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Analysis of the Radiation Field for 100 MeV Beam Line of the PEFP

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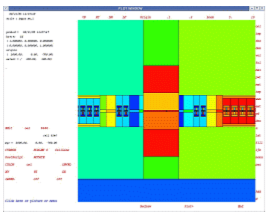
1. Introduction

In Korea, the Proton Engineering Frontier Project(PEFP) is building a proton linear accelerator facility with 100 MeV - 20 mA. For these facilities, a radiation shielding is considered necessary because of the high current of the proton beam. The analysis of the Radiation field from 20MeV beam line of the PEFP was performed in the previous study. In this study, The DTL tanks for acceleration in the energy range of 20~100 MeV were added to a previous facility model and analysis of the prompt and residual radiation field are performed.

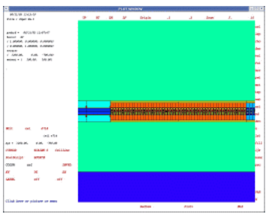
2. The Model and Source

2.1 Facility Modeling of the PEFP

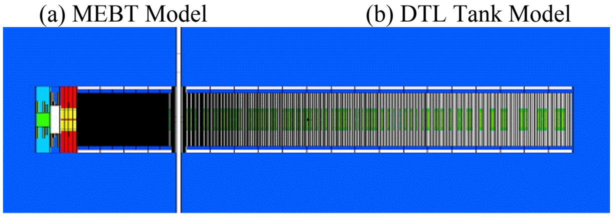
The accelerator tunnel building inside and 100 MeV beam line were modeled with the MCNPX 2.5e. The 100 MeV beam line consists of an injector, LEBT, RFQ, 20 MeV DTL tank assembly with 4 tanks, MEBT and 20~100 MeV DTL tank assembly with 16 tanks. In this study, modified model from 20 MeV beam line model of the previous study was used for accelerator equipments modeling. MEBT and 20~100 MeV acceleration DTL tank assembly was added to 20 MeV beam line model and 20 MeV beam dump was excluded. MEBT consists of two bunchers and one bending magnet. The 20 MeV beam is extracted from the magnet filed in this equipment to send the beam utilization building. 20~100 MeV DTL tank assembly consists of 16 tanks of DTL. The results of modeling are shown in Figure 1.



(a) MEBT Model



(b) DTL Tank Model



(c) 100 MeV Beam Line Model

Figure 1. MCNPX Model for Beam Line of the PEFP

2.2 Evaluation of the Radiation Source Term

The prompt radiation field should be evaluated for safety analysis and determining operation conditions. And residual radiation field should be evaluated for determining the operation schedule and control of the exposure for the maintenance or other works. The radiation sources of prompt radiation field are the energetic particles produced from operating accelerator. These are mainly neutrons from proton induced reactions with materials of accelerator equipments. And other particles are produced also from proton induced and neutron induced reactions. Using MCNPX code, the prompt radiation sources, neutron, proton, electron, and gamma-ray from operating accelerator were evaluated from operating accelerator. And prompt β^+ and gamma-ray are evaluated also with NMTC/JAERI97 code. From calculation, neutrons are evaluated as a main radiation source, because other particles have very low production rates. The radiation source terms were evaluated for each component of the accelerator equipments for calculation efficiency. As a result, total 22 source terms are evaluated for each of the injector-LEBT, RFQ, 20 MeV DTL 4 tanks, and MEBT- 100 MeV DTL 16 tanks. The neutron spectra in the 100 MeV DTL 16 tanks from these calculations are shown in Figure 2.

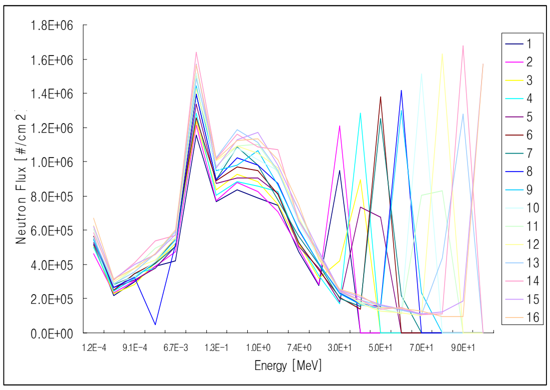


Figure 2. The Neutron Spectra in the 20~100 MeV DTL tanks 16 units

The radiation sources of the residual radiation field are activation products from proton induced reaction or neutron induced reaction. There are two kinds of the these sources. First are activation products produced from the reactions between accelerated protons or neutrons and the materials of the accelerator equipments. The production rate of activation products from these reactions were calculated using DCAHIN-SP code and MCNPX code. Second one air activation products produced from the reaction between air and neutrons escaped from accelerator equipments. The main activation products, ^{3}H, ^{7}Be, ^{11}C, ^{13}N, ^{15}O, and ^{41}Ar, are evaluated with the neutron spectra from the radiation source of the prompt radiation field using MCNPX code. The production rates of the activation products in air are shown in Figure 3.

