# Heat Transfer and Thermal Tests of a 100-Ton Class Dry-Type Spent Fuel Transport Cask

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## INTRODUCTION

In order to transport spent fuel, both a wet–type transport cask using water as the coolant and a dry–type transport cask using gas as the coolant are used. We have been able to verify the safety of the dry–type cask based on the demonstration test results which have so for been carried out on the wet–type cask, paticulay with respect to drop–test behavior. The details of these data are described in *Demenstration Test of 100 ton Class Spent Fuel Transport Cask*, T.Nagakura et al.,1986. With regard to temperatures in each part of the cask for heat transfer and thermal tests, however, no demonstration data is available because the method for removing heat is different.

Using a 100–ton class transport cask (see Fig. 1 and Table 1) , heat transfer and thermal tests were conducted in order to evaluate the heat transfer and fire resistance characteristics of the dry–type transport cask. Furthermore, by simulating to the result of these tests, the adequate methods for heat transfer and thermal analysis on dry–type transport cask were established.
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## HEAT TRANSFER TEST

### Test Method

A heat transfer test which allows the cask to stand for 1 week at an ambient temperature of 38 ℃, was conducted by placing the cask horizontally in a hood with an ambient temperature of 38℃. In this test, a simulated spent fuel assembly ( heat load : 56kw) was housed within the cask, and the inside of the cask heated. After the temperature of the cask reached a steady state, it was allowed to stand for 1 week.
The test was carried out in two ways ; one, a case where the cavity was filled with helium gas and the other, where the cavity was filled with nitrogen gas which are normally used in the dry type transport cask.

### Test Result

The temperatures measured in each part in this test are as shown in Fig.2, Fig.3, and

Table1 Principal Specifications of the 100−ton Class Dry−Type Transport Cask

| Items | Description |
|---|---|
| (1) Type of Pacage | Type B(M) |
| (2) Maximum Gross Weight of Pacakage<br>For PWR Fuel | Approx. 101 tons (When 10 Assemblies are Housed) |
| (3) Principal Dimensions of Packagng<br>Maximum Width<br>Maximum Length<br>Outside Diameter of Body<br>Length of Body<br>Cavity Diameter<br>Cavity Length | <br>3, 000 mm<br>6, 177 mm<br>2, 500 mm<br>5, 187 mm<br>1, 240 mm<br>4, 570 mm |
| (4) Weight of Packaging | Approx. 84 tons (Excluding Shock Absorber) |
| (5) Material of the Main Parts of Packaging<br>Body(Inner Shell, Outer Shell)<br>Lid, Bottom Plate<br>Neutron Shielding<br>Fuel Basket<br>Radiating Fin<br>Shock Absorber | <br>Stainless Steel (SUS 304)<br>Stainless Steel (SUS 304)<br>Silicon Rubber<br>Aluminum Alloy<br>Copper+Nickel+Plating<br>Wood (Fur Plywood)+Steel Cover |
| (6) Specifications on Simulated Fuel Assembly<br>Type<br>Quantity<br>Decay Heat (Kw) | <br>PWR 15×15<br>10<br>56 |

