Drop Test I.II and Thermal Test of Full Scale Spent Fuel Shipping Cask for a Research Reactor JMTR

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INTRODUCTION

The purposes of the tests are to confirm the validity of the design and an evaluation method applied for safety analyses of the JMTR spent fuel shipping casks.

In order to perform the tests, a full scale mock-up cask (hereafter reffered to as ' specimen') with mock-up fuels was fabricated. After these mock-up fuels were loaded in the specimen, Drop Test I .II and Thermal Test were performed under the specific conditions at Cask Experiment Station in Central Research Institute of Electric Power Industry in Japan. Drop Test I , Drop Test II and Thermal Test were performed in turn and the procedures, methods and conditions were based upon IAEA Regulation for Safe Transport of Radioactive Material.

Deceleration, strain and deformation on each part of the specimen were measured in the drop tests. And the thermal response of surfaces and inners of the specimen was measured in the thermal test. The experimential data were compared with the analysis values. As the result, the experimential data of the deceleration, the generated stress from which the strain was calculated and deformation were smaller than the analysis values, so that the validity of the structural analysis is confirmed. And the maximum temperatures at various points observed in Thermal Test were lower than analysis results except for an outer surface where the temperature was largely increased by flame from Fir-plywood.

Consequently it is confirmed that the validity of an evaluation method applied for Thermal Test is totally satisfactory.

SHOCK-2, FIN-200 and ANSYS code were used in the structural analysis, and TRUMP code was used in the thermal analysis as well.

DROP TEST I.II

SPECIMEN

The specimen with dimensions of 2 m height, 1.9 m in diameter, and weight of 18,060 kg were composed of several components, such as a cask body, a lid, a basket, a upper shock absorber and a bottom shock absorber. The specimen is illustrated in Figure 1.

Wiring slots and holes for measuring wires etc, were added to the specimen. this caused the specimen to differ from the actual packaging in some respects. And three kinds of mock-up fuels to simulate the actual fuels in outershape, in weight and in heat generation were fabricated.

TEST FACILITIY

The drop test facilities were composed of a crane with dropping divice for lifting weight 120 tons and a target which consists of the concrete foundation (1500 tons weight) of which upper position was covered with 10 cm thickness steel plate. A steel bar on the target was used for Drop Test II. Instrumentation was composed of sensors and a data acquisition system. Strain gauge type accelerometers and the strain gauges were used as sensors.

TEST CONDITION AND PROCEDURE

Thirty mock-up fuels were loaded int the specimen. The arrangement of these mock-up fuels is shown in Figure 2. However, heat generation type mock-up fuels without heater were not used for the drop tests. Five accelerometers and fourteen strain gauges were installed in the specimen and their sensor locations are shown in Figure 3. The experimental deceleration and strain data were filtered at 320 Hz.

For drop I, the specimen was dropped onto the target from the heights of 9 m with being kept in a horizontal attitude (As a result of the preliminary analysis, an attitude of the specimen to cause maximum stress was found to be horizontal.).
For drop II, after the specimen was positioned for a part of the upper shock absorber associated with the mutual location for O-ring of the lid to strike a steel bar on the target, the specimen was dropped onto a steel bar rigidly fixed perpendicularly on the target from the height of 1 m with being kept in a horizontal attitude (An impacting part and an attitude of the spcimen were sellected so that it would lead to the maximum damage in the following thermal test.).

TEST RESULT AND DISCUSSION

Results of deceleration, stress and deformation measured in Drop Tests are shown in

Table 1~3. It can be seen in Table 1~3 that the analysis results of deceleration, stress and deformation are larger than the test results, so that it can be granted that these analyses gives conservative evaluation. But, since the real fuel plates are made of uranium aluminum alloy clad with aluminum alloy, while the mock-up fuel plates are made of aluminum alloy, it is not reasonable to compare the test results with the analysis results. However, even if considering the difference of weight, the analysis values were still higher than the test results.

