

Packaging of Whole Submarine Reactor Pressure Vessels

(Conceptual stage)

Summary of Assessment Report

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Introduction

Babcock Marine on behalf of the Ministry of Defence has sought Conceptual stage endorsement of proposals for the packaging of whole Reactor Pressure Vessels (RPVs) from the decommissioning of Pressurised Water Reactor type 1 (PWR1) and type 2 (PWR2) equipped submarines.

This Assessment Report provides the basis and findings of the Conceptual stage disposability assessment by NDA Radioactive Waste Management Directorate (hereafter RWMD) for packages containing PWR1 and PWR2 RPVs. The assessment has been carried out through the Disposability Assessment process, whereby RWMD examines the disposability of proposed waste packages by assessment against relevant standards and specifications and the reference Intermediate Level Waste concept. Given that the packaging proposal is not standard, the assessment has been examined against the Generic Specification for Waste Packages Containing Low Heat Generating Waste, and where applicable WPS/330, the standard specific to the 4 metre box, which is the closest analogue. The reference concept has been developed as part of the programme to implement geological disposal for the UK's higher activity wastes. Further information on the Letter of Compliance process is available elsewhere¹.

Background

Babcock Marine is providing advice to the Ministry of Defence (MoD) on decommissioning the existing nuclear powered submarine fleet. These consist of 23 Pressurised Water Reactor (PWR) type 1 reactor equipped submarines and 4 PWR type 2 equipped submarines. Some of the PWR type 1 equipped submarines and all of the PWR type 2 submarines are still in service and will not all be decommissioned for several decades. In particular, the PWR type 2 submarines are likely to be in service for up to thirty years (i.e. to 2042 or beyond). There are currently eleven submarines ready for final dismantling, with a further five in various stages of final de-fuel and de-equipment operations.

The Radioactive Waste Management Directorate (RWMD) has had a number of previous interactions with MoD regarding the disposal of submarine reactor dismantling wastes, which has led to the current developed disposal strategy. The baseline waste packaging strategy, which has been endorsed at the Conceptual stage, involves the size reduction of the PWR1 RPV and Primary Shield Tank, and subsequent packaging as Intermediate Level Waste. In this scenario, wastes would be loaded into 3m³ boxes and encapsulated utilising a cementitious grout.

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

The present submission requires RWMD to consider an alternative to the baseline, the feasibility of the disposal of whole PWR type 1 and PWR type 2 RPVs without size reduction. The 'whole' RPV would include the core barrel, thermal shields and support skirt (PWR type 1 only), but excluding the RPV head and bolting ring, packaged within overpacks. Two different overpacks are proposed, reflecting the different dimensions of the two RPV types. The detailed design of the overpacks was not provided in the submission, only estimates of dimensions and masses. A single overpack design could be utilised but its dimensions would be dictated by the larger PWR type 2 RPV.

It is anticipated that decommissioning and waste packaging operations will require waste packages to be interim stored until a GDF is available. This may require transport off-site to an interim storage facility from 2017. Transport to an interim storage site and the interim storage process was not considered by RWMD as part of the assessment. The waste packages would subsequently be transported to the GDF for disposal, a process that is assessed to begin in 2040, which has been addressed by this assessment.

In order to progress the dismantling of the submarines, the waste packager has sought advice from RWMD on the disposability of proposed waste packages using the Letter of Compliance disposability assessment process. This is to ensure that the higher activity radioactive waste will be packaged in compliance with RWMD requirements as currently foreseen. The submission provided to RWMD describes the wastes, preparatory conditioning and packaging of the wastes for both the PWR type 1 and type 2 RPVs.

Waste packaging proposal and scope of assessment

The waste addressed by this proposal forms parts of UK Radioactive Waste Inventory waste streams 7G102 & 7G104, *Short-Lived ILW from Decommissioning Submarines* and *Long-Lived ILW from Decommissioning Submarines* respectively.

The wastes derive from the operation of the UK nuclear powered submarine fleet and consist of most of the RPV, which will have been exposed to heavy neutron irradiation and activation during the service lifetime of each boat. The extent of neutron irradiation and activation will vary between boats and will depend on the individual reactor operating histories, which include the replacement of cores during refit periods. In some cases the replacement cores were of differing design, although the RPV itself was always retained.

The RPV consists of an external cylindrical shell with an ellipsoidal base. The RPV shell has four nozzles that connect it to the primary cooling circuit and a series of integral internal thermal shields of varying thicknesses, a core barrel and additional internal furniture. Details of the composition of the steel items were provided.

The proposed strategy would be to remove the RPV as a single entity and place it in a steel overpack (excluding the RPV head and bolting ring, which are known to be Low Level Waste), for transfer to an on- or off-site interim storage facility, prior to transport to a Geological Disposal Facility (GDF). The four nozzles which enable connection to the primary coolant loops would be removed as this allows significant size reduction of the final package overpack design. It is unclear from the submission whether or not the nozzles will be disposed of as LLW; they are not however included in the scope of this assessment.

The core barrel would need to be secured in position and the RPV closed and sealed at the locations of the removed RPV head and nozzles. This would retain any corrosion product within the RPV. A conceptual design for sealing the larger opening at the RPV head is to fit a light stainless steel cover welded to the RPV top flange face (stainless clad) with spacer underneath resting on the core barrel top flange. A

heavy cover would then be fitted using the 40 stud holes in the RPV top flange face; this cover would provide strength to the closure.

