The Design of Shielding for Target Room of the Proton Accelerator Research Center

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1. Introduction

Proton Engineering Frontier Project (PEFP) has been developing a 100 MeV proton linear accelerator. Also, PEFP has been designing the building of the Proton Accelerator Research Center (PARC).

In Accelerator Tunnel & Beam Experiment Hall in PARC, 5 target rooms for the 20 & 100 MeV beamline facilities exist in the Beam Experiment Hall, respectively. For the 20 MeV target rooms under normal operating conditions, because dose limit is satisfied with concrete wall thickness determined by structural design analysis, the additional shielding design of 20MeV target rooms is unnecessary. Therefore, a major concern of the target rooms shielding design in this paper is 100MeV target room design. For the 100MeV target rooms during 100MeV proton beam irradiation, a number of high energy neutrons, ranging up to 100MeV, are produced. Because of high beam current and space limitations of each target room, shielding design of each target room should be considered seriously.

For the shielding design of the 100MeV target rooms of PEFP, permanent and removable local shield structure was adopted. From the shielding calculation results using the MCNPX simulation code[1], we confirmed that proposed shielding design makes it possible to keep dose rate below the ALARA objective.

2. Design Parameters of Target Rooms of PARC

In Accelerator Tunnel & Beam Experiment Hall of PARC, 5 target rooms for 20 MeV and 100 MeV exist to utilize proton beam. Layout of the 20MeV and 100MeV target room is illustrated in Fig. 1.[2]

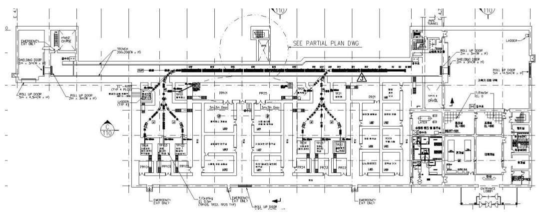

Fig. 1 Layout of the 20 and 100MeV Target Room of PEFP

2.1 Design Limits for the Target Room Shielding

To keep radiation exposure below regulatory limits of Korea, shielding requirements (design limit) are based on maintaining exposure assuming 2,000 hours occupancy per year for a worker and 50 % safety margin. Design limits for the radiation worker and general public are 12.5 uSv/hr and 0.25 uSv/hr, respectively.

Table 1 describes design limit for radiation area classification of the Proton Accelerator Research Center of PEFP.

Table 1. Classification of Radiation Area and Dose Limit

Area	Design Limit (uSv/hr)
General Public Area	≤0.25
Radiation Worker Area	0.25 < DL ≤ 12.5
High Radiation Area	> 12.5

2.2 Operation Scenario & Accessibility for Target Room

To design the radiation shielding appropriately, we should know the operation scenario and accessibility. Target system operation scenarios of PEFP were modeled as follows:

Assumption: 20 MeV and 100 MeV beam utilities are not operated together.

Operation Scenario: In 100 MeV Target Systems operation

- The five rooms are categorized as 3 groups which are operated exclusively to each other.

Group 1 : TR101
Group 2 : TR105
Group 3 : TR102, TR103 or TR104

For the 100MeV target rooms, access to TR102, TR103 and TR104 can be permitted after beam shut down. Although its beam shut down, access to TR101, TR105 and beamline enclosure is restricted when one of the 100MeV beams is in operation.

2.3 Operation Conditions & Design Parameters for each Target Systems of PEFP

Operation conditions of each target system of PEFP, such as average beam current, the reference target materials and target dimension is described in Table 2.

Table 2. Target Rooms Operation Condition in PEFP

Target Room	Average Beam Current (mA)	Target Material	Target Dimension [mm] (L X W X H)
TR101	0.6	Ag	300 X 300 X 20
TR102	0.01	H20	300 X 300 X 150
TR103	0.3	Si	300 X 300 X 100
TR104	0.01	Si	300 X 300 X 100
TR105	1.6	W	300 X 300 X 20

3. Calculation Results

The neutron production yields from 100MeV target of PEFP were calculated using MCNPX 2.5, which are described in Fig. 2.

