date, nineteen vessels have been generated. A total of twenty-four such vessels are expected to arise during the lifetime of the existing HD test facility. These twenty-four vessels are referred to as 'legacy' HD vessels in recognition of plans by AWE to upgrade its HD capability in the future, whereupon a new design of HD vessel known as 'Hydrus' would be used[1].

Each of the twenty-four legacy HD vessels are of the same basic design, though the specific construction details have evolved since the first (V1) vessels were introduced in the 1960s, resulting in four vessel designs described as V1, V2, V3 and V4. As a general rule, the thickness of steel used to fabricate the vessels and complexity of experimental furniture increases from the V1 through to the V4 design that is currently in use.

AWE has been working with RWMD to develop a solution for packaging the legacy HD vessels with a view to ultimate disposal in a GDF as ILW. The proposals that are being worked up by AWE are based on entombment of the legacy vessels in square-cornered $3m^3$ boxes. The void between the vessel and box walls would be infilled with cementitious grout. The void within the vessels would remain unencapsulated. AWE has received Conceptual stage endorsement for these proposals from RWMD in 2010[2] on the grounds that package performance requirements for safe handling and transport would be achieved through a combination of the high integrity of the HD vessel coupled with the additional protection offered by the $3m^3$ box and surrounding cement grout.

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1 RWMD has previously endorsed Conceptual stage packaging proposals for the larger Hydrus vessels (NDA Assessment Report, Conceptual *Stage Assessment of Packaging Proposals for Hydrus Hydrodynamic Vessels from AWE*, NXA/13293263, November 2010)

2 NDA, *Conceptual Stage Letter of Compliance for the packaging of legacy hydrodynamic vessels from AWE Aldermaston*, LOC/12085510, July 2010

Since 2010, AWE has been working with RWMD to more fully demonstrate that RWMD requirements for the proposed packages can be fulfilled. Eight Action Points were raised by RWMD in the Conceptual stage disposability assessment[3] that AWE will be required to address before the packaging proposals could be endorsed at the Interim stage. AWE has been addressing each of these Action Points separately with a longer term view to undertake a full Interim stage disposability assessment seeking endorsement at the Interim stage with a Letter of Compliance (LoC) during 2013/14.

One of the key Action Points that will need to be resolved to support Interim stage endorsement of the packaging proposals for the legacy HD vessels relates to the accident performance of the waste packages:

> **Action Point E10/005**: *AWE to demonstrate that the packages containing legacy hydrodynamic vessels are capable of retaining the entirety of the vessel contents under credible fire and impact accident conditions*.

Action Point E10/005 was raised by RWMD with a view to AWE demonstrating that the proposed 3m^3 boxes containing legacy HD vessels would not release radioactive material in response to the most limiting fire and impact accident scenarios envisaged in the GDF concept. This is in response to the assumption in the Conceptual stage disposability assessment[3] was that the packages would not release radionuclides under accident conditions.

This assessment report has been prepared in response to a formal request by AWE to consider progress made against Action Point E10/005. AWE has performed detailed finite element computer modelling to demonstrate how the 3m^3 boxes containing legacy HD vessels would perform under fire and impact accident conditions. The advice set out in this report sets out the RWMD position with respect to progress against Action Point E10/005 based on the results of the finite element modelling.

Fire Accident Performance

AWE calculated the temperatures that would be experienced by the various components of the proposed waste packages in response to the most limiting fire scenario considered by RWMD, which is a fully engulfing 1,000°C fire lasting for one hour. Thermal modelling was used to show how the temperature of the legacy vessel within the package changes both during the one hour fire, and for a twenty-three hour period following the fire. The results were then analysed to determine the potential for radionuclide loss from the packages.

Two package variants were considered: one containing the thinnest wall legacy HD vessel (the V1 vessel) and the second containing the thickest walled legacy HD vessel (the V4 vessel). These two variants represent the two extremes of vessel design, thereby encompassing all of the legacy vessel designs (V1, V2, V3 and V4 designs).

The design of the 3m^3 box waste packages is such that the cement grout provides a large degree of thermal insulation to the legacy vessels, located in the centre of the box. The results of the fire assessment show that the maximum temperature change experienced by the legacy vessel itself would be small (up to a maximum temperature of 84°C) due to the insulating effect of the cement grout. The supplied evidence supports the assumption that there should be no release of radionuclides from the proposed packages under the most limiting fire accident conditions.

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[3] NDA, *Conceptual Stage Assessment of Packaging Proposals for Legacy Hydrodynamic Vessels from AWE*, NXA/11793836, February 2010

Although the results of the modelling demonstrate adequate fire performance, this is based on a very simplified representation of the legacy HD vessels within the packages, for example, the models do not account for the external features (ports) on the different vessels. RWMD will expect to see the features of the waste packages fully defined to support the future Interim stage disposability assessment. The finalised design of the waste package will also be reviewed at that stage to establish that the external features of the vessels will be insulated by a layer of cement grout that is at least as thick as that currently shown in the finite element modelling.

Impact Accident Performance

AWE has developed finite element models to demonstrate the performance of the $3m^3$ box packages containing legacy HD vessels to the most limiting impact accident conditions that might be experienced during transport and operational phases of the GDF concept.

