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PERIODIC INSPECTION OF THE SPENT FUEL TRANSPORT PACKAGE

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ABSTRACT

Periodic inspection has been performed to confirm the integrity of a spent fuel transport package. The areas of the periodic inspection include: visual inspection, nondestructive weld inspection, load inspection, maximum operating pressure inspection, leakage inspection, shielding inspection, thermal inspection, external surface contamination inspection. Damages or defects could not be found with the visual inspection, the nondestructive weld inspection and the load inspection. Leakage inspection was performed using the helium leakage test method in accordance with ANSI N14.5. The measured leakage rate was lower than the allowable leakage rate. There was no pressure drop during the 10 minute hydrostatic pressure inspection. The shielding and thermal inspections were performed with 12 loaded spent PWR fuel assemblies. The measured dose rates and temperatures were compared with the radiation shielding and thermal analysis results. There were good agreements between the test and analysis results. As a result of the external surface contamination inspection, the contamination levels on the cask surfaces were lower than the allowable values.

INTRODUCTION

Spent fuel transport package is classified as a type-B package. According to the Korea Atomic Energy Act, all type-B transport packages should be inspected every five years to ensure their performance. A periodic inspection of a spent nuclear fuel transport package was performed to receive a license for its reuse. The cask was designed to transport twelve spent PWR fuel assemblies under wet and dry conditions. The cask was developed and licensed in 2002 in accordance with the Korea and the IAEA's safe transport regulations. This paper includes the details of the inspection methods, procedures, evaluation criteria and inspection results of the spent fuel transport package.

DESCRIPTION OF THE KN-12 CASK

The KN-12 transport cask is designed to transport 12 PWR spent nuclear fuels. The cask was licensed in accordance with requirements of the Korea Atomic Energy Act and IAEA regulations for a Type B(U)F transport package.

Figure 1 shows the configuration of the KN-12 transport cask. The cask consists of a cask body, a lid, polyethylene rods, fuel baskets, trunnions and impact limiters. A forged cylindrical cask body which constitutes the containment vessel is closed by a cask lid. Polyethylene rods for a neutron shielding are arranged in two rows of the longitudinal bore holes in the cask body wall. A fuel basket to accommodate up to 12 PWR fuel assemblies provides a support for the fuels, a control of the criticality and a path to dissipate the generated heat. Impact limiters to absorb the impact energy from the hypothetical accident conditions are attached at the top and at the bottom side of the cask.

Table 1 shows a description of the design criteria for the KN-12 cask. The outer diameter of the cask is 1.942 m and the overall length is 5.744 m. The gross weight of the cask is approximately 84 tons. The cask is designed to transport 12 PWR spent fuel assemblies with a burn-up of 50,000 MWD/MTU and a cooling time of 7 years. The decay heat load from the 12 PWR assemblies is 12.6 kW.

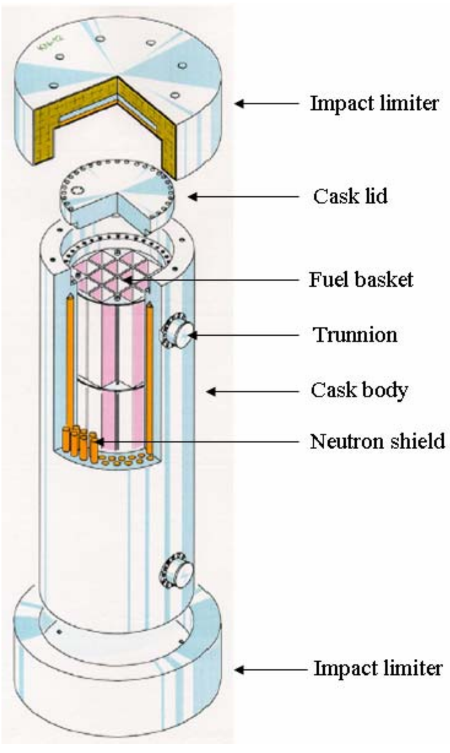

Figure 1. Overview of the KN-12 Cask.

