

Waste Packaging and Encapsulation Plant (WPEP) Periodic Review Including Post-Reprocessing Feeds (Final Stage)

Summary of Assessment Report

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EXECUTIVE SUMMARY

Background

Sellafield Ltd (SL) has been operating the Waste Packaging and Encapsulation Plant (WPEP) since the early 1990s. The plant encapsulates (in cementitious powders) flocs from the Enhanced Actinide Removal Plant (EARP) into 500 litre drums. The EARP receives four main effluent feeds originating from the Thermal Oxide Reprocessing Plant (THORP) and Magnox reprocessing. The drums are stored in the Waste Product Encapsulation Plant Store (WPEPS) and Encapsulated Product Stores (EPS). Future effluent feeds will arise from Post Operational Clean Out (POCO) and decommissioning of THORP and Magnox following the end of fuel reprocessing in 2020. These post-reprocessing feeds (PRFs) would be managed and processed through EARP and WPEP under the existing arrangements. These feeds were previously excluded pending further assurances about the nature of the feeds.

History of Interactions

RWM and SL have had a number of interactions since WPEP commenced operations in the early 1990s starting with the provision of the original Letter of Compliance (LoC) in 1993 for two of the main effluent feeds. This was followed by a LoC for the third main effluent feed in 1997 and the fourth feed in the early 2000s. A number of advice letters and extensions to these previous LoCs for these feeds were provided to SL in the intervening period to the current day. Variations to SL's packaging specifications were also endorsed by RWM from 2011- 2015. Finally, a pre-Periodic Review technical audit was conducted in 2015 in preparation for a Periodic Review. This Periodic Review represents the first full disposability assessment encompassing all WPEP feeds since the plant started operations in the 1990s, and following the production of around 18,000 waste packages to date.

RWM Reference Basis for Assessment and Endorsement

The Disposability Assessment process considers the compatibility of the WPEP packages with the requirements for safe long-term management, including interim storage at the site of arising, transport, emplacement and potentially extended storage underground, and disposal. The current reference basis for such an assessment is the documented disposal system

concept and safety case for a Geological Disposal Facility (GDF) derived from the generic Disposal System Safety Case (DSSC). Further information on the Disposability Assessment process is available elsewhere¹.

The general requirements placed on waste packages for disposal in a GDF are embodied in the Generic Waste Package Specification (GWPS)². Further requirements for particular types of waste package are embodied in the relevant Waste Package Specification (WPS). In the case of the WPEP waste packages, the relevant WPS is that for packages based on the 500 litre drum.

Objectives of the Periodic Review

Radioactive Waste Management Limited (hereafter RWM) (formerly NDA Radioactive Waste Management Directorate (RWMD)) has undertaken a Periodic Review of existing packages of floc manufactured at the WPEP. This Periodic Review is the first comprehensive Disposability Assessment completed for WPEP and is the last of the legacy encapsulation plants at Sellafield to complete a Periodic Review. The objectives of the Periodic Review are to provide SL with:

- An assessment of disposability with the aim to maintain confidence that existing WPEP waste packages in interim storage are likely to be and would remain disposable;
- Supporting advice on disposability including the assessment of non-conforming packages, four outstanding Action Points, and four findings from a previous audit;
- Where appropriate, endorsement of the existing packages via issue of an updated LoC;
- Supporting advice on disposability of PRFs; and
- Where appropriate, removal of the current exclusion of PRF feeds and extension of the endorsement to include PRFs.

The waste addressed by the Periodic Review originates from measures taken to reduce the activity of liquid effluent discharges from the Sellafield site and comprises the following 2013 UK Radioactive Waste Inventory (UK RWI) stream: *2D27/C - Encapsulated Floc from Effluent Treatment*.

Nature of the Existing Waste

The two main liquid effluents transferred to the EARP for processing in WPEP include Bulks and Concentrates:

- Bulks streams consist of a number of streams from both Magnox and THORP operations, and effluents generated in the Solvent Treatment Plant. Bulks floc is produced in EARP and is predominantly an iron

¹ *An Overview of the RWM Disposability Assessment Process, WPS/650/03, April 2014.*

² *NDA, Generic Waste Package Specification, NDA Report NDA/RWMD/067, March 2012.*

hydroxide floc with small quantities of other heavy metals and actinides. A small quantity of phosphates may be retained in the floc and Sodium Nickel Hexacyanoferrate (SNH) is added to remove caesium from the effluent feed and capture it in the floc.