Figure 3~4 are photographs showing the full-scale model cask in Drop Test I and II. By visual inspections after Drop Test I, it was observed that the shock absorbers were deformed and their covers were cracked about 10 cm long and one bolt fastening the shock absorber was failed. In drop II, it was observed that the cover material was partially ruptured by a steel bar. But no damage on outershape-type mock up fuels, inners of cask body and a basket was observed, by visual inspection after the lid of the specimen was taken off. And by the visual inspection of the specimen, no damage in term of shielding and criticality was observed.

The helium leakage tests were performed before and after drop tests. In both tests, the helium leak rates were less than 1.0×10^{-4} atm·cc/s which were less than the allowable leak rate of 2.22×10^{-2} atm·cc/s given in the design criteria.

THERMAL TEST

TEST FACILITIY

The thermal test facility were composed of a direct fire heating type furnace with car truck and a stand. Figure 5 shows the construction of the thermal test facility. As temperature sensors, thirty thermocouples were installed on the specimen as shown in Figure 6. The sheathed thermocouples were attached on outer surface of the specimen by using a pad type thermocouple, and by welding or fixing by bolts to its surface, and on inner parts of the specimen by screwing after the sensors were inserted into holes with diameter of 4 mm.

TEST CONDITION AND PROCEDURE

In order to simulate the decay heat of spent fuels, 14 pieces of the mock-up fuels with heater with total 2.8 kw were loaded in the specimen as shown in Fugure 6. In order to minimize the cooling effect by the natural convection associated with fins, the specimen was placed horizontally on the stand. After the temperature of the specimen was saturated, it was transferred into the furnace with a temperature of 800 °C and held for 30 minutes. And then the specimen was taken out from the furnace and cooled naturally . Temperature measurements were continued until the temperature at the center of the specimen began to decrease.

TEST RESULT AND DISCUSSION

The highest temperatures at main parts in the thermal test are shown in Table 4.

During heating, gas bursting out of the crevice formed on the cover material was observed. This flame continued for about 10 minutes after the termination of heating the specimen. It was observed that the disclosed Fir-plywood carbonized and partly burned down, and all of the fusible plug on the shock absorber was open. The leakage tests were performed before and after the thermal test. The leak rates were 1.8×10^{-4} atm·cc/s and 5.4×10^{-4} atm·cc/s respectively. Furthermore no damage was observed in outershape-type mock-up fuels, inners of cask body and a basket by visual inspection after the lid of the specimen was taken off.

It was assumed on safer side in the safety analysis model that deformations of the shock absorber would be incurred uniformly in circumferential direction of the shock absorber by vertical drop, horizontal drop and corner drop, and that the equivalent heat input caused burning the shock absorber would be limited on the external part of Fir-plywood.

As the result, the maximum temperature at each part of the specimen was lower than the analysis results, except for the outer surface of the cask body exposed directly to flame, and the temperature increase at the inner surface due to the burning was about 35 ℃. The temperatures at O-rings and fuels which are important for safety design were 92℃ and 244℃ respectively.

CONCLUSIONS

Following conclusions can be drawn from this study.

- Test results are satisfactory.
- Analyses are totally conservative comparing with test results, so that analyses are able to be applied for detailed evaluation of cask.

Moreover, the test results are now used for verifying various analysis codes.

