Design of Spent-Fuel Storage Cask

M. Mikata, K. Iwasa
Hitachi Zosen Corporation

A. Nishikawa, K. Kawakami, T. Nakatani
OCL Corporation

INTRODUCTION

The spent fuels discharged from Japanese LWR are transported to the domestic or overseas reprocessing plants after a cooling period. However, the annual balance between the quantity of discharged fuels and the reprocessing capacity may surpass the reactor pit capacity of the spent fuels. Therefore, additional on-site storage facilities should be installed.

In order to solve this issue, Hitachi Zosen has designed a dry storage cask for Japanese high-enriched and high-burnup BWR fuels that is compact and able to contain a large number of fuel assemblies.

SUMMARY OF DESIGN

As shown in Figure 1, the storage cask is constructed of a cask body, lid, and basket. The cask body consists of three cylinders; the inner shell, intermediate shell and outer shell, and a bottom plate. The major shieldings of the cask are lead, for gamma shielding, and resin, for neutron shielding. The cask lids consist of a primary and secondary lid, which are fixed to the upper flange by lid bolts. The containment boundary is made of an inner shell, bottom plate, upper flange, primary lid, and valve covers that are inside the primary lid.

Fuel assemblies, with the channel boxes removed, are inserted into the basket's compartments in the cask. To keep subcriticality of the cask, neutron-absorbing plates, consisting of aluminum alloy surrounding borated aluminum alloy, are inserted between the aluminum alloy channels in the basket.

The cask cavity is dried and filled with helium gas to easily remove decay heat. Also, the cavity is maintained with negative pressure to keep radioactive materials contained over a long period of time. The secondary lid is set on the primary lid and used to monitor the pressure of the narrow cavity between the lids and also used to monitor the performance of the cask sealing.

The cask is vertically held down with four bottom screwed trunnions during storage. In addition, this cask has the sealing and shielding performance to meet the Japanese regulations for on-site transportation.

The typical specifications of the cask are shown in Table 1.

Table 1 Specifications of Storage Cask

Dimension	overall diameter overall height	approx. 2390mm approx. 5730mm
Weight		approx. 118 MT (fuel loaded)
Loading Capacity 	 enrichment burnup cooling time	61 BWR Assemblies approx. 3.4% cask average 39500 MWD/MTU max. fuel 50000 MWD/MTU 7 years
Material	primary structure gamma shielding neutron shielding	stainless steel lead resin
Sealing	lid gasket	double lids metallic O-ring

OUTLINE OF SAFETY DESIGN

Because the dry storage cask described in this paper is designed for the exclusive use of storage, the cask needs to have the sealing, shielding, and subcriticality performance that meet the Japanese regulations for on-site transportation.

Structural Design

It is necessary for the structural materials of the cask to withstand the thermal stress and stress of the inner and outer pressure of the cask.

Thermal Design

It is necessary that the decay heat of the spent fuels in the storage cask is removed to maintain the integrity of the fuels, structural members, sealing, and shielding materials. The basket is manufactured from aluminum materials which have high thermal conductivity. The cask cavity is filled with helium gas that has high thermal conductivity.

Heat transfer fins are incorporated to improve the heat transfer performance in the resin layer with low thermal conductivity.

Containment Design

This cask aims for the leaktightness to maintain a negative pressure in the cask cavity up to 40 years, which is this design's storage period. Double metallic O-rings are used for the sealing of the lids and valve covers which comprise the containment boundaries.

The secondary lid is set on the primary lid and used to monitor the pressure between lids and the integrity of the cask sealing. Therefore, the pressure between lids needs to be set to positive and this serves as a pressure barrier against the cask cavity's negative pressure and outside atmosphere.

If leakage occurs at either of the metallic O-rings, it is detected by a pressure reduction of the barrier. Even if this is observed by either the primary lid sealing or the secondary lid sealing, the negative pressure of the cask cavity is maintained. The detail of this containment structure is shown in Figure 2.

Shielding Design

According to the Japanese regulations for on-site transportation, the dose rate is limited to be below 2 mSv/h at the cask surface and to be below 100μSv/h, one meter from the cask surface under the transport condition.

