INTEGRATED SPENT FUEL STORAGE AND TRANSPORTATION SYSTEM USING NUHOMS®

R. Lehnert, W. McConaghy, J. Rosa
Pacific Nuclear Fuel Services, Inc.
145 Martinvale Lane
San Jose, CA 95119

ABSTRACT

As utilities with nuclear power plants face increasing near term spent fuel storage needs, various systems for dry storage such as the NUTECH Horizontal Modular Storage (NUHOMS®) system are being implemented to augment existing spent fuel pool storage capacities. These decisions are based on a number of generic and utility specific considerations including both short term and long term economics. Since the US Department of Energy (DOE) is tasked by the Nuclear Waste Policy Act with the future responsibility of transporting spent fuel from commercial nuclear power plants to a Monitored Retrievable Storage (MRS) facility and/or a permanent geologic repository, the interfaces between the utilities at-reactor dry storage system and the DOE's away-from-reactor transportation system become important. This paper presents a study of the interfaces between the current at-reactor NUHOMS® system and the future away-from-reactor DOE transportation system being developed under the Office of Civilian Radioactive Waste Management (OCRWM) program.

INTRODUCTION

The NUHOMS® system utilizes a reinforced concrete Horizontal Storage Module (HSM) to store spent nuclear fuel assemblies which are sealed in a Dry Shielded Canister (DSC). The DSC has an internal basket assembly designed to hold 24 PWR or 57 BWR spent fuel assemblies for various vendor specific fuel assembly designs and in-core operating histories. The HSMs are arranged in back-to-back, side-by-side arrays on the utility's reactor site with each HSM holding one DSC. The HSMs and DSCs are the principal components of the Independent Spent Fuel Storage Installation (ISFSI) for which plants are granted a 10CFR72 (1) license by the US Nuclear Regulatory Commission (NRC) for interim dry storage. Most utilities are electing to seek a license for a life-of-plant capacity ISFSI with a canister loading frequency which ensures that full core reserve storage capacity in the spent fuel pool is maintained. Such a license has been granted to the Duke Power Company for use of the NUHOMS® system at the Oconee Nuclear Station (7). A complete description of the NUHOMS® system for dry storage of spent fuel and its operation is contained in the NRC approved NUHOMS Topical Report and related publications (2,3,4).

The configuration of the standard NUHOMS® DSC is shown in Fig. 1. The DSC provides the primary containment boundary for confinement of radioactive materials and helium atmosphere during storage. The DSC will also serve as a secondary containment boundary to that of the transportation cask for future off-site shipment. The DSC has redundant welded end closures, shielded end plugs to minimize occupational dose, and provisions for horizontal transfer utilizing a hydraulic ram. DSC handling and transfer operations between the plant's spent fuel pool and the HSM are performed utilizing a NUHOMS® on-site transfer cask which provides additional shielding to further reduce occupational dose and provide protection against postulated accidents such as a cask drop or extreme natural phenomena. A composite illustration of the DSC, transfer cask, and spent fuel is shown in Fig. 2. The standard NUHOMS® system configuration for DSC transfer to or from an HSM is shown in Fig. 3.

OPTIONS FOR FUEL/CANISTER SHIPMENT

Irradiated fuel will be shipped off-site to either a Monitored Retrievable Storage (MRS) facility or a geologic repository. In keeping with the oldest fuel first (OFF) criteria for spent fuel acceptance, fuel that is already in dry storage may become the first candidates for shipment. Alternately, fuel may be shipped directly from the pool. This scenario could become viable for direct shipment to the MRS while the MRS, in its initial configuration, is utilized for storage only. The range of alternative scenarios for away-from-reactor shipment are depicted in the Fig. 4 flow chart. The alternative means available to a particular plant will depend upon the compatibility of the interfaces between the plant and the OCRWM cask, as well as the accessibility to rail, barge, or truck transportation systems at or near the reactor site. Rail/barge transportation is the most desirable since the number of fuel assemblies and casks transported for each shipment is maximized and the number of shipments minimized, thus minimizing the risk to the public and the unit cost of transport. Transportation utilizing truck casks is the least desirable transportation alternative and would require down-loading of the spent fuel assemblies from the DSCs at the utility's reactor site.

