Dual-purpose Transport and Storage Dry-type Metal Casks for Spent Nuclear Fuel

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OVERVIEW: Independent storage of spent fuel away from nuclear power plants is required until it can be reprocessed. We plan to use a dual-purpose dry metal cask for transport and storage for this interim storage. Regulations, guide lines, and standards are being developed to achieve this around 2010. Hitachi has developed this cask to maximize number of loaded spent fuel to reduce frequency of transportation. As economical efficiency and long-term reliability were also sought, an easy-to-fabricate structure was adopted in order to prevent deterioration. A 1/3 scale-model drop test was done to evaluate the integrity of elements and total function and to confirm safety. Moreover, a 1/1 scale-model dual-purpose transport and storage dry-type metal cask was fabricated, inspected and tested, which would be required at the actual cask fabrication stage. Knowledge acquired from these results is being reflected in the design and fabrication of actual casks to improve them.

INTRODUCTION

SPENT fuel from nuclear power plants needs to be reprocessed in Japan. However, the volume of spent fuel is larger than the reprocessing capacity, and it needs to be properly stored and controlled as a fuel resource for recycling until it can be reprocessed. For this purpose, large-scale ISFSI (independent spent-fuel-storage installation) away from nuclear power plants are necessary.

Dry-type metal casks are already used to store spent

(a) (b)

Fig. 1—1/3 Scale-model Drop Test (a) and External View of 1/1 Scale-model (b).
Using results of several element tests and a design method established through a 1/3 scale-model drop test for comprehensive evaluation, a 1/1 scale model was fabricated and inspected assuming this was an actual product. A thermal conduction test was made, and cask design was confirmed.

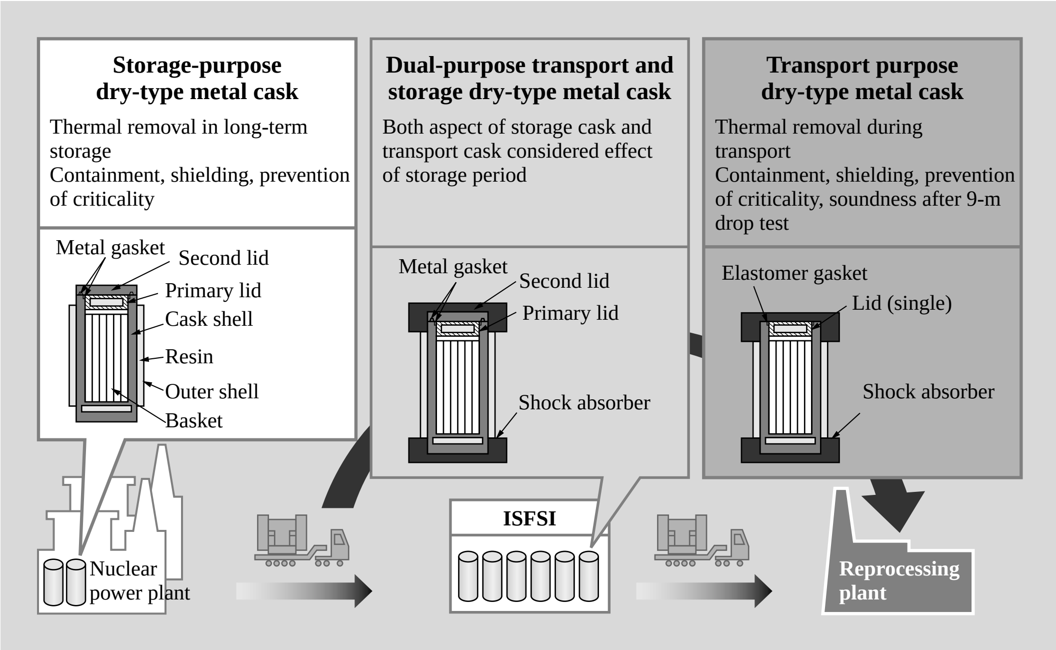


Fig. 2—Characteristics of Dual-purpose Transport and Storage Dry-type Metal Cask.
Design with considering storage before and after transport is required.

