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Radiation Source Term Analysis for Wolsong Unit 1 Using MCNP/ORIGEN-2

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***Abstract*—Wolsong unit 1 in South Korea reached their design life time. In order to classify the decommissioning waste and estimate costs, the evaluation of the inventory of radioactive waste should be performed before decommissioning. In this study, radiation source term was evaluated for Wolsong unit 1, which is a CANDU type reactor, using MCNP and ORIGEN-2. In this evaluation, ORIGEN-2 was used to calculate radiation source term using revised ORIGEN-2 library, in which one group cross-section of relevant isotopes are revised by the neutron spectrum calculated by MCNP.**

***Keywords*—Radiation Source term, MCNP, ORIGEN, CANDU.**

I. INTRODUCTION

After the commercial operation of Kori unit 1, South Korea became a country that produced electricity from nuclear power plants. KHNP (Korea Hydraulic and Nuclear Power) has successively operated nuclear power plants for over the past thirty years. Now, in South Korea, twenty three nuclear power plants are operating and five nuclear power plants are under construction. Recently, some plants reached their design life time. In case of Kori unit 1 which started commercial operation in 1978, it has been operated more than 30 years, reaching the design life time. After a licensing renewal, it was permitted additional 10 years operation. In case of Wolsong unit 1 which started commercial operation in 1983, it reached the design life time last year, and is now waiting the result of the license renewal.

In this study, we conducted preliminary source term calculation for Wolsong unit 1. MCNP and ORIGEN-2 were used for the source term analysis. Using these two codes, we calculated the source term on pressure tubes, calandria tubes, and calandria tank and examined if it is possible that the decommissioning wastes can be sent to Wolsong radioactive waste disposal facility which is the only radioactive waste disposal facility in South Korea.

II. ANALYSIS PROCEDURE

The inventories of radioactive waste at pressure tubes, calandria tube, and calandria tank are calculated by ORIGEN-2 code [1]. ORIGEN-2 code uses one group neutron flux and equal neutron cross-section for each structure, which means no consideration of neutron spectrum variation in a core. To reflect neutron spectrum variation on cross-section data, MCNP code [2] is used to calculate full-core neutron spectrum used to evaluate cross-section data.

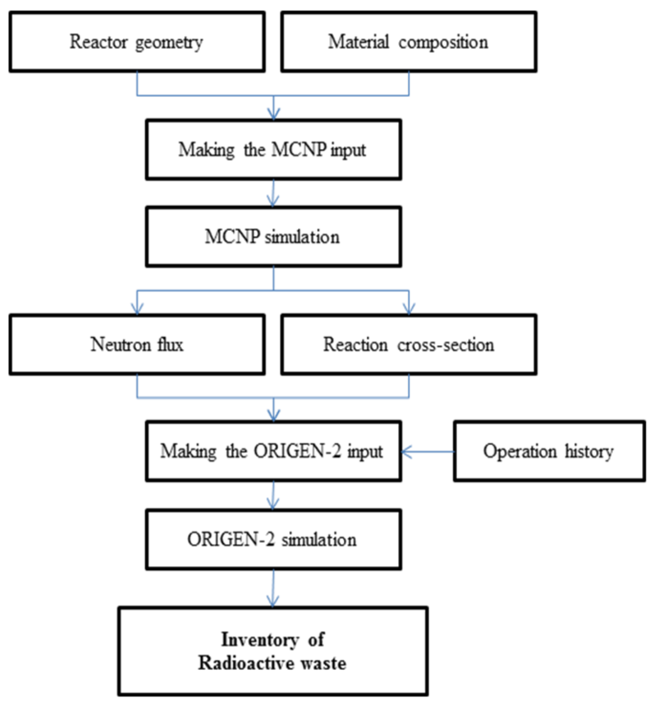

FIGURE 1 SOURCE TERM CALCULATION PROCESS

Figure 1 shows the radiation source term calculation procedure performed in the research. In ORIGEN-2 simulation phase, the cross-section revised by MCNP neutron spectrum is applied to each structure.

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A. MCNP model

Wolsong unit 1 is a CANDU type reactor. Because it uses natural uranium as fuel, it can uses heavy water as coolant, moderator, and reflector. There are 380 fuel channels containing coolant and fuel assemblies in the caldaria tank. Each fuel channel consists of pressure tube and calandria tube. There is filled by CO_2 gas between pressure tube and calandria tube. Each pressure tube has 12 fuel bundles [3]. Based on this information, we made a MCNP full core model. In order to calculate the neutron flux precisely, we modelled the reactivity devices such as adjust rods, liquid zone controllers, and guide tubes. Figure 2 shows the MCNP full core model.