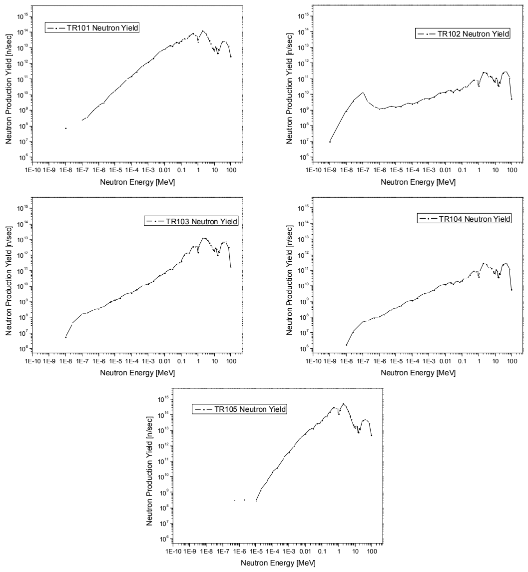

Fig. 2. Neutron production rate in each 100 MeV target room

The shielding design was optimized with 4 different shield materials (concrete, HDPE, lead, iron) over limited maximum wall thickness.

In this paper, the shielding scheme of TR101 is described, and the others skip the detailed description because of using the repeated method.

Dose calculation at the forward wall respect to beam direction of TR101 was performed both outside the shielding wall and outside the hot cell lead glass. Fig. 3 describes dose rate of TR101 according to the forward iron shield thickness increases up to 120cm. Calculation results show that when the thickness of the iron plate in the concrete shield wall increased up to 90cm, dose rate outside of the total shielding of TR101 are decreased accordingly. Whereas, as shown in Fig. 3, as iron plate thickness increases of more than 90cm, dose rates outside the total shielding wall increase with increased iron plate thickness. Therefore, iron plate thickness is fixed to 90cm, which is described in Fig. 3. For 90cm iron plate, the dose rate is still found to exceed the design limits. Therefore, forward shielding need to be supplemented by additional local shielding.

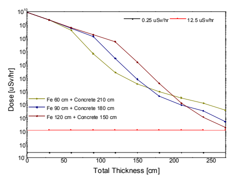

Fig. 3. Dose rate of TR101 according to the iron thickness up to 120 cm

Fig. 4 describes dimensions and structure of the local lead shielding block. As shown in Fig. 4, lead block arrangement is analogous to a T-shape having laterally extending wings. The purpose of the lateral wings is to shield peak neutrons emitted in the forward direction. Additionally, the lateral wings would make it possible to minimize lead block size. Fig. 4 describes the effect of changes in dose rate outside the target room shield wall and outside the hot cell window by the lead block length of Part A. We assumed that lead block length of Part A changes up to 60cm.

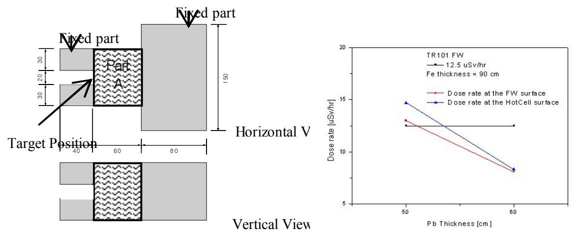

Fig. 4. Local Lead Shield Structure for the 100MeV Target Room (cm)

To reduce prompt radiation(neutron and gamma), 270cm thickness of roof shield is needed in the roof of TR101. The dose rate outside the roof should be at least below 0.25μ Sv/hr. Shielding structure for the roof is concrete-iron-concrete structure. The thickness of iron shield was changed as 90, 100, 110 and 120cm, leaving the total thickness of the roof shield unchanged (270cm thickness of roof shield), which are described in Fig. 5.

Calculation results show that when the thickness of the iron plate in the concrete shield wall increased up to 120cm, dose rate outside the roof are decreased accordingly. When the iron thickness is 120cm, the dose rate outside the roof is found to satisfy the design limits.

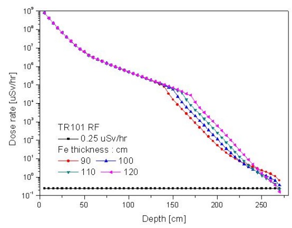

Fig. 5 Dose Rate changes at the roof surface according to the iron shield thickness

REFERENCES

[1] MCNPX User's Manual Ver. 2.5.0, April, 2005, LA-CP-05-0369

[2] J.M. Nam, K.J. Mun and J.Y. Kim, "Optimization of the Facility Plot of the Proton Accelerator Research Center", 2007 KAPRA & KPS/DPP Conference.