RETHINKING MULTIPURPOSE SPENT NUCLEAR FUEL CASKS AND CANISTERS

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Manuscript Date: December 26, 2001
File Name: SNF.Seminar.2002.ArticleII

Article Prepared for
Spent Fuel Management Seminar XIX
Institute of Nuclear Materials Management
Washington, D.C.
January 9–11, 2002

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

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ABSTRACT

The use of multipurpose casks and canisters for storage, transport, and disposal of spent nuclear fuel (SNF) is proposed to avoid the need for separate casks and canisters for each of these tasks. Multipurpose canisters and casks may lower costs and risks by making it unnecessary to move SNF from one container to another and avoid the need for multiple baskets and casks. Although multipurpose casks and canisters have been considered in the past, they were not adopted because of technological limitations and uncertainties in requirements. Recent terrorist events, the approaching licensing of repositories, changes in repository design, new technologies, and new institutional structures may now make multipurpose casks and canisters a competitive approach for SNF management.

1. INTRODUCTION

In the 1980s, the concepts of multipurpose canisters and casks for storage, transport, and disposal of spent nuclear fuel (SNF) were investigated by the Yucca Mountain Project (YMP). Similar studies were performed in other countries. Multipurpose canisters and casks were rejected for several good and sufficient reasons. Many changes that have occurred in the last 20 years that suggest multipurpose casks and canisters should now be reconsidered. This paper identifies and examines these changes that may now make multipurpose canisters and casks a competitive method for SNF management.

1.1 Methods to Manage SNF

There are many ways to store, transport, and disposal of SNF. Options include:

- *Separate casks*. The SNF assembles can be (1) transferred from the reactor SNF pond to a dry storage cask, (2) stored in a dry storage cask, (3) transferred to a separate transportation cask, (4) transported from the reactor to the repository, and (5) transferred to a waste package (WP) for disposal. Each cask protects the SNF, provides a means of limiting the temperature of the SNF from the decay heat in the SNF, assures criticality control, and provides radiation shielding. The transport cask must also be designed to withstand transport accidents. The disposal cask is designed to remain intact after burial for extended periods of time to minimize the potential release of radionuclides to the environment. This is the conventional approach.

- *Multipurpose canister*. Most storage, transport, and disposal casks contain many SNF assemblies. Much of the cost and risk associated with transferring the SNF from one type of cask to another (such as storage to transport cask) is associated with the labor and radiation exposure from moving the individual SNF assemblies. With a multipurpose canister (Fig. 1), 20+ SNF assemblies are loaded into a thin-walled canister that is welded shut and then placed in the storage cask. The canister can later be transferred as a unit from the storage cask to the transport cask or from the transport cask to the WP. Risk is reduced by transfer between casks of a smaller number of sealed canisters with clean exteriors rather than many SNF assemblies with contaminated surfaces. Costs are reduced by use of the same basket in different casks and simpler transfer operations. The multipurpose canister can be for (1) storage and transportation; (2) transportation and disposal; or (3) storage, transportation, and disposal. The discussions herein refer to multipurpose canisters for all three tasks.

- *Multipurpose cask*. A single cask (Fig. 1) can be used for (1) storage and transportation; (2) transportation and disposal; or (3) storage, transportation and disposal. The cask can be designed to meet all requirements or only a select set with other requirements met by specific overpacks for storage, transport, or disposal. The multipurpose cask differs from a multipurpose canister in that it meets additional functional requirements (shielding and physical protection) beyond those for a multipurpose canister. The discussions herein refer to multipurpose casks for all three tasks.

