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Fire Test using a 1/3 Slice Model of the KORAD-B/II Shipping Package

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1. Introduction

To safely transport the radioactive waste arising from nuclear power plant, a shipping package is required. Therefore, Korea Radioactive Waste Agency (KORAD) is developing a KORAD-B/II shipping package to transport the high-level radioactive waste arising in the nuclear power plant. The regulatory requirements for a shipping package are prescribed that a Type B package must be able to withstand a temperature of 800 °C for a period of 30 min. Therefore, a fire test was conducted using a one-three in the length of the KORAD-B/II shipping package in a furnace with chamber dimensions of 3 m (W) × 4 m (L) × 2 m (H).

The KORAD-B/II shipping package was designed as a shipping cask to transport C4 concrete package which is temporarily stored at the HANUL nuclear power plant. Its outer diameter is 1,592 mm and its overall height is 1,570 mm. It weighs approximately 14.6 t. It consists of a thick-walled cylindrical cask body, a lid, adaptor to hold the C4 concrete package, and impact limiters (Fig. 1). The cask body is made of carbon steel with cladding. The lid is made of stainless steel and is fixed to the cask body using stud bolts and cap nuts. The shock absorber is made of stainless steel and the inner space is filled with spruce wood.

This paper discusses the experimental approach used to estimate the thermal integrity of the KORAD-B/II shipping package at a temperature of 800 °C for a period of 30 min.

2. Fire Test

To maintain the thermal integrity of the KORAD-B/II shipping package, its components must compliance with permitted temperature limits.

The object of the fire test is to estimate whether the highest temperature of the components comprising the KORAD-B/II shipping package exceeds the allowable value or not, when the canister is exposed in 800 ºC flame for 30 minutes.

Fire tests were carried out for two times. In the first fire test, the surface temperature of the cask body exceeded the allowable value. The second fire test, therefore, was performed.

2.1 Description of the Test Model

The test model is a one-three in the length of a real KORAD-B/II shipping package where the thermal conditions could potentially be the most severe. The test model had an outer diameter of 1,592 mm and an axial length of 600 mm. To minimize heat loss in the axial direction, both ends of the test model were covered with an insulator. The test model contained 18 thermocouples. These thermocouples were located on the surface and inside of cask body.

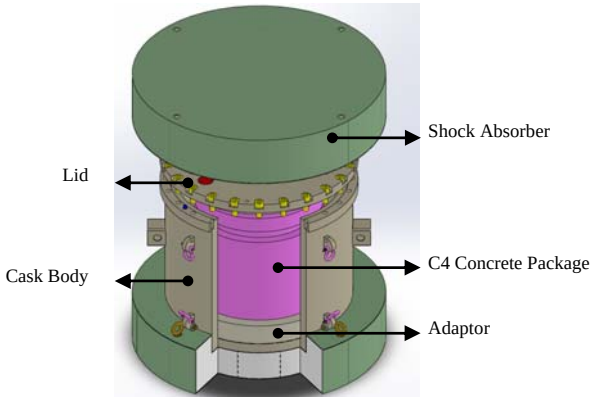

Fig. 1. Configuration of KORAD-B/II Shipping Package

2.2 Fire Test

The fire tests were carried out in a furnace with dimensions of 3.5 m(W) × 4.0 m(L) × 3.0 m(H). The fire tests were performed as follows:

- The test model was installed in the center of the furnace.
- Twelve thermocouples were installed to measure the flame temperature inside the furnace.
- The furnace was heated at 800 ºC.
- The test model was allowed to stand for a period of at least 30 minutes under a thermal environment with an average temperature of at least 800 ºC.
- Upon completion of the thermal test, the test model was allowed to naturally cool down.

2.3 Test Results and Discussion

Figure 2 shows the change in the average flame temperature during the fire tests. In the first fire test, the average flame temperature during the fire test was 810 °C. Therefore, the thermal conditions prescribed in the regulatory guidelines were satisfied.

