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Evaluation of Radiation Dose rate of SNF in a simple Accident

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1. Introduction

In this investigation a simple accident case during a transport of spent nuclear fuel (SNF) is considered. The radiation dose rate of CE type SNF, PLUS7^{TM}, is evaluated under the atmospheric and flood conditions. The basis fuel assembly is assumed that it has properties with U-235 enrichment of 5wt%, burnup of 50,000MWD/MTU and cooling time of 5years. The evaluation of the source terms is performed using SAS2H/ORIGEN-S of SCALE5.1 code. MCNP5 Code is applied to the evaluation of the radiation dose rates at the surface and 1m away from the surface of SNF.

2. Methods and Results

2.1 Source Terms

The following source terms are usually considered to calculate the radiation doses of SNF correctly.[1]

► *Gamma ray sources*
- 1st gamma ray generated from decay of fission products and actinides
- Secondary photons generated from neutron capture [(n,γ) reaction]
- Gamma rays generated from activation of structural materials

► *Neutron sources*
- Neutrons generated from spontaneous fission
- Neutrons generated from (α,n) reaction of nuclear fuel
- Neutrons generated from (γ,n) reaction of nuclear fuel
- 2nd neutrons generated from subcritical multiplication

Evaluations of the source terms of SNF are determined by design information of the fuel assembly, operation histories of the reactor and characteristics of the burnup. The SAS2H/ORIGEN-S calculation was performed with the 44 group ENDF/B-V Library. 17.49435MW is assumed as an average specific power, which is 1.1 times greater than the specific power in real operation. The spectrum of gamma ray in 18 energy groups and neutron in 27 groups is applied to the active fuel region.[2] The gamma rays generated from the activation of Co-60 in the structural materials are also included. The secondary gamma rays and the delayed neutrons are considered in the dose rate evaluation using MCNP5 Code without separate calculation process.[3] The results of source terms are shown in table 1.

Table 1. Results of evaluations for source terms

Items	Source terms [photons/sec·FA] / [neutrons/ sec·FA]
1st Gamma rays generated from active fuel region	6.72117E+15
Gamma rays generated from activation of Co-60 in structural materials	4.1156E+13
2nd Gamma rays, [(n,γ) reaction]	2.9330E+08
Neutrons generated from active fuel region	2.9330E+08

2.2 PLUS7^{TM} Model

PLUS7^{TM} has 236 fuel rods, 4 guide tubes and one instrument tube in the center of the fuel assembly. Figure 1 and 2 show the MCNP model of PLUS7^{TM} and the evaluation positions of radiation dose rate.

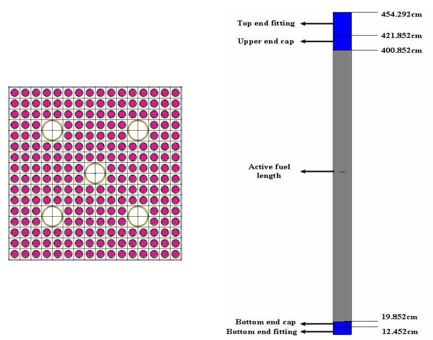

Fig 1. PLUS7^{TM} model

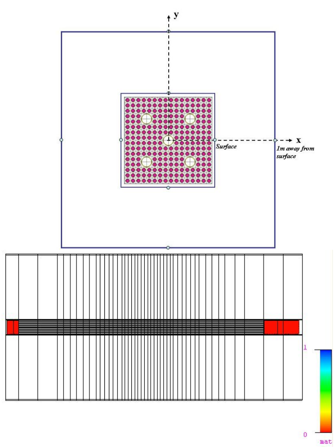

Fig 2. Evaluation points of radiation dose rate

ICRP-74(1996) is chosen as the flux-to-dose conversion factor and the number of history as $2x10^9$.[4]

2.3 Results

Table 2 shows results of the average radiation dose rates in the center of fuel assembly. The axial distributions of the dose rates are given in Fig. 3~6.

