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Evaluation of Exposure Rate for Operators during the Spent Fuel Handling

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1. Introduction

The purpose of this study is to evaluate the exposure rate for operators during the spent fuel handling. A large amount of personal exposure to radiation is associated with refueling operations. The exposure rate shall be limited for the operator working on the spent fuel handling machine. The minimum water depth above the top of the spent fuel assembly is designed to provide a shielding for operators of the spent fuel handling. Several approaches for reducing the radiation exposure have been studied in the refueling operations. The evaluation of this study can be a beneficial suggestion related to the reduction of the exposure rate for operators.

2. Operating Condition for Spent Fuel Handling

The fuel handling equipment consists of various components performing safety functions and interlocks [1] to handle the fuel assembly safely and should satisfy the operation performance by transferring fuel assembly as rapid as possible. The fuel offloading and reloading between the Reactor and the SFSR (Spent Fuel Storage Rack) are performed by the RM (Refueling Machine), the SFHM (Spent Fuel Handling Machine), the FTS (Fuel Transfer System), and the Upender in the Containment Building and the Fuel Building as shown on Fig. 1.

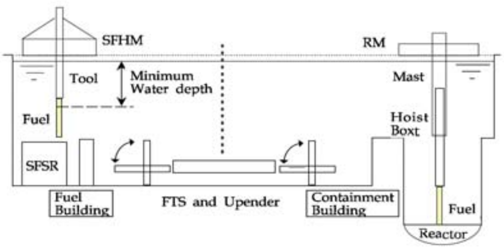

Fig. 1 Arrangement of Fuel Handling Equipment

The SFHM transfers a fuel assembly between the FTS upender and the Spent fuel storage rack with the spent fuel handling tool (SFHT). The SFHT is manually handled for movement of the fuel assembly within the spent fuel storage pool. The length of this tool is such that the spent fuel assembly cannot be raised above the safe water level. For APR1400, the SFHM with a fixed type hoist box was designed based on the KURD (Korean Utility Requirement Document). The hoist box of the SFHM is identical to that of the RM in its structure and function. The SFHM hoist assembly is designed so as to mechanically preclude the raising of the spent fuel assembly top above the minimum safe water cover depth as shown in Fig.1.

3. Evaluation of Exposure Rate for Operators

The exposure rate in the spent fuel pool is determined as a function of the distance from the top of active fuel along the axial direction of the fuel assembly at a decay time of 100 hr after plant shutdown. The exposure rate of the spent fuel assembly with discharge burn-up is based on the 3 batch-18 month refueling scheme. A radial peaking factor of 1.55 is applied to the calculated exposure rate to conservatively estimate the exposure rate. The shielding effects of the structure for the RM and SFHM are also considered in the analysis. Fig. 2 shows the calculated exposure rate of the RM and the SFHM with a tool and a fixed type hoist box at a decay time of 100 hr after plant shutdown.

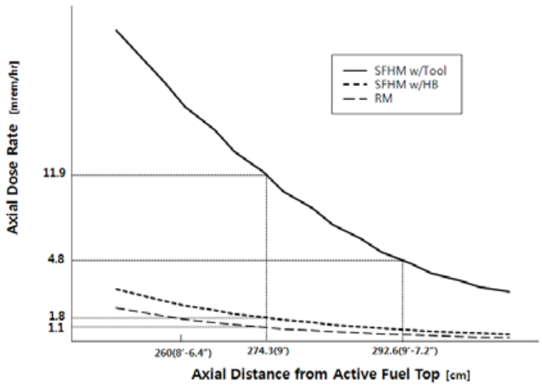

Fig. 2 Exposure Rate at a decay time of 100 hr from a spent fuel assembly in the spent fuel pool

