

Packaging of Windscale Piles Fuel and Isotope Cartridges

(Conceptual stage)

Summary of Assessment Report

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Background

UKAEA has sought Conceptual stage endorsement of the proposed packaging of the fuel and isotope cartridges that remain to be retrieved from the Windscale Piles reactors (Piles 1 and 2).

This document summarises the results of the assessment carried out by NDA Radioactive Waste Management Directorate in response to the submitted proposals. The assessment has been carried-out as part of the Letter of Compliance process, whereby NDA examines the disposability of the proposed waste packages by assessment against intermediate level waste (ILW) packaging standards and specifications and the Phased Geological Repository Concept (PGRC). Further information on the Letter of Compliance process is available elsewhere¹.

Scope of the Proposals

The waste addressed by these proposals comprises approximately 15 tonnes of lightly irradiated metallic uranium fuel cartridges and a substantial quantity of irradiated isotope cartridges that remained in the Pile 1 reactor at Windscale after the fire in 1957. In addition, the small number of irradiated isotope cartridges remaining in the Pile 2 reactor is also included. The wastes are subject to varying degrees of damage, ranging from fully intact to melted and degraded (for some cartridges in the fire-affected zone of Pile 1). The net volume of the waste is small and is expected to give rise to about 150 packages of waste (based on the use of 500 litre drums). Due to the low degree of irradiation, the radionuclide inventory of the waste is moderate and is consistent with packaging and disposal as ILW.

Packaging Proposals

The proposals are based on the premise that all the wastes under consideration could be conditioned, packaged and eventually consigned for deep geological disposal as intermediate level waste. The proposed processing of the waste, subsequent to retrieval, may be summarised as follows:

- separation of the substantially intact fuel and isotope cartridges from more extensively degraded material (debris) using a screen;
- dispensing of the debris to a 360 litre stainless steel liner equipped with a lost paddle for immobilisation by in-drum mixing with an encapsulant (various options for which are currently under consideration);
- dispensing of substantially intact fuel and isotope cartridges to a 360 litre stainless steel liner equipped with a helix to distribute these cartridges throughout the container.

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

These cartridges would then be immobilised by introduction of an encapsulant (various options for which are currently under consideration);

- subsequent transfer of the liners to a buffer store;
- retrieval of the liners from the buffer store for final encapsulation into 500 litre drums using cementitious grout;
- transfer of completed waste packages for storage using either a dedicated store or storage facilities available elsewhere on the Sellafield site.

The nature of the encapsulating material within the liners remains to be determined and at present two types of encapsulating material have been suggested by UKAEA; cementitious grout, such as a grout based on 3:1 mix of pulverised fuel ash (PFA) and ordinary Portland cement (OPC), and polymer. The polymer remains to be selected and although vinyl ester styrene (DT-901) has been used in other applications, UKAEA has proposed that other polymers be investigated.

The waste package would be based on a stainless steel 500 litre drum, the design of which has been developed previously for use in the proposed waste packaging plant at Dounreay.

Assessment of Disposability

The acceptability of the proposed packages has been assessed against criteria established within the Phased Geological Repository Concept and associated Generic Waste Package Specification (GWPS).

The Assessment of Disposability is based upon the inventory data supplied by UKAEA for the fuel and isotope cartridges, but extended to consider greater irradiation of the fuel as a conservative, bounding case. The irradiation of the fuel and isotope cartridges has been extensively reviewed and modelled and this information forms the basis for the assessment inventory. It is expected that these data also will inform the radionuclide fingerprints to be used in deriving waste package inventories.

The proposed waste packages examined herein are consistent with the requirements of the GWPS and the process has been judged to follow established practice by waste producers for the immobilisation and packaging of solid wastes. The immobilisation of the debris by the addition of fluid encapsulant is relatively novel but a similar process has been demonstrated for other wastes. Further development work would be required to select, demonstrate and characterise the chosen encapsulant and to demonstrate that the process as proposed can be implemented in practice.

Existing development work and general information has been assessed by NDA and provides confidence that a good quality wasteform could be produced by the use of a polymer encapsulant. In contrast, currently available evidence indicates considerable uncertainty regarding the reactivity of uranium metal immobilised in cement and therefore it is concluded that the use of a cement encapsulant should not be endorsed at this time.

The assessment of transport safety shows that packages containing fuel and isotope cartridges, whether substantially intact or in the form of debris, encapsulated in polymer can comply with all relevant criteria if transported in 285 mm thick walled Type B transport containers such as the Standard Waste Transport Container (SWTC-285). In particular, the modelling of impact and fire behaviour for groups of four packages in an SWTC-285 shows that the criterion of activity released in a week following a transport accident would be met.

