Developing New Transportable Storage Casks for Interim Dry Storage

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Introduction

Transportable storage metal casks are to be consistently used during transport and storage for AFR interim dry storage facilities planning in Japan. The casks are required to comply with the technical standards of regulations for both transport (hereinafter called “transport regulation”) and storage (hereafter called “storage regulation”) to maintain safety functions (heat transfer, containment, shielding and sub-critical control). In addition to these requirements, it is not planned in normal state to change the seal materials during storage at the storage facility, therefore it is requested to use same seal materials when the casks are transported after storage period.

The dry transportable storage metal casks that satisfy the requirements have been developed to meet the needs of the dry storage facilities. The basic policy of this development is to utilize proven technology achieved from our design and fabrication experience, to carry out necessary verification for new designs and to realize a safe and rational design with higher capacity and efficient fabrication.

Basic Features of Design for Hitz Casks

The followings are the basic features of new design (Hitz casks). Three casks are designed for three types of fuel assemblies. The fuel specifications are shown in Table 1. The design requirements are shown in Table 2. Except for basket design, the designs of three casks are almost the same. The overviews of the casks are shown in Figure 1 (in transport) and Figure 2 (in storage). And main specifications of three casks are shown in Table 3. Each cask consists of a main body, double lids, a basket and a pair of impact limiters.

(1) Main body

The main body consists of inner shell and bottom plate made of forged carbon steel, neutron shielding made of resin (NS-4-FR), heat transfer fins made of cupper, outer shell and top and bottom resin covers made of carbon steel, and top and bottom trunnions made of stainless steel. The cavity surface of main body is treated by aluminium thermal spraying and the outer surface is treated by painting. The main body and double lids are designed to consider the maximum inner pressure of 2.0MPa occurred in water drainage process and maximum outer pressure of 2.0MPa occurred at the accident condition of 200m submersion test.

Resin (NS-4-FR) is used as neutron shielding material. As the thermal conductivity of resin is very low, copper fins are installed by welding between the inner and outer shells longitudinally to obtain enough thermal path, which is one of our proven technologies used for previous designs.

For handling and tie-down of the cask, screw-in trunnions, which are also part of our proven technologies, are designed. There are two pairs (long and short) of trunnions for top part of the cask and one pair (long) for bottom part. Screw-in trunnion has the merit to save mounting space and to reduce the lack of neutron shielding. This type of trunnion was used for the storage casks at Tokai-2 power station.

Drain-pipe is installed in the cask for drainage, vacuum drying, helium gas filling and reflooding.

The helium gas pressure of cask cavity is set to be negative during whole operation period.

(2) Double Lids

The double lids are composed of primary lid made of stainless steel and secondary lid made of carbon steel. Neutron shielding made of NS4-FR is installed in primary lid to reduce radiation exposure to cask operators at the fuel loading and secondary lid setting work.

Because of setting the primary lid under fuel pool, stainless steel is used for primary lid to prevent corrosion. Drain and Vent are equipped on the primary lid for drainage, vacuum drying, helium gas filling and reflooding. "Quick-Connective Fluid Couplings" are used as the drain and vent valve to facilitate the connection work between cask and auxiliary equipment and to reduce the radiation exposure to operators.

The port for vacuum drying, helium gas filling and pressure sencer for monitoring pressure between the double lids during storage is equipped on the secondary lid. Whole surface of secondary lid is corrosion-proofed by stainless steel overlay or painting.

Gasket grooves are machined on the primary and secondary lids. Double type of metallic gasket, whose section diameter is 10mm, is installed on each lid.

Abnormal leakage from the containment boundary can be detected by monitoring the pressure drop between the double lids.

The tertiary lid can be attached to top part of the cask for the abnormal leakage from the double lids.

(3) Basket

Square tubes are used as lattice components of basket. The overviews of three types of baskets are shown in Figure 3.

Basket for BWR fuel has the tube-and-block structure, which is composed of square tubes made of aluminium alloy containing neutron absorbing material to store fuel assemblies with channel boxes and periphery support blocks made of aluminium alloy with high thermal conductivity.

Basket for PWR fuel has the tube-and-disk structure, which is composed of square tubes made of stainless steel attached neutron poison plates on their outer surfaces to store fuel assemblies with burnable poisons and alternately laminated structure including support disks made of stainless steel and heat transfer disks made of aluminium alloy with high thermal conductivity.