Table 1. Description and Design Criteria of the KN-12 Transport Cask

Item	Description
Loading capacity	12 PWR assemblies
Weight	- Gross weight : 84.3 tons (Empty weight : 62 tons)
Dimensions	- O.D : 2.45 m (cask body : 1.942 m) - Length : 5.744 m (cask body : 4.809 m)
Materials	- Structural : Carbon steel, Neutron shield : PE - Impact limiter : Balsa wood, red wood
Cooling type	_ Dry (helium) & wet (water)
Design basis fuel	- PWR 17x17, 14x14, 16x16 - Burn-up : 50,000 MWD/MTU - Cooling time : 7 years, Enrichment : 5.0 %
Decay heat	12.6 kW
Radioactivity	1.39×10^{17}Bq
Design pressure	0.7 MPa

PERIODIC INSPECTION

Visual inspection

Visual inspections have been performed for the cask body, lid, lower plate, upper and lower trunnions, impact limiters, fuel baskets, tie-down structure and name plate. Visual inspection, dimension check and nondestructive test for the critical point were performed to confirm the integrity of the cask. As a result of the visual inspections, there were no cracks, pinholes, uncontrolled voids, or other defects that could significantly reduce the effectiveness of the cask. Therefore, the integrity of the cask was verified form the visual inspection.

Figure 2. Visual Inspection of the Cask.

Nondestructive Weld Inspection

Nondestructive weld inspection was performed to confirm the structural integrity of the welding parts. The containment vessel for the cask consists of a forged cylindrical cask with an integrally-welded carbon steel bottom. The outer cask region is covered by a welded stainless steel cladding for a corrosion protection. Therefore, the leak test(LT) method was applied for the nondestructive weld inspection. The leak test was performed using the helium leakage test of sniffer method, in accordance with ANSI N14.5 A.5.8[1] and ISO 12807 A.4.3[2]. Helium gas was filled into the cavity of the cask at a pressure of 1 bar and the welding parts of the cask body were scanned by using a sniffer probe. The measured helium rate of the cask was lower than the background level. Therefore, the structural integrity of the welding parts was verified.

Figure 3. Nondestructive Welding Inspection.

Load Inspection

Load inspection was performed to confirm that the trunnions can cope satisfactorily with an applied load. Each lifting attachment of the cask should be retain a test load equal to 150% of the weight of the loaded transport package for a period of 10 minutes. The weight of the KN-12 cask is 72.6 tons and a total weight of 111.96 tons was applied to the trunnions. There were no cracks, deformations and other defects at the trunnions and the trunnion's bolts from the non-destructive test and visual inspection. Therefore, the structural integrities of the trunnions were verified under the applied load test condition.

Figure 4. Load Inspection of the Cask.

Maximum Operating Pressure Inspection

Hydrostatic pressure inspection for the containment vessel was performed in accordance with the ASME Sec.III, Subsection WB. The test was carried out on the welded cask body with the lid in place sealed by O-ring seals. According to the Korea Atomic Energy Act it requires a test pressure at not less than 125% of the maximum normal operating pressure for the hydrostatic pressure test. Maximum normal operating pressure of the KN-12 cask is 0.7 MPa. Pressure inside the cask was increased up to 0.875 MPa during 10 minutes. There was no pressure drop during the pressure test. Therefore, the integrity of the containment system was verified under the maximum operating pressure test.

Figure 5. Pressure Inspection of the Cask.

Leakage Inspection

The leakage inspection was performed using the evacuated envelope gas test method of the helium leakage test, in accordance with ANSI N14.5. Leakage rate was calculated as a following equation. Where, C is a pressure compensation coefficient

$$C = P_{He} / 1\ \text{bar},\quad Q_{He} = (Q_{LD} - Q_B) / C \qquad (1)$$

The allowable leakage rate of the KN-12 cask is 1.0E-4 std cm^3/s. And the maximum leakage rates for the O-ring of the lid and valve box were measured with background. Consequently, the integrity of the containment system was verified under the leakage test condition.