Similarly, the assessment of operational safety shows that it should be possible for packages containing the waste encapsulated in polymer to be handled and stored safely within the repository. The current assessment indicates assessed doses that, in the worst cases, remain considerably lower than the criteria currently applied by NDA. Consideration of the conservatism in the assessments and expected future revisions to methodologies and assumed parameters would be expected to further reduce the assessed doses considerably.

It is concluded that this provides robustness against any future revisions to risk or dose targets.

The potential long-term risk resulting from the disposal of the fuel and isotope cartridges has been assessed. The inventory associated with individual packages is generally not significant, with the exception of the quantity of carbon-14 associated with aluminium nitride (type AIN) isotope cartridges, which could exceed the annual risk target of 10^{-6} if it were to be released over a period of less than 140 years. Further development work is required to demonstrate that the risk from carbon-14 can be managed by the proposed means of packaging and consequently the relevant isotope cartridges have been excluded from endorsement at this time.

A preliminary case has been put forward to establish the safe fissile mass for the proposed packages, which would ensure that a criticality would be very unlikely during transport or operations, or in the post-closure period. The assessment inventory complies with this safe fissile mass, showing that the packages would not present a significant criticality hazard.

In summary, the Assessment of Disposability has concluded that a Disposability Safety Case ultimately could be made for packages containing fuel and isotope cartridges encapsulated in polymer, and that the proposals for the packaging of these wastes can be endorsed at the Conceptual stage (with the exclusion of the isotope cartridges containing carbon-14). During the course of the assessment, areas requiring additional work to progress the proposals beyond the Conceptual stage were identified, and these are summarised below.

Requirements for further development work

It is understood that, in light of the uncertainties regarding the behaviour of uranium in cement, the polymer encapsulant is currently the preferred option of UKAEA. On this basis, the principal requirements for further development, to be reported at the Interim stage, would be as follows:

- resolution of continuing queries regarding the assessment inventory and provision of data for suitable bounding cases;
- identification and characterisation of a suitable polymer encapsulant, with particular emphasis on demonstrable understanding of the mechanisms of chemical and radiolytic degradation, and the physical effects and products of such degradation;
- demonstrate that the selected encapsulant performs satisfactorily in the immobilisation of both intact and degraded fuel and isotope cartridges using the relevant designs of liner;
- development of a package-specific assessment of criticality safety to substantiate the preliminary fissile limit;
- provision of design drawings for the two types of liner;
- further development of proposals for producing waste package records;
- specification of the conditions for the storage of completed waste packages (subsequent to interactions with NDA on store design);
- provision of evidence that activities such as development work have been, and will be, performed under a suitable (Quality) Management System.

As indicated above, the potential release of mobile, gaseous species containing carbon-14 due to the degradation of the type AIN isotope cartridges have been assessed as presenting a potentially significant risk in the post-closure phase. This potential risk may be addressed through the use of a suitable barrier material to inhibit degradation by excluding groundwater for a sufficient time period. It is recognised that a polymer encapsulant potentially could provide such a barrier, but at present insufficient evidence is available to substantiate any such conclusion. In light of the significance attributed to carbon-14 releases, further

evidence therefore would be required before the packaging of the type AIN isotope cartridges could be endorsed at the Conceptual stage.

It is currently not possible to endorse at the Conceptual stage the packaging of the fuel using a cement encapsulant, or that of the type AIN isotope cartridges. Prior to such an endorsement, the following issues would need to be addressed satisfactorily:

- demonstration that the packaging of metallic uranium in cement does not result in excessive or unpredictable corrosion and/or the formation of pyrophoric uranium species (such as uranium hydride);
- demonstration that the behaviour of aluminium nitride in cement is understood and does not give rise to unacceptable releases of carbon-14.

Conclusions

The assessment of the proposals has concluded that packages containing fuel and isotope cartridges encapsulated using polymer can be shown to be consistent with disposal under the PGRC and therefore this packaging option can be endorsed at the Conceptual stage. This endorsement would be subject to the exclusion of the type AIN isotope cartridges until such time that it can be shown that the polymer provides a persistent barrier to the ingress of water.

The assessment of the proposals has concluded that packages containing fuel and isotope cartridges encapsulated using cement cannot yet be demonstrated to be consistent with disposal under the PGRC and therefore this packaging option cannot be endorsed at the Conceptual stage.