The gamma shielding is mainly constructed of a lead layer poured between the inner and the intermediate shells, which are made of stainless steel plates, and also the bottom plate and the lids are made of thick stainless steel.

The neutron shielding is mainly constructed of resin and stainless steel. The resin is installed between the intermediate and the outer shell and in the bottom plate and in the primary lid. Because the storage cask is dry, it needs sufficient external neutron shielding. Therefore, the length of this storage cask is longer and has unique trunnions to intensify shielding performance at diagonal directions.

Subcriticality Design

The cask must be prevented from reaching criticality in any condition that cask may encounter. Specifically, it is necessary that the neutron multiplication factor dose not exceed 0.95 including any calculational errors.

For this purpose, enriched borated aluminum alloy plates are inserted between the aluminum alloy channels in the fuel basket. Also, in order to prevent the disadvantage of assuming that the fuels are fresh, this subcriticality design introduces the "gadolinia credit" with regard to BWR fuels. This "gadolinia credit" takes into consideration the negative reactivity of gadolinia contained in the BWR fuel pellets in the subcriticality evaluation.

CONCLUSION

Hitach Zosen has developed a high capacity cask for BWR fuels which is exclusively used for storage. In this same design philosophy a high capacity cask for PWR fuel could be developed.

ACKNOWLEDGEMENT

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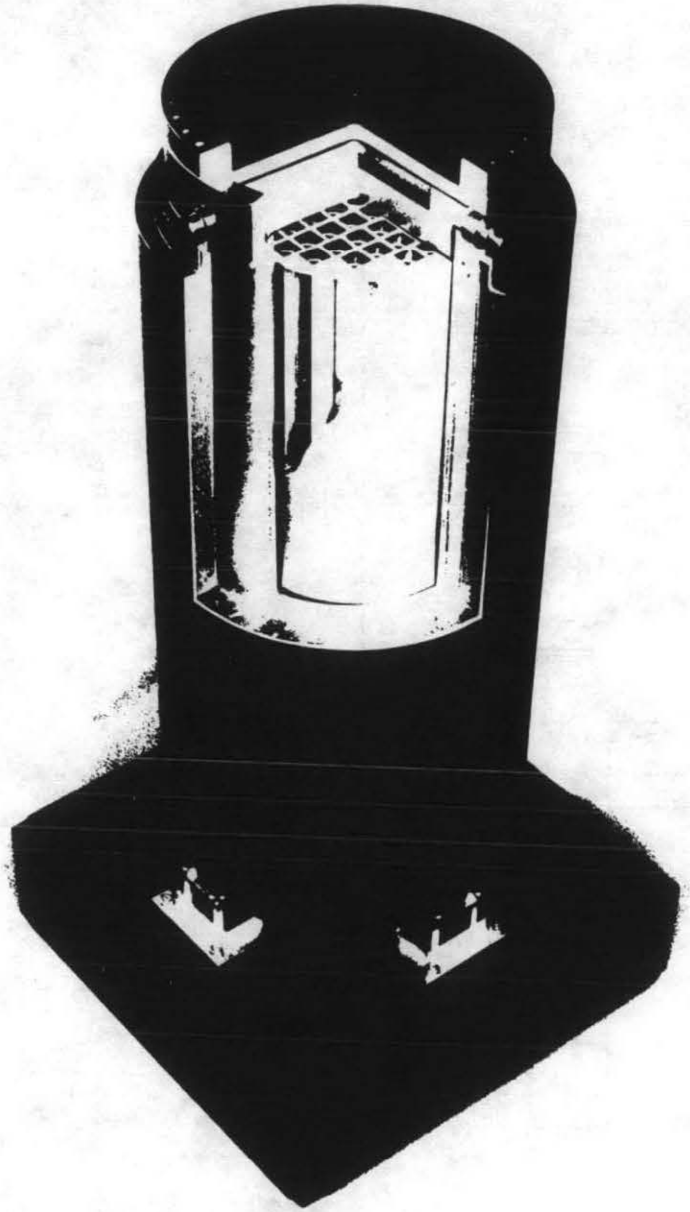
REFERENCE

Kawakami, K. et al., *The Use of Gadolinia Credit for Criticality Evaluation of a Spent Fuel Cask*, PATRAM'95 Paper - Session Ⅶ-3.1 (1995).



