Thermal Test of the KN-18 Shipping Cask

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1. Introduction

A shipping package should satisfy the requirements which are prescribed in the Korea MEST Act 2008-69, IAEA Safety Standard Series No. TS-R-1 and US 10 CFR Part 71 [1~3].

These regulatory guidelines state that a Type B package for transportation radioactive materials should be able to withstand a period of 30 minutes under a thermal condition of 800 ℃.

The KN-18 shipping cask is designed as a shipping cask for accommodating a spent fuel assembly which is discharged from PWR reactors. As a type B(U) cask fitted with impact limiters, it has to meet the transport requirements according to above applicable regulations.

Accordingly, the thermal test by using the 1/8 sliced model of the real cask have been performed to estimate the thermal integrity of the KN-18 shipping cask under a thermal condition of 800 ℃.

2. Thermal Test

2.1 Description of the KRI-BGM shipping cask

The KN-18 shipping cask is designed as a shipping cask for accommodating 18 spent fuel assemblies which are discharged from PWR reactors. The KN-18 shipping cask, shown in figure 1, consists of a thick-walled cylindrical cask body, neutron shield, outer-shell and lid.

The cask body consists of carbon steel (SA350). The lid is made of stainless steel (SA350) and is fixed to the cask body with stud bolts and cap nuts. The outer-shell is made of stainless steel (SA350). The inner cavity between the outer-shell and the cask body is filled with NS-4-FR, which acts as a neutron shield.

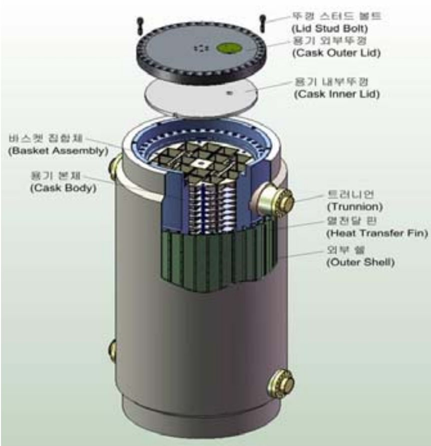

Fig. 1. Configuration of KN-18 Shipping Cask..

The thermal conductivity of the NS-4-FR is not good. Therefore, the cooling fin is embedded to enhance the heat transfer from the cask body to the outer-shell.

2.2 Measurement System

The temperature data acquisition system, which is to be used in the thermal test, consists of a thermocouple scanner, a signal conditioner, an A/D converter and a P/C.

The thermocouple scanner can connect thirty-two thermocouples. The signal, which is detected in the thermocouple scanner, is filtered and amplified through the signal conditioner, and it converts the analog signal to a 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. Also, a change of the temperature according to a transient is monitored through the P/C.

2.3 Thermal Test

As shown in figure 2, the thermal tests were 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.
- The thermocouples for measuring the flame temperature inside the fire test facility were installed.
- The total heat flux of 2.8 ± 0.1 kW from the 18 dummy heaters was maintained for sufficient time to allow a steady state temperature distribution to be reached in the slice model.
- After the temperature distribution of the slice model is reached at thermal equilibrium state, the water was filled with a height of 5 cm in the test chamber.
- The kerosene was filled with a height of 10 cm from the surface of the water.

Fig. 2. Test model in the fire test facility

- 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℃.
- The constant heat flux from the dummy heaters was maintained all through the thermal test and cooling period.
- After the thermal test was finished, the test model was left in order to be cooled naturally.

2.3 Test Results and Discussion

The K type thermocouples were used to monitor the temperature of the flame and the test model.

In the thermal test, the environmental temperature in the fire test facility was maintained at approximately 28 °C before the ignition of the fire. The fire was applied for approximately 37 minutes, because the fire would not extinguish easily. Figure 3 shows the shape of the fully engulfed flame.

Figure 4 shows the flame temperature during the thermal test. The average flame temperature measured during the thermal test was 861 °C. Therefore, the thermal condition, which is prescribed in the regulatory guide-lines, was satisfied.

The temperature data for the thermal tests are shown in table 1. The maximum temperature of the cask surface was measured at 709 °C. The maximum temperature of the basket was measured at 274 °C after the fire was extinguished and 12 hours had passed. The maximum temperature of the neutron shield was measured at 210 °C after the fire was extinguished and 0.2 hours had passed. From the results of the thermal test, the thermal integrity of the KN-18 shipping cask can be maintained under a thermal condition of 800 ℃.

Fig. 3. The shape of the engulfed flame

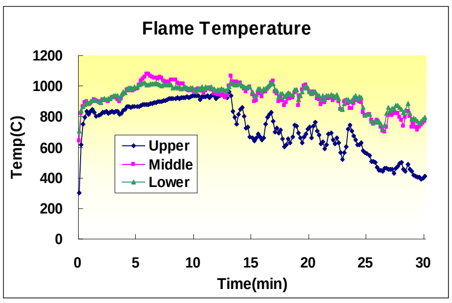

Fig. 4. Flame temperature during the thermal test

Table 1. Summary of the Thermal Test Results

Location \ Temp(°C)		Steady State	Transient	Elapsed Time(h)
Basket		249	274	12.0
Cask Body	Inside	125	162	8.0
	Outside	115	153	4.5
Neutron Shield		102	210	0.2
Cask Surface		94	709	
Ambient(Average)		28	861	

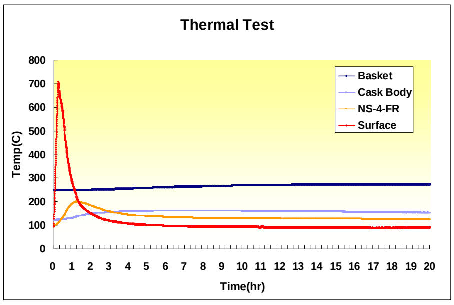

Fig. 5. Temperature profile during the thermal test

3. Conclusion

As a part of safety tests, a thermal test was carried out to evaluate the thermal integrity of the KN-18 shipping cask, which is to transport 18 spent fuel assemblies which are discharged from PWR reactors.

The main results were as follows:

ⅰ) The maximum temperature of the cask surface was measured at 709 °C. Accordingly, the heat transfer from the flame to the KN-18 shipping cask is estimated to be protected properly.

ⅱ) The maximum basket temperature of the KN-18 shipping cask was measured as 274 ℃ less than the limit temperature of a spent nuclear fuel. Accordingly, the integrity of a spent nuclear fuel is estimated to be maintained.

ⅲ) Therefore, the thermal integrity of the KN-18 shipping cask is enough safe under a thermal condition of 800 ℃.

4. Acknowledgments

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REFERENCES

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[3] U.S. Code of Federal Regulations, Title 10, Part 71, "Packaging and Transportation of Radioactive Material", 2004 Ed.