Operational Experiences of On-Site Transport of Spent Nuclear Fuels in Korea

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INTRODUCTION

Since 1990 more than 800 PWR spent nuclear fuel assemblies has been on-site transported using two kinds of transport casks from one unit to nearby another unit in order to secure the storage capacity of spent nuclear fuel of the Kori nuclear power plant in Korea. The complete on-site transport system, which includes two transport casks, the related equipment and two transport vehicles, had been provided. Considerable amount of modification to the existing power plant equipment and facilities had been carried out. Two kinds of the KSC-4 cask and the CASTOR KN-12 cask were developed and licensed in accordance with the Korea and the IAEA's safe transport regulations. From 1990 to the first half of 2002 two KSC-4 casks were used and more than 420 spent nuclear fuels were transported. From the second half of 2002 two CASTOR KN-12 cask have been used to transport more than 400 spent nuclear fuels. About 180 spent nuclear fuels of Kori site are transported using the CASTOR KN-12 cask this year, and the KSC-4 casks are no longer used.

The CASTOR KN-12 cask was designed to transport twelve spent nuclear fuel assemblies from pressure water reactors and to comply with the requirements of the Korea and the IAEA regulations for Type B(U)F package. PWR spent nuclear fuels with maximum initial enrichment of 5.0wt.%, maximum average burn-up of 50,000MWD/MTU and minimum cooling time of 7 years are loaded and subsequently transported under dry and wet conditions. The loaded weight of the cask with impact limiters is 85 tons. Two casks were fabricated in accordance with ASME B&PV code Section III Division 3. The related equipment to handle the cask and to perform on-site transport are cask lifting devices, cask lid handling tools, crane adapters, vacuum drying and helium back-filling equipment and cask cool-down equipment, spent nuclear fuel handling tool, decontamination equipment using high pressure water and transport vehicles. However, spent nuclear fuels of the Kori site has been transported under wet condition to save the whole transport cycle time, and then the related equipment for the wet transport condition has been used excluding vacuum drying and helium back-filling equipment and cask cool-down equipment.

The Quality Assurance Program through the whole progress including design, fabrication and transport has been established and the strict Quality Control has been carried out. For each transport the transport inspection of the Korea regulatory body in accordance with the Korea Atomic Energy Act has been performed so as to achieve the required safety and reliability of the on-site transport of spent nuclear fuels. No accident of any kind has occurred up to the present and spent nuclear fuels of Kori site have been safely transported.

This paper describes the transport system and the operational experiences for the on-site transport of spent nuclear fuels using the CASTOR KN-12 transport cask in Korea.

TRANSPORT SYSTEM

The on-site transport system consists of the components including the transport cask, the related equipment and the transport vehicle as shown in Fig.1. Detailed description of each component of the transport system is provided as follows;

Transport cask

The CASTOR KN-12 transport cask is a new design of a transport package intended for dry and wet transportation of up to twelve spent nuclear fuels from pressure water reactors. The cask has been designed basing on NETEC's requirements and evaluated as a transport package that complies with the requirements of the Korea Atomic Energy Act[1] and the IAEA Safety Standards Series No.ST-1[2] for Type B(U)F package. The cask provides containment, radiation shielding, structural integrity, criticality control and passive heat removal for normal transport and hypothetical accident conditions[3]. The W.H 14x14, 16x16 and 17x17 spent nuclear fuels will be loaded and subsequently transported in the cask. The maximum allowable initial enrichment of the fuel is 5.0wt.%, the fuel burn-up is limited to a maximum average of 50,000MWD/MTU, and the fuel must have a minimum cooling time of 7 years. Two casks were licensed in accordance with the Korea Atomic Energy Act and fabricated in Korea in accordance with the requirements of ASME B&PV code Section III, Division 3[4].

