§16. Radiation Shielding Analysis for LHD Deuterium Plasma Experiment

Yamanishi, H., Nishimura, K.

There is a plan of D-D reaction experiments for the next phase of the LHD. The number of neutrons generated from a standard one-shot experiment was assumed to be 9.8×10^{15} for 2.45 MeV with a DD reaction, and 1.8×10^{14} for 14 MeV with a DT reaction. Fig. 1 shows the vertical cross section of the LHD building. The room installed the LHD has a size of 45 m depth ×75 m width ×45 m height, and has 2-m-thick concrete walls and a 1.3-m-thick concrete ceiling. The dose rate at inner surface of the building wall is 71 mSv/shot, and that outside the building wall is 2.7×10^{-7} mSv/shot. All pipes related with the LHD cross the ducts of the floor with 2 m thick concrete, and go through the cellar in order not to penetrate neutron with streaming to above the ground. Neutrons go through many holes from the cellar to the adjacent rooms. The work place exposed the highest dose during plasma experiment is the Diagnostic room (D-room) where is the adjacent to the cellar. In this study, the neutron energy fluence in D-room has been evaluated, and a monitoring instrument for this room has been discussed.

In this study, here shows only a result for an example, but there may have some other conclusions on the other conditions. Although the experimental shot is planned up to 3200 shot in annual, the all shots would be assumed to do in three month for planning the radiation protection. Since the dose at the boundary of controlled area is limited to 1.3 mSv per 3 months, in Japan, the dose per shot at this place should be limited less than 4×10^{-4} mSv. Additionally, because there are many pipe holes on the wall of the room, the upper planned dose should be half of that.

Neutrons from the LHD go through to the cellar via the ducts in the floor of LHD room. There are many through-holes in the wall between the cellar and the D-room. Neutrons in the cellar go through to the D-room via these holes. The dose at the outlet of a through-hole in the D-room is derived by the following three steps of calculations.

In the 1st step, the LHD and its room were modeled with R-Z geometry, and the neutron fluence data including the direction and the energy distribution on the floor of the LHD room were obtained using the two dimensional Sn radiation transport code DORT with MATXLIBJ-33 nuclear data set. This obtained neutron intensities are varied with the distance from the center of the LHD. There are many ducts in the floor of the LHD room, which go through to the cellar. These ducts are categorized as four types according to the distance from the center of the LHD. In the 2nd step, using this obtained neutron source, the dose distribution in the cellar from each duct was estimated by means of DORT code. The size of the cellar is 45 m depth ×45 m width ×11 m height. These ducts are modeled in four types to be annular in shape, with a center axis that coincides with the distance from the center of the LHD. Calculations for a single annular duct were modeled and performed. The dose distributions for four types of duct were modified according to the ratio of these real duct areas to the annular area. Then, the whole dose at a space point was obtained by summing up the contributions from all ducts, with the modified results for the four types of duct. In this manner, the total neutron and gamma ray dose distribution in the cellar was obtained. Dose is evaluated by fluence data and dose conversion factors. The dose before entering to the D-room, the inlet of the through-hole, was calculated as 0.88 mSv/shot. In the 3rd step, the dose at the outlet of the through-hole with diameter 20 cm was 1×10^{-3} mSv/shot obtained with MCNP using this source. This result suggest that it needs some additional shield for reduction the dose to 2×10^{-4} mSv/shot. Finally, it is found when it needs to remain a 5-cm-diameter aperture to this hole, the plug of a 1-m-length polyethylene cylinder is required to reduce the dose to less than 2×10^{-4} mSv/shot. Fig. 2 shows the energy spectrum at the inlet and outlet of the through-hole in the D-room. The components of low and intermediate of energy constitute a great portion.

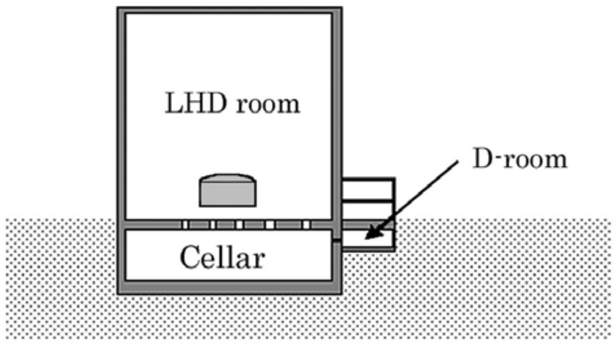

Fig. 1. Cross-sectional view of the LHD building.

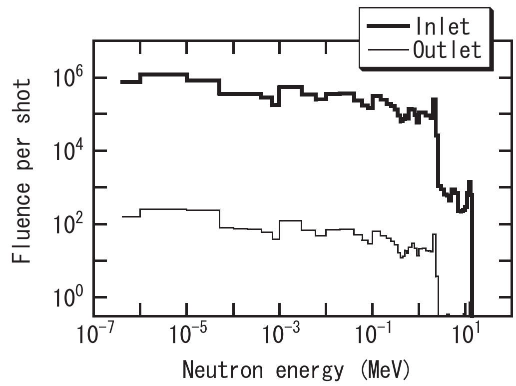

Fig. 2. Calculated neutron fluence inlet and outlet of the through-hole.