NUHOMS® TRANSPORTATION SYSTEM INTERFACES

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ABSTRACT

As utilities with nuclear 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 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 systems 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 and attempts to demonstrate the flexibility and adaptability of the NUHOMS® technology.

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 60 BWR spent fuel assemblies for various vendor specific fuel assembly designs and in-core operating histories. The HSMs are constructed in interconnected 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 to ensure that full core reserve storage capacity in the spent fuel pool is maintained. A complete description of the NUHOMS® System for dry spent fuel storage and its operation are contained in the NUHOMS® Topical Report and related publications (2, 3, 4).

The DSC provides the primary containment boundary for confinement of radioactive materials during transfer and storage. The DSC has redundant welded end closures, shielded end plugs for occupational ALARA, 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 for occupational ALARA and protection against postulated accidents such as a cask drop or extreme natural hazard. A composite illustration of the DSC, transfer cask, and spent fuel is shown in Fig. 1. The standard NUHOMS® system configuration for DSC transfer to or from an HSM is shown in Fig. 2.

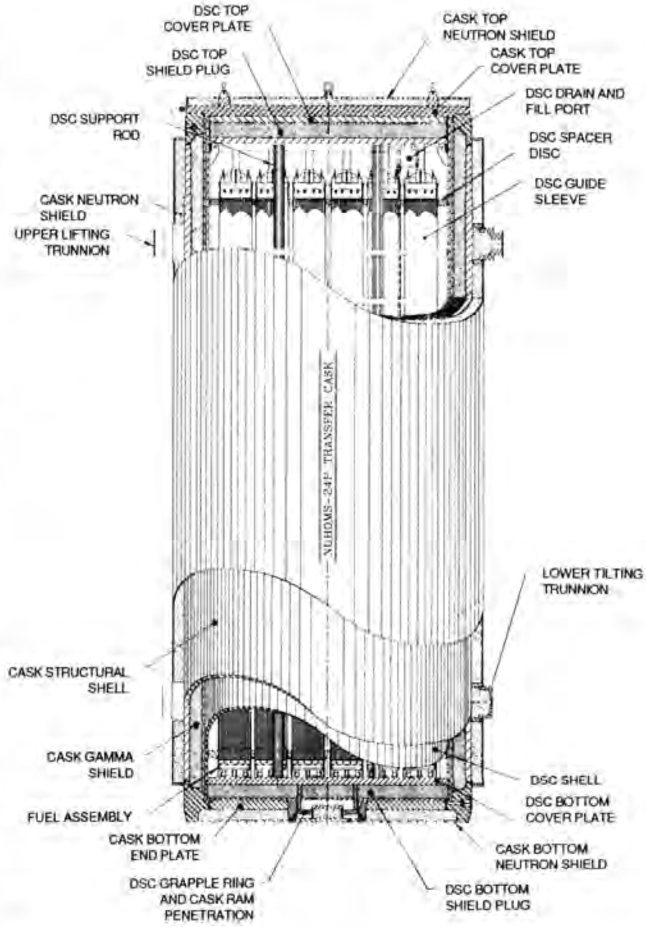

Fig. 1. NUHOMS®24P Cask/Canister General Arrangement.

Following at-reactor dry storage, several alternatives exist for transportation of the spent fuel contained in a NUHOMS® ISFSI to the DOE's MRS or geologic repository as depicted in the Fig. 3 flow chart. The alternate

