Radioactive Waste Management Directorate

Packaging of Windscale Pile Reactors Core Graphite and Aluminium Charge Pans

(Conceptual stage)

Summary of Assessment Report

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Background

UKAEA has sought Conceptual stage endorsement of the proposed packaging of the core graphite and aluminium charge pans which will be generated from the decommissioning of the Windscale Pile 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 elsewhere[1].

Scope of the Proposals

The two Windscale Pile reactors (also known as the British Production Piles) were operated by UKAEA at the Windscale site during the 1950s with the primary aim of producing nuclear materials for military purposes. The Piles were also used to produce a range of other radionuclides through the activation of selected precursor materials introduced into the reactors as 'isotope cartridges'. The reactors were fuelled with slightly-enriched metallic uranium fuel and operated with a relatively low neutron flux and short irradiation times.

The reactors were graphite-moderated and air-cooled. The operating regime resulted in a relatively low temperature during normal operations and it was found that significant quantities of stored energy (Wigner energy) were built-up in the graphite core. This resulted in the requirement for a regime of periodic annealing of the core, achieved by allowing the core temperature to rise under controlled conditions to significantly increased temperatures. In 1957, unexpected problems during an anneal of Pile 1 resulted in a major fire in the reactor core, causing considerable damage to the core and a proportion of the fuel charge and isotope cartridges present. Subsequent to the extinguishing of the fire, Pile 1 was made safe and left in a passive state to await eventual decommissioning. Pile 2 was not damaged but was de-fuelled soon after the fire and also left, without being annealed, to await future decommissioning.

The wastes that form the subject of the current submission are the core graphite of the Windscale Pile Reactors and aluminium charge pans (these are mounted on the charge face graphite blocks using self-tapping screws). Extra material from Pile 1 comprises relatively small quantities of graphite dowels which formed part of the fuel stringer assemblies, the exact quantities of which are subject to some uncertainty, and residual fuel debris remaining

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

after a separate fuel and isotope cartridge removal programme. It is the stated intention that loose particulate and fuel debris will be segregated from the waste for separate treatment and these wastes are outside the scope of this assessment.

The wastes covered by the current submission comprise 2004 UK Radioactive Waste Inventory waste streams 5F302 (Windscale Pile 1 Undamaged Graphite) and part of 5F313 (Windscale Pile 1 Miscellaneous ILW). The submission also refers to 5F304 (Windscale Pile 2 ILW) however this appears to contain erroneous data as 5F304 reports 0% wt graphite. It appears that Pile 2 core graphite is not included in the 2004 UK Radioactive Waste Inventory. This has been acknowledged by UKAEA who have committed to rectifying this for the 2007 inventory returns. The inventory used as the basis for this assessment differs from that reported in the 2004 National Inventory and does include all the Windscale Piles core graphite expected to require disposal as ILW.

The proposed packaging process is expected to result in the production of up to 422 off 4 metre Boxes (5675 m^3 packaged volume). When compared to a reference case conditioned volume of Shielded ILW (SILW) of 14,000 m^3, the Windscale Pile Reactors Core Graphite and Aluminium Charge Pans constitute a significant fraction of the SILW waste considered in the Phased Geological Repository Concept. Due to the nature of the proposals, NDA Radioactive Waste Management Directorate (RWMD) has judged that this submission would be assigned category W when judged against the classification criteria given in the recent regulatory consultation document for the management of radioactive wastes at nuclear licensed sites (Category W: “Projects or modifications that regulators will wish to be consider and assess in most cases”). This is on account of the volume of waste (2,962 m^3 raw waste) (Category W2A) and on account of the issues raised concerning the use of the 4 metre Box (Category W3C).

Packaging Proposals

Graphite items would be removed using a variety of remote tooling which would be able to lift up to a group of 32 blocks in a 4 x 8 array. These items would be lifted out of the pile cap opening and moved to the waste processing area for placement into “project boxes”. These project boxes would be used to move the waste from the waste processing area to the packaging area and would be loaded into 4 metre Boxes, which would take 4 project boxes.

