Thermal Shielding Effects of a Damaged Shock Absorber and an Intact Shock Absorber

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1. Introduction

In order to safely transport the radioactive waste arising from the hot test of an ACP(Advanced Spent Fuel Conditioning Process) a shipping package is required. Therefore, KAERI is developing a shipping package to transport the radioactive waste arising from the ACPF during a hot test.

The regulatory requirements for a Type B package are specified in the Korea MOST Act 2009-37, IAEA Safety Standard Series No. TS-R-1, and US 10 CFR Part[1~3]. These regulatory guidelines classify the hot cell cask as a Type B package, and state that the Type B package for transporting radioactive materials should be able to withstand a test sequence consisting of a 9 m drop onto an unyielding surface, a 1 m drop onto a puncture bar, and a 30 minute fully engulfing fire. Greiner et al. investigated the thermal protection provided by shock absorbers by using the CAFE computer code[4].

To evaluate the thermal shielding effect of the shock absorber, the thermal test was performed by using a 1/2 scale model with a shock absorber which was damaged by both a 9 m drop test and a 1 m puncture test. For the purpose of comparison, the thermal test was also carried out by using a 1/2 scale model with the intact shock absorber.

2. Thermal Tests

2.1 Description of the Hot Cell Cask

The hot cell cask is used to transport the radioactive waste arising out of the ACPF during a hot test.

The hot cell cask, shown in figure 1, consists of an outer shell, an intermediate shell, an inner shell, a neutron shield, a gamma shield, and a shock absorber.

The outer shell, intermediate shell, and inner shell are made of stainless steel. The inner cavity between the outer shell and intermediate shell is filled with resin, which acts as a neutron shield. The inner cavity between the intermediate shell and inner shell is filled with lead, which acts as a gamma shield. The shock absorber is made of carbon steel and the inner space is filled with balsa wood.

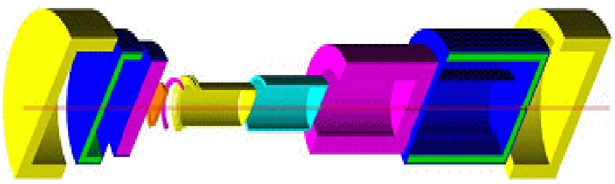

Figure 1. Configuration of the hot cell cask.

2.2 Thermal Tests

As shown in figure 2, the thermal tests were carried out in a furnace with chamber dimensions of 300 cm(W) x 400 cm(L) x 200 cm(H).

The temperature data acquisition system used in the thermal test consists of a thermo-couple scanner, a signal conditioner, an A/D converter, and a PC.

The thermal tests were carried out for two cases. In the first case, a 1/2 scale model with a shock absorber which was damaged by both a 9 m drop test and a 1 m puncture test was used. In the second case, a 1/2 scale model with an intact shock absorber was used.

The test model was installed with 16 thermocouples. These thermocouples were located on the surface, K-resin, inner-shell, intermediate-shell and O-ring.

Figure 2. Test models installed in the furnace.

The required duration for the test was determined by comparing the scale model heat input to the full-scale cask regulatory specific heat input. The specific heat input for the full-scale cask can be calculated by:

$$Q_P = \left(\pi DL + 2 \times \frac{\pi D^2}{4}\right) \sigma F \frac{T_R^4}{M_P} \tau_R$$

where, Q_P is the full-scale specific heat input, D is the full-scale package diameter, L is the full-scale package length , σ is the Stefan-Boltzmann constant, F is the view factor for a fully engulfing fire, T_F is the fire temperature , M_P is the mass of the full-scale package, and τ_R is the regulatory fire duration.

Therefore, the fire duration for the scale model was calculated as 938 seconds based on the following equation:

$$\tau_T = \frac{Q_p M_M}{\left(\pi D_M L_M + 2 \times \frac{\pi D_M^2}{4}\right) \sigma F T_F^4}$$

where, D_M is the scale model diameter, L_M is the test model length, T_F is the furnace temperature, M_M is the test model mass, and F is the view factor for a package in a furnace.

2.3 Test Results and Discussion

The most important concerns for the thermal test are the seal temperature, and the peak temperature of the canister component.