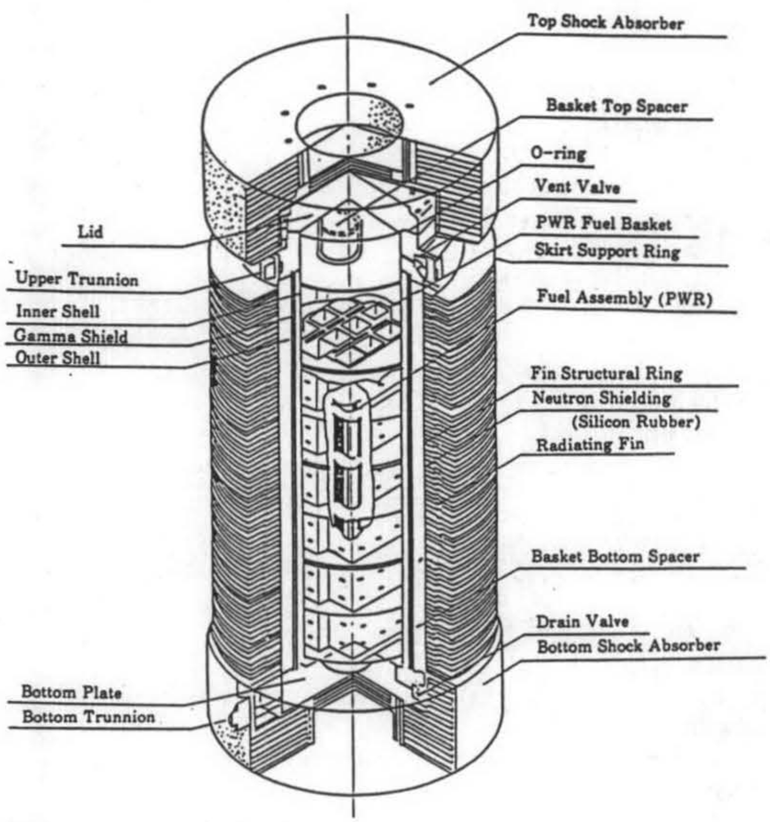



Fig. 1 General View of 100−ton Class Transport Cask

Table 2. The maximum temperature on the protection cover of the cask when the cavity was filled with helium gas and nitrogen gas was 53℃ in both cases, while the maximum surface temperature of the simulated fuel rod was 354℃ and 426℃, respectively, thus satisfying the allowable value.
As for the heat transfer characteristics owing to the different gases, the temperatures of the fin, outer shell, lead and inner shell were almost identical when either gas was used. However, the temperature inside the basket was higher where nitrogen gas was used than with helium gas. The temperature difference ranged from 15 to 20℃ in the basket, and 70 to 75℃ in the simulated fuel assembly. This is because the thermal conductivity of nitrogen gas is less than that of helium gas (about 1 / 4) .

## THERMAL TEST

### Test Method

A thermal test was carried out by placing the cask horizontally and heating the inside of the cavity at a fixed output (decay heat : 56kw). After the temperature in the cavity reached a steady state, the cask was promptly carried into an 800℃ furnace and held for 30 minutes, in accordance with the IAEA regulations. The cavity was filled with nitrogen gas which caused the temperature of the fuel rod under steady state to increase.

### Result

The temperatures measured in each part in this test are as shown in Table 3. The lead and O-ring sections of the cask exhibited maximum temperatures of 212℃ and 117℃, respectively are below the 327℃ melting temperature of lead and 300℃ woring critical temperature of O-ring (within 3 houres). The surface temperature of the simulated fuel rod was 434℃ which is below the spesified temperature of 532℃, The integrity of the dry cask is maintained.

## HEAT TRANSFER AND THERMAL ANALYSIS ON THE DRY-TYPE TRANSPORT CASK

### Analytical Method

To establish a method which can adequately evaluate the heat transfer characteristics of a dry-type transport cask under normal and accident conditions, an improvement in general-purpose F.E.M analysis codes (ABAQUS) and advances in analysis conditions were effected so that the behaviors obtained by the heat transfer and thermal tests were able to be reproduced.
To improve the analysis codes, and inter-radiation function which adequately models the combustion behavior of shielding material and a characteristic of the dry-type transport cask was added.
An axially symmetrical model was used for this analysis by modelling the −180° section with the center of a sectionally split cask.
The analytical conditions were established as follows :

(1) The heat balance between the cask and atmospher was assumed to be attributable to convection and radiation.
(2) In the cavity section, convection and radiation were also taken into account in addition to heat conduction.
(3) It was considered that there is a heat gap between the fin mounting cylinder and

