Extended Summary

RETRIEVABLE DEPLETED URANIUM DIOXIDE–STEEL CERMET SNF MULTIPURPOSE CASKS

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It is proposed that spent nuclear fuel (SNF) be disposed of in retrievable multipurpose self-shielded casks constructed of a depleted uranium dioxide (DUO_2)–steel cermet. The cask shells would be constructed of a cermet [DUO_2 embedded in the steel], which, in turn, would be contained between clean layers of steel. Multipurpose cermet casks (Fig. 1) would be loaded with SNF at the reactor or at interim storage locations. These casks would then be used for interim storage, long-term storage, transport, and final geological disposal—with no additional handling of the SNF itself. The use of such a cask has significant strategic, engineering, and economic advantages in terms of repository retrievability.

- *Strategic advantages.* The most likely scenario that would require recovery of SNF from a repository is a situation in which the price of uranium has increased and breeder reactor technology has become more economic. Under such circumstances, society will require the fissile materials from the SNF, as well as the DUO_2 itself, both for further extraction of ^{235}U and as a fertile material for reactors. With a waste package (WP) made of DUO_2, the required fissile and fertile materials for such a fuel cycle are in the same package.

- *Engineering*. A self-shielded cask is highly robust and avoids the need for remote-operated equipment in the retrieval process. The conditions of retrieval are unknown and could vary from a repository in excellent condition to one that has experienced some event that partly disrupted the repository. Recovery is greatly simplified and accelerated if the package is sufficiently robust that the impact of a mining machine or other equipment will not cause significant damage to the package. Recovery is also simplified if contact-handling procedures can be used and if there is confidence that high radiation levels will not be encountered. A shelf-shielded package also avoids the need to build a storage facility for recovered SNF. The system is fully reversible in that any casks that are retrieved can be shipped to another site.

- *Retrieval economics*. A self-shielded package greatly simplifies underground operations with significant cost reductions in any retrieval operation. Equally important, the self-shielded package avoids the costs to construct major surface facilities to handle the retrieved SNF. The shielded casks with SNF can be set out in the open.

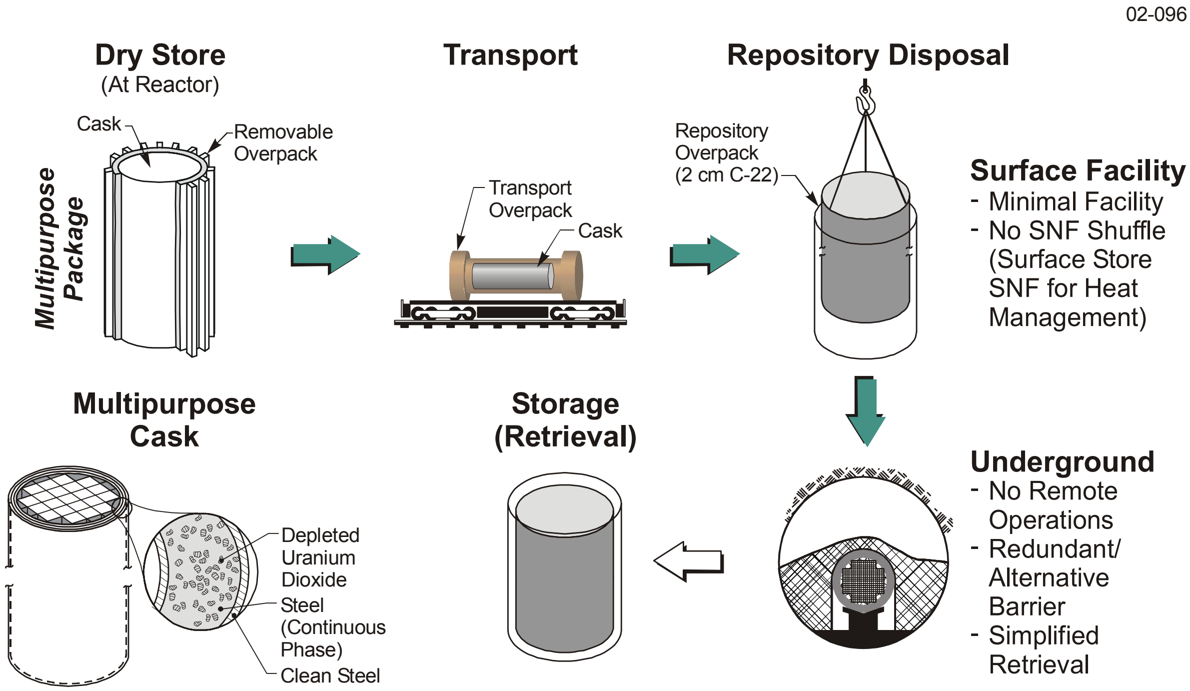

Fig. 1. DUO_2–Steel Cermet Multipurpose Cask System, Including SNF Retrieval.

