

## Packaging of PFR Raffinate

### (Conceptual stage)

#### Summary of Assessment Report

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#### **Introduction**

This is a summary of an assessment carried out by Nirex in response to a proposal from UKAEA for the packaging of PFR raffinate by in-drum mixing with cement in 500 litre drums.

#### **Background**

The Nirex mission is, in support of Government policy, to develop and advise on safe, environmentally sound and publicly acceptable options for the long-term management of radioactive materials in the UK. This includes all intermediate-level radioactive waste and some low-level radioactive waste (ILW and LLW).

As part of this role, Nirex sets standards and specifications for the packaging of ILW and some LLW, based on its Phased Geological Repository Concept (PGRC). Nirex issues Letters of Compliance when the proposed packaging methods are judged to be capable of producing waste packages that would be consistent with Nirex requirements for long-term management and protection of the environment. This process is intended to minimise the risk of inappropriate treatment, the need for future repackaging or the creation of a new legacy of wastes to be dealt with by future generations, with all the attendant safety, environmental and cost implications. The process of obtaining a Letter of Compliance is embedded in the regulators' arrangements for the conditioning and packaging of ILW, as described in the guidance issued by the regulators.

In line with regulatory guidance, Nirex carries out independent assessment of the specific waste packaging proposals in particular to assess disposability of the proposed waste packages by consideration of requirements for future storage, transport and disposal as embodied in the Nirex PGRC.

#### **UKAEA's Proposals for PFR Raffinate**

The Prototype Fast Reactor (PFR) at Dounreay was designed, built and operated to explore a nuclear fuel cycle based on the use of Pu-239 and U-238. The reactor used a fissile core fuel, consisting of mixed natural UO<sub>2</sub> and PuO<sub>2</sub>, and fertile breeder material, consisting of depleted UO<sub>2</sub>.

The raffinate was produced as a by-product of the reprocessing of approximately 35 tonnes of spent fuel and breeder elements. A quantity of unirradiated fuel and residues from fuel manufacturing were also processed in the same plant, but in separate campaigns.

Fuel and breeder pins were cropped and placed in a brass lined dissolver basket and dissolved in strong nitric acid. Cadmium was added to the dissolver in some campaigns as a neutron poison. The dissolver liquor was fed to the solvent extraction plant to recover the useful actinides. The remaining highly acidic liquor (raffinate) was transferred to a series of four subterranean, high active liquor storage tanks (Tanks 13-16) at Dounreay. The total volume of PFR raffinate is approximately 206 m<sup>3</sup>.

The current strategy for treatment of PFR raffinate is to transfer the liquor to a new processing, encapsulation and storage facility. This facility is being designed to treat a variety of waste streams, including PFR raffinate, DFR raffinate, ADU floc and Dounreay solid RHILW.

UKAEA proposes to treat the PFR raffinate by first neutralising the acidic liquor, and then blending with cementitious powders in 500 litre stainless steel drums. To minimise excessive heat generation and final liquor volume, neutralisation of the raffinate would proceed by a two-step process.

Cementation in 500 litre drums would proceed by the controlled addition of a 1:1 PFA:OPC feedstock to a metered volume of the neutralised liquor, blended inside a 500 litre drum using a sacrificial in-drum paddle. Once cured, the wasteform would be capped with a 3:1 PFA:OPC grout and lidded.

The waste packages would then be transferred to an adjacent purpose-built, ILW store in the same building to await the availability of a national long-term waste management facility.

The proposals have been identified by UKAEA as representing the Best Practicable Environmental Option (BPEO) for these materials. UKAEA has consulted with stakeholders during the course of the BPEO studies.

## ***Disposability Assessment***

### ***Transport Safety***

The assessments of transport safety show that it will be possible for drums of PFR raffinate to comply with all relevant transport safety criteria if transported in 285 mm thick walled Type B containers such as the SWTC-285. It has been possible using a heat transfer computer model combined with a conservative estimate of appropriate decontamination factors, to show that the performance of the transport package (i.e. the raffinate waste package within the transport container) is expected to be compliant with appropriate transport safety limits.

