CALCULATION OF PHOTON DOSE FOR DALAT RESEARCH REACTOR IN CASE OF LOSS OF REACTOR TANK WATER

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ABSTRACT: This paper presents the results of institutional R&D project "*Calculation of gamma dose from the Dalat RR core in case of loss of reactor tank water*" performed by Reactor Center, Dalat Nuclear Research Institute.

Photon sources of actinides and fission products were estimated by ORIGEN2 code with the modified cross-section library for DRR using new cross-section generated by WIMS-ANL code. Photon sources of reactor tank water calculated from the experimental data.

MCNP4C2 with available non-analog Monte Carlo model and ANSI/ANL-6.1.1-1977 flux-to-dose factors were used for dose estimation. The agreement between calculation results and those of measurements showed that the methods and models used to get photon sources and dose were acceptable.

In case the reactor water totally leaks out from the reactor tank, the calculated dose is very high at the top of reactor tank while still low in control room. In the reactor hall, the operation staffs can access for emergency works but with time limits.

Keywords: ORIGEN2, WIMS-ANL, MCNP, analog, non-analog, weight windows, geometry splitting/russian roulette, point detector.

INTRODUCTION

Dalat Nuclear Research Reactor (DRR) was renovated and upgraded from a TRIGA MARK II reactor and put into operation in 1983. A series of credible incidents and consequences were estimated and presented in [1] but in case of loss of reactor tank water, photon dose in the reactor hall and control room have not yet been calculated.

In the framework of this institutional R&D project, gamma dose in the reactor hall area from the reactor core and leakage reactor water were estimated by MCNP4C2[2].

Photon sources of reactor core from the actinides and fission products were calculated by ORIGEN2 [4,5] code with modified cross-section library using WIMS-ANL [7] results for DRR.

An experiment was carried out to validate the codes and used methods. Comparison between measured and calculated results showed a fairly good agreement.

The study provide the data for dose prediction of operation staffs taking part in emergency works.

CALCULATION METHODS

The first step in calculating of the gamma dose is photon source calculation, then these results will be used for next step of dose calculation. ORIGEN2 code was used in first step to get photon sources of actinides and fission products. The cross-section library was modified for DRR by using heavy nuclide's cross-section generated by WIMS-ANL code. MCNP4C2 was used to estimate gamma dose in the reactor hall and control room in case of loss of reactor tank water. Outline of the calculation scheme is as follows:

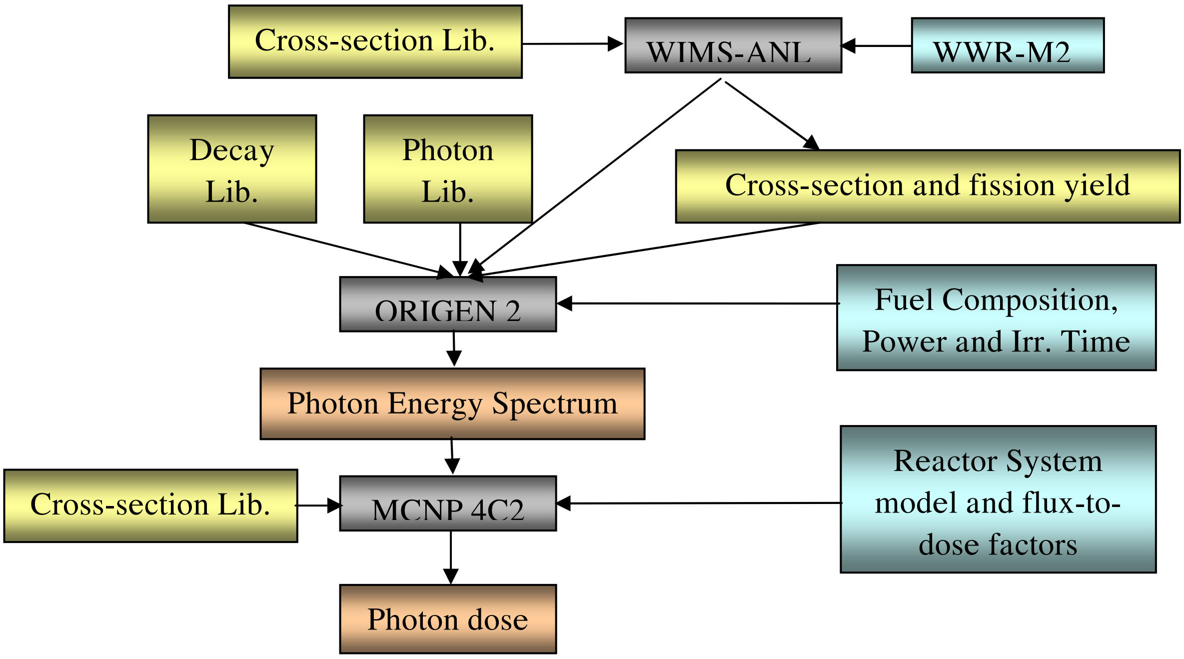

Fig. 1. Calculation Scheme of photon dose

CALCULATION RESULTS

Calculation of photon sources of actinides and fission products

As a 0-D computer code, geometry description of the system for ORIGEN2 is not necessary. The input of ORIGEN2 requires providing the fuel composition, reactor power (or neutron flux), and irradiation history. Geometrical effects were taken into account during generation of the actinides cross-sections by WIMS-ANL. Because of the cross-section changes during the irradiation time as result of material composition change, the calculated results will depend on irradiation time segmentation. In principle, the best results can be obtained by segmenting irradiation time as real operation history if it is not so complicated. In this study, the 10 latest 108 h operations were exactly modeled, the father history was segmented of about 50 day operations and 285 day cooling time alternately.