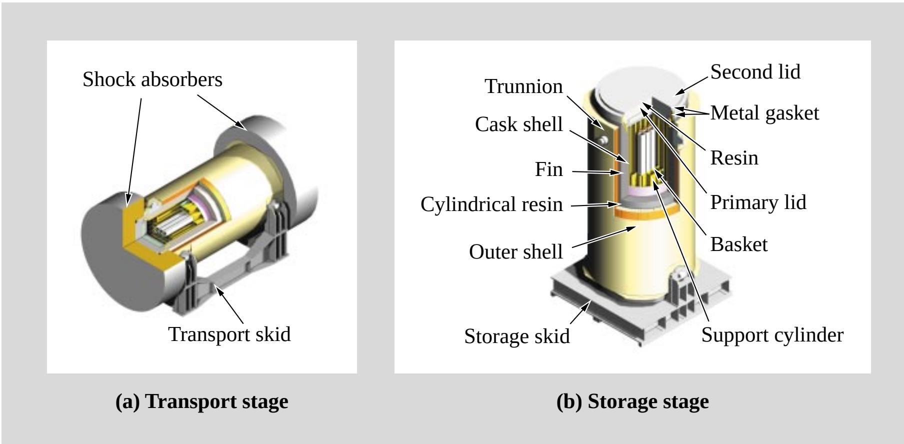


Fig. 3—Outlines of Developed Dual-purpose Transport and Storage Dry-type Metal Cask.
69 bundles of BWR fuel (Step I, 10-year cooling) can be loaded. Its length is approx. 5.5 m and outer diameter is approx. 2.5 m. Mass is approx. 130 t during transport and approx. 120 t in storage.

fuel in interim storage at the nuclear power plants. However, ISFSIs are currently being evaluated and dual-purpose transport and storage dry-type metal casks are planned to be used because of their superior safety, flexibility and economical efficiency. The increased risk for repacking spent fuel is reduced by adopting these casks. Here, we describe the casks, element test results, and the development status of their design established by comprehensively evaluating them in a 1/3 scale-model drop test and in 1/1 scale-model fabrication (see Fig. 1).

OUTLINE OF DUAL-PURPOSE DRY-TYPE METAL CASKS

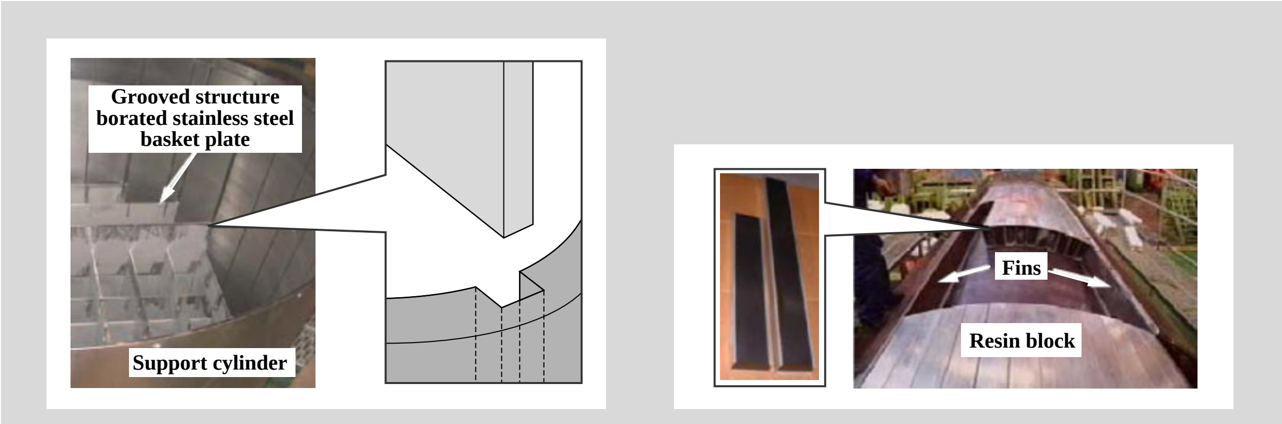
These dry-type metal casks are used for transport and storage. The guide lines and standards for them are being established by Atomic Energy Society of Japan (AESJ) and The Japan Society of Mechanical Engineers (JSME). Complying with these, Hitachi has developed these casks to maximize number of loaded spent fuel to reduce frequency of transportation (see Fig. 2).