The use of a suitable rail/barge transportation cask makes possible the shipment of intact DSCs which offers substantial advantages over shipment of non-canisterized spent fuel. These advantages include enhanced safety provided by the second containment boundary to that of the shipping cask, reduced occupational dose since individual spent fuel assemblies are not re-handled at the reactor site, and greater economy since spent fuel pre-packaged in a

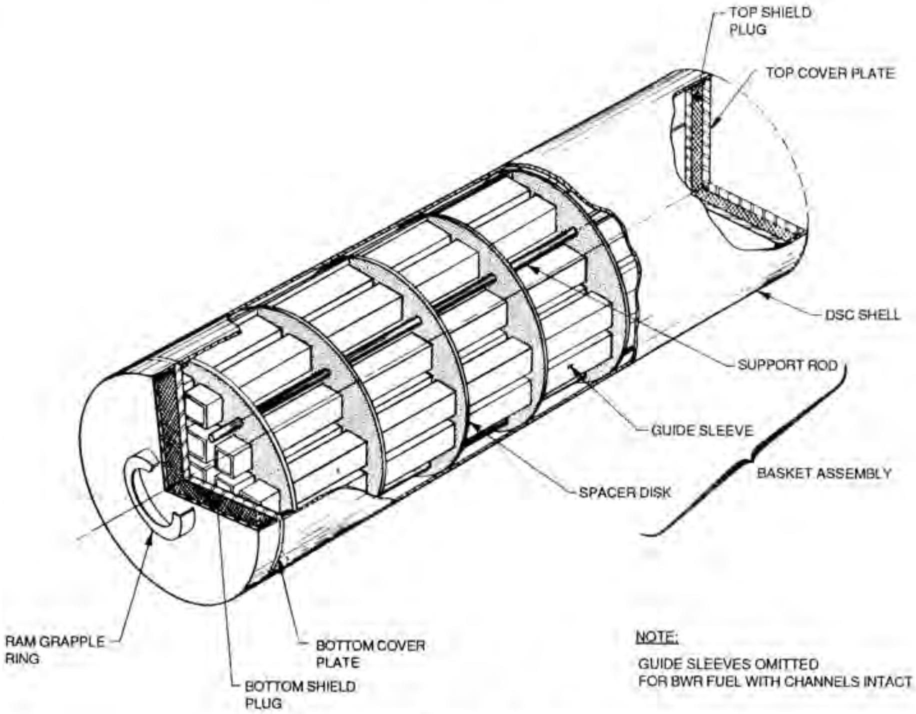

Fig. 1. NUHOMS® Dry Shielded Canister.

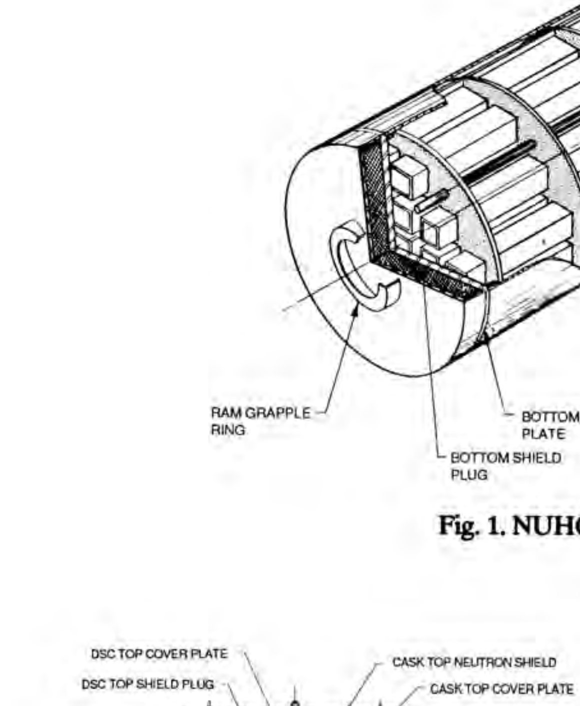

Fig. 2. Composite View of NUHOMS® Transfer Cask, Canister and Fuel.

DSC affords the minimum OCRWM transportation system cycle time. Thus, the risk and cost to the public is reduced.

CANISTER DESIGN FEATURES AND OCRWM CASK INTERFACES

The NUHOMS® DSC is currently licensed for on-site dry storage applications in accordance with the requirements 10CFR72 (1). The generic safety analysis for the DSC is documented in the NRC approved NUHOMS® system Topical Report (2), which delineates the design provisions for criticality control, decay heat removal, minimization of radiation dose, and structural integrity. The standard NUHOMS® DSC design features for storage are summarized in Table I (Column A). The DSC internal basket assembly design details are customized to suit the physical design and operating histories of the present and future fuel contained in each plant's spent fuel inventory. The outer DSC shell assembly design is standardized so that the physical features and design capacity of the DSCs for all fuel types are the same, providing a standard package with the same characteristic interfaces for away-from-reactor transportation.

