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THERMAL SHIELDING OF THE WOOD SHOCK ABSORBER

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ABSTRACT

Regulatory requirements for a Type B package are specified in the Korea MEST Act 2009-37, IAEA Safety Standard Series No. TS-R-1, and US 10 CFR Part 71. These regulatory guidelines require that a 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 period of 30 minutes under a thermal condition of 800 °C. This paper discusses the experimental approach used to simulate the response of a hot cell cask to a furnace fire using a 1/2 scale model that was pre-damaged by both a 9 m drop test and 1 m puncture test.

INTRODUCTION

In order to safely transport the radioactive waste arising from a hot test of ACP (Advanced Spent Fuel Conditioning Process), a shipping package is required. Therefore, KAERI is developing a shipping package to transport the radioactive waste arising in an ACPF during a hot test. Regulatory requirements for a Type B package are specified in Korea MEST Act 2009-37, IAEA Safety Standard Series No. TS-R-1, and US 10 CFR Part 71[1~3]. These regulatory guidelines classify the hot cell cask as a Type B package, and state that a 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 period of 30 minutes under a thermal condition of 800 °C. In particular, the containment of the package must be maintained at the conclusion of this sequence. The fire duration of concern for a containment seal or lead shield is the minimum amount of time that causes that component to reach its temperature of concern [4~5]. This duration depends on the damage to the package before the fire, the fire size and location, and the wind conditions.

Greiner et al. investigated the thermal protection provided by shock absorbers to a containment seal using the CAFE (Container Analysis Fire Environment) computer code[6]. In that study, Greiner explained that a no-shock absorber package protects the seal from fire for 0.7 h, while the intact package protects the seal in fires of roughly 2 h in duration.

This paper discusses the experimental approach used to simulate the response of a hot cell cask to a furnace fire with chamber dimensions of 300 cm (W) x 400 cm (L) x 200 cm (H) using a 1/2 scale model that is pre-damaged by both a 9 m drop test and 1 m puncture test.

THERMAL TEST

Description of a Hot Cell Cask

A hot cell cask is used to transport radioactive waste arising in an 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 diameter of the hot cell cask is 800 ㎜ and its overall height is 1140 ㎜. It weighs approximately 4.4 tons.

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.

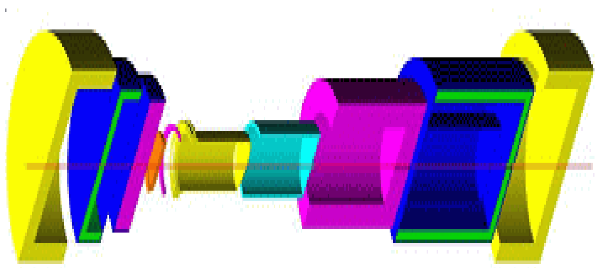

Fig. 1. Configuration of a hot cell cask.

Measurement System

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 signal, which is detected in the thermocouple scanner, is filtered and amplified through the signal conditioner, and converts an analog signal to a digital signal through the A/D converter. This signal is stored and analyzed via the software installed in the PC.

Thermal Test

Before the thermal test, the test model was damaged by both a 9 m drop test (Fig. 2~3) and 1 m puncture test (Fig. 4~5). Prior to the thermal test, the accelerometers and strain gages installed in the test model were removed, and the upper shock absorber was removed. Then, as shown in figure 6, 16 thermocouples were installed in the test model. These thermocouples were located on the surface, and in the K-resin, inner-shell, intermediate-shell, and O-ring. After installation of the thermocouples, the upper shock absorber was re-installed.

As shown in figure 7, the thermal test was carried out in a furnace of Fire Insurers Laboratories of Korea (FILK).

