

## Packaging of PFR Mixer Breeder Sections (Conceptual stage)

### Summary of Assessment Report

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### **Background**

UKAEA has sought Conceptual stage endorsement of waste packages proposed for mixer breeder sections from fuel and radial breeder sub-assemblies removed from the Prototype Fast Reactor (PFR) at Dounreay.

This document summarises the results of the assessment carried out by NDA Radioactive Waste Management Directorate (hereafter RWMD) in response to the submitted proposals. The assessment has been carried-out as part of the Letter of Compliance process, whereby RWMD examines the disposability of the proposed waste packages by assessment against ILW packaging standards and specifications and the Phased Geological Repository Concept (PGRC). Further information on the Letter of Compliance process is available elsewhere<sup>1</sup>.

The RWMD Letter of Compliance assessment process provides advice on the suitability of proposals for conditioning higher-activity waste in anticipation of geological disposal. The assessment is based on standards derived from the RWMD geological disposal concept, but is also compatible with a range of other possible long-term management options. The regulators' view is that packages conditioned in anticipation of geological disposal, and assessed under the Letter of Compliance process, will also be also suitable for long-term storage in accordance with Government policy in Scotland.

### **Scope of the Proposals**

The PFR mixer breeder sections were a component of both reactor fuel and breeder sub-assemblies, and were designed to mix the circulating sodium coolant as it passed through and out of the sub-assemblies. The mixer breeder sections also included 'pins' of breeder material (depleted uranium oxide) to provide additional scope for breeding plutonium. The mixer breeder sections were included in the PFR reprocessing programme, although they were removed from the sub-assemblies and reprocessed in separate campaigns. The waste for packaging represents the sections remaining upon cessation of reprocessing at Dounreay.

The mixer breeder sections previously have been considered to be a resource and were not included in the 2004 UK Radioactive Waste Inventory. The waste for packaging consists of 192 intact stainless steel mixer breeder sections containing depleted uranium oxide pellets, 151 of which were derived from fuel sub-assemblies and 41 from radial breeder sub-assemblies. Of these sections, 189 have been irradiated and three are derived from sub-assemblies not irradiated in the reactor. In addition, there are a further four sections that contain solid stainless steel pins that are to be packaged along with the 'fissile' mixer breeder sections.

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<sup>1</sup> *Guide to the Nirex Letter of Compliance Process*, Nirex Document WPS/650, June 2006.

The assessment has considered the compatibility of the proposed packages containing PFR mixer breeder sections with the requirements for safe long-term management, including storage, transport, emplacement and extended storage underground, and disposal, as currently expressed by the PGRC and standards and specifications for waste packaging as expressed in the Generic Waste Package Specification (GWPS).

This report also provides an assessment of disposability under the PGRC. This represents our advice as to the disposability of the proposed waste packages based upon the standards and specifications developed from our disposal concept. This considers safety and environmental protection requirements for transport, handling and disposal of radioactive waste. We would expect the assessment of disposability 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.

Summary of Assessment Inventory		Inventory at 2040	
		Average	Maximum
Number of packages		28	
Total content (TBq per package)		2.0	5.2
Total content (TBq per package)		6.4	29
Total A <sub>2</sub> content (per package)		2000	5300
Fissile content (g)	U-235	410	490
	Pu-239	760	2000
Soluble activity (TBq)	Sr-90	1.8	6.1
	Cs-137	3.3	11
Heat output (W per package)		2.8	11
Dose rate (mSv/hr)	3m from bare package	11	79
	1m from RSTC-285	1.8x10 <sup>-3</sup>	0.018

### ***Packaging Proposals***

The proposed packaging process is to load an appropriate number of mixer breeder sections into a 500 litre Drum, using suitable furniture, and to grout them into place using a 3:1 PFA/OPC grout. This is expected to be undertaken in the proposed Immobilisation and Encapsulation Plant (IEP) at Dounreay. Based on the size and shape of the sections, it is currently assumed that seven sections would be packaged into each 500 litre Drum. This would require 28 drums for the packaging of the waste.

### ***Assessment of Disposability***

The acceptability of the proposed packages has been assessed against criteria established within the PGRC and associated GWPS.

The Assessment of Disposability is based upon a radionuclide inventory supplied by UKAEA. During the review of the inventory data, a number of adjustments were made to capture the full scope of the inventory and to reduce uncertainty in the assessment inventory. UKAEA will be required to justify that this inventory is suitably representative of the PFR mixer breeder sections at Interim stage.

It is expected that a suitable wasteform could be produced from the encapsulation of the mixer breeder sections. NDA is aware of numerous examples of the successful infiltration of solid wastes using a relatively fluid cement grout such as the 3:1 PFA/OPC grout to be used for the encapsulation of solid wastes in the Dounreay IEP. The additional containment by the fuel cladding and wrapper, and the relatively robust nature of oxide-based fuel, provides reassurance regarding the performance of the wasteform.