The containment system of the cask as shown in Fig.2 consists of a forged thick-walled carbon steel cylindrical body with an integrally-welded carbon steel bottom and is closed by a lid made of stainless steel, which is fastened to the cask body by lid bolts and sealed by double VITON O-rings. The steel thickness of the cask body wall and of the lid meet the dose rate limits of the regulations together with neutron shielding material. Neutron shielding in radial direction is provided by polyethylene rods arranged in two concentric rows of axial bore holes and in axial direction is provided by polyethylene plates. The fuel basket to accommodate up to twelve PWR fuels provides support of the fuels, control of criticality and a path to dissipate heat from the fuels to the cask body. The stainless steel fuel receptacles to enclose and secure the fuels are assembled as a grid-work together with boronated aluminum plates. Four trunnions are attached to the cask body for lifting and for rotation of the cask between vertical and horizontal positions. Impact limiters filled with woods to absorb the impact energy under 9m free drop conditions as a hypothetical accident are attached at the top and at the bottom side of the cask during transport. The overall cask length is 4,809mm with a wall thickness of 375mm. The cylindrical cask cavity has an internal diameter of 1,192mm and an internal length of 4,190mm. The lid is 290mm thick. Each impact limiter is 2,450mm in diameter and extends 700mm along the side of the cask in axial direction. The handling weight loaded is about 75 tons and the transport weight with the impact limiters is about 85 tons.

During transport, the cask is supported by a specially designed tie-down structure on the transport trailer and horizontally mounted on the tie-down structure as shown in Fig.3. The tie-down structure was so designed that it is used to maintain a controlled geometric relationship between the cask and the transport trailer, to support the cask, and to facilitate rapid loading and unloading of the cask in accordance with the Korea Atomic Energy Act, and was rigidly fastened to the trailer by bolting.

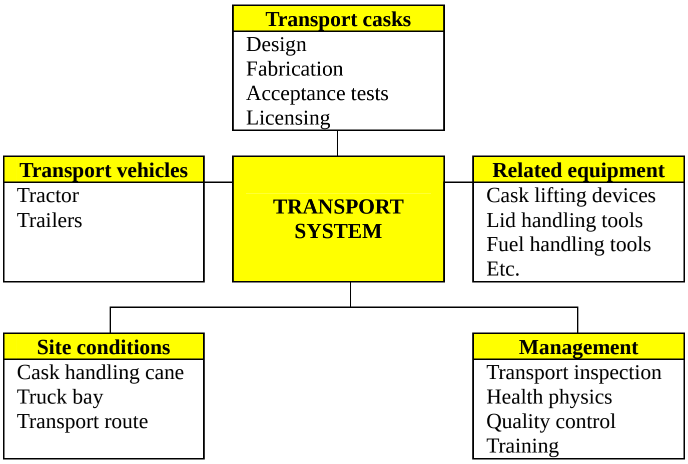

Fig. 1 Transport system

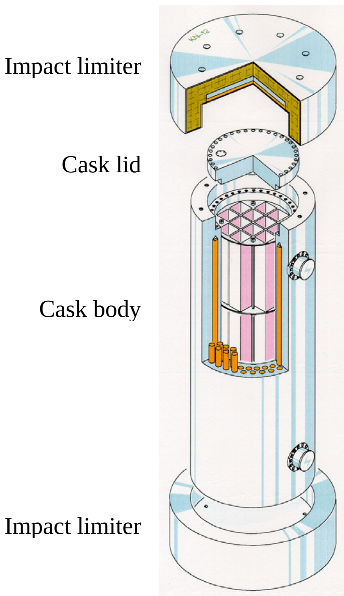

Fig. 2 Overview of the cask

Fig. 3 Cask on the tie-down structure

Transport trailer

The loaded cask is transported by the heavy-haul trailer as shown in Fig.4 and Fig.5. The trailer is capable of supporting the stationary weight of the loaded cask with impact limiters and the tie-down structure, and movement of the trailer during loading or unloading of the cask is prevented. The trailer with 8 axles and 32 tires was specially designed and fabricated in Korea, and has the overall length of 15m and the width of 2.5m. The weight of the trailer is about 25 tons and the maximum loaded weight is about 110 tons. The hood in which air inlets and outlets are arranged to guarantee the free flow of cooling air to the cask provides the weather protection for the cask and represents a personnel barrier to prevent unauthorized access to the cask as shown in Fig.5.