(4) Impact Limiter

Top and bottom impact limiters are bolted to top and bottom mounting plates of the cask body to absorb impact force affecting the cask at the condition of 9m drop test. The impact limiter is composed of the welded structure including outer plates and ribs made of stainless steel and shock absorbing material made of plywood filled into it. In addition, stepped structure of impact limiter can reduce its acceleration in the end drop.

Major Topics of Development for Hitz Casks

The design of Hitz casks have been considered to be compliant with domestic transport and storage regulations. Some items of our development are described here.

(1) Design of double lids closure system and containment boundaries

Hitz cask has a double lids closure system. The metallic gaskets are used for both primary and secondary lids seal materials. The primary lid seal is determined as the containment boundary during storage, and secondary lid seal as the containment boundary during transportation. As the change of seal material during storage is not planned in normal state, the same gasket should be used as seal material for the transportation after storage.

The secondary lid gasket is the component of the containment boundary in transport.

NUPEC reported its verification test for containment boundary’s aged degradation and full scale model drop test in Reference [1]. The relation of both opening and slide displacement to maintain the containment function of metallic gasket for transportation after 50 years storage is described in it.

Based on the details, the specifications of metallic gasket and the criteria to maintain the containment function, opening and slide displacement, were determined.

The criteria of double type metallic gasket, whose section diameter is 10mm, is set 0.1mm for opening, and 3mm for slide displacement, which includes total distance of side caused by slip of secondary lid and elastic deformation of flange. Considering the criteria, the torque of tightening bolt is determined as about 940Nm and the clearance between secondary lid and flange of main body is designed as fit.

The primary lid metallic gasket is the component of the containment boundary during storage.

During the storage period, the cask is kept on steady state and no load equivalent for 9m drop impact occurred. However, the same type of gasket is used for primary lid seal material to satisfy the criterion for leak rate in storage and to endure the impact such as abnormal landing.

The 1/3 scale model 9m drop test shown in Figure 4 was carried out to measure the dynamic behaviour of containment boundary of secondary lid, which verified that the design of lid and impact limiter can keep the opening and slide displacement occurred at the condition of 9 m drop test within the criteria mentioned above, and can maintain the containment function during transportation after storage period. The details are reported in Reference [2].

(2) Considering degradation of neutron shielding material

Considering the degradation of neutron shielding material, resin (NS-4-FR), during long-term storage is necessary for structural and shielding designs of the cask. While NUPEC reported the behaviour of resin in Reference [1], the verification test shown in Figure 5, which is reported in Reference [3], has been carried out to verify the thermal behaviour of resin. The data of increase of pressure in shielding material installation space and loss of resin’s weight caused by degradation are used for structural design of outer shell and resin covers, and neutron shielding design.

(3) Basket design

The basket composed of square tubes made of aluminium alloy and borated aluminium plates installed in the space between square tubes was designed for Tokai-2 power station. Based on the experience of the basket design, square tube made of aluminium alloy containing neutron absorbing material has been developed to improve the basket capacity. As the new aluminium alloy has enough strength for structural design and neutron absorbing function, the fact of using the square tube allows eliminating borated aluminium plates and obtaining a higher capacity. Figure 6 shows the square tubes. The details of square tube made of the new aluminium alloy containing neutron absorbing material are reported in Reference [4].

PWR fuel basket is designed based on a tube-and-disk design used for the baskets of transport cask and canister. It is easy for the basket to secure water gap for keeping sub-critical condition during fuel loading.

Summary

Hitz casks, which are developed for spent fuel interim storage facilities, can achieve safety design, higher capacity and economical efficiency by carrying out the following processes.

(1) Proven technologies achieved in previous design and fabrication are utilized.

(2) 1/3 scale model drop test was carried out to verify the behaviour of containment boundary at transport accident condition not only before but also after storage period.

(3) The test was carried out to verify the thermal behaviour of neutron shielding material, resin (NS-4-FR), in storage.

(4) Square tubes made of aluminium alloy containing neutron absorbing material is used for BWR fuel basket.