Figure 6. Leakage Inspection of the Cask.

Shielding Inspection

The shielding test and analysis were performed for an evaluation the shielding integrity of the cask. The spent fuel source terms were calculated by Origen-Arp [3] and the shielding analysis was performed with MCNP5 [4]. Gamma and neutron dose rates were measured at 35 points of the external surface of the cask under the loading condition of real spent nuclear fuels. Gamma dose rates were measured with a SURVEYOR 2000 from BICRON and the neutron dose rates were measured with a commercial device PTS200 from Atlan Techand. There were good agreements between the shielding test and analysis results. Therefore, it was found that the shielding integrity of the cask was maintained.

Figure 7. Measurements of the Gamma and Neutron.

Thermal Inspection

Thermal inspections of the KN-12 cask were performed to confirm its heat transfer capability under a loading of spent PWR fuels. Decay heat from the 12 spent PWR fuel assemblies was calculated at 4.97 kW from the ORIGEN-S code. Cask surface temperatures calculated by a theoretical method were compared with the measured temperatures.

Governing equation for a convective and radiation heat transfer at the cask surface to the environment is expressed as follows.

$q = h_{nc}A(T_s - T_a) + \sigma\varepsilon A(T_s^4 - T_a^4)$ -- (2)

Natural convection heat transfer coefficient can be derived as follows.

$h_{nc} = NU_L\ k/L$ -- (3)

The cask was placed in a vertical position during the thermal inspection and the heat transfer coefficient was derived by the following correlation.

- $Nu = 0.10\ (Gr\ Pr)^{1/3}$: Turbulent range ------------------------------------ (4)

Heat transfer coefficient was calculated as 3.2 W/㎡-K form the equations (3, 4).

The cask's surface material is carbon steel and this surface is painted with a white color. In the thermal analysis, an emissivity of 0.93 is applied to the painted surface.

The average cask surface temperature was calculated as 37 ℃ under an ambient temperature of 16 ℃ from the equation (3). Environmental temperature was measured as 16 ℃ during the thermal test. The cask surface temperatures were measured from 32 ℃ to 37 ℃ under the steady state for the ambient temperature of 16 ℃. There were good agreements between the test and analysis results.

Figure 8. Measurement of the Temperature.

External Surface Contamination Inspection

External surface contamination inspections were carried out for a fixed and non-fixed contamination of the cask. The non-fixed contamination on the external surfaces of the cask should be kept as low as practicable and under routine conditions of a transport should not exceed the following limits; 4 Bq/㎠ for beta and gamma emitters and low toxicity alpha emitters, or 0.4 Bq/㎠ for all the other alpha emitters. These limits are applicable when averaged over any surface area of 300 ㎠. Non-fixed contamination was measured with a background level and 0.023 Bq/㎠ for alpha emitters and beta-gamma emitters, respectively. The allowable value for a fixed contamination is 5 μSv/h. For the fixed contamination, dose rates at 12 points were measured for the cask surface. The maximum dose rate was measured as 0.01 μSv/h. The measured external surface contaminations were lower than the allowable values.

Figure 9. Measurement of the Contamination.

CONCLUSIONS

Periodic inspection methods and procedures were established to acquire a license for a reuse of a cask. Through the periodic inspection, it was found that the safety capabilities of the cask satisfied the requirements of the regulations. The license was successfully acquired for the reuse of the cask.

REFERNCES

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[3] [1]"SCALE: A Modular Code System for Performing Standardized Computer Analyses for Licensing Evaluations", ORNL/TM-2005/39, Version 5.1, November 2006.
[4] X-5 Monte Carlo Team, "MCNP: A General Monte Carlo N-Particle Transport Code, Version 5", LA-UR-03-1987, Los Alamos National Laboratory, April 2003.