Radioactive Waste Management Directorate

Packaging of AWE Pyrochemical Salts in Calcium Phosphate Ceramics

(Conceptual stage)

Summary of Assessment Report

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Introduction

Pyrochemical processes are used by AWE to purify plutonium metal. These processes result in the generation of salt residues that are contaminated with actinides (plutonium and americium). AWE has been developing options for the ultimate disposition of these pyrochemical wastes.

AWE has previously received advice from the NDA Radioactive Waste Management Directorate (RWMD) on the disposability of a proportion of the pyrochemical salt residues based on encapsulation in polymer in 500 litre drums[1]. The polymer encapsulation process would be reserved for packaging pyrochemical salt residues with low levels of actinide contamination. A separate process has also been developed by AWE to package the pyrochemical salt residues containing higher levels of actinide contamination. The products from this latter process form the subject of this conceptual stage disposability assessment.

To account for the greater radioactivity in the more highly contaminated pyrochemical residues, AWE has developed a conditioning process based on incorporation of the salt into a ceramic product. The pyrochemical salts would be calcined in the presence of calcium phosphate to incorporate the actinides into a number of mineral phases. The resulting granular mineral product would then be bound together by sintering in the presence of a phosphate binder to generate a solid ceramic product. The solid pieces of ceramic material would be sealed within steel cans. The steel cans would then be safely stored on site pending a decision to package the waste for final disposal.

AWE has submitted proposals to package a number of such cans within a stainless steel 500 litre drum that includes an additional inner stainless steel liner. Individual cans would be placed within the inner liner before the voidage within the entire 500 litre drum is backfilled with cement grout. The 500 litre drum would then have a lid fitted to form a monolithic waste package for disposal in a GDF as Intermediate Level Waste (ILW).

This Assessment Report provides the basis and findings of the conceptual stage disposability assessment by RWMD for pyrochemical salt residues in calcium phosphate ceramic packaged in 500 litre drums. The assessment has been carried out through the Disposability Assessment process, which has been developed to evaluate the properties of proposed waste packages and to assess their safety performance, to determine whether they are likely to be disposable. This process tests whether the proposed waste packages comply with both the generic Disposal System Safety Case (DSSC)[2] for a GDF and regulatory expectations for the long-term management of the waste. The compliance of proposed waste packages with all of these requirements is signified by the issue of a Letter

[1] NDA, *Packaging of Pyrochemical Waste by AWE: Conceptual Stage*, NXA/12757676, January 2011

[2] Nuclear Decommissioning Authority, *Geological Disposal: An overview of the generic Disposal System Safety Case*, NDA Report NDA/RWMD/010, 2010

of Compliance, which signifies RWMD's endorsement of the disposability of that specific design of waste package. Further information on the Disposability Assessment process (also known as the Letter of Compliance process) is available elsewhere[3].

The Disposability Assessment process is an important risk management tool for the waste owner, giving confidence that the risk of inappropriate treatment and non-compliance with transport and disposal acceptance criteria has been minimised. The process is also important to RWMD as it gives confidence that the DSSC is compatible with "real" waste packages.

Scope of Assessment

The objective of the assessment is to provide a Conceptual stage disposability assessment to AWE on the proposals for packaging, transport and disposal of 500 litre drums containing the pyrochemical salt immobilised in calcium phosphate ceramic. A key aspect of this is the identification of future development activities that would be necessary to underpin the disposability of these packages.

The assessment of disposability would be expected to contribute to the Radioactive Waste Management Case to be produced by licensees as required by the regulators, and specifically to the reasoned judgement that the conditioned waste will meet the anticipated requirements for acceptance from the potential disposal site operator.

Consideration is given to the compatibility of the proposed packages containing calcium phosphate ceramic with the requirements for safe long-term management, including transport, emplacement and extended storage underground, and disposal, as currently expressed for the Reference ILW Disposal Concept (as described in the generic DSSC). This also addresses compatibility of actinide bearing calcium phosphate ceramic with the specification for waste packaging as expressed in the Generic Waste Package Specification[4]. An essential component of this includes consideration of the effects of interim on-site storage of the conditioned waste at AWE's Aldermaston site.

