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HI-STAR/HI-STORM: MULTI-PURPOSE CANISTER BASED SYSTEMS FOR TRANSPORT AND STORAGE

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ABSTRACT

Building upon over ten years of experience in the supply of high-density spent fuel rack systems, Holtec International has developed the MPC-based HI-STAR and HI-STORM spent fuel management systems. These systems provide a high-capacity, low-cost solution to the long-term storage of spent nuclear fuel.

Building upon current transport and storage cask designs and operational systems, Holtec has optimized proven design principles to address multi-purpose canister (MPC) based system requirements.

The paper provides an overview of the major system components, discusses unique design features, and the improved operational characteristics of the HI-STAR and HI-STORM systems.

BACKGROUND

Due to continuing delays in the U.S. Department of Energy's (DOE) spent nuclear fuel (SNF) and high-level waste program in the U.S., and the delay or deferment of SNF reprocessing in many countries in Europe and in Asia, there is an increasing need for cost-effective long-term spent fuel storage both at reactor sites and at centralized storage facilities. To date, many utilities have selected to store excess SNF inventories in dual-purpose metal casks. The initial selection of this technology for SNF storage were based on the proven capabilities of metal casks to meet rigorous transport regulations. Although metal transport cask design was a mature technology, some design changes were needed to adapt metal transport casks to long-term SNF storage duties. Several of these changes included the use of double closure lid designs; the use of metallic O-rings in place of standard elastomer seals; and the installation of a monitoring system to provide assurance of closure lid seal integrity.

The major drawback of using metal dual-purpose casks for storage of SNF is the purchase cost. Dual-purpose cask prices are in the $1.5 - $2.5 million range depending on design features, materials of construction, and specific country regulatory requirements.

An alternative to metal casks that has been pursued in the U.S. are the storage-only canister based systems stored in either horizontal or vertical concrete modules. These systems offered the advantages of a simple, low-cost design. However, as the canisters are not transportable, the stored SNF will require removal from the canister and repackaging in a transport cask for ultimate off-site shipment whether for disposal, reprocessing, or further storage at a centralized storage facility.

In response to the need for a multi-capable, low cost storage and transport system, Holtec International initiated development of the HI-STAR and HI-STORM systems in 1993. Building upon our successful wet SNF storage systems technology, these systems provide a high capacity, low cost solution for utilities' current on-site storage needs and future off-site transport requirements.

The Multi-Purpose Canister (MPC)

The central component of the HI-STAR and HI-STORM systems is the MPC. In MPC-based systems, the fuel basket is housed in a cylindrical pressure vessel defined as the confinement boundary. For the HI-STAR MPC, the enclosure vessel is an all-welded ASME Section III, Class 1 pressure vessel with a design pressure of 100 psig (7.8 bar). The use of a fully welded vessel provides assurance that the SNF is totally isolated from the external environment.

Located within the MPC enclosure vessel is the fuel basket which performs its classical function. The fuel basket provides an array of vertical fuel cavities, the number of which vary depending on the fuel type to be stored, and the fuel's physical and nuclear characteristics. The current HI-STAR/HI-STORM system incorporates four separate MPC basket deigns for standard PWR and BWR fuel assemblies. Other fuel baskets can be designed to accommodate other fuel types (e.g., Siemans PWR, VVER-440), etc. The current MPC designs are the following:

- MPC-24 for the storage and transport of 24 standard PWR fuel assemblies including control components;
- MPC-68 for the storage and transport of 68 standard BWR fuel assemblies with or without channels;
- MPC-32 for the storage and transport of 32 standard PWR fuel assemblies based upon boron credit in storage and burnup credit in transport; and
- MPC-GTCC for the storage and transport of irradiated and contaminated hardware.

The SNF content conditions for the HI-STAR/HI-STORM systems are presented in Table 1.

The MPC-32 basket is shown in Figure 1. As can be seen, the basket is an array of cells created by arranging a gridwork of plates in a rectilinear arrangement. The resulting honeycomb construction provides for complete connectivity between adjacent fuel cells at all contiguous corners. Thus the flow of the decay heat from the SNF to the exterior of the basket occurs throughout the entire volume of the fuel basket. In each of the MPC designs, Boral neutron absorbing plates are incorporated into each fuel cell wall by a fully-welded sheathing process.

