Nuclear Decommissioning Authority

Radioactive Waste Management Directorate

Packaging of PFR Fuel

(Preliminary stage)

Summary of Assessment Report

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Background

A generic concept for the geological disposal of high level waste (HLW) and spent fuel has been developed, initially based on consideration of the HLW stored at Sellafield and spent fuel from the oxide-fueled commercial reactors in the United Kingdom (Advanced Gas-cooled Reactors (AGRs) and Pressurised Water Reactors (PWRs)).

Such a repository represents a potential disposal route for a number of wastes in addition to the commercial reactor fuels upon which the concept has been based, including relatively smaller volumes of other reactor fuels that would not be compatible with packaging and disposal as intermediate level waste (ILW). In recognition of the complexity, diversity and number of such additional wastes, it is anticipated that any extensions of the concept would need to be founded on a process of assessment, applied to each waste on a case-by-case basis (analogous to the Letter of Compliance process adopted for the endorsement of proposals for the packaging of ILW).

In order to develop the necessary assessment process and to establish the availability of the necessary assessment tools, a preliminary assessment for the extension of the spent fuel concept has been undertaken. The remaining Prototype Fast Reactor (PFR) fuel currently stored at Dounreay has been identified as a suitable case for consideration in this assessment. The conclusions of the assessment by NDA Radioactive Waste Management Directorate (hereafter RWMD) are presented in this report.

This assessment has been undertaken using information relating to PFR fuel supplied informally by UKAEA and does not represent a response to a formal proposal by UKAEA. The assumed nature of the PFR fuel, its inventory and the possible approach to packaging represents the understanding developed by the author. Information provided in this report does not necessarily represent the current strategy for the management of PFR fuel.

The PFR fuel currently represents a spent fuel rather than waste and has not been included in the 2004 National Radioactive Waste Inventory.

Scope of the Proposals

The preliminary assessment has considered the 71 essentially intact PFR fuel sub-assemblies and 3266 separated fuel and breeder pins that it understood currently remain in store at Dounreay. This quantity of loose pins would be equivalent to 10-20 additional sub-assemblies, depending on the exact design assumed.

Packaging Proposals

It is assumed that the PFR fuel would be packaged into canisters of essentially the same design as are currently assumed for the disposal of commercial reactor fuels. Based on the geometry of the sub-assemblies, it has been assumed that the assessment of the packaging of PFR fuel should be based on a loading of seven sub-assemblies per disposal canister as a bounding case. This loading would necessitate the use of about 10 disposal canisters.

This represents a small fraction of the total quantity of spent fuel considered in the HLW/spent fuel concept (less than 1% of the number of canisters).

PFR fuel sub-assemblies and loose pins are currently stored in storage containers. UKAEA has indicated that these containers are to be replaced by a new design of container. It is surmised that these storage containers also would be used to facilitate the handling and packaging of PFR fuel for disposal.

The current concept for the disposal of HLW/spent fuel assumes that the waste would be packaged at the disposal site. Nevertheless, this expectation is not reflected in the current Lifetime Plans (LTPs) for sites holding spent fuel and HLW, and therefore it has also been necessary to consider the option of packaging at the site of arising (on-site packaging). This latter option would require the transport of PFR fuel within a disposal canister, using a transport system designed for such canisters. Although the options for on-site packaging and packaging at the disposal facility both currently remain possible, it is speculated that the latter ultimately would be adopted. Nevertheless, where appropriate this preliminary assessment has considered the implications of both options.

Assessment of Disposability

UKAEA has supplied information relating to the inventories of the intact sub-assemblies and loose pins currently held in store at Dounreay, including basic dimensions, original enrichment (Pu content), burn-up, cooling time, quantities of U and Pu, the Pu isotopic spectrum, heat output and the inventories of a limited number of key fission products. The supplied information also included some details of the cladding and wrapper materials, but does not provide information on the radionuclides resulting from activation of these materials. This information, supplemented by general activation calculations from other sources, has been used to define average and bounding assessment inventories for the sub-assemblies and the assumed disposal canisters.

Formal assessments of the potential transport of PFR fuel to a disposal facility and the handling, packaging and emplacement of PFR fuel have not been performed, since the necessary underpinning safety assessments, and the relevant toolkits, are not yet available. Consequently, preliminary assessments were performed by simple examination, consideration of existing methods and requirements based on safety assessments for ILW waste packages, and comparison with the assumed inventories of commercial reactor fuels.

The comparison with commercial reactor fuels suggests that many of the significant properties of PFR fuel, in particular the total inventory, dose rate and heat output, are bounded by the case of highly irradiated PWR fuel, despite the high Pu content and higher average irradiation of the PFR fuel. This suggests that a concept developed for commercial reactor fuels potentially would be able to accommodate PFR fuel.

