WM'00 Conference, February 27 - March 2, 2000, Tucson, AZ

CASTOR® X/32 S – A NEW DUAL-PURPOSE CASK FOR THE STORAGE AND TRANSPORT OF SPENT NUCLEAR FUEL

Mr. George Jobson
GNB (USA)

Dr. Harry Spilker, and Mr. Dieter Methling
GNB (Germany)

ABSTRACT

Recently, GNB designed a new dual-purpose forged steel CASTOR® cask for the storage and transport of U.S. PWR fuel. The CASTOR® X/32 S is designed to accept up to 32 PWR fuel elements (a cask for BWR fuel elements will be developed based on the concept of the PWR cask). The system will accept 10-year old fuel with initial enrichments in the range of 5% and burnup in the range of 45 GWd/MTU. In addition, the design will accommodate certain irradiated components integrated with the fuel, a specific need by the PWR reactors. The system can be provided in both a bolted lid and welded lid version; the welding technique utilized is an innovative approach developed by GNB based on our extensive experience in cask fabrication. The cask SAR for Part 72 Storage of PWR fuel was submitted to the USNRC in late 1999. The CASTOR® X/32 S offers specific benefits over current cask systems including reduced cask handling and personnel exposure, flexibility in secondary lid closure design (bolted versus welded), and reuse as a SNF container (versus one-time use of canisters).

INTRODUCTION

Previously, GNB of Essen, Germany developed the CASTOR® series of ductile cast iron container systems for the storage and shipping of spent nuclear fuel (SNF). The CASTOR® system has been accepted and deployed internationally by GNB/GNS including storage systems for the U.S. PWR market. To date, GNB has sold over 600 storage casks internationally including its CASTOR® series.

In 1985, GNB delivered the first CASTOR® V interim storage cask to the DOE for a test program at the INEEL. Based on the successful results of that testing, GNB sold 27 CASTOR® casks to Virginia Power; the Surry Power Station became the first interim storage facility with SNF casks in the U.S. However, the CASTOR® ductile cast iron (DCI) system was licensed only for storage; the USNRC would not accept DCI as a material for transport. Thus, GNB has developed a new cask system utilizing the CASTOR® design but fabricated of ferritic ASME steel. This system is named the CASTOR® X/32 S.

The CASTOR® X/32 S is designed to store/transport 32 PWR elements with cooling time of up to ten years. Currently, GNB has submitted the Part 72 SAR to the USNRC for the CASTOR® X/32 S only. Subsequently, GNB will submit the Part 71 SAR for the CASTOR® X/32 S, and in the future will prepare SARs for a BWR version.

DESIGN SUMMARY

The cask CASTOR® X/32 S shown in Figure 1 has a capacity of 32 PWR fuel assemblies and consists of the following components:

- A cylindrical forged carbon steel containment vessel. The containment vessel includes a closure consisting of a primary and a secondary lid. The containment vessel provides radioactive material containment within a cavity permanently filled with helium. The vessel closure is provided in two versions:

  - Version 1 (Figure 2): A closure consisting of a bolted primary and a bolted secondary lid. Both lids are equipped with a metallic seal. A monitoring system is provided to monitor the pressure in the interspace between the lids as a means of leak detection. This monitoring system is described below.

  - Version 2: A closure consisting of a bolted primary lid with a metallic seal and a welded secondary lid (same as Figure 1 but with a welded secondary lid). A means of monitoring the pressure in the lid interspace is not required in Version 2.

- A pressure monitoring system for the interspace between the primary and the secondary lid of Version 1 as a means of leak detection. The initial helium pressure in the interspace is set higher than the pressure in the cask cavity so that a leak in the seal of the primary lid would cause flow of helium from the interspace into the cask cavity. In the event of such a leak, the decrease in pressure in the interspace would activate a pressure switch located in the secondary lid. The pressure switch would provide a signal to activate an alarm in the cask monitoring system provided by the ISFSI to indicate to the ISFSI operators the possibility of a leak in the containment boundary.

- An outer rain cap on the top of the cask to provide weather and mechanical protection for the secondary lid, the lid seal components, and the pressure switch.

- Neutron shielding material arranged in longitudinal boreholes in the body wall and arranged as plates in the top and bottom of the cask.

- A fuel basket that locates and supports the fuel assemblies, transfers heat to the cask body wall, and provides boron for neutron absorption to satisfy nuclear criticality safety requirements (Figure 3).