The top end of the MPC incorporates a redundant closure system. The MPC lid is a circular plate edge-welded to the MPC outer shell. The lid is equipped with vent and drain ports which are utilized to remove water and air from the MPC, and to backfill the MPC with helium. The ports are covered and welded prior to the installation of the closure ring.

The closure ring is a circular ring edge-welded to the MPC shell and lid. The MPC lid provides sufficient rigidity to allow the entire MPC loaded with SNF to be lifted by threaded holes in the MPC lid. A cross sectional view of the MPC is presented in Figure 2.

The MPC is constructed entirely from stainless steel alloy materials except for the neutron absorbing materials. No carbon steel materials are permitted in the MPC, thereby eliminating concerns regarding adverse interactions between coated carbon steel materials and various operating environments.

The HI-STORM Storage Overpack

The HI-STORM 100 overpack is an optimized combination of steel structural components and concrete radiation shielding. The HI-STORM overpack is a rugged, heavy-walled cylindrical vessel creating a vertical ventilated storage cask. The main structural function of the overpack is provided by interior and exterior shells of carbon steel, and the main shielding function is provided by concrete poured into the annulus between the steel shells.

The HI-STORM overpack has convective ducting at the base and top of the overpack to allow for passive cooling of the contained MPC. The storage overpack is completed with a steel and concrete lid, and a thick steel baseplate. The overpack provides an internal cylindrical cavity of sufficient height and diameter for housing the interchangeable MPCs.

Four removable lifting lugs, located on 90° centers, can be attached to the top of the overpack for lifting of the cask body. The overpack may also be lifted from the bottom using a specially-designed lifting device including hydraulic jacks, airpads, or rollers.

A cross sectional view of the HI-STORM 100 System with an MPC inserted is presented in Figure 3.

The shield design of the HI-STORM is optimized to provide low dose rates at the cask radial, vent opening, and top surfaces. This provides low operator exposures and minimal site boundary dose rates. The HI-STORM module is loaded with the MPC using a HI-TRAC transfer overpack. The transfer overpack provides structural support and shielding for the wet loading of the MPC, transfer of the MPC into the HI-STORM, and for transfer of the MPC from the HI-STORM storage overpack to the HI-STAR overpack.

The HI-TRAC On-Site Transfer Cask

Working in conjunction with the HI-STORM storage overpack, the HI-TRAC transfer cask provides a means to load the fuel into the MPC in the fuel pool. The HI-TRAC transfer cask is designed for on-site use only to facilitate underwater loading of the MPC, MPC closure operations, and the transfer of the sealed MPC to the HI-STORM storage overpack or HI-STAR dual-purpose overpack. The HI-TRAC transfer cask provides optimal shielding of the fuel housed in the MPC to minimize personnel exposure during handling and MPC closure operations. Additionally, the HI-TRAC transfer cask provides the means to handle the loaded MPC and remotely transfer the MPC to an overpack for storage or transport.

The HI-TRAC transfer cask cylindrical body is a heavy-walled carbon steel cask with lead gamma shielding and water neutron shielding. The lead is housed within an annulus formed by two thick concentric carbon steel shells. The inner and outer carbon steel shells are welded to a top flange forging and a bottom flange. Radial channels are vertically welded to the exterior of the outer shell at equal intervals around the circumference. Carbon steel panels are vertically edge welded to each of the circumferentially-spaced radial channels to form the water jacket outer shell. The radial channels act as fins for improved heat conduction.

The HI-TRAC transfer cask is equipped with a top lid which provides additional shielding for the MPC and provides a center penetration which accesses to the MPC lid threaded holes to allow remote lowering and raising of the MPC into or out of the storage or transport overpack. The HI-TRAC transfer cask is provided with two bottom lids. The pool lid is provided for in-pool operations and is composed of steel-lead-steel layers to provide sufficient shielding. The transfer lid is provided to allow the bottom of the HI-TRAC transfer cask to be remotely opened to allow lowering or raising of the MPC. The transfer lid is composed of a housing and two shield doors. The shield doors are fabricated in a multi-layered fashion to provided gamma and neutron shielding. The use of the pool lid prevents excessive contamination of the transfer lid's operating mechanism, and provides a smaller footprint for in-pool clearance considerations.