- Concentrates comprise the following and have higher quantities of heavy metals:
 - Medium Active Concentrates (MAC) and Medium Active Liquors (MAL). MAC effluent was actinide-bearing nitric acid packaged at WPEP up until 2003. Additionally, from 2003-2006 MAC was treated with Tetra-Phenyl- Phosphonium Bromide (TPPBr) to capture Tc99 in the floc. MAL effluents originate from solvent transferred from reprocessing operations to tanks which receive wash out liquors from reprocessing. Both MAC and MAL flocs are predominantly iron hydroxide. SNH is also added to remove caesium and capture it in the floc.
 - Salt Evaporator Concentrate (SEC) is actinide-bearing salt-rich nitric acid and is also an iron hydroxide with SNH added to remove caesium from the feed and capture it in the floc.
 - Flocs from B241 originated from the historic treatment of active liquid effluents generated during historic fuel reprocessing. There are six tanks of this floc which is an iron aluminium hydroxide in ammonium nitrate.

Waste Processing and Packaging

The Enhanced Actinide Removal Plant (EARP)

EARP is the waste consignor to WPEP and supports plants associated with both THORP and Magnox reprocessing. It provides the means for the removal of actinides from liquid waste streams. Effluent streams enter EARP where ferric nitrate is added to precipitate iron hydroxide, removing activity into an insoluble floc. The floc is dewatered by ultrafiltration before being sent to WPEP for encapsulation.

The Waste Packaging and Encapsulation Plant (WPEP)

At WPEP, the concentrated flocs are encapsulated in 500 litre stainless steel drums. Floc is transferred to the 500 litre drums where lime and cement is added and mixed using an in-drum paddle to form a solid matrix. A grout cap is added between the matrix top and the drum lid to ensure loose activity on the surface of the matrix grout is immobilised. The drum has a bayonet fitting lid and tang that is embedded in the capping grout. Finished packages are swabbed before export and transfer to the drum store.

Storage

WPEP drums are stored fully retrievable, self-contained, ventilated dedicated waste package interim storage facilities on the Sellafield site. Environmental conditions within these stores are controlled by forced ventilation. The temperature of the stores remains below 30°C throughout the year and relative humidity is maintained below 80%. Condition Monitoring and Inspection (CM&I) strategies are in place for these stores including inspection

of drums to assess the rates of corrosion and the suitability of the storage environment.

Number of Packages

Around 18,000 packages have been produced at WPEP with an additional 10,000 packages forecast to be produced in the future, including packages generated from processing PRFs. Based on this number of drums RWM has calculated the total quantity of waste which has been and will be encapsulated at WPEP to be 9,800m³.

Package Radionuclide Inventory

SL has provided quantitative radionuclide data based on sampling of the feeds. Based on this data, RWM has derived average and maximum waste package inventories. The average package assessment inventory is a weighted average across the four floc waste feeds. The individual radionuclide activity in an average package was calculated under the assumption that there is 350 litres of waste (target floc volume per drum) in a 500 litre drum. The resulting weighted average inventory was then used to derive the assessment inventory parameters at 2040 (assumed time of emplacement in a GDF) and 2150 (assumed time of post-closure of a GDF). For the maximum assessment inventory, the highest activity value from each individual floc type was selected for each radionuclide to create a composite maximum inventory. These inventories were used in the course of the disposability assessment to represent the typical and bounding case waste packages.

Waste Package Properties

WPEP package wasteforms are a homogeneous combination of active floc and cement powders mixed to form the encapsulated matrix with a grout cap. The WPEP wasteform has been well defined and underpinned through comprehensive testing during the late 1980s.

Waste Package Evolution

Once the floc/lime mixture has set, there is negligible interaction between the waste and the encapsulant. Under the current assumption that PRF flocs would be managed to fit within the packaging envelope of existing flocs, the same waste/encapsulant interactions are expected. Any metals contained within the floc would have already reacted so no expansion of WPEP packages is expected due to corrosion of metals. Overall, there is confidence in dimensional stability of cemented EARP flocs through the evaluation of historic samples and from evidence generated through inspection of real packages.