References

[1] Nuclear Power Engineering Corporation, "The demonstration examination for metal cask storage technology establishment", 2003 Edition (Japanese)

[2] H. Tobita: "Containment Performance of Transportable Storage Casks at 9 m Drop Test", PATRAM2004

[3] N. Yamada: "Thermal Behaviour of Neutron Shielding Material, NS-4-FR, under Long Term Storage Conditions", PATRAM2004

[4] J. Kusui: “Development of Basket for Transport/ Storage Cask Using Square Tube made of Aluminium Alloy Containing Neutron Absorbing Materials”, PATRAM2004

Table 1 Specifications of Fuel Assemblies

Item \ Fuel Type		BWR 8X8 (STEP1)	BWR 8X8 (STEP2)	PWR 17X17
Initial Enrichment [%]		3.1	3.6	4.2
Burn-up [GWd/t]	Average	34	44	44
	Max.	40	50	48
Cooling Time [year]		15	8	15

Table 2 Limiting Conditions for Designs

Item \ Cask Type	Hitz-B69	Hitz-B54	Hitz-P26	Remarks
Length (Max.) [m]	6.7			At transportation
Height (Max.) [m]	3.6			
Width (Max.) [m]	3.55			
Weight (Max.) [t]	125			At lifting after fuel loading
	150			At transportation including transport frame and lifting yoke

Table 3 Specifications of Casks

Item \ Cask Type		Hitz-B69	Hitz-B54	Hitz-P26	Remarks
Fuel Type		BWR 8X8 (STEP1)	BWR 8X8 (STEP2)	PWR 17X17	
Capacity [Number of Fuel Assemblies]		69 with C/B	54 with C/B	26 with B/P	C/B=channel box B/P=burnable poison
Radioactivity (Max.) [PBq]		1.48×10^{2}	1.90×10^{2}	1.96×10^{2}	
Decay Heat Power (Max.) [kW]		12.8	17.5	17.2	
InTransport	Weight [ton]	130	124	126	Excluding transport frame
	Overall Length [m]	6.7	6.7	6.4	
	Outer Diameter [m]	3.5	3.5	3.55	
In Storage	Weight [ton]	118	113	115	Excluding support frame
	Overall Length [m]	5.4	5.4	5.1	
	Outer Diameter [m]	2.5	2.4	2.5	

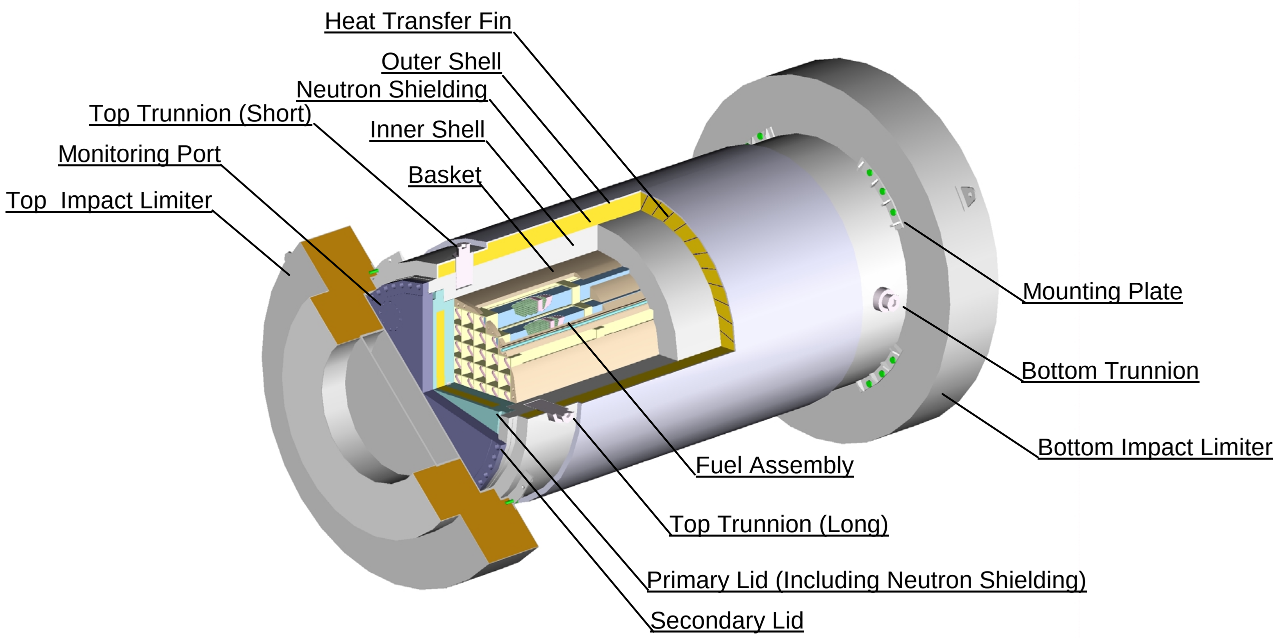


Figure 1   Overview of Hitz Type Cask (In Transport)

