Thermal Test of KORAD-21 Cask

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1. Introduction

A KORAD-21 cask containing 21 spent fuel assemblies is under development by the KOrea RADioactive waste agency (KORAD) in Korea.

Since the KORAD-21 cask is used for not only storage but also transport of the spent fuel assemblies, it should satisfy the requirements that are prescribed in the Korea NSSC Act 2017-56, IAEA Safety Standard Series No. TS-R-1 and US 10 CFR Part 71 [1~3]. These regulatory guidelines classify the KORAD-21 cask as a Type B package, and state that a Type B package for transportation of radioactive materials should be able to withstand a period of 30 minutes under a thermal condition of 800°C. Accordingly, a thermal test using a 1/6 sliced model of a real cask have been performed to estimate the thermal integrity of the KORAD-21 cask under a thermal condition of 800°C.

2. Thermal Test

2.1 Description of the KORAD-21Cask

The KORAD-21 cask was designed as a shipping cask to accommodate 21 pressurized water reactor (PWR) spent fuel assemblies with a burn-up of 45,000 MWD/MTU and a cooling time of 10 years. The decay heat from the 21 PWR spent fuel assemblies is 16.8 kW. Its outer diameter is 2,126 mm and its overall height is 5,285 mm. It weighs approximately 125 t. It consists of a thick-walled cylindrical cask body, a neutron shielding, a dry shielded canister (DSC), a lid, baskets to hold the spent nuclear fuel, and impact limiters (Fig. 1). The cask body is made of carbon steel. The outer-shell is made of stainless steel. The baskets containing the spent fuel assemblies are made of stainless steel. The inner cavity between the outer-shell and the cask body is filled with NS-4-FR, which acts as a neutron shielding. NS-4-FR has a low thermal conductivity. Therefore, heat transfer fins are embedded to enhance heat transfer from the cask body to the outer-shell.

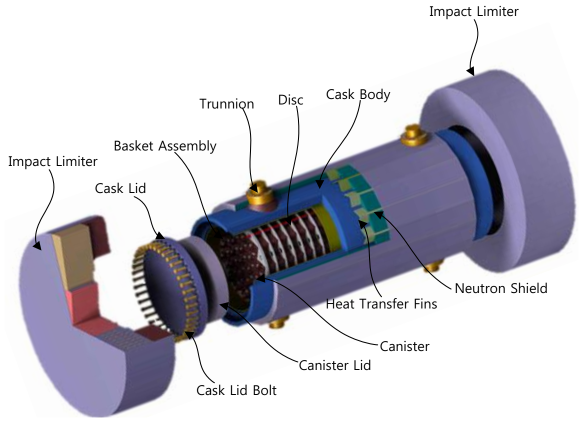

Fig. 1. Configuration of KORAD-21 Cask.

2.2 Open Pool Fire Test

As shown in Fig. 2, the thermal test was carried out in a fire test facility with the dimensions of 3.5 m x 4.0 m x 3.0 m.

The thermal test was performed as follows:

- The supporter to set the test model within the fire test facility was installed.
- The test model was set onto the supporter.
- 21 thermocouples for measuring the flame temperature inside the fire test facility were installed.
- The water was filled with a height of 5 cm in the pit, and the kerosene was filled with a height of 10 cm from the surface of the water.
- The test model was allowed to stand for a period of at least 30 minutes under a fully engulfed thermal environment with an average flame temperature of at least 800°C.

Fig. 2. Test model in the fire test facility.

2.3 Test Results and Discussion

In the fire test, the environmental temperature in the fire test facility was maintained at approximately 25°C before the ignition of the fire. The fire was applied for approximately 35 minutes. Fig. 3 shows a photograph of the test model fully engulfed in flames. Fig. 4 shows the change in the flame temperature during the fire test. The average flame temperature during the fire test was 438°C in the growth period, 851°C in the steady-state period, and 462°C in the decay period. Therefore, the thermal conditions prescribed in the regulatory guidelines were satisfied.

The maximum temperatures measured in the test model during the fire test are listed in Table 1. The maximum surface temperature was 957°C after 24 min in the middle part. The surface temperature was very high because the flame temperature was at the maximum of 1000°C during this time, and the conductive heat transfer coefficient of the neutron shielding was not good, leading to the accumulation of thermal energy at the model surface. However, the temperature of the surface where the heat transfer fin was installed was 624°C. From these results, we can determine that the surface temperatures were lower in the presence of the heat transfer fins because the high heat generated by the flame was transferred to the body of the test model through the heat transfer fin.

The maximum temperature of the neutron shield was was measured to be 151°C after 75 min.

The initial temperature of the basket before the pool fire test was 23°C. The maximum temperature was 58°C after the fire was extinguished and when 19.8 h had passed. Accordingly, the temperature rise in the basket during the fire test was 35°C. Therefore, the temperature rise of the spent nuclear fuel rod can be anticipated to be within this range.

Fig. 3. Test model engulfed in flames.

From the results of the pool fire test, the thermal integrity of the dual purpose cask can be maintained at a temperature of 800°C for a period of 30 min.

3. Conclusion

As a part of the safety tests, the thermal test was carried out to evaluate the thermal integrity of the KORAD-21 cask. The main results were as follows:

ⅰ) The temperature rise of the basket during the fire test was 35°C. Therefore, the temperature rise of the spent nuclear fuel rod can be anticipated to be within this range. Accordingly, the integrity of a spent nuclear fuel is estimated to be maintained.

ⅱ) The surface temperature was lower when a heat transfer fin was installed because the high heat generated by the flame was transferred to the body of the test model through the heat transfer fin. The neutron shielding was therefore adequately protected by the heat transfer fin.

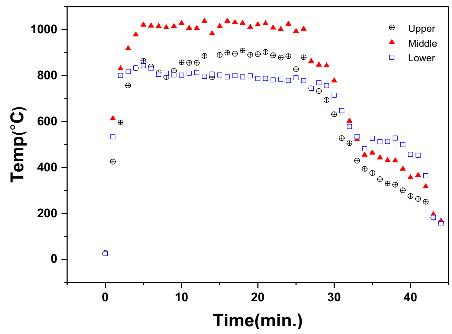

Fig. 4. Flame temperature during the thermal test.

Table 1. Summary of the thermal test results

Temp(°C) / Location	Steady State	Transient	Elapsed Time(h)
Basket	23	58	19.8
Canister Surface	24	64	10.9
Body Surface	26	141	0.3
Neutron Shield	32	151	1.25
Cask Surface	43	957	0.4
Ambient(Average)	25	851	

REFERRENCES

[1] KOREA NSSC Act. 2017-56, “Regulations for the Safe Transport of Radioactive Material”, 2017.

[2] IAEA Safety standard Series No. SSR-6, "Regulations for Packaging and Transportation of Radioactive Material”, 2012 Ed.

[3] U.S. Code of Federal Regulations, Title 10, Part 71, "Packaging and Transportation of Radioactive Material”, 2005 Ed.