The HI-TRAC transfer cask is equipped with lifting trunnions to allow vertical handling of the loaded HI-TRAC while meeting heavy-lifting requirements. Pocket trunnions which allow for the rotation of the loaded HI-TRAC to the horizontal position are attached to the bottom of the HI-TRAC transfer cask. The pocket trunnions are located slightly off-center to ensure proper rotation direction.

The HI-TRAC is designed to interface with either the HI-STORM storage module or with the HI-STAR dual purpose overpack. The HI-TRAC system is designed to transfer the loaded MPC within the fuel storage building or at the storage pad. Specially designed single-failure proof lifting systems have been developed to facilitate the storage pad transfer operations.

The HI-STAR Transport Overpack

The HI-STAR dual-purpose overpack is a heavy-walled steel cylindrical vessel. The HI-STAR is designed to perform both storage and transport functions similar to standard dual purpose casks. In the transport mode, the containment boundary is formed by an inner shell welded at the bottom to a cylindrical forging, and at the top, to a heavy flange forging with a bolted closure lid. Two concentric grooves are machined into the closure plate for placement of metallic O-rings. The closure lid is recessed into the top flange and the bolted joint is configured to provide maximum protection to the closure bolts and seals in the event of a transport accident. The inner surfaces of the HI-STAR form an internal cylindrical cavity for housing the MPC.

The outer surface of the inner shell is buttressed with intermediate shells of gamma shielding which are installed in a manner to ensure a permanent state of interfacial pressure between adjacent layers. Besides serving as an effective gamma shield, these layers provide additional strength to the inner shell wall to resist potential punctures or penetrations from impacts and external missiles. Radial channels are vertically welded to the outside surface of the outermost intermediate shells at equal intervals around the circumference. These radial channels act as fins for improved heat conduction to the overpack outer enclosure shell surfaces, and as cavities for retaining and protecting the solid neutron shield.

Lifting trunnions are attached to the overpack top flange forging for lifting and for rotating the cask body between vertical and horizontal positions. The pocket trunnions are welded to the lower side of the cask to provide pivoting axis for rotation. The pocket trunnions are located slightly off-center to ensure proper rotation direction.

An overview of the HI-STAR 100 overpack is presented in Figure 4. For transport operations, transport impact limiters are installed at the top and bottom of the HI-STAR. The HI-STAR impact limiters are fabricated from aluminum honeycomb materials of various crush strengths retained within an outer stainless steel shell. The impact limiters are attached to the HI-STAR overpack by bolting into the sides of the top flange forging and bottom forging.

Licensing and Deployment Status

The HI-STAR/HI-STORM Systems are currently under licensing review by the USNRC for transport and storage approval in accordance with 10CFR71 and 10CFR72 (Reference Docket Nos. 71-9261, 72-1008, and 72-1014). Approval of the systems is expected by the middle of 1998.

The HI-STAR/HI-STORM systems have been selected by ComEd for the Dresden 1 Independent Spent Fuel Storage Installation and by the Private Storage Facility, LLC, for the planned private centralized storage facility in Utah.

Conclusion

The unique design and fabrication features of Holtec International's HI-STAR and HI-STORM systems provide a high capacity storage and transport system at a significantly lower cost than currently available technology. As increasing amounts of SNF require long-term storage, the Holtec International spent fuel management systems will provide significant cost and operating benefits to user utilities.

