9m Drop Test by 1/3 Scale Model of the High Performance Spent Fuel Shipping Cask

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INTRODUCTION

The High Performance Spent Fuel Shipping Cask (HP-Cask) has been developed for the domestic transportation of spent fuel to the Rokkasho Reprocessing plant, which is expected to be operated in near future.

The HP-Cask is designed in consideration of high burn-up fuel and maximizing the contents (number of the fuel assemblies).

The HP-Cask was designed to absorb the impact energy of a 9m horizontal drop test by the external fins in addition to the impact limiters.

In impact analysis performed in the design stage, deceleration and deformation were calculated by superposing those of both impact limiters and fins. The former was calculated by computer code CRUSH and the latter was calculated by using the results of the fin impact test performed prior to the test.

The 9m drop test was carried out by mean of the 1/3 scale model of the HP-Cask to confirm the propriety of the design and to verify the analysis method based on the design.

TEST MODEL

It is well known by the previous test results that the scale law holds good on a model of larger than 1/4 scale at the 9m drop test. Therefore, a 1/3 scale model was selected for this test program.

The model is built to 1/3 scale of the large type HP-Cask, of which constituent materials are lead-steel-resin. The fuel basket and fuel were not to scale but the weight was adjusted for the test.

The model is 2100mm in length and 850mm in diameter, and the total weight is about 4 tons. Figure 1 and Figure 2 show the outline of the model.

Cask body and Lid

Cask body is 1771.3mm in length and 826.4mm in outer diameter (tip of the external fins) and its weight is 2800 kg. The body consists of an inner vessel, intermediate shell, outer shell, gamma shielding and neutron shielding.

The lid is made of forged stainless steel and attached to the cask body by 36 bolts. There is an expansion tank on the inner surface of the lid. The outer diameter of the lid is 546.7mm and the length is 185mm including the expansion tank.

One cask body and lid is fabricated for the test.

Impact Limiter

The impact limiter consists of a stainless steel housing and wood which was filled in the housing. Wood is energy absorbing material, and oak wood was filled in at the outer periphery of the housing and fir-plywood was used at the center part of the housing. The outer diameter of both absorbers is 883.3mm, and the width of their cutting part is 853.3mm. The lengths are 224.6mm for the top impact limiter and 94.6mm for the bottom impact limiter.

Three top impact limiters and two bottom impact limiters were fabricated for the tests.

TESTING

Direction of Drop

The 9m drop test was conducted as specified in the IAEA transport regulations. As the main purpose of the test is to examine the response of energy absorbing system which consists of impact limiters and fins, 2 horizontal drop tests and 1 vertical drop test were performed. The test was performed in the following order:

(1) Horizontal drop 1
(2) Horizontal drop 2
(3) Vertical drop (from the lid side)

Test Method

The model set up in the proper attitude was lifted up to 9m high and dropped on to the unyielding target. The model as lifted is shown in Figure 3.

Deformation, deceleration, strain, inner pressure and leak rate at the containment boundaries were measured at each drop test. Measuring locations of deceleration and strain are indicated in Figure 4. Inner pressure due to the impact of cavity water was measured at vertical drop test. Leak rate was measured by pressure rise method before and after the test.

TEST RESULT

Deformation

Impact limiter

(1) Horizontal drop test
The deformation of impact limiters due to each horizontal drop test was almost the same, and the reproducibility of the test was confirmed. Main features of the deformation were summarized as follows.

(a) Deformations of impact limiters near the connecting surface to the cask body was from 3mm to 9mm more than the other side, but the wood inside the housing deformed uniformly throughout the length.

(b) Deformation of the bottom impact limiter was about 5mm more than that of top impact limiter. It is supposed that the difference of length between the top and bottom impact limiter caused such a result.

(2) Vertical drop test
The deformation was approximately the same as that predicted in the analysis. The main features of the deformation were as follows.

(a) The fir-plywood was deformed about 27mm uniformly.

(b) The oak wood located around the periphery of the housing did not contribute to the energy absorption

(c) Buckling occurred at the inner shell of housing and bolt hole near the impact surface. Outer shell of the housing swelled about 16mm to outside.

External fins

The deformation of fins at two horizontal drop tests was almost same. Main features of the deformation are as follows.

(1) Deformation of the fin was of double hinge mode. Fins bent in random direction, and no regularity was observed.

