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A New Generation of Dry Transportable Storage for Spent Nuclear Fuel: NAC International's Technology for Modular, Advanced Generation, Nuclear All-purpose Storage – The MAGNASTOR™ System

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ABSTRACT

U.S. nuclear utilities have been using dry storage of spent nuclear fuel for more than 20 years, and over the last decade or so, most nuclear plants that use dry spent fuel storage have shifted to transportable dry storage technologies, or multipurpose systems. Today, almost 470 canister-based concrete multipurpose canister systems (MCS) are loaded and stored at U. S. reactor sites. NAC has supplied more than 190 (>40%) of these loaded, first-generation concrete MCS, and a number of lessons have been learned about the design, licensing, and operations of dry storage technologies.

NAC has taken a leading role in the development of a new generation of multipurpose technology that applies those lessons learned and improves the capabilities and economics of dry storage. The MAGNASTOR System was developed during 2003 and 2004 with extensive design review by NAC's customer base, and, over the last three years, substantial progress has been achieved. This paper presents the characteristics and developments embodied within the MAGNASTOR design and provides a current update on the storage certification of the system. NAC has also pursued an ambitious and aggressive demonstration program that has included three phases of prototype fabrication using three separate manufacturers. These efforts definitively demonstrate the ease and simplicity of system fabrication and give us great confidence that the MAGNASTOR System can become a global technology.

A key purpose of the MAGNASTOR System has been to improve the economics of dry MCS storage for the U. S. dry storage market. This paper will provide a summary of the economic impact that the MAGNASTOR System can have on dry storage costs for utility users, and similar impacts can be achieved globally.

Finally, this paper will review the unique transport cask approach for MAGNASTOR, which represents an evolution in cask technology while retaining a number of successful and proven elements of earlier NAC rail/marine transport cask designs.

INTRODUCTION

Multipurpose canister systems (MCS) have been in use for spent fuel storage in the U.S. for more than a decade. These systems use thin-shelled canisters with internal baskets for spent fuel containment. The transportable canisters are sealed with redundantly welded field closures and are typically stored in concrete-based overpacks at reactors for shielding and protection. The canisters may be transferred into transport packagings for shipment from the reactor, and canister designs do not preclude their use in waste disposal overpacks.

Over the last decade, more than 600 MCS have been procured by U.S. utilities and about 470 have been loaded with spent fuel and placed into Independent Spent Fuel Storage Installations (ISFSI) at reactor sites. To date, NAC's first generation multipurpose systems constitute more than 40 percent of all loaded concrete MCS in the U.S. However, the market for dry storage technology in the U.S. has changed over the last decade in that plants first entering the market for dry storage typically are of newer design, with more space, more clearance and headroom, and higher crane lifting capacities.

NAC has learned a number of significant lessons in the deployment of its first generation MCS and has developed a new generation MCS that considers these lessons learned. The new system is the Modular, Advanced Generation, Nuclear All-purpose STORage (MAGNASTOR) System. Some of the major features of this system are:

- a higher system spent fuel capacity, with a cost that is close to competitive technologies
- a unique developed-cell basket design, under patent review, that simplifies fabrication while providing high strength and heat removal efficiency
- an improved canister closure design to simply operations and reduce personnel doses
- a vertical concrete cask design that offers low site dose rates and threat limitations for beyond-design-basis events, while maintaining simple construction/operation features
- a transfer system that helps control personnel doses with a simple approach to handling.

SYSTEM DESCRIPTION

MAGNASTOR storage components consist of a concrete cask and a stainless steel transportable storage canister (TSC) with a welded closure lid to safely store spent fuel. The TSC is stored in the central cavity of a concrete cask and is compatible with the MAGNASTOR Transport (MAGNATRAN) System for future off-site shipment. Figure 1 shows storage configurations for MAGNASTOR, including a segmented body design for reduced height entrance and egress. The concrete cask provides structural protection, radiation shielding, and internal airflow paths to remove decay heat from the TSC contents by natural air circulation.

MAGNASTOR safely stores up to 37 PWR or 87 BWR spent fuel assemblies in a TSC. This capacity, combined with enhanced operational features, reduces the time and dose required for placing spent fuel into dry storage on a per assembly basis.

