Demonstration Test for Transporting Vitrified High-Level Radioactive Waste* – 0.3m Free-Drop Test–

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INTRODUCTION

The object of this demonstration test program is to ensure safe transport of vitrified high-level radioactive wastes resulting from the reprocessing plants of COGEMA at La Hague and of BNFL at Sellafield, and which will be returned to Japan according to the contracts signed by the reprocessors with Japanese utilities.

A test cask for shipping high-level radioactive wastes was designed and fabricated [Tamaki et al]. The cask was then subjected to the series of tests stipulated by the IAEA regulation. This paper describes the results of a 0.3m free-drop test and simulation analysis by FEM analysis.

1. TEST CASK

The demonstration test cask design combines the specific structural features of both the COGEMA & BNFL casks.

The specifications and external view of the cask used for the drop test are shown in Fig.1. Instead of vitrified high-level waste, glass or mortar was packed in the canisters. Electric heaters were also installed to simulate the real heat conditions. The cask is characterized structurally as follows:

(1) The cask body is covered with a neutron absorber enclosed by a thin steel plate.

(2) Impact energy is supposed to be absorbed mainly by inelastic deformation of the neutron absorber and thin steel plate.

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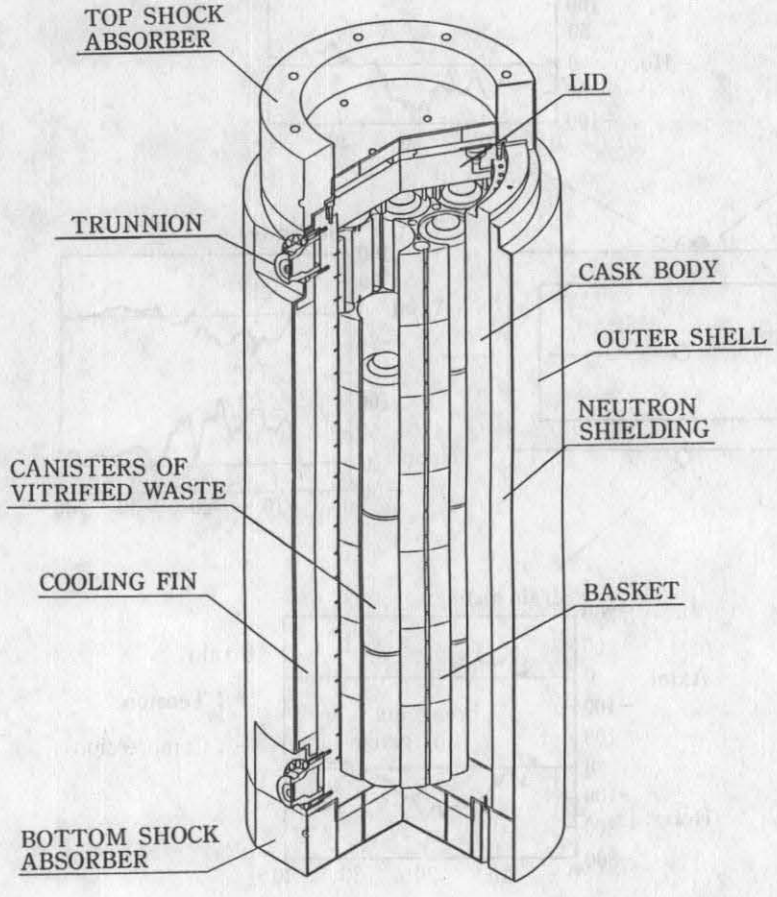
2. TEST METHOD

The drop test was carried out at the YOKOSUKA laboratory of CRIEPI. Horizontal orientation was chosen for the drop test because the maximum acceleration is yielded by this orientation compared to other orientations according to the design base analysis. The mechanism for absorbing impact energy is relatively new and has not been fully clarified yet.

The electric heaters were turned off just before the drop. The strains and accelerations at various points in the cask body and inner structure resulting from the impact caused by the drop were measured using strain gauges and accelerometers. Leak tests for the lid gasket were carried out before and after the drop test to evaluate the tightness of the gasket.



SPECIFICATIONS

Total Weight : 115 ton

Total Length : 6800 mm

Diameter of Cask : 2400 mm
(including outer Shell)

Thickness of Cask Body
: 254 mm

Thickness of Outer Shell
: 20 mm

Total Number of Canisters
: 28

Quantity of Heat
: 1.46 kW/canister

Fig. 1 Concept and Specifications of Demonstration Test Cask

3. TEST RESULTS

The acceleration and strain time histories are shown in Fig. 2. The measured maximum acceleration and strain are summarized in Table 1. The measured leak rate is shown in Table 2.
These results are summarized as follows ;

(1) The maximum strain at the cask as a result of the impact force caused by the free drop is in the elastic range.
(2) The leak rate did not change before and after the impact load.

We conclude that the integrity of the cask was maintained under the 0.3m free-drop test conditions.

