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Calculation of Water Levels in Spent Fuel Pool and Effective Dose Followed by the Worker Geometrically Exposed to Radiation using Gamma-ray Source

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1. Introduction

During the Fukushima nuclear accident, it is known that operation halted because greater than allowable effective doses were detected in the process of dropping seawater by helicopters into the spent fuel pool. In our nation's nuclear power plant, which is different in structure from the Japanese plant, there is a need for estimating data on worker wave doses in case of a spent fuel pool. Therefore, the effective dose influencing workers according to the level of the spent fuel pool was calculated and analyzed using the MCNP program. If the total effective dose value is lower than the surface dose rate of the water, the worker is able to work in a safe environment.

2. Method of Calculation

MCNP, as a generalized geometry that holds continuous spectrum energy used for general purposes, stands for *Monte Carlo transport code*, which is linked, according to time, to neutrons, photons, and electrons. This is used as several transport modes; out of the reactions that are formed by their reactions, there are neutron/photon transport, neutron/photon/electron, photon/electron, and electron/photon modes. The energy range of neutrons for all isotopes is from 10^{-11}Mev to 20Mev, and can reach up to 150 MeV for some isotopes. The photon energy range is from 1 Kev to 100 Gev and the neutron energy range is from 1keV to 1Gev.

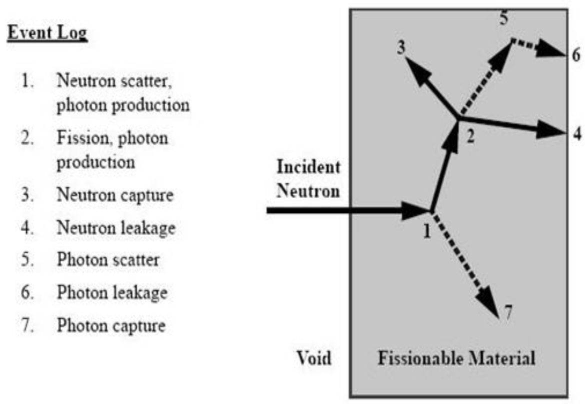

Fig. 1. Diffusion of absorbed neutrons

Some typical irradiation geometries are described in the above paragraphs. These geometries are shown schematically in Figure 2. In AP geometry, the ionizing radiation is incident on the front of the body in a direction orthogonal to its long axis. In PA geometry, the ionizing radiation is incident on the back of the body in a direction orthogonal to its long axis. In LAT geometry, the ionizing radiation is incident from either side of the body in a direction orthogonal to the long axis of the body. LLAT and RLAT indicate left and right lateral geometries, respectively. In ROT geometry, the body is irradiated by a parallel beam of ionizing radiation, which rotates at a uniform rate around the long axis from a direction orthogonal to the long axis of the body. ISO geometry is defined by a radiation field in which the particle influence per solid angle is independent of its direction and location in space.

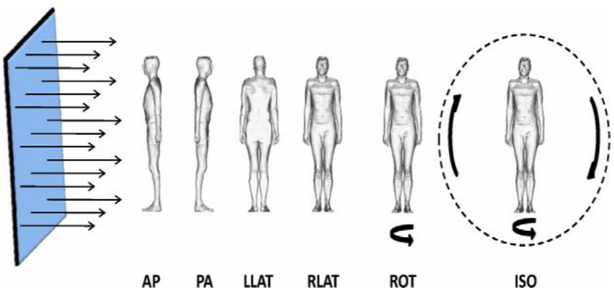

Fig. 2. Schematic representation of the ideal considered - antero-posterior(AP), postero-anterior(PA), left lateral(LLAT), right lateral(RLAT), rotational(ROT), and isotropic(ISO).

Figure 3 is an image of nuclear fuel saved within the spent fuel pool. <**A**> is a three-dimensional representation of the geometric phenomenon of the water tank. The yellow is the part above the surface of the water, and the blue is the coolant that fills the water tank. <**B**> is on the right is a two-dimensional representation of the water tank storage. The white is the part above the surface of the water, the blue is the coolant, and the red is the fuel assembly.