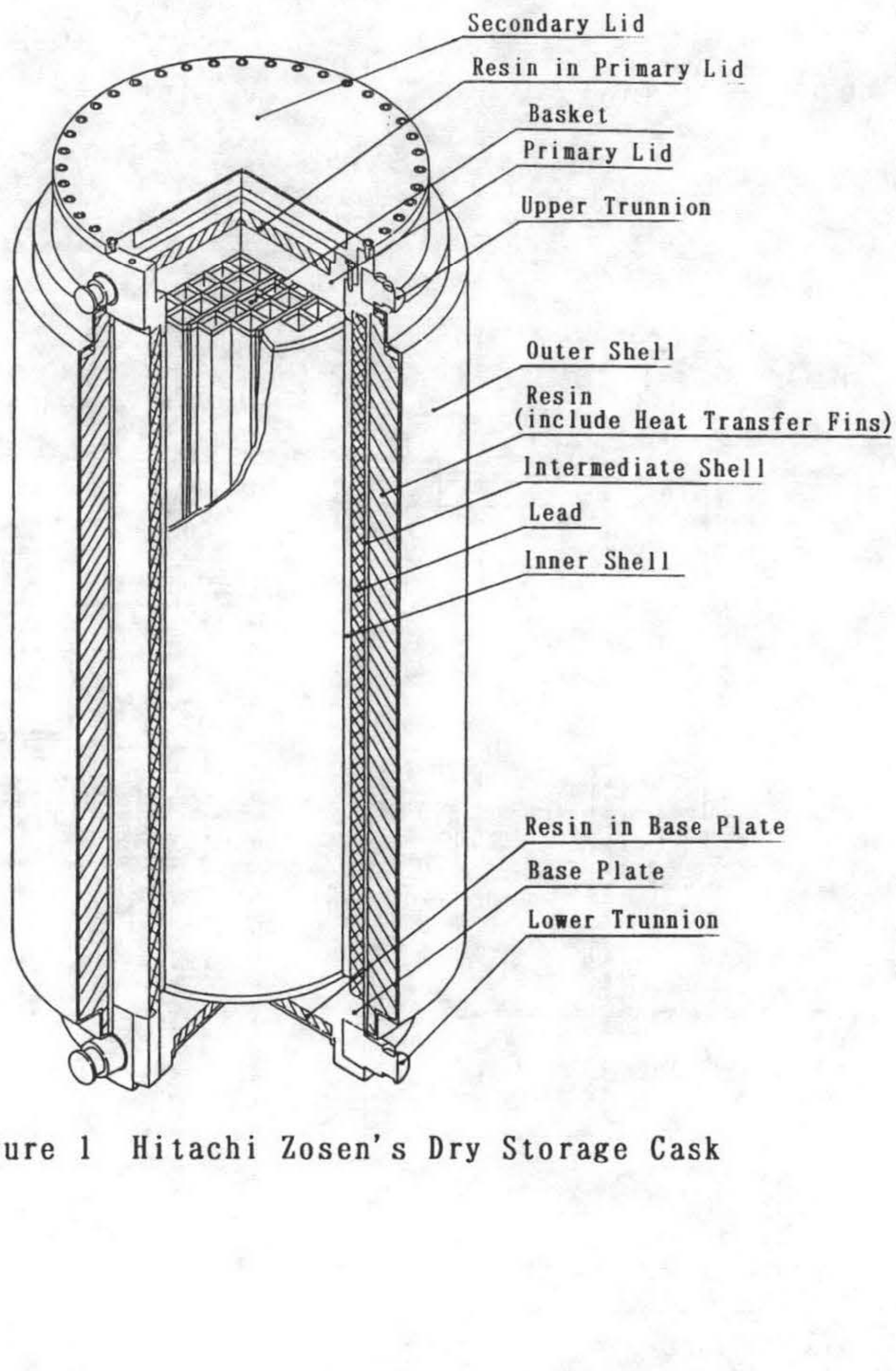


Figure 1 Hitachi Zosen's Dry Storage Cask