(2) Deformation was greater at the bottom side, and smallest at the center. Slight incline of attitude toward top side at the impact and the difference of length between top and bottom impact limiters were estimated to be the causes of the difference.

Cask body

Slight flattening was observed at the center of the body. However, overall deformations were negligible.

Deceleration

Maximum value of the decelerations occurred in drop direction is summarized in Table 1.

Horizontal drop

(1) The decelerations at lid and bottom center which were considered to correspond to the energy absorption of impact limiter were around 250G.

(2) The deceleration at the center of the body (lower side) which was considered to correspond to the energy absorption of external fins was around 300G.

Vertical drop

(1) The deceleration of the lid center was maximum and that of basket was almost the same value.

Water Pressure

Maximum pressure at vertical drops was 78.9kg/cm2 which corresponded well to the deceleration peak measured at the lid center.

Leakage Test

In order to examine the soundness of the containment boundaries, leakage test was carried out before and after the drop tests. Results are shown in Table 2.

No appreciable leakage was detected and it was confirmed that the containment boundaries did not deform at the drop tests.

COMPARISON WITH ANALYTICAL RESULTS AND SUMMARY

Using the analytical method applied to design, deceleration and deformation were calculated for 1/3 model, which were compared to the test results. Results are shown in Table 3.

The analytical values for the horizontal drop test are greater than the test results. The analytical method for horizontal drop is thus found to be conservative.

The vertical value could be conservatively evaluated by considering the housing plate and internal ribs of the impact limiters as shown in the Table.

Through the all test results, it is confirmed that HP-Cask retains the integrity under 9m drop test and the analytical method was verified .

The method will be applied to the detailed design of the HP-Casks.

Table 1. Measured Deceleration

(unit: G)

	horizontal 1	horizontal 2	vertical (from lid)
inner vessel center	326	276	338, 330
intermediate shell	135	175	-
lid center	247	243	494
bottom center	204	250	418

table 2. Leak Test Results

		leakage rate (atm cc/s) lid	vent	drain	total
horizontal 1	before	3.43E-5	1.43E-6	3.87E-6	3.96E-5
	after	4.82E-5	1.60E-6	1.92E-6	5.17E-5
horizontal 2	before	2.93E-5	9.65E-7	1.29E-6	3.16E-5
	after	6.95E-5	9.75E-7	1.93E-6	7.24E-5
vertical (from lid)	before	2.47E-5	1.45E-6	1.97E-6	2.81E-5
	after	6.48E-5	4.57E-7	1.30E-6	6.66E-5
criteria					2.00E-3

Table 3. Comparison between Analysis and Test

	Analysis	Test	
		impact limiter	fin(lower)
Horizontal			
deformation(mm)	47	Max 30	-
deceleration(G)	353	Max 250*	Max 326**
vertical(with housing plate and ribs)			
deformation(mm)	32	Max 30	-
deceleration(G)	506	Max 494	-

* deceleration measured at the bottom center
** deceleration measured at the inner vessel center