Table 2 Results of Heat Transfer Test (Temperatures Under Steady State)

| Measured Elements | | Filling Gas (℃) | | Allowable Value (℃) |
|---|---|---|---|---|
| | | He gas | $N_2$gas | |
| Simulated Fuel Assembly | | 354 | 426 | 532 |
| Basket | Inner Surface | 199 | 221 | – |
| | Outer Surface | 173 | 191 | – |
| O–ring | | 85 | 91 | 200 |
| Inner Surface of Inner Shell | | 148 | 159 | – |
| Lead | | 133 | 143 | 327 |
| Outer Surface of Outer Shell | | 110 | 115 | – |
| Tip of Fin | | 79 | 80 | – |
| Trunnion | | 60 | 60 | – |
| Lid | | 79 | 84 | – |
| Shock absorber | Top | 40 | 42 | – |
| | Bottom | 49 | 51 | – |
| Protection Cover | | 53 | 53 | 85 |

Table 3 Results of Thermal Test

| Measured Elements | | Test Value (℃) | Allowable Value (℃) |
|---|---|---|---|
| Simulated Fuel Assembly | | 434 | 532 |
| Basket | Inner Surface | 256 | – |
| | Outer Surface | 228 | |
| O–ring | | 117 | 300 |
| Inner Surface of Inner Shell | | 213 | – |
| Lead | | 212 | 327 |
| Outer Surface of Outer Shell | | 454 | – |
| Meutron Shielding | | 618 | – |
| Tip of Fin | | 995 | – |
| Trunnion | | 100 | – |
| Lid | | 129 | – |
| Shoc Absorber | Top | 751 | – |
| | Bottom | 767 | – |

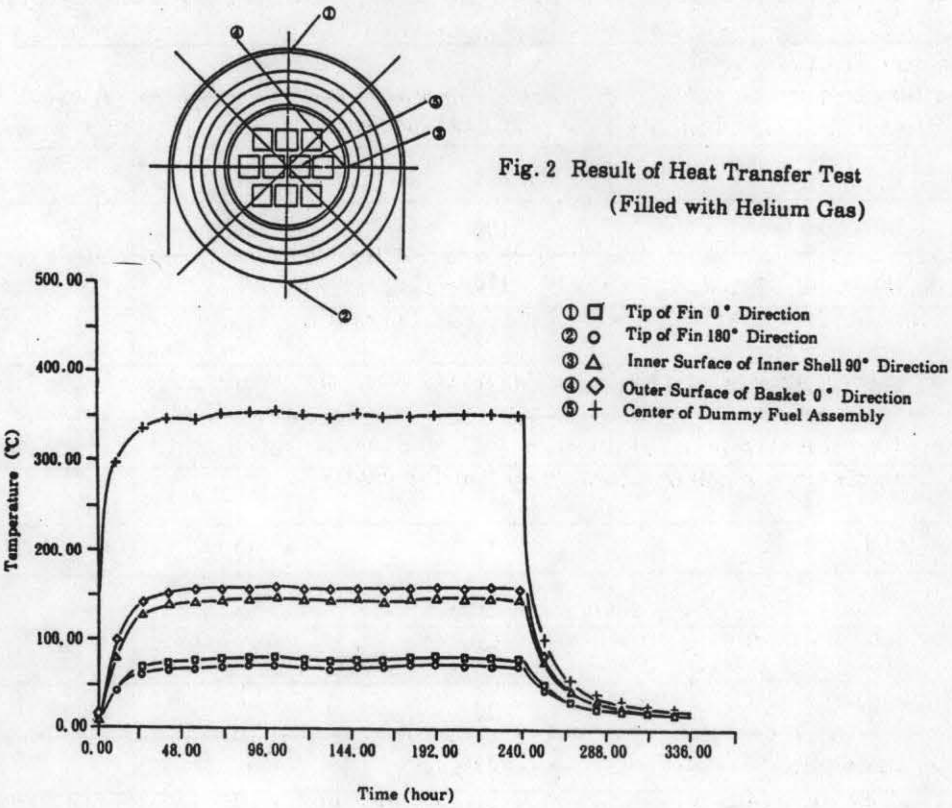



Fig. 2 Result of Heat Transfer Test
(Filled with Helium Gas)