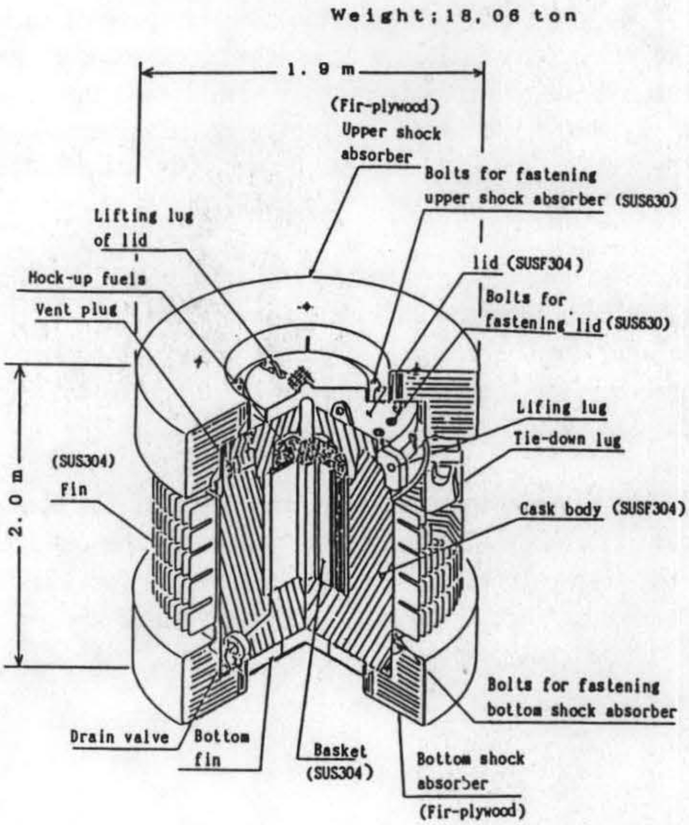


Figure 1. Overall view of the specimen

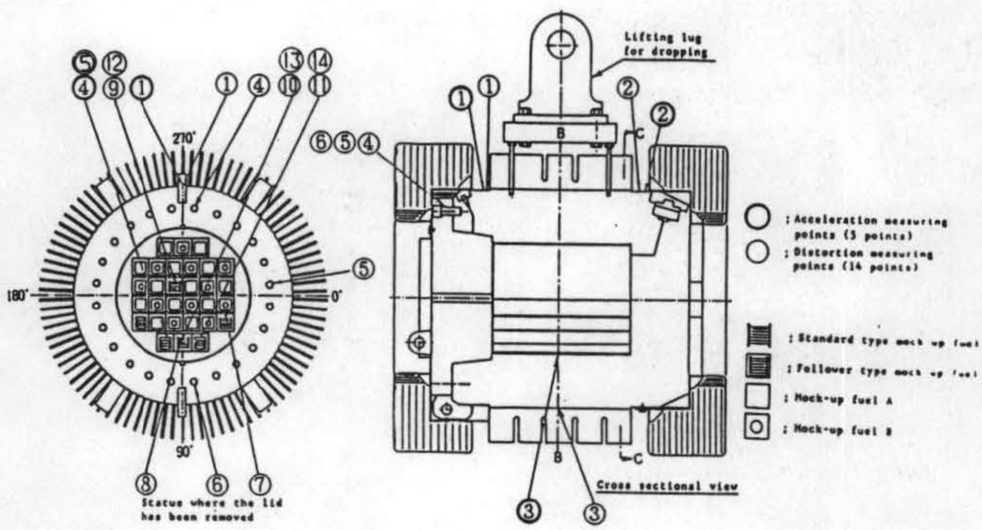
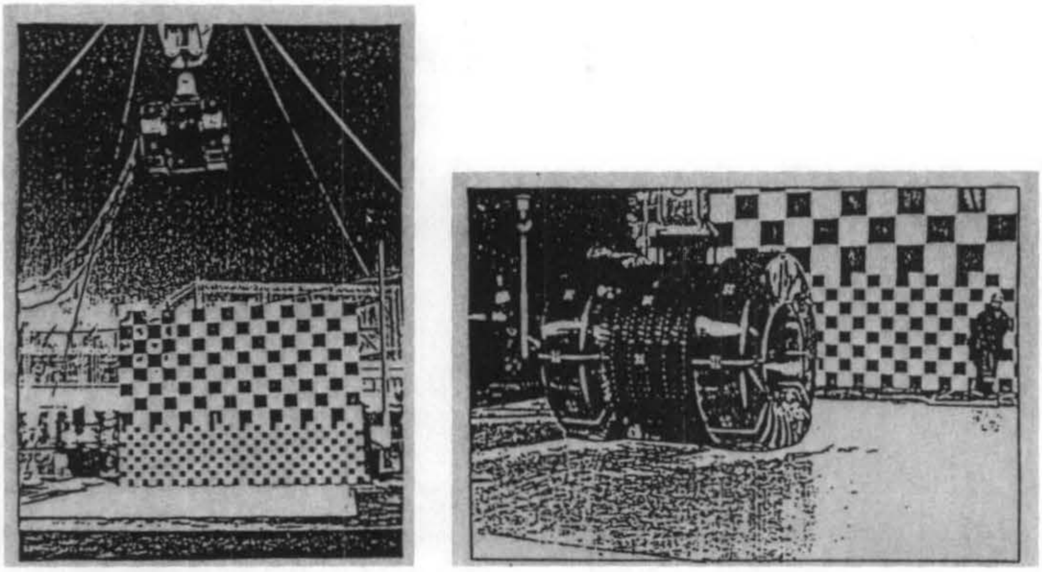