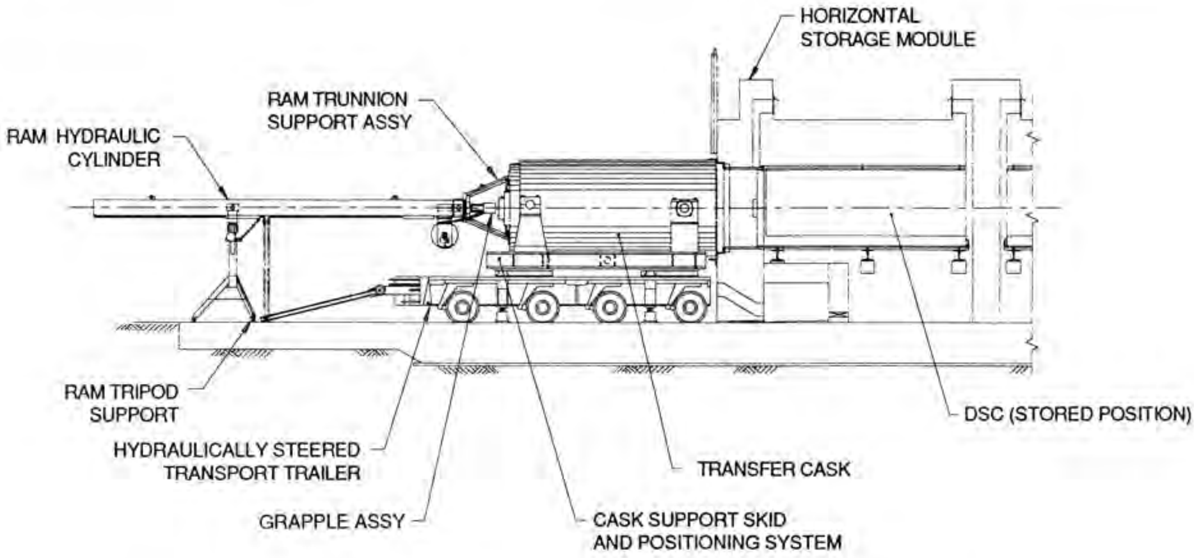

Fig. 2. Standard NUHOMS®24P System Components, Structures and Transfer Equipment.

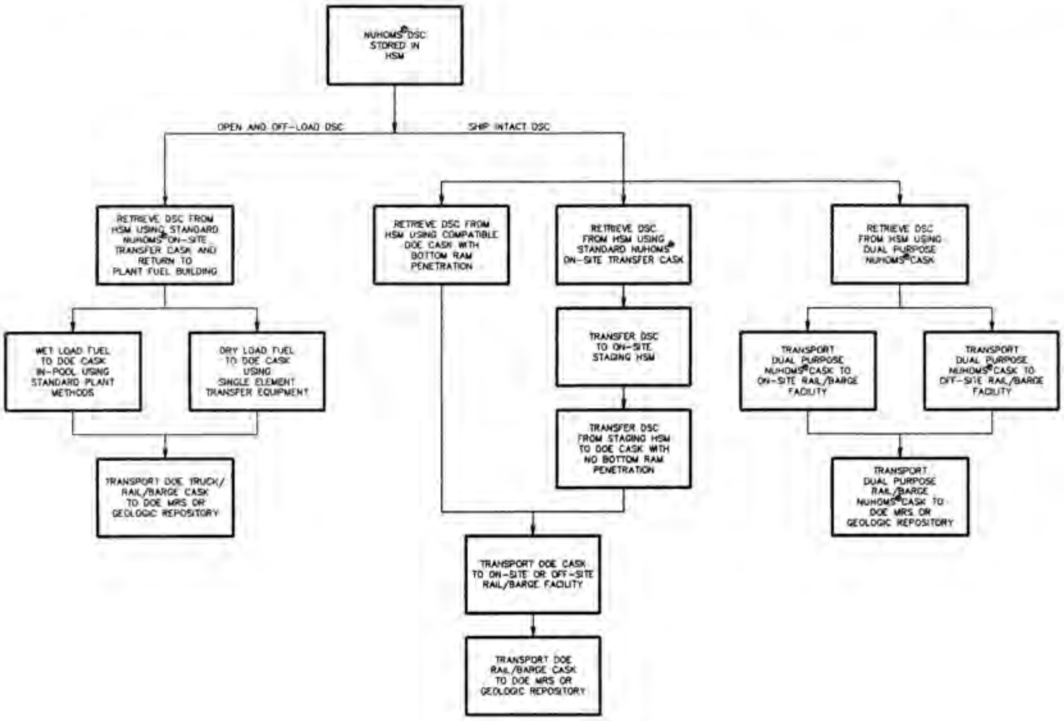

Fig. 3. Options for Away-From-Reactor Shipment of Spent Fuel with NUHOMS® System.

means available to a particular plant will depend on the compatibility of the plant/DOE system interfaces and available access 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 is maximized and the number of trips minimized, thus minimizing the risk to the public. Transportation utilizing smaller heavy-haul truck cask is the least desirable 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 also makes possible the shipment of intact DSCs which offers substantial advantages over shipment of non-canisterized spent fuel. These include enhanced safety provided by a second containment boundary to that of the shipping cask, reduced occupational ALARA since individual spent fuel assemblies are not re-handled at the reactor site, and economy since spent fuel pre-packaged in a DSC affords the minimum DOE transportation system cycle time. Thus the risk and cost to the public is reduced. The alternative means of shipment of intact NUHOMS® DSCs and the associated plant/NUHOMS®/DOE system interface requirements are presented in the remaining portions of this paper along with a conceptual plan for how such an approach could be implemented.