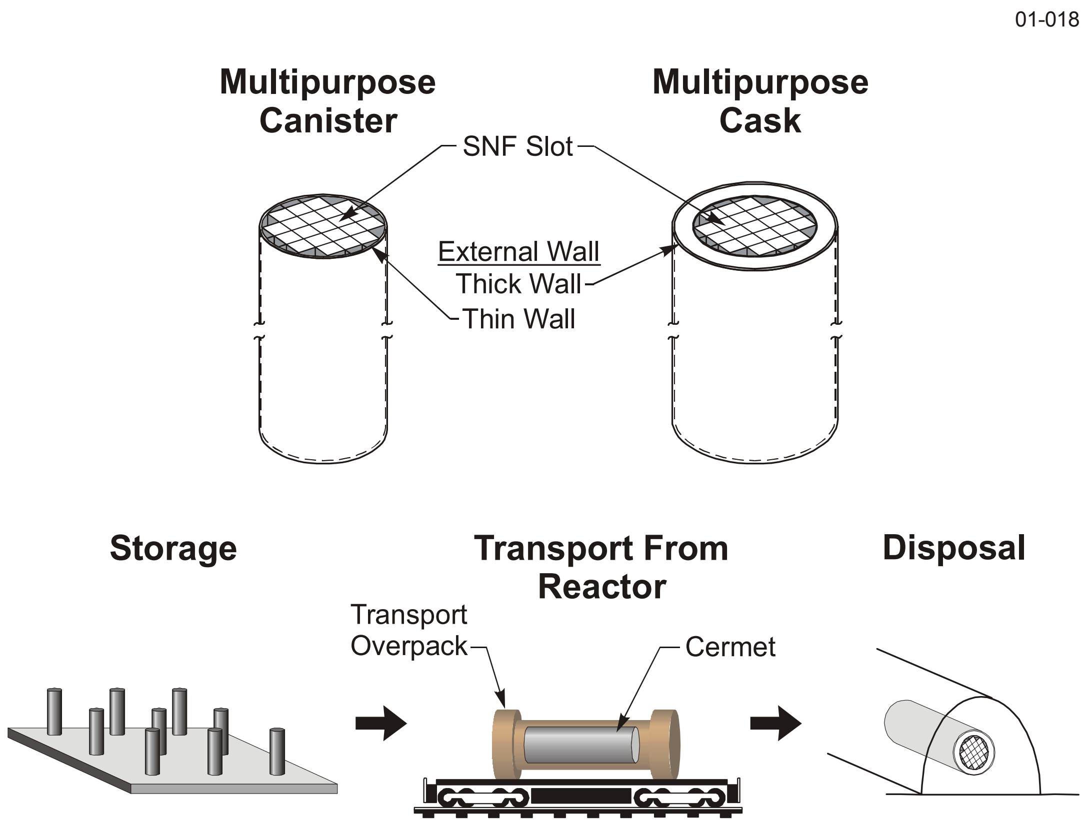

Fig. 1. Multipurpose Canisters and Casks for Storage, Transport, and Disposal.

1.2 Management Requirements for SNF

Three tasks are required for safe management of SNF after discharge from the reactor: storage, transport, and disposal. Each of these tasks has specific requirements. Once the requirements are defined, the preferred system is dictated by economics and institutional considerations.

1.2.1 Storage

When a nuclear reactor is refueled, the SNF removed from the reactor is placed in a pool near the reactor. The water provides cooling for the SNF as well as radiation shielding. The radioactivity and decay heat of SNF decrease rapidly (Table 1, Fig. 2). Even in countries with central storage facilities (e.g., France, Germany, and Sweden.), the SNF is stored at the reactor for several years before transport:

- *Cost*. Truck and rail transport cask capacity is limited by weight. Most of the weight in a transport cask is associated with the radiation shielding. As the radioactivity decreases, the amount of required shielding decreases as well. The reduced weight allows for use of larger casks with more SNF per cask.

- *Risk*. SNF contains many short-lived radionuclides which decay away with a few years of storage. The total radioactivity that must be shipped is thus reduced by a factor of ten or more.

Table 1. SNF Radioactivity and Decay Heat Vs Time[a]

Time from reactor discharge (years)	Radioactivity (curies/MTIHM)	Decay heat (kW/MTIHM)
1	2.4×10^6	10.38
2	1.4×10^6	5.65
5	6.7×10^5	2.22
10	4.7×10^5	1.44
20	3.4×10^5	1.10
30	2.6×10^5	0.91
50	1.5×10^5	0.66
70	9.6×10^4	0.50
85	6.9×10^4	0.42
100	2.4×10^4	0.36

[a]PWR fuel with a burnup of 40,000 MWd/MTIHM; initial enrichment 4.2 % ^{235}U.