Figure 3 shows the flame temperature during the thermal test. The average flame temperature measured in the thermal test was 813 °C in the first case and 811 °C in the second case. Therefore, the thermal condition, which is prescribed in the regulatory guide-lines, was satisfied.

The temperature data for the thermal tests are shown in table 1. The temperature profile in the thermal test is shown in figure 4.

The maximum surface temperature of the hot-cell cask was measured at 682 °C in the first case and 655 °C in the second case. The maximum temperature of the K-resin was measured at 438 °C in the middle position and 479 °C in the top position, respectively. The maximum temperature of the intermediate-shell was measured at 112 °C after 52 minutes. Therefore the maximum temperature of the lead which acts as a radiation shield can be predicted to be below a melting temperature that would be of concern.

Figure 5 shows the temperature history at the O-ring during the fire test and cool-down periods. In the first case, the maximum temperatures of the seal in the upper part and middle part, as measured by the thermocouples installed in the lid to the depth of the seal, were measured as 273 °C and 251 °C, respectively. These temperatures are higher than the manufacture's recommended maximum temperature[5]. It is because the shock absorber, which was broken in the drop test, was burned.

In the second case, the maximum temperatures of the seal in the upper part and middle part were measured as 249 °C and 206 °C, respectively.

Table 1. Thermal Test Results

Location \ Temp.(°C)		Damaged Absorber	Intact Absorber
Surface	Top	682	-
	Mid	602	-
	Bot	-	655
K-Rsin	Top	346	479
	Mid	438	419
	Bot	426	305
Intermediate-shell	Top	112	101
	Mid	101	118
	Bot	105	134
O-ring	Top	273	249
	Mid	251	206

3. Conclusion

The thermal test was carried out to evaluate the thermal shielding effects of the shock absorber.

The main results were as follows:

i) The maximum temperature of the seal in the upper part was measured at 273 °C which is higher than the manufacture's recommended maximum temperature. It is because the shock absorber which was broken in the drop test was burned.

ii) The maximum temperature of the seal in the upper part was measured at 249 °C which is lower than the manufacture's recommended maximum temperature.

iii) Therefore, in order to maintain the containment boundary of the hot-cell cask, it is important that the manufacture of the shock absorber prevents breakage.

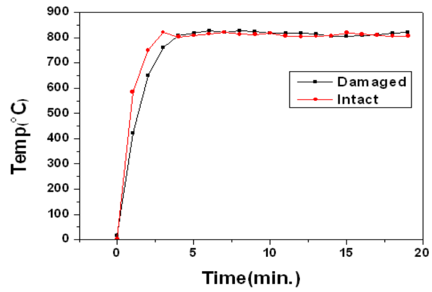

Figure 3. Average flame temperature.

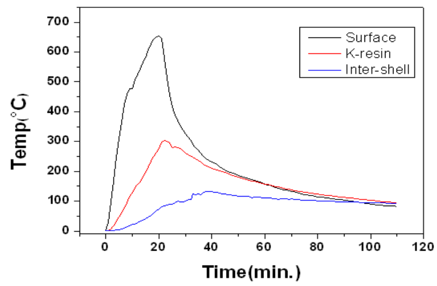

Figure 4. Temperature history in the 2nd thermal test.

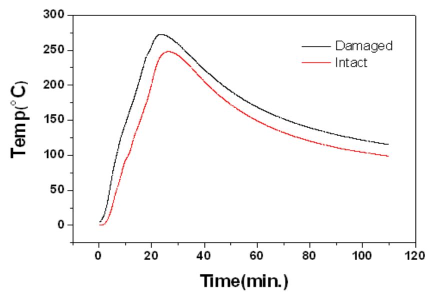

Figure 5. Temperature history at O-ring.

REFERENCES

[1] KOREA MOST Act. 2009-37, "Regulations for the Safe Transport of Radioactive Material", 2009.
[2] IAEA Safety standard Series No. TS-R-1, "Regulations for Packaging and Transportation of Radioactive Material", 2009.
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[4] Greiner et al., "Thermal Protection Provide by Impact Limiters to a Containment Seal within a Truck Package," ASME J. Pressure Vessel Technology, Vol. 130, 011209-1~7, 2008.
[5] www.parker.com/portal/site/parker