- Upper and lower trunnions to provide support for lifting and for rotation of the cask from the vertical to the horizontal position.

The type of fuel to be stored in the CASTOR® X/32 S is Light Water Reactor (LWR) fuel of the Pressurized Water Reactor (PWR) type. The maximum initial enrichment is 5 %. The cask is designed for a maximum heat load of 32.0 kW. The maximum assembly-averaged burnup is presently limited to a maximum of 45 GW/MTU. Depending upon the initial enrichment and the burnup, the minimum cooling time range will be between 2.9 and 9.5 years. Known or suspected

failed fuel assemblies (rods) with cladding defects greater than pin holes or hairline cracks are not to be stored in the CASTOR® X/32 S.
Along with the spent fuel assemblies, BPRAs may be stored within the CASTOR® X/32 S. These components are not credited for providing any poison material for criticality control. Only six (6) BPRAs may be inserted in PWR assemblies; other PWR assemblies will be equipped with specifically engineered insertable absorber rod modules (ARMs), i.e., absorber rods made of borated aluminum, must be used in thimble tube locations within the fuel assemblies to meet criticality safety requirements.

The criteria for acceptance of assemblies for storage in the CASTOR® X/32 S depend upon the cooling time in storage and the cumulative exposure of assemblies. These parameters are used to determine the source term for shielding and thermal analyses.

The casks are intended for storage singly or in an array on a reinforced concrete pad at either nuclear power reactor sites or other approved sites away from reactor storage facilities (Figure 4).

GENERAL DESCRIPTION OF THE CASTOR® X/32 S

The cask is a cylindrical and self-supporting vessel that is placed in a vertical position under normal storage conditions.

Each storage cask consists of:

- A containment vessel comprising a cask body with shell, bottom, and primary and secondary lids
- A pressure switch in the secondary lid with connection to the lid interspace (This is provided in Version 1 only.)
- Neutron shielding
- Fuel basket assembly
- Trunnions for handling
- Penetrations in the bolted primary lid with sealed cover lids to facilitate draining, drying, backfilling, leak testing and venting
- Penetrations in the bolted secondary lid with sealed cover lids to facilitate leak testing and venting (Version 1 only.)
- Closure bolts
- Metallic O-ring seals on all bolted lids and penetration closures
- A rain cap.

During loading of fuel elements into the cask in the fuel pool, contamination of the outside of the cask will be prevented by a contamination protection skirt used by GNB in Germany. Impact limiters will be provided when the cask described herein is licensed and used for off-site transportation.

Heat is dissipated from the cask CASTOR® X/32 S by passive methods utilizing external aluminum fins. Dimensions and weight of the CASTOR® X/32 S are shown in Table I.

Containment Vessel

The containment vessel for the CASTOR® X/32 S consists of a forged carbon steel cylinder with an integrally-welded carbon steel bottom, a bolted primary lid made of stainless steel with a metallic O-ring seal, and a vent and drain opening closed by a lid with a metallic O-ring seal. A secondary lid is arranged over the primary lid. This secondary lid is different for Versions 1 and 2 as previously noted.

The O-ring seating surfaces are overlaid with Inconel to provide corrosion protection. These welded surfaces are machined to provide the necessary finish for the seating of the O-ring seals.

The general arrangement of components are shown in Figure 1. The overall containment vessel length is 4950 mm (195 in) with a wall thickness of 298 mm (11.8 in). The cylindrical cask cavity has an internal diameter of 1730 mm (68.1 in) and an internal length of 4255 mm (167.5 in). The cask cavity is pressurized to 0.12 MPa (17.4 psi) with helium via the drain and vent port of the primary lid.

The primary lid for both Versions 1 and 2 is made of stainless steel and is 260 mm (10.2 in) thick. It is fastened to the cask body by 49 studs with nuts and 3 bolts. A metallic O-ring seal provides the lid closure seal. (See Figure **3**.)

The secondary lid for Version 1 (Figure 2) is made of stainless steel and is 80 mm (3.15 in) thick. It is fastened to the cask body by 52 bolts. The interspace between the primary lid and the secondary lid is utilized as part of the cask monitoring system as described below. (See Figure **3**.)