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 as follows:

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

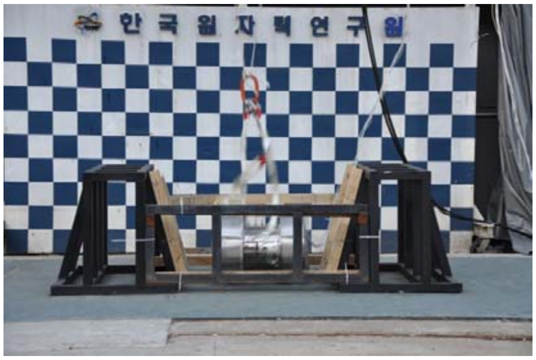

Fig. 2. Horizontal drop impact instance.

Fig. 3. Deformed shape of shock absorber.

Fig. 4. Side Puncture impact instance.

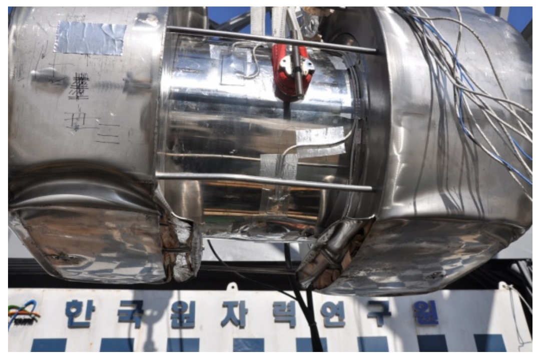

Fig. 5. Deformation of outer shell.

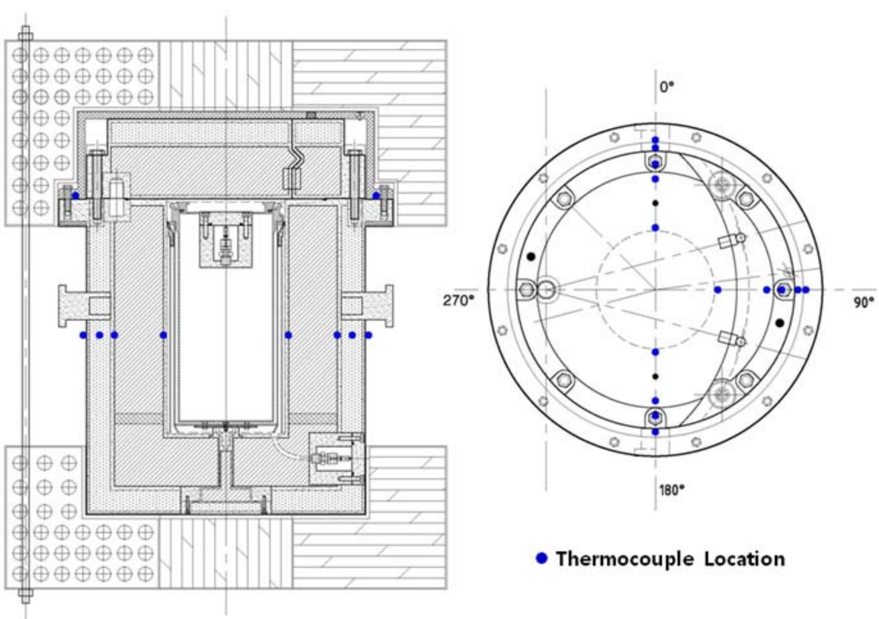

Fig. 6. Cross section of the thermal test model.

Fig. 7. Test model installed in the furnace.

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.

TEST RESULTS AND DISCUSSION

The most important items of concern for a thermal test are the seal temperature and peak temperature of the canister component.

Figure 8 shows the flame temperature during the thermal test. The average flame temperature measured in the thermal test was 813 °C. Therefore, the thermal condition, which is prescribed in the regulatory guidelines, was satisfied.

The temperature profile in the thermal test is shown in figure 9. The temperature data for the thermal tests are shown in table 1.

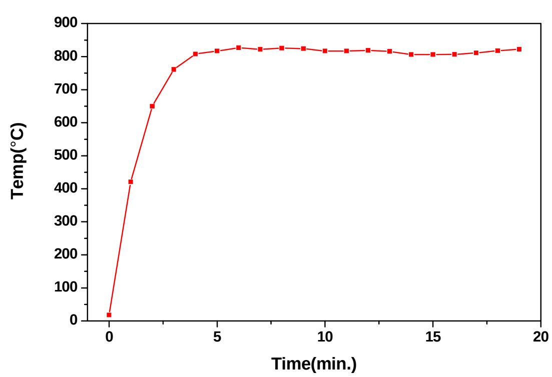

Fig. **8**. Average flame temperature.