CANISTER DESIGN FEATURES AND 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 NUHOMS® system Topical Report, (2), which delineates the design provisions for criticality control, decay heat removal, minimization of off-site radiation dose, occupational ALARA, and structural integrity. The standard NUHOMS® DSC design features are summarized in Table I. The DSC internal basket assembly design details are individually 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, however, such that the physical features and design capacity of the DSCs for all fuel types are the same, thus providing a standard package with the same characteristic interfaces.

The shipment of intact DSCs off-site would require qualification and certification of the DSC to the requirements of 10CFR71, (4), 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). Minor modifications 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. These modifications are summarized in Table I and illustrated in Fig. 4.

DIRECT CANISTER TRANSFER TO COMPATIBLE DOE RAIL/BARGE CASK

At-reactor direct transfer of an intact NUHOMS® DSC from an HSM to a DOE rail/barge cask requires that the cask have a compatible cavity size, a bottom end penetration for insertion of the hydraulic ram, and a recess for the bottom end DSC grapple ring similar to that of a standard NUHOMS® on-site transfer cask as shown in Fig. 1. It may also be feasible to adapt a rail/barge cask with a compatible cavity diameter and payload capacity by placing an insert in the bottom end of the cask cavity (not shown)

TABLE I
NUHOMS® 24P Standard Dry Shielded Canister Design Features.

Physical Parameters:
- Outside Diameter = 1.71m (67.25 in.) - **standard**
- Maximum Length PWR Fuel ≤ 1.72m (186 in.)
- Maximum Dry Loaded Weight ≤ 32,660kg (72,000 lbs.)

Criticality Control Capability:
- Credit for Burnup
  - No-Poison Basket
  - No Burnable Poisons
  - Nominal Case $K_{eff} < 0.95$
  - Extreme Case $K_{eff} < 0.98$
- Governing Conditions
  - Axial Burnup Variation
  - Optimum Moderation
  - Fresh Fuel Misload
  - Combined Effects
- Biases and Uncertainties
  - Fission Products
  - Actinides
  - Mechanical
  - Geometric
  - Material
  - Statistical

Radiological and ALARA Provisions:
- Maximum Contact Dose DSC in Cask ≤ 100 mrem/hr
- Maximum DSC Shield Plug Contact Dose
  - Wet ≤ 200 mrem/hr
  - Dry ≤ 400 mrem/hr
- Smearable Contamination ≤ 22,000 dpm/ 100 cm^2

Decay Heat removal Capacity:
- Decay Heat Generation
  - 2/3 kW per Fuel Assembly
  - 16 kW per DSC
- Maximum Fuel Cladding Temperature
  - Long Term Storage ≤ 340°C
  - Short Term Conditions ≤ 570°C

Structural Capacity:
- Postulated Cask Drop Accident Decelertion
  - Horizontal Side Drop or Slab Down 75g's
  - Vertical Top or Bottom End Drop 75g's
  - Oblique Corner Drop 25g's
  - Capacity Comparable to Fuel Itself
- Internal Pressure
  - Normal Storage Conditions ≤ 10 psig
  - Worst Case Postulated Accident ≤ 50psig