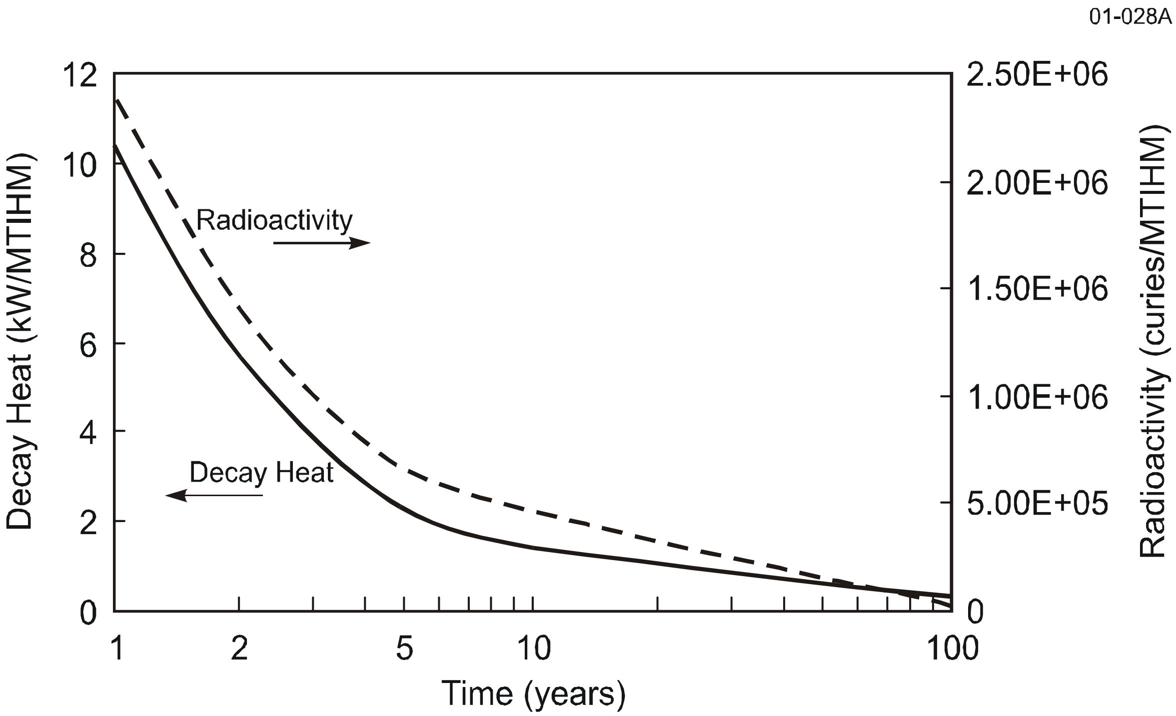

Fig. 2. SNF Radioactivity and Decay Heat Vs Time.

Additional storage time is required before geological disposal of SNF. For all proposed repositories, limits exist on the maximum allowable temperature to prevent degradation in repository performance. High temperatures may degrade the SNF, the WP, and the repository geology. To prevent such degradation, designers use three approaches to limit long-term SNF temperatures:

- *Spacing*. WPs are spaced out underground in the repository to reduce local temperatures. For example, in the proposed Yucca Mountain Repository, the 10,000+ WPs will be spaced over 100+ kilometers of tunnel.
- *Package capacity*. The number of SNF assemblies in each WP is limited by the allowable decay heat per WP.
- *SNF storage*. The SNF is stored for a period of years to decades to reduce the decay heat before placement in the repository.

SNF storage for several decades to reduce decay heat can significantly reduce total repository costs by allowing the use of larger WPs and smaller repositories (less underground dispersal of SNF with fewer kilometers of tunnel). The minimum allowable storage time for SNF in the United States is currently defined as 10 years while the corresponding period in Sweden is about 40 years. Minimum storage times depend upon the repository geology and design.

1.2.2 Transportation

SNF transport requirements and design methods are well defined [Shappert 1998]. For a multipurpose cask, the primary issue is determining which functions should be provided by the cask and which functions should be provided by the overpack. In all cases, there will be a transportation overpack that, at a minimum, includes impact limiters for protection of the cask in severe accidents.

1.2.3 Repository

The repository WP is designed to prevent the release of radionuclides to the environment for many thousands of years. The proposed YM WP [DOE May 2001a] consists of an inner package and a close-fitting outer package. At the repository, SNF assemblies from transport casks are individually transferred to the inner package. The full inner package is welded shut. The inner package contains the SNF, assures criticality control, and provides long-term structural support for the thinner outer package under the expected geological conditions. The inner package is placed in the outer package that is welded shut. The outer package is constructed of 2- to 2.5-cm thick C-22 (a corrosion-resistant nickel alloy) that, under expected repository conditions, will last more than 10,000 years.

In a multipurpose canister system, the cannister would be placed inside the inner WP. The canister would provide criticality control. The inner package would still be needed to provide structural support for the outer C-22 package. There is the option of constructing a multipurpose canister system that replaces the inner package. This would require significantly thicker walls for structural support.

In a multipurpose cask system, the cask would replace the inner package. A multipurpose cask can perform all the functions of the inner package, including structural support. A multipurpose cask would likely have a mechanical seal system that would seal the cask at the reactor, with a secondary weld at the repository.

The period of performance is the major difference between WP requirements and those for storage and transport. Because the WP must perform over many millennia in the repository, the different materials in the canister and cask must be compatible with each other over geological time and not potentially cause accelerated degradation of the SNF or WP. As a consequence, some traditional canister and cask materials cannot be used in a repository environment: uranium metals (Leeds 2000), organics (such as found in some neutron moderators), and concrete.

1.3 Change

The preferred methods for SNF management depend upon requirements, institutional structure, and technology. Major changes are occurring in each of these areas. As a consequence, the preferred SNF management options may change. These changes are described herein.