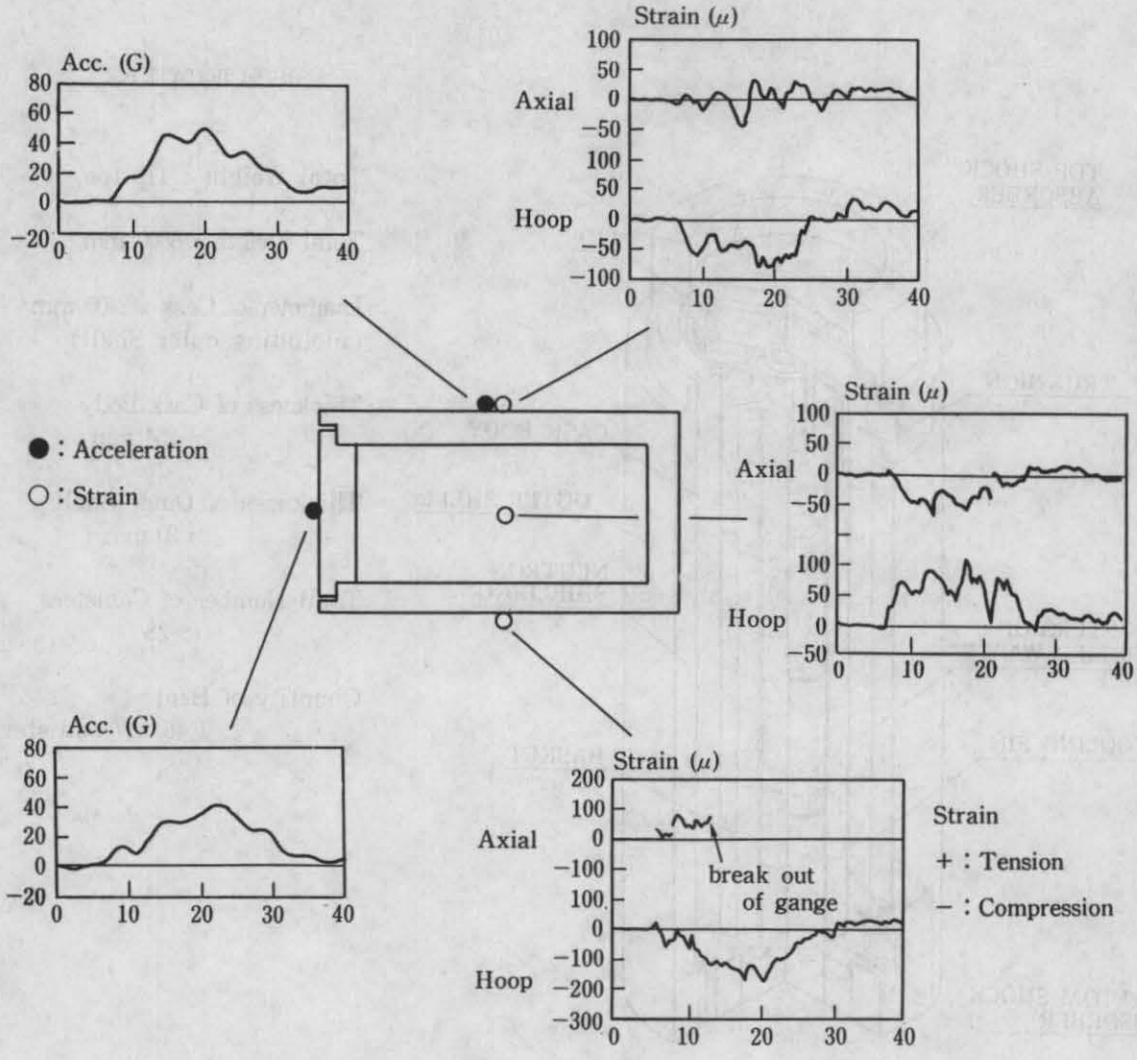


Fig. 2 Acceleration and Strain Time Histories

4. ANALYSIS

We used the DYNA-3D and NIKE-2D codes to analyze the drop test. A half-symmetrical model was applied to overall analysis to calculate the strains and accelerations at the cask by DYNA-3D. Then, the maximum acceleration value obtained from the above overall analysis was put into the plane strain model for the section of the cask normal to the longitudinal axis to calculate the strains at the basket by NIKE-2D. Fig. 3 and Fig. 4 show the half-symmetrical model and the plane strain model, respectively.

The impact energy was absorbed mainly by the inelastic deformation of the neutron absorber and thin shell plate. Therefore, the mechanical properties of the neutron absorber play an important role in the analysis. The structure of the neutron absorber is slightly complex because heat transfer fins are attached to the cask body. It is hard and unreasonable to model such a complicated structure with DYNA-3D. Consequently, to obtain the stress-strain relationship of the neutron absorber, the procedure shown in Fig. 5 was used. The static stress-strain curve was obtained by FEM using the partial neutron absorber mode including one heat transfer fin.

This curve was put into the DYNA-3D model as homogeneous material.

The comparison between the test and calculated results is shown in Table 3 and 4. It is clear from these results that the agreement between the test and calculated results is fairly good.