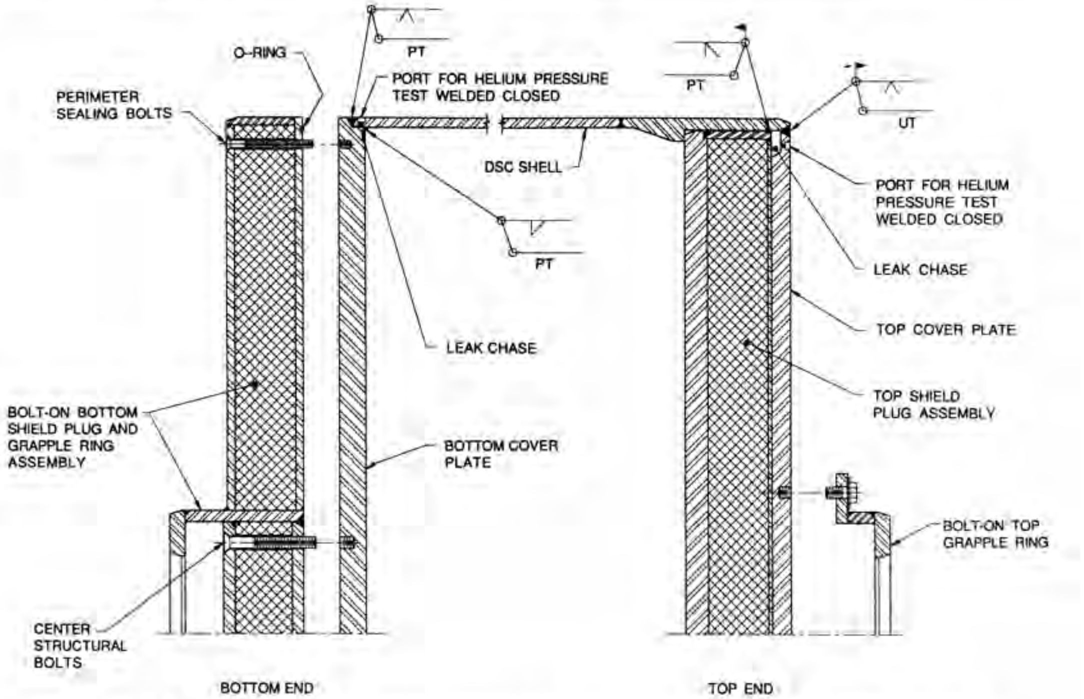

Fig. 4. Canister Design Enhancements to Improve Compatibility and Shipability.

Table II
Canister Design Enhancements to Improve Compatibility and Shipability.

Enhancement	Benefits
1. Use of thicker stainless or borated guide sleeves.	1. Permits shipment of higher enriched, more reactive fuel with credit for burnup or no credit for burnup criticality assumptions.
2. Full penetration, UT-able top cover plate to shell field weld.	2. Permits full, volumetric exam of field placed top end closure weld.
3. Leak chase between primary and secondary seal welds for DSC top and bottom end closures.	3. Permits high pressure helium leak test of DSC redundant seal welds. All other pressure boundary welds are radiographically examined during DSC fabrication.
4. Bolted, removable bottom shield plug and ram grapple ring assembly.	4. Permits shortening of DSC length and use of DOE cask with no bottom penetration. Transfer of DSC to/from DOE cask must be performed using *staging module*.
5. Provisions for lifting/handling/ horizontal transfer of loaded DSC via top cover plate.	5. Permits handling of DSC in hot cell using overhead crane or horizontal transfer to staging module at DOE facility following shipment.

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 DOE rail/barge cask with the HSM.

Operations for direct transfer of an intact DSC to a DOE rail/barge cask would be performed using standard NUHOMS® transfer equipment and transfer techniques as shown in Fig. 2, except that the standard NUHOMS® cask support skid would be changed-out or modified to be compatible with the rail/barge cask if necessary. Transport of the DOE 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 DOE 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 means (not shown) and secured for shipment to the DOE 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® transport trailer which is a modular, multi-wheel set, hydraulically suspended, all-wheel steered trailer specifically designed to evenly distribute heavy loads and minimize wheel loads on commercial grade pavement. Additional wheel sets or an entire dolly with a load spreading device could be utilized to reduce the wheel load magnitudes and total load distribution to be within local limits for road surfaces and overpasses (these types of heavy-haul trailers are commercially available and have been utilized in such applications as transport of the NASA space shuttle). Prior to off-site transport, cask impact limiters would be installed to provide added safety margin. The 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 DOE rail/barge cask and intact NUHOMS® DSC would be lifted onto a rail car or barge and secured for shipment to the DOE MRS facility or permanent geologic repository as shown in Fig. 7.

INDIRECT CANISTER TRANSFER TO DOE RAIL/BARGE CASK

At-reactor indirect transfer of an intact NUHOMS® DSC to a DOE rail/barge cask with compatible cavity diameter and payload capacity but without a bottom penetration can be achieved by first retrieving the DSC from an ISFSI HSM using the standard NUHOMS® on-site transfer cask, transfer equipment and transfer techniques. Subsequent direct transfer of an intact DSC from a NUHOMS® on-site transfer cask to a DOE rail/barge cask may be possible, however, this alternative is not preferred since the fuel assemblies would be oriented top down and the DSC bottom shield plus and grapple ring assembly would be oriented top up, thus complicating the canister opening and fuel handling process at the DOE's MRS or geologic repository following shipment.

The preferred method of transferring an intact NUHOMS® DSC to a DOE rail/barge cask at-reactor following retrieval of the DSC from an ISFSI HSM using a standard NUHOMS® on-site transfer cask is to first off-load the DSC to a 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 and ram operation module design is similar to that first utilized for demonstration of the NUHOMS® 07P system. The front access door of the staging module would have increased shielding capacity as compared to a standard NUHOMS® HSM door should it be necessary to remove the bolt-in DSC bottom shield plug and grapple ring assembly shown in Fig. 4 for compatibility with a DOE rail/barge. The staging module door would be designed for opening and closing with a cask docked to the module as discussed below.