2. CHANGING REQUIREMENTS

If the requirements for SNF management change, the economics may dictate alternative SNF management approaches. The rationale for separate storage, transport, and disposal casks is that different requirements make multiple specialized casks for specific purposes less expensive than multipurpose casks. If the requirements were identical, there would be no incentive for separate types of casks. The differences in the requirements for storage, transport, and disposal casks are becoming smaller.

2.1 Accidents and Terrorism

The destruction of the World Trade Center in New York City, on September 11, 2001, has resulted in a reevaluation of the threats against which SNF must be protected; however, no international agreement exists on what constitute realistic threats. Because of the extremely heavy air traffic (commercial and military) during the Cold War and the large number of accidents, Germany has required that SNF be stored in facilities and casks that can withstand many types of aircraft collisions. In response to these requirements, German utilities have preferred dry storage casks leaving only limited quantities of SNF in “bunkered” storage pools—primarily inside reactor containments. Other countries that have much less air traffic—and thus a much lower probability of an aircraft collision—do not have such requirements. If terrorism is a threat, the requirements may change, encouraging dry cask storage over pool storage for several reasons.

- *Inventory*. The inventory of each cask is limited. In a severe accident or terrorist event, this limits the consequences of any single event, which may offer significant advantages.

- *Passive cooling*. Because of the limited inventory of SNF and thus the limited decay heat load, casks are cooled using passive conductive cooling techniques. Avoiding the use of active cooling systems, such as in SNF pools, offers a major advantage.

- *Fire*. In aircraft collisions and some other types of accidents, fire is a primary threat. The high thermal inertia of a cask provides significant protection against very high external heat fluxes experienced over a finite (or short) period of time. In this context, casks in which the heat is conducted through the cask shielding offer potential safety advantages compared with casks with canisters and air cooling between the canister and cask.

  The modular characteristics of casks make it relatively easy to limit the duration of any fire. In refineries and other facilities with the potential for long-duration fires, the ground is (1) sloped to allow liquid fuels to drain away from equipment to burn pits or (2) covered with crushed rock to allow drainage of fuel underground (away from air, thus extinguishing the fire). This limits the duration and intensity of any fire near sensitive equipment. The same strategy may be used when multipurpose casks are stored outside. In contrast, the World Trade Center was destroyed by fire (not the aircraft collision) because there was no effective way to rapidly drain jet fuel away from the building and the building had a significant inventory of combustibles (paper). The heat from the fire weakened the steel sufficiently that the buildings collapsed.

- *Physical protection*. The thick walls of a cask provide significant protection against aircraft impacts. In Germany, metal casks have been successfully tested against aircraft collisions by firing 1-tonne heavy metal poles (the size of jet engine rotors—the strongest and most damaging component in an aircraft) at 300 m/s into SNF casks (Droste 2001). Metal casks have also been tested against a variety of military munitions (Lange 2001).

Casks have a special property that buildings do not share. Casks do not have foundations, they will move under high impact loadings. This process dissipates the energy in many severe events and makes it more difficult to destroy a cask than a building of the same wall structure and thickness.

The above factors also favor (1) multipurpose casks over multipurpose canisters and (2) multipurpose canisters over separate storage, transport, and disposal casks with individual baskets.

- *Merging requirements*. If physical protection or similar requirements control the cask design, the differences are reduced between multipurpose casks and separate storage, transport, and disposal casks.

- *SNF transfers*. SNF transfer operations between separate storage, transport, and disposal casks become more complex and expensive as protective requirements increase. A multipurpose cask provides continuous protection from the reactor into the repository.

The SNF can be stored at the reactor, at a separate storage site, or near the repository. Because transport risks and costs are reduced by storage of SNF at the reactor before shipment (reduced radioactivity and cost), an incentive exists for the SNF to remain at the operating site until repository disposal. However, use of an interim storage site is preferred when it offers lower cost or risks for storing SNF. At the same time, increased incentives exist for earlier disposal because a repository (located hundreds of meters underground) is the most secure place for SNF.

2.2 Repository Licensing and Design

In the late 1980s, the YMP examined multipurpose casks and canisters and determined that they had potential advantages. However, neither was adopted because the requirements for the repository WP were not fully defined and the repository design was evolving. Several changes have occurred since then.

- *Licensing*. The U. S. Environmental Protection Agency and the U. S. Nuclear Regulatory Commission regulatory requirements for the repository have now been defined. The number of repository design options has been narrowed and licensing is likely to occur within the next decade. As the licensing proceeds, the detailed WP requirements will be fully defined and agreed upon. When this occurs, all information necessary for design of an efficient multipurpose canister or cask will become available.