UKAEA has proposed that the mixer breeder sections would be packaged into stainless steel 500 litre Drums conforming to the proposed solid wastes drum design for the IEP. The utilisation of an existing, modern container design is welcomed. The proposed waste package would also be expected to include suitable furniture, the design of which remains to be finalised. Overall, it is currently concluded that the proposed waste containers potentially offer an appropriate solution to the challenges presented by the safe packaging of the mixer breeder sections.

The IAEA Transport Regulations specify the package requirements for the safe transport of radioactive materials. The assessments of transport safety show that it should be possible for packages containing PFR mixer breeder sections to comply with all relevant criteria if transported in an IAEA Type B transport container with 285 mm thick steel walls, such as the Standard Waste Transport Container (SWTC-285). The most significant issue is the requirement to produce a package-specific criticality safety assessment to demonstrate that the proposed package loadings would be acceptable during transport. It has been judged that sufficient precedents are available to indicate that such an assessment could be produced at the Interim stage.

The performance of waste packages under accident conditions is quantified as a set of Release Fractions (RF) that express the fraction of a package radionuclide inventory that could be released. The expected RF values for the packages containing mixer breeder sections have been evaluated through a comparison with existing data for generic and analogous waste packages to quantify the expected releases. The current operational safety assessment (based on generic RF values) indicates that, in fault conditions, doses could represent a significant challenge to the radiological protection criteria applied by RWMD.

In practice, the robust nature of the uranium oxide pellets and the containment and protection offered by the closed, stainless steel cladding would be expected to minimise releases of activity under accident conditions. The current conclusion, that it should be possible for 500 litre Drums containing PFR mixer breeder sections to be handled and stored safely within a repository based on the PGRC, is therefore based on the assumption that the generic Release Fraction (RF) values are a very conservative representation of the performance of the packages. Further development of more realistic RF values based on the known nature of the sections will be sought at the Interim stage.

The post-closure safety assessment has revealed no significant areas of concern that should prejudice disposal of packages containing PFR mixer breeder sections. This waste stream contains large amounts of fissile material, and at the Interim stage a criticality safety assessment will be required for the post-closure phase, justifying the proposed fissile material loading. The low effective enrichment and the well-defined nature and configuration of the mixer breeder sections give confidence that a post-closure safety case could be produced. Suitable management of the loading of sections into packages may offer further margins to criticality.

In summary, the Assessment of Disposability has concluded that a Radioactive Waste Management Case ultimately could be made for packages containing PFR mixer breeder sections.

## ***Requirements for further development work***

The following issues are considered to be of significance and further information and/or evidence would need to be provided as part of any Interim stage packaging proposal for the PFR mixer breeder sections:

- further justification of the assessment inventory;
- provision of radionuclide fingerprints and methodologies for the determination of package inventories for mixer breeder sections, including quantification of expected uncertainties and errors;
- development of a strategy for package loading (in this case the selection of individual sections for co-packaging) to provide any necessary control of the radionuclide inventory, thereby providing a realistic bounding assessment inventory as the basis for further endorsements, taking any uncertainties into account;
- confirmation that the effect of any previous sodium diffusion into the stainless steel cladding would not significantly increase corrosion rates, thereby undermining the assumed containment of radionuclides within the intact mixer breeder pins;
- develop and justify the wasteform formulation envelope, including any necessary development work to substantiate the proposed encapsulation grout;
- provide a draft Waste Product Specification covering the packaging of PFR mixer breeder sections;
- produce a package-specific criticality safety assessment (covering transport, operational and post-closure phases) for packages containing PFR mixer breeder sections to substantiate the proposed fissile loading. Early interaction with RWMD on this point is encouraged;
- produce and submit a draft of the Criticality Compliance Assurance Document to demonstrate that packaging would be controlled to ensure compliance with the package-specific criticality safety assessment;
- provide the finalised design of the drum furniture required for the placement of mixer breeder sections in the container;
- provide specific RF values for the packaged mixer breeder sections to substantiate the current assumption that the sections offer significantly improved containment compared with generic values derived for packaged solid wastes.

The above points have been raised as a series of Action Points within the Assessment Report.

## ***Conclusions***

The Conceptual stage proposal from UKAEA for the packaging of PFR mixer breeder sections by encapsulation into 500 litre Drums using cement grout has been assessed.

The assessment concluded that the proposed packages would be expected to be consistent with disposal under the PGRC and can be endorsed at the Conceptual stage. The consistency of the proposed waste packages with the PGRC has been demonstrated through the provision of an Assessment of Disposability. It is suggested that the proposals potentially may need to be considered to be MEDIUM or HIGH priority under the current regulatory prioritisation scheme<sup>2</sup>. The principal reason for this judgement is the significant fissile inventory of the proposed packages and the requirement for a package-specific

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<sup>2</sup> *The Management of Radioactive Waste on Nuclear Licensed Sites – Part 1: The Regulatory Process*, Guidance from the Health and Safety Executive, the Environment Agency and the Scottish Environment Protection Agency to nuclear licensees, December 2007.

criticality assessment. UKAEA is therefore advised to seek the necessary interaction with regulators to confirm this position.

A number of Action Points have been raised which will require to be addressed as part of any Interim stage proposals for the waste.