Container Integrity

RWM requires that the integrity of the waste container shall be maintained for a period of 150 years and should be maintained for a period of 500 years following manufacture of the waste package. Existing drums have been in storage for no longer than 28 years (based on the oldest packages). The packages will continue to be interim stored until a GDF is available which is currently assumed to be from 2040 (around 50 years in storage before emplacement in a GDF).

The drums are manufactured from stainless steel grades which have low corrosion rates under controlled environmental conditions. Testing indicates that stainless steels are ductile and would last 2,500 years under suitable storage conditions where chloride contamination and condensation are controlled.

The WPEP wasteform is inorganic, does not contain reactive metals, and is very unlikely to be threatened by Microbial Induced Corrosion. External corrosion due to adverse environmental storage conditions is a credible mechanism which could affect disposability of WPEP packages so CM&I of the storage environment is essential.

The package interim storage facilities were inspected by the Environment Agency and the Office for Nuclear Regulation (and RWM) in 2012 with follow-on inspections from 2013 to 2017. SL has responded to the recommendations raised through these inspections and further demonstrated that there is no evidence of swelling, surface corrosion or degradation of package integrity on any of the WPEP drums inspected. It is concluded that provided SL continues to manufacture adequate wasteforms in line with process specifications at WPEP and implement the defined CM&I strategies, then the evolved WPEP packages would be expected to meet integrity requirements.

Assessment of Disposability

Compliance with the Transport System Design and Safety Case

It is assumed that the waste packages would be transported to a GDF within a Standard Waste Transport Container (SWTC)-285. The total expected mass of an SWTC-285 with four WPEP packages will be approximately 58 tonnes which is below the maximum transport package weight of 65 tonnes.

Therefore, WPEP packages will require either rail or sea transport, although short distances could be made using a Special Category 3 Road Vehicle.

Estimates of the heat output and dose rates from the packages meet RWM requirements and are therefore acceptable. The anticipated peak bulk gas generation rate from WPEP packages is well within the bulk gas generation rate limit of 76 litres per day, therefore the expected bulk gas generation rates from WPEP packages are acceptable.

There are around 12,500 existing WPEP packages which contain SNH which is a hazardous compound. SNH is only present in small quantities and is homogeneously mixed within the wasteform. Therefore, no additional packaging arrangements (other than appropriate labelling) are required.

During a fire accident, WPEP packages would experience an increase in temperature resulting in gas and steam release. The WPEP packages containing SNH could be hazardous under some scenarios when traces of hydrogen cyanide (HCN) could be produced under high temperatures. However, any volatilisation of this compound during a fire would be limited to the small quantities available in the outer 10 mm of the wasteform. Therefore, releases in a fire accident scenario are judged not to represent a chemical

hazard. The hazards relating to asphyxiation are likely to inherently outweigh that of HCN.

RWM considers that existing WPEP packages are consistent with meeting transport system design requirements.

Compliance with Engineering Design and the Operational Safety Case

Under normal conditions of operation at a GDF, operators would not be exposed to direct doses from WPEP packages due to remote operations and shielding. The total dose contribution from these packages to the operators is therefore expected to be low and well within the design target.

Under accident conditions, the doses from WPEP packages would be well below the Basic Safety Objective (BSO) for both the public workers. Only a scenario involving impact damage to multiple emplaced packages in the vault due to stack collapse was found to exceed the BSO, but even then the doses were calculated to be well below the most restrictive Basic Safety Level of 20mSv. In any case, none of the design basis fault sequences involving individual waste packages, or small groups of packages, could result in the final safety barrier (the active ventilation filtration system) being rendered ineffective. RWM is developing the safety case for each identified fault and a hierarchy of risk control measures in managing and assessing hazards. The hierarchy starts with eliminating a potential fault and if this is not practical then the consequences should be reduced. This could be achieved by reducing the lift height or passive safety measures. Overall, it is concluded that the radiological risk posed by the handling of WPEP packages in a GDF would be acceptable and well within design targets.