Table I
Dimensions and Weight of the CASTOR® X/32 S Cask

Dimension	**mm**	**in**
Overall Length	4950	195.0
Outside Diameter	2326	91.6
Cavity Diameter	1730	68.1
Cavity Length	4255	167.5
Body Wall Thickness	298	11.8
Primary Lid Thickness	260	10.2
Secondary Lid Thickness	80	3.16
Bottom Thickness	177	7.0
Bottom Plate Thickness	35	1.38
Moderator Rod Thickness	70	2.76
Cask Weight:	**kg**	**lb**
Cask Empty	83,049	183,089
Basket	14,539	32,052
Cask After Loading (without water and secondary lid)	105,449	232,471
Loaded On Storage Pad	107,901	237,877

The primary lid for both closure versions and the secondary lid for Version 1 is sealed with metallic O-ring seals. An elastomer O-ring seal is installed to provide a space between the seals; this space is used for leak testing of the metallic O-ring seals. Metallic O-ring seals are used together with bolts to seal the lid covers on all penetrations.

The inside cask cavity surfaces are painted with a special silicon-based coating for corrosion protection. This special silicon coating has been tested and proven in practice not to release hydrogen or deteriorate. The coating is resistant to high temperatures and is resistant to high levels of radiation. The external surfaces of the cask are painted for ease of decontamination and corrosion protection.

The secondary lid for Version 2 is made of forged carbon steel (like the cask body) and is attached to the cask body with a narrow groove weld (a specialty welding procedure developed by GNB for its cask applications).. There are no penetrations of the lid in Version 2 and the pressure in the interspace between the lids is not monitored.

Containment Monitoring (Version 1 only)

The interspace between the primary and the secondary lid is filled with helium and is utilized as part of the cask monitoring system. The pressure in the interspace is set higher than the pressure in the cask cavity so that leakage of the seal of the primary lid will cause leakage from the interspace into the cask cavity. A pressure switch is mounted in the secondary lid and is wired to an alarm in the ISFSI. A drop in the helium pressure in the interspace will activate an alarm to alert the ISFSI operators to the possibility of a leak in the containment boundaries. This system of interspace pressure monitoring as a means of leak detection has been in use at one ISFSI in the United States since 1986.

Neutron Shielding

Neutron shielding is provided in both the radial and axial directions. Neutron shielding in the radial direction is provided by polyethylene rods that are set into two concentric rows of axial bore holes in the wall of the cask body. Each concentric row contains 62 bore holes for a total of 124 bore holes. The boreholes in the two concentric rows are offset to provide an unbroken line of neutron shielding for radiation from the cask cavity. The polyethylene rods are firmly secured in the long direction by springs located in the bottom of the boreholes.

Polyethylene disks provide neutron shielding in the axial direction. For Version 1 with the bolted secondary lid, a 40 mm (1.57 in) thick polyethylene disk is attached with bolts to the underside of the secondary lid. For Version 2 with the welded secondary lid, the polyethylene plate is attached to the top of the primary lid and is not connected to the secondary lid. This approach is to isolate the polyethylene plate from the heat that will be generated by the welding of the secondary lid to the cask body. To provide neutron shielding at the bottom of the cask, for both versions, a thick polyethylene disk is inserted into a cavity in the outside bottom of the cask and is secured in place with a cover plate.

Adequate volume is allowed in the bore holes in the cask body to allow for thermal expansion of the polyethylene rods under normal, off-normal, and accident conditions.

Fuel Basket

The fuel basket provides support of the fuel assemblies, control of criticality, and a path to conduct heat from the fuel assembly to the cask body.

The fuel basket is designed to accommodate up to 32 intact PWR fuel assemblies. Fuel receptacles are manufactured by the welding of stainless steel plates to enclose and secure the fuel assemblies. The stainless steel fuel receptacles are held in place by a basket gridwork of borated aluminum plates assembled inside the cask cavity (Figure 3). The borated aluminum plates of this basket gridwork provide heat conductivity. The boron content of these plates assures nuclear criticality safety.

The inner stainless steel fuel receptacles are each fully surrounded by the borated aluminum plates of the basket gridwork. The outer stainless steel fuel receptacles have thicker stainless steel plates on the outside to provide additional shielding as an integral part of the fuel receptacle.

Except for the welding along the length of the stainless steel fuel receptacles, the fuel basket for the CASTOR® X/32 S is manufactured with no welding. The fuel receptacles and borated aluminum plates are manufactured to close tolerances. Mechanical techniques are used to form the basket gridwork and to assemble it together with the fuel receptacles inside the body cavity of the CASTOR® X/32 S.

