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BENEFITS/IMPACTS OF UTILIZING DEPLETED URANIUM SILICATE GLASS AS BACKFILL FOR SPENT FUEL WASTE PACKAGES

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ABSTRACT

An assessment has been made of the benefits and impacts which can be derived by filling a spent nuclear fuel multi-purpose canister with depleted uranium silicate (DUS) glass at a reactor site. Although the primary purpose of the DUS glass fill would be to enhance repository performance assessment and control criticality of geologic times, a number of benefits to the waste management system can be derived from adding the DUS glass prior to shipment from the reactor site.

1. INTRODUCTION

In a companion paper[1] to be presented at the 1996 International High Level Radioactive Waste Management Conference, a new technology is proposed for backfilling spent nuclear fuel (SNF) waste packages with depleted uranium silicate (DUS) glass beads to enhance repository performance and reduce uncertainties in assessing that performance. This technology, which is called DUSCOBS (Depleted Uranium Silicate COntainer Backfill System), (1) reduces radionuclide release rates from the waste package during geologic times and (2) reduces the potential for package or zone repository nuclear criticality events.

In order to fully assess the viability of the DUSCOBS concept, it was desirable to better understand the system implications including benefits and impacts of backfilling a multi-purpose canister (MPC) at the reactor site, and having the DUS glass present during all further handling, transport, and storage activities preceding emplacement in a repository. It has been assumed that the reactor operators would be capable of adequately drying and then backfilling the casks with the DUS glass, and that they would be able to handle the casks should they be slightly heavier than the conceptual design,[2] i.e., that the systems impacts of performing these tasks would not be unacceptable.

2. ANALYSES

A preliminary set of analyses were performed to determine whether such issues as criticality, burnup credit, shielding, and heat transfer in the storage and transport environments would be positively or negatively impacted by inserting the DUS glass at the reactor during MPC loading. This study was undertaken with the support of the

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This study was undertaken with the support of the U.S. Department of Energy (DOE) Environmental Restoration and Waste Management (EM) office, which has been given responsibility for defining beneficial uses of more than 400,000 tons of depleted uranium hexafluoride owned by DOE. EM funded the evaluation because the DUSCOBS concept offers the potential of providing a beneficial use for much of this inventory. The details of the results of these initial studies are published.[3]

The studies undertaken considered the MPC and transportation cask concept developed by the DOE in 1994.[2] Efforts were not made to adapt these designs, to evaluate structural changes which would be needed, or to initiate new designs. The concepts were used only to provide a basis for making top-level estimates of system performance and defining general impacts on the system if the DUSCOBS concept were used with the MPC concept in transport and disposal. Various properties of DUS glass are possible, and if the concept is pursued, optimization of the glass used will be necessary. The properties of the glass were assumed as follows:

- 29.5 wt % U_3O_8, 11.2 wt % CaO, 7.4 wt % Na_2O, and 51.9 wt % SiO_2;
- 0.2% depleted uranium (i.e., 0.0014 wt % ^{234}U, 0.2000 wt % ^{235}U, 0.0009 wt % ^{236}U, and 99.7977 wt % ^{238}U);
- DUS glass density = 4.1 g/cm^3, with an effective density of 2.7 g/cm^3 assuming 65% of space is DUS glass beads; and
- Thermal conductivity (same as dry sand) = 0.33 W/m°C

3. CONCLUSIONS

Shielding, criticality, and heat transfer analyses, and weight trade-off studies were performed. From the brief analyses performed, the following preliminary conclusions were reached.

1. Relative to criticality performance of the transport cask, loading the MPC with DUS glass at the reactor could eliminate all need to consider burnup credit in the design and certification and could significantly cut the costs associated with designing, certifying and operating casks for the Civilian Radioactive Waste Management System (CRWMS) program.

2. Relative to cask shielding, based upon the large MPC/cask concept,[2] significant amounts of the gamma shielding could be removed from the cask body. It was estimated that all of the lead shielding and 15% of the depleted uranium shielding in the cylindrical portion of the cask body could be eliminated. Additional shielding might be eliminated from the ends of the casks, but further studies will be needed to verify this.

3. Relative to heat transfer, adding DUS glass has a negative impact of virtually eliminating radiative and convective exchange of heat between fuel pins. However, the preliminary assessment showed that the loss of these heat transfer mechanisms will be approximately offset by a significant increase in the thermal conductivity between the fuel pins. As a result, the thermal performance of SNF in an MPC/cask configuration loaded with DUS glass is approximately the same as that for an MPC/cask configuration with a gaseous backfill.

4. Relative to the mass of the backfill material, it was estimated that some of the added mass introduced by the DUS glass would be offset by the reduction in gamma shielding in the cask body.

For a design with fixed geometry and fixed number of SNF assemblies (the large conceptual MPC/cask), additional mass would result but the mass growth was projected not to be sufficient to eliminate the concept. The mass of the large MPC/cask system was projected to increase from 109 to 114 tons (an increase of approximately 4,300 kg), an increase which was within the projected limit for the 125-ton MPC/cask.

For a design in which the geometry is modified from that of the large, 125-ton MPC/cask concept, the mass of the system was projected to decrease. In this case, in order to accommodate the added weight of the DUS glass, it was assumed that the MPC wall thickness would need to increase from 2.54 to 5.08 cm (from 1 to 2 in.), and that the number of assemblies loaded into the MPC would decrease from 21 to 17 [pressurized water reactor (PWR) assemblies] and from 40 to 32 [boiling water reactor (BWR) assemblies]. On this basis it was projected that:

a. although the loaded weight of the MPC would increase slightly, the overall MPC/cask system weight would decrease by approximately 10 tons (8,809 kg);

b. the number of shipments would increase by approximately 24% (from about 7,211 to 8,954); and

c. the amount of depleted uranium utilized would increase from about 110,000 tons to 147,000 tons (about 99,800 to 133,400 tonne).

Thus, a number of subsidiary benefits could be derived from filling the void spaces in an MPC with DUS glass for controlling criticality in the repository and improving repository performance assessment if (a) the glass is added at the reactor site, and (b) the system is designed with that in mind.

4. ADDITIONAL STUDIES NEEDED

It must be emphasized that should the DUSCOBS concept be pursued with any seriousness, studies of many factors will be needed to that ensure important systems issues are adequately addressed. This includes:

- developing and demonstrating the ability to produce the DUS glass;
- performing leaching tests on the DUS glass;
- defining a preferred method for loading the DUS glass into MPCs after they have been loaded with SNF assemblies;
- performing design alternative studies and defining costs and benefits of the various alternatives, including assessments of MPC, transportation cask, storage cask, and waste package alternatives; and
- assessing trade-offs for and defining systems and interfaces for a proposed concept applying the DUSCOBS concept to the CRWMS.

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