The shipment of intact DSCs off-site requires qualification and certification of the DSC to the requirements of 10CFR71 (5) for use with a compatible shipping cask. The basic design of the NUHOMS® DSC is suitable for both on-site storage (10CFR72) and off-site shipment (10CFR71). The design requirements for the DSC for off-

TABLE I
NUHOMS®-24P Canister and Cask Design Requirements for Transportation

NUHOMS®-24P CANISTER		NUHOMS®-24P TRANSPORTATION CASK	
(A) 10CFR72 STORAGE DESIGN BASIS	(B) 10CFR71 TRANSPORTATION DESIGN BASIS	(C) 10CFR71 DESIGN BASIS	
PHYSICAL PARAMETERS:			
• OUTSIDE DIAMETER	67.25 IN.	• CAVITY DIAMETER	68 IN.
• MAXIMUM LENGTH	186 IN.	• CAVITY LENGTH	187 IN.
• MAXIMUM LOADED WEIGHT	72,000 LBS	• MAXIMUM LOADED WEIGHT	125 TONS
CRITICALITY CONTROL:			
• BURNUP CREDIT OR	• BURNUP CREDIT OR	• BURNUP CREDIT OR	68 IN.
BORON CREDIT	MODERATOR EXCLUSION	MODERATOR EXCLUSION	187 IN.
• Keff < .95 (NOM)	• Keff < .95	• Keff < .95	125 TONS
DECAY HEAT REMOVAL:			
• 16 Kw/DSC	16Kw/DSC	16Kw/DSC	
• MAXIMUM CLADDING TEMP			
< 340°C (LONG TERM)	N/A	N/A	
< 570°C (SHORT TERM)	380°C	380°C	
RADIOLOGICAL:			
• DOSE (NORMAL)	< 200 MREM/HR (CONTRACT)	< 200 MREM/HR (CONTRACT)	68 IN.
		< 10 MREM/HR @ 2M	187 IN.
• CONTACT DOSE (ACCIDENT)	N/A	1R/HR @ 1M	125 TONS
• SMEARABLE CONTAMINATION	< 22,000 dpm/100cm^2	< 22,000 dpm/100cm^2	
STRUCTURAL:			
• NORMAL/OFF-NORMAL LOADS			
N/A	1 FT FREE DROP	1 FT FREE DROP	
• ACCIDENT LOADS			
- SIDE DROP 75g's	30 FT DROP	30 FT DROP	
- END DROP 75g's	30 FT DROP	30 FT DROP	
- CORNER DROP 25g's	30 FT DROP	30 FT DROP	
N/A	N/A	40 IN PUNCTURE	
• INTERNAL PRESSURE			
NORMAL < 10PSIG	< 10PSIG	N/A	
ACCIDENT < 50 PSIG	< 50PSIG	N/A	
OTHER:			
N/A	FIRE	FIRE	
N/A	N/A	SUBMERSION	

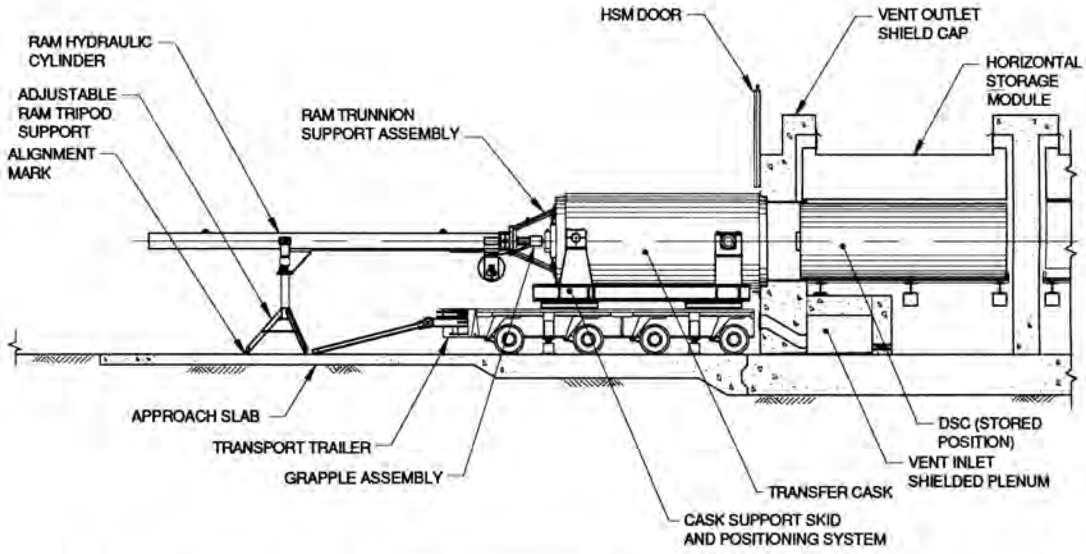

Fig. 3. Standard NUHOMS® System Components, Structures, and Transfer Equipment.