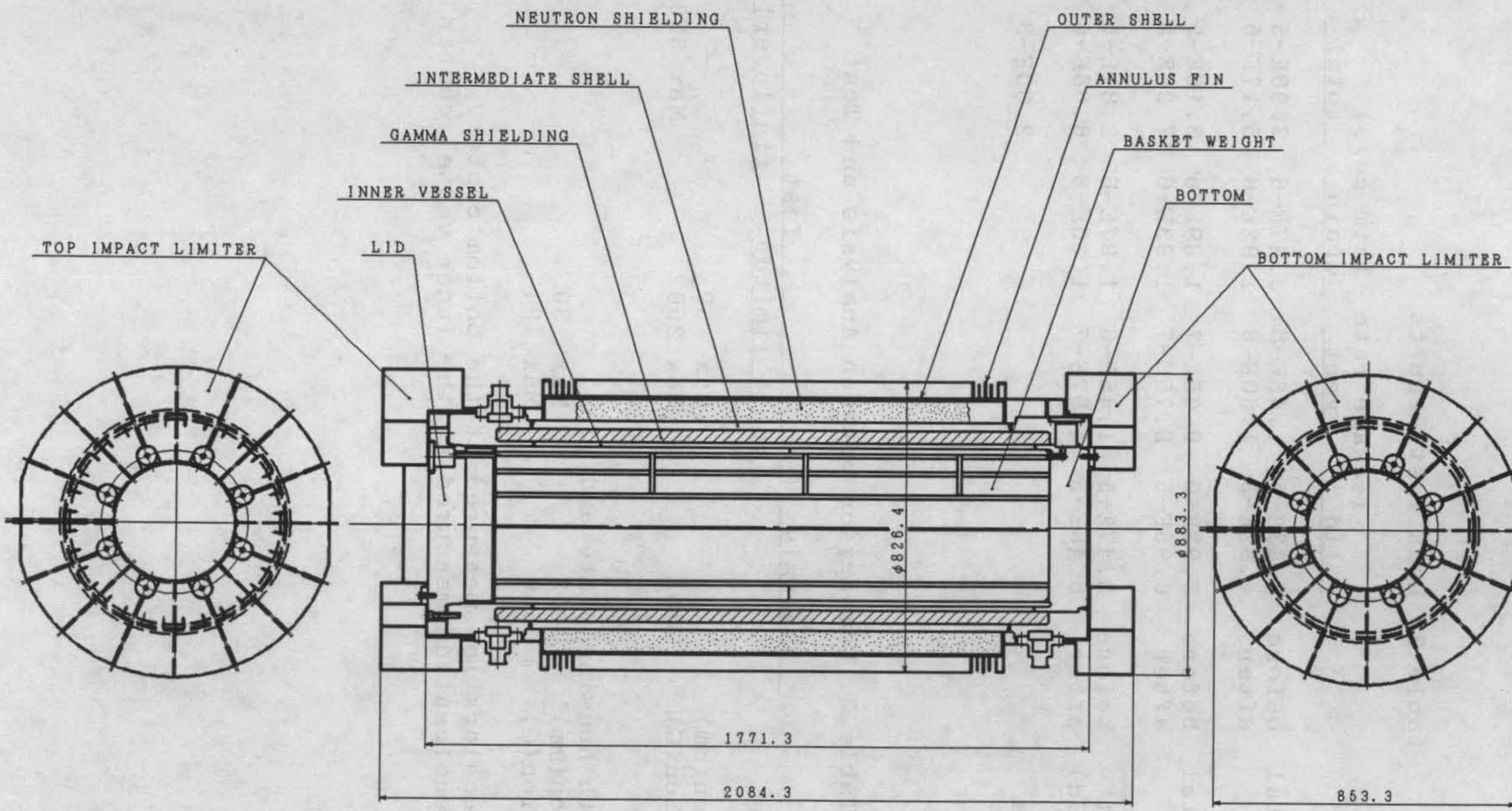

Figure 1 Outline of 1/3 Scale Model

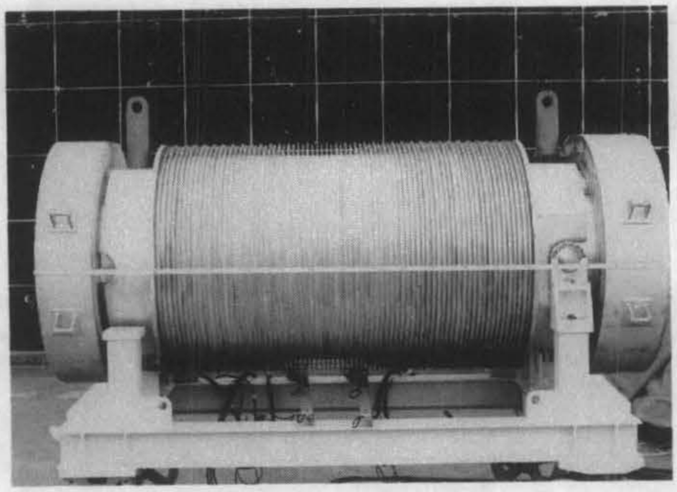

Figure 2   1/3 Scale Model

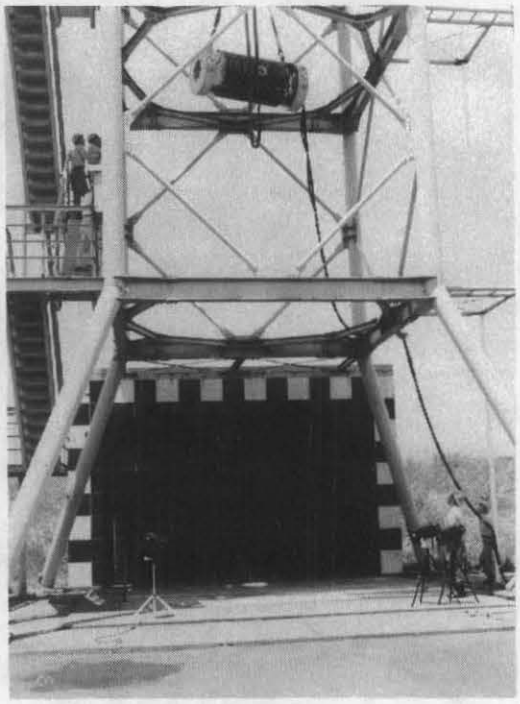