At-reactor off-loading of the DSC from the NUHOMS® on-site transfer cask to the staging module occurs in a manner similar to that shown in Fig. 2 for a standard DSC transfer. As a prerequisite to this operation, the specific interface requirements of the DOE rail/barge cask without a bottom end ram penetration are accommodated. For example the rail/barge cask cavity length or bottom end configuration may require removal of the bolted DSC bottom shield plug and grapple ring assembly shown in Fig. 4. This is done by first removing the perimeter sealing bolts of the bolt-on bottom shield plug assembly prior to initial retrieval of the DSC from an ISFSI HSM into the NUHOMS® on-site transfer cask, leaving the center structural bolts in place so that the DSC can be pulled from the HSM. Also, following removal of the NUHOMS® on-site cask top head transfer prior to docking the cask with the staging module, the DSC top end bolt-on grapple ring is installed as shown in Fig. 4.

Following docking of the NUHOMS® on-site transfer cask in preparation for pushing the DSC into the staging module, the center structural bolts of the bolt-on DSC bottom shield plug and grapple ring assembly shown in Fig. 4 are removed. 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. The hydraulic ram is then retracted with the ram grapple engaged so that the DSC bottom end shield plug and grapple ring assembly is pulled back into the on-site transfer cask. The door to the staging module is then lowered, and the NUHOMS® on-site transfer cask. The door to the staging module is then lowered, and the NUHOMS® on-site transfer cask is pulled away from the staging module.

At-reactor loading of the intact DSC from the staging module to the DOE rail/barge cask is achieved by first setting up the standard NUHOMS® hydraulic ram in the

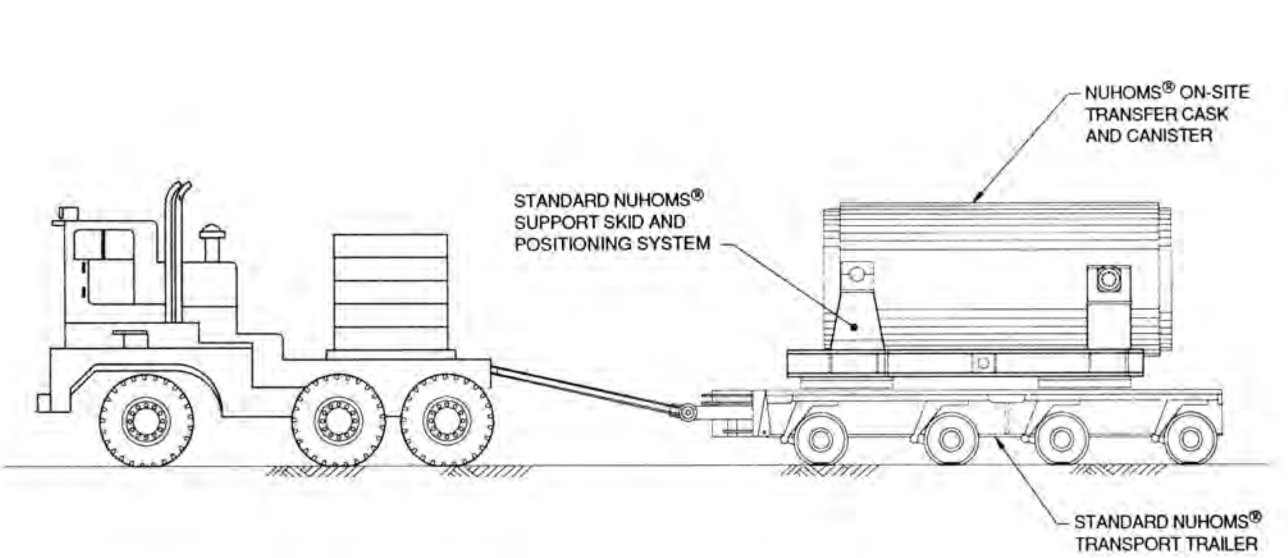

Fig. 5. On-Site Transport of NUHOMS® Canister Staging Module or Rail/Barge Facility.