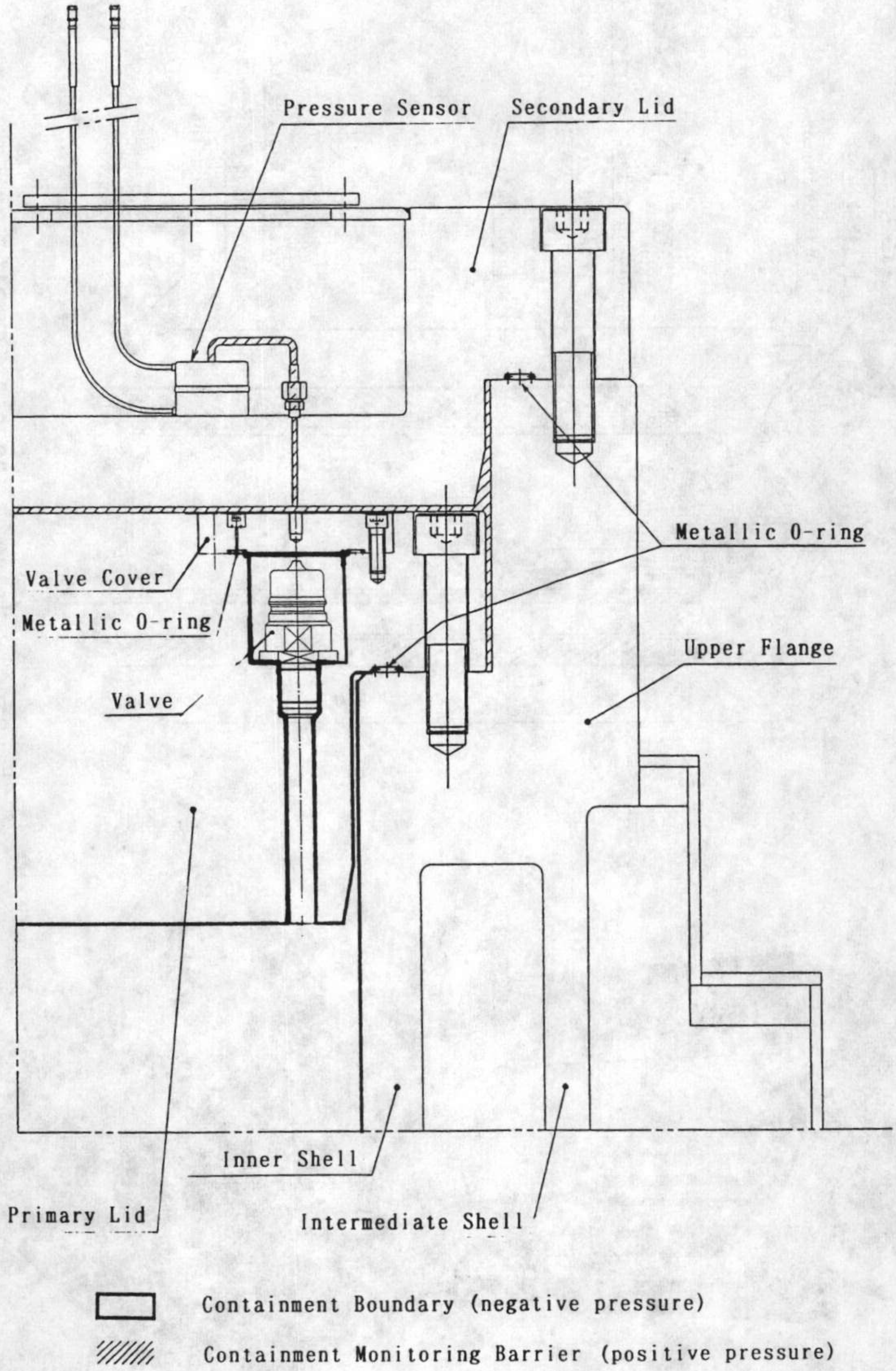


Figure 2 Detail of Containment Boundary and Monitoring System