The proposals are expected to give rise to less than 250 off 500 litre drum waste packages. These packages would represent less than 1% of the total volume of unshielded ILW being considered in the reference case for the GDF.

The proposed use of calcium phosphate ceramic to package UK radioactive waste is unique and may therefore set a precedent. Moreover, the high actinide content of the waste means that the packages could represent some of the most significant in the ILW inventory in terms of their radioactivity and fissile content. For these reasons, the findings from this Assessment Report have been referred to RWMD's Nuclear Safety and Environment Committee (NSEC) for consideration. The conclusions of this Assessment Report incorporate the views of the NSEC.

Outcome of assessment

At this stage in the development of the proposals, the exact details of the packages and their associated inventory and wasteform are not fully defined. Accordingly, it has been necessary to apply a conservative approach in the derivation of waste package properties. This is typical for a conceptual stage assessment since it is expected that these uncertainties would reduce as the proposals become more developed towards the interim stage.

The conditioning of the pyrochemical residues using a ceramic wasteform would be expected to generate a high quality wasteform for disposal. This is because both the actinides and chlorides within the residues should be well immobilised within the mineral phases of the ceramic. The wasteform also offers advantages from the perspective of criticality safety due

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

[4] Nirex, *Generic Waste Package Specification. Volume 1 – Specification*, Nirex Report N/104, March 2007

to the known distribution of fissile material within the packages and isolation of the fissile material from moderating materials, such as water. The ceramic should also provide a high degree of resistance to the re-distribution of fissile material. Initial calculations indicate that a high safe fissile mass could be tolerated for these packages for transport and operational scenarios. The ceramic component of the wasteform would also be chemically compatible with the cement based material that is expected to be used to backfill ILW vaults of a GDF.

The assessment has identified that the heat output of the waste is likely to be a more restrictive parameter than the fissile content in controlling the quantity of pyrochemical waste in each 500 litre drum. The high actinide content of the waste means that the package heat output could exceed the current 50 W package limit at 2040. This compares to the average ILW package heat output of 6 W at 2040. It would be possible to achieve compliance with the 50 W limit simply by reducing the amount of pyrochemical waste in each package, but this would lead to a significant increase in overall package numbers and may not represent an optimised approach for disposal. Further to this, RWMD is undertaking work to better understand the constraints on package post-closure heat output .

The lack of detailed definition of the waste packages at this stage has necessitated pessimistic assumptions to be made regarding the performance of the packages under accident conditions. This is seen as a necessary precaution given the potentially high inventory of the packages and novel nature of the ceramic wasteform, for which there are no similar waste package types that can be drawn upon to infer potential performance.

A consequence of adopting these pessimistic assumptions is the potential for releases under accident conditions and hence for worker and public exposure to radionuclides. It should be feasible to make a transport safety case for these packages due to the combined effectiveness of the package and transport container in preventing exposures. On the other hand, calculated worker exposures from the most severe package handling accidents at the GDF have been calculated to be significant. For this reason RWMD considers that it would not be appropriate to endorse the proposals at the conceptual stage at this time. Notwithstanding the results of the operational safety assessment, RWMD believes that the potential for excessive exposure is substantially due to the pessimistic estimate of the potential releases from the packages under impact accident scenarios. AWE is therefore requested to provide objective evidence to better define the magnitude of potential releases from the packages. This information can then be used to reassess the consequences of design basis accidents. This would demonstrate whether operational exposures would be tolerable, or otherwise identify the need to provide design enhancements to the package to mitigate such releases.

It is a generally held view that ceramic materials are chemically stable and are likely to be resistant to degradation under the conditions which might be experienced in a GDF. Nevertheless, the effects of self-irradiation over very long timescales are less well understood. It is possible that the ceramic could become less durable with time as a consequence of this self-irradiation, allowing for more rapid rates of chemical dissolution. Given the potentially high fissile content of the ceramic product, it will be important to establish that the ceramic does not age more rapidly than the surrounding cementitious material. This will be necessary to ensure that the probability of post-closure criticality in a GDF remains low.

