§8. Installation of the Comprehensive Gas Analytical System for Hydrogen Isotopes in the Exhaust Detritiation System

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The gas analysis in the exhaust gas from Large Helical Device is one of the important issues to understand the behavior of hydrogen isotopes. Under the deuterium plasma experiments by LHD, a small amount of tritium will be produced in the LHD plasma. The produced tritium atom could be used as a tracer. The tracer tritium in the plasma will be transported to the edge region and a part of tritium will be trapped in the first wall. Then the rest of tritium would be exhausted with other hydrogen isotopes and operation gas from the vacuum vessel via the vacuum pump system and the pipe line. The gas compositions and the chemical components of hydrogen isotopes will vary by the operational conditions of LHD and auxiliary heating system. Thus, a combined gas analysis system is necessary to analyze the complex gas compositions.

The schematic diagram of gas analysis system for the Exhaust Detritiation System (EDS) is shown in Fig.1. The gas analysis system consists of a gas chromatography system (GC) for quantitative analysis, a quadrupole mass spectrometer (QMS) for separation analysis of deuterium and helium, an ionization chamber (IC), original water bubbler system with/without the discriminating the tritium chemical forms (WB) and a proportional counter (PC) for tritium monitoring. These analysis devices are connected to the gas piping lines in the EDS.

The GC, QMS, IC and WB-I and II measure the gas composition in the plasma exhaust gas. The GC is used micro gas chromatography column modules for fast, high efficiency separations. The module has 3 different type separation columns for the analysis of multi gas compositions. Also the GC equips with a gas selector for the multi points sampling in EDS. It collects from the inlet gas of EDS, the inlet of catalyst in EDS and the outlet of EDS. The each sampling interval time is about 3 minutes. The aim of GC system is the quantitative gas analysis. However, since the GC cannot separate the hydrogen isotopes of hydrogen H_2 and deuterium D_2 under normal temperature operation, the QMS is also applied to separate the hydrogen isotopes gas in the inlet gas. On the other hands, the inlet gas of EDS includes with deuterium gas and helium which have same mass number, 4. Thus, the threshold ionization mass spectrometry (TIMS) type QMS[1] is used to discriminate analysis of deuterium gas and helium. Since the QMS has to operate under the high vacuum condition, it is equipped with differential exhaust pumping system for the sample gas at the atmospheric pressure. The time resolution of QMS depends on the number of gas species and may be less than few minutes. The detection limits of GC and QMS are about ten ppm. The IC monitors continuously the total tritium concentration in the inlet of catalyst. The variation of tritium concentration would indicate the conditions of plasma operation. The detection limit of IC is about 7.4 mBq/cm^3. The tritium gas exist various chemical forms such as molecular, hydrocarbons and water vapor etc. The WB-I tritium monitoring system for discriminating chemical forms has been developed and installed[2]. Although the tritium detection limit depends on the sampling condition, it will be less than 10^{-6} Bq/cm^3 by use of a low background liquid scintillation counter.

The PC and other WB-III measure the tritium concentration in the vacuum vessel exhaust gas during LHD maintenance. The PC is applied as in-line monitor. The detection limit is about 1.3 mBq/cm^3 at ten minutes counting, which is lower than the detection limit of the ionization chamber. The WB-III measures total tritium concentration in the outlet of EDS to confirm the tritium concentration after the tritium removal.

The installation of gas analysis system has been done as shown in Fig. 2. These gas analysis devices are remotely controlled and monitoring from the LHD control building via the Ethernet system. The monitoring will be started after the deuterium plasma experiment.

1) Daives S. et al., Vacuum, **101**, 416, (2014)
2) Tanaka M., Annual report of NIFS April 2014-March 2015 (2015).

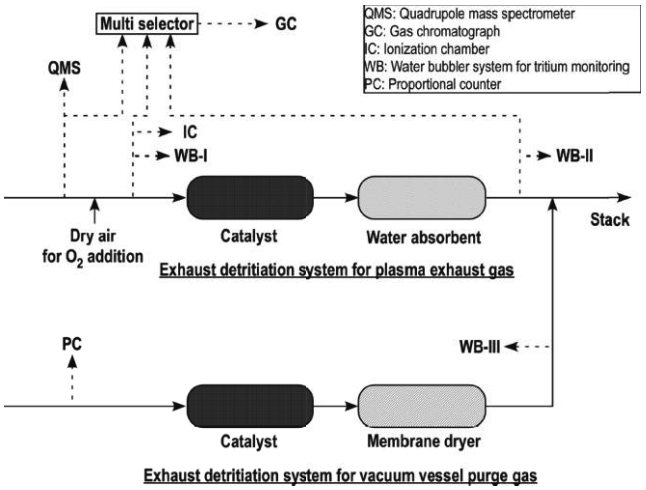

Fig. 1. Schematic diagram of gas analytical system for hydrogen isotopes in EDS.

Fig. 2. Phots of gas analysis system; the appearance of QMS and GC in the left photo, and PC (left), IC (center) and WB (right) in the right photo.