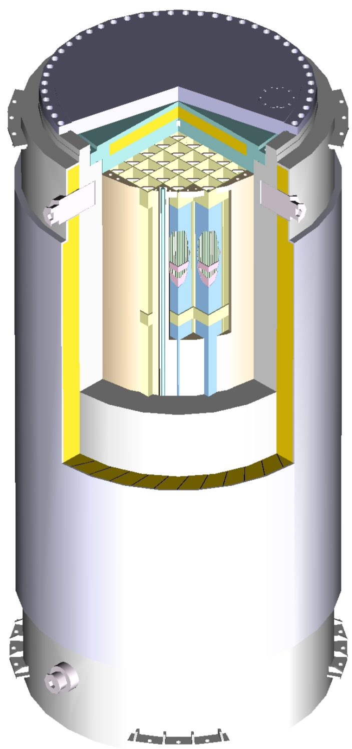
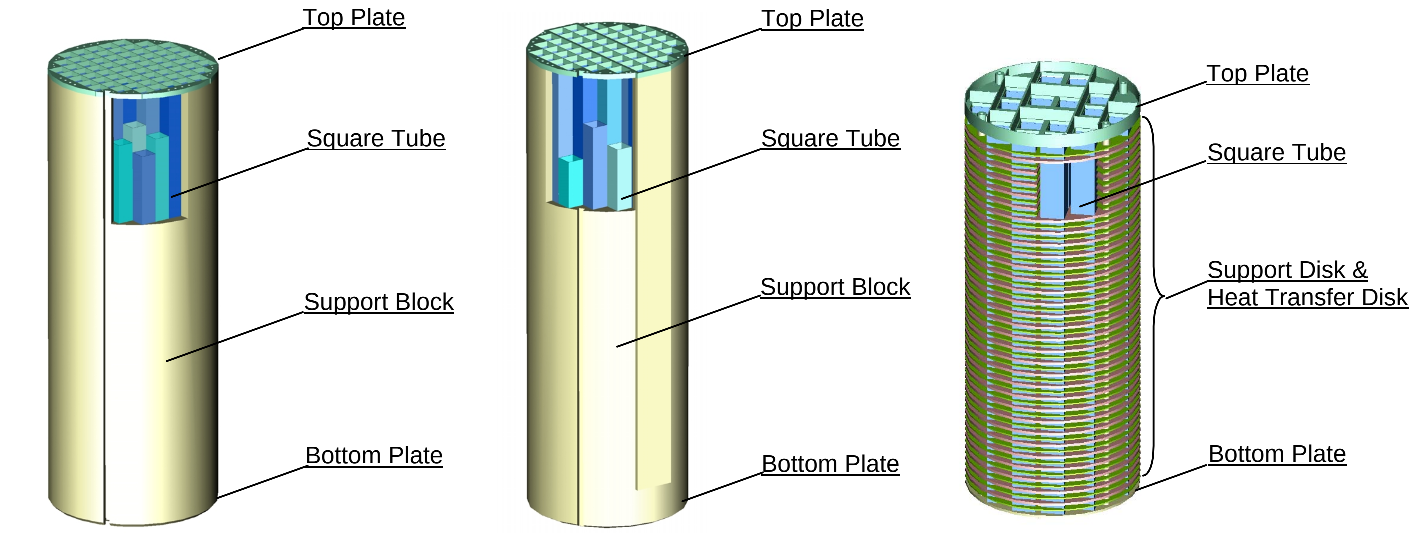


Figure 2   Overview of Hitz Type Cask (In Storage)



For Hitz-B69 Type Cask   For Hitz-B54 Type Cask   For Hitz-P26 Type Cask

Figure 3 Overviews of Baskets

Figure 4   Scale Model 9m Drop Test

Figure 5   Resin Heat Degradation Test

Figure 6   Tubes Made of Aluminum Alloy containing Neutron Absorbing Material