- *Repository design*. The size and design of the repository inner WP has become similar to many shipping and storage casks; thus, the economics of a multipurpose cask have significantly improved. Research and development has improved the understanding of repository behavior and resulted in new repository designs. One of the largest changes [Benton 2001] is that the number of fuel assemblies per WP at the proposed YM repository has increased from 3 pressurized-water reactor (PWR) SNF assemblies to 21 PWR SNF assemblies (Fig. 3). This growth in WP size has eliminated most of the transport and storage penalties associated with multipurpose cask systems. Twenty years ago, the use of a multipurpose cask implied 3 fuel assemblies per cask. That implied many SNF shipments. Shipping 20+ SNF assemblies in a single cask was incompatible with a small multipurpose canister or cask. Large WPs, such as for the proposed YM repository, eliminate this type of penalty associated with earlier generations of multipurpose canisters and casks.

The growth in WP size is a consequence of several design changes. There are limits on WP temperatures to prevent early degradation of the SNF and WP. Early repository designs placed the WP in boreholes in the floor of the repository. Heat conducted slowly from the WP to the rock. To limit temperatures, the SNF and decay heat per WP were highly constrained. The current repository design has the WP placed horizontally in the middle of the tunnel disposal tunnels (drifts). Air in the drift can move heat from the WP to the larger area of the tunnel wall. WPs with higher decay heat loads (more SNF) can be used. Second, larger WPs are also possible because the age of the SNF has increased (more storage time) with reduced decay heat per SNF assembly. Last, the horizontal WP placement with rail transport in the repository allows handling of heavy WPs.

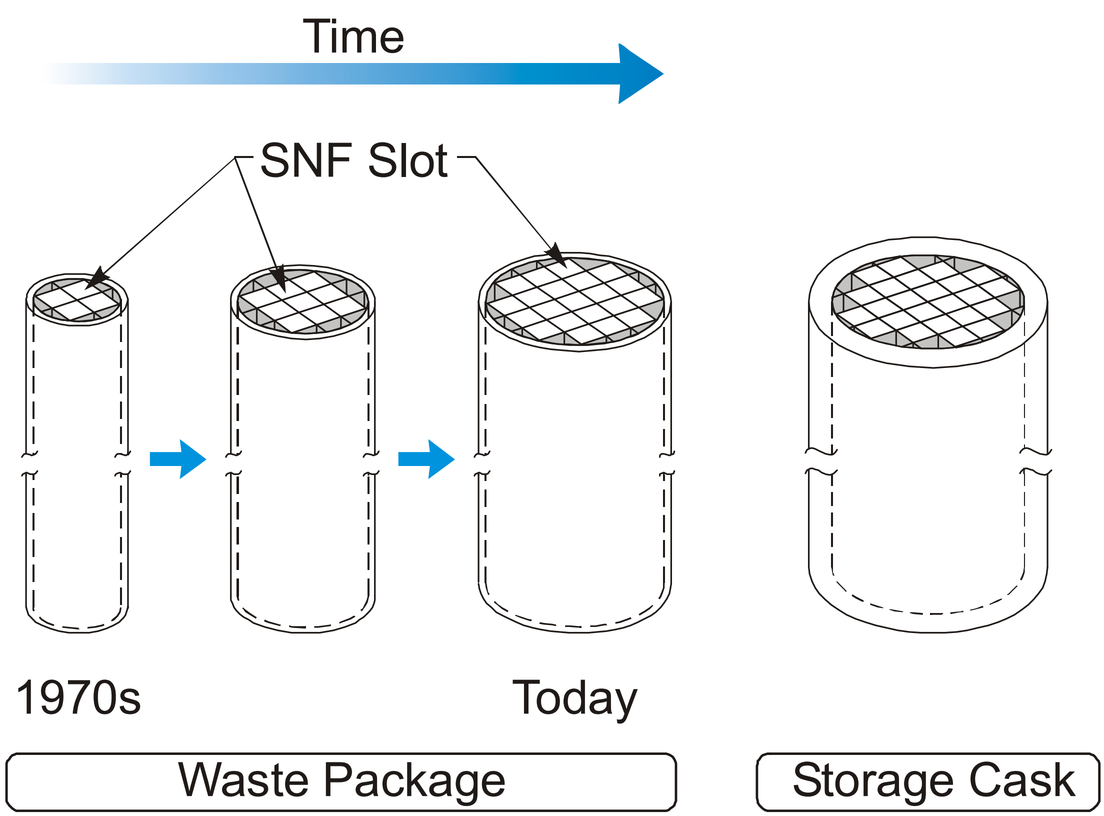

Fig. 3. Evolution Over Time in the Size of Repository WPs.