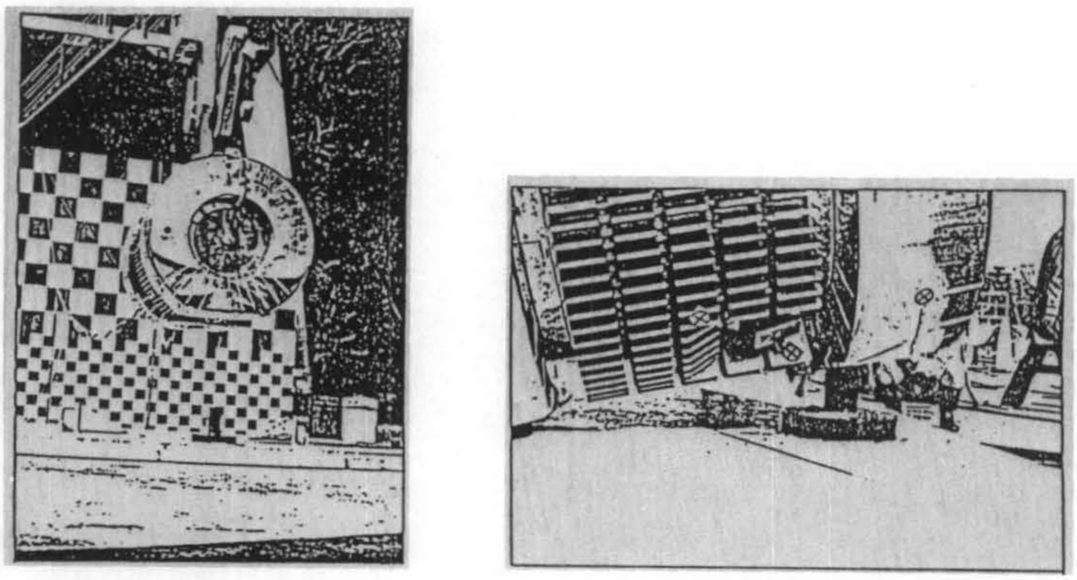
Figure 2. Arrangement of mock-up fuels and sensors on drop tests



The moment the specimen dropped.

After Drop I

Figure 3. Photographs of the full-scale model cask in Drop Test I



The moment the specimen dropped.

After Drop II

Figure 4. Photographs of the full-scale model cask in Drop Test II

Table 1. Maximum deceleration in Drop Test I

Location	Test results		Analysis result
	Measuring point	Deceleration (G)	Deceleration (G)
Cask body	1	109	169
Basket	3	93	
Mock-up fuel	4	140	

Table 2. Maximum stress in Drop Test I

Location	Test results			Analysis results
	Measuring point	Strain (-)	Stress (N/mm^2)	Stress (N/mm^2)
Cask body	3	247×10^{-6}	48.2	101
Basket	8	600×10^{-6}	117	243
Mock-up fuel	9	170×10^{-6}	11.7	19.2

Table 3. Maximum deformation in Drop Tests

Location	Drop test I		Drop test II	
	Test results	Analysis results	Test results	Analysis results
Shock absorber	98 mm	112 mm	63 mm	69 mm
Fin	25 mm	38.5 mm	—	—