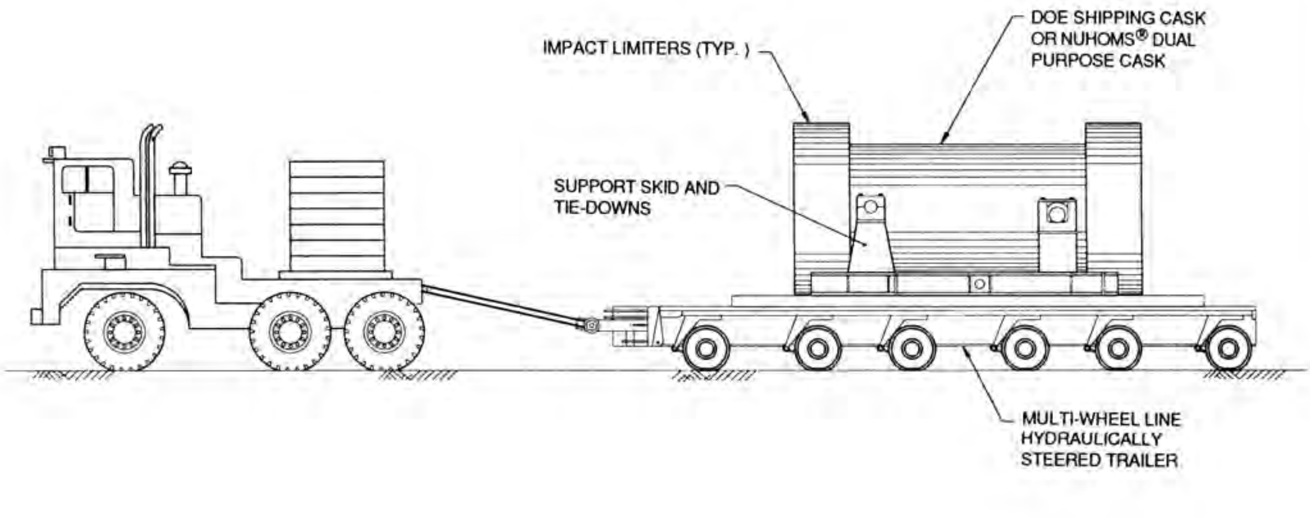

Fig. 6. Off-Site Transport of Cask/Canister to Rail/Barge Facility.

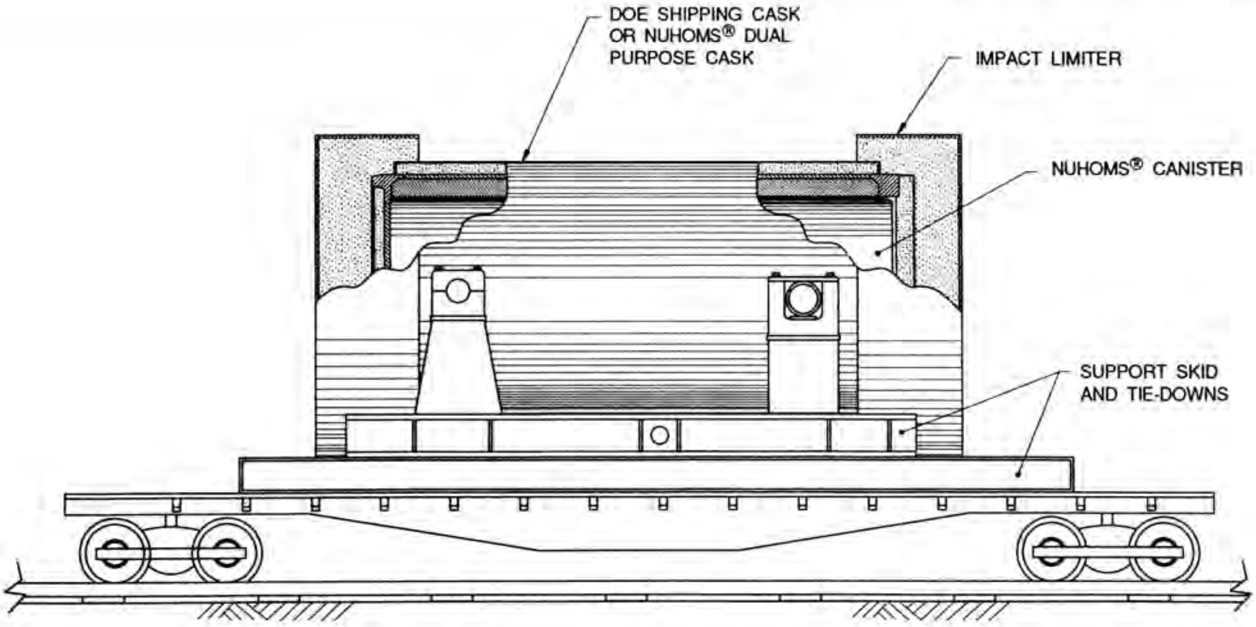

Fig. 7. NUHOMS® Dual Purpose Cask and Canister on Rail Car.

rear of the module. The rail/barge cask and compatible support skid are then placed on the NUHOMS® transport trailer and positioned and docked with the front of the staging module as shown in Fig. 8. The ram grapple is then inserted and engaged with the previously installed bolt-on DSC top grapple ring and the hydraulic ram actuated to initiate pushing of the intact DSC into the DOE 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 and installing the cask top head. The DOE 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 DOE's MRS facility or permanent geologic repository as shown in Fig. 7.

