Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 10-11, 2007

Periodic Inspection of KN-12 Spent Nuclear Fuel Transportation Cask

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1. Introduction

Spent nuclear fuel transportation cask is classified as a type B transportation packaging. And every packaging of type B should be periodically inspected every 5 years to assure that packaging performance and effectiveness is maintained throughout its service life [1]. Two KN-12 casks were certified as the Pressurized Water Reactors (PWR) spent fuel transportation casks in 2002. Periodic safety inspections for the two KN-12 casks were performed and this paper briefly describes the inspection items, methods, results and discussion.

2. KN-12 Spent Nuclear Transportation Cask

The KN-12 is a transportation cask intended for dry and for wet transportation of up to 12 spent nuclear fuel assemblies from PWR. KN-12 cask is a cylindrical and self-supporting vessel that is placed in the horizontal position on a tie-down structure during transportation. It consists of a cylindrical thick-walled cask which constitutes the containment vessel made of forged carbon steel, polyethylene rods for neutron shielding, a fuel basket that locates and supports the fuel assemblies in fixed positions, upper and lower pairs of trunnions to provide support for lifting and for rotation, a set of impact limiters manufactured from wood encased in steel sheeting. During transportation, the cask will be supported by a specially designed transport frame, tie-down structure.

The overall length and diameter of the cask body are 4,809mm and 1,942mm respectively. The overall weight of empty cask is 6,200 kg, and in case of wet transportation, the maximum weight of cask without impact limiters is over 7,200 kg. The typical Westinghouse 14x14, 16x16, 17x17 fuel assemblies can be loaded into the KN-12 cask. The maximum allowable initial UO_2 enrichment of the fuel is 5.0wt % and the assembly burnup is limited to a maximum average of 50,000 MWD/MTU. Total decay heat of 12 PWR fuel assemblies is 12.6 kW and prior to load in the KN-12, the fuel must have a minimum cooling time of 7 years. The maximum design radioactivity for the KN-12 cask is 1.37×10^5 TBq.

3. Periodic Performance Inspection

The periodic performance inspections for the KN-12 cask include visual inspection of the cask surface, and particularly sealing surfaces for defect occurring as the results of use, load inspection for lifting and tie-down structure, gamma and neutron shielding inspection, welding integrity inspection by non-destructive test methods, external surface contamination inspection, maximum operation pressure inspection on the cask cavity, leakage inspection for containment system verification and heat transfer inspection for verification of the heat rejection of the cask [2].

4. Inspection Results and Discussion

Periodic performance inspections for two KN-12 casks were carried out at Kori Nuclear Power Plant (NPP) site from December 7, 2006 to February 26, 2007.

4.1 Visual Inspection

Visual inspections were performed to assure that the important parts of KN-12 casks were not breached by defects, such as cracks, holes or deformation. Surface scratches are acceptable. Visual inspection results showed that KN-12 casks have no cracks, deformation and damage.

4.2 Load Inspection

For load test, 1.5 times of the total weight of the cask should be applied to the cask lifting fixtures for 10 min. The weight of the KN-12 cask including fuel is 72,600 kg and total weight of 111,960 kg was applied to the upper and lower trunnions of the cask. The ultrasonic and penetrant inspection results for the trunnions and trunnion bolts after load tests showed no recordable cracks or deformations.

4.3 Shielding Inspection

At 35 points of the external surface of the KN-12 casks, gamma and neutron dose rate were measured to inspect the shielding integrity of the cask. The maximum dose rates at the external surface were 0.8 mSv/hr for gamma on the upper part of the cask and 0.52 mSv/hr for neutron at the center of the upper lid. These values are acceptable as the limit of the dose rate at the external surface of the transport cask is 2 mSv/hr.

4.4 Welding Integrity Inspection

As the non-destructive inspection for major welding parts of the KN-12 casks, tracer gas test method of ANSI N14.5 was applied [3]. Helium gas was used as the tracer gas and filled into the cask until the internal pressure reached to 1 kgf/cm^2 and using a sniffer probe, welding parts of the lower cask body were scanned. The background helium rate was about 8x10^{-6} std.cm^3/s and the integrity of the welded parts was confirmed as detected helium leakage rates didn't exceed the background levels.

4.5 Surface Contamination Inspection

External surface contamination inspections were performed for the fixed and removable surface contamination of the KN-12 casks. Acceptable criteria for the fixed surface contamination is less than 5 μSv/hr, and in case of the removable contamination, the limit value is 4 Bq/cm^2 for the beta and gamma emitter or low toxic alpha emitter and is 0.4 Bq/cm^2 for every other alpha emitters. At 18 points of the cask, the removable contamination was measured by smear test of over 300 cm^2 for the alpha, beta, gamma emitters, and the maximum detected values were 0.023 Bq/cm^2 for the beta and gamma emitter, and for alpha emitter, the measured value did not exceed the background value of 0.06 Bq. For the fixed contamination, 12 points were measured and the maximum value was 0.13 μSv/hr, which was slightly over than the background value of 0.1 μSv/hr.

4.6 Maximum Operating Pressure Inspection

The transportation cask for spent nuclear fuel should be proof tested at an internal pressure at least 1.25 times the Maximum Normal Operation Pressure (MNOP). The design MNOP of the KN-12 cask is 7 kg/cm^2 and test pressure of 8.9 kg/cm^2. The hydrostatic pressure test was applied as the maximum operating pressure test method. The pressure was gradually applied to the test pressure to avoid over pressuring the system and maintained for 10 min. No pressure drop was occurred during the hydrostatic pressure test of KN-12 casks.

4.7 Leakage Inspection

The containment boundaries of the KN-12 cask should be leak-rate tested to confirm the leak tightness of the cask. As the leakage inspection method, the evacuated envelope gas test method of ANSI N14.5 was applied with helium gas and the acceptable leak rate for the KN-12 cask is 3.44 x 10^{-4} std.cm^3/sec. The leak tests were performed for the cask lid O-ring and the gas evacuation port O-ring and the background value of the helium leak rate were 9.5 x 10^{-8} std.cm^3/sec for cask lid O-ring and 1.4 x 10^{-9} std.cm^3/sec for the gas evacuation port O-ring respectively. Test results demonstrated that the leak-rate of the containment boundaries of the KN-12 casks didn't exceed the background value.

4.8 Heat Transfer Inspection

The KN-12 cask is designed to dissipate the decay heat from the fuel to the basket and from the basket to the outer cask body surface. Heat transfer inspection was performed to assure the heat transfer capability of the cask is maintained during the service operation. At 12 points, the temperatures of the cask body surface were measured with portable thermometer. The acceptable maximum temperature of outer surface for a B type package, like the KN-12 cask, under exclusive use should be less than 85℃. The measured maximum temperature of the KN-12 cask loaded with 12 spent fuel assemblies didn't exceed 37 ℃.

5. Summary

Periodic performance inspections for two KN-12 casks were performed. Through several performance inspections, it was confirmed that the overall safety capability of two KN-12 casks meet the requirements of the regulations for the safe transportation of PWR spent nuclear fuel. The obtained experience and skills through the periodic performance inspection of the KN-12 casks can be utilized to the manufacturing inspection of KN-12 casks, which are being manufactured, and other type B transportation casks for radioactive materials.

REFERENCES

[1] Notice of the Ministry of Science and Technology, 2001-19, Regulations on the manufacturing and periodic inspection of the transportation packaging of radioactive materials, 2001.
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[3] ANSI N14.5-1997, Leakage Tests on Packages for shipment, Annex-A, American National Standards Institute, 1998.