The closely fitting borated aluminum plates of the basket gridwork fix the square-shaped stainless steel fuel receptacles in a central position inside the cask cavity. This compact close-tolerance arrangement is intended to minimize the movement of the fuel assemblies relative to each other and to the cask body under normal, off normal, and accident conditions.

Penetrations

The primary lid has a penetration for draining, drying and venting. It is closed with a bolted and sealed penetration cover.

In Version 1, penetrations are provided through the secondary lid for venting and for mounting the pressure switch. The penetration for venting is closed with a bolted and sealed penetration cover. In Version 2, the welded secondary lid has no penetrations.

Weather Protection

For storage at the ISFSI, the cask top will be covered with a rain cap to provide weather protection for the lid.

SCHEDULE

The Part 72 Storage SAR for the CASTOR® X/32 S was submitted in December 1999. GNB expects to receive questions regarding this SAR during calendar year 2000. The Rulemaking Process is expected during 2001. During 2000, GNB will prepare and submit its Part 71 Transport SAR for the CASTOR® X/32 S.

Also during 2001, GNB will initiate preparation of the Part 72 Storage SAR for the CASTOR® S BWR Version of the cask system. The Part 71 Transport SAR for this cask system will be prepared and submitted by the end of 2001.

BENEFITS OF THE CASTOR® XS SERIES

The CASTOR® XS Series has been designed to optimize the storage/transport of PWR/BWR spent fuel and thus, reduce life-cycle costs for SNF management. Specifically, the CASTOR® X 32/S offers the following benefits:

- As a dual-purpose cask system, the client handles SNF only once. It will not be necessary to reload the fuel into a future transport container (savings in cost and personnel exposure).
- Should the DOE establish an Interim Storage Facility, the CASTOR® X/32S cask is well suited to the single handling of the SNF throughout the entire process; again, this type of system results in less handling of the SNF, lower costs, and lower personnel exposures.

- The CASTOR® X/32S is offered in two versions: a bolted secondary lid (with a monitoring system) and a welded secondary lid. This provides flexibility to the client in selecting a cask system appropriate to their future concerns regarding fuel inspection.
- Should the DOE require fuel inspection prior to shipping to the repository, the dual-purpose CASTOR® X/32S facilitates the return of the cask to the fuel pool and the unloading/inspection/reloading of the SNF prior to shipment.
- It is expected that the DOE will offer "credit" for the use of a dual-purpose cask system. Such credits can mean additional cost-savings to the client. In addition, the DOE will more easily handle the off-loading of SNF at the repository from a system like the CASTOR® X/32S when compared to SNF in canisters.
- The CASTOR® X/32S Series is a reusable system; there is no need to buy new canisters for each off-load of SNF at the power plant.