DUAL PURPOSE NUHOMS® CASK

In the event that there is 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 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 III.

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. 1 and described in the NUHOMS® Topical Report, (1). The on-site transfer cask design would be modified to be in compliance with 10CFR71, (3), criteria taking credit for the additional primary containment boundary, axial shielding, and structural capacity provided by the standard NUHOMS® 24P 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 DOE rail/barge cask and shown in Figs. 2, 6 and 7. Thus, the added safety and economy of shipment of intact NUHOMS® DSCs is apparent.

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 DOE 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/from a DOE rail/barge cask or a dual purpose NUHOMS® cask.

Alternatively, the intact DSC could be off-loaded to a hot cell and opened using remote mechanical cutting tools to facilitate down-loading of the spent fuel assemblies to short-term rack storage for subsequent processing and preparation for permanent storage. The emptied DSC could then be decontaminated and re-qualified for use or disposed of as low level waste.

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.

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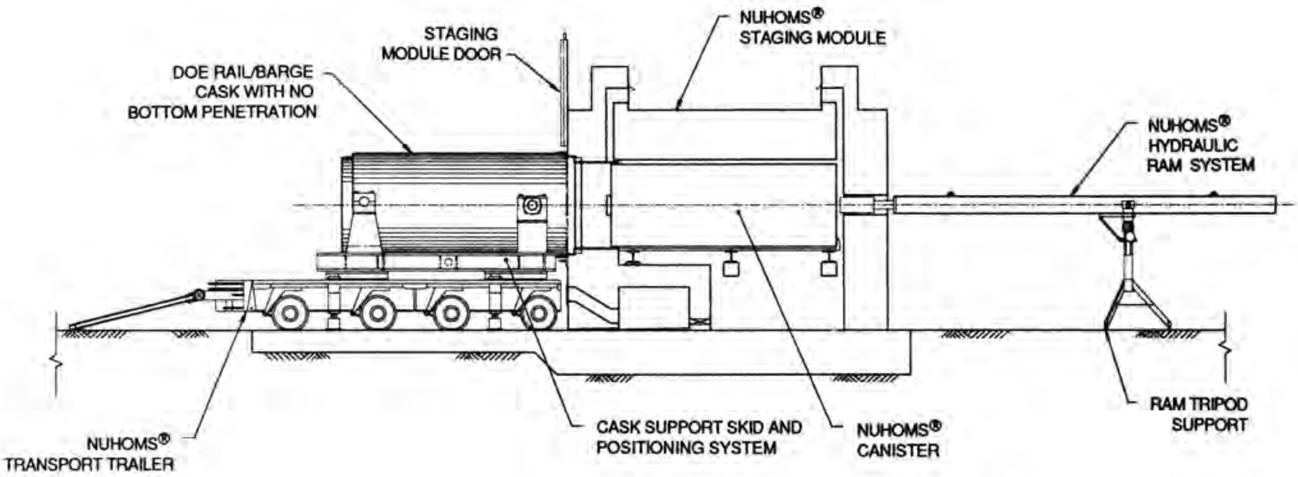

Fig. 8. NUHOMS® Canister Transfer From Staging Module to DOE Shipping Cask.

