A Collaboration to Develop the Next-Generation SNF/HLW Cask

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EXTENDED ABSTRACT

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Abstract—*Several organizations have joined together to develop, design, license, and deploy next generation SNF/HLW casks. These casks will be smaller, weigh less, be capable of higher heat loads, and be terrorist and proliferation resistant. These characteristics are enabled by new materials. The ultimate objective of the collaboration is to develop a single, inexpensive, multipurpose cask that can be used for storage, transport, and final disposition in a geological repository.*

I. INTRODUCTION

The U.S. Department of Energy (DOE) national laboratories have, for some time, been developing new uses for the depleted uranium (DU) contained in the by-product uranium hexafluoride "tails" of enrichment facilities.[1] One obvious application for DU is as a shielding material. Laboratory work to produce new DU shielding materials has progressed to the point of commercialization. Oak Ridge National Laboratory (ORNL) and General Nuclear Services, Inc. (GNSI), are entering into a collaborative research and development agreement to commercialize this shielding material technology into a next-generation spent nuclear fuel (SNF)/high-level waste (HLW) cask.

The objective of this collaboration is to design, license, and deploy next-generation casks that (1) have smaller dimensions, (2) weigh less, (3) are capable of higher heat loading from shorter-cooled SNF, (4) are more terrorist resistant, and (5) are more proliferation resistant. The ultimate objective of the collaboration is to develop a multipurpose cask that can be used in various parts of the nuclear fuel cycle (storage, transport, and disposition).[2]

Newly developed materials that will enable these objectives to be achieved are DU oxide aggregate (DUAGG) in concrete (DUCRETE™) and DUO_2-steel cermets. DUCRETE™ concrete was developed by Idaho National Engineering and Environmental Laboratory[3,4] and licensed to Teton Technologies, Inc., which has nearly commercialized its use for concrete storage casks. ORNL, in cooperation with Teton and GNSI, is continuing its material and processing development for use in steel and concrete SNF transport and storage casks. ORNL is also developing DUO_2 -steel cermets that are specifically designed for SNF casks.

II. PARTICIPANT'S ROLE

Time-dependent objectives of each collaboration participant are shown in Fig. 1, and a schedule of activities is shown in Fig. 2.

	2003	2004	2005	2006	2007
ORNL	Chem testing; optimize DUAGG	Test bricks	Test blocks, conclude mechanical test	Continued longevity chem tests	Final reports
Y-12	Produce ~100 kg for DUAGG lab samples	Produce ~1.2 t for DUAGG block samples			
Russia	Task approved; facility prep	Refine recipe, ship test samples to United States	Produce 100–200 kg of DUAGG; ship to United States		
GNSI	Cask conceptual design	Cask design, modeling	¼-scale demo	Full-scale demo, final design, licensing	Deploy

Fig. 1. Objectives.