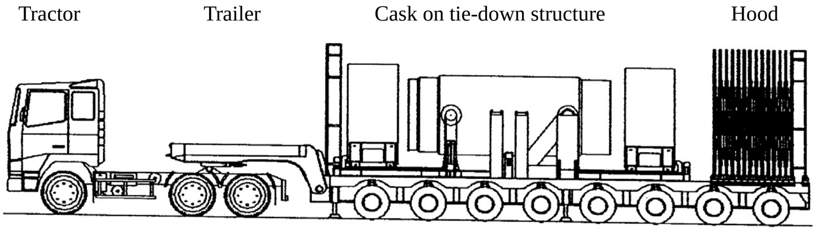

Fig. 4 Transport mode

Fig. 5 Hood on the trailer

Cask lifting device

The cask lifting device as shown in Fig.6, which is engaged to lift the cask, was so designed that it can lift, handle and move the loaded cask safely and easily. The device consists of a traverse, lifting arms and drive elements. The traverse is a welded construction, two lifting arms, which are coupled to the traverse, allow the cask to be lifted, and the lifting arm securing devices are adjusted with an electro cylinder. And the carne adapter is used to connect the double hook of the cask handling crane in the fuel building to the cask lifting device. The cask lifting device and the crane adapter were designed with a minimum safety factor of three against the yielding strength of the material when used to lift the loaded cask in the intended manner in accordance with the requirements of the Korea Atomic Energy Act and ANSI N14.6.

Cask lid handling tool

The cask lid handling tool as shown in Fig.7 is a suspension device for handling of the lid of the cask, and was so designed that it can lift and handle the lid of the cask safely and easily when the cask is located in the water or out of the water. The cask lid handling tool was also designed with a minimum safety factor of three against the yielding strength of the material when used to lift the loaded cask in the intended manner in accordance with the requirements of the Korea Atomic Energy Act and ANSI N14.6. The cask lid handling tool consists of the adapter to attach the crane hook and handling tool to attach to the cask lid. The components are joined together by screwed connections.

Fig. 6 Cask lifting device

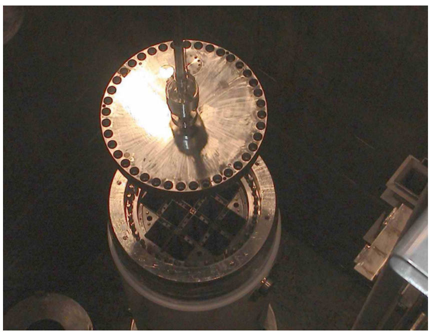

Fig. 7 Cask lid handling tool

ON-SITE TRANSPORT PROCESS

Figure 8 illustrates the sequence of the stepwise procedures of the on-site transport process using two CASTOR KN-12 transport casks and the related equipment. Each step for one cask is performed simultaneously at each unit. It takes five working days to complete one turnaround of the on-site transport at the Kori site. Generic stepwise operating procedures that take into consideration the tools, facilities available, the procedures of the nuclear power plant and the Korea Atomic Energy Act has been used. The Quality Assurance Program through the whole transport process has been established and the strict Quality Control has been performed. For each transport the transport inspection of the Korea regulatory body in accordance with the Korea Atomic Energy Act has been performed so as to achieve the required safety and reliability of the on-site transport of spent nuclear fuels.

