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Radiation Shielding of KSTAR device in 2017 campaign and future Plan

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1. Introduction

The KSTAR device is a superconducting fusion experiment device. The fusion reaction takes place inside the plasma. During plasma experiments, neutrons and other ionizing radiation are released and radioactive materials are generated by neutron nuclear reactions. In this paper, we have dealt with designing and measuring the shielding of radiation generated during plasma experiments to satisfy the design conditions.

2. Methods and Results

This section describes the structure for radiation shielding of KSTAR devices and the measurement method for checking the shielding performance.

2.1 Shielding Overview

The source of KSTAR is the D (deuterium) -D (deuterium) reaction and the D (deuterium) -T (tritium) reaction. KSTAR tests the DD reaction during the fusion reaction, but the T and D Secondly, DT fusion reaction is also induced.

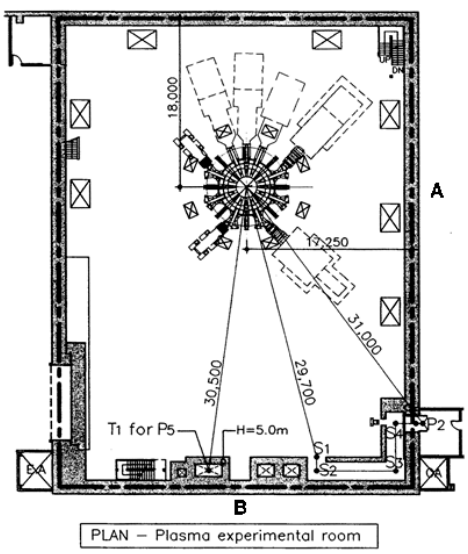
(Primary fusion reaction)
D + D = 3He (0.82 MeV) + n (2.45 MeV)
D + D = T (1.01 MeV) + p (3.02 MeV)

(Secondary fusion reaction)
D + T = 4He (3.5 MeV) + n (14.06 MeV)
D + 3He = 4He (3.6MeV) + p (14.7MeV)

In the above equation, neutron 2.45 MeV and 14.06 MeV are important sources of radiation safety management in KSTAR operation, so special care is required. When the neutron generation rate is 1.2E20 [1], the thickness of the shielded wall made of concrete is calculated as 150 cm. The neutron and secondary gamma rays are generated from the outer surface of the wall at the shortest distance (1800 cm) from the center of KSTAR in the plasma experiment room the sum of radiation dose was calculated as 0.55mSv/year. Therefore, although the outside of the shielding wall can be freely accessed by the general public, safety margin is not large because it is possible to release a high radiation dose locally due to various utility holes and the like. Therefore, additional shielding and access to the public should be restricted to the local area.

The entrance of the radiation management area minimizes the exposure of the radiation worker by installing an internal scattering wall as shown in Figure 1 in consideration of scattering which is characteristic of the neutron. The concrete shielding wall for shielding the photons that can be generated by the interaction of the neutron and the fusion experiment equipment is 150 cm. This shielding wall was installed to prevent radiation from leaking out of the radiation management area. To confirm the shielding performance, a cumulative instrument is installed on the shielding wall.

Fig. 1. Horizontal cross-section of plasma laboratory



(radiation dose evaluation points: A, B)

2.2 Measuring devices for Shielding

Two measurements are used to determine the shielding of radiation that occurs during plasma experiments. One uses a cumulative dosimeter and the other uses a radiation monitoring system (RMS). The cumulative dosimeter measures the dose and the RMS monitors the dose rate in real time. The cumulative dosimeters use OSL (Optical Stimulated Luminescence) neutron and gamma ray dosimeters. The OSL dosimeter measures the emitted fluorescence by irradiating the irradiated aluminum oxide with light of a specific wavelength. The amount of this fluorescence is proportional to the amount of radiation irradiated. Neutrons are also measured using the nuclear reaction of Li-6. The measured dose range is 0.01mSv-10Sv and can be measured repeatedly. [2] And the same measurer is wearing by radiation workers. The OSL dosimeter was read quarterly like the radiation worker, and the values were used in Summed up

Table 1. Dose measurement in 2017(unit : mSv)