System operations involve placing spent fuel into the TSC while it is in the transfer cask and positioned in the cask loading area of the spent fuel pool. The transfer cask provides radiation shielding during TSC closure and preparation activities. Maximum system handling weight on the crane hook is less than 115 tons (104 t). The loaded TSC is drained and dried, and the closure lid redundantly welded to the canister. The loaded TSC is then moved to the concrete cask using the transfer cask. The TSC is transferred into the concrete cask by positioning the transfer cask containing the TSC on top of the concrete cask, opening the shield doors, and lowering the TSC into the concrete cask. Figure 2 depicts the major components of MAGNASTOR in such a configuration.

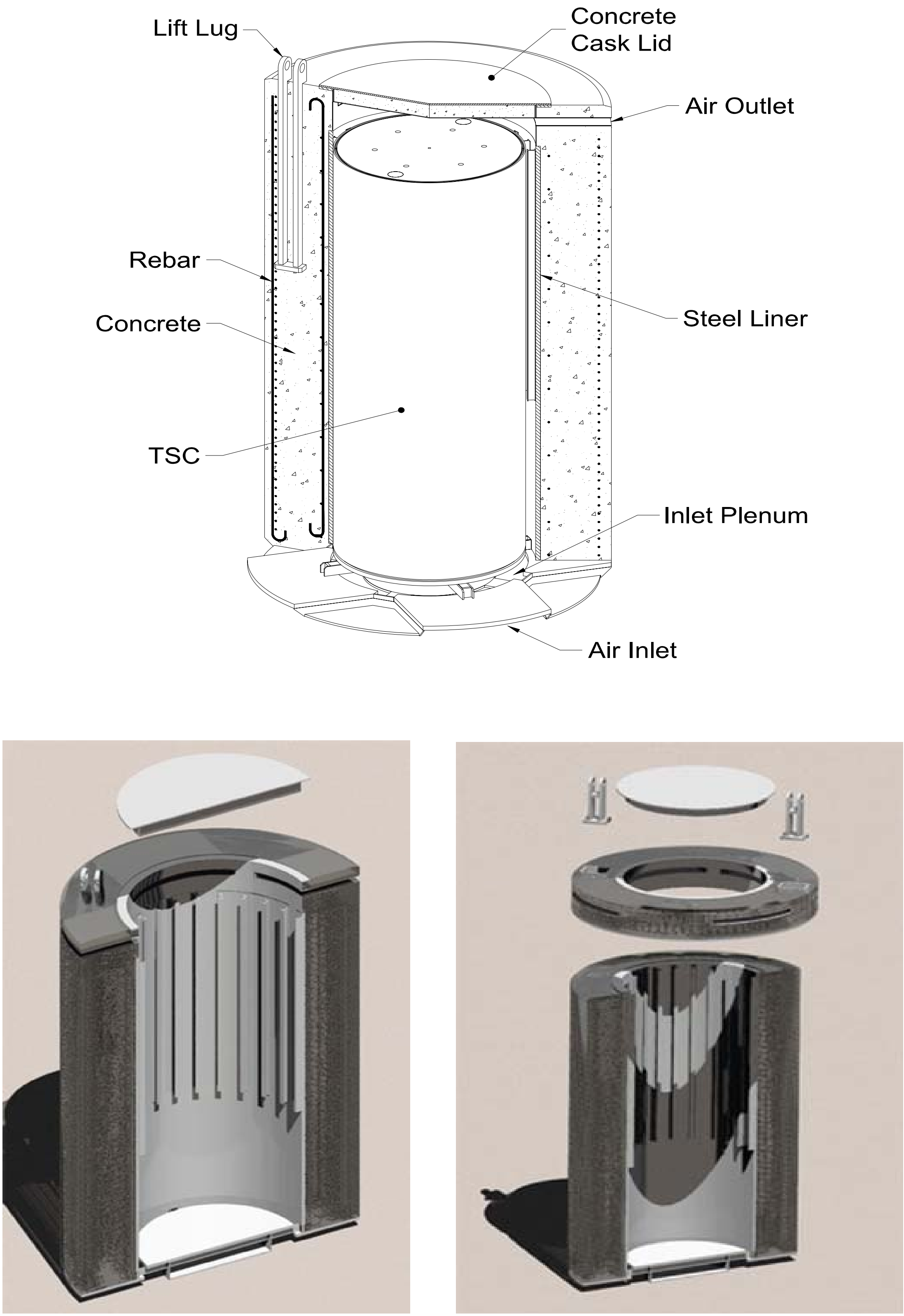
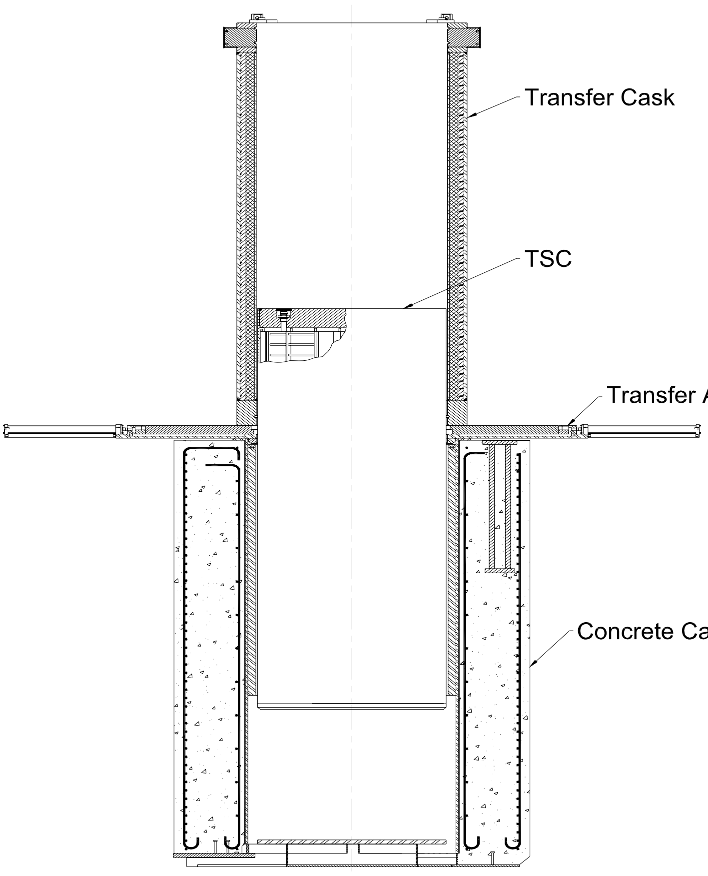