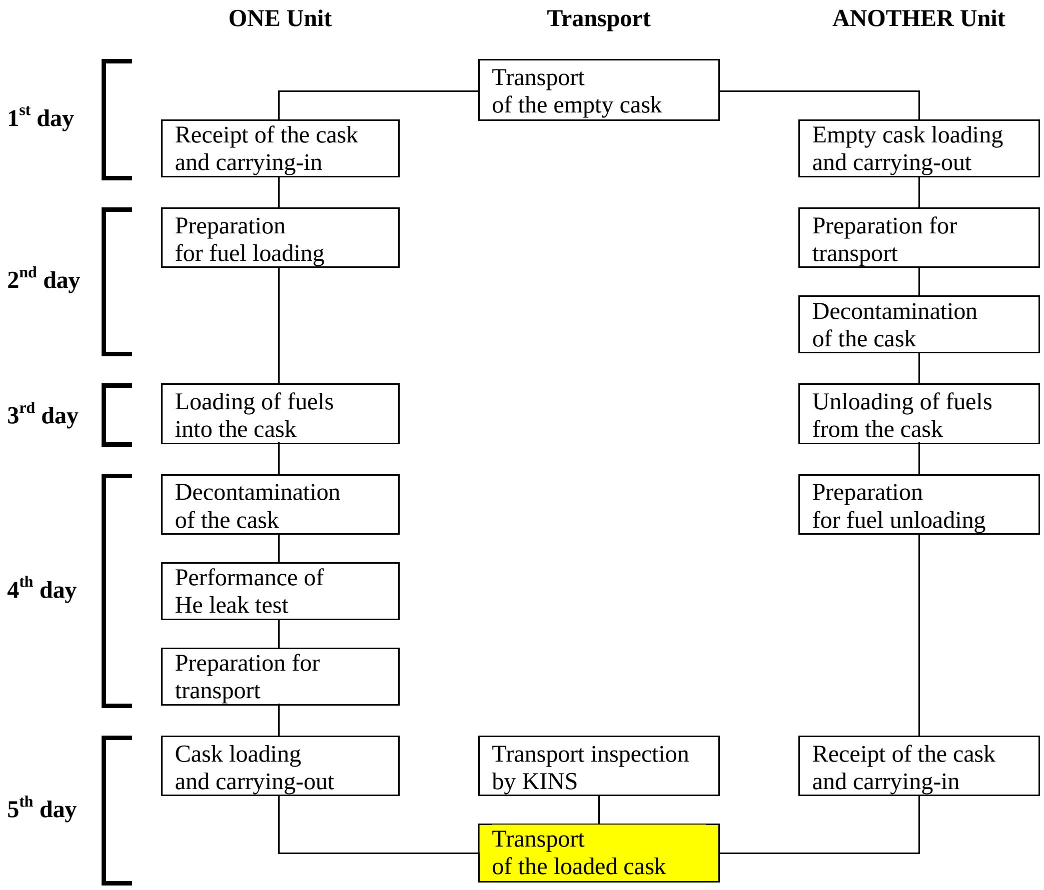

Fig. 8 Sequence of stepwise procedures of on-site transport process

The on-site transport of spent nuclear fuels begins with the receipt of the empty cask. After removing the hood and impact limiters, the empty cask is lifted from the tie-down structure, moved to and sat in the decontamination pit in the fuel building using the cask lifting device(Fig.9). The cask lid is removed by unfastening the lid bolts, and the cask is lifted, moved to the drained cask loading pit in the spent nuclear fuel storage pool. The cask loading pit is filled with water. Twelve spent nuclear fuel assemblies which identification number of the fuels is confirmed are subsequently loaded into the cask using the fuel handling tool specially designed in Korea(Fig.10). When all spent nuclear fuel assemblies loading into the cask, the cask lid is transferred to and lowered carefully and properly placed on the cask using the cask lid handling tool. The water is drained from the cask loading pit until the water is 0.2m above the top of the cask. As the water drains, the exposed surface of the cask is sprayed with deionized water to remove as much contamination as possible, and the loaded cask is lifted and moved to the decontamination pit. The lid bolts are sequentially installed. All accessible outer surfaces of the cask including the cask bottom are decontaminated according to proper methods and contamination measurement is performed. The leak rate for the cask lid and the closure lid on the lid, which allowable leak rate is $1x10^{-4}$cc/sec, is determined by the helium leak test. The cask lifted from the decontamination pit, moved to the transport trailer, lowered and placed to the tie-down structure. As the impact limiters are installed, dose rate and contamination as required by Korea Atomic Energy Act are measured, and temperatures at the cask surfaces are measured. The transport hood on the trailer is installed and documentation for transport is completed including labeling. The transport inspection by the Korea regulatory body, KINS, is carried out for the transport unit including the loaded cask, which is then dispatched to nearby another unit in the Kori site(Fig.5).

