Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 29-30, 2014

Open Pool Fire Test of Dual Purpose Cask for Spent Fuel

K. S. Bang, S. H. Yu, S. H. Lee, J. C. Lee, K. S. Seo
Korea Atomic Energy Research Institute, 111, Daedeok-daero 989 beon-gil, Yuseung-gu, Daejeon, Korea 305-353
nksbang@kaeri.re.kr

1. Introduction

The management of spent nuclear fuel generated at nuclear power plants has become a major policy issue owing to continued delays in obtaining a safe and permanent disposal facility. Most nuclear power plants store their spent nuclear fuel in wet storage pools. However, after decades of use, most storage pools have reached maximum capacity. For the nuclear industry, finding sufficient capacity for the storage of spent nuclear fuel is essential if the nuclear power plants are to be allowed to continue their operation. Therefore, a dual purpose cask containing 21 spent fuel assemblies is under development by the KOrea RADioactive waste agency (KORAD) in Korea.

Since the dual purpose 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 2012-49, IAEA Safety Standard Series No. TS-R-1 and US 10 CFR Part 71 [1~3]. These regulatory guidelines classify the dual purpose 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 fire test using a 1/6 sliced model of a real cask have been performed to estimate the thermal integrity of the dual purpose cask under a thermal condition of 800 °C.

2. Thermal Test

2.1 Description of the Dual Purpose Cask

The dual purpose cask was designed as a shipping cask for accommodating 21 spent fuel assemblies that are discharged from PWR reactors. The dual purpose cask, shown in figure 1, consists of a thick-walled cylindrical cask body, a neutron shield, a dry shielded canister (DSC), a lid, baskets, and impact limiters. The cask body consists of carbon steel. The lid is made of stainless steel and is fixed to the cask body with stud bolts and cap nuts. 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 shield. The thermal conductivity of the NS-4-FR is not good. Therefore, a cooling fin is embedded to enhance the heat transfer from the cask body to the outer-shell. The outer diameter of the dual purpose cask is 2,126 mm and its overall height is 5,285 mm. It weighs approximately 120 tons.

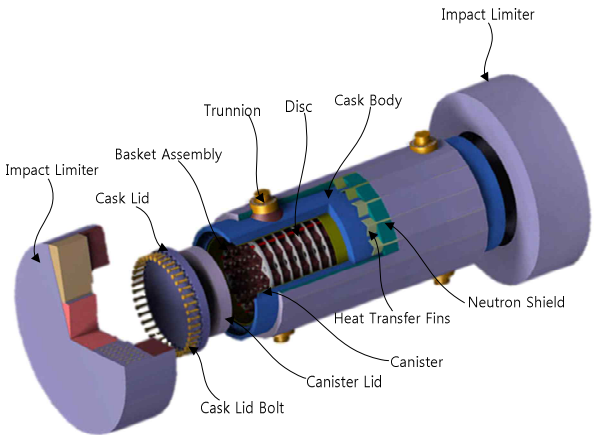

Fig. 1. Configuration of Dual Purpose Cask

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. In addition, a change in the temperature according to a transient is monitored through the P/C.

2.3 Open Pool Fire Test

As shown in figure 2, the open pool fire 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 open pool fire 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.
- 19 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.
- 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.
- After the thermal test was finished, the test model was left in order to be cooled naturally.

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 5 °C before the ignition of the fire. The fire was applied for approximately 36 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 fire test. The average flame temperature measured during the thermal test was 834 °C. Therefore, the thermal condition, which is prescribed in the regulatory guide-lines, was satisfied.

The temperature data for the pool fire tests are shown in table 1. The maximum temperature of the cask surface was measured as 897 °C in the middle part, because the then flame temperature was the highest at 984 °C. However, the maximum temperature of the neutron shield was measured as 183 °C after the fire was extinguished and 0.1 hours had passed.

The maximum temperature of the cask surface in which the cooling fin is embedded was measured as 634 °C. This is because heat generated by the fire source was transferred to the cask body through the cooling fins.

The initial temperature of the basket before the pool fire test was 4 °C, and the maximum temperature of it was measured as 33 °C after the fire was extinguished and 19 hours had passed. Therefore, the temperature rise of the basket during the fire test was 29 °C.

From the results of the pool fire test, the thermal integrity of the dual purpose cask can be maintained under a thermal condition of 800 °C.

Fig. 3. The shape of the engulfed flame.

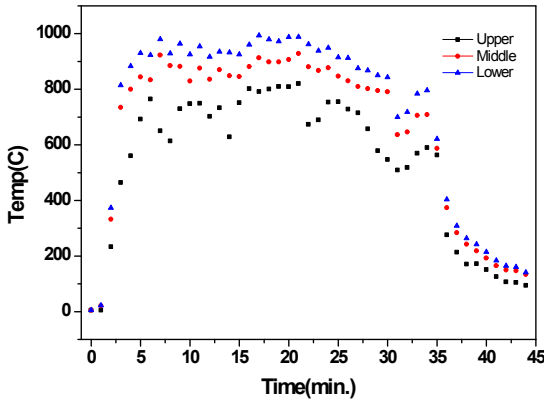

Fig. 4. Flame temperature during the thermal test

Table 1. Summary of the Thermal Test Results

Temp(°C) / Location	Steady State	Transient	Elapsed Time(h)
Basket	4.0	33.0	18.45
Canister Surface	3.8	40.0	9.52
Body Surface	5.0	103.0	0.55
Neutron Shield	6.5	183.0	0.57
Cask Surface	8.4	897	0.37
Ambient(Average)	5.0	834	

3. Conclusion

As a part of the safety tests, an open pool fire test was carried out to evaluate the thermal integrity of the dual purpose cask. The main results were as follows:

i) The maximum temperature of the neutron shield was measured as 183 °C. Accordingly, the heat transfer from the flame to the dual purpose cask is estimated to be protected properly.

ii) The temperature rise of the basket during the fire test was 29 °C. Accordingly, the integrity of a spent nuclear fuel is estimated to be maintained.

iii) Therefore, the thermal integrity of the dual purpose cask is safe enough under a thermal condition of 800 °C.

4. Acknowledgments

This paper was supported by MKE (The Ministry of Knowledge Economy), Korea, under the Radioactive Waste Management Technology Development Project.

REFERENCES

[1] KOREA NSSC Act. 2012-49, “Regulations for the Safe Transport of Radioactive Material”, 2012.
[2] IAEA Safety standard Series No. TS-R-1, "Regulations for Packaging and Transportation of Radioactive Material”, 2009 Ed.
[3] U.S. Code of Federal Regulations, Title 10, Part 71, "Packaging and Transportation of Radioactive Material”, 2005 Ed.