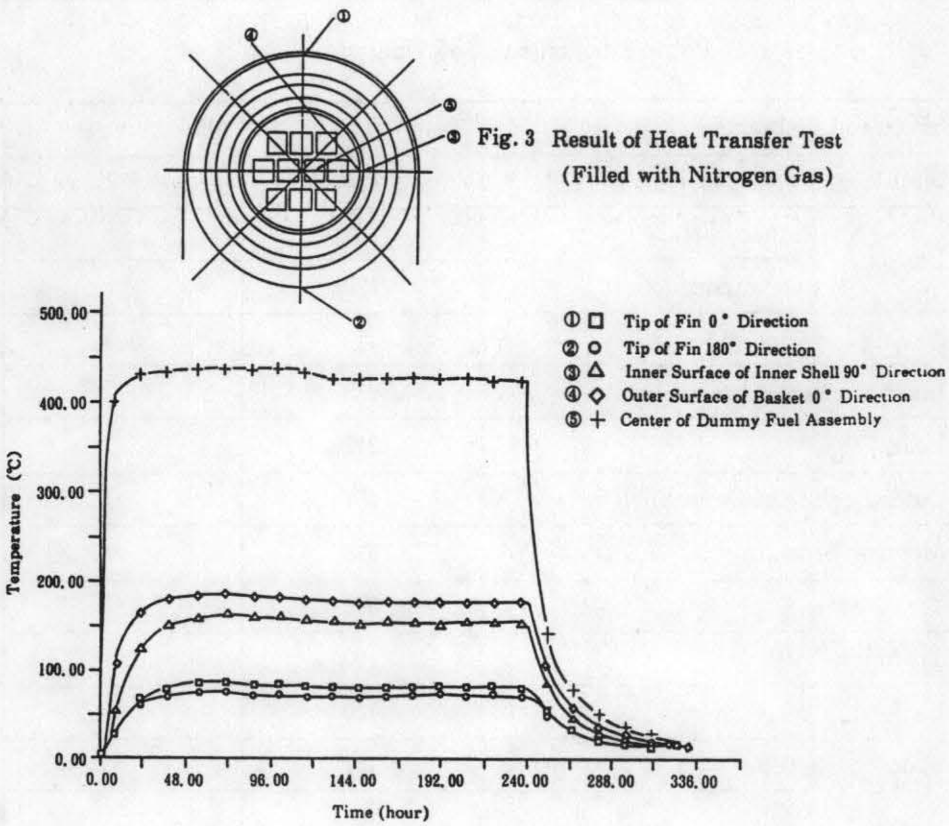



Fig. 3 Result of Heat Transfer Test
(Filled with Nitrogen Gas)

the outer shell during the thermal test because this cask is of multi–layer construction. In these analysis, therefore, the effect of the heat gap is dealt with as radiant heat transfer.

(4) The effect of neutron shielding material on combustion is given as heat flux owing to a acalorific value obtained by a material test carried out separately.

**Rusules of Analysis**

Comparisons between the analytical results and the test results are shown in Fig. 4 to 6. These results reveal that the analytical ressults agree well with the test results at the tip of the fin, on the outer surface of the basket as well as on the inner surfaces of the lead and inner shell.

From the results of the above mentioned studies, the analysis methods for heat transfer under normal and accident conditions with advanced heat transfer boundary conditions were successfully established with respect to the dry–type transport cask which is characterized by heat transfer within the cavity.

## CONCLUSION

The results of this study revealed the following ;