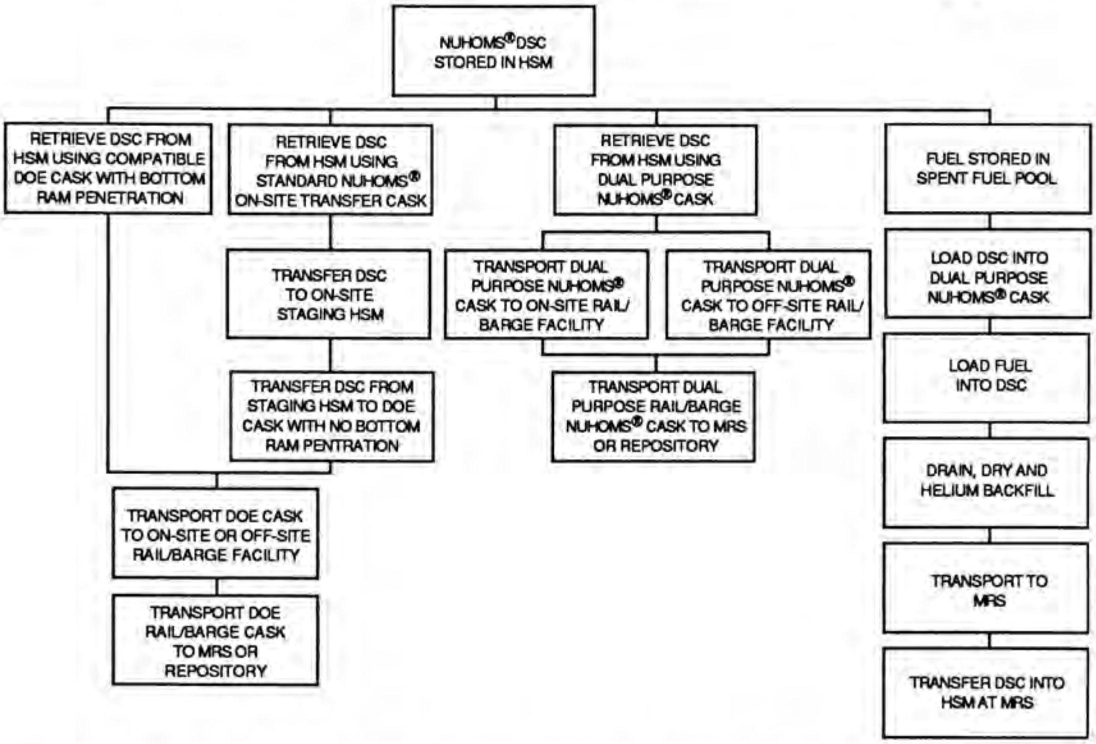

Fig. 4. Options for Away-From Reactor Shipment of Spent Fuel with NUHOMS® System.

site transportation are shown in Table I (Column B). Minor revisions to the basic design of the NUHOMS® DSC are possible to further enhance the compatibility and shipability of the DSC, and to exercise the advantages of shipping canisterized spent fuel to the fullest extent. For example, a DSC to be used for direct transfer of fuel from the pool to the MRS could be designed with a bolted shield plug and cover plate, with or without seal welds, to facilitate downloading at the MRS.

DIRECT CANISTER TRANSFER TO OCRWM RAIL/BARGE CASK

At-reactor direct transfer of an intact NUHOMS® DSC from an HSM to an OCRWM rail/barge cask requires that the transportation cask have a compatible cavity size, and a bottom end penetration for insertion of the hydraulic ram similar to that of a standard NUHOMS® on-site transfer cask as shown in Fig. 2. It appears to be feasible for the DOE, in a subsequent initiative of the OCRWM transportation system development program, to develop a cask design which is slightly larger, having a cavity diameter of 68 inches, a cavity length of 187 inches, with a maximum loaded weight under 125 tons. Such a cask could accommodate an intact maximum length standard NUHOMS® DSC. It is important to note that the direct or indirect horizontal transfer of intact DSCs on site eliminates the need to return either the shipping cask or the DSC/spent fuel to the plant spent fuel pool, thus minimizing loading time and reducing or eliminating decontamination time for the OCRWM cask, which in turn will minimize turn-around time for the transportation cask(s) at-reactor.

It may also be feasible to adapt a multi-purpose OCRWM rail/barge cask with a compatible cavity diameter and payload capacity, such as a cask for BWR fuel with a removable basket, by placing an insert in the bottom end of the cask cavity designed to support the DSC and to accommodate the DSC grapple ring. Similarly, it may be feasible to place a collar/adapter between the cask top head and the cask body (not shown) to extend the cask cavity length and/or provide a compatible interface for docking of the OCRWM rail/barge cask with the HSM.

