 Conditioning of Plutonium Residues by Hot Isostatic Pressing and Options for Packaging and Disposal  
(Pre-Conceptual stage)  
Summary of Assessment Report  
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Introduction
Sellafield Ltd has submitted proposals for conditioning a range of specific plutonium and uranium residues from Sellafield (hereafter simply referred to as Pu residues). The proposals are based on sorting, pre-treatment and Hot Isostatic Pressing (HIP) of the residues to form small glass-ceramic, ceramic or copper matrix wasteforms. For the purposes of assessing the suitability of these wasteforms for geological disposal, two options for overpacking the wasteforms to produce disposal packages have been considered. The two options considered correspond to disposal in an Intermediate Level Waste (ILW) geological disposal concept or a High Level Waste /Spent Fuel (HLW/SF) concept.

The proposals for treating plutonium residues have been assessed previously, albeit at a relatively high level, in 2004. The view of the assessment then was that the proposed product was considered likely to be capable of meeting the needs of the disposal concept for ILW, although a number of areas of the proposals were identified for development before this could be confirmed. It was recommended that the next development stage would consider a HLW/SF disposal concept.

The assessment has been performed in accordance with the terms and conditions of the Transport and Packaging Contract between Sellafield Ltd and NDA, and is based on the information provided by Sellafield Ltd.

Scope of Assessment
The Pu residues are highly diverse in nature and originate from BNFL, MoD and UKAEA, but are now understood to be all a liability of the NDA. The submission report identifies in excess of 50kg of plutonium within the residues. The cover letter to the submission report refers to an extended inventory of material, a total of 250kg plutonium and 400kg uranium (small quantities of neptunium and thorium are also stated to be present). Though not presented in the submission documents and correspondence, it is understood that this additional residue material primarily arises from the MOX fuel production process. This assessment covers the full 250 kg of plutonium. The submission breaks down the ‘50kg Pu residues’ into 52 families of materials with differing descriptions, using information available from records, although some families are not well characterised or are described as ‘unknown’.

The assessment has considered the compatibility of the proposed packages containing immobilised Pu residues with the requirements for safe long-term
management, including storage, transport, emplacement and potential extended storage underground, and disposal, as currently expressed for the geological disposal concept and standards and specifications for waste packaging as expressed in the Generic Waste Package Specification (GWPS) for ILW and the Specification for Waste Packages Containing Vitrified High Level Waste and Spent Nuclear Fuel. Where appropriate, the effects of prolonged storage of the waste on the site of arising and during care and maintenance of a geological disposal facility have also been assessed.

The report also provides a draft Assessment of Disposability, intended to demonstrate that the waste packages produced would comply with safety and environmental protection requirements for transport, handling and disposal of radioactive waste as foreseen by RWMD. The assessment has also given consideration to the process by which the residues could be formally incorporated into the developing Geological Disposal Facility (GDF) concepts, since the current inventory, design and supporting safety assessments do not account for these radioactive materials.

The Pu residues described in the proposals assessed here form only a small fraction of plutonium containing materials that may eventually, depending on policy decisions, require disposal. According to the 2007 UK Radioactive Waste Inventory report on other radioactive materials\(^1\), a further 81 tonnes of UK owned plutonium as plutonium oxide is reported, and forecasts that a further 21 tonnes will arise from future reprocessing. RWMD has concluded that the assessment of Pu residues and proposals for conditioning and packaging can be used to inform future thinking on the management of the much larger stocks of plutonium oxide.

**Proposed Packaging Process**

Sellafield Ltd. proposes to remove unsuitable materials, pre-treat the waste and produce wasteforms by HIP. Three wasteform types and associated matrices are proposed:

- Ceramic for materials suitable for solid state sintering, produced to achieve >97% crystalline matrix of zirconolite and pyrochlore
- Glass/ceramic for oxidisable waste components, to contain zirconolite and a vitreous phase
- Metal for non-oxidisable metal, produced using copper powder.

The proposals for characterisation of wastes and their pre-treatment processing are significant, since there is a need to route wastes to the appropriate matrix and convert the materials into a form compatible with HIP. For the ceramic and glass-ceramic matrices, the waste would need to be converted to an oxide powder using high energy size reduction processes and furnace calcination in an oxidising atmosphere. The oxide powder waste feed is blended with a powdered matrix feed, sealed into a HIP can and the can heated in a furnace under high gas pressure to sinter the materials and form a hot pressed compact. Size reduced metal items that cannot be oxidised would be blended with copper powder for Hot Isostatic Pressing.

The HIP compacts would be loaded into steel plutonium product cans for on-site storage and which in the future would be loaded to furniture within disposal containers. For the purposes of the current assessment two options for packaging and disposal have been considered. It has been assumed that a 500-litre drum of similar design to other Sellafield Ltd 500-litre drums would be used for overpacking the residue containers for disposal in an ILW concept, or alternatively a container intended for vitrified HLW canisters or PWR fuel elements would be used for disposal in a HLW/SF concept.