Calculation results of photon dose

Benchmark of measured data

The computer code and methods used to estimate photon sources and doses were validated by comparing to the measured dose from an irradiated fuel assembly withdrawn above water surface and under the reactor tank steel cover. A fairly good agreement between calculated and measured data affirmed that the codes and methods used in this study were acceptable.

The calculated doses using ANSI/ANL-6.1.1-1977 flux-to-dose factors were 10% as higher as those obtained by using ICRP-21. Therefore, the first ones were used in this study as a conservative choice.

Dose by the reactor core

Calculation model

The analog Monte Carlo model works well when a significant fraction of the particles contribute to the tally estimate. For the problems when the fraction of particles detected is small (< 10^{-6}), the analog Monte Carlo fails because few of the particles tally and the statistical uncertainty is unacceptable.

In the problem calculating the photon dose for the DRR in reactor tank water accident, fraction of the particles from the core contributes to the tally at the floor of the reactor building is very small. Therefore, a non-analog model (as geometry splitting or weight windows) should be used and the concrete shielding structure has to be modeled as many thin cylindrical layers. This model is acceptable as the contribution of the particles penetrate the concrete structure is very small (predicted to be one thousandth) compared to those penetrate the tank cover then scatter from the roof of reactor building and the air in the reactor hall.

Reactor core was modeled as a cylinder source divided into five homogeneous layer vertically and the proof of the reactor building was modeled flatly instead of a small slope proof.

Results of calculation

The calculated results of photon dose above reactor tank cover by the activity of actinides and fission products from the core with different water level presented in Table 1. At the water level of 0.5m above the core, photon dose predicted about 12 mSv/h after 1h of cooling and decreases to 0.8 mSv/h after 24h.

Table 2 shows calculated doses when the reactor tank water totally leaking out. After 1h of cooling time, photon dose above reactor tank was predicted as high as 144 mSv/h and 13.6 mSv/h after 24h cooling time. At the other places in the reactor hall, photon dose estimated in a range 37-83μSv/h and decreases about 10 times after 24h. At the control room, and the distances of 12m and 20m outside the reactor building, the dose were predicted to be 2,6 μSv/h, 2,12μSv/h, and 1,56μSv/h respectively.

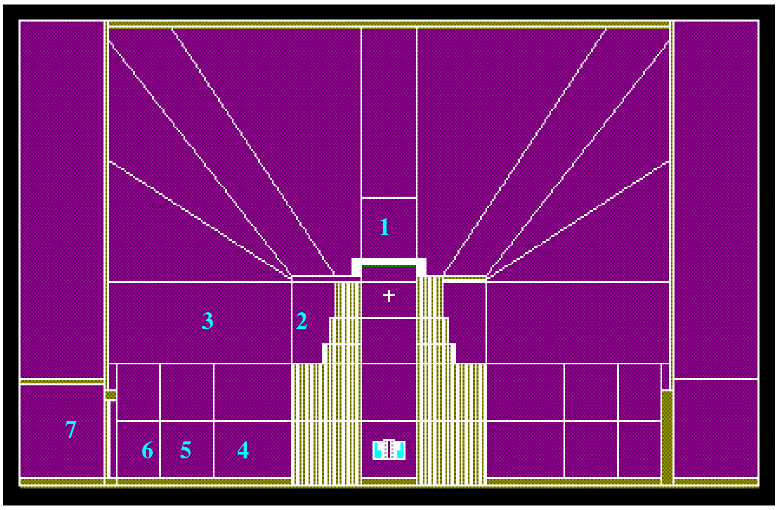

Fig. 2. Model of reactor system for MCNP (x,z)
1-Tank cover; 2-Upper part of concrete structure; 3-Above room number 148; 4,5,6-Floor of reactor building; 7- Control room

