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Radiation-Shielding Calculation of concrete wall in Hotcell using high burnup spent fuel rod

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1. Introduction

The hot cell facility at the Korea Atomic Energy Research Institute (KAERI) has been operating for the irradiated material experiment since 1994. Its shielding thicknesses were designed not to exceed 1mrem/hr of the regulatory dose limit, based on the result of QADS-CG code calculation [1].

The radiation source terms used in that calculation were all point sources, γ-ray, 1Mev, 10^6 Ci for 120cm-concrete wall and γ-ray, 1Mev, $2X10^5$ Ci for 110cm-concrete wall. The standard of the source term for 120cm-concrete wall was an assembly of PWR, a 14 by 14 array with 33GWD/MTU burnup and a cooling period of more than 180day. The standard of the source term for 110cm-concrete wall was a fuel rod of PWR, a 14 by 14 array with 45GWD/MTU burnup and a cooling period of more than 180 days.

As the higher burnup and the higher enrichment of fuels were developed and used in the current commercial reactor fuels, it is required that how many high burnup fuel rods can be applied in each concrete wall hot cell when compared to the old source term.

2. Methods and Calculation

In this study, the standard of source term is Westinghouse 17 X 17 PWR fuel assembly type with 5wt% of enrichment and a cooling period of 180 days. For each burnup case of 40GWD/MTU, 50GWD/MTU, 60GWD/MTU, 70GWD/MTU, gamma spectra were calculated using the ORIGEN-S module in the SCALE6.1 code system [2].

Depletion of PWR fuel assembly was applied as 3 cycle of 3 irradiation and 3 downtime. Irradiation time is 540 days, downtime is 30 days between irradiation, and a cooling period of 180 days was applied after the 3^{rd} irradiation. The constant power was used for each burnup case even though the actual rod will have a decreasing power history. The power is 24.66, 30.83, 36.99, 43.16MW/MTU for 40, 50, 60, 70GWD/MTU burnup, respectively. Gamma is the only considered in this shielding calculation analysis, so 18 groups of gamma spectra data were obtained and it was used in source in calculating shielding with Microshield 7.0 [3].

Miroshield calculates photon fluence rate at dose points and estimates the exposure rate with buildup from gamma ray radiation. In this shielding calculation, as same as the previous QADS-CG calculation at the time of hotcell design, a point source was applied and it is 30cm away from inner shielding wall. As described in Fig.1, the point source is located at the origin and two slabs were chosen as shield in the x-axis direction. Shield 1 is air and shield 2 is heavy concrete, whose densities are 0.00122g/cm^3 and 3.45g/cm^3, respectively. The dose point (detector point) is placed on the surface of outer shielding wall.

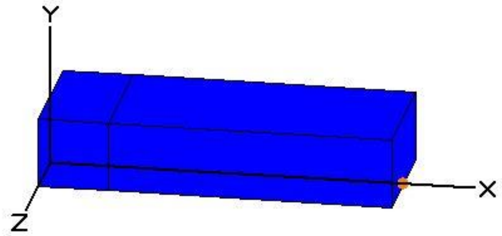

Fig. 1.Shielding wall schematic as displayed in Microshield

Source energy and strength are γ-ray, 1Mev, 10^6 Ci for 120cm-concrete wall and γ-ray, 1Mev, $2X10^5$ Ci for 110cm-concrete wall, which were the source term value used in hotcell design. As mentioned above, source data from ORIGEN were used as activity (photons/sec) at gamma energy of each burnup case.

3. Results

Results by Microshield were exposure rates (mR/hr) with buildup. The results were multiplied by a conversion factor of 8.8 in order to convert from the units of mR/hr to μSv/hr [4]. The results of dose rates for various burnup are given in Table Ⅰ.

Table Ⅰ: Dose rates of concrete wall

Burnup (GWD/MTU)	120cm-concrete (1 assembly)	110cm-concrete (1 rod)
40	5.29 μSv/hr	0.09 μSv/hr
50	6.68 μSv/hr	0.115 μSv/hr
60	8.09 μSv/hr	0.139 μSv/hr
70	9.53 μSv/hr	0.164 μSv/hr

The highest dose rate is 9.53 μSv/hr for 70GWD/MTU, which is the value that does meet the dose limit of hotcell design standard, 10 μSv/hr and also the regulatory dose limit, 12.5 μSv/hr of Zone 7000, a main working area of hotcell facility workers.

The dose rates calculated from the previous source term in hotcell design are 0.653 μSv/hr for 120cm-concrete wall and 1.181 μSv/hr for 110cm-concrete wall. Based on these dose rate results, available number of fuel rod with high burnup at 5wt% enrichment is derived in Figure 2 and 3.

A PWR assembly with high burnup cannot be applied in 120cm-concrete wall. For 60GWD/MTU, only 21 high burnup fuel rods is suggested to use in the 120cm-concrete wall.

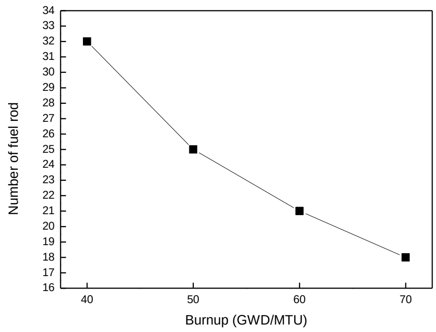

Fig. 2. Number of fuel rods in 120cm-concrete wall

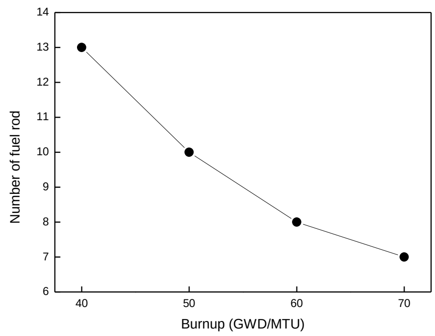

Fig. 3. Number of fuel rods in 110cm-concrete wall

For 110cm-concrete wall, more than one fuel rod with high burnup can be applied. Maximum of 8 high burnup fuel rods can be used in the 110cm-concrete wall for 60GWD/MTU.

UO_2 weight per rod is 1.984kg in Westinghouse PWR 17 by 17 assembly so that for 60GWD/MTU, 19.83kg and 41.64kg of UO_2 can be handled in 120cm and 110cm-concrete wall, respectively.

3. Conclusions

Using high burnup spent fuels, radiation shielding calculation is performed in concrete wall of hotcell. The dose rates from gamma-ray sources were calculated using the Microshield 7.0. As a result, radiation shielding capability in two kinds of different thickness concrete wall of hotcell is effective to high burnup fuel rods. Available number of high burnup fuel rods according to various burnup can be basically useful for the safe operation of hotcell facility.

REFERENCES

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