Table 2. Results of the average radiation dose rate

Item	Evaluation position of dose rates	
	Surface	1m away from the surface
Atmosphere	630 ~ 680 Sv/hr	~ 60 Sv/hr
In the water	510 ~ 570 Sv/hr	~ 8 mSv/hr

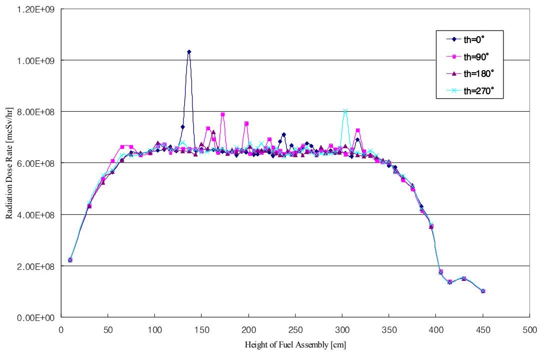

Fig 3. Axial distribution of dose rates
(fuel assembly surface, Void case)

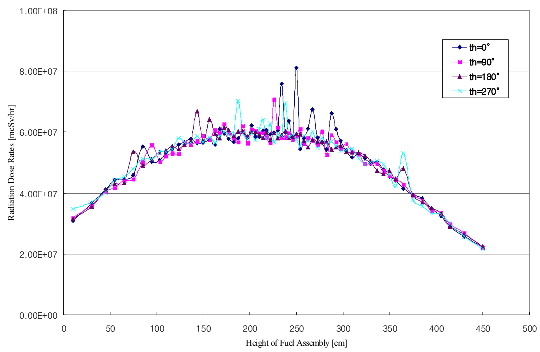

Fig 4. Axial distribution of dose rates
(1m away from the fuel assembly surface, Void case)

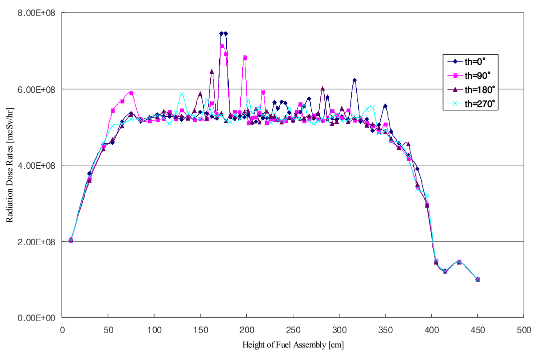

Fig 5. Axial distribution of dose rates
(fuel assembly surface, Flood case)

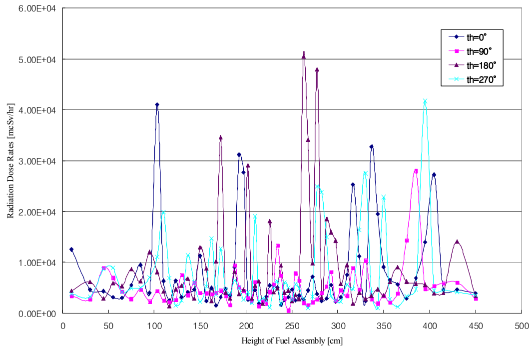

Fig 6. Axial distribution of dose rates
(1m away from the fuel assembly surface, Flood case)

Table 3 shows the radiation dose rates of each source term. The radiation dose rate comes mainly from gamma rays generated in the active fuel region. It can also be recognized that the effect of Co-60 can not be neglected in the structural materials. The neutron is more energetic than gamma rays and can survive in a large distance from SNF. The results show again the well known fact that water is a very good shielding material, especially against the neutrons.

Table 3. The maximum radiation dose rates per source terms

Item		Max. dose rates per source terms [mSv/hr]			
		Γ	Sec. γ	Co-60*	n
Void case	Surface	6.75E+5	2.8E-2	1.36E+5	2.4E+1
	1m	6.01E+4	2.0E-3	2.69E+3	1.8E+1
Flood case	Surface	5.69E+5	1.113	1.30E+5	4.262
	1m	7.865	5.5E-4	4.000	0.00

* *The value of Co-60 is the upper part or the lower part of SNF*

3. Conclusions

The radiation dose rate around a CE type SNF (PLUS7^{TM}) was evaluated. This is the simplest simulation case of the drop accident during the transport of SNF. As peripheral mediums the void and water are considered. The results reveal only the rough estimation of radiation dose rates around SNF. But those tendencies and physical backgrounds are very meaningful to understand the characteristics of SNF. We hope this paper can be the basis for the future investigations about the accident cases related to SNF.

REFERENCES

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[3] Los Alamos National Laboratory, MCNP Ver5.-User Guide, 2003.
[4] Conversion Coefficients for use in Radiological Protection against External Radiation, Annals of the ICRP, Publication 74