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PERIODIC INSPECTION FOR KN-12 IN KOREA

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ABSTRACT

According to the atomic energy act, it is need to be issued the certificate of design approval by the Ministry of Science and Technology (MOST) to transport spent nuclear fuel packages in Korea. After design approval, the packaging has to be inspected during manufacture. And the packaging should be undergone the periodic performance inspection in every 5 years.

CASTOR KN-12 is the spent nuclear fuel transport cask that was certified as type B(U) package. It can contain 12 pressurized water reactor(PWR) spent fuel assemblies that cooled more than 7 years, enriched up to 5 weight percent, and burnt up to 50 GWD/MTU. There are two KN-12 casks that had been used for 5 years in Kori nuclear power plant of Korea.

According to the atomic energy act, two casks had been undergone first periodic performance inspections during late 2006 and early 2007. The periodic performance inspections for the KN-12 cask included 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 operating 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.

Through the inspection, it had been approved that two KN-12 casks maintained good performances. The results of the inspection will be put to practical use as useful experience in the manufacturing inspection for three additionally manufactured KN-12 casks and in the safety review for other type of developing casks.

INTRODUCTION

Spent nuclear fuel transport cask is classified as a type B package.[1] According to the atomic energy act every packaging of type B should be inspected periodically to assure that performance and effectiveness are maintained throughout its service life.[2] Two sets of CASTOR KN-12 were certified as a pressurized water reactors (PWR) spent fuel transport cask in 2002. Recently periodic safety inspections for the two KN-12 casks had been performed and this paper describes the inspection items, methods, results and discussion.

CASTOR KN-12 spent nuclear fuel transport cask

The CASTOR KN-12 is a transport cask designed 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 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 sufficient cooling time no less than 7 years. The maximum design radioactivity for the KN-12 cask is 1.37×10^5 TBq.

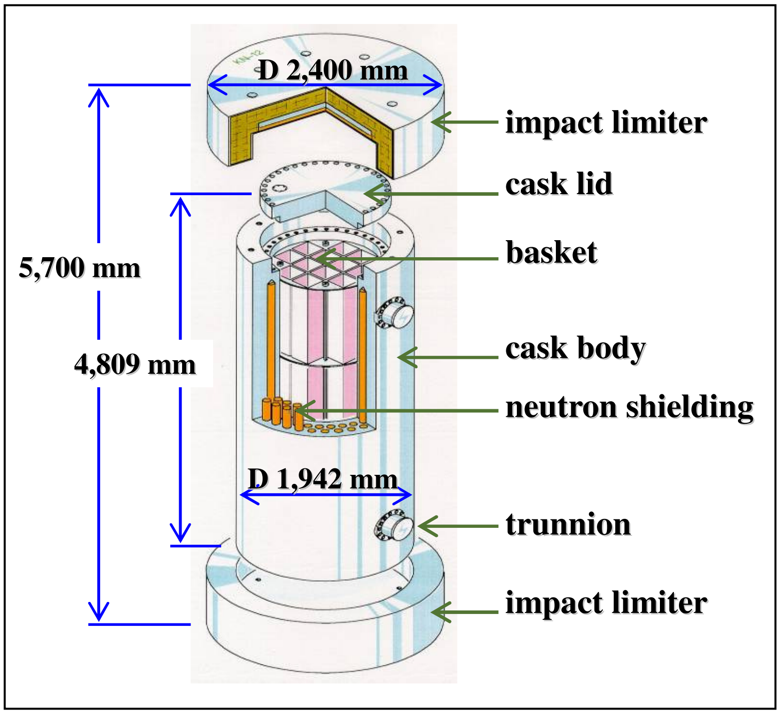


Figure 1. CASTOR KN-12

Inspections for transport casks

Through the amendment of the Atomic Energy Act (AEA) and relative regulations, Korea adopted the IAEA Regulations for Safe Transport of Radioactive Material (ST-1, Revised) in 2001.[3] According to AEA, everyone who would like to transport type B(M), type B(U), type C and fissile material packages has to get design approvals from the Ministry of Science and Technology (MOST), the competent authority of Korea. Anyone who wants to manufacture and use such kinds of packaging has to undergo two kinds of transport packing inspections. The packaging has to be inspected when it is manufactured and it also has to be inspected in every 5 years after the 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 operating 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.[4][5]

INSPECTION RESULTS

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. The casks had been used for 5 years to transport spent nuclear fuel assemblies from Kori NPP unit #1 & #2 to unit #3 & #4 because of the limit of spent fuel storage capacity of unit #1 and #2.

Through out the periodic performance inspections, two KN-12 casks were tested and checked.

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 cask bodies, lids, base plate, upper and lower trunnions, impact limiters, sealing cap, internal baskets and name plates of KN-12 casks have no cracks, deformation and damage.