As the transport unit is carried in the fuel building of another unit, the transport documentation is reviewed. The cask is moved to the decontamination pit and prepared for fuel unloading. After removing the lid bolts, the cask is sat in the drained cask loading pit. The cask loading pit is filled with water, and the cask lid is removed. Twelve spent nuclear fuel assemblies are unloaded from the cask into the storage rack of the spent nuclear fuel storage pool. The cask lid is seated on the cask and the water is drained from the cask loading pit. As the water drains, the exposed surface of the cask is sprayed with deionized water to remove as much contamination as possible, and the empty cask is moved to the decontamination pit. The lid bolts are sequentially installed. All accessible outer surfaces of the cask including the cask bottom are decontaminated according to proper methods and contamination measurement is performed. The cask moved to the transport trailer and placed to the tie-down structure. As the impact limiters are installed, dose rate and contamination are measured and the transport hood on the trailer is installed, the transport unit with the empty cask is carried out and is dispatched to the former unit.

Fig. 9 Cask carrying-in to the fuel building

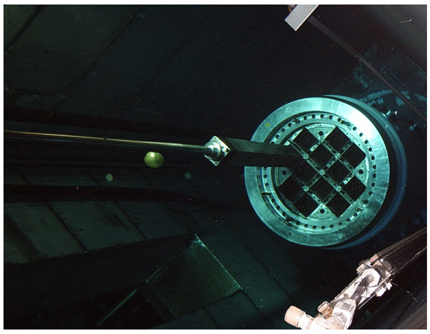

Fig. 10 Fuel loading into the cask

Through the transport process including handling of the cask, the following points are always to be taken into account:

(1) Only qualified tools and equipment are to be used for the assembly and measurements during loading, unloading, and preparation of the cask for transport. The identification number and the certificate of calibration of each measuring equipment have to be recorded in the documentation of the loading or unloading.

(2) On all screws including the cask lid bolts, a suitable lubricant is to be applied before assembly. At the same time the screws and the corresponding thread holes are to be examined. Bolted connections can only be tightened with the specified torque, which are to be recorded.

(3) The contamination limit value for outer surfaces of the cask is determined in the Korea Atomic Energy Act for radiation protection as well as in the IAEA's transport regulations.

(4) The leak tightness of the cask lid is to be proved according to the Korea and IAEA's transport regulations. All applicable operating rules, specifications, handling instructions which are connected to the loading, unloading, and preparation of the cask for transport are to be taken into account. They are measurement of the dose rate, measurement of the contamination, temperature measurement, cask draining and drying and helium leak test.

CONCLUSION

In order to secure the storage capacity of spent nuclear fuel of the Kori nuclear power plant in Korea, spent nuclear fuel assemblies has been on-site transported from one unit to nearby another unit in the same Kori site. The complete on-site transport system that includes two transport casks, the related equipment and two transport vehicles had been developed and provided. From 1990 to the first half of 2002 more than 420 spent nuclear fuels were transported using two KSC-4 casks, from the second half of 2002 more than 400 spent nuclear fuels has been transported using two CASTOR KN-12 casks. About 180 spent nuclear fuels are transported this year. The Quality Assurance Program through the whole on-site transport progress as well as the transport system has been established and the strict Quality Control has been carried out. For each transport the transport inspection of the Korea regulatory body in accordance with Korea Atomic Energy Act has been performed so as to achieve the required safety and reliability of the on-site transport of spent nuclear fuels. No accident of any kind has occurred up to the present and spent nuclear fuels of the Kori site have been safely transported.

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