The concept of steel overpacks is proposed, into which the RPV could be lowered and finally sealed by a top lid. Detailed designs were not available for this assessment stage. The disposal overpacks would need to include attachments for lifting and securing onto transport vehicles and potentially for stacking. The overpack designs would need to satisfy shielding and strength requirements. The packages are intended to be Type IP-2 packages for transport, as the waste is expected to fall within the definition of low specific activity.

The current assumption would be to not encapsulate the RPV internals or the external volume between the RPV and the overpack. It is proposed by the waste packager that the very small quantity of corroded particulate within the RPV and the robust nature of the overall waste package would permit a non-encapsulated wasteform. This would also significantly reduce the mass of the produced waste packages.

Outcome of assessment

Compliance with Waste Package Specification

The assessment considered the requirements for transporting the RPVs as low specific activity waste. Based on the information provided at the Conceptual stage, the assessment concluded that the packages would appear to meet the requirements for low specific activity and hence would be transportable as Type IP-2 packages.

Dose rates were calculated based on the evidence provided in the submission and clarified with the waste packager at the time of assessment. This information, as interpreted by RWMD, did not include additional shielding at the top of the RPV. Dose rates at this location therefore were found to exceed both the IAEA Transport Regulations dose rate limits for transport and RWMD limits for operational handling, and are therefore not compliant. On further discussion with the waste packager about shielding requirements, it is understood that the proposed approach for sealing the top of the RPV will include sufficient shielding to reduce dose rates to compliant levels.

Heat output, package surface contamination, gas generation and criticality safety were all found to be within the limits of compliance. The accident performance was assessed qualitatively using arguments based on the robust nature of the RPV and the addition of the surrounding overpack, and shown at this stage of being capable of being compliant.

Based on the data provided in the submission, the non-encapsulated PWR1 package was assessed to be within the 65 tonne mass limit, as defined in RWMD's generic specification for low heat generating wastes. However, the non-encapsulated PWR2 package exceeded this limit by a considerable margin. Should the PWR1 package require encapsulation, the mass limit would also be exceeded. Both packages types were found to exceed the external dimension limits as stated in the generic specification. In practice, exceeding the height limit for transport by rail and the width limit for the PWR1 package for general transport are unlikely to have noticeable consequences for transport to or at a GDF. The increased dimensions of the PWR2 package, however, have potentially significant consequences for both the mode of transport to a GDF and operational movements at a GDF.

Compliance with concepts for a Geological Disposal Facility

The assessment identified a number of compliance gaps, some of which affect the handling and movement of the waste packages at a GDF. The packaging proposals are non-standard and therefore at this stage are not consistent with meeting

handling, storage and disposal system design and safety requirements as currently foreseen. The waste packager has been recommended to request GDF concept changes, both to challenge RWMD's requirement for the minimisation of voidage, should the waste packager wish to continue with a non-encapsulated waste package approach, and to accept larger packages and heavier packages, should encapsulation ultimately be required.

The outcome of such concept changes depends, not only the technical ability to accommodate them, but also on the justification that such changes provide net benefit across the life cycle of this waste. The baseline strategy for size-reducing the RPVs and packaging in 3m³ boxes has been assessed and endorsed at the Conceptual stage. The waste packager is required to show that the detriment to the GDF concept associated with any necessary changes to accommodate the overpacks has been considered in a lifecycle analysis. RWMD will need more details of overpack designs to facilitate an assessment of the necessary changes to the concept and to estimate the impacts including the associated costs.

RWMD's guidance for the minimisation of open voidage in waste packages for geological disposal is consistent with joint regulatory guidance (from the Environment Agency and the Office for Nuclear Regulation). The open voidage in each of the PWR1 RPVs is estimated to be at least 6m³, and is not consistent with this guidance. If the option to void fill the overpacks is adopted, this would have transport consequences because of the increased mass, both to and at a GDF, in particular for access below ground. This option would also affect handling equipment across the facility and potentially the use of a stacker truck for disposal in an underground vault. The assessment of these concept changes can only be undertaken with a sufficiently detailed design of the overpack, including its mass, dimensions, and lifting, handling and tie-down features. Nevertheless, the significance to the GDF safety assessment of not filling voidage could be considered further as part of a GDF concept change assessment.

Statement of disposability

At this stage, the PWR1 and PWR2 packages are not consistent with meeting handling, storage and disposal system design and safety requirements as currently foreseen.

Conclusions

The waste packaging proposal to dispose of whole submarine reactor pressure vessels from the PWR1 and PWR2 has been assessed. The submission represents an innovative departure from the standard waste packaging options and is welcomed since it may represent dose and cost savings across the waste disposal life-cycle, from decommissioning by the waste packager to disposal at a GDF. Further development of the overpack designs is required to facilitate the GDF concept change control and to enable lifecycle benefits to be assessed by the waste packager.

The PWR2 package significantly exceeds the dimensional package limits for transport below ground at a GDF. The cost for increasing the size of the drift tunnel alone, is likely to be considerable as well as mechanically challenging. This would be considered in detail during concept change control, but this assessment suggests there is higher risk of unsuccessful change control for the PWR2 overpack.

The conclusions of this assessment were taken to the RWMD Nuclear Safety and Environment Committee for their advice. The views of this safety committee have been incorporated into this assessment report.