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 liquid penetrant inspection results for the trunnions and trunnion bolts after load tests showed no recordable cracks or deformations. And inspection results for lifting devices and crane adapters didn't show damages or defects

Figure.2 Visual inspections for top lid and basket.

Figure 3. Load inspection with total weight of 111,960 kg

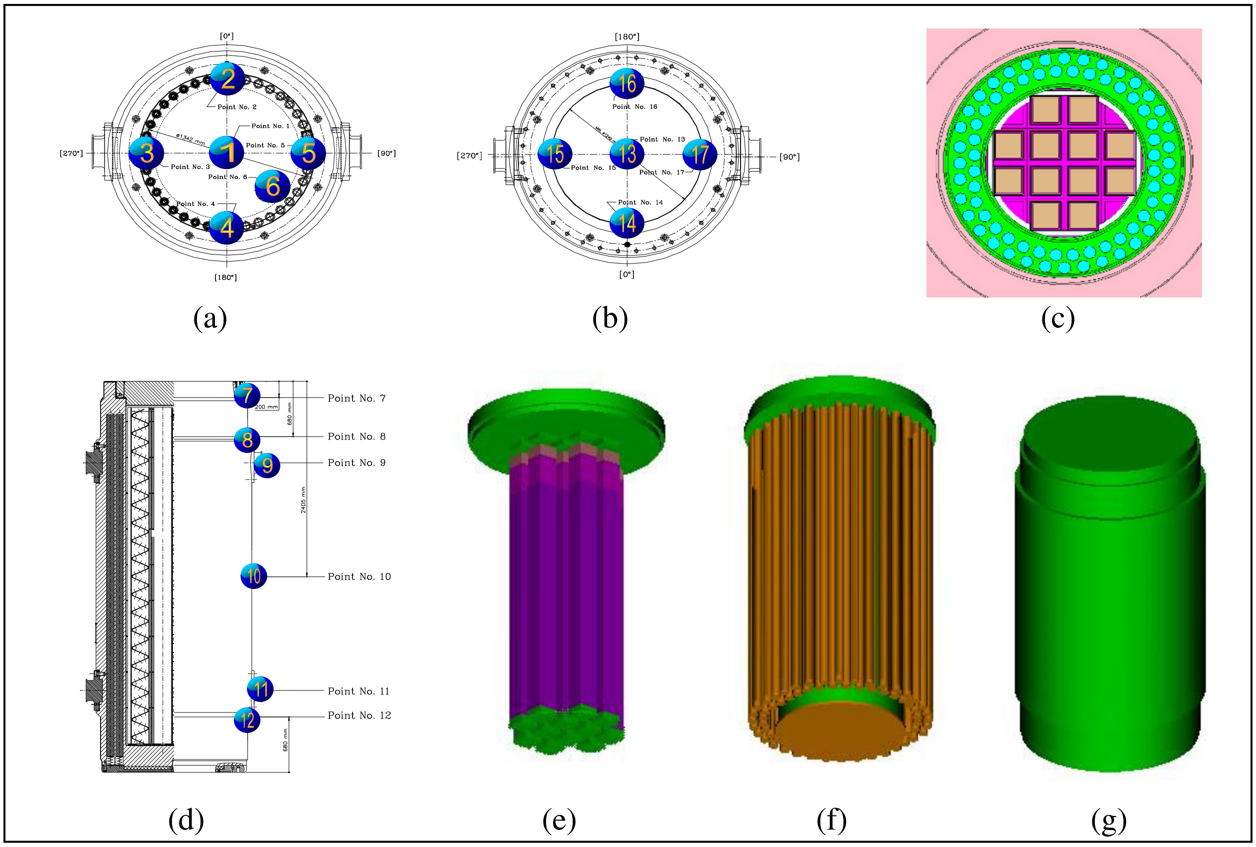


Figure 4. KN-12 Modeling (a) top layer (b) bottom layer (c) cross section(MCNPX) (d) side layer (e) basket view(MCNPX) (f) neutron shielding view (MCNPX) (g) outer view(MCNPX)