Figure 1. MAGNASTOR System Storage Cask Configurations



Transfer Operations **Transfer Cask**

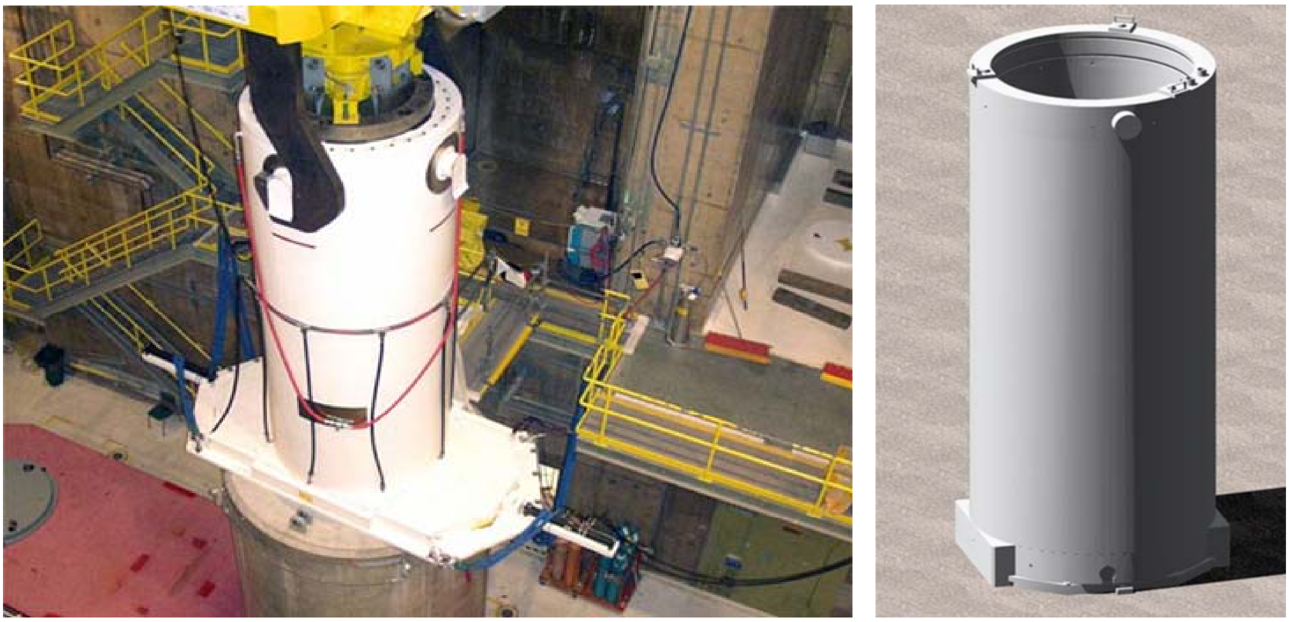


Figure 2. Major Components and Configuration for Loading the Concrete Cask

GENERAL DESCRIPTION OF THE MAGNASTOR SYSTEM

The principal components of MAGNASTOR are briefly described below.

TSC

The TSC is designed for both storage and transport and is defined as the confinement boundary during storage. Each TSC contains either a PWR or BWR fuel basket, which positions and supports the fuel, provides a heat transfer path for the fuel assemblies, and maintains a critical configuration for all of the evaluated normal, off-normal, and accident conditions.

The TSC, shown in Figure 3, consists of a cylindrical stainless steel shell with a welded stainless steel bottom plate at its closed end and a 9-inch (229 mm) thick stainless steel closure lid at its open end having large vent and drain ports. The redundantly field-welded single lid closure reduces operations time and personnel exposures. The lid port, internal drain system, and basket designs represent significant improvements that facilitate removal of retained water, reducing drying times for the TSC.

The basket uses a proprietary, developed-cell technology that optimizes convective heat transfer from the fuel to the TSC outer shell using pressurized helium as a backfill gas. The structural components are fabricated from low alloy steel with an electroless nickel plating to minimize corrosion and the generation of combustible gases during fuel loading. The basket is an arrangement of square fuel tubes, each with an enclosed neutron absorber sheet on up to four interior sides, held in a right-circular cylinder configuration using support weldments bolted to the outer fuel tubes. The tubes are assembled so that each functions as an independent fuel position and as a sidewall for adjacent fuel positions in the array. Consequently, the total fuel storage positions require about 45 percent fewer tubes.

Concrete Cask

The concrete cask is the storage overpack for the TSC and it provides structural support, shielding, protection from environmental conditions, and an annular air passage for natural circulation of air around the TSC to remove decay heat, with lower inlets and elevated outlets at the top of the cask. The main body uses reinforced concrete attached to a structural steel inner liner and base, which provide the radial neutron and gamma radiation shielding for the stored spent fuel and protect the TSC during events such as tornado wind loading, tornado missiles, and non-mechanistic tip-over events. The concrete surfaces remain accessible for inspection and maintenance over the life of the cask so that restoration actions may be taken to assure decades of license-compliant service.

A carbon steel and concrete lid provides axial radiation shielding and serves to protect the TSC from the environment and postulated missiles. The design provides vertical lift fixtures for cask movement, even prior to lid installation, improving system movement through restrictive door openings.

Transfer Cask

The transfer cask is used to lift and move the TSC while providing biological shielding and structural protection. The cask also shields the vertical transfer of a TSC into the concrete cask or transport cask.

During TSC loading and handling operations, the retractable bottom shield doors are closed and secured. As shown in Figure 2, with the transfer cask placed on the concrete cask or transport cask and the crane lifting the TSC, the doors are opened with hydraulic cylinders to lower the TSC.