**Summary of Assessment Findings**

**Benefits of Hot Isostatically Pressed Wasteforms**

The assessment of disposability provided in this Assessment Report is at an early stage of development, but it appears likely that the benefits of a high quality ceramic or glass/ceramic wasteform relate primarily to homogeneous mixing of fissile materials and ceramic components and their subsequent resistance to re-distribution, justifying a high safe fissile mass within a waste package and thus minimising the number of waste packages for disposal, unless other factors are more constraining, such as high radiogenic heat output. It could also be argued that there is significant qualitative benefit compared to either raw waste or some other potential wasteform types from a passively safe, stable and robust wasteform. In the future the safety case for the GDF may also benefit from taking credit for the beneficial properties of these wasteforms. It is recommended that Sellafield Ltd identify what minimum product characteristics can be guaranteed by HIP processing of Pu residues.

**Disposability**

A draft case is presented demonstrating that the resulting waste packages are likely to be suitable for disposal. There are some residual questions concerning the acceptability of neutron dose rates and how the additional fissile material may influence a criticality safety assessment for the GDF under post-closure repository conditions. More importantly, it should be noted that GDF concept development to date has not accounted for disposal of Pu residues, mainly because they have not yet been defined as a waste material. Before a Letter of Compliance could be issued it will be necessary to introduce Pu residues into the GDF concept, its design and supporting safety assessments. This is currently being undertaken through the Disposal System Safety Case (DSSC) which is being developed to include consideration of the disposal of plutonium materials. On the assumption that the generic DSSC is published in late 2010, it will be possible before or around this time to consider issuing a Conceptual stage LoC for the production of the primary wasteforms and for future overpacking for disposal. It should then be the aim to progress proposals to achieve Interim and Final stage LoC’s for production of the primary wasteforms.

As the project progresses, Sellafield Ltd will need to develop the details of the process and product envelopes that define the bounds of the wasteform formulations. Future activities to progress this waste treatment process will need to address development of a waste treatment protocol and processes to ensure wastes which are not compliant with wasteform product envelope(s),
and thus with achieving ascribed wasteform content and properties, are excluded.

At this stage much of the development work has focused on wasteform production. It will also be necessary to develop a data collection and recording system to define, acquire and preserve information on Pu residue primary wasteforms during treatment, manufacture and interim storage. This may affect process design, for example in terms of analysis techniques that may need to be developed and applied.

As part of this assessment simple scoping calculations have been carried out to consider criticality safety of the wasteforms. Based on these simple calculations and an assumption of wasteform homogeneity, a critical mass of at least 200kg Pu-239 is calculated for a zirconolite wasteform. Larger critical masses are calculated for poisoned systems that incorporate gadolinium, hafnium and U-238. Sellafield Ltd is requested to work with RWMD prior to seeking an Interim stage Letter of Compliance to develop a detailed criticality safety assessment, more accurately representing the composition of the wasteform and waste packages. Consideration should be given to inclusion of neutron poisons and the extent of the benefits provided.

It should be noted that RWMD is developing a post-closure criticality safety assessment to address the likelihood and significance of criticality to repository post-closure safety. This is a generic activity within the GDF programme and is not addressed within the context of this specific assessment report. Although the total inventory of fissile materials in the defined Pu residues is modest compared to the 5.5 tonnes of plutonium dispersed within the large volume of ILW, and HIP processing may provide beneficial features to the wasteforms (e.g. slow dissolution and re-distribution of fissile materials), it should be recognised that the concentration of fissile materials will be high compared to ILW or HLW.

Optimisation

Since concepts for disposal of ILW and HLW/SF are not based on plutonium-rich wastes such as Pu residues, they may not necessarily represent optimised solutions for its disposal. For example, ILW is expected to typically have a much lower specific heat output than HIP Pu residues. As a consequence the packaging efficiency would need to be very low to maintain consistency with the basis of existing ILW vault designs which assume an average heat output of less than 6Wm⁻³. This assessment has calculated that nearly 500 off 500-litre waste packages could be required for the 250kg Pu in the ILW disposal route utilising the current vault design. In contrast packaging for the HLW/SF route might be more appropriate given the heat generating nature of these materials and such an approach would require only 18 HLW/SF canisters. However this must be balanced against the implications on disposal facility footprint and suggests careful consideration of the advantages and disadvantages of existing, modified or new options will be required to identify an optimum disposal solution. This would also be significantly affected by the total quantity of plutonium destined for disposal. The benefits of designing a disposal system to suit plutonium materials will be considered as part of development of the DSSC and associated GDF design.

**Conclusion**
Sellafield Ltd has submitted proposals for conditioning a range of specific plutonium and uranium residues from Sellafield. The results of the assessment reported here suggest there is good chance that the relatively small quantity of Pu residues described could be compatible with geological disposal.

The Pu residues form just a small fraction of Pu materials that may eventually, depending on policy decisions, require disposal. Whilst the disposability assessment for Pu residues can inform future thinking on plutonium oxide stocks, the preferred management routes are not dependent on one another. The concepts for disposal of ILW and HLW/SF, are not based on plutonium-rich wastes such as Pu residues, so they are also not yet necessarily optimised for their disposal. The generic Disposal System Safety Case and associated GDF design will explicitly consider options for disposal of plutonium stocks. This work will provide a suitable baseline for further consideration of optimised solutions for Pu residues in 2010-11.