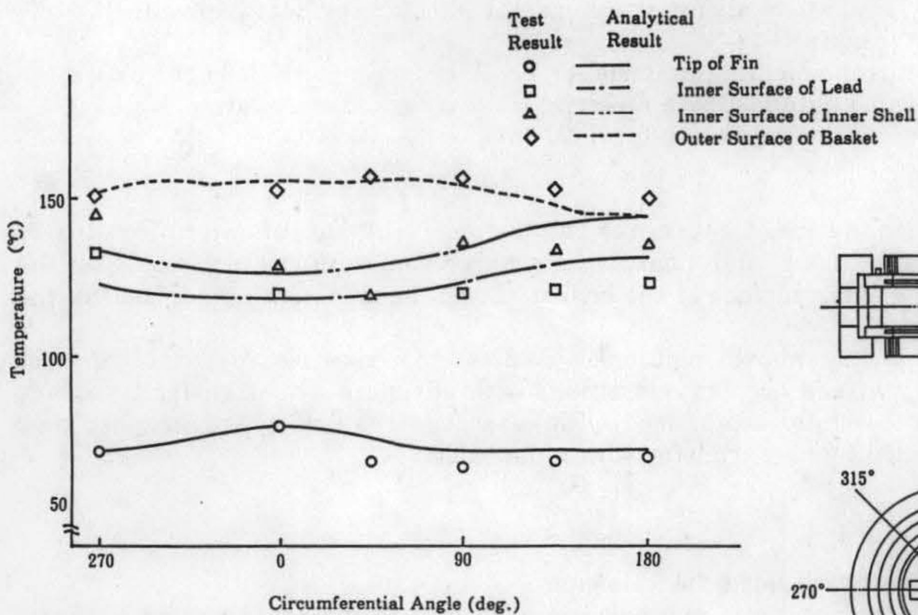
① The maximum temperatures measured in each part in the heat transfer test were lower than each allowable temparatures, and the integity of the dry cask was maintained.
As for the heat transfer charactaristics owing to the different cavity gases, the temperature of the cavity section was different.

② The maximum temperature on the lead, O-ring, and the fuel rod were lower than each allowable tempereture, and the integrity of the dry cask was maintained.

③ The analytical results, and the methods of the heat transfer analysis and fire resistance analysis were successfully established.

## REFERENCE

T. Nagakura et al., *Demonstration Test of* 100 *ton Class Fuel Transport Cask*, From the Proccedings of IAEA International Symposium on the PATRAM '86(1986)



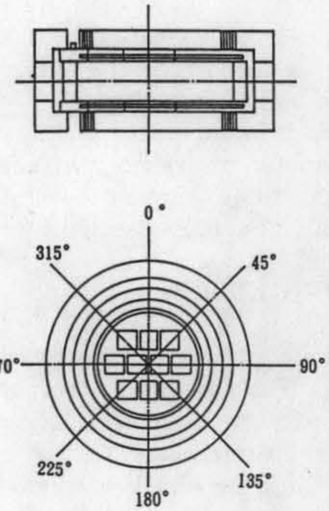
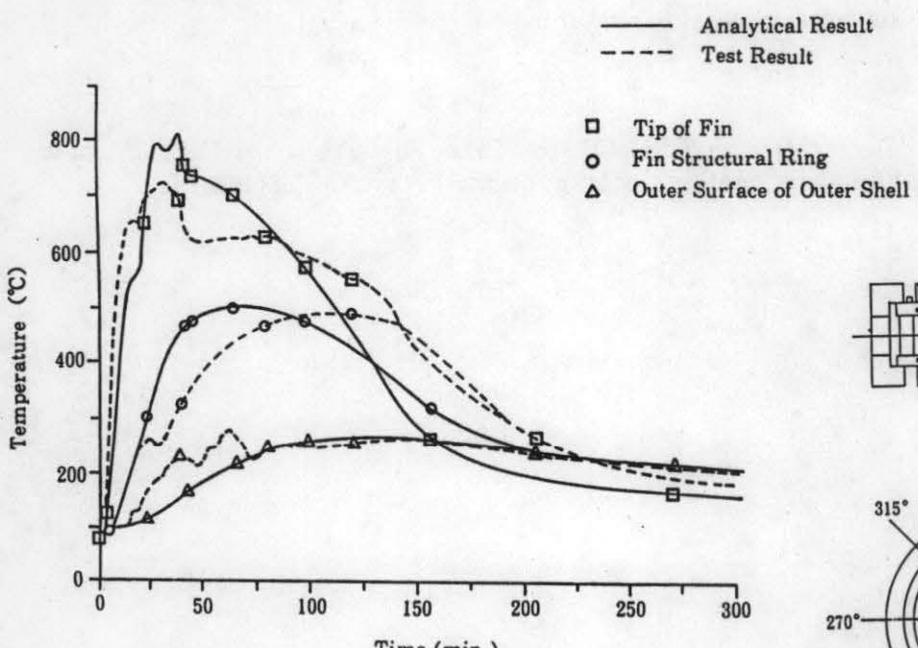