<u>Shielding Inspection</u>

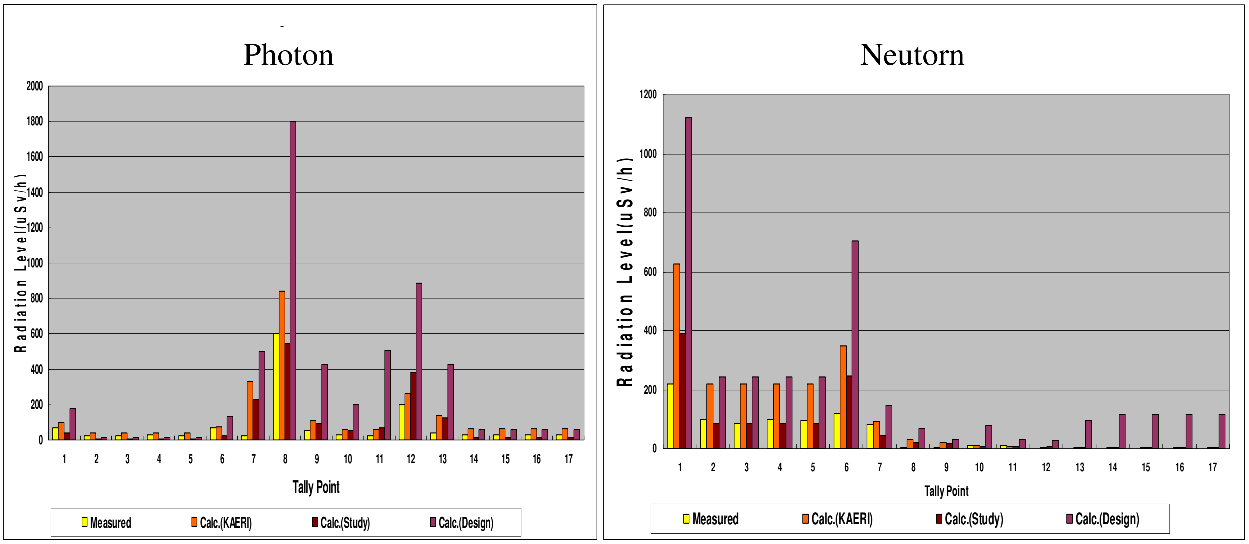
The acceptable surface dose rate limit for any radioactive material transport package is 2 mSv/hr. KN-12 casks were certified to be able to contain 12 PWR spent fuel assemblies with maximum burnup 50GWD/MTU. But in the real inspection we can't use spent fuel assemblies fit to the condition.

For the shielding performance inspection, we loaded 12 real spent fuel assemblies (burnups were about 32GWD/MTU) in the spent fuel storage pool, pumped out 550 liters of water from the cask. And we calculated expected radiation surface dose rates with computer codes, measured dose rates on several surface points, and estimate that the performance of radiation shielding is acceptable or not.

For the source term calculation, we used ORIGEN-S which included in SCALE5 package. And for the surface dose rate calculation, MCNPX Ver.2.5 was used.

Figure 4-(a), (b), (d) show calculated and measured points of surface dose rate. For the points No. 7 ~ No. 12 of Figure 4-(d), dose rates were estimated on every 90 degrees around the cask. 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 rate at the external surface was 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 cask lid. These values did not exceed calculated values, and were acceptable as the limit of the dose rate at the external surface of the transport cask, 2 mSv/hr.



(a) (a)

Figure 5. KN-12 Shielding (a) photon dose rate (b) neutron dose rate
- measured data (yellow), calculated data (orange & red), calculated with designed fuel (purple)

After the comparison between calculated value and measured data, we estimated the case that KN-12 contains spent nuclear fuels with maximum allowable burnup, 50 GWD/MTU. The maximum surface dose rates were expected on the position No.8 for gamma ray, and No.1 for neutron. And total dose rates did not exceed 2mSv/hr at any point. These results are also shown on Figure 5.

Welding Integrity Inspection

The cask body of CASTOR KN-12 is composed with mainly two parts, such as cylindrical side wall and bottom plate. The two parts were combined with welding, and inner and outer surfaces were cladded with stainless steel plates. Because the cladded material couldn't be removed for the periodic inspection, as the non-destructive inspection for major welding parts of 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.

Surface Contamination Inspection

External surface contamination inspections were performed for the fixed and removable surface contamination of two 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.

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.

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 3.44×10^{-4} $std.cm^3/sec$.[6] 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 9.5×10^{-8} $std.cm^3/sec$ for cask lid O-ring and 1.4×10^{-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.

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 that the heat transfer capability of the cask is maintained during its operation. For the purpose, we calculated expected surface temperature of KN-12 which contains 12 real spent nuclear fuel assemblies that had been burnt up 32GWD/MTU, cooled for 17 years. 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 and calculated temperature of the KN-12 cask loaded with 12 spent fuel assemblies didn't exceed 37 ℃.

CONCLUSIONS

Main concerns of the periodic performance inspection for transport packaging are to confirm if the packaging maintains initial performances or design criteria. But, because available radiation sources or spent nuclear fuel assemblies are different to permissible radioactive contents of the package, we have to compare measured data to predicted values in some items of the inspection, such as radiation shielding inspection, heat transfer inspection. So we calculated expected results with computer code, compared with measured values, and estimated its integrity.

Periodic performance inspections for two KN-12 casks were performed with several tests, measurements, calculations and comparisons. And 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.

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