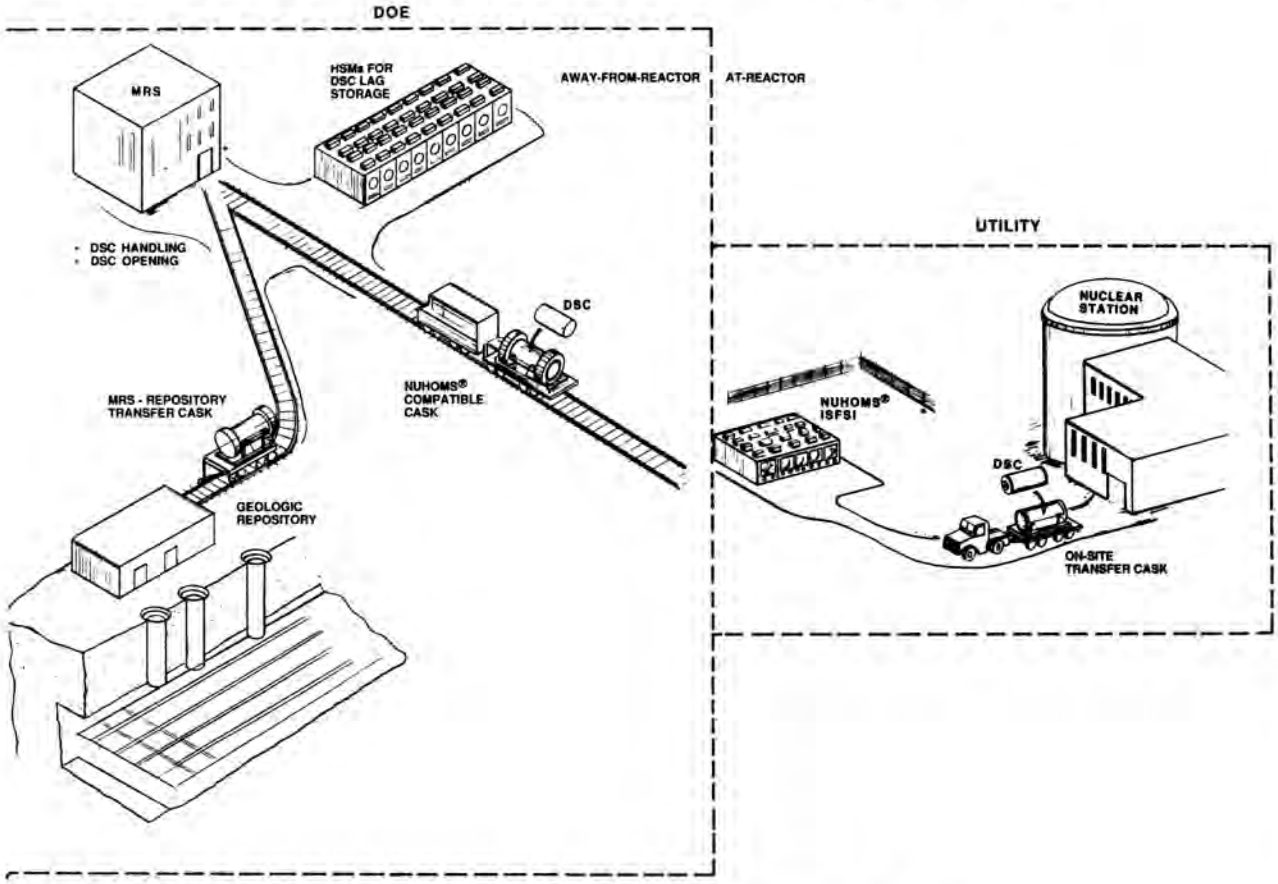

Fig. 9. Conceptual Transportation Cycle Using NUHOMS® System.

TABLE III
NUHOMS®-24P Dual Purpose Cask Design Criteria.

Operational Capabilities:
- Standard NUHOMS®At-Reactor Dry Stroage Operations (10CFR72)
  - Wet Loading of Spent Fuel into DSC
  - Transport DSC to HSM
  - Transfer DSC to/from HSM
- Away-From-Reactor Transport of Intact DSC (10CFR71)
  - Transport to Rail/Barge Facility
  - Load Cask/DSC/Skid onto Rail Car or Barge
  - Transport Cask/DSC to DOE MRS or Repository
  - Off-Load DSC to Lag Storage or to Hot Cell

Physical Parameters:
- Compatible with Standard NUHOMS®24P DSC
  - Cavity Diameter 1.73m (68 in.)
  - Cavity Length 4.75m (187 in.)
  - Payload Capacity 34,020kg (75,000. lbs.)
- Maximum Cask/DSC Gross Weight < 113mtons (125 tons)

Radiological and ALARA Provisions:
- In Accordance with 10CFR71 Limits
  - Maximum Contact Dose
  - Dose Versus Distance
  - Smearable Contamination

Decay Heat Removal Capacity:
- 16 kW per DSC

Postulated Accident Conditions:
- In Accordance with 10CFR71
  - Extreme Environmental Conditions
  - Free Cask Drop onto an Unyielding Surface
  - Crushing Due to Drop of Heavy Object on Cask
  - Puncture Due to Projectile Impact or Cask Drop
  - Exposure to Sustained Fire
  - Deep Submersion in Water

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