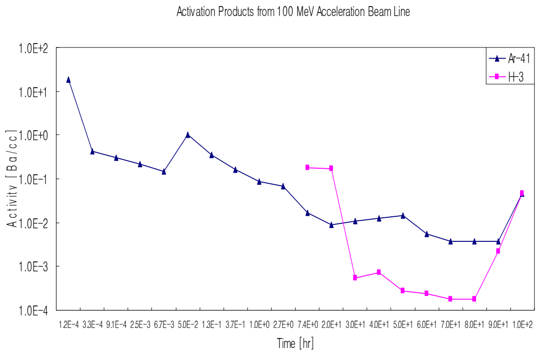


Figure 3. The Production Rate of the Activation Products in Air

3. Results of the Calculation

3.1 Prompt Radiation Field Distribution Mapping in the PEFP

With 22 unit of the radiation source terms and facility model of the PEFP, the prompt radiation field distribution are calculated as a form of the dose map. The space in the accelerator tunnel building is divided into $5 \times 1 \times 1$ m meshes. The average ambient dose for each mesh is calculated using the mesh tally cards of the MCNPX code and with the option for an ambient dose calculation based on the ICRP-74. The calculated dose distribution is shown in Fig 4. The doses at the outer surface of the accelerator equipment range from 1.59×10^{-7} to 70.6×10^{1} mSv/hr from a beam loss. The maximum dose rate is calculated near the 16th DTL tank assembly of the 20~100 MeV DTL tank assembly.

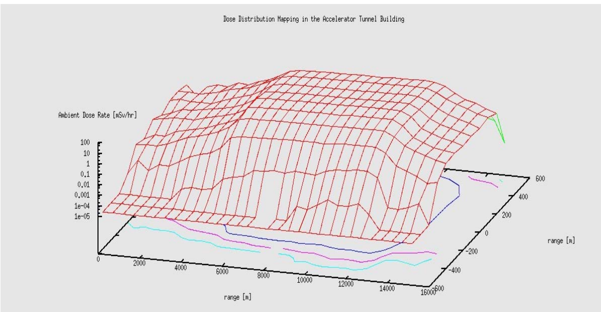


Figure 4. The Ambient Dose Distribution Map in the Accelerator Tunnel Building for Prompt Radiation Field

3.2 Analysis of the Residual radiation field with Time Evolution

With the evaluated production rate of the radionuclide for air and accelerator equipments, the analysis of the residual radiation field was performed. Because the radiation sources of the residual radiation field are the decay of the radionuclides, this field changes with cooling time. Additionally, for the case for the air activation, this field changes ventilations of air also. Therefore the analysis of the activation with time evolution was performed for each of the air and accelerator equipments. and the gamma-ray spectrum from the radionuclide of the equipments was applied as source and the distribution in the accelerator tunnel building are calculated. And for the case of the air activation, the ventilation condition was studied to satisfy the limits of the radionuclide concentration. The activity in the air from calculations is shown in Figure 5.

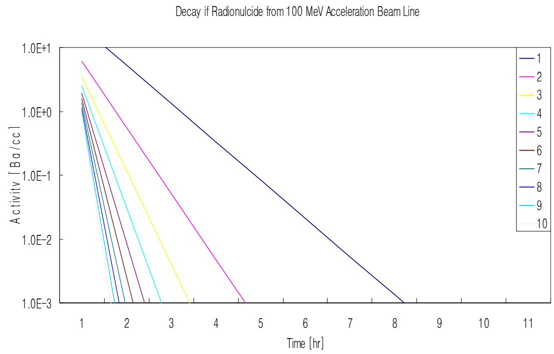


Figure 5. Activities of the Activation Products in Air with Time evolution and ventilation

4. Conclusion

In this study, modeling for the 100 MeV full acceleration beam line of the PEFP and the evaluation of the radiation source term from operating accelerator and activation products were evaluated. from these results, the analysis of the prompt and residual radiation field in PEFP was performed. And this study will be extended to safety analysis including an accident analysis.

REFERENCES

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