It is envisaged that the project boxes would be constructed from mild steel and would include furniture to aid their positioning within the 4 metre Box, but no designs have yet been developed for the furniture or the project boxes.

The project boxes would be loaded into 4 metre Boxes as they arise (i.e. there would be no buffer storage of project boxes), up to a maximum of four project boxes per 4 metre Box. It is proposed not to encapsulate these wastes (if required, retrospective infilling would be possible). The completed waste packages would be transferred to the Piles Project ILW store for interim surface storage.

There is potential for significant quantities of stored (Wigner) energy to be present in the graphite material. UKAEA proposes to undertake a development programme to determine the potential for this energy to be released under foreseeable conditions during transport to a repository or emplacement in a repository.

The UKAEA submission indicates that the intention is to design a 4 metre Box for the Piles wastes. This design will build upon the work previously undertaken by Nirex to develop a 4 metre Box. It is proposed that 100mm of concrete shielding will be used, although UKAEA notes that up to 200mm shielding could be used, if required.

UKAEA has not proposed any treatment for particulate recovered from the Piles, or generated during retrieval and packaging. It would not be acceptable for recovered particulates to be added to the wastes in the 4 metre Boxes and therefore this material has been excluded from the scope of the assessment.

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 core graphite and aluminium charge pans, but these data have been revised to create a conservative, bounding case for a package.

UKAEA has proposed not to encapsulate these wastes. Although non-encapsulation represents a significant variation from common practice, it is expected that certain wastes would have the required equivalence in wasteform performance to enable a non-encapsulation proposal to be accepted. UKAEA has argued that such equivalence in wasteform performance could be demonstrated for these graphite wastes and therefore proposes non-encapsulation for the ILW generated from decommissioning. Additionally, non-encapsulation of these wastes ensures that if the wastes require annealing post-packaging, this would be achievable. Encapsulation would present significant challenges to successfully annealing these wastes. This assessment has considered whether non-encapsulation of these wastes would be acceptable and has identified only one area of where the proposals (at the Conceptual stage) are not consistent with the requirements of the GWPS. The GWPS requires a demonstration that voidage is minimised and UKAEA asserts that that voidage would be minimised by the efficient packaging of graphite bricks. However, the proposed volume of waste in an average package is only 5.83 m^3, compared with a package payload of 13.4 m^3 for a 4m box with 100 mm shielding. This implies a voidage of some 56%, so the assertion that voidage will be minimised appears to be inconsistent with the proposed package loading.

It may also be argued that the current proposal to package the waste without annealing the graphite may result in packages that are not passively safe. UKAEA has proposed a work programme to examine the potential for this energy to be released under foreseeable conditions during transport, handling, emplacement or disposal. As a result of this development programme, UKAEA will be required to provide information on waste package performance to enable NDA RWMD to assess the disposability of the wastes. If the information provided by UKAEA cannot demonstrate the passive safety of these packages, then proposals for these wastes could not be endorsed at the Interim stage unless the proposal is changed to annealing the wastes prior to packaging. It is considered that this programme of work will prove extremely challenging and UKAEA should work closely with RWMD throughout this programme. It is not yet clear that the proposed work programme will satisfactorily demonstrate that the wastes do not require annealing.

It has been assumed at this stage that if the graphite requires to be annealed, it will be possible to successfully anneal it. UKAEA will be required to demonstrate this at the Interim stage.

When filled with waste, the 4 metre Box is designed to meet the requirements for an Industrial Package Type 2 (IP-2) Freight Container as specified in the IAEA Transport Regulations and the radioactivity content is restricted to that classified as solid Low Specific Activity (LSA) material or Surface Contaminated Objects (SCO) at the time of transport through the public domain.

