§1. Investigation of LHD Exhaust System

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In order to realize the planned deuterium plasma experiments using the Large Helical Device (LHD), the National Institute for Fusion Science (NIFS) is planning to install systems for tritium recovery from exhaust gas[1)-3)].

To determine the fabrication specifications, it is necessary to understand the conditions at the transition point between the LHD vacuum pumping system and the tritium recovery system, such as the hydrogen gas concentration and exhaust gas flow rate. For this purpose, measurements were carried out on the present vacuum pumping system.

To measure the hydrogen concentration and gas flow rate simultaneously, gas sampling lines were installed before and after the exhaust blower.

Table 1 compares the specifications of two different hydrogen monitors used in the investigation, a thermal conductivity sensor and a combustible gas sensor (Model:PE-2DC, New Cosmos Electric Co., LTD, Japan). The two monitors were installed in the sampling line at the blower exit and the hydrogen concentration was measured. Pure He gas was fed to the sampling line at the blower entrance at a constant flow rate.

The increment in concentration by the addition of He gas was determined based on the difference in values measured by the combustible gas sensor (where only hydrogen can be detected) and by the thermal conductivity sensor (where both hydrogen and helium can be detected).

The flow rate of the exhaust gas was evaluated from the dilution rate of the pure He gas.

Table 1 Specification of different H_2 monitors used

Hydrogen monitor	Type of sensor	Detection range	Detection limit
No.1	Gaseous heat conduction	0 -10%	0.1 %
No.2	Gaseous heat conduction	0 – 100%	0.5 %
No.3	Flammable gas combustion	0 – 4%	0.1 %

The hydrogen concentration measured during regular exhaust operation, in which the inside of the LHD vacuum vessel is maintained under a high vacuum condition, was below the detection limit of the hydrogen concentration monitor (0.1%), in contrast to the expected concentration (about 60%). Upon investigation of the source of the unexpectedly high exhaust gas rates (500 to 600 Nm3/h), it became clear that evaporated liquid nitrogen from cooling of the cryo-pumps of the Neutral Beam Injector (NBI) was being discharged into the vacuum pumping system.

A detectable concentration of hydrogen was observed during NBI cryo-pump regenerative operation. The simultaneous measurement of the exhaust gas flow rate and hydrogen concentration under continuous helium gas addition at a fixed flow rate (20 NL/min) was carried out.

The value measured by the thermal conductivity sensor corresponds to the sum of the hydrogen and helium concentrations. Again, based on the difference between the values measured by the two types of hydrogen monitor, it is possible to determine the increase in helium gas concentration under continuous helium gas addition at a fixed flow rate.

Based on the measured increase in helium gas concentration, the time dependence of the exhaust gas flow rate can be estimated as shown in Fig. 1.

The intermittent increase in exhaust gas flow rate suggests that the hydrogen discharge time is about 5 minutes and the discharge hydrogen gas flow rate is about 50 Nm3/h, giving a discharge volume of hydrogen gas of about 4 m3. The evaluated volume of hydrogen gas agrees fairly well with the average amount of hydrogen gas consumed during the NBI operation (1.7 m^3 per unit NBI). The sharp increase in exhaust gas flow rate at the time of about 110 minutes corresponds to the feed of dilution air for reducing the hydrogen concentration in the exhaust gas.

The results of the present investigation have led to planned remodeling of the vacuum pumping system and an optimized plan of operation for tritium removal [4)].

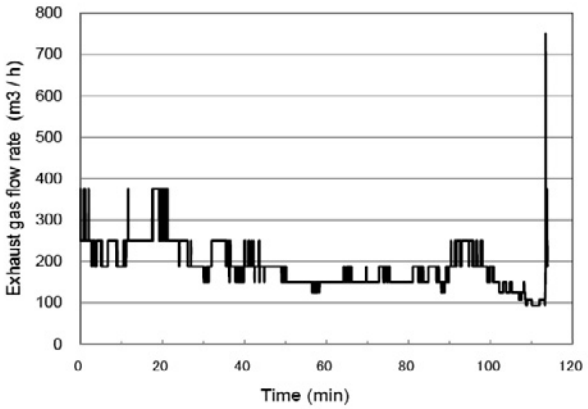

Fig.1 Estimated exhaust gas flow rate during NBI cryo-pump regenerative operation

1) Y. Asakura, et al., J. Nucl. Sci. Technol. **41**, 863 (2004)
2) Y. Asakura, et al., J. Nucl. Sci. Technol. **46**, 641 (2009)
3) Y. Asakura, et al., Fusion Sci.Technol. **60**, 1363 (2011)
4) Y. Asakura, et al., Plasma Fusion Res. **7**, 2405009(2012)