Operations for direct transfer of an intact DSC to a compatible OCRWM rail/barge cask would be performed using standard NUHOMS® transfer equipment and transfer techniques as shown in Fig. 3, except that the standard NUHOMS® cask support skid would be changed-out or modified to be compatible with the rail/barge cask as necessary. Transport of the OCRWM rail/barge cask to an on-site rail car or barge would proceed using the standard NUHOMS® transport trailer as shown in Fig. 5. Once at the on-site rail head or barge facility, the OCRWM rail/barge cask and intact NUHOMS® DSC would be lifted onto the rail car or barge using a suitable bridge crane, gantry crane, or other special purpose handling equipment and secured for shipment to the MRS facility or permanent geologic repository as shown in Fig. 7.

For plants which do not have on-site access to a rail or barge, off-site transport to a nearby rail head or barge facility could be accomplished by adapting the standard NUHOMS® transfer trailer, which is a modular, multi-wheel set, hydraulically suspended, all-wheel steered trailer specifically designed for such heavy haul transport on commercial pavement. Additional wheel sets or an entire second trailer with a load spreading device could be utilized to reduce the maximum wheel loads and to distribute the total load in compliance with local limits for road surfaces and overpasses. Prior to off-site transport, cask impact limiters would be installed and the cask readied for shipment in compliance with the 10CFR71 certification for the cask. The

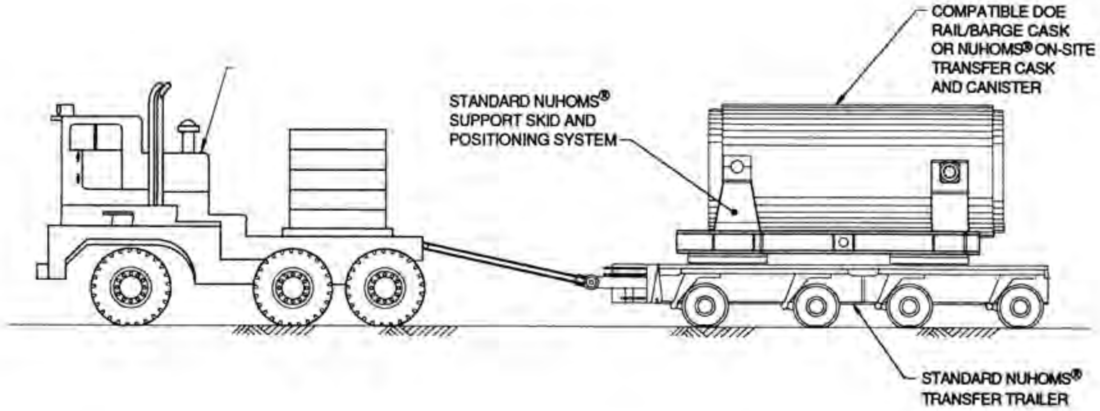

Fig. 5. On-Site Transport of Cask/NUHOMS® Canister to Staging Module or Rail/Barge Facility.

extended transport trailer and cask readied for off-site transport is shown in Fig. 6. Once at the nearby rail head or barge facility, the OCRWM rail/barge cask and intact NUHOMS® DSC would be lifted onto a rail car or barge and secured for shipment to the MRS facility or permanent geologic repository as shown in Fig. 7.

INDIRECT CANISTER TRANSFER TO OCRWM RAIL/BARGE CASK

At-reactor indirect transfer of an intact NUHOMS® DSC to an OCRWM rail/barge cask with a compatible cavity diameter and payload capacity, but without a bottom penetration, can be achieved by first retrieving the DSC from storage in an HSM using the standard NUHOMS®

