Radioactive Waste Management

Dragon Fuel Waste in Magnox Encapsulation Plant at Sellafield

(Conceptual stage)

Summary of Assessment Report

Issue date of Assessment Report: 25 October 2013

Introduction

The Dragon Reactor was a 20 megawatt high-temperature helium-cooled experimental reactor, used to develop high temperature gas cooled reactors and uranium/thorium fuel cycle technology. The reactor was located at Winfrith, was funded as an international project under the auspices of the OECD, and was operated from June 1965 to September 1975.

A significant portion of the fuel charged to the reactor was driver fuel and consisted of highly enriched (~93% U-235) uranium oxide spheres embedded in a pyrolytic carbon and graphite matrix. Throughout the lifetime of the reactor several different designs and compositions of fuel were trialled to develop understanding of the thorium fuel cycle and materials behaviour.

Following the end of the Dragon project approximately 6.5 tonnes of fuel remained in UK ownership. The fuel was stored at Winfrith in mild steel containers (Full Length Containers). Options for the long-term future of the fuel were considered. Initially reprocessing was explored, but no facility could be found that was capable of the reprocessing task. In recognition that it may take some time to reach a long-term safe management solution, the fuel wastes were re-packaged into 251 high integrity stainless steel Third Length Containers (TLCs) within which they currently reside.

As part of the longer-term storage strategy the materials were transferred from Winfrith to the Harwell site. The transfer operations were completed in 2004. As part of the current NDA-led hazard reduction and exotic fuel consolidation strategy, the fuel wastes are now due to be transferred from the Harwell site to Sellafield.

To support this new approach, a Conceptual stage disposability assessment was produced in 2011 for the packaging of Dragon Fuel Wastes in the Wastes Encapsulation Plant (WEP) plant at Sellafield. The assessment identified 12 Action Points and the packaging proposals were not endorsed.

Sellafield has now sought Conceptual stage endorsement of proposals for the packaging of Dragon fuel wastes within the Magnox Encapsulation Plant (MEP) at Sellafield. In support of this, further inventory data has been provided and a new package-specific Criticality Safety Assessment (CSA) has been developed to underpin the disposability of the wastes.

RWMD reference basis for assessment

Disposability assessment considers the compatibility of the proposed packages with the requirements for safe long-term management, including storage, transport, emplacement and potentially extended storage underground, and disposal. The current reference basis for this assessment of disposability is the conceptual designs for a Geological Disposal Facility (GDF) and the supporting generic Disposal System Safety Case (DSSC). Further information on the disposability assessment process is available elsewhere[1] .

The general requirements placed on Low Heat Generating Wastes (LHGW) packages for disposal in a GDF are embodied in the RWMD Packaging Specifications.

Objective and scope of the assessment

The primary objective of this assessment is to assess new material from Sellafield Ltd, and potentially close out the Conceptual stage Action Points. The disposability assessment produced in 2011 has not been updated. In particular the assessment focused on the close-out of the Action Point relating to criticality safety, which was prioritised for completion after review by RWMD's Nuclear Safety and Environmental Committee (NSEC) in 2011.

The remaining open Action Points were either re-issued with revised wording to reflect the changes to the packaging proposals or closed out if suitable supporting evidence had been provided.

To support the main objective Sellafield Ltd. provided two updated inventories for the fuel wastes: an updated post-irradiation inventory and, for the first time, a pre-irradiation inventory. The main task was therefore to assess these radioactive inventories for the wastes for their veracity and suitability to comply with the packaging limits derived from the recently created package-specific CSA.

This Assessment Report describes the findings of the assessment of the Action Points placed in 2011 by NDA Radioactive Waste Management Directorate (RWMD).

The assessment has been performed in accordance with the terms and conditions of the Transport and Packaging Contract between Sellafield Ltd and Nirex, dated 1 April 2005 (as novated to NDA, Agreement Number 4610000943) under Purchase Order number 9030/4510326522.

Packaging Proposals

Nature of the waste

Dragon reactor fuel assemblies were constructed such that six driver fuel rods surrounded an experimental rod. Therefore a large portion of the Dragon reactor fuel was highly enriched uranium for use as driver fuel within the reactor. Initially the enrichment was as high as 93%, but later charges of driver fuel were of much lower enrichment (~20%). This driver fuel was in the form of carbon/graphite pucks of annular design, called compacts. The compacts contain small spheres, of diameter less than one millimetre, made of enriched uranium oxide and binding materials. These composite fuel particles are surrounded by tough impermeable coatings of pyrolytic carbon and silicon carbide. The particle and the coating are collectively called kernels.