At this stage, RWMD is confident that the ceramic product should possess durability that is equivalent to, if not more enduring than, the surrounding cementitious materials in a GDF. The expected durability of the ceramic is supported by evidence from natural analogues. However, natural analogues do not contain such high loadings of radioactive elements where radiation damage could influence the properties of the material. Therefore further evidence to demonstrate the durability of the calcium phosphate ceramic will be required to underpin future disposability assessments. In line with this, it is noted that AWE has already commenced studies to evaluate the effects of ageing on the characteristics of the ceramic in

a disposal environment. The conclusions of this work will be important to establish the package safe fissile mass.

Ultimately, it is concluded that it should be feasible to make a disposability case covering transport, handling and disposal of the proposed packages, subject to suitable development work, coupled with the potential to restrict the content of each package to demonstrate compliance with heat and safe fissile limits.

Recommendations for Future Development Work

A number of areas for further development of the proposals have been identified which AWE will need to address to take the proposals forward for future endorsement by RWMD. The first of these activities is the provision of evidence to better quantify potential release from the packages in impact accidents, to support safety assessments. Once it can be demonstrated that radioactive releases from the packages are small and would not result in excessive exposure, RWMD should be in a position to endorse the proposals at the conceptual stage.

A number of additional Action Points have been raised that would need to be addressed by AWE to underpin the disposability assessment and which would be expected as part of an Interim stage submission. These include:

- Continuing development of the ceramic product, which ultimately needs to show that a good quality product can be manufactured for the full range of expected waste loadings;
- Provision of evidence to support the assumption that the ceramic product behaves in a predictable fashion and does not prematurely age in relation to typical cement wasteforms in the longer term. Such evidence will be essential if credit is to be taken for the properties of the wasteform in immobilising fissile material;
- Better definition of the nature of the waste and ceramic product in terms of volume, radionuclide inventory and number of packages;
- Finalisation of the details of the full waste package, including definition of the cement grout properties and confirmation of in-drum furniture design;
- Completion of a package-specific criticality safety assessment and definition of a package safe fissile mass;
- Development of a data recording methodology that describes what information would be recorded for each package along with details of how this would be obtained, taking due account of uncertainties in the data;
- Preparation of a draft Waste Product Specification and a draft Criticality Compliance Assurance Document for the packages.

RWMD will also seek evidence that the underpinning development activities have been performed under a robust quality management system.

Conclusions

Although the proposed packages are novel and raise unique issues, RWMD ultimately believes that the concept of incorporating the pyrochemical residues into calcium phosphate ceramic is a proportionate approach to manage the risk presented by this waste stream. Furthermore, subject to adequate development work and demonstration activities, the packages as proposed should provide a good quality disposable product. Nevertheless, further evidence is required at the Conceptual stage to fully underpin this position and enable endorsement of the proposals at the Conceptual stage.

The assessment has identified that while the ceramic product may be suitable for disposal via an ILW concept, this may not represent the most optimum approach to disposal. For example, the need to comply with heat limits may dictate a reduced packaging efficiency if the ceramic is required to be distributed between a greater number of final waste packages than currently planned. Previous work by RWMD in assessing the disposability of other plutonium residues has indicated a need to explore a more optimised disposal concept for plutonium-rich wasteforms due to the unique issues that such wastes raise.

The development of a separate plutonium disposal concept is largely being driven by the strategy for managing the UK stock of separated civil plutonium. While the Government's currently preferred option for this material is conversion into mixed oxide fuel for use in third generation civil power stations, alternative management options are being explored with a view to offering the best available solution. RWMD is continuing to develop and assess alternative disposal solutions for plutonium-rich materials to ensure that all potential eventualities are accounted for. Any disposal solution would potentially also offer a more optimised solution for the smaller plutonium-rich waste streams, including the AWE pyrochemical wastes and Sellafield plutonium residues. To this end, RWMD considers that conversion of the AWE pyrochemical residues into a ceramic form would still allow alternative packaging solutions being exploited in the future, should such opportunities arise.

The conclusions from this Assessment Report have been referred to RWMD's Nuclear Safety and Environment Committee (NSEC) for consideration. The conclusions of this Assessment Report incorporate the views of the NSEC.