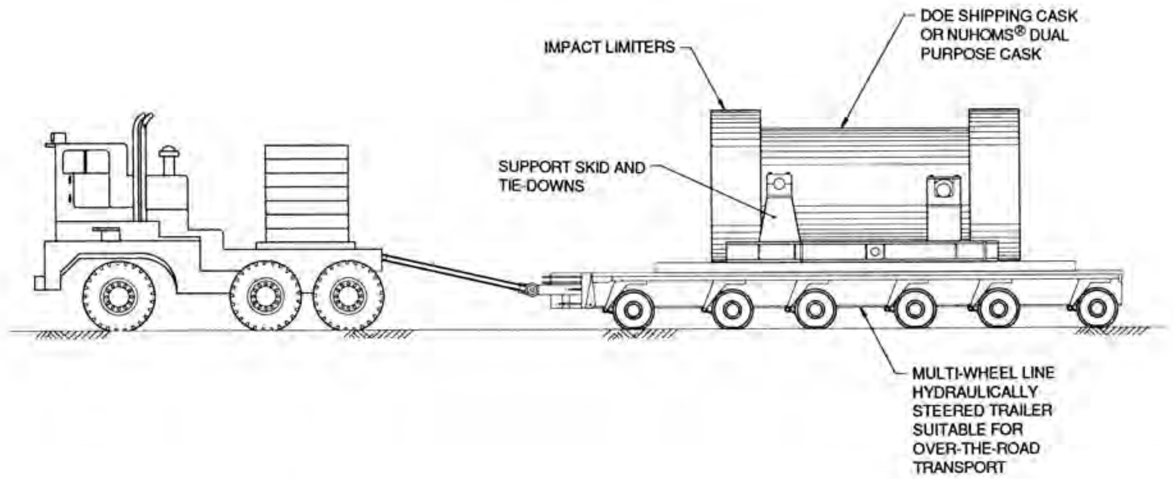

Fig. 6. Off-Site Transport of OCRWM or Dual Purpose NUHOMS® Cask Canister to Rail/Barge Facility.

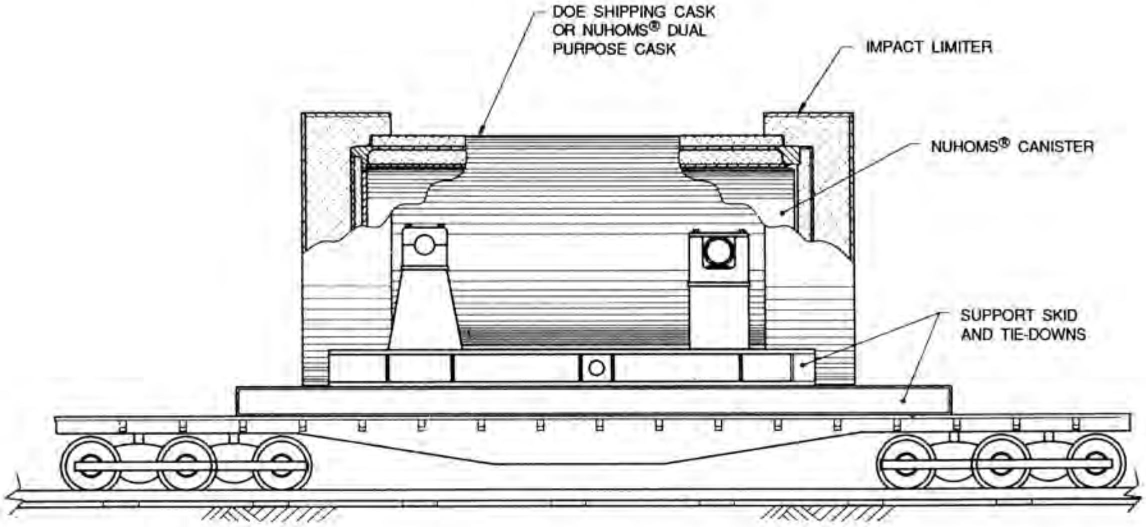

Fig. 7. OCRWM Cask or Dual Purpose NUHOMS® Cask and Canister Secured for Shipment on Rail Car.

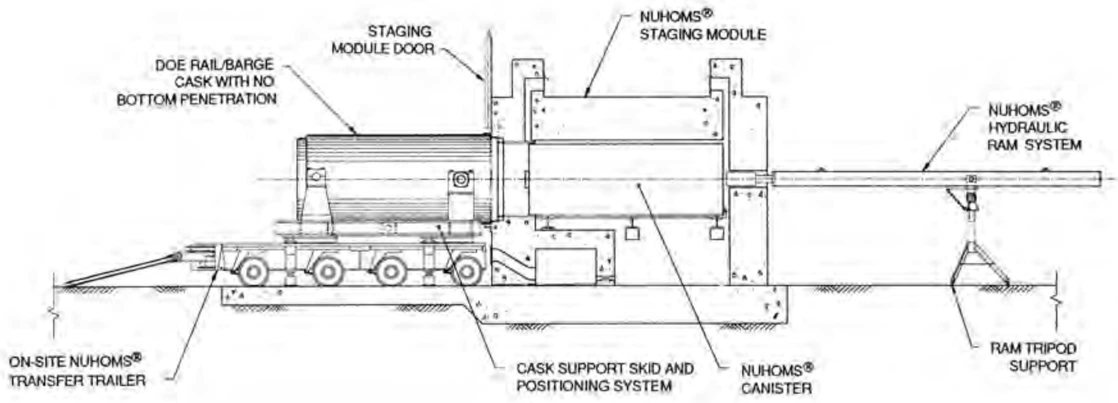

Fig. 8. NUHOMS® Canister Transfer from Staging Module to OCRWM Cask.

on-site transfer cask, transfer equipment, and transfer techniques. While subsequent transfer of an intact DSC from a NUHOMS® on-site transfer cask directly to a OCRWM rail/barge cask is feasible, this method of transfer is not preferred since the fuel assemblies would be oriented top down and the DSC bottom shield plug and grapple ring assembly would be oriented top up, thus complicating the canister opening and fuel handling process at the MRS or geologic repository following shipment.