[1] NDA, Guide to the Letter of Compliance Process, NDA Document WPS/650, March 2008

Experimental fuel was mainly of a similar design to the driver fuel except different chemical forms and actinide compositions were utilised in the kernels, i.e. mixes of carbides or oxides of thorium or uranium. A limited number of other designs of experimental fuel were also charged to the reactor. Fuel designs explored were loose kernels contained within carbon/graphite boxes or as carbon/graphite 'teledial' pins.

The reactor was operated under a diverse range of conditions and burn-ups which saw the fuel repositioned many times to maintain reactor control or to specifically test the limits of the materials.

When the fuel was eventually transferred for long-term safe storage into TLCs, it was found that not all of the information on each fuel compact could be clearly read. This resulted in a hierarchy of inventory assignments to the TLCs. Therefore some of the TLCs have less well defined contents, which challenges how the contents of these TLCs can be underpinned to provide confidence for their suitability for long-term safe disposal in a Geological Disposal Facility (GDF).

Waste processing and packaging

The current packaging proposal is to process the wastes through the Sellafield MEP facility. Following receipt, each TLC would be placed in a 500 litre drum fitted with centralising furniture. The 500 litre drum would then be processed in line with standard MEP procedures: filled with cement grout, allowed to cure, capped with grout, lidded, decontaminated, and transferred to the Encapsulated Product Stores (EPS) for interim storage prior to transfer to the GDF. As such the proposal is not to intimately grout the wastes within the TLC, but to effectively entomb the TLCs, creating an annulus of grout within the 500 litre drum.

Assessment inventories and number of packages

The current proposal would utilise the MEP facility at Sellafield where a single TLC would be placed within a 500 litre drum, thereby generating 251 disposal packages.

Assessment basis

The disposal package physical characteristics are such that they fall within the Low Heat Generating Waste (LHGW, which covers most ILW) rather than in the High Heat Generating Waste (HHGW, which generally includes spent fuel) category. It is noted that the wastes have a higher fissile material burden than most LHGW currently being considered, and this may challenge the long-term safe disposal in LHGW compared to the HHGW disposal concept.

Assessment Conclusions

This report details several strands of work to address the Conceptual Stage Action Points:

- Nature and Quantities: assessment of the provenance and veracity of the inventory
- Criticality: assessment of the findings from a package-specific CSA
- Wasteform: assessment of the potential for and consequences of methane generation within the proposed packages
- Other Action Points: assessment of the remaining open Action Points

The main objective of this assessment was to underpin criticality safety for the safe disposal of the wastes in a GDF. The inventory and criticality tasks are interrelated as the findings collectively support the aim to demonstrate compliance of the proposed inventories with the Safe Fissile Masses (SFM) derived in the CSA.

Nature and Quantity of Waste

The original Conceptual stage Action Point required that the waste producer present a corrected radionuclide inventory for the wastes. As noted above, Sellafield Ltd provided two inventories for assessment: an updated post-irradiation inventory and a pre-irradiation inventory. The former of these two inventories provided only radionuclide data, whereas the latter provided radionuclide data and carbon contents of the TLCs. These inventories were assessed for their provenance and veracity as well the likely compliance with the findings from the package-specific CSA.

It was determined that greater confidence can be placed in the pre-irradiation than the post-irradiation TLC inventory data. This is because the post-irradiation TLC inventories have also to rely on the provenance and veracity of the burn-up calculations as well as the accuracy of initial fuel starting compositions (as defined in the fuel element dossiers) and TLC re-packaging notes. Consequently RWMD has concluded that only the pre-irradiation TLC inventories should be used to demonstrate compliance with the SFM derived in the CSA. It is recognised that using the pre-irradiation inventory would derive higher fissile masses for the waste packages. This approach is highly conservative and may present a challenge to the demonstration of compliance with the SFM derived in the package specific CSA.

It was also concluded that further work is required to justify the pre-irradiation fissile and carbon inventory data, as no clear link has been established between the derivation of the data presented and the records for the Dragon project (fuel element dossiers and the TLC re-packaging notes).

