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Release of tritium from the Large Helical Device in the mid-term deuterium plasma experiment

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When a plasma experiment using deuterium (D) gas is conducted in a large fusion test device, a small amount of tritium is produced in the plasma. The produced tritium can be used to evaluate tritium behavior and inventory in fusion systems as a tracer because of its small amount. As one of the large fusion test devices, the deuterium plasma experiment with the Large Helical Device (LHD) have started on March 7th, 2017. From the viewpoint of public acceptance, the exhaust detritiation system (EDS) was installed in LHD to remove tritium in the vacuum exhaust gas or purge gas in vacuum vessel during maintenance activity. The EDS is connected to all the exhaust systems of the LHD, and tritium monitoring at the inlet of the EDS is suitable for evaluating the tritium balance. From the start of the deuterium experiment to the present, tritium released from the vacuum vessel has been continuously observed both during the plasma experiment and during vacuum vessel maintenance activities. In this study, the tritium release behavior from LHD was investigated during the mid-term deuterium plasma experiment.

Tritium was released from the vacuum vessel either directly by vacuum pumping under the plasma discharges or by wall conditioning operations or by air exposure operations due to opening the vacuum vessel to the atmosphere. Tritium in the exhaust gas was measured by an ionization chamber for real-time monitoring and a water bubbler system with chemical form discrimination for accumulated monitoring. On the other hand, the tritium produced in the deuterium plasma was estimated by neutron measurements, assuming that the number of neutrons is the same as the tritium produced by the D-D fusion reaction. Figure 1 shows the amount of released and produced tritium, accumulated tritium exhaust rate, and tritium inventory in LHD from 2017 to 2021. The tritium inventory shown in Figure 1 (c) takes into account tritium decay with a half-life of 12.3 years. Tritium released from the vacuum vessel was mostly during D and hydrogen (H) plasma discharges but was also observed when the vacuum vessel is opened to the atmosphere. The accumulated tritium exhaust rate, defined as the ratio of the amount of produced tritium to the amount of released tritium since the start of the deuterium plasma experiment, decreases when deuterium plasma experiments are conducted, indicating that some of the tritium produced remains in the vacuum vessel. The tritium analysis of the plasma-facing material after the 1st deuterium plasma experiment suggests that most of the tritium is retained in the divertor plates. However, during H plasma discharges and when the atmosphere is opened, the exhaust rate increases and approaches a constant exhaust rate (~44%). Since the annual tritium exhaust rate is about 40~50%, the tritium inventory in the vacuum vessel is increasing year by year. The tritium in the vacuum vessel is not saturated in the mid-term of the deuterium experiment, probably due to the low tritium yield.

Speaker's Affiliation

National Institute for Fusion Science, National Institutes of Natural Sciences, 322-6, Oroshi, Toki

Member State or IGO

Japan

Author: TANAKA, Masahiro (National Institute for Fusion Science)

Co-authors: Ms KATO, Hiromi (National Institute for Fusion Science, National Institutes of Natural Sciences); Mr CHIMURA, Hiroki; Mr SUZUKI, Naoyuki (National Institute for Fusion Science, National Institutes of Natural Sciences)

Presenter: TANAKA, Masahiro (National Institute for Fusion Science)

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