The following scenarios were explored in the modelling by AWE:

- Package drop from a height of 15 m, impacting onto the package lid edge;
- Package drop from a height of 15 m, impacting onto the package corner post; and
- Another square-cornered $3m^3$ box being dropped from a height of 15 m corner-first onto the lid of a $3m^3$ box containing a legacy HD vessel (the aggressive feature scenario).

As with the fire models, representations of the V1 and V4 vessels were developed to explore the two extremes of package variability.

The results of the package impact modelling suggest that the packages should be capable of withstanding lid-edge and corner post drops from 15 m without releasing any of the radionuclide content of the vessels. This is because the degree of damage inflicted on the package would appear to be insufficient to cause deformation of the legacy vessels themselves, which are well protected by the stainless steel $3m^3$ box and cement grout. Greater confidence of this can be given for the more robust V4 vessel design, yet the evidence provided also suggests that the thinner walled V1 design should also give acceptable performance when packaged in a $3m^3$ box.

As already highlighted, the waste packages are not yet fully defined. For example, the design of the furniture that would be used to hold each vessel in position within the $3m^3$ box is not yet fully specified. Accordingly, the modelling also did not account for the specific location of the external ports on the vessels. Another important point is that the mass of each package is not accurately established. Therefore, although the results of the lid-edge and corner impacts suggest acceptable performance should be achieved, this position will need to be confirmed in the light of finalised package design information and data. Again, the expectation is that this information will be made available for all twenty-four of the legacy HD vessels during the future Interim stage disposability assessment, when the results of the modelling will be reviewed to confirm acceptable package performance.

The ability of the packages to retain radionuclides following an aggressive feature impact is less certain. Based on a drop height of 15 m, and given the uncertainties inherent in the modelling approach, the results of the modelling suggest that the potential exists for a breach of the containment offered by the impacted vessel. This is particularly true for packages containing the thinner-walled V1 vessel. Furthermore, the way that the modelling has been undertaken may not represent a conservative treatment. This is because the package being dropped is assumed to have a mass of 8 tonnes, when the potential exists for packages of up to 12 tonnes in mass to be dropped onto the AWE packages in a vault at the GDF. The

consequences of a heavier package being dropped onto an AWE package would be more onerous that that modelled with an 8 tonne package.

In respect of the 15 m drop height, work is underway within RWMD to reduce the maximum drop height of the package-on-package aggressive feature scenario to 10 m. This proposed reduction in drop height is currently undergoing evaluation through the GDF change control process. Although the drop height of 10 m has not yet been formally adopted, this situation may change in the future. AWE is therefore recommended to undertake sensitivity analyses on the finite element models using package drop heights of 10 m and 15 m and provide this to RWMD in support the future Interim stage submission. Further to this, AWE will also need to consider the consequences of packages with masses up to 12 tonnes being dropped onto the AWE packages, for both 10 m and 15 m drop heights.

Given the potential challenge presented by aggressive feature impacts, AWE is encouraged to consider additional engineering solutions to enhance the protection offered to the vessels within the package. For example, it might be feasible to develop a simple plate that could be fitted to the underside of the lid or on the top of the vessel support frame to dissipate some of the impact energy across a larger surface area of the package and away from the vessel itself.

Finally, opportunities also exist for RWMD to mitigate the risk of aggressive feature impacts onto the AWE packages by implementation of management controls at the GDF. For example, the AWE packages could be selectively emplaced towards the top of a stack of seven $3m^3$ boxes in the GDF vaults. By doing so, the potential for other packages to be dropped onto the AWE packages is eliminated. At the very least, the height from which other packages could fall onto the AWE packages would be significantly reduced. Selective emplacement may be a feasible approach in this instance given that only twenty-four AWE packages would be produced against a disposal concept which envisages many thousands of packages. Nevertheless, the need for management controls should be viewed as a final line of defence in the GDF operational safety case, since there is a general requirement that packages should be passively safe in their own right. RWMD will therefore seek assurance that the package design has been optimised before considering implementation of management controls for these packages.

Conclusion

Although AWE has made considerable progress, there is currently insufficient certainty to substantiate the assumption that there would be zero release of radionuclides from the packages under accident conditions. This is particularly true for aggressive feature impact scenarios. Therefore, Action Point E10/005 cannot be closed at this time.

Progress with Action Point E10/005 will be reviewed as a component of the forthcoming Interim stage disposability assessment for these waste packages, based on the recommendations for further work described in this assessment report.

Recommendations and Future Work

The RWMD review of the accident performance of the AWE legacy HD vessel packages has identified the following areas for further consideration by AWE:

- Finalise the design features of the $3m^3$ box waste packages, including the detailed container design, the properties of the cement grout, the design of the internal furniture and the exact orientation of external vessel features relative to the outer container. The mass of each of the twenty-four individual packages should also be estimated based on this information. This point is the subject of a separate Action Point (E10/002);

- Consider the effects of internal pressure within the legacy HD vessels on package performance under impact scenarios (the effect of vessel internal pressure was disregarded in the finite element modelling);
- Re-run the finite element models for the aggressive feature impact scenario to explore the consequences of the potential reduction in package drop height from 15 m to 10 m;
- Undertake sensitivity analyses to changes in the mass of the dropped package in the aggressive feature impact model for packages of up to 12 tonnes; and
- Consider design enhancement of the packages to provide enhanced protection to the legacy HD vessels from aggressive feature impact.

The above information should be submitted to RWMD to support the future Interim stage disposability assessment for the proposed packages. RWMD would be pleased to provide further guidance and support to AWE to address these matters.