Features of Dual-purpose Dry-type Metal Cask

Outlines of the dry-type metal cask are shown in Fig. 3.

For economical efficiency and long-term reliability, welds were minimized to improve ease of fabrication, and materials with less deterioration were adopted. The structures of the basket and resin block are shown in Fig. 4.

The basket plates were slit in the axial direction of



(a) Basket assembly in 1/1 scale model fabrication

(b) Resin block placement in 1/1 scale model fabrication

Fig. 4—Outline of Basket Structure (a) and Resin Block Structure (b).
To improve reliability and reduce fabrication costs, grooved and block structures were adopted.

the cask, and the plates were inserted into the grooves of the support cylinder. Borated stainless steel was used for the basket plate, which does not deteriorate much over time. The basket structure maintains reliability of spent fuel at the transportation after long term storage.

A block-structure resin was adopted for the radiation shielding to enable parallel fabrication with the cask's main body and to reduce the fabrication time. The resin block was fabricated with an aluminum

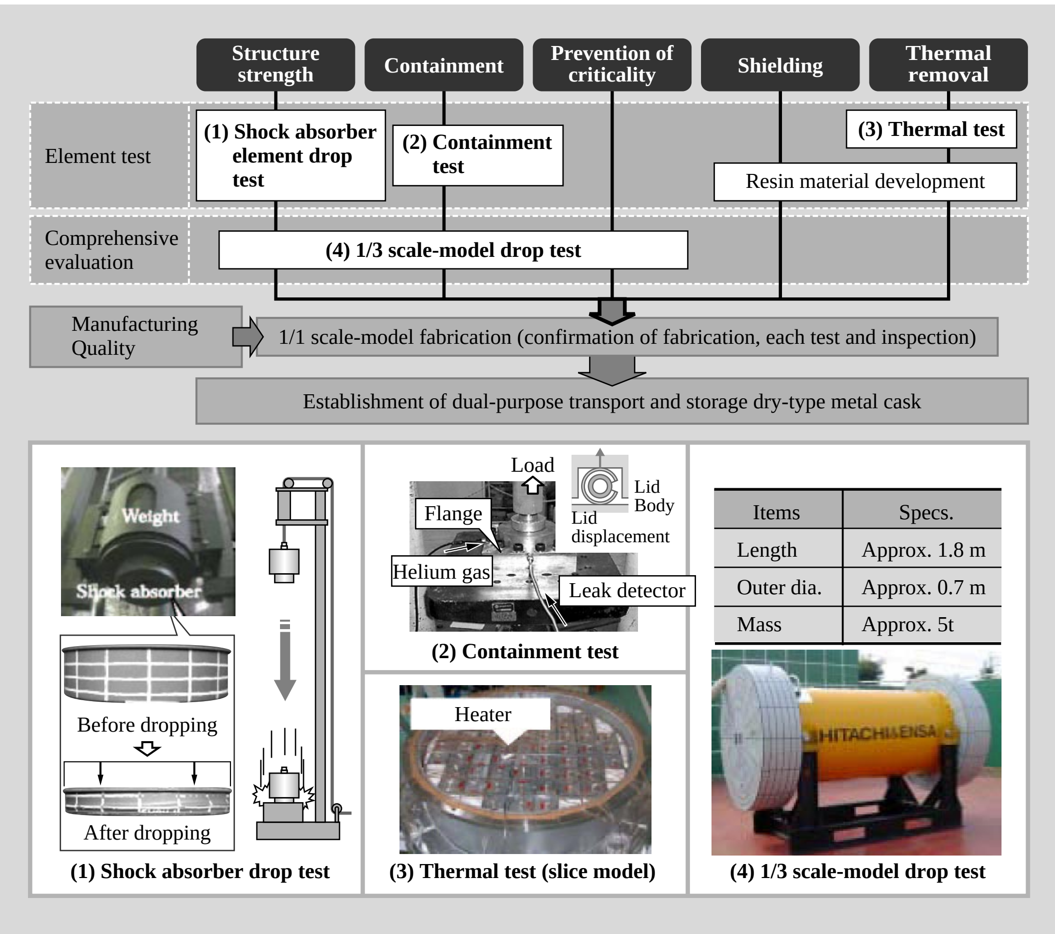


Fig. 5—Development Flow for Dual-purpose Dry-type Metal Cask.
Confirmation of safety and establishment of a design method were done through several element tests and a 1/3 scale-model drop test.

casing and resin was poured into the casing. The blocks were placed into the space between the inner shell (cask main body) and the outer shell. The block structure was divided into eight sections in the circumferential direction by the thermal conduction fin made of carbon steel. The block can be inspected for mass, dimensions, cracks, and blowholes before installation.

Development of Dual-purpose Dry-type Metal Casks

The flow of development for the dry-type metal casks is outlined in Fig. 5.

Their basic safety functions are containment, prevention of criticality, shielding, thermal removal and structural integrity.

Several element tests on these functions were done in the development, the soundness was confirmed, and a method of evaluating safety was established. In the shock absorber element drop test, a 1/15 scale-model shock absorber was used to develop the actual shock absorber, which would effectively reduce impact acceleration in drops at the transportation. Various kinds of wood properties were accumulated for the designing of shock absorber, and arranged and an analytical method was established to simulate the deformation behavior at the drop. By using this, a 1/3 scale-model, which will be discussed later was designed.