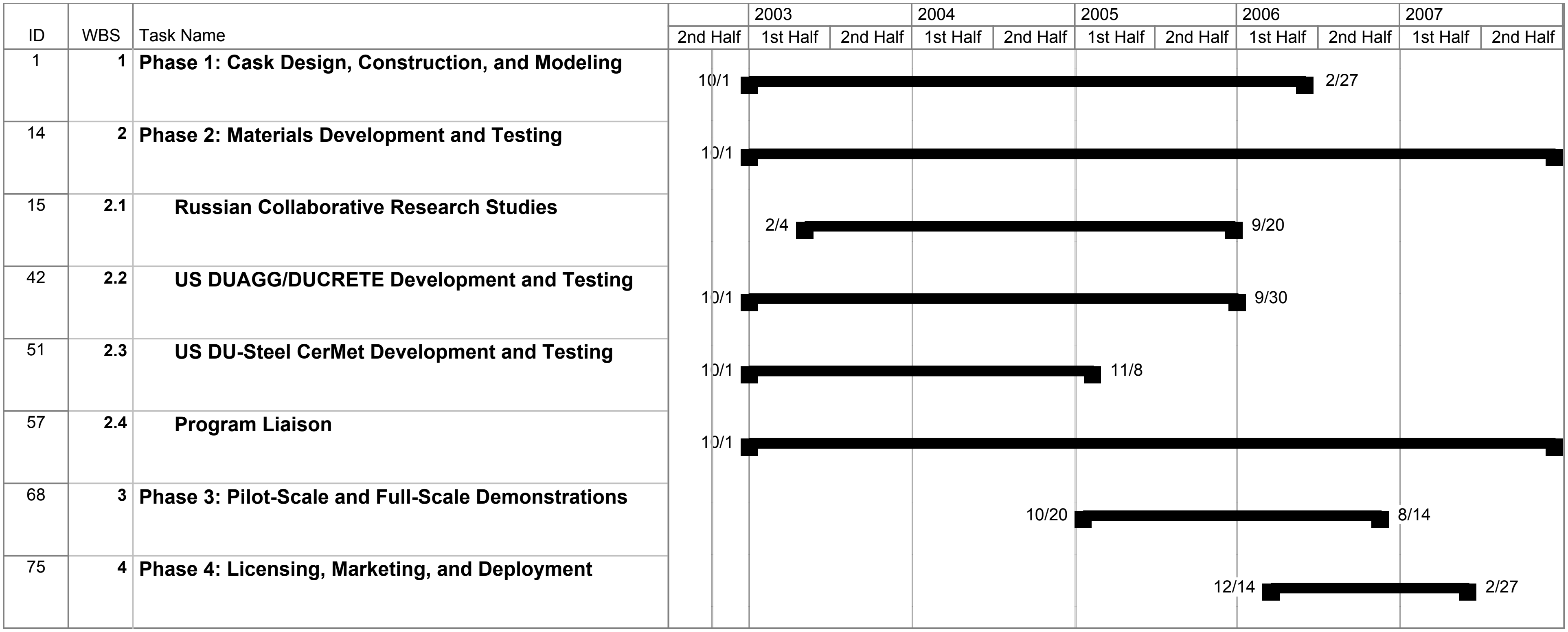

Fig. 2. Collaborative Research on DU Storage Casks: Overview.

ORNL is the lead organization and is responsible for materials development and testing. ORNL generated the agreements that organized the collaboration and is primarily responsible for the integration of each participating organization's work scope to accomplish the collaboration's goal. ORNL is responsible for the chemical and physical testing of new materials. For example, as described below, ORNL is currently measuring the extent and rates of surface reactions of the DUAGG under the simulated chemical environments of cement pastes. Similarly, ORNL is conducting testing programs for DUO_2-steel cermets.

GNSI is responsible for cask design, licensing, and deployment. During the 2002 ANS Winter Meeting[5], GNSI announced that they plan to enter the U.S. cask market by obtaining a U.S. license for their current CONSTOR® cask, which is sold around the world. GNSI's goal is to obtain a U.S. license by 2005 and to begin CONSTOR® deployment in the United States by 2007. A schematic of the CONSTOR® cask is shown in Fig. 3. This figure shows the location of an existing section of heavy (fabricated with steel granules as the aggregate) concrete. Conceptually, a next-generation cask would simply consist of replacing CONSTOR®'s existing heavy concrete with DUCRETE™. However, the collaboration is much more ambitious than this. For example, ways will be sought to reduce or eliminate the rebar matrix present in the existing cask. An ultimate goal is to deploy inexpensive multipurpose casks for use in all aspects of the nuclear fuel cycle, perhaps utilizing DUCRETE or the DUO_2-steel cermet technology.

The Y-12 National Security Complex will refine process parameters and produce test quantities of material. A couple of hundred kilograms of DUAGG will be produced by mid fiscal year 2003, and up to 1.2 t, by the end of fiscal year 2004. This material will be used for brick-size and concrete-block-size physical and mechanical tests. The Y-12 Complex, working with ORNL, will refine the reference recipe (e.g., composition and process conditions) for DUAGG, if value will be added.

It is anticipated that the Russian VNIIEF Laboratory will produce demonstration quantities of new material (i.e. DUAGG). Some material (~100 kg) will be shipped to the United States for next-generation cask testing. The VNIIEF Laboratory, working with ORNL, will refine the reference DUAGG recipe. Also, VNIIEF will produce DU-steel cermet material for testing. Proposals have been submitted to the International Science and Technology Center (ISTC) for VNIIEF to develop both DUCRETE and DU-steel cermet materials.

III. MATERIALS DEVELOPMENT

III.A DUCRETE™

DUCRETE™ consists of a DU ceramic that replaces the DUAGG used in standard concrete. The DUAGG is combined with Portland cement, sand, and water in the same volumetric ratios used for ordinary concrete. This matrix has both high-Z materials for gamma attenuation and low-Z material for neutron attenuation. The DUAGG made from sintered uranium oxide (UO_x) has a very high density (>95% theoretical density). Thus, a theoretical heavy concrete density of - 7.2 g/cm^3 is possible. While the manufacture of DUCRETE™ for a given application is expected to be more expensive than standard concrete, there are circumstances where the reduced volume and weight are expected to yield compensating cost reduction or other advantages. Reference 6 gives a description of DUAGG and DUCRETE technology.

DUAGG is formulated with a "basalt-like" sintering phase that ultimately coats the sintered DUO_2 particles and retards their surface reactions. ORNL is conducting standardized American Society for Testing and Materials exposure tests that greatly accelerate the onset and progress of surface interactions to determine their potential impact on the longevity and durability of DUCRETE™ casks. ORNL's early test results[7] confirm that the surface reactions of DUAGG are much less than expected. Initial results indicate that DUAGG/DUCRETE™ casks can be expected to endure service lives that meet the projected needs of DOE and the commercial nuclear power industry.

IIIB. DUO_2-STEEL CERMET

Cermets are ceramic-metal composites. For DU applications, the cermet consists of DUO_2 particulates embedded in steel with clean layers of steel on both sides of the cermet. The clean layers of steel on the outside of the cermet prevent contamination and make the DU application "invisible" to operations. A cermet would be a good shielding material with somewhat better properties than steel (e.g., a higher density of 9 to 10 g/cm^3). A schematic of a cermet cask is provided in reference 8.

