—Summary—

DEPLETED URANIUM DIOXIDE–STEEL CERMETS FOR SPENT NUCLEAR FUEL MULTIPURPOSE CASKS

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Multipurpose casks, constructed of depleted uranium dioxide (DUO_2)–steel cermets, were investigated for storage, transport, and disposal of spent nuclear fuel (SNF). The analysis defined the bases for this use of DUO_2-steel cermets and established associated constraints in designing multipurpose casks.

Multipurpose cermet casks would be loaded with SNF at the reactor or initial interim storage location. The multipurpose casks would be used for interim storage, long-term storage, transport, and final geological disposal with no additional handling of the SNF itself. The cask shells would be constructed of a cermet of DUO_2 embedded in the steel which, in turn, would be contained between clean layers of steel. The cask functional design-criteria include: (1) short- and long-term criticality control, (2) gamma and neutron radiation shielding, and (3) physical protection. For short-cooled SNFs, the casks may require an overpack (jacket) to provide augmented shielding and cooling. By the time the SNF is transported from the reactor, this temporary overpack would not be needed. The multipurpose cask alone would provide adequate shielding and cooling capacity. For final disposal, the multipurpose casks at the repository would be inserted into corrosion-resistant overpacks—identical in design to the currently proposed disposal overpacks for disposal of wastes at the Yucca Mountain (YM) repository.

Multipurpose, cermet casks offer several advantages.

- *Safeguards and physical protection*. The multipurpose casks (1) minimize the number of times that SNF is handled [avoids separate transfer of SNF from the pool, to a storage cask, to a transport casks, and to a disposal cask]; (2) minimize the potential for diversion and theft because of their large size; (3) provide strong physical protection compared to many other SNF storage methods; and (4) simplify tracking of the SNF. These benefits may be particularly advantageous in managing highly-enriched and foreign-origin SNF. Compared to other shielding materials, the multilayer structure of cermets may provide stronger physical protection against various accidents and assault scenarios.

- *Criticality control and repository performance*. The depleted uranium in the cermet assists in providing long-term repository criticality control[1] by isotopic dilution—a major benefit when disposing of high-enriched SNF. The cermet may also improve long-term repository performance[2] by slowing the degradation of the SNF.

- *Shielding*. DUO_2-steel cermets may be the highest-performance shielding material[3] that can meet all performance requirements. Cermets provide better gamma shielding than steel because of their higher densities. Cermets have better neutron shielding capabilities than steel because of the high oxygen content that moderates neutrons. High performance shielding materials minimize cask weight and size; in turn, this maximizes cask capacity for any given set of handling constraints. Many of the more efficient shielding materials are prohibited by one or more of the storage, transport, and disposal criteria. An examination of these criteria eliminates (1) chemically reactive materials, such as uranium metal; (2) materials that may impact repository performance, such as concretes, organics, etc.; (3) high-cost materials, such as tungsten; and (4) RCRA metals, such as lead.

- *Repository interim storage and disposal*. Multipurpose casks minimize the requirements for extensive surface facilities at the repository. This is a major cost advantage in managing both U.S. Department of Energy and foreign SNF, which come in hundreds of configurations. It is expensive and time-consuming to develop the capabilities and train operating crews to handle such a wide variety of SNF at the repository. However, handling facilities already exist for each type of SNF at the site where the SNF was generated or is currently stored.

These analyses examined various options for cermet, multipurpose cask systems with the following conclusions:

- *System configurations*. There are potentially large incentives (financial, physical protection, and safeguards) for early transfer of SNF to multipurpose casks at the sites of origin—even though early transfer of SNF may require storage overpacks to enhance short-term cooling and shielding until the SNF decays.

- *SNF cooling*. Methods to improve cask cooling of short-cooled fuel were investigated. Limiting SNF temperatures may be the single most difficult design constraint when storing short-cooled SNF in large casks. A jacket with liquid-filled cooling fins, similar to those used in most electrical transformers, may offer one method to improve cooling performance. The liquid coolant in the jacket would flow by natural convection (1) up the cask wall in enclosed channels and cool the cask; (2) down through hollow fins, where the heat is transferred to the air; and (3) back to the cask wall. The large external area of the fins improves heat transfer to the surrounding air. A jacket with multiple independent flow-circulation loops and the fins minimizes the cooling losses caused by any single leak. The fins provide some cooling by conduction if the coolant was lost. Jackets with liquid-filled fins also provide additional gamma and neutron shielding needed for short-cooled SNF.

- *Repository transfer to final disposal*. At the repository, the multipurpose cask would be placed in a corrosion-resistant overpack. In the proposed Yucca Mountain repository, the inner container with the SNF provides structural support for the relatively expensive, thin-wall (2-cm) repository overpack. Consequently, cooling fins (needed only while the SNF is hot) and any other protrusions to the multipurpose cask must be designed to be removed before the repository overpack is placed over the cask. In practice, these protrusions are likely to be removed before transport of the SNF to the repository.

References

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