Location	2017		
	Gamma	Neutron	Total
1.D-Port	11,682	15,913	27,596
2.G-port flange	1,727	2,295	4,022
3.Surface of Cryostat	270	1,004	1,274
4.Inside of Tokamak hall	50	552	602
5.Tokamak hall D1	8	49.98	57.91
6. Tokamak hall D3	0.47	5.53	6.01
7. Top center	101.47	360.88	462.36
8. NBI Ion source	61.14	359.94	421.09
9. NBI dummy	105.49	397.64	503.14
10. Inside of Tokamak hall	55.09	484.94	540.04
11.Entrance	0.11	1.9	2.02
12.Helium facility room 1	0	0.19	0.19
13.Heating device room	0	0	0
14.ERMS post 1	0	0	0
15.ERMS post 2	0	0	0
16.ERMS post 3	0	0	0
17.Helium facility room 2	0.1	0	0.1
18.Gyrotron	0.07	0	0.07
19.Diagnostic room D1	0.29	0	0.29
20.Rooftop	0	0	0

Measurement tools 1-11 are radiation management areas. However, since it is prohibited to enter during plasma experiments, it is not related to human exposure. And the 12th to 20th instrument is a general area. Management 1 is attached inside the cassette. This position is the closest to the plasma and the highest dose is measured. In 2016, helium 1 room, which recorded 0.77 mSv, decreased to 0.54 mSv after shielding replenishment, and in 2017 it decreased to half of that in the previous year. The plasma laboratory inner wall in the heater chamber direction is 540 mSv, but the outside of the shield wall is shielded from most of the radiation below the recording level(0.1mSv/quater). Even with leakage due to the installation of the helium line, the direction of the helium installation room is less than the allowable dose (1 mSv / year) due to the shielding effect. In addition, since the dose limit of radiation workers is 100mSv / 5years, there is no risk of exposure exceeding the restricted level. ERMS posts 100m, 200m and 300m from the KSTAR device were recorded below the record level and the shielding level was satisfactorily evaluated on the roof of the plasma laboratory. However, the area of the basement diagnosis room is 0.29mSv, which is the same as 2016 and it is 0.29mSv.

RMS uses a He-3 detector for neutron measurements and a semiconductor detector for gamma rays. The neutron dose rate inside the shielding wall during the plasma experiment is shown in Fig3. The neutron dose rate in the interior of the shielding wall (N16) was 527 mSv / h maximum during the entire operation period in 2017, but the dose rate outside the shielding wall was measured as the natural radiation level. The gamma ray dose rate of the inside of the shielding wall (G13, 14, 15) was recorded as 141mSv / h maximum as shown in Fig. 4 and the outside of shielding wall (G11) was measured as natural level like neutron.

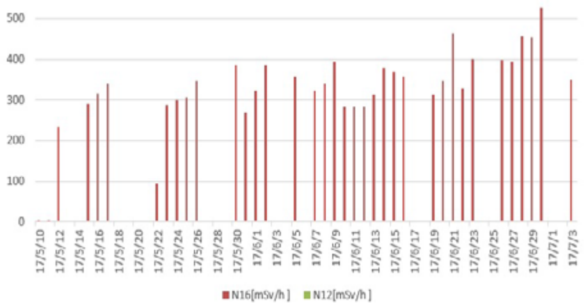


Fig.3 Neutron dose rate on daily max in 2017

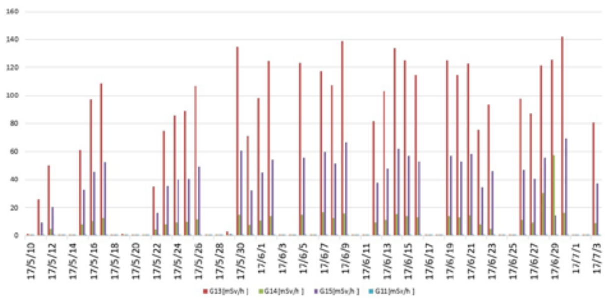


Fig.4 Gamma dose rate on daily max in 2017

3. Conclusions

Cumulative radiation dose and dose rate were measured in the plasma laboratory and outside. Because the amount of neutron generated per year is less than the design standard and the shielding margin is high, only the natural level is measured outside the shielding wall as a result of the two measurements. In the cumulative dosimeter, the radiation dose around the opening was slightly higher than the natural level. These parts will continue to be of interest and should be shielded if necessary.

REFERENCES

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[2] E.G.Yukihara "Development of newoptically stimulated luminescence (OSL) neutron dosimeters" Radiation Measurements 43, p.309–314, 2008.