The preferred method of transferring an intact NUHOMS® DSC to an OCRWM rail/barge cask at-reactor following retrieval of the DSC from storage in an HSM using a standard NUHOMS® on-site transfer cask, to first off-load the intact DSC to a NUHOMS® staging module. The single, stand-alone staging module is similar in most respects to a standard NUHOMS® HSM, except that the rear wall of the staging module would have a penetration to facilitate use of the hydraulic ram for DSC transfer to a cask with no bottom penetration. The rear penetration module design and ram operation is similar to that first utilized for demonstration of the NUHOMS® -07P system.

At-reactor off-loading of the intact DSC from the NUHOMS® on-site transfer cask to the staging module occurs in a manner similar to that shown in Fig. 3 for a standard DSC transfer. As a prerequisite to this operation, the specific interface requirements of the OCRWM rail/barge cask *without a bottom*-end ram penetration are accommodated. For example, a DSC top end bolt-on grapple ring could be installed on the DSC following removal of the NUHOMS® on-site transfer cask top cover plate prior to docking the cask with the staging module. Following docking of the NUHOMS® on-site transfer cask. The DSC transfer operation proceeds by inserting the hydraulic ram through the on-site transfer cask bottom end penetration and engaging the ram grapple with the DSC grapple ring. DSC transfer takes place by actuating the hydraulic ram and pushing the DSC into the staging module as shown in Fig. 3. Alternatively, this operation may be performed by pulling the DSC into the staging module with the hydraulic ram at the rear of the module as shown in Fig. 9. Following DSC transfer, to the HSM, the door to the staging module is lowered to provide adequate shielding, and the NUHOMS® on-site transfer cask is pulled away from the staging module. Once in the staging module, at-reactor loading of the intact DSC from the staging module to the OCRWM rail/barge cask is achieved by first setting up the NUHOMS® hydraulic ram at the rear of the staging module. The rail/barge cask and compatible support skid are then placed on the NUHOMS® transfer trailer and docked with the staging module as shown in Fig. 8. The hydraulic ram grapple is then inserted through the staging module cavity to engage the bolt-on DSC top grapple ring and the hydraulic ram actuated to initiate pushing of the DSC into the OCRWM rail/barge cask. The rail/barge cask is then pulled away from the staging module and made ready for shipment by removing the DSC top end bolt-on grapple ring if necessary and installing the cask top head. The DSC may also be leak tested to ready the DSC for shipment in compliance with the 10CFR71 certification. The OCRWM rail/barge cask and intact NUHOMS® DSC is then transported to an on-site or nearby off-site rail head or barge facility as shown in Fig. 6 for transportation to the MRS facility or permanent geologic repository as shown in Fig. 7.

DUAL PURPOSE NUHOMS CASK

In the event that there are no compatible transportation casks available with a cavity size and payload capacity suitable for shipment of an intact NUHOMS® DSC, a NUHOMS® cask which is designed, licensed, and certified for both at-reactor NUHOMS® system storage operations (10CFR72) and away-from-reactor transportation (10CFR71) could be utilized. The design requirements for such a dual purpose NUHOMS® cask are summarized in

Table I (Column C). The existing 10CFR72 NUHOMS® on-site transfer cask design basis is comparable with, to that required to meet 10CFR71 (5) with the addition of impact limiters and redundant top cover plate seals. The DSC double seal welds already meet 10CFR71 containment requirements and can be supplemented by the addition of O-ring seals in the top and bottom closure heads of the cask. The puncture, fire, and more restrictive radiation dose limits specified for a 10CFR71 cask can also be incorporated into the cask design with minimal changes.

Many of the design features of a dual purpose NUHOMS® cask would be similar to those of a standard NUHOMS® on-site transfer cask shown in Fig. 2 and described in the NUHOMS® Topical Report (1). The on-site transfer cask design would be modified to be in compliance with 10CFR71 (5) criteria as discussed above, taking credit for the additional primary containment boundary, axial shielding, and structural capacity provided by the standard NUHOMS® DSC. The at-reactor operations for away-from-reactor shipment of intact DSCs using a dual purpose NUHOMS® cask would be similar to those described above for direct canister transfers to a compatible OCRWM rail/barge cask as shown in Figs. 3, 6, and 7.