Compliance with the Environmental Safety Case

Technetium-99 (Tc99) is a long-lived fission product with a half-life of 211,000 years and is highly soluble and mobile. It is therefore a key radionuclide of interest in the long-term Environmental Safety Case. Tc99 is expected to be retained in significant quantities in around 2,500 WPEP drums which contain encapsulated MAC floc and found in very small quantities within the other flocs. In reducing conditions the rate of sorption of Tc99 will increase due to its changing oxidation state. Reducing conditions will likely be prevalent at depth in the geosphere. Additionally, reducing conditions are thought to be prevalent soon after closure of the GDF due to the corrosion of steel containers. This will help to retain the technetium within the engineered barrier system. Therefore, though it is a significant radionuclide, the assessed inventory does not challenge the risk guidance level.

Overall, RWM considers WPEP packages to be compliant with the environmental safety case as currently foreseen.

Status of Management System and Data Recording

The data recording system including the system for generating and maintaining waste package records has been evaluated against RWM

requirements. While SL operates a robust records management system, a number of recommendations for improving the indexing of these records have been made to support a future records approvals exercise. This finding is common with the other legacy encapsulation plants at Sellafield where SL and RWM are working collaboratively to develop a common and agreed format for a Package Records Specification (PRS). The learning which comes from these interactions will be extended to the ongoing evolution of the WPEP PRS. Additionally, four long-standing data recording-related Action Points have been assessed and have been shown to be adequately resolved.

RWM is satisfied that the WPEP quality management system is acceptable and compliant with requirements. This includes appropriate container sentencing, including control of non-conforming products.

Sentencing of Non-Conforming WPEP Packages

SL defines non-standard drums as a product drum which cannot be demonstrated to meet manufacturing specifications and/or cannot be demonstrated to be within the appropriate product quality envelope. SL then reviews these non-standard drums and determines whether or not the package is non-conforming or conforming.

Since the start of operations, WPEP has produced approximately 18,000 drums against the defined and underpinned parameters. However, SL has identified that around 42 are non-conforming against the defined parameters³. The nature of the non-conformities includes unsecured lids (5 drums), defective/no/partial caps (33 drums), drum damage (3 drums), the cement content of the cementitious powders is >8% (15 drums), the cement content of the cementitious powders is <8% (ten drums), and no/limited floc/powder mixing (22 drums)⁴. RWM concludes that further work will be necessary to make the non-conforming packages suitable for future disposal and therefore they remain non-compliant until such evidence is provided. SL needs to demonstrate that all non-confirming packages would still maintain the primary safety function of containing active materials under normal operations.

Packages Generated from Post Reprocessing Feeds (PRFs)

SL has indicated that future feeds that may be generated following the end of reprocessing operations would likely possess similar chemical properties to those already treated at EARP and WPEP and that process conditions would be maintained to ensure that these feeds remain within the existing wasteform envelope. However, at the current time, SL has yet to provide evidence to confirm that this is the case, and so PRFs remain excluded from the scope of the current endorsement until this evidence is provided.

Any PRFs that fall outside of the existing envelope and operational capability of EARP and WPEP (such as PRFs containing detergents, surfactants and

³ The total number of drums that had capping grout washed away during the drum decontamination process is unknown and is not included in these figures.

⁴ Note that the total number of non-compliances does not add up to 42 since a number of the 42 drums possess one or more features that are deemed to be non-compliant.

complexants) have not been assessed at this time and so also remain excluded from the endorsement.

PRFs are identified as a specific exclusion from the endorsement for WPEP.

Requirements for Further Work

Nature and Quantity of Waste

SL has made theoretical estimations for the lifetime inventory of I129 and Tc99. Although SL still samples for these radionuclides in order to comply with discharge requirements, they do not use this data to construct their inventories for these radionuclides because the summation of analytical uncertainty leads to significant over-reporting of the activity of these nuclides in both the floc feeds and site aqueous discharges. Instead, the calculated inventories are based on statistical modelling which SL has confirmed to be more representative.

RWM requires that future UK Radioactive Waste Inventory submissions should use the revised figures. Furthermore, because these values underpin the radionuclide inventories used in the RWM assessments SL needs to submit the underpinning reports to RWM as soon as possible. This forms a qualification to endorsement.