Fig. 4 Result of Heat Transfer Analysis on Dry-Type Transport Cask (Normal Conditions of Transport)



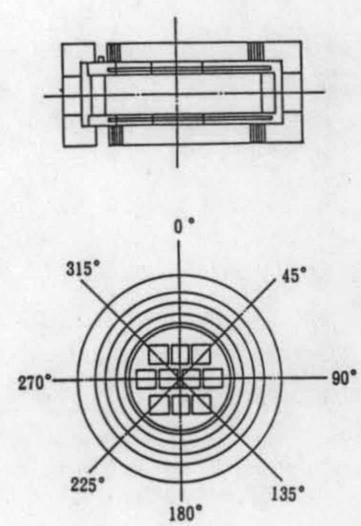




Fig. 5 Results of Fire Resistance Analysis on Dry-Type Transport Cask (0° Direction) (Accident Conditions of Transport)

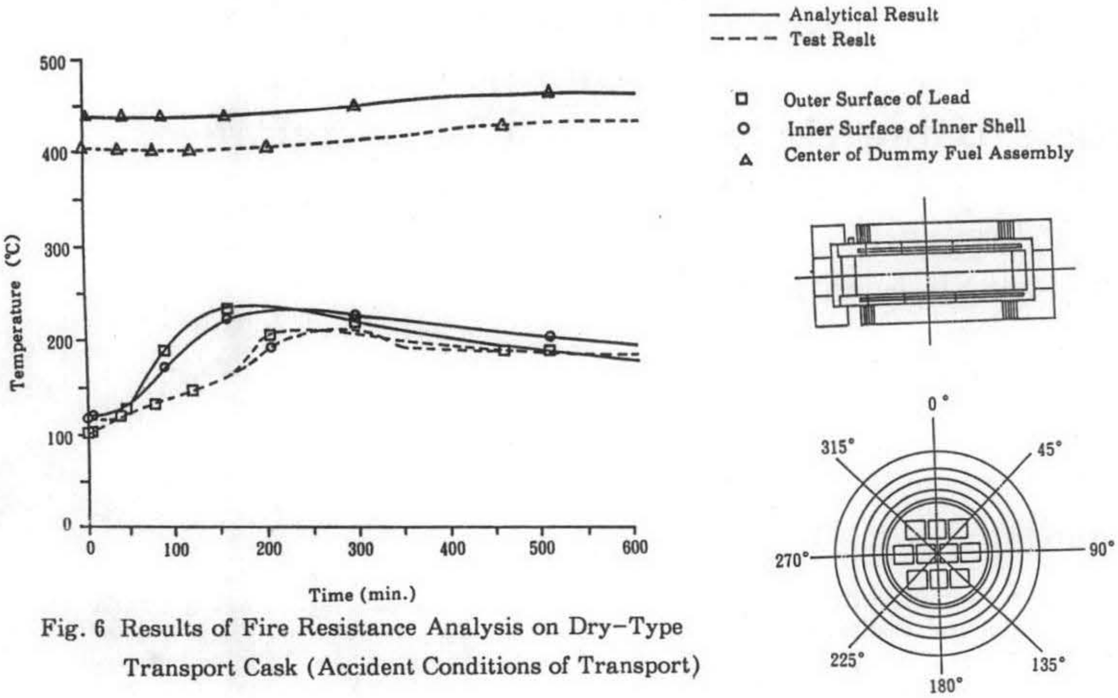



Fig. 6 Results of Fire Resistance Analysis on Dry-Type Transport Cask (Accident Conditions of Transport)