A seal-ability test was done under conditions where we simulated displacement of the lid in a drop during transportation. We also simulated degradation by heating the metal gasket to seal the lid. In this test, the margin of seal-ability for the metal gasket versus lid displacement was confirmed.

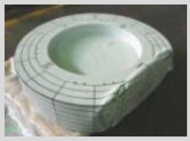
We established a method to evaluate the thermal conduction in the 3D grooved basket and validated it.

Based on these element test results, a 1/3 scale-model was fabricated and used for the drop test. We comprehensively evaluated the developed casks as follows:

(1) Design of shock absorber
  (a) Reduction of impact acceleration
  (b) Deformation behavior of shock absorber
(2) Soundness of cask
  (a) Seal ability by metal gasket
  (b) Deformation behavior of inner shell and lids
  (c) Soundness of contained components versus impact force

The results for the 1/3 scale-model drop test are shown in Fig. 6.

Drop orientation	Horizontal
Drop height	9 m



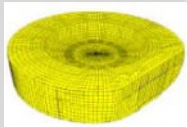


Fig. 6—1/3 Scale-model Drop Test Results.
The shock absorber's deformation behavior versus impact force was re-created using analytical method established through the shock absorber element drop test.

From these results, we established a design method for the shock absorber and confirmed its high-shock absorbance. The resin material, which constitutes the resin block, was also developed to increase number of options in cask design. Heat curing epoxy resin was used as the base resin and magnesium hydroxide was used as the fire retardant. The cross-link density of the epoxy resin was high, and the dehydration temperature of the magnesium hydroxide was also high. Because of this, the depletion of resin caused by heating up could be reduced. According to our accelerated test on thermal deterioration properties, mass depletion under 60-year storage simulating conditions was less than 1%. The main material produced by depletion was carbon dioxide. Other tests such as a γ-ray exposure test were also done, and we confirmed that the casks conformed to the required specifications when heat curing epoxy resin was adopted.

1/1 SCALE MODEL FABRICATION

Status of 1/1 Scale Model Fabrication

A 1/1 scale model was fabricated to improve the quality of the developed dual-purpose dry-type metal cask and to ensure the design was optimal. The schedule for fabrication is shown in Fig. 7, and test and inspection items performed assuming as actual product are shown in Table 1.

1/1 Scale Model Thermal Conduction Test

69 heaters which had the same heat output and same heat area as the actual spent nuclear fuel were used in

TABLE 1. Test and Inspection Items for 1/1 Scale Model
Tests and inspections were done to comply with a standard being established by AESJ, and it was confirmed that the design, fabrication flow, and fabrication method conformed to the requirements.