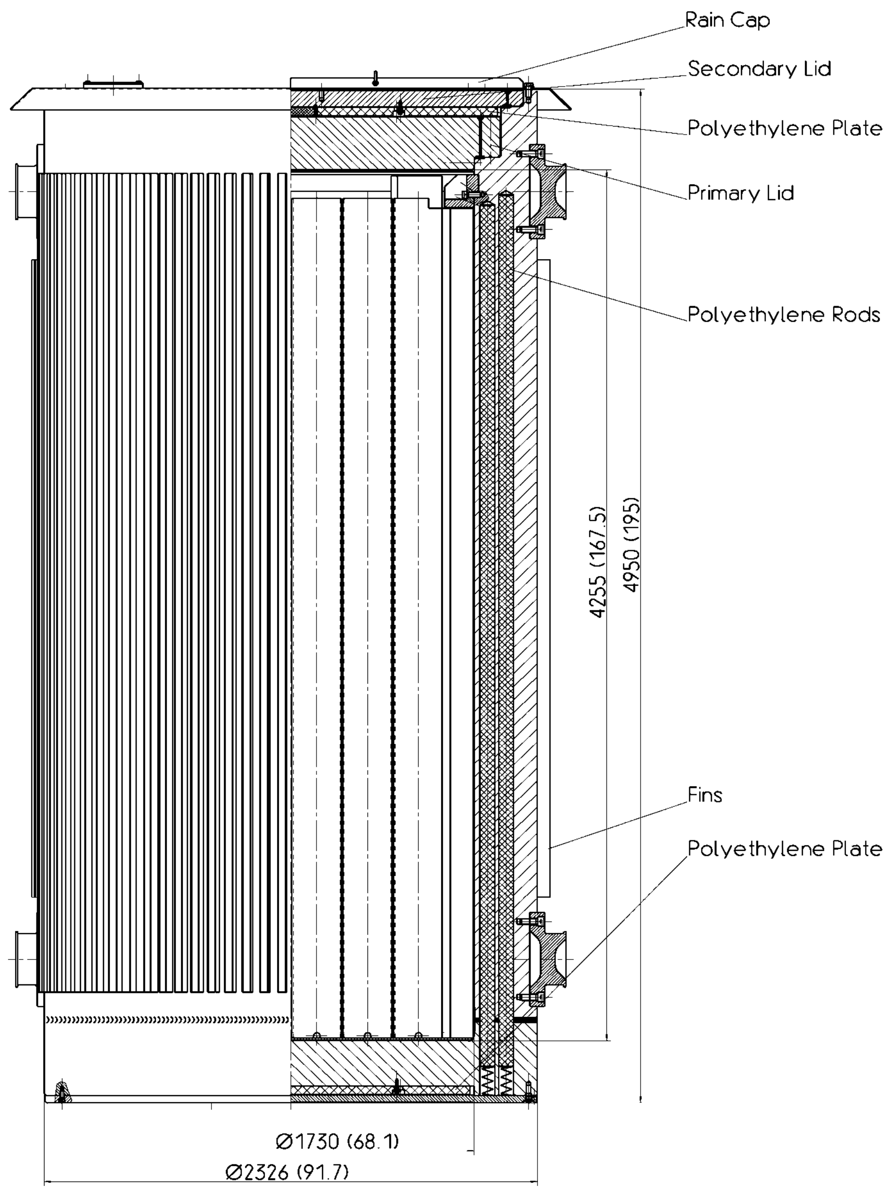
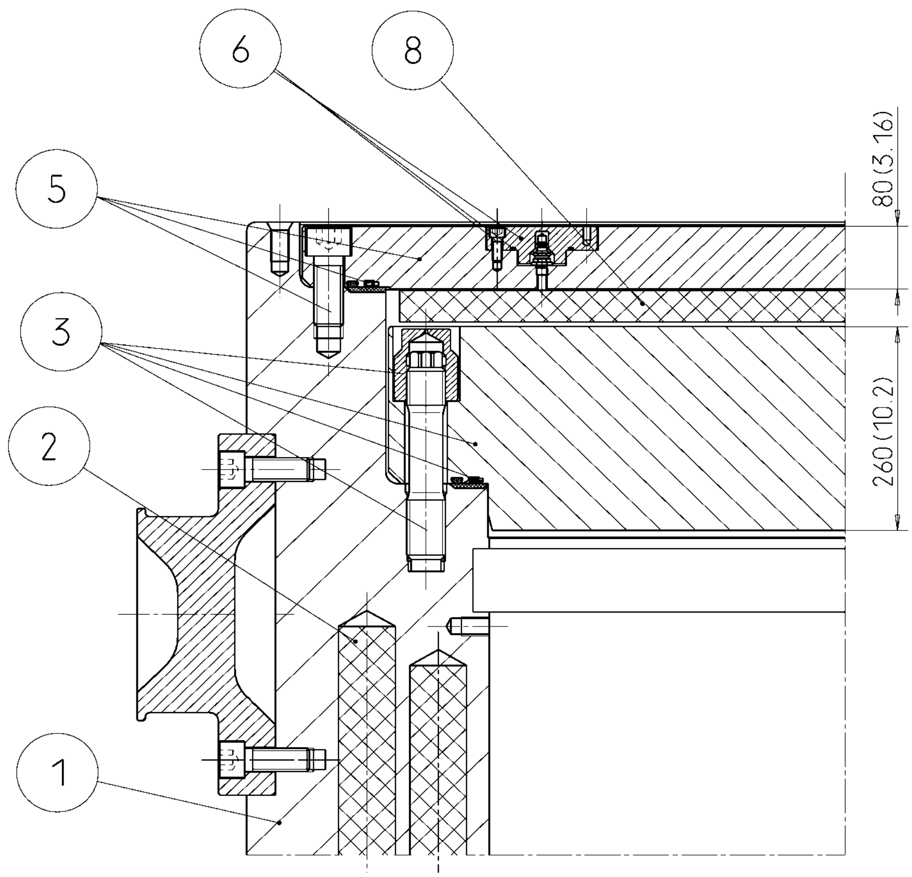