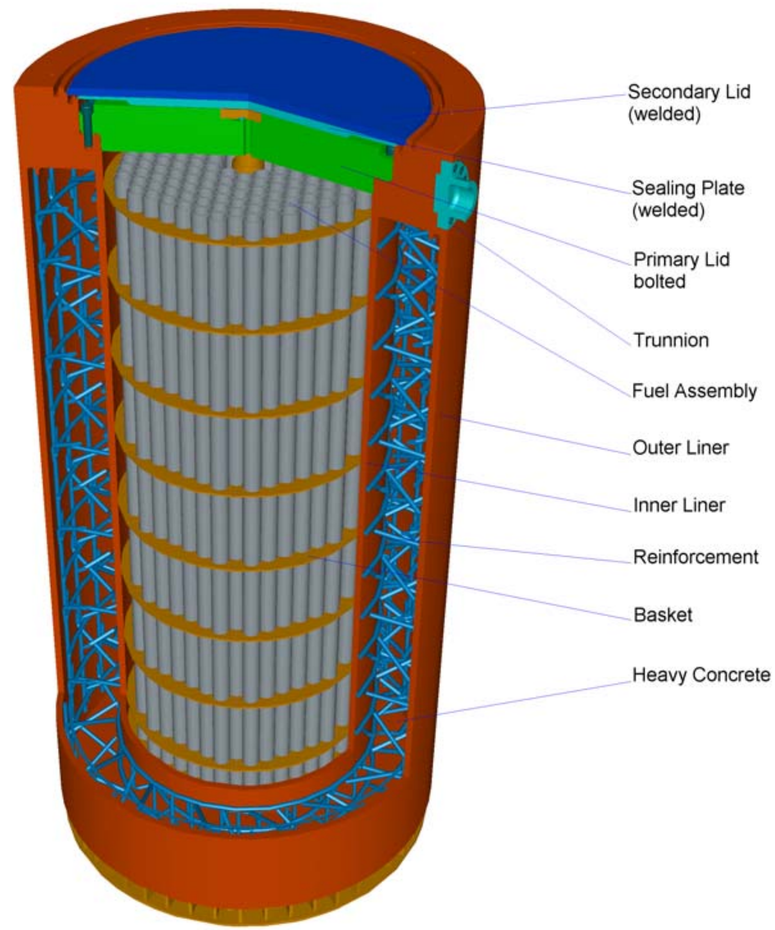

Fig. 3. Multipurpose Constor® Storage, Transport, and Disposal Cask.

High-temperature manufacturing techniques are used to make cermets; consequently, DUO_2 is the preferred chemical form because most other chemical forms of DU would decompose or react with the steel in the production process. Steel-UO_2 cermets have been manufactured in small quantities for use as nuclear fuels. Large quantities of nonuranium cermets are manufactured for other purposes. New methods may allow low-cost heavy-section UO_2-steel cermet production.

The concept of a DUO_2 cermet multipurpose cask system (load SNF at repository, store, transport, and dispose of in same cask) is reported elsewhere at this conference.[2]

IV. ACHIEVING OBJECTIVES

Smaller Dimensions. More efficient shielding characteristics enable smaller shield thickness. For example, use of higher-density DUAGG causes a reduction of a conceptual SNF dry storage cask diameter by -39 in. and the cross-sectional area is reduced from 92 to 44 ft^2. Smaller cask diameters will enable loading and moving next-generation casks on railroad cars.

Lighter Weight. The cask described in the preceding paragraph is 35 t lighter than the cask made with conventional concrete. Cask weight varies as the square of the radius; thus, using a denser shielding material for gamma radiation shielding lowers the overall cask weight.

Higher Heat Loading. A DUCRETE™ cask has a higher thermal loading capacity due to reduced wall thickness and increased thermal conductivity compared with conventional concrete casks. Cermets have a thermal conductivity between that of DUCRETE and that of steel.

More Resistant to Terrorist Attack. Improved resistance of SNF casks to assault has become an important issue as a consequence of the terrorist events of September 11, 2001. DUCRETE is an assault-resistant material when brittle and ductile materials are alternated in cask design. This is a key principle for effective armor. Many types of armor are made of cermets. It should be noted that one of GNB's storage casks survived a TOW missile explosion during testing at the U.S. Army Aberdeen Proving Grounds. Also, a cask survived a simulated airplane crash. The DUO_2 cermet is chosen for its shielding capability and repository performance. These requirements define the materials of construction and the relative amounts of DUO_2 and steel. However, assault resistance strongly depends upon the ceramic (DUO_2) particle size and location of the ceramic within the cermet. Consequently, optimization of the cermet design (within other constraints) can enhance assault resistance.

More Proliferation Resistant. The use of multipurpose casks will reduce the number of handling operations with individual fuel assemblies, thus reducing the potential for proliferation. The accountability and control of storage, transport, and disposal casks are easier than those for a multitude of individual fuel assemblies. The ultimate objective of the collaboration is to develop a multipurpose cask that can be used in various parts of the fuel cycle (storage, transport, and disposition).

V. ACKNOWLEDGMENT

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