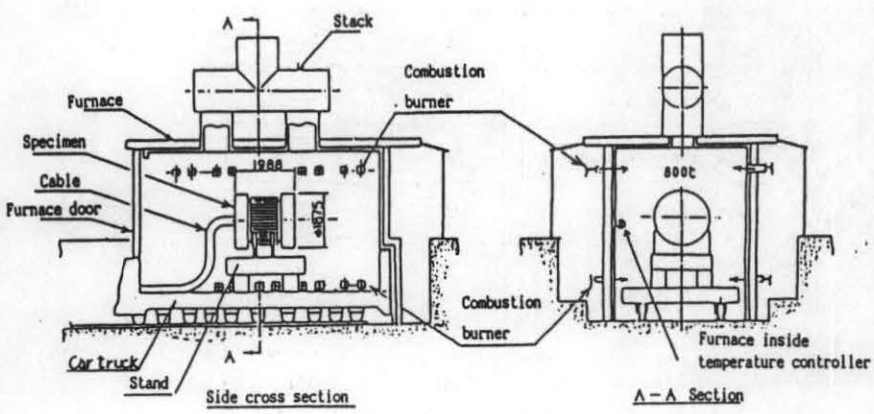


Figure 5. Construction of thermal test facility

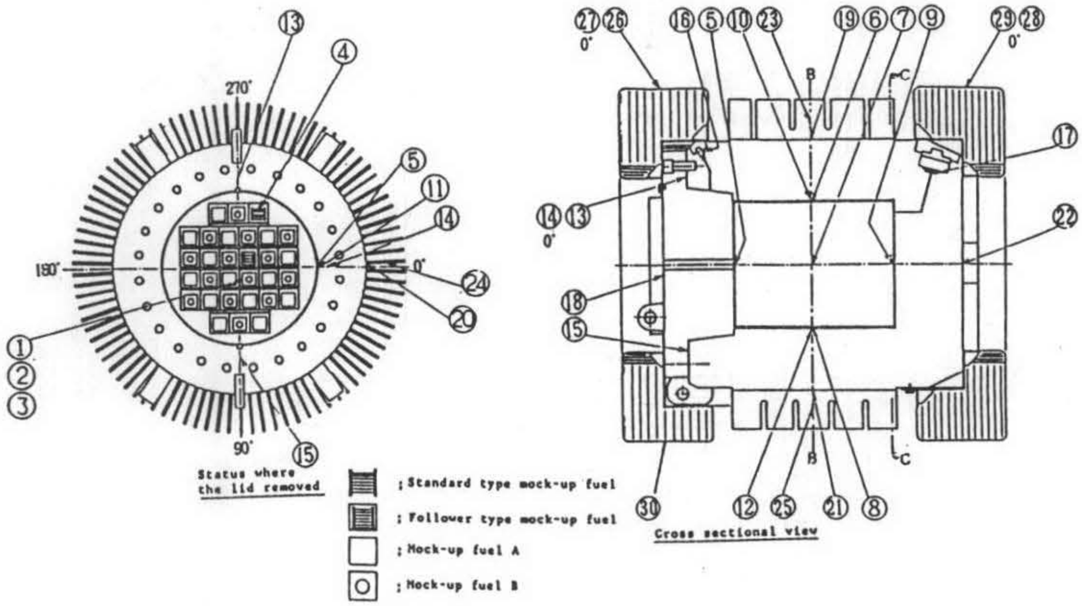


Figure 6. Arrangement of mock-up fuels and thermocoples in Thermal Test

Table 4. Maximum temperature in Thermal Test

Location	Test results (°C)	Analysis results (°C)
Fuel	244	345
Basket outer surface	134	193
Cask body inner surface	124	163
O-ring for lid	92	163
Vent plug	94	160
Drain valve	89	164
Middle of fin *	708	545
Cask body outer surface *	377	256

* Combustion heat of the gas generated from heated Fir-plywood was not evaluated in the analyses.