If packages are produced at the upper-end of the estimated heat-loading a despatch strategy would be required to ensure that these are mixed with raffinate drums at lower heat outputs in order to ensure that the 200 W total heat load limit for the transport package is complied with.

### ***Operational Safety***

The proposed waste packages are at the upper end of the activity spectrum for ILW. This means that the waste packages will have characteristics that place them amongst the upper-quartile that the Nirex repository concept will have to handle. This manifests itself as waste packages with above average heat loading and packages that will be close to operational safety targets. Assessment against the concept Generic Operational Safety Assessment (GOSA) identifies the following issues:

1. The assessed consequences of fire and impact accidents approach the limits for Design Basis Accident fault sequences. This suggests that the packaging system needs to be improved so that the packages provide improved performance under accident conditions, for instance by the utilisation of an annular waste package. Planned work by Nirex to review the operational safety methodology would also help as we envisage that this could lead to removal of some of the inherent conservatism in the current approach.
2. The PFR raffinate due to its origin does not contain a significant fissile loading and hence criticality is not expected to be major concern in practice. However at this conceptual stage the “bounding” package fissile content exceeds the generic screening level and so further work will be required to make the case for criticality safety. We have agreed with regulators that we will adopt the principles of the “band methodology” for operational criticality safety and this is being taken forward within our generic programme.

3. The heat output of the raffinate packages being at the upper end of the spectrum does raise design and safety issues for the Nirex concept. These are not major issues for the emplacement and storage phase but are discussed further under the heading of post-closure.

### ***Post-Closure Safety***

The post-closure safety assessment has revealed no areas of concern that should prejudice disposal of packaged PFR raffinate in the quantities indicated in the submission. It has been noted that the waste packages are at the upper-end of activity but the radionuclides concerned are not those that are considered to be of significance to the post-closure safety assessment.

The high heat output from the waste has been noted. At the upper-end of the estimate it would exceed the package temperature target specified within the Generic Waste Package Specification (GWPS) for the time of backfilling. As the packaging proposal is developed further improved waste inventory information will remove uncertainty from heat-output estimates and the package may fall into compliance. If heat loading remains a concern then special measures might be called for to limit temperature rises after backfilling. Various solutions are available including emplacement at the edge of vaults, provision of increased spacing or emplacement with low heat loading waste packages.

The packages possess no other features that might adversely affect repository post-closure performance.

### ***Potential Design Improvements***

In order to assess the proposed waste packages against Nirex packaging standards and specifications and concept safety assessments it is necessary to have an understanding of the characteristics and performance of the proposed waste package. In the case of PFR raffinate UKAEA has supplied research and development results which give confidence in the viability of the proposals and give a foundation for the future development programme. The Assessment Report includes a number of Action Points directing UKAEA to future development work needed to complete the disposability assessment.

The key areas are:

- Development of the detailed design of the 500 litre drum waste package. The design will need to incorporate features to provide enhanced performance under fire and impact accident conditions such as by provision of a grout annulus or double-skinned wall.
- The development of an optimum wasteform formulation. Initial work gives confidence that a cementitious wasteform can be used successfully for the incorporation of PFR raffinate. Further development is required to optimise the formulation of the cement based wasteform to provide maximum immobilisation of activity and hold-up of potentially soluble radionuclides such as Cs-137 and Sr-90.

### ***Other Requirements***

At future LoC stages of submission, UKAEA will also need to comply with various mandatory requirements. These will include:

- to conduct all phases of the PFR raffinate project under an appropriate quality management system (QMS);
- to provide a suitable data recording methodology for the waste packages;
- to consider international safeguards and physical protection issues.
- to provide a Waste Product Specification and Criticality Compliance Assurance Documentation.

## ***Summary and Conclusions***

UKAEA has undertaken a BPEO study to examine options for the conditioning and treatment of high-active liquid PFR raffinate. The BPEO has been shown to be conditioning the raffinate in a cementitious wasteform and packaging as ILW. UKAEA has consulted with stakeholders on this BPEO.

A conceptual stage assessment of UKAEA proposals for the packaging of PFR raffinate has determined that the proposed waste packages are likely to be compliant with the Generic Waste Package Specification and safety assessments underpinning the phased geological repository concept. A conceptual stage disposability assessment has been conducted and an Assessment Report produced.