It is recognised that the transport of PFR fuel to a disposal facility prior to packaging for disposal would require a purpose-designed transport container for irradiated PFR fuel. It is known that such a container is under development in France (the IR-500), providing confidence that such a transport container is a viable concept. In the case of on-site packaging, it would be necessary to transport disposal canisters. It is not known if this requirement is practical.

The potential performance of PFR fuel under accident conditions has not been characterised and only limited data of questionable relevance have been identified from other sources, based on analogies with other types of fuel. The RF values so obtained suggest that accident performance is potentially acceptable, but significant additional effort would be necessary to substantiate this preliminary conclusion. It has been noted that the condition of the fuel and cladding, and the containment offered by the transport container, are important uncertainties at present.

In the case of operations at packaging and disposal facilities, the RF values applied suggest that accident performance is potentially acceptable, with the illustrative estimates of the potential releases being below the BSL values as they are currently applied to the PGRC. Nevertheless, the current estimated releases generally exceed the BSO values for both on-site and off-site doses and further optimisation is indicated. It has been noted that the condition of the fuel and cladding, and the containment offered by the proposed new storage containers (should these be used for the disposal of the PFR fuel), are important uncertainties at present. These areas potentially offer significant opportunities to reduce the expected releases.

The principal challenge to the provision of a transport safety assessment has been judged to be criticality safety, due to the high fissile content of PFR fuel, as compared to commercial reactor fuels. It is anticipated that a consignment would contain several times the minimum critical mass of Pu-239 and an explicit and carefully argued case for the safety of the transport would need to be produced. Some confidence in this area may be gained from the understanding that the IR-500 represents a viable concept, although it is noted that the payload of this container is perhaps smaller than has been assumed in the current assessment.

The issue of criticality safety is also potentially a significant challenge to the provision of an operational safety assessment due to the extremely high fissile content of PFR fuel, as compared to commercial reactor fuels. In the absence of a detailed definition of the relevant Design Basis Accidents (DBA), it has not been possible to determine whether the necessary re-organisation of the fissile material into a reactive configuration is plausible, with the properties of the fuel sub-assemblies again being recognised as an important uncertainty. Nevertheless, the previous handling and storage of the PFR fuel gives grounds for optimism.

Overall, it is judged that, once general transport and operational safety assessments for the HLW/spent fuel concept have been developed, the extension of such assessments to encompass PFR fuel potentially would be viable. Nevertheless, significant additional and specific work would be required for PFR fuel, particularly in the areas of accident performance and criticality safety.

The post-closure safety assessment has also identified criticality safety as a significant issue that could prejudice disposal of canisters containing PFR fuel. It is anticipated that further work would be required to underpin the expected evolution of the fuel, to establish the basis for a criticality safety assessment. It is also noted that the risk of a criticality in the post-closure period could influence the design of the canister (including a possible need to incorporate neutron poisons or to limit the permitted fuel loading).

The remaining potential risks arising from PFR fuel, in particular those due to the simple radionuclide inventory, have been assessed to be relatively small compared to those due to the expected larger quantities of commercial reactor fuels. On this basis, it is currently concluded that the PFR fuel could be accommodated within a disposal facility dominated by commercial reactor fuels without significantly perturbing the overall inventory and the resulting risks.

Requirements for further development work

The preliminary assessment of the potential packaging of PFR fuel for disposal under the concept for HLW/spent fuel has identified a number of recommendations for further work that would be required to facilitate any future formal endorsement of such packages. This would be in addition to the further development and codification of the overall HLW/spent fuel concept.

The recommendations arising from the assessment are divided into those relating to information or development work to be undertaken by the waste owner, which should be provided in a formal submission (14 recommendations) and those relating to the development of assessment methods and tools for use by RWMD (12 recommendations).

Conclusions

The preliminary assessment of the acceptability of PFR fuel disposal has been challenged by the absence of a number of important assessment tools, in particular safety assessments for the transport of spent fuel to a disposal facility and the operation of a packaging plant for the fuel. Nevertheless, comparison with relevant aspects of the equivalent cases for the disposal of waste packages containing ILW has allowed some preliminary judgements to be reached. It is also noted that information on the condition and properties of PFR fuel was not available for assessment and the definition of relevant RF values was challenging. Further work in this area is required.

The assessment has highlighted significant differences between PFR fuel and the commercial reactor fuels previously considered in the spent fuel concept, with the former exhibiting relatively large radionuclides inventories, with resulting high dose-rates and heat outputs, and a considerably larger inventory of fissile materials. Nevertheless, the aforementioned comparison has suggested that ultimately the consistency of the packaging of PFR fuel with the existing concept potentially could be demonstrated.

The principal challenge to the acceptance of PFR fuel under the existing concept is the high fissile content compared to commercial reactor fuels and the resulting expectation that specific criticality safety assessments would be required.