INTERFACES FOLLOWING CANISTER SHIPMENT TO DOE FACILITY

A conceptualization of a complete transportation cycle utilizing an intact NUHOMS® DSC transported from an at-reactor NUHOMS® ISFSI to an away-from-reactor MRS facility and/or permanent geologic repository is shown in Fig. 9. Once at the MRS or repository, the intact DSC could be off-loaded to lag storage consisting of NUHOMS® HSMs using standard NUHOMS® transfer equipment as discussed previously for direct or indirect transfer of NUHOMS® DSCs to or from an OCRWM rail/barge cask or a dual purpose NUHOMS® cask. The inherent economy of such an MRS system is substantial since only the construction of NUHOMS® modules in necessary to implement a fully functional system for storage of spent fuel awaiting a permanent repository. Alternatively, the intact DSC could be off-loaded to a hot cell and opened using semi- or fully remote cutting tools so that spent fuel assemblies could be downloaded for immediate processing and packaging for permanent storage in a geologic repository. The emptied DSC could then be decontaminated and refurbished for use or disposed of as low level waste.

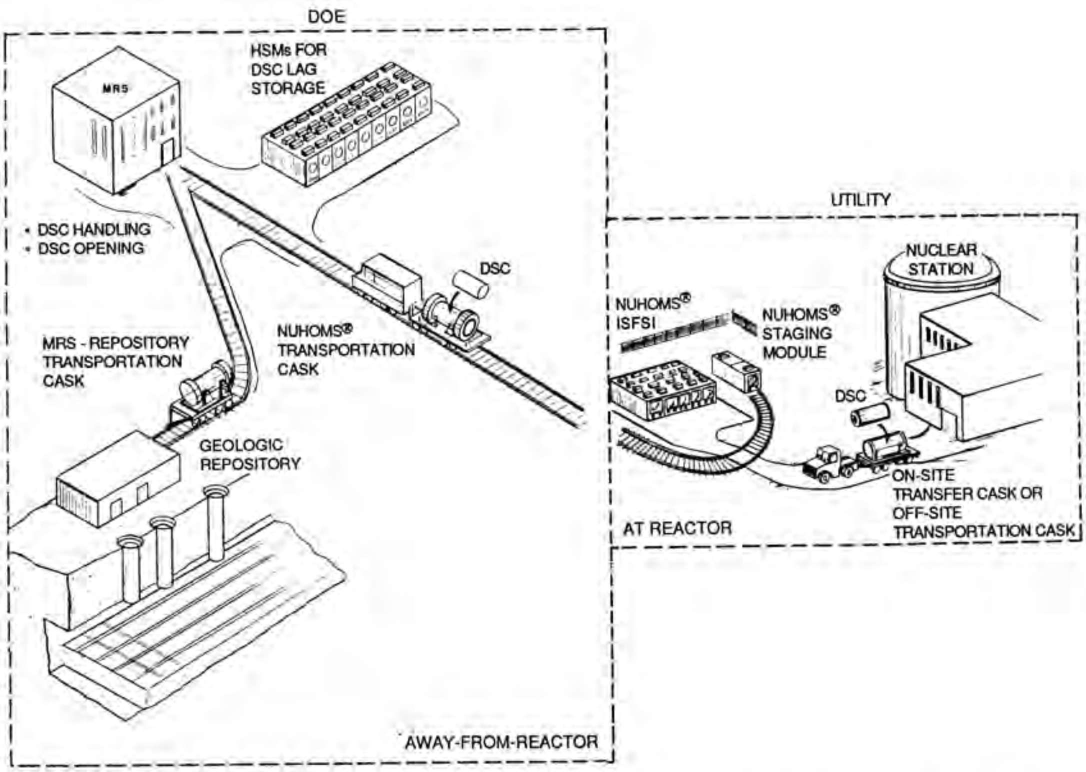

Fig. 9. Conceptual Storage and Transportation Cycle Using NUHOMS® System.

SUMMARY

The shipment of intact NUHOMS® DSCs appears to offer enhanced safety, flexibility, and economy to the DOE, the utilities, and ultimately the general public, and meets the need for interim at-reactor dry storage utilizing an integrated, compatible system for away-from-reactor transportation of spent fuel. In addition, the reduced cask loading and unloading time at-reactor and the MRS afforded by shipment of intact canisters may make it possible to utilize a smaller OCRWM cask fleet with the same or greater system capacity than might otherwise be required.

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