Figure 1

General Arrangement Vertical Section



1 Cask Body

2 Neutron Moderator Rods

3 Primary Lid Assembly, Closure Bolts and Metallic Seal

5 Secondary Lid Assembly, Closure Bolts and Metallic Seal

6 Vent Port for Secondary Lid with Metallic Seal

8 Neutron Moderator Plate

Figure 2
CASTOR® X/32 S Lid Assembly Version 1 (Bolted Secondary Lid)

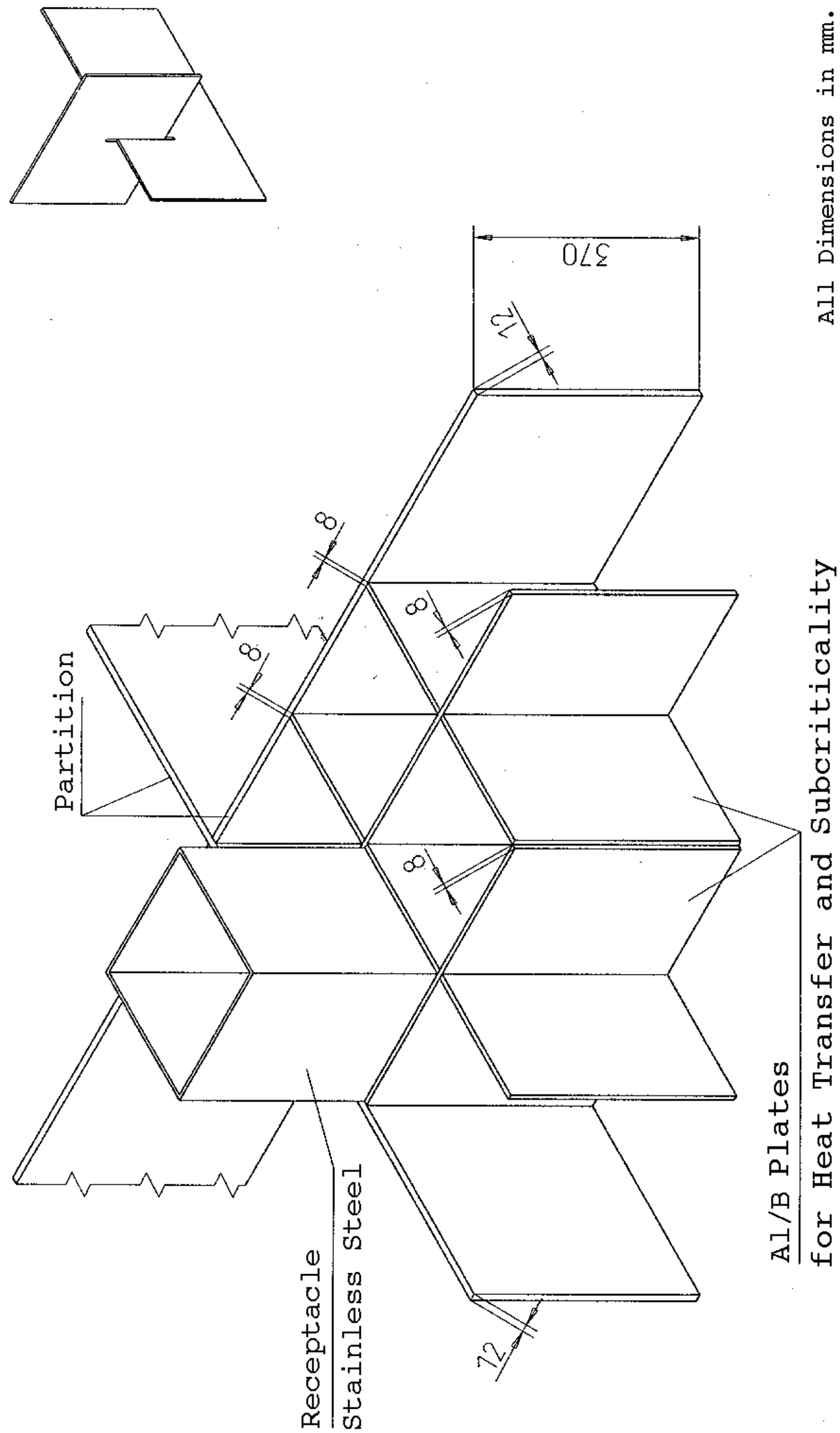


Figure 3
CASTOR® X/32 S Partial Basket Layer (General Arrangement)