CANISTER DESIGN	MPC-24		MPC-68		MPC-32	
DESIGN PARAMETER	HI-STORM STORAGE	HI-STAR TRANSPORT	HI-STORM STORAGE	HI-STAR TRANSPORT	HI-STORM STORAGE	HI-STAR TRANSPORT
CAPACITY	24 PWR	24 PWR	68 BWR	68 BWR	32 PWR	32 PWR
Maximum Average Burnup(s) (MWD/MTU)	42,500 (@5) 45,000 (@6) 47,500 (@6)	40,000 (@10) 42,500 (@13) 45,000 (@15)	42,500 (@5) 45,000 (@6)	40,000 (@10) 42,500 (@13) 45,000 (@15)	40,000	40,000
Minimum Cooling Time (Years)	5	10	5	10	7	18
Decay Heat Load - per assembly (Watts) - per canister (kw)	1177 28.25	699 16.8	399 27.12	244 16.6	836 26.76	567 18.1
Fuel Enrichment (w/o U235)	4.1-4.6	4.1-4.6	4.2	4.2	4.2 (w/burnup credit)	1.9

Table 1

HI-STAR/HI-STORM CONTENT CONDITIONS

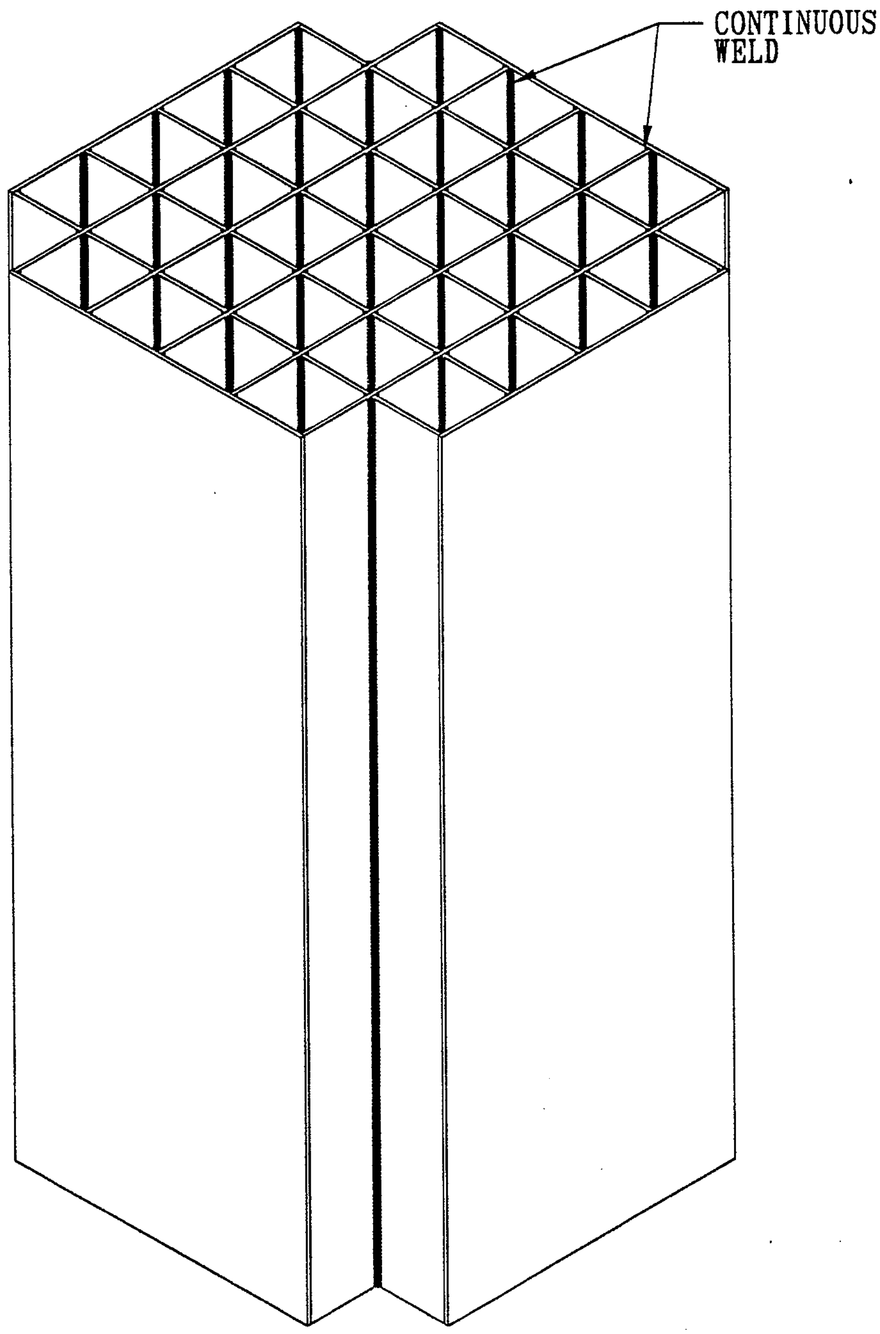

FIGURE 1; MPC-32 BASKET FOR HI-STAR 100

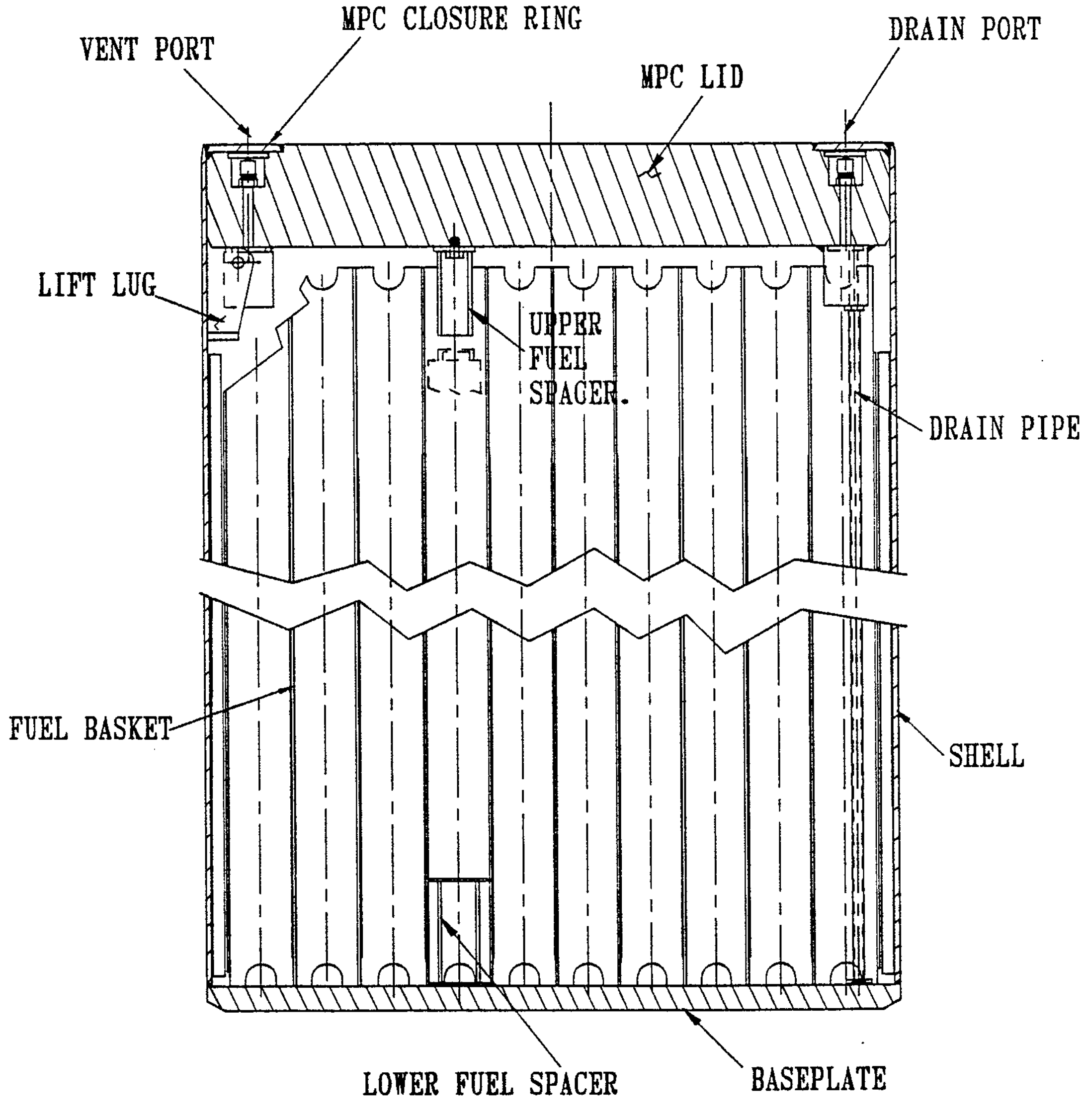