Wasteform

The specified iron limit in the wasteform has increased from 108 g/l to 160 g/l. RWM has reviewed the research and development undertaken by SL to underpin the product quality of WPEP packages with up to 160 g/l iron and accepts that suitable packages would be generated. Nevertheless, RWM recognises that the proposed 160g/l is not a true product limit, and it is therefore suggested that this limit is removed from the Waste Product Specification (WPrS). It is recommended that the WPrS (or another suitable document) should be updated to state that the iron content is controlled operationally (due to the thickness of the floc) and is underpinned by the trials to justify the acceptability of the 108g/l iron content and the theoretical maximum of 160g/l.

Criticality Safety

WPEP packages do not currently have representative criticality safety cases covering the transport, operations, and post-closure phases because they do not fit within any of the existing generic criticality safety cases. RWM recognises that WPEP packages represent a low criticality risk due to the nature of the waste, but it has been identified that a package specific criticality safety case needs to be developed that establishes package safe fissile masses for each phase, with demonstration of compliance captured in an updated criticality compliance assurance document. This is a qualification to endorsement for all WPEP packages.

Waste Package Data Records

The WPEP PRS follows a format that is common to all Sellafield legacy encapsulation plants. The first of these to be formally evaluated by RWM is the PRS for MEP. In the course of the MEP PRS evaluation, RWM has

identified that the format of the PRS does not align entirely with RWM expectation, although the logic in the approach that SL has proposed shows some merit. As a consequence of this uncertainty, and in order to ensure the future success of the records approvals process, it has been agreed that it will be necessary to carry out an initial trial to establish the usability of the plant-level PRS for MEP waste packages as well as the Sellafield site-level PRS. This will seek to confirm that the PRS is suitable for future use in the records approval process for MEP waste packages, or otherwise provide specific guidance for updating the PRS in the event that deficiencies are identified. The ultimate aim of the exercise is to get the MEP PRS into a state where RWM can be confident in its likely success in a future records approvals process. The learning from this exercise will be carried forwards into the PRS's for other legacy plants including WPEP. SL requested to carry forward any learning from the MEP PRS trial in the future update to the WEP PRS. Our review process has also identified a number of areas where the WPEP PRS itself does not fulfil the requirements of WPS/400/03. SL is requested to update the PRS for WPEP in the future in line with these findings, as highlighted through a qualification to endorsement.

RWM recognises that SL retains all relevant package information, but there is also a need to reconcile radionuclide inventory information from the relevant databases to individual WPEP packages to eliminate the risk of losing key information over time. In order to minimise this risk, SL should confirm the back-up arrangements for the raw data and address the outstanding RWM comments identified in the *Radionuclide Inventory Recording for WPEP Products* paper since this is a key document for WPEP data recording practices. RWM emphasise that there is a risk in losing key information over time. In order to minimise this risk, SL should confirm the back-up arrangements for the raw data in the MBSS and hard copy records which contain the majority of key information relevant to WPEP packages.

Conclusions

The disposability assessment has confirmed that existing WPEP packages are compatible with the requirements necessary for storage, transport to a GDF, handling and disposal as these are currently foreseen.

Further work is required to demonstrate the disposability of the 42 non-conforming packages, and so these remain non-compliant at this time. SL and RWM need to work together establish that these packages would fulfil future disposability requirements, in particular maintaining containment of active materials.

Packages that could be generated from future PRFs also remain excluded from endorsement until SL demonstrates and provides evidence that these future feeds are compatible with the existing package envelopes defined in the current WPrS. This should include evidence of any changes to operational arrangements or additional testing to ensure that the PRFs are suitable for packaging at WPEP. This is also likely to require an update to key documents within the QMS.

An updated Final stage Letter of Compliance will be issued with this Assessment Report to summarise this position. The updated Letter of Compliance will include the following qualifications to endorsement, along with exclusions around PRFs:

- An appropriate WPEP package Safe Fissile Mass and package specific CSAs needs to be developed and agreed covering the Transport, Operations, and Post-Closure phases with demonstration of compliance captured in an updated CCAD.
- SL will need to address a number of recommendations made in respect of the Package Records Specification for WPEP before the WPEP package records can be subject to the RWM records approvals process.
- SL will need to revise and submit key documentation which underpin the lifetime inventory estimations for I129 and Tc99.