DEPLETED-URANIUM-DIOXIDE STEEL CERMET FOR SPENT-NUCLEAR-FUEL WASTE PACKAGES

Charles W. Forsberg

Oak Ridge National Laboratory*
P.O. Box 2008
Oak Ridge, Tennessee 37831-6180
Tel: (865) 574-6783
Fax: (865) 574-9512
Email: forsbergcw@ornl.gov

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INTRODUCTION

It is proposed that spent nuclear fuel (SNF) waste package (WP) structural components and the internal basket structures be constructed of a depleted-uranium-dioxide (DUO_2) steel cermet. The cermet consists of DUO_2 particulates embedded in steel. The exterior of the WP would have a layer of C-22 (a high-nickel alloy), copper, or other corrosion-resistant metal with the outer layer chosen to maximize corrosion resistance in the particular geological environment.

The DUO_2 steel cermet (a) reduces the long-term potential for nuclear criticality in the repository, (b) reduces radionuclide releases by altering the chemical environment near the SNF, and (c) beneficially uses excess depleted uranium (DU). The use of a cermet as a one-to-one replacement of steel components in the WP may create an option for use in a second-generation WP that does not require significant changes in the basic repository design or licencing basis. The use of a cermet is not repository design specific; thus, it would be applicable to repository designs throughout the world.

BARRIERS TO RADIONUCLIDE RELEASE FROM A REPOSITORY

WPs have several components to meet the functional requirements: (1) a container for transport of SNF to the underground location, (2) a basket structure to aid the loading of SNF in the WP and prevent nuclear criticality, and (3) a corrosion-resistant outer layer to delay groundwater access to the SNF. The use of a DUO_2 steel cermet in the WP creates added chemical and nuclear barriers, which would further slow the release of radionuclides from the repository by several mechanisms[1].

- *Maintaining chemically reducing conditions*. SNF UO_2 does not degrade under chemically reducing conditions. Radionuclides are trapped in the UO_2 pellets and can not escape until the SNF UO_2 is dissolved in groundwater. The UO_2 must be oxidized to UO_2^{+2} for rapid degradation to occur. Chemically reducing conditions may be maintained after WP failure by adding materials to the WP that remove oxygen from the groundwater. Iron removes oxygen by oxidation to rust. DUO_2 removes oxygen by oxidation to a mixture of U_3O_8 and UO_3"$x$$H_2O$. Iron oxidizes before the DUO_2 does.

- *Removing radionuclides from groundwater*. Recent SNF leaching experiments show certain long-lived radionuclides (e.g., neptunium) are retained[2] by hydrated uranium oxides—such as created by oxidation of DUO_2.

- *Assuring nuclear criticality control*. The average enrichment of LWR SNF is equivalent to ~1.5 wt % ^{235}U in ^{238}U. At Okla, Gabon, natural reactors operated at enrichments as low as 1.3 wt %. Adding DU to the WP would lower the WP enrichment to <1 wt % ^{235}U in ^{238}U and thus decrease the potential for long-term nuclear criticality in the repository[3]. As the WP degrades, the DU mixes with the SNF enriched uranium.

The use of a DUO_2 cermet is preferable to uranium metal in WPs for several reasons. The SNF is UO_2; thus, the addition of DUO_2 to the WP does not create new repository long-term chemical compatibility issues. Uranium oxides are less costly than uranium metal.

USE OF DUO_2 AND CONTAMINATED STEEL

Large quantities of contaminated steel and DU exist. The worldwide inventory of DU, for which only limited uses exist, is $\sim 10^6$ tons with about 40% of the inventory in the United States[4]. There are also large inventories of slightly contaminated steel and nickel. The beneficial use of these materials could avoid significant disposal costs.

CERMETS

There is a large experience base in cermet manufacture. Many cermet reactor fuels have been manufactured. However, the cermet manufacturing costs must be significantly lower for this application compared to traditional applications. This may be viable because (a) the quantities that are required ($>10^5$ tons) are very-large compared to traditional nuclear uses of cermets and (b) the requirements on the cermet are significantly less restrictive. The primary requirement, beyond the use of iron and DUO_2 in the cermet, is to provide structural strength for the WP. Because added cermet improves repository performance, a thicker WP wall is desirable. Consequently, the strength of the cermet can be less than its steel equivalent. The allowable cost for a cermet WP would be higher than a traditional WP because it would (a) improve repository performance and (b) avoid the potentially high costs of disposal of DUO_2 and contaminated steel.

The cermet manufacturing technique includes several steps. Initially DUO_2 and iron powder are mixed and pressed into a flat compact. Very large "picture frames" are fabricated from thick steel sections. The compact is placed in the picture location within the picture frame. A thin sheet of steel is put above and below the picture frame with the compact. The edges are welded together and the compact is vacuum degassed. The entire thick section is heated to a high temperature and rolled into a thinner plate. This creates a cermet with (a) the iron surrounding the DUO_2, (2) the iron powder fused into a single piece by the heating and pressure from the rolling mill, and (c) layers of uncontaminated steel fused to each side of the cermet. These operations are typical of many large, industrial, steel-fabrication activities, and, in principle, are low-cost operations.

CONCLUSIONS

Scoping evaluations indicate the potential value of a DUO_2 steel cermet WP. However, several uncertainties must be addressed before definitive conclusions can be drawn: (a) the tradeoffs between cermet properties and production costs, (b) the economic benefits of avoiding disposal costs for DUO_2 and contaminated steel, and (c) the value of improvements in repository performance.

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