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Fire Test of Fresh Fuel Transport Cask for the Gijang Research Reactor

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1. Introduction

Designed to safely transport fresh fuel, a fissile material needed for the operation of the Gijang Research Reactor(GRR), from the Korea Atomic Energy Research Institute (KAERI) to the GRR, the fresh fuel transport cask consists of an over-pack, a canister, and an internal structure. The canister and internal structure were made of stainless steel. The over-pack was made of stainless steel and the inner space was filled with balsa wood.

According to domestic and international regulations on transport packages (Korea Nuclear Safety Security Commission Act 2021-2, 2014[1]; IAEA Safety Standard Series No. SSR-6, 2018[2]; US 10 CFR Part 71, 2005[3]), the fresh fuel transport cask is classified as Type IP-2(F) shipping package. These regulatory guidelines require that a Type IP-2(F) shipping 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. Therefore, a fire test using a test model that is pre-damaged by a 1.2-meter drop test, a 9-meter drop test, and a 1-meter puncture test was conducted in the presence of approval authority to evaluate whether the fresh fuel transport cask for the GRR maintains its integrity under 800 ℃ fire conditions.

2. Fire Test

2.1 Description of the Test Model

The test model used for the fire test was a prototype model of the fresh fuel transport cask for the GRR that was subjected to a 1.2-meter drop test, a 9-meter drop test, and a 1-meter puncture test.

To measure the temperature of the test model, 9 thermocouples, three each on the top, center, and bottom of the outer surface of the model body, two to measure the temperature of the model lid surface, and 9 thermocouples, three each on the top, center, and bottom of the inner surface of the canister, were attached.

2.2 Fire Test

The fire test was carried out in a furnace with dimensions of 3.5 m(W) × 4.0 m(L) × 3.0 m(H). For the fire test, the top lid of the furnace was opened and the test model was placed in the centre of the furnace using a crane, as shown in Figure 1. A total of 12 thermocouples were installed to measure the flame temperature inside the furnace during the fire test.

Prior to the fire test, the test model was exposed to a calm, stationary, ambient temperature of approximately 26 °C with no solar heat flux. The test model was then placed in a flame of over 800 °C for at least 30 minutes and allowed to cool naturally.

Fig. 1. Photo graph of the test model in the furnace

2.3 Results and Discussion

During the fire test, the average flame temperature for 30 minutes was 816 °C. The time it took for the average flame temperature inside the furnace to reach 800 °C in the fire test was approximately 6 minutes, and the fire test was conducted for 30 minutes at an average flame temperature of 800 °C or higher. The actual heat received by the test model in the fire test was much more heat. Therefore, the thermal conditions prescribed in the regulatory guidelines were satisfied.

Table 1 shows the maximum temperature of the test model measured after the fire test, and Figure 2 shows the temperature history of the canister over time. In the fire test, the maximum temperature of the outer surface of the body was 809 °C after approximately 23 minutes from the start of the fire test, and the maximum temperature of the lid was 887 °C after approximately 27 minutes.

Table 1. Fire test results

Location			Temp(°C)	Time(hr)
Canister Inner-surface	45°	S-1	257	23.28
		S-2	200	22.08
		S-3	185	23.47
	135°	S-4	292	5.52
		S-5	247	5.48
		S-6	330	6.12
	225°	S-7	234	9.6
		S-8	241	18.15
		S-9	257	18.7

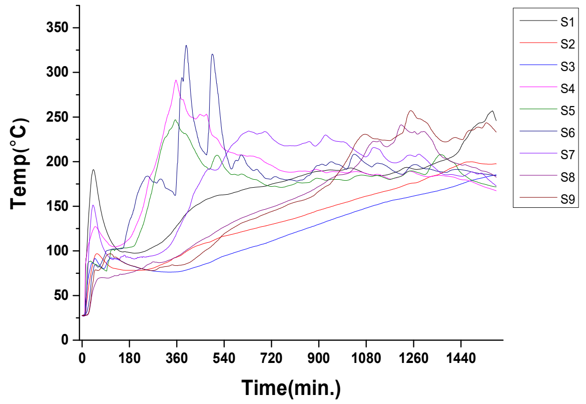

Fig. 2. Temperature history in the fire test

The maximum temperature of the inner surface of the canister was 330 °C at the bottom of the 135° orientation after about 6 hours, the maximum temperature at the 45° orientation was 257 °C at the top, and the maximum temperature at the 225° orientation was 257 °C at the bottom.

The allowable temperature in the short term exposure, that the structure strength of the stainless steel is not changed, is prescribed as 538 ºC (ASME Code Case N-47-33). 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 fresh fuel transport cask for the GRR can be maintained.

Under accident transport conditions, the allowable temperature of the fresh fuel for the GRR is 570 °C. The temperature of the fresh fuel loaded in the basket located inside the canister will be below 330 °C, which is the maximum temperature measured on the canister's inner surface. Therefore, the thermal integrity of the fresh fuel for the GRR can be maintained.

Figure 3 shows the test model at the end of the fire test. The test model shows that the balsa-wood exposed at the broken welds continues to burn even after the end of the fire test. This is because the shock absorber, which was broken open in a horizontal drop of 9 meters, was burned. As can be seen in table 1 and Figure 2, the surface temperature of the canister continued to rise for about 24 hours after the end of the fire test. Therefore, we can know that the balsa wood continued to burn for about 24 hours after the fire test ended.


Fig. 3. Test model after the fire test

The thermal integrity for a transport cask can also be evaluated by performing a thermal analysis. However, it is not easy to simulate the combustion effect of the balsa wood in the thermal analysis. Therefore, if the material like the wood and resin is used as the components of the transport cask, it is desirable that the thermal integrity of the transport cask is evaluated by the thermal test.

As a result, it is expected that the fresh fuel transport cask for the GRR and the fresh fuel will maintain their thermal integrity under fire conditions of exposure to flames above 800 °C for a minimum of 30 minutes.

3. Conclusion

The fire test was conducted to estimate the thermal integrity of the fresh fuel transport cask for the GRR at a temperature of 800 °C for a period of 30 min. The main results are described below.

1) The maximum temperature of the canister surface was lower than the permitted maximum temperature limits of 537 °C. Therefore, the thermal integrity of the fresh fuel shipping package could be estimated to maintain.
2) The maximum temperature of the fresh fuel was predicted to be lower than the permitted maximum temperature limits of 570 °C. Therefore, the thermal integrity of the fresh fuel could be estimated to maintain under 800 ℃ fire conditions.
3) It is not easy to simulate the combustion effect of the balsa wood in the thermal analysis. Therefore, if the material like the wood and resin is used as the components of the transport cask, it is desirable that the thermal integrity of the transport cask is evaluated by the thermal test.

ACKNOWLEDGMENTS

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