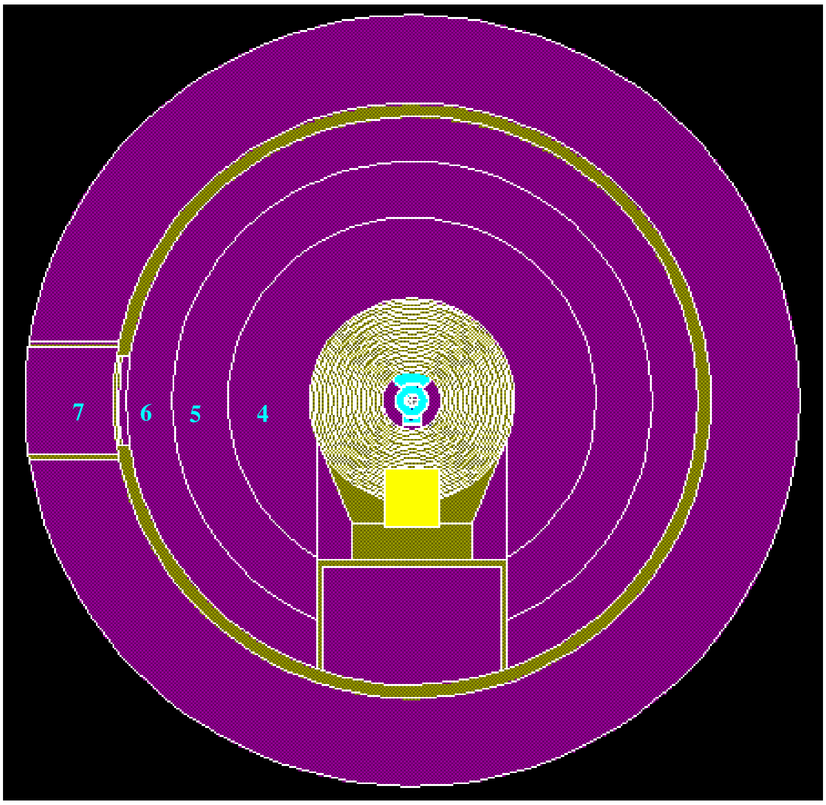

Fig. 3. Model of reactor system for MCNP (x,y,z=0)

Tab 1. Photon dose above rector tank cover (mSv/h) at different water level

Water level	Cooling time			
	1 h	5 h	10 h	24 h
0,5m	12.400	3.289	1.549	0.811
1,0m	1.600	0.362	0.154	0.076
1,5m	0.208			
2,0m	0.034			

Tab 2. Photon dose (mSv/h) of the core in reactor building and control room

Tally position	Cooling time									
	1 h	3h	5h	10 h	16 h	20 h	24 h	48 h	7 d	30 d
1	144.02258	71.73889	46.34129	24.91552	17.31536	15.01782	13.59063	10.44708	7.52413	2.43792
2	0.08323	0.04421	0.03054	0.01841	0.01343	0.01172	0.01056	0.00761	0.00485	0.00172
3	0.07832	0.04481	0.03320	0.02225	0.01695	0.01493	0.01344	0.00918	0.00507	0.00108
4	0.03693	0.01960	0.01353	0.00812	0.00591	0.00528	0.00464	0.00336	0.00215	0.00076

5	0.04792	0.02525	0.01731	0.01028	0.00745	0.00649	0.00585	0.00426	0.00276	0.00097
6	0.04676	0.02459	0.01680	0.00993	0.00718	0.00625	0.00564	0.00411	0.00268	0.00094
7	0.00264	0.00140	0.00096	0.00059	0.00043	0.00037	0.00033	0.00024	0.00015	0.00005

Dose by reactor tank water

Calculation Model

To estimate the photon dose of leakage reactor tank water, all water supposed leaking out and was modeled as a layer of 8.7cm on the floor of the reactor building.

Photon source of the reactor tank water was calculated using the experimental data[6] mainly from the activated nuclides with high activity and not too short life time as ^{24}Na, ^{27}Mg, ^{28}Al, ^{41}Ar, ^{56}Mn, ^{99m}Tc, ^{101}Tc.

Results of calculation

Table 3 presents the calculated results of dose when all reactor tank water leaks out. After 1h cooling time, photon dose in reactor hall and control room was predicted to be 30 μSv/h and 1,7μSv/h respectively.

Tab 3. Photon dose (μSv/h) of leakage tank water

Tally position	Cooling time					
	1 h	**3 h**	**5 h**	**10 h**	**15 h**	**24 h**
1	0.63	0.56	0.51	0.43	0.31	0.24
2	2.37	2.12	1.92	1.62	1.18	0.92
3	4.51	4.04	3.67	3.10	2.25	1.75
4	30.37	27.41	24.99	21.21	15.38	11.97
5	31.48	28.41	24.99	21.98	15.94	12.40
6	25.81	23.27	21.20	17.99	13.04	10.15
7	1.70	1.56	1.43	1.23	0.89	0.69

CONCLUSION

Comparison between measured and calculated results affirmed that the used computer codes and the methods were acceptable for problems of radiation protection calculation.

In case all reactor tank water leaks out and after 1h cooling time, calculated photon dose above the tank cover is very high. At the other position in reactor hall, photon dose values are not too high so that operation staffs can access for emergency works with time limits.

Calculated photon dose in control room and at the distance of 20m outside the reactor building are much lower than permissible value for operation staffs [8].

The idea of establishment of a emergency control system outside of the reactor building to avoid high radiation dose seems not to be necessary in this kind of accident.

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