Table 1. Summary of Test Results

Item		Test Results	Allowable Limit
Acceleration (G)		50	——
Stress (kgf/mm^2)	Cask Body	6.0	18.5
	Bolt at lid	50.80 (initial tightness) 0.56 (due to drop)	56.0
Radial Deformation of Outer Shell (mm)		12.5 ~ 13.0	——

Table 2. Results of the Leak Test

Item	Leak Rate	Allowable Limit
Before Drop Test	4.12×10^{-4}	2.30×10^{-2}
After Drop Test	3.95×10^{-4}	

(atm· cc/sec)

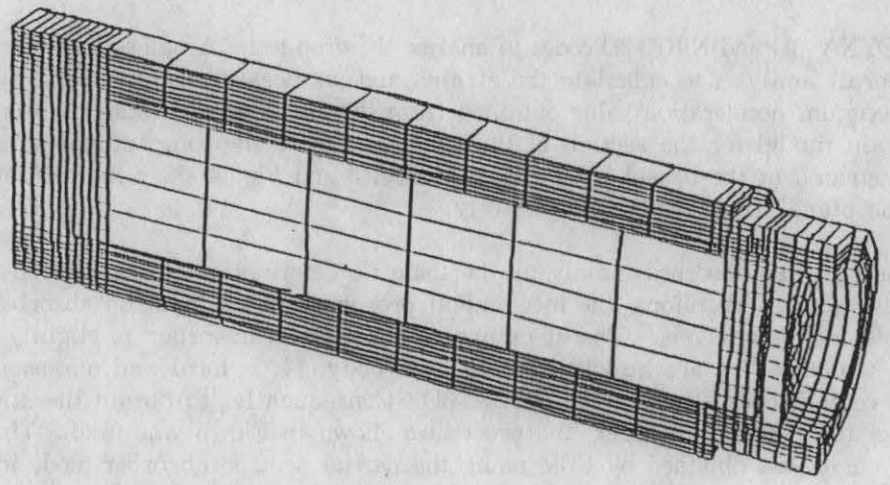


Fig. 3 Half-Symmetrical Model

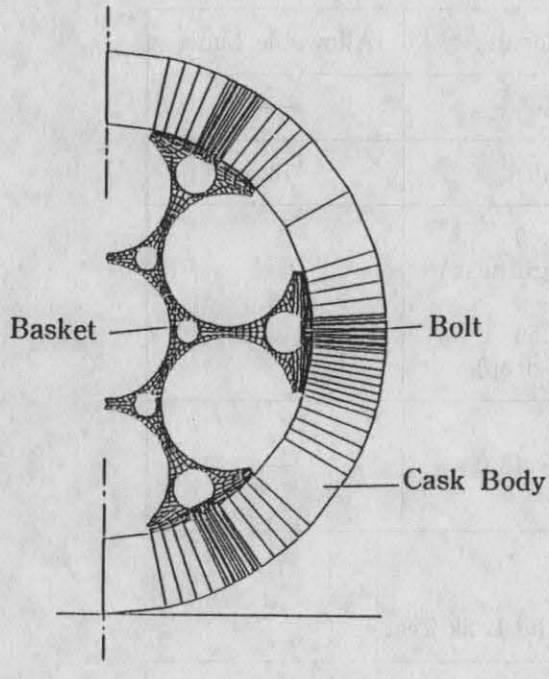


Fig. 4 Plane-Strain Model

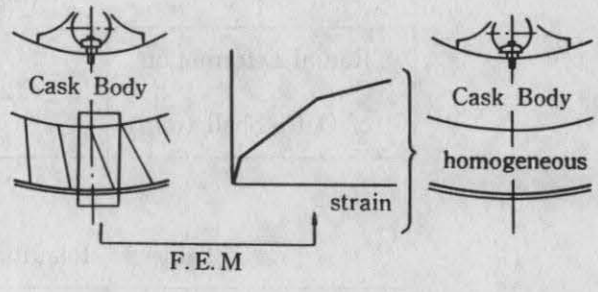


Fig. 5 Procedure for Obtaining Stress-Strain Curve of Neutron Absorber

Table 3. Comparison Between Test and Calculated Results (Half-Symmetrical Model)

Item	Calculated	Test	Allowable limit	Remarks
Acceleration (G)	68	50	——	——
Stress (kg/mm²)				
Cask Body	10.6	6.0	18.5	——
Bolt at Lid	——	50.8	56.0	Initial tightness
	2.1	0.56		due to impact

Table 4. Comparison Between Test and Calculated Results (Plane-Strain Model)

Stress (kg/mm²)	Calculated	Test	Allowable limit
Basket	6.2	3.9	7.3
Basket Bolt	55.2	32.0	91.0

5. CONCLUSION

The integrity of the cask for shipping high-level radioactive waste was confirmed by the drop-test method. The accuracy of analysis by DYNA-3D was benchmarked by comparing the test and analytical results.

REFERENCE

H.Tamaki et al.
Demonstration Test for Transporting Vitrified High-Level Radioactive Waste, PATRAM'92, 1992.

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