—Summary—

REPOSITORY CRITICALITY CONTROL WITH DEPLETED-URANIUM-DIOXIDE CERMET 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

File Name: Cermet.DuCermet.Criticality
Session: Geological Disposal

Prepared for
Session: Geological Disposal
Embedded Topical Meeting on Practical Implementation of Nuclear Criticality Safety
American Nuclear Society
Reno, Nevada
November 11–15, 2001

Limit: 1000 words
Actual: 823 words

*Oak Ridge National Laboratory, managed by UT-Battelle, LLC, for the U.S. Department of Energy under contract DE-AC05-00OR22725.

REPOSITORY CRITICALITY CONTROL WITH DEPLETED URANIUM DIOXIDE CERMET WASTE PACKAGES

It is proposed that the structural components and internal basket structures of spent nuclear fuel (SNF) waste packages (WPs), which will be sequestered with the SNF at the repository, be constructed of depleted uranium dioxide (DUO_2)–steel cermets. The cermet used for the WP basket would also contain neutron absorbers with high-absorption-cross-sections such as boron or rare earth oxides. This strategy would provide both operational and long-term (repository post-closure) criticality control. As the WP degrades, the ^{238}U in the depleted uranium (DU) would mix with the degrading SNF and isotopically dilute ^{233}U and ^{235}U to levels (<1 wt % ^{235}U in ^{238}U; <0.66 wt % ^{233}U in ^{238}U) that ensure critically will not occur. It is currently projected that most of the other fissile materials, such as ^{239}Pu, will have decayed to ^{233}U or ^{235}U by the time that significant degradation of the SNF and WP has occurred.

The cermet consists of DUO_2 particulates embedded in a continuous-steel phase (Fig. 1). Typical cermets use sandwich construction with a clean uncontaminated steel layer on each side of the cermet. The DU cermet can be used for structural components, shielding, and the basket. Different grades of steel may be used for the various applications, and the ratio of DUO_2 to metal will be different. If a cermet were used for the WP body, an outer layer of corrosion-resistant metal would be chosen to maximize corrosion resistance in the particular geological environment. Cermets may meet near-term WP requirements (structural support, radiation shielding, criticality control) while (1) improving the repository post-closure WP performance, (2) beneficially using excess DU, and (3) addressing the post-closure repository criticality control issue. Cermets could be used as either a first generation or second generation WP.

A DUO_2-steel cermet provides a means for adding DU to a WP in a form where (1) there is no DUO_2 contamination during WP handling operations, (2) the DU is in a ductile form suitable for a WP, and (3) the DU is in a chemical form acceptable to the repository and the Nuclear Regulatory Commission (NRC). The DU chemical form is the same as that of uranium in light-water reactor SNF; thus, repository chemical compatibility issues are minimized. A recent NRC advisory letter on DU disposal indicated that oxides would be an acceptable DU disposal form; however, the letter indicates that significant questions remained about the inclusion of DU metal in a disposal site because of its long-term chemical behavior.

Non-UO_2 cermets are produced in large quantities (>100,000 tons/year) for a variety of applications. Uranium dioxide stainless-steel cermets have been produced with loadings up to 90 vol % UO_2. Cermets have been used as nuclear fuels and are currently being investigated in Europe for use as very-high-burnup pressurized-water reactor (PWR) fuels. Cermets containing integrated neutron absorbers have been manufactured for use in construction of SNF transport and storage cask baskets.

There are operational and long-term criticality control issues associated with a repository. Traditional methods are viable to assure operational criticality control; however, it is difficult to ensure post-closure criticality control. In the post-closure environment (1) the WP will fail, (2) the SNF will fail, (3) the geometry will change with time, and (4) the composition will change with time. The various materials involved (uranium, traditional neutron absorbers, etc.) will dissolve and be transported by groundwater at different rates.

If DU is used in the WP, it will intermix with fissile uranium isotopes as the WP and SNF degrade. Because all uranium isotopes behave similarly in a geological environment, they can not be separated by the environment once they become mixed. DU is the only neutron absorber with this property. The success of isotopic dilution for criticality control depends on three factors:

- *Excess DU*. The greater the excess of DU in the WP, the higher the probability that all fissile uranium in the WP will be isotopically diluted to safe levels.

- *Intermixing*. The greater the extent to which DU is intermixed with the SNF (in the basket vs the WP wall), the higher probability of mixing.

- *Chemistry*. Similar degradation rates of SNF and DU maximize intermixing.

The implications of these factors for different conceptual designs are described and evaluated for several types of cermet WPs. Each of the WPs is a cermet variant of the 21 PWR Yucca Mountain WP with (1) different ratios of DUO_2 to SNF and (2) different design goals [self-shielded, unshielded, etc.].

The above logic would also apply to other types of SNF. Cermets may be particularly useful for the disposal of higher-enriched SNF in cases where long-term nuclear criticality control is a major design constraint.

At present the United States has >500,000 tons of excess DU. Using this DU as a component of cermets in the WP would avoid the disposal costs for this material. If self-shielded WPs are used, the potential exists to use half or more of this inventory. The avoided costs for DU disposal may be a significant factor in the overall economics of DU-cermet WPs.

ORNL DWG 2001-103

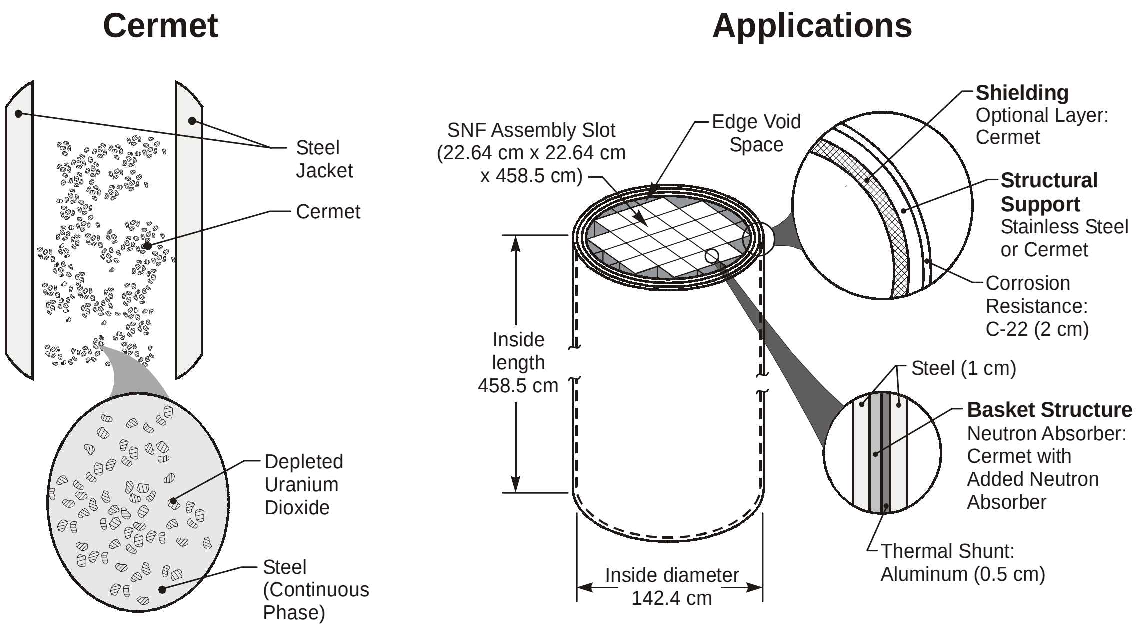

Fig. 1. Cermet characteristics and uses in PWR SNF WP.