In case of the SFHM with a tool, the axial dose rate shows a steep drop as the axial distance from the active fuel top increases. This graph shows that the exposure rate is more sensitive to a water depth in the spent fuel pool. As shown in Fig.2, at a minimum water depth, 9 ft (274.3 cm) from the top of active fuel, the exposure rates for the RM, the SFHM with a fixed type hoist box and a tool are calculated to 1.1 mrem/hr, 1.8 mrem/hr and 11.9 mrem/hr, respectively. The value for the

SFHM with a tool is calculated 6.6 times higher than that of the SFHM with a fixed type hoist box, which is equivalent to the shielding effect of about 40 cm of the water depth. The result of the exposure rate for the RM is 0.6 times lower than that of the SFHM with a fixed hoist box, which results from the fact that the structure of the RM has a double coverage with the mast. This result also shows that the hoist box can reduce the exposure rate more effectively. As shown on Fig. 2, the actual shielding water depth for the fuel movement is limited to 9'-7.2"(292.6 cm) in operation, which is deeper than that of design value 9'(274.3 cm). The exposure rate for the limited water depth is calculated to 4.8 mrem/hr. This value was dropped by 60% for the case of the SFHM with a tool. From this study, we can get some tips for the design of the SFHM and the building structure in order to reduce the exposure rate by introducing the SFHM with the hoist box instead of the SFHM with a tool.

4. Schemes and Suggestions for Reduction of Exposure Rate

To reduce the exposure rate for the operator working in the SFHM, several schemes are proposed. As mentioned early, the value of the exposure rate is sensitive to a water depth, it is recommended to increase physically the water depth in the spent fuel pool to reduce the exposure rate for operators. But it is not easy to increase the water depth of the spent fuel pool by changing the building arrangement due to its interference with other structures and the view point of economic loss. So we have to find other solutions to reduce the exposure rate. To meet this goal, a change of operating conditions for the SFHM hoist and a modification of the SFHT can be considered. For the change of operating conditions, the interlock of up-limit for the SFHM hoist should be reset downwards. In this case, the minimum clearance for fuel movements between the bottom of the fuel assembly and the top of the upender and the spent fuel storage rack should be verified. And any interference with the spent fuel inspection device over the upender should be also verified for the clearance during the fuel movement. To find another solution, the modification of the flange size and thickness for the SFHT are considered. The results of radiation analyses show just 2% reduction effects for this modification. The change of the flange size located in the bottom of the tool can hinder the spent fuel assembly during the handling over the spent fuel storage rack. The operator usually uses this flange as a tool for alignment for inserting and withdrawing a fuel assembly at the top of the cavity over the spent fuel storage rack. The current design of the tool should be recommended to keep for operating efficiency.

We can get some tips from this study for evaluations of the exposure rate for the operator during the spent fuel handling as follows; 1) the exposure rate is very sensitive to a water depth in the spent fuel pool, 2) the exposure rate for the SFHM with a fixed type hoist box is equivalent to the shielding effect of about 40 cm of the water depth, 3) the effects of the double coverage structure like the RM can be negligible comparing to the fixed hoist box used in the SFHM, 4) the modification of the flange size and thickness for the SFHT is little effective for reduction of the exposure rate, 5) the change of up-limit for the SFHM hoist would be beneficial if we can ensure a minimum clearance between the bottom of the fuel assemby and the top of the upender and the spent fuel storage rack.

5. Conclusion

In this study, we evaluate the exposure rate for operators during the spent fuel handling. The water depth above the top of the spent fuel assembly provides the most effective shielding for operators. The structure of the hoist box in the SFHM and the RM has a shielding effect, but the reduction of the exposure rate by the double coverage of the RM can be negligible. The change for up-limit interlock of the SFHM hoist would be applicable after verifying minimum clearances for the spent fuel handling. The evaluation of this study can be a beneficial suggestion related to the reduction of the exposure rate for operators.

REFERENCES

[1] ANSI/ANS-57.1, Design Requirements for Light Water Reactor Fuel Handling Systems, 1992 (Re-affirmed 2007).