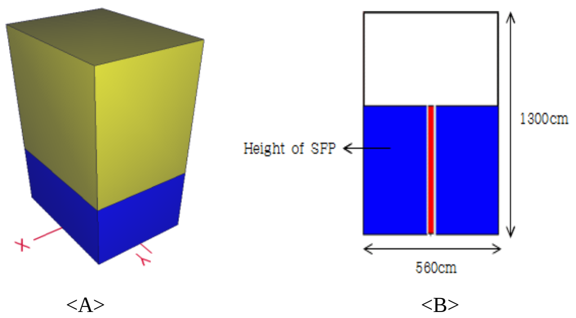

Fig. 3. The geometry of a spent fuel pool with fuel

3. Results and Conclusion

<fig.4> and <fig.5> are the graphs that shows the comparison between surface dose rate and the converted value of effective dose in <table.1>. In the case that the level of spent fuel pool is up to 550cm, there exists the limitation for workers to access to the storage pool because the result value is about 8 times higher than surface dose rate. In the case that the level of spent fuel pool is higher than 600cm, however, it can be safe work environment because the result value is lower than surface dose rate. Therefore, in the case of ISO geometry which is the same with practical situation, when considering Gamma-ray emission from spent fuel, effective dose is much higher than surface dose rate when the level of storage pool is lower than the height of fuel, 452.8cm. On the other hand, the level of effective dose decreases rapidly when the level of storage pool is higher than the level of the fuel. This means that it is not the safe environment when the level of fuel below 140cm is lower than surface dose rate. That is why the access of workers should be limited. Whereas, in the case of the level of storage pool above 600cm which is about 140cm higher than the level of the fuel, it is the safe environment for workers because the result value becomes lower than surface dose rate
As a result, the level of wet storage of spent fuel should be at least 600cm for workers to work in safe environment because lower dose than surface dose rate makes less radiation exposure.

Table. 1 - Comparison of calculation results

Calculation of flux and dose (gamma-rays + neutrons + secondary neutrons)			
Water level(cm)	Flux (photons/㎠ sec)	Dose (mSv/hr)	Dose limit comparison (dose/0.025)
50	5.27×10^{7}	2.019×10^{2}	8.08×10^{3}
75	5.27×10^{7}	1.993×10^{2}	7.97×10^{3}
100	5.25×10^{7}	1.969×10^{2}	7.88×10^{3}
150	5.20×10^{7}	1.908×10^{2}	7.64×10^{3}
200	5.11×10^{7}	1.8358×10^{2}	7.34×10^{3}
250	4.91×10^{7}	1.7378×10^{2}	6.95×10^{3}
300	4.61×10^{7}	1.608×10^{2}	6.43×10^{3}
350	4.14×10^{7}	1.45×10^{2}	5.80×10^{3}
400	3.27×10^{7}	1.204×10^{2}	4.82×10^{3}
450	2.11×10^{7}	9.027×10	3.61×10^{3}
500	1.57×10^{6}	5.3426	2.14×10^{2}
550	5.22×10^{4}	2.0936×10^{-1}	8.37
600	5.17×10^{3}	1.5494×10^{-2}	6.2×10^{-1}

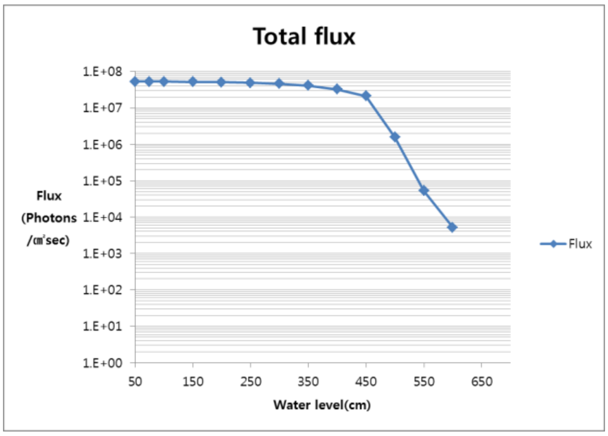

Fig. 4. Flux changes at various water levels
(neutrons + secondary neutrons + gamma rays)

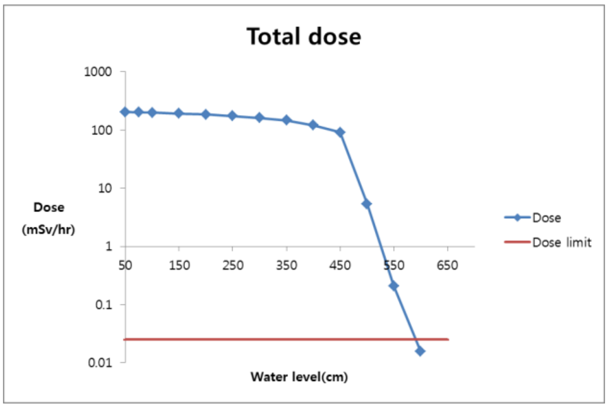

Fig. 5. Dose changes at various water levels
(neutrons + secondary neutrons + gamma rays)

References

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