Safety function	Test and inspection items for 1/1 scale model
Structural strength	Materials, dimensions, visual inspection, welding, hydrostatic properties, leakage, trunnion load, and weight
Containment	Helium leaks
Prevention of criticality	Materials, dimensions and visual inspection
Shielding	Materials, dimensions and visual inspection
Thermal removal	Thermal test, materials, dimensions and visual inspection

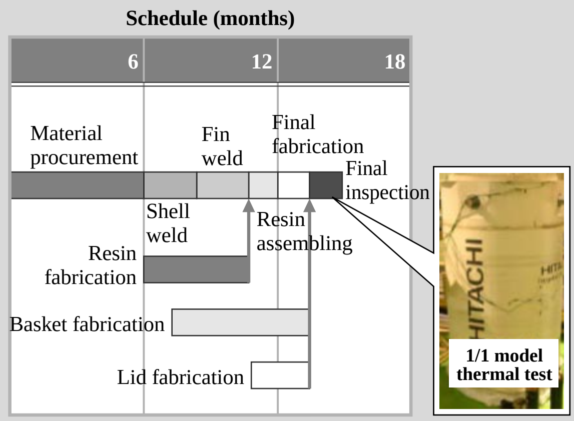
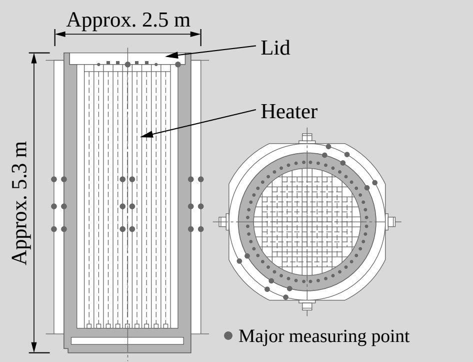


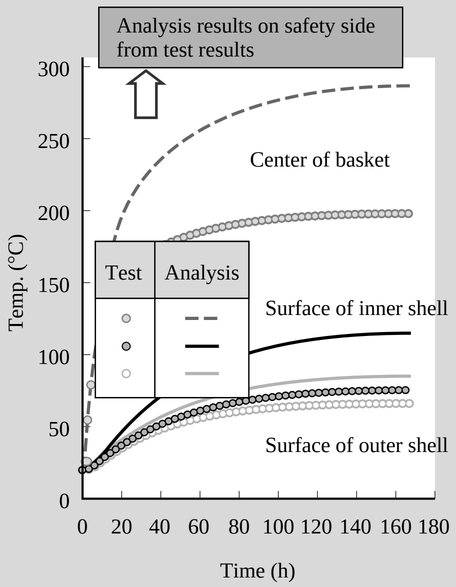
Fig. 7—Fabrication Schedule of 1/1 Scale Model.
We confirmed that there would be no problems with the fabrication of the developed cask by making a 1/1 scale model.



(a) Major spec. of thermal test equipment

Item	Test condition
Cask orientation	Vertical
Heater output	280 W/heater (19.32 kW/cask)
Atmosphere	Helium 101,325 Pa at room temp.

(b) Test conditions



(c) Comparison of 1/1 model thermal test and analysis results

Fig. 8—1/1 Scale-model Thermal Test Conditions and Outline of Results.
We found that the temperature in parts of the actual cask was below that permitted and the spent fuel temperature was well below 300°C providing a sufficient margin.

the 1/1 scale model thermal conduction test. A special lid for the test was used for the cables of the heaters and thermocouples for temperature measurements. Helium gas was pumped into the cask to simulate actual storage conditions. As a result, we confirmed that our analytical method to evaluate thermal conduction established through the slice model thermal conduction test, effectively proved temperature distribution on the safety side (see Fig. 8).

CONCLUSIONS

We described a development and design method for dual-purpose dry-type metal casks. Hitachi will introduce these in the near future. We also confirmed that they performed well through several tests and 1/1 scale-model fabrication, and established a design method. We plan on making improvements toward an optimal design in the future.

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