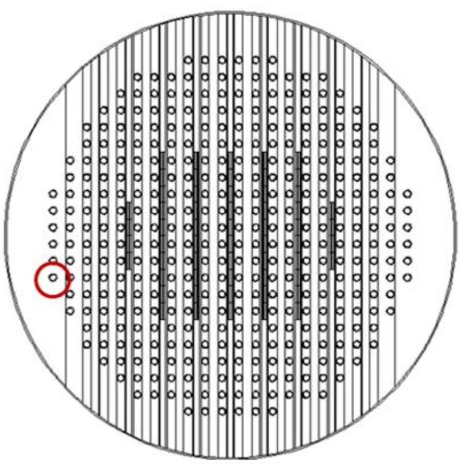

FIGURE 2 MCNP FULL CORE MODEL

B. ORIGEN-2 : Neutron Spectrum and Cross-section

In case of pressure tubes and calandria tubes, the data were extracted from left-end fuel channel. For calandria tank, the data were obtained from last 10cm region. The red circle in Figure 2 shows the position at which the neutron flux was obtained.

Each structure has different neutron spectrum. Neutron spectrum can be affected by the distance from the fuel elements, geometry of the reactor, and material composition. Figure 3 shows the neutron spectrum for each structure. Both pressure tube and calandria tube have similar neutron spectrum because they are located nearby and the material composition are similar. In case of calandria tank, it has quite different neutron spectrum because it is far from fuel element and has different material composition from pressure tube or calandria tube.

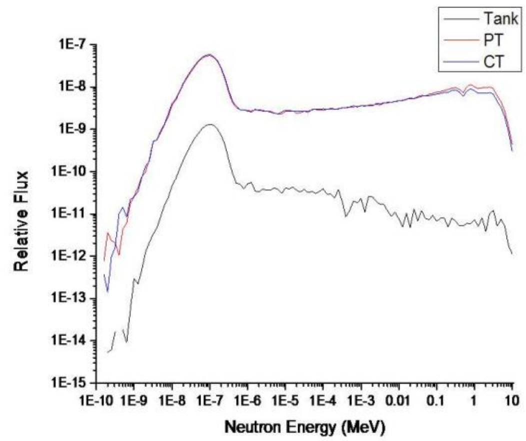

FIGURE 3 NEUTRON SPECTRUM CALCULATED BY MCNP SIMULATION FOR EACH STRUCTURE

Neutron spectrum can affect the neutron reaction cross-section. In order to get fine source term results, we have to consider neutron spectrum at interested region. ORIGEN-2 has its own cross-section library, CANDUNAU.LIB, which was derived from typical spectrum. If we use ORIGEN-2 library to calculate source term, the effect of neutron spectrum cannot be considered. Therefore, neutron spectrum corrected cross-section for each structure are derived from MCNP simulation. In this study, the (n,γ) reaction is major reaction to activate material by neutron incident; we only calculated the (n,γ) reaction cross-section from MCNP simulation. Table 1 shows the (n,γ) reaction cross-section of Ni-58 from ORIGEN-2 library (CANDUNAU.LIB) and revised cross-section from MCNP simulation. Cross-section at calandria tank is 70% larger than cross-section in ORIGEN-2 library.

TABLE 1
(N,Γ) REACTION CROSS-SECTION OF NI-58

(n,γ) reaction cross-section of Ni-58 (unit: barn)	
ORIGEN-2 library	1.373
Pressure tube / Calandria tube	1.767 / 1.882
Calandria tank	2.414

In case of pressure tubes and calandria tubes, operation history of the plant should be correctly inputted in ORIGEN-2 input. The average capacity factor of Wolsong unit 1 is 79.6 % for last 30 years. There was a grand outage to prepare license renewal from 2009 to 2011. Except this period, average capacity factor is 85.8 %. We used 85.8 % of capacity factor as representative value for the evaluation of radiation source term of Wolsong unit 1.

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III. Results Of Radiation Source Term

In order to send the radioactive waste to Wolsong radioactive waste disposal facility, activity concentration of relevant isotopes should be lower than the limit of the long-lived radioactive nuclides specified the Nuclear Safety and Security Commission Notice 2012-53 [5]. The colored-numbers in Tables 2, 3 and 4 exceed the limit of Nuclear Safety and Security Commission Notice 2012-53.

A. Pressure Tube

Table 2 shows the results of pressure tube. Specific activity of Nb-94 isotope exceeds the limit for all irradiation period. It is because pressure tube contains 2.5% of Nb-93 isotope that can be converted to Nb-94 by the (n,γ) reaction and pressure tube was exposed to high neutron flux due to close distance from fuel elements. Based on the results, pressure tubes cannot be sent to Wolsong disposal facility after decommissioning even when considering the calculation error.