The most important item of concern for the fire test is the temperature of the cask body which is made of carbon steel. The maximum surface temperature of the cask body was 567 °C after 39 min in the lower part of

the 0° direction. The maximum inner-surface temperature of the cask body was 469 °C after 44 min in the lower part of the 0° direction.

The allowable temperature in the short term exposure, that the structure strength of the carbon steel is not changed, is prescribed as 538 ºC [1]. The maximum surface temperature of the cask body in the lower part is higher than the permitted maximum temperature limits. Therefore, the thermal integrity of the KORAD-B/II shipping package cannot be maintained.

The figure 3 shows the soot on the surface of the test model after the fire test. We don't know what the cause is. However, this is considered due to incomplete combustion in the 0° direction of the test model.

If the soot is accumulated on the surface of the cask body in fire test, the surface temperature of the cask body could be lowered because the thermal conductivity of the soot is low. If the soot is thin, soot surface became black-body, then a radiation heat transfer is increased. Therefore, the surface temperature could be increased.

In the second fire test, the average flame temperature during the fire test was 816 °C. Therefore, the thermal conditions prescribed in the regulatory guidelines were satisfied, as well.

The maximum surface temperature of the cask body was 441 °C after 40 min in the middle part of the 180° direction. In the 90° direction, the maximum surface temperature of the cask body was 440 °C in the lower part. In the 0° direction, the maximum surface temperature of the cask body was 408 °C in the middle part. The soot was not formed on the surface of the cask body in 2nd fire test

The maximum inner-surface temperature of the cask body was 391 °C after 49 min in the middle part of the 180° direction. In the 0° direction and 90° direction, the maximum inner-surface temperature of the cask body 363 °C after 48 min in the middle part, 372 °C after 48 min in the upper part.

The maximum temperature of the cask body was lower than the permitted maximum temperature limits. Therefore, the thermal integrity of the KORAD-B/II shipping package could be estimated to maintain.

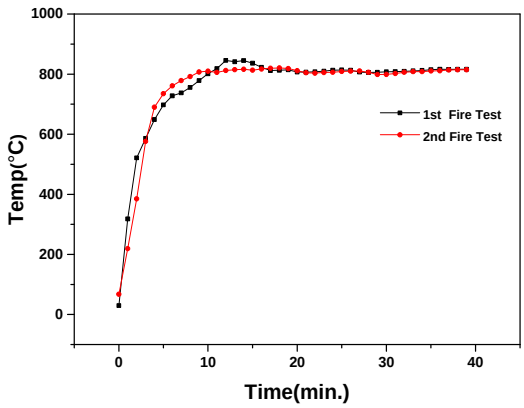

Fig. 2. Average flame temperature

Fig. 3. Test model of the 0° direction after the 1st fire test

Table 1. Thermal test results

		Surface		Inner-surface	
		1st	2nd	1st	2nd
0°	Upper	472	386	414	349
	Middle	538	408	458	363
	Lower	567	394	469	353
90°	Upper	354	413	304	372
	Middle	347	409	310	353
	Lower	-	440	325	326
180°	Upper	297	421	282	382
	Middle	333	441	297	391
	Lower	375	430	324	385

3. Conclusion

The fire tests were conducted to estimate the thermal integrity of the KORAD-B/II shipping package at a temperature of 800 °C for a period of 30 min. The main results are described below.

Firstly, the maximum surface temperature of the cask body is lower than the permitted maximum temperature limits. Therefore, the thermal integrity of the KORAD-B/II shipping package could be estimated to maintain.

Secondly, if soot is tenuously formed on the surface due to incomplete combustion, soot surface becomes the black-body, and then a radiation heat transfer is increased. Therefore, the surface temperature could be increased..

REFERENCES

[1] ASME Code Case N-47-33, Class 1 Components in Elevated Temperature Service, American Society of Mechanical Engineers(ASME) Boiler and Pressure Vessel Code, 1995 Code Case, Nuclear Components, 1995 Edition.