The maximum mass of the packages will be in excess of 30t. For packages transported by road, the maximum package mass that can be transported on an ordinary heavy goods vehicle is 30t. Packages with masses exceeding 30t can only be transported by road if they are deemed to be 'indivisible', which is defined in the legislation as being: *"…a load that cannot without undue expense or risk of damage be divided into two or more loads for the purpose of being carried on a road…".*

Guidance on this issue suggests that a waste producer should not proceed with a packaging proposal that leads to the creation of an indivisible load if an alternative packaging scheme is available. It may be possible for UKAEA to make an argument to the DfT to justify the creation of an indivisible load, although there is a potential risk that this would be unsuccessful.

It is not evident that these packages comply with the requirements of the IAEA Transport Regulations for fissile excepted transport packages. On these grounds, it has been concluded that the proposals cannot be endorsed at the Conceptual stage. As noted earlier, the 2004 National Inventory does not include the entire volume of graphite that will require disposal as ILW. The Generic Transport Safety Assessment used the 2004 National Inventory as an input. The proposal to package all of these wastes in 4 metre Boxes, results in increases in accident risk to the public by a maximum of 9.7%. Although this does not result in any limits being breached, it may be considered unacceptable for 422 off 4 metre Boxes of waste to significantly increase accident risk for the entire transport operation to the repository. A robust justification must be made, at the Conceptual stage, to support the proposal to package these wastes in 4 metre Boxes.

The assessment of operational safety has demonstrated the proposed packages are considered to be relatively low risk. This is shown within the Design Basis Accident analysis which, although conservative, gives rise to protected doses well below the most stringent basic safety limits in all but the most extreme (and therefore most unlikely) scenarios. This provides confidence that a safety case can be made for these waste packages, given the conservatisms in the assessments.

The nature of the wastes and the absence of a cementitous encapsulation material is such that that the amounts of radioactive gases likely to be generated are negligible. Similarly, the amounts of hazardous materials or materials likely to degrade to form hazardous materials in this waste are also negligible.

The post-closure safety assessment has revealed no significant areas of concern that should prejudice disposal of packages containing Windscale Pile Reactors Core Graphite and Aluminium Charge Pans.

In summary, the Assessment of Disposability has concluded that it may not be possible to make a Disposability Safety Case for these wastes in a 4 metre Box due to issues related to voidage, generation of particulate and the ability to transport these wastes, and that it is therefore not possible to endorse these proposals at the Conceptual stage.

Requirements for Further Development Work

It has been concluded that it is not possible to endorse at the Conceptual stage. Prior to such an endorsement, the following issues would need to be addressed satisfactorily:

- consideration of the proposed waste loading to ensure that waste loading is optimised, voidage is minimised and generation of particulates through abrasion is minimised;
- a number of issues have been raised due to the proposal to package these wastes in a 4 metre Box;
- the potential for an impact accident to result in a loss of containment to the extent that a subsequent fire accident could result in a very high release fraction.

On this basis, the principal requirements for further development at Conceptual stage are as follows:

- reanalysis of the proposed waste loading, taking account of the proposed design of the project boxes;
- demonstration that the 4 metre Box is an appropriate container for these wastes;

- demonstration that in the event of an impact accident, sufficient protection would be maintained to ensure that release fractions would be acceptable in the event of a subsequent fire accident.

If Conceptual stage endorsement can be issued, the principal requirements for further development at the Interim stage are as follows:

- provision of impact accident performance data;
- demonstration that the graphite wastes do not require annealing;
- demonstration that it would be practicable to anneal the wastes, to avoid the need for re-work at a later stage, should requirements change;
- demonstration that the volume of particulate material per package will be minimised;
- development of detailed container designs including box furniture and proposed project boxes;
- demonstration that the proposed data recording methodology will be sufficient to create package records and to demonstrate compliance with the requirements for fissile excepted packages;
- specification of the conditions for the storage of completed waste packages;
- provision of evidence that activities such as development work have been, and will be, performed under a suitable (Quality) Management System.

Conclusions

The assessment of the proposals has concluded that Windscale Pile Reactors Core Graphite and Aluminium Charge Pans packaged in a 4 metre Box cannot yet be demonstrated to be consistent with geological disposal, and therefore this packaging option cannot be endorsed at the Conceptual stage.