Thermal Shielding of the Shock Absorber to a Seal of a Hot-cell Cask

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1. Introduction

In order to safely transport the radioactive waste arising from the 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 the ACPF during a hot test.

Regulatory requirements for a Type B package are specified in the Korea MOST Act 2008-69, 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. performed a research on the thermal protection provided by shock absorbers by using CAFE computer code[4].

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

2. Thermal Tests

2.1 Description of the Hot Cell Cask

The hot cell cask is to transport the radioactive waste arising in 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 is 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.

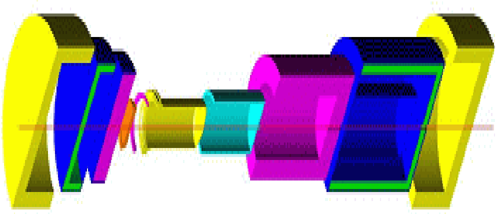

Figure 1. Configuration of the hot cell cask.

2.2 Measurement System

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

The signal, which is detected in the thermocouple scanner, is filtered and amplified through the signal conditioner, and converts the analog signal to the digital signal through the A/D converter. This signal is stored and analyzed by means of the software that is installed in the P/C.

2.3 Thermal Tests

As shown in figure 2, the thermal test was carried out in a furnace of Fire Insurers Laboratories of Korea (FILK).

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 model 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 from the below 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. Therefore, the thermal condition, which is prescribed in the regulatory guidelines, was satisfied.

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

The maximum surface temperature of the hot-cell cask was measured at 682 °C. The maximum temperature of the K-resin was measured at 438 °C after 17 minutes. 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 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. 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. 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.

3. Conclusion

The thermal test was carried out to evaluate the thermal integrity of the hot-cell cask.

The main results were as follows:

i) The maximum temperature of the intermediate-shell was measured at 112 °C. Therefore the maximum temperature of the lead which acts as a radiation shield can be predicted to be below melting temperature that would be of concern. Accordingly, the integrity of the lead shield is estimated to be maintained.

ii) 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. 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.

Table 1. Thermal Test Results

Location		Temp.(℃)	Time(hr)
Surface	Top	682	0.3
	Mid	602	0.3
K-Rsin	Top	346	0.3
	Mid	438	0.28
Intermediate-shell	Top	112	0.87
	Mid	101	1.41
Inter-shell	Top	106	1.40
	Mid	103	1.43
O-ring	Top	273	0.38
	Mid	251	0.37

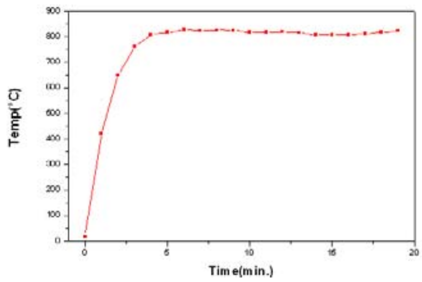

Figure 3. Average flame temperature.

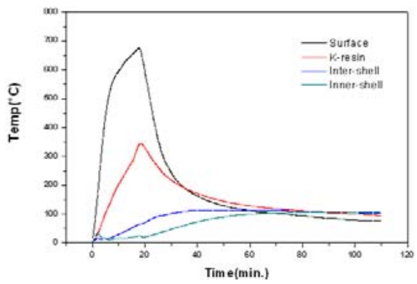

Figure 4. Temperature history in the thermal test.

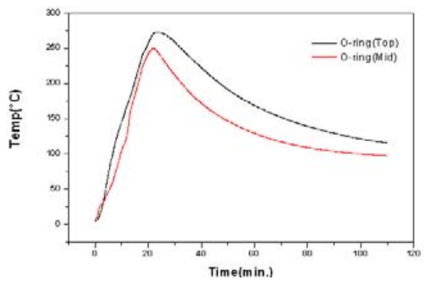

Figure 5. Temperature history at O-ring.

REFERENCES

[1] KOREA MOST Act. 2008-69, "Regulations for the Safe Transport of Radioactive Material", 2008.
[2] IAEA Safety standard Series No. TS-R-1, "Regulations for Packaging and Transportation of Radioactive Material", 2005.
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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