FIGURE 2; CROSS SECTION ELEVATION VIEW OF MPC

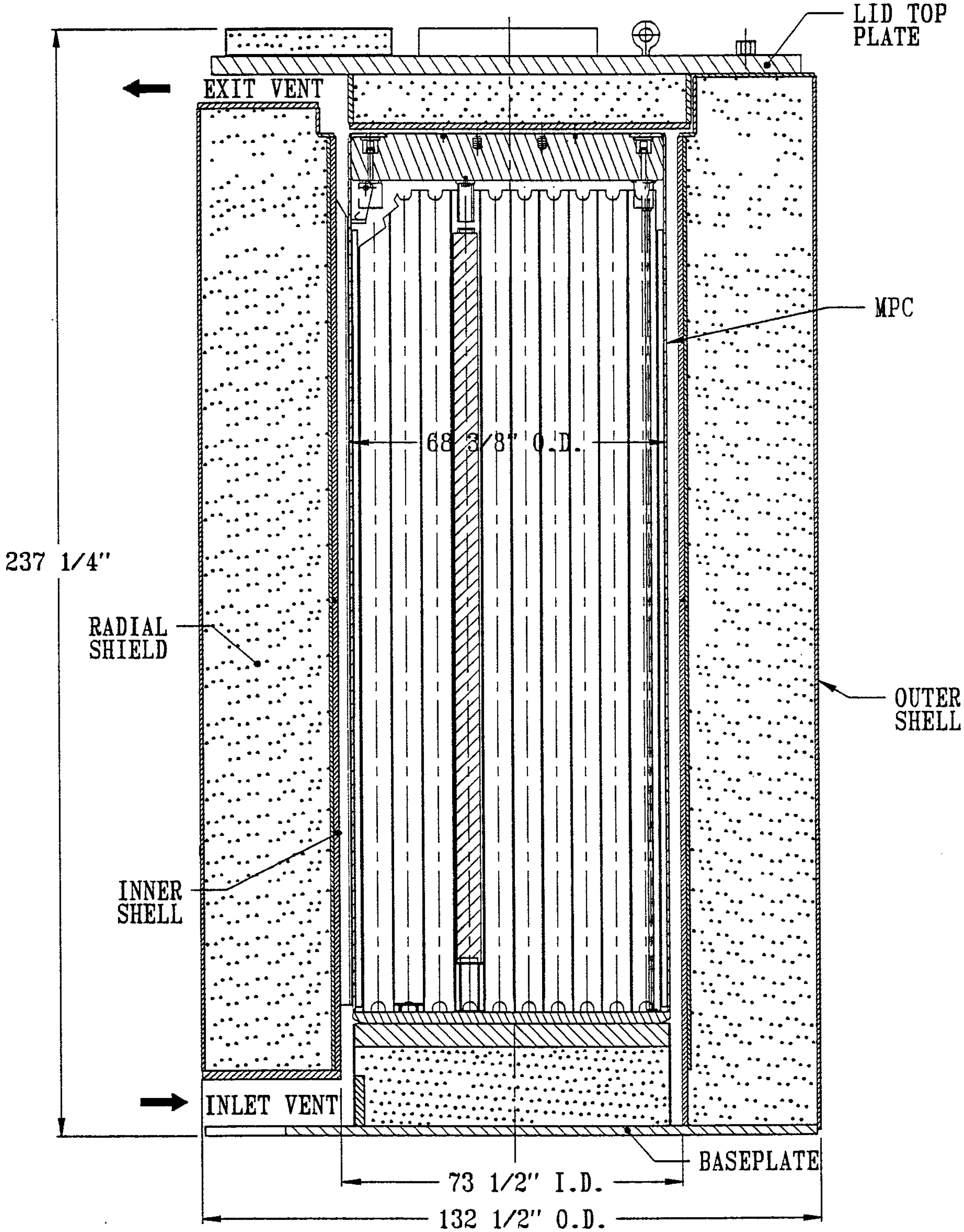

FIGURE 3; CROSS SECTIONAL VIEW OF THE HI-STORM 100 SYSTEM

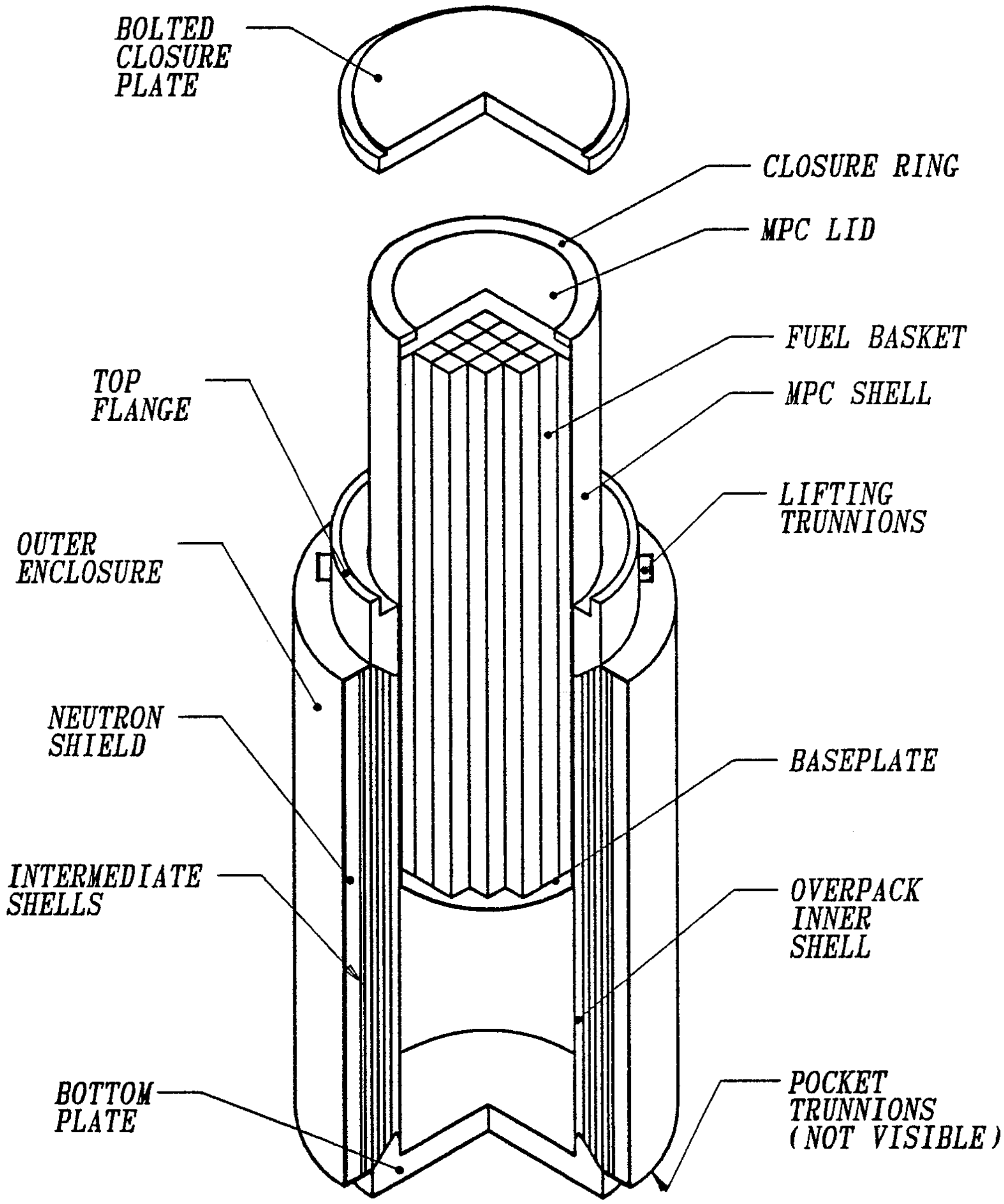

FIGURE 4; HI-STAR 100 OVERPACK WITH MPC PARTIALLY INSERTED