B. Calandria Tube

Table 3 shows the results of calandria tube. Specific activity of Nb-94 isotope exceeds the limit for the irradiation periods over 15 years. Based on the results, some parts of calandria tubes can be sent to Wolsong disposal facility after decommissioning when irradiation period is smaller than 15 years.

C. Calandria Tank

Table 4 shows the results of calandria tank. Specific activity of Ni-59 and Ni-63 isotope excesses the limit with all irradiation period. It is because calandria tank contains 10% of Ni element and calandria tank was exposed to neutron flux for a long time. Based on the results, pressure tubes cannot be sent to Wolsong disposal facility after decommissioning even when considering the calculation error.

Table 2
Results of Pressure Tube (Bq/g)

Irradiation period	Limit	5 yr	15 yr	25 yr
C-14	2.22E+5	5.48E+03	1.47E+04	2.38E+04
Co-60	3.70E+7	4.45E+05	4.85E+05	4.52E+05
Ni-59	7.40E+4	5.90E+01	1.48E+02	2.24E+02
Ni-63	1.11E+7	7.86E+03	1.89E+04	2.76E+04
Sr-90	7.40E+4	9.68E-01	5.24E+00	1.15E+01
Nb-94	1.11E+2	**2.68E+05**	**7.07E+05**	**1.13E+06**

Table 3
Results of Calandria Tube (Bq/g)

Irradiation period	Limit	5 yr	15 yr	25 yr
C-14	2.22E+5	3.30E+03	8.84E+03	1.43E+04
Co-60	3.70E+7	3.29E+05	3.60E+05	3.37E+05
Ni-59	7.40E+4	2.00E+03	4.98E+03	7.53E+03
Ni-63	1.11E+7	2.66E+05	6.40E+05	9.34E+05
Sr-90	7.40E+4	7.03E-01	3.63E+00	7.89E+00
Nb-94	1.11E+2	3.95E+01	**1.04E+02**	**1.67E+02**

Table 4
Results of Calandria Tank (Bq/g)

Irradiation period	Limit	30 yr	40 yr	50 yr
C-14	2.22E+5	6.53E+04	9.41E+04	1.23E+05
Co-60	3.70E+7	4.10E+04	8.57E+04	1.20E+05
Ni-59	7.40E+4	**1.79E+05**	**2.58E+05**	**3.36E+05**
Ni-63	1.11E+7	**2.18E+07**	**3.06E+07**	**3.88E+07**

IV. Conclusions

In this study, MCNP/ORIGEN-2 model for Wolsong uni1 source term evaluation was verified and the preliminary source term calculation was carried out for Wolsong unit 1 which is a CANDU type reactor. The MCNP/ORIGEN-2 codes were used for this calculation. The neutron spectrum in the core was calculated from MCNP simulation, and reaction cross-sections were revised to reflect the neutron spectrum effect. Using the results of the MCNP simulation, ORIGEN-2 code was used to estimate the inventory of radioactive nuclides. These results were compared with NSSC Notice 2013-53 to access if it is possible that the decommissioning wastes can be sent to Wolsong radioactive waste disposal facility.

According to the preliminary calculation, pressure tubes and calandria tank cannot be sent to Wolsong disposal facility because of long-lived radioactive nuclides such as Nb-94, Ni-59, and Ni-63. In order to dispose of these decommissioning wastes, we have to consider alternative method to store the waste containing long-lived radioactive nuclides. In case of calandria tube, it can be partially sent to Wolsong disposal facility when irradiation period is smaller than 15 years. We only conducted source term calculation at low neutron flux region and it is expected that specific activities of calandria tube in the core would exceed the limit of disposal in case of more than 5 years operation.

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REFERENCES

[1] G. Croff, A User's Manual for the ORIGEN2 Computer Code, ORNLTM-7175, Oak Ridge National Laboratory, (1980) .

[2] DX-5 Monte Carlo Team, MCNP-A General Monte Carlo N-Particle Transport Code, Version 5, LAUR-03-1987, LosAlamos National Laboratory, (2003).

[3] Design Manual: CANDU 600 Generation Station Physics Design Manual,'' DM-59-01100, Atomic Energy of Canada Limited, (1980).

[4] 2014 Nuclear Energy White Paper, Ministry of Science, ICT and Future Planning, (2014).

[5] NSSC Notice 2012-53, Delivery Regulation for Low- and Intermediate-level waste, Nuclear Safety and Security Commission, (2012).