The proposed system [2] consists of a multipurpose cask (constructed of a DUO_2–steel cermet), a storage overpack, a transportation overpack, and a repository overpack (Fig. 1). The overpacks address conflicting storage and disposal requirements that cannot be easily met by the multipurpose cask.

- *Multipurpose cask.* The multipurpose cask performs several functions: (1) serving as a handling package for SNF from the reactor to the repository and during any retrieval operations, (2) providing primary radiation shielding, (3) offering physical protection against assault and accidents, and (4) functioning as a sealed safeguards package. Multipurpose casks also simplify repository surface operations. To ensure long-term repository performance, decay-heat limits are imposed on each WP. WP heat loads at the proposed Yucca Mountain (YM) repository are to be controlled by selection of hot and cold SNF for each WP, which involves sorting and handling of the SNF. In a multipurpose cask system, casks with high heat loads would be stored until the decay heat in each cask has decreased to the allowable repository WP limits. Thus storage, not SNF sorting and handling, would be used to control WP heat loads. This practice has implications for retrievability. Because any cask recovered from the repository can be used for SNF storage, no SNF storage facility needs to be built if SNF is to be retrieved.

- *Dry storage overpack.* Conflicting design requirements apply to high-capacity cask storage of short-cooled SNF and disposal of SNF. In storage, the primary design constraint is the need to avoid high temperatures, which would degrade the SNF. The storage cask requires a high ratio of surface area to volume (small casks or fins) to dissipate heat. For disposal, the primary design constraint is to ensure long-term WP integrity (decay heat levels are lower). The WP should have a low ratio of surface area to volume to minimize both (1) the interactions between groundwater and the WP and (2) the cost of expensive corrosion-resistant materials. This requirement implies a bare cylinder with smooth surfaces. The use of a removable overpack with heat removal features (fins) during storage can resolve these conflicting performance requirements.

- *Transport overpack.* The transport overpack provides the added protection required for transport. If a multipurpose cask is shipped to the repository, it should be possible to ship the SNF retrieved from the repository in the same cask.

- *Disposal overpack.* The proposed YM WP has an inner container for the SNF and an outer container of a corrosion-resistant alloy (2 cm of C-22). The inner container provides the structural support for the corrosion-resistant overpack. In this proposed system, a multipurpose cask replaces the inner container. The outer container, which remains unchanged, is placed over the multipurpose cask at the repository.

Separate and distinct from retrieval economics are system economics. The nuclear power system in the United States was originally designed for recycle of light-water-reactor SNF and evolved into a once-through fuel cycle. If the system were designed as a once-through fuel cycle, it might look very different from the current system. Recent terrorist events and limits to SNF pool storage capacity have resulted in increased use of dry storage casks. If utilities make the financial investment required for the transition to dry storage casks, the incremental cost of producing multipurpose casks would be expected to be small. Thus, the United States has the potential to adopt a multipurpose cask system for future SNF that simultaneously enhances retrieveability. As is true for any industrial facility that operates for decades, repository operations will change with time, based on experience. It is therefore logical to envision a second phase of repository operation that uses a multipurpose cask system for future SNF that is not already committed to other storage systems. There is a logical non-disruptive pathway from the current system to the new proposed system. The multipurpose cask system provides the maximum versatility to address the uncertainties of the future—including the potential option for low-cost retrieveability.

While multipurpose casks can be built of many materials, there are advantages of DUO_2–steel cermets, beyond the strategic advantages listed above. The DUO_2–steel cermets may be the highest-performance shielding material [1] that can meet all the requirements. High-performance shielding materials minimize cask weight and wall thickness; in turn, this maximizes cask capacity for any given set of size and weight constraints during SNF loading at the reactor, in storage, during transport, and in the repository (tunnel diameter). The greater the SNF capacity of each cask, the fewer casks that must be built and handled.

Cermets provide better gamma shielding than steel because DUO_2 (10.9 g/cm^3) has a higher density than steel (7.8 g/cm^3). Because of the high oxygen content associated with the DUO_2, which moderates neutrons, cermets also have better neutron shielding capabilities than steel. The cermet would include a neutron absorber such as gadolinium oxide for efficient absorption of thermal neutrons. The use of more-efficient shielding materials is prohibited by one or more of the storage, transport, or 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 or organics—the traditional materials for neutron shielding; (3) high-cost materials, such as tungsten; and (4) Resource Conservation and Recovery Act metals, such as lead.

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