The original Action Point placed in 2011 was closed and replaced with a new Conceptual stage Action Point to embody the concerns regarding the veracity of the pre-irradiation fissile and carbon inventory data.

Criticality Safety Assessment

The major safety concern for the disposition of this waste lies with the demonstration of criticality safety. Currently RWMD is undertaking a large research programme to underpin the post-closure criticality safety within the LHGW disposal concept. Early indications were that the proposed Dragon fuel packages lie outside the envelope of wastes considered within this programme. This was the main driver for the production of a package specific CSA, which will derive a SFM for each phase of a GDF (transport, operational and post-closure).

It was found that the most onerous SFMs were for the deterministic evolutionary scenarios in the post-closure period. Despite the fact that the stack collapse post-closure scenario had the most limiting SFM, RWMD believes that a case for ‘selective emplacement’ can be made such that the packages are never stacked above or near to each other. Therefore the most restrictive SFM is the package-scale, post-closure scenario and the fissile contents of the packages will have to show compliance with this limit.

A conclusion from the CSA was that higher SFMs are derived if more carbon is present in the packages (i.e. at higher carbon to uranium ratios). These higher values apply where the carbon is intimately mixed with the fissile portion of the wastes and acts as a neutron diluent.

Currently the deterministic scenario used to derive the post-closure package scale SFM assumes a pessimistic evolution for the carbon content, namely that it is selectively removed from the packages leaving behind only uranium oxide. A new Conceptual stage Action Point has been created to update the CSA to include higher and more realistic carbon contents of the packages. This finding adds extra complexity to the demonstration of compliance of the packages with the CSA, requiring evidence to provide confidence that the carbon contents of the packages are maintained throughout the post-closure period.

Criticality Compliance

By comparing the recently submitted inventories with the SFMs derived in the package specific CSA it is currently believed that, if the fissile inventories and carbon contents of the proposed packages can be adequately underpinned, a case can be made for transport to and handling at a GDF, as the quoted fissile masses do not challenge the derived SFMs.

The post-closure, package-scale SFM currently assumes a very pessimistic scenario regarding the evolution of the packages and wasteforms, so that only 80% of the Dragon packages (using the pre-irradiation data) comply with the defined limit. As such, further justification for disposability for the remaining ~20% of the packages is required, and this is embodied in a further Conceptual stage Action Point for the production of a draft Criticality Compliance Assurance Document (CCAD). The CCAD should present the main aspects of the inventory, which in this case will be the fissile and carbon content of the wastes, along with a justification of the expected errors in those values. The CCAD should also justify the maintenance of a minimum carbon to uranium ratio throughout the post-closure period, thus completing the criticality safety case for the deposition of the packages within a GDF.

Wasteform

Previously, a Conceptual stage Action Point was placed to address the concern that ingress of water into the packages post-grouting would produce an explosive atmosphere by reaction with carbide actinides present in the fuels.

It was shown that it is extremely unlikely that such an atmosphere could be generated within the packages, given the current proposals and nature of the wastes, and in the unlikely case that it were to be formed, there was no plausible mechanism for an initiating event to occur in normal operations. Despite this the consequences were explored, and it was shown that even the maximum plausible energy release did not remotely challenge the integrity and hence safety of the packages. The study concluded by the closure of the Action Point.

Other Action Points

The remaining nine open Action Points, which were created in 2011, were reviewed for their continued relevancy and given the changes to the packaging proposal (i.e. to package the wastes within MEP not WEP as assessed in 2011), several were found to be superseded. These Action Points were closed and new equivalent Action Points opened.

The remaining Action Points were either closed, dependent on the merit of information provided, or reworded to ensure clarity for future interactions.

Conclusions

A Conceptual stage assessment has been undertaken of the updated proposals for the packaging of Dragon fuel wastes at Sellafield through MEP, superseding the previous proposals in the WEP. At the present time endorsement cannot be given and three new Conceptual stage Action Points have been created to capture the outstanding concerns.

RWMD's Nuclear, Safety and Environment Committee has endorsed the conclusions of this assessment and proposed future approach to endorsement.

Approaches to Endorsement

A phased approach to endorsement has been offered should it offer benefits to the progression of the management of the wastes. Should the pre-irradiation inventory be underpinned, endorsement could be offered at Conceptual stage for those packages that meet the post-closure, package-scale SFMs currently reported, subject to RWMD being able to selectively emplace the wastes.