A multipurpose cask or canister cannot be developed until the repository requirements are fully defined. In the United States, this implies that the first 10 to 30 thousand tons of SNF are not candidates for such a packaging system. This SNF will already be in some type of dry storage before a multipurpose cask system could be deployed. However, as the repository is licensed, the specific requirements will be known and defined. At that time (probably within this decade), it will become feasible to design and use multipurpose casks and canisters for the 40,000+ tons of SNF that will be generated after the repository license is issued. Thus, these systems should be considered as part of a second-generation repository WP system.

Two characteristics of the repository specifically impact multipurpose cask and canister designs.

- *Phased design, construction, and operation*. A repository will be built in stages over many decades. Tunnels are not drilled until needed. The designs of the later stages of the repository will be different from the designs of the first sections of the repository. Experience from operations and technological advances will drive the changes in the repository. Costs are expected to decrease with learning. This intrinsic characteristic of a facility that will be expanded over many decades provides a cost-effective method to allow the introduction of new technologies such as multipurpose casks.

- *Repository design*. The repository program is currently evaluating several design options (DOE May 2001b). Some of these options may further reduce the differences between storage, transport, and disposal casks. One of the leading alternative designs is the ventilated repository which remains open for 100 to 300 years after placement of the WPs. The ventilation system cools the repository until the decay heat per fuel assembly is very low (Table 1). This has several potential benefits: (1) lowering the temperatures in the repository by active ventilation reduces many of the uncertainties in repository performance and thus may simplify licensing, (2) costs may be reduced by avoiding expensive methods (limited decay heat per package, wide dispersal of spacing of WPs underground, etc.) needed to control the short-term temperatures in the repository, and (3) an open repository provides more long-term options for SNF. Such options also have implications for multipurpose casks and canisters:

  - <u>Shielded WPs.</u> The current WPs have limited shielding. Use of a ventilated repository that remains open for decades or centuries creates stronger incentives to use fully shielded WPs, such as multipurpose casks, to allow inspection and repair.

  - <u>Cask size and SNF age.</u> Ventilated repositories allow disposal of shorter-cooled SNF while maintaining the same temperature limits on the fuel. Such concepts may also allow somewhat larger WP sizes. The practical consequence is that storage, transport, and disposal cask design is rapidly being controlled by the same factors: facility handling, transport from the factory, and related issues.

3. CHANGING INSTITUTIONS

Institutional structures can strongly impact SNF management. France, Germany, and Sweden have central storage facilities for SNF whereas the U.S. has highly decentralized SNF storage. Some of the differences are a consequence of different requirements; but, many of the other differences reflect different institutional structures.

The utilities in the United States are undergoing the most radical change since they were formed in the early 1900s. Historically, the U.S. has had a large number of relatively small, state-regulated utilities. Ongoing deregulation of the utilities is resulting in the rapid consolidation of the nuclear power industry into a few large nuclear utilities with many reactors at multiple sites. This may result in large changes in SNF management practices.

- *Siting*. Large multi-site utilities may prefer consolidation of SNF on a few sites to reduce storage costs. This may change the preference for storage versus dual purpose storage and transport casks.

- *Cask design*. Large utilities imply standardization of SNF storage into a few types of storage systems. Because a large utility may purchase many identical casks, the economics of cask design and construction change. The design and manufacturing methods to produce a small number of items are usually very different from the methods used to produce many identical items. The classical example is the auto industry that stamps many components. The molds for a stamping operation are very expensive but the cost to produce the n^{th} item is very low. Historically casks have been designed to avoid materials and manufacturing methods that require significant investment in manufacturing facilities. However, with the new utility structures, cask designs that require significant front-end investment for manufacturing but have low incremental manufacturing costs become more attractive.

- *Repository interface*. A repository system that accepts SNF from 60 companies and a 100 reactors is different from a repository system that accepts SNF from a small number of companies with the same 100 reactors. If a mega utility decides it may be economic to build a multipurpose cask for storage, transport, and disposal, it is reasonable to negociate with the repository on a standardized design for management of five or ten thousand tons of SNF. In contrast, it is not practical nor economic for a repository to use 60 or a 100 different WPs with one type of WP for each owner of reactors.

4. NEW TECHNOLOGY

New technologies can alter the preferred SNF management methods.

- *Decay-heat removal*. Better heat removal allows casks to contain more SNF or allows loading casks with shorter-cooled SNF with higher heat loads. This improves cask economics compared to other methods of SNF management. Better design of baskets, addition of solid fins, and addition of liquid-filled fins are among the many methods being investigated to improve cooling.

- *Shielding materials*. For a given radiation dose reduction and specific inside cask diameter, cask weight is lowered as shield density increases and wall thickness decreases. Cask weight and size limits exist at many power reactors. Rail transport cask capacity is limited by cask diameter and mass. At the repository, the disposal tunnel diameter is partly a function of the expected diameter of the WP. Inefficient shielding materials can lead to larger-diameter tunnels with higher tunnel excavation and lining costs. Better shielding materials reduce the constraints for multipurpose casks that see different environments.