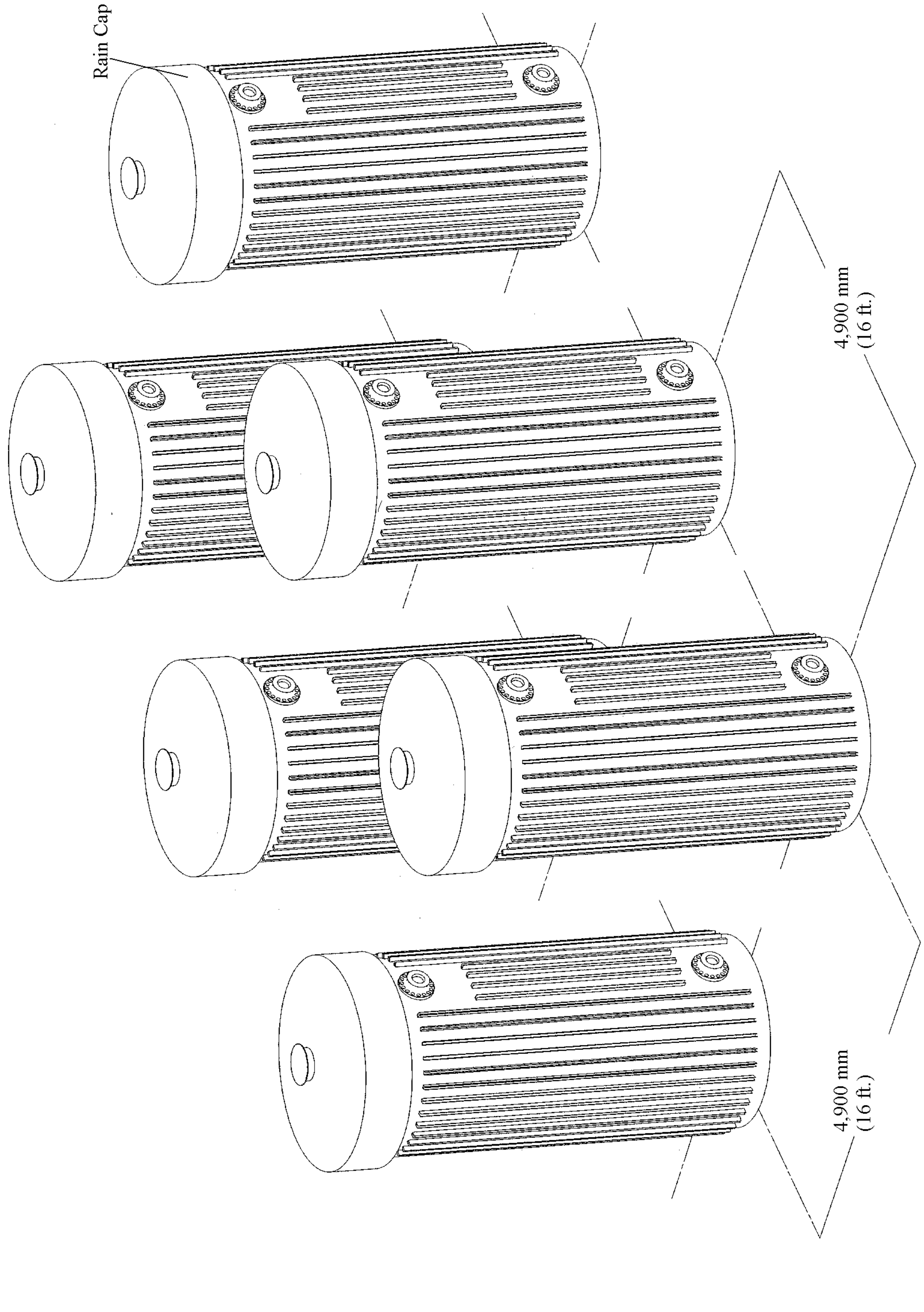


Figure 4

CASTOR® X/32 S Storage Configuration