Figure 3   The Model as Lifted

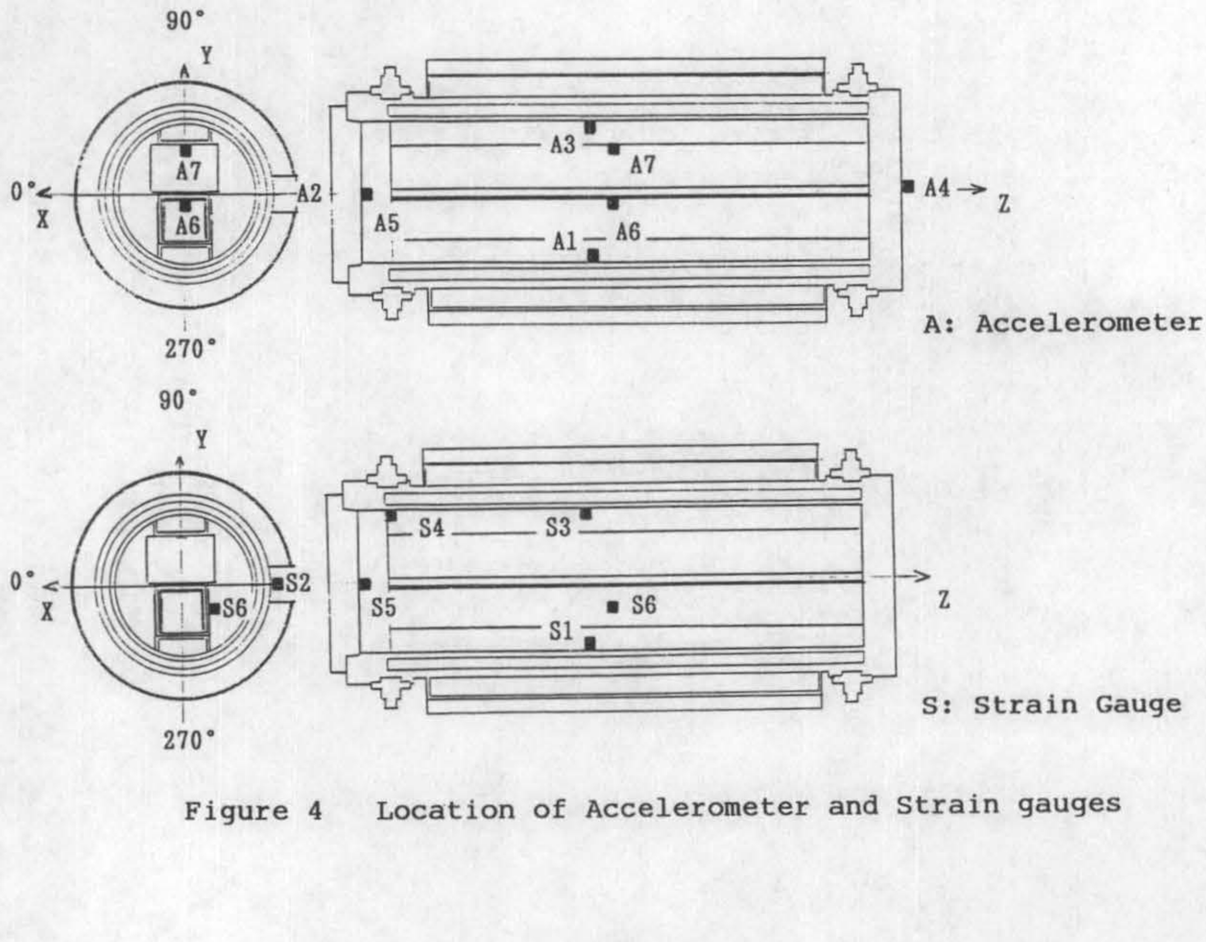

Figure 4   Location of Accelerometer and Strain gauges

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