An example of a new potential cask material can provide (1) an indicator of what may be possible with new materials and (2) identify potential issues associated with multipurpose cask shielding materials. DUO_2–steel cermets are being investigated as a new material for cask body construction [Forsberg September 2001]. In the cermet, DUO_2 embedded in the steel with clean layers of steel located on both sides of the cermet (Fig. 4). In the 1950s, cermet fuels were investigated and used in 11 research and test reactors in the United States [Authur 1964]. However, cermets were not investigated at that time as a shielding material. Low-cost nonnuclear cermets have been produced in large volumes. Significant work is required before it will be known if DUO_2 cermets can be economically used as an advanced cask material.

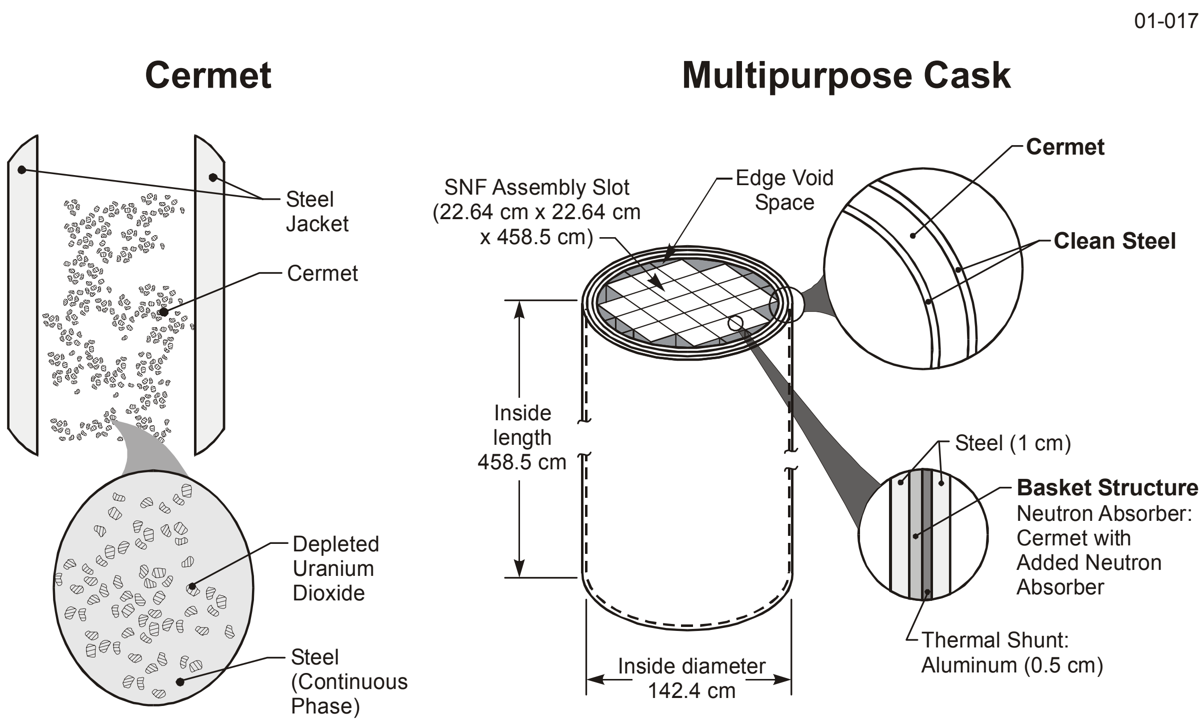

Fig. 4. Cermet Multipurpose Cask with YM Repository WP Internal Structure.

The DUO_2-steel cermets provide excellent gamma shielding [Forsberg September 2001]—up to 30+% greater density than steel, with resultant reductions in cask size and weight. Cermets provide some neutron shielding. The high oxygen content in DUO_2 (1.3 g/cm^3) provides a neutron moderator to slow down fast neutrons and allow capture by thermal neutron absorbers.

Cermets are of particular interest because, by default, they may be the best-performing shielding material available for multipurpose casks. Many high-density shielding materials (gold, tungsten, etc) are unacceptable because of cost. Resource Conservation and Recovery Act (hazardous waste) regulations eliminate materials such as lead from the repository. Potentially adverse impacts on repository performance at YM have eliminated the use of such traditional cask materials as uranium metal, concrete, and organics (including traditional polymer-based neutron moderators used in cask shielding).