Penetrations at the top and bottom of the transfer cask body provide cooling water or gas to and from the transfer cask annulus with the TSC. This annulus can be isolated using inflatable seals located near the upper and lower ends of the transfer cask. These penetrations can be used to minimize contamination of the canister in the pool and to cool the TSC using water or gas during closure operations.

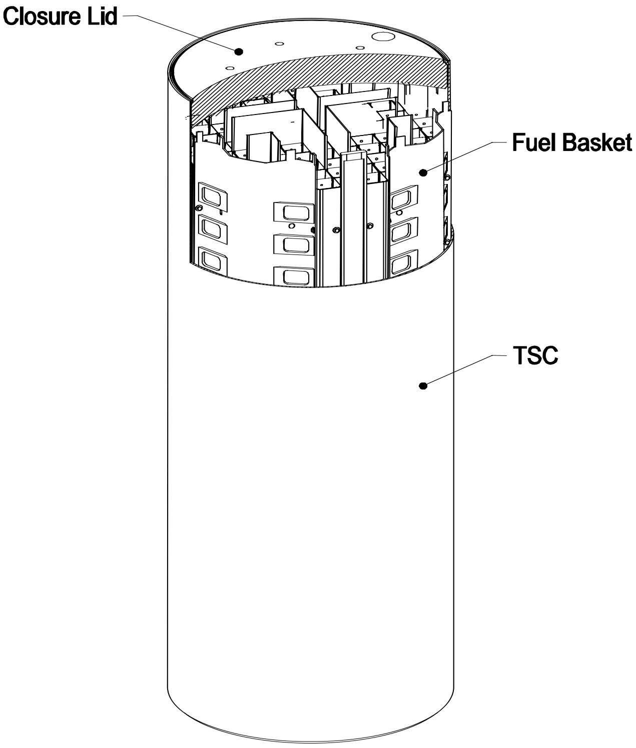


Figure 3. MAGNASTOR TSC and Basket

DEVELOPMENT AND LICENSING STATUS

The MAGNASTOR System development effort began in 2003. Our unique development approach included a multidisciplinary design review team for MAGNASTOR, comprised of NAC staff and engineers and plant personnel from potential customers. Customer insights were beneficial in optimizing design features and in identifying particularly desirable licensing approaches.

The ability to fabricate the system with the quality, schedule, and cost necessary was of paramount importance. NAC performed full-scale prototype work with several fabricators on basket components to assure fabrication, tolerance, and assembly requirements could be met. Working with Hitachi Zosen Diesel and Engineering in Japan, NAC conducted a full scale fabrication demonstration project for the MAGNASTOR System basket, which was completed in a timely manner and demonstrated the simplicity of fabrication, with tolerances well within those specified and those assumed in the MAGNASTOR System safety analysis. The full scale fabricated basket is shown in Figure 4.

The MAGNASTOR System has been under NRC review for dry storage certification since late 2004, and, in early August 2007, NAC submitted a revised MAGNASTOR System storage application to the NRC, in compliance with the NRC's Rules of Engagement, to complete its review for storage approval.

NAC believes that the draft spent fuel storage Certificate of Compliance for the MAGNASTOR System can be expected in the next several months.

Figure 4. Fabricated Full Scale MAGNASTOR System Basket

MAGNASTOR'S POTENTIAL FOR ECONOMIC IMPACT ON DRY STORAGE IN THE U.S.

Between 2010 and 2020, U.S. utilities will need to buy dry storage systems for about 44,000 BWR spent fuel assemblies and 23,000 PWR spent fuel assemblies. In addition to buying the storage systems, these utilities will also have to load the systems and place them into storage at an ISFSI. With current dry storage technologies in the U.S., such an inventory of spent fuel would require about 1,400 dry storage systems. The cost to U. S. utilities for just the capital and loading costs for this dry storage approaches $1.7 billion in 2007 dollars, assuming the use of canister-based concrete multipurpose storage systems.

If, instead, all of this spent fuel were placed in MAGNASTOR systems for dry storage, U. S. utilities would save about $300 million in capital and loading costs, and could also achieve other savings in ISFSI construction, routine operations, collective operator dose, decommissioning, and spent fuel transportation. It is just these types of savings that make the MAGNASTOR System an ideal technology for global deployment.