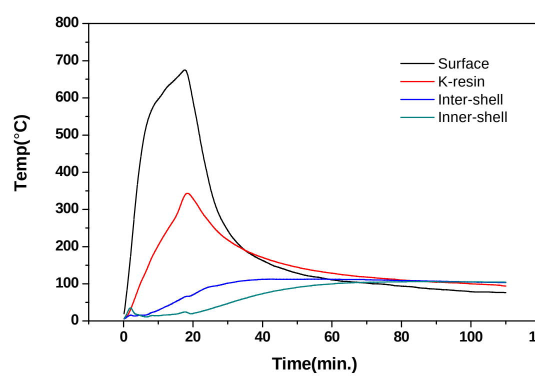

Fig. 9. Temperature history during a thermal test.

Table 1 Thermal test results

Location		Temp.(℃)	Time(hr)
Surface	Upper (0°)	682	0.3
	Mid. (90°)	602	0.3
	Lower(180°)	-	-
K-Resin	Upper (0°)	346	0.3
	Mid. (90°)	438	0.28
	Lower(180°)	426	0.33
Intermediate-shell	Upper (0°)	112	0.87
	Mid. (90°)	101	1.41
	Lower(180°)	105	0.97
Inter-shell	Upper (0°)	106	1.40
	Mid. (90°)	103	1.43
	Lower(180°)	102	1.45
O-ring	Upper (0°)	273	0.38
	Mid. (90°)	251	0.37

The maximum surface temperature of the hot cell cask was measured as 682 °C. The maximum temperature of the K-resin was measured as 438 °C after 17 minutes. The maximum temperature of the intermediate-shell was measured as 112 °C after 52 minutes.

Figure 10 shows the temperature history in the O-ring during the fire test and cool-down periods. The maximum temperatures of the containment seal in the upper and middle parts, measured using the thermocouples installed in the lid to the depth of the seal, were measured as 273 °C and 251 °C, respectively. The temperature of the containment seal in the upper part was higher than that in the lower part, because the combustion was initiated from the broken upper part of the shock absorber. These temperatures are higher than the manufacturer's recommended maximum temperature [7]. This is because the shock absorber, which was broken in the drop test, was burned. Therefore, in order to maintain the containment boundary of the hot cell cask, it is important that the manufacturing of the shock absorber prevents breakage.

To ensure thermal integrity, KAERI is currently improving the thermal problem of the hot cell cask.

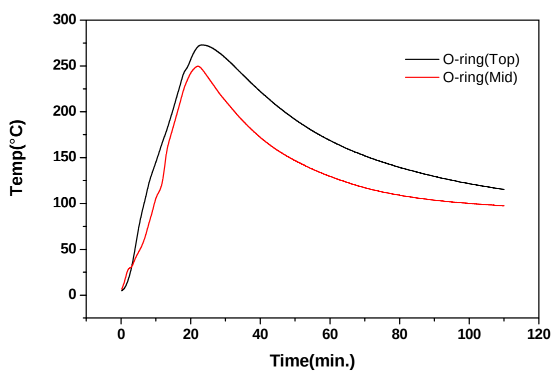

Fig. 10. Temperature history at O-ring.

CONCLUSIONS

A thermal test was carried out to evaluate the thermal integrity of a hot cell cask. The main results are as follows:

(i) The maximum temperature of the containment seal in the upper part was measured as 273 °C, which is higher than the manufacturer's recommended maximum temperature. This is because the shock absorber, which was broken in the drop test, was burned. Therefore, in order to maintain the containment boundary of the hot cell cask, it is important that the manufacturing of the shock absorber prevents breakage.

ACKNOWLEDGMENTS

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