Cermets are also an example where a material (DUO_2) in the cask has benefits to the repository that are independent of its cask application. The DUO_2 (1) may help minimize the potential for long-term criticality in the repository [Forsberg November 2001] and (2) may improve repository performance by modification of the geochemical environment near the SNF [Forsberg September 2000; Forsberg December 2001]. Worldwide, several repository programs are investigating different materials for such dual purpose applications.

Last, cermets are also an example of advanced materials whose properties can be modified to meet potential future requirements. In this specific case, properties are modified by altering the DUO_2/metal ratio, the choice of metal, and the method of construction. The body of the cask can be constructed with (1) the cermet sandwiched between layers of clean steel or (2) wrapping a "thin" cermet with steel layers around an inner shell to create a multilayer structure of alternating metal and cermet. This layered approach (hard/ductile) gives the structure improved characteristics against many types of accidents and assault. Such layered designs are used in bank vaults and tank armor to prevent penetration by different tools and weapons.

5. SYSTEM CONSIDERATIONS

A brief description of one multipurpose cask system is provided herein to provide some understanding of the tradeoffs in system design. There are many variants. The multipurpose cask is designed to meet requirements for (1) the basket, (2) radiation shielding during transport and disposal, and (3) protection against accidents and assault. Separate overpacks are provided for reactor storage, transport, and disposal. The multipurpose cask is that shown in Fig. 4 where the interior is identical to the proposed 21-PWR YM WP and the cask wall contains 25 cm of a cermet with an average of 50 vol % steel and 50 vol % DUO_2.

Storage. The SNF is assumed to be transferred from pool storage to the multipurpose cask several years after reactor discharge. The SNF remains on-site for 25 years (current assumed age of SNF going into the YM repository). The storage overpack is used to provide additional shielding during on-site storage at the reactor until radioactive decay reduces the SNF radiation levels to the extent that the multipurpose cask can provide the required shielding for transport and disposal. The thickness of the overpack shielding depends upon how soon after reactor discharge the SNF is placed in dry storage. The requirements for the storage overpack are determined by two factors:

- *Storage*. Long-term storage requires low radiation levels because of the cumulative radiation dose to workers, and potentially the public, over long periods of time. Cask storage arrays require more shielding than a single cask would. A single cask may meet all requirements; however, if many casks are co-located, the total radiation dose from multiple casks may easily result in high background dose rates over a much wider area than might otherwise be expected. This array factor encourages the use of storage overpacks.

- *Allowed occupational dose levels*. In the controlled environment of the reactor site, radiation exposures are controlled by (1) use of shielding, (2) increased distance between workers and casks, and (3) decreased time spent near the casks. Because distance and time can be used for radiation dose control, the overpack may not be required during cask transfer from the reactor SNF pond to the cask storage yard. The allowable cask radiation levels for moving a loaded cask during operations may be a hundred times higher than is practical in long-term storage in an array of SNF casks.

For this application, the overpack may be a simple concrete shell with cooling slots. The overpack provides incremental radiation shielding and limited additional physical protection.

Transport. A transport overpack with impact limiters and other special components would be used to move the multipurpose cask from the reactor to the repository.

Repository. The current YM WP consists of an inner package with the SNF and a separate 2-cm-thick exterior overpack of corrosion-resistant C-22 metal. The multipurpose cask would replace the inner WP. The multipurpose cask is designed to meet the functional requirements of the inner WP. The exterior repository overpack remains unchanged.

For storage applications, the multipurpose cask may include fins or other devices to control SNF temperatures until the decay heat decreases sufficiently with time. One repository requirement is that the multipurpose cask provide support for the repository overpack. As a consequence of this requirement, if the multipurpose cask has fins or other devices for decay heat removal during storage, these have to be removed before the repository overpack is added. If cooling fins are used in storage (as a separate component or part of the storage overpack), the fins can be (1) part of a jacket designed for easy removal before transport or disposal or (2) cut off at the repository.

6. CONCLUSIONS

The rationale for separate storage, transport, and disposal casks is that their requirements are sufficiently different that there are economic incentives to custom build casks for these three applications. As the requirements for the three tasks (storage, transport, and disposal) become similar (such as protection against accidents and assault), the rationale for separate canister and cask systems tend to disappear. Changes in the utility structure in the United States and new technologies are may also encourage the use of multipurpose canisters and casks. Whether these multiple changes are sufficient to alter the preferred methods of SNF management is unknown at this time. However, the balance between separate and multipurpose canisters and casks is being tipped in favor of the latter. It is time to reexamine the potential for multipurpose canisters and casks.

ACKNOWLEDGMENT

This work was done under the auspices of the U.S. Department of Energy Depleted Uranium Uses Research and Development Program.

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Additional information on DU applications in a geological repository can be found at the following URL: "web.ead.anl.gov/uranium/uses/index.cfm." Copies of many of the references are also available at this site.

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