THE MAGNASTOR TRANSPORT (MAGNATRAN) SYSTEM

The next phase of MAGNASTOR System development is the NRC transport certification of the MAGNATRAN transport system. The major component of this system is the MAGNATRAN transport cask. The transport cask has been developed using NAC's historical approach to rail transport cask designs and includes a lead/stainless steel cask body surrounded by solid neutron shielding. However, the cask must also have the capability to transport MAGNASTOR TSCs with very high heat loads. A key feature of the MAGNATRAN transport cask, then, is a new approach to neutron shielding design and installation.

Because of the high thermal capacity of the transport cask and a desire for improved installation efficiencies, an enhanced neutron shielding system is important. The new shield system comprises modular shield section components incorporating a lightweight cooling fin design that serves to physically retain the neutron shield material. The approach reduces the peak temperature of the neutron shield material while simplifying the shield material installation. A patent application is under review for this advancement.

Finally, the MAGNATRAN transport cask will utilize the highly effective impact limiter system that NAC has previously developed and licensed on both the UMS and MPC System designs. The impact limiter material testing program that NAC has performed for these designs is without peer in U.S. transport licensing experience. Figure 5 provides some technical details of the design and computer generated views of the transport cask.

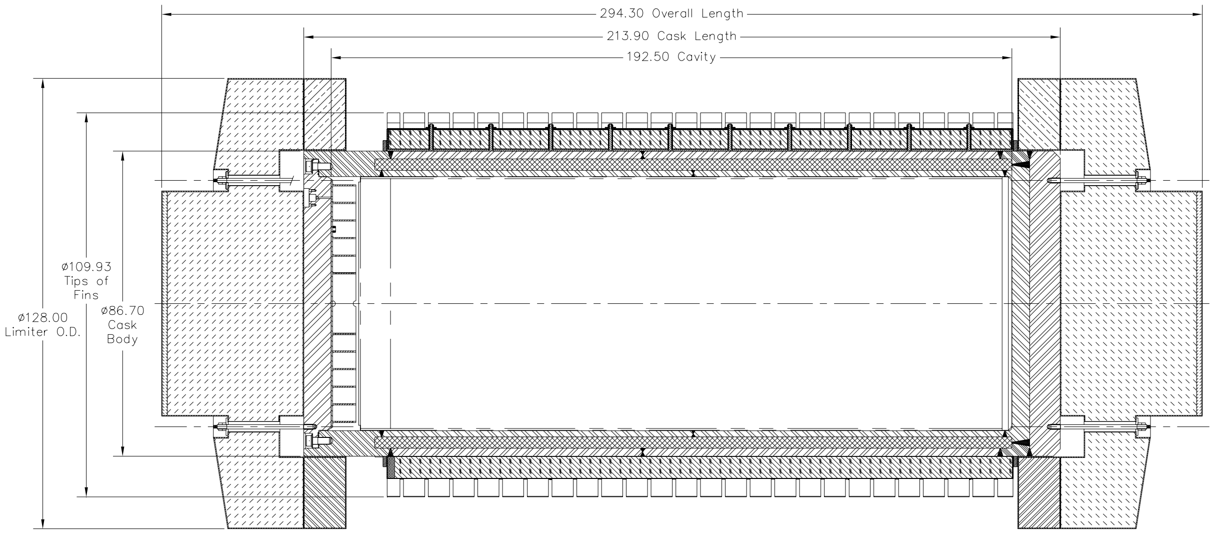


Figure 5. MAGNATRAN Transport Cask

CONCLUSIONS: SAFE, EFFICIENT, ADVANCED SPENT FUEL STORAGE AND TRANSPORT FOR THE GLOBAL MARKET

NAC's MAGNASTOR System is based upon integrating proven technology and experience into a robust, economical, ultra-efficient, multipurpose system for the future. MAGNASTOR represents a new generation of dry MCS technology for use in the global market for spent fuel storage and transportation. With a focus on incorporating many lessons learned from NAC's extensive experience and improving the economics of dry storage for its customers, NAC has developed a system that will be safe under any set of credible conditions, will be more efficient to load and operate than other designs, and will become a significant factor in improving the financial performance of dry spent fuel storage programs.