§7. Construction and Commissioning of Exhaust Detritiation System for Large Helical Device

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In the Large Helical Device (LHD), a small amount of tritium is produced by deuterium–deuterium reactions in the core plasma. A portion of this tritium is exhausted from the vacuum vessel and the rest is retained in the first wall and the diverter tiles. Although the exhausted tritium is a comparatively small amount, any waste gas streams arising from the vacuum vessel and the auxiliary equipment must be treated by the exhaust detritiation system (EDS) to comply with safety requirements. To design the EDS for a large fusion test device, the behavior of the exhaust gas stream has been observed to be understood quantitatively under the various operation modes. The exhaust gas streams originate from (1) the plasma discharge operation, (2) regeneration by cryopumps and ice pellet injection systems, (3) rough pumping of the vacuum vessels of both the fusion test device and the Neutral Beam Injection (NBI) system, (4) a purge gas used in the vacuum vessel during maintenance. The design of the EDS has been done according to the observation results of the exhaust gas stream and the main system components have been installed in 2014. To complete the EDS, the gas piping, electrical equipment, instrumentation system and the control system were constructed and installed in 2015. After the rotary machine unit tests and the automatic control system tests, the comprehensive commissioning of the EDS was carried out. The commissioning test was performed in the two steps. First step is the integrated system commissioning by use of hydrogen gas, second step is the process of exhaust gas from LHD and NBI. The commissioning results are summarized in Table 1 and 2.

In the integrated system commissioning, hydrogen gas was introduce into the main process line to be about 3%. The PM type system was also introduced the wet room air to perform with the flow rate of 300 Nm^3/h. As the results, the recovery rate of both MS type system and PM type system was achieved more than 95%, which is the design specification of EDS, as shown in Table 1.

In the comprehensive process test, the roughing pumping flow, regeneration flow from cryopumps and normal vacuum exhaust gas was performed. Maximum flow rate of roughing pumping from NBI exceeded the design process flow. Although the EDS system has an adequate margin against the flow rate, the process system could perform without a hitch. The water vapor concentration in the inlet of EDS reached to 2.7% which would condense on the inside wall. The accumulated regeneration gas volume from 5 NBIs cryopump system was about 16.7 Nm^3. It was reached at 60% of the design accumulated volume and well within the capacity of the gas storage tank. However, the hydrogen gas concentration in the inlet of EDS increased by 55.5%. Since this condition is accompanied with a danger of hydrogen explosion, a mixture of air or oxygen gas into the exhaust gas must be avoided. The regeneration gas from other cryopump system was low flow rate and low hydrogen concentration. Thus, they can be processed by normal operation mode via the main process line. The exhaust gas flow rate after rough pumping was 2-4 Nm^3/h which was less than half of design flow rate. However, the moisture was present in relatively high amounts. According to the comprehensive process test, the amount of annual waste water due to the plasma discharge operation is estimated to be about 0.44 m^3. The waste water recovered from the EDS will be annually delivered to JRIA.

Table 1. The integrated system commissioning results using hydrogen gas

	H_2 conc. in inlet [%]: a	H_2O conc. in inlet [ppm]: b	Inlet total: A=a+b [%]	H_2 conc. in outlet [%]: c	H_2O conc. in outlet [ppm]: d	Outlet total: B=c+d [%]	Recovery rate [%]: [(A-B)/A] x100
MS type system [20 Nm^3/h]	0.24	< 130	~0.25	< 0.003	< 11	~0.004	> 98.4
PM type system [300 Nm^3/h]	0.3	5760	~0.88	< 0.001	33	~0.004	> 99.5

Table 2. The comprehensive process results of exhaust gas from LHD and NBI

Process operation	Design flow rate or accumulated volume	Observation results	H_2O concentration in inlet of EDS	H_2 concentration in inlet of EDS
Rough pumping: LHD	300 Nm^3/h	~ 296 Nm^3/h	~ 1.0 %	-
Rough pumping: NBI		~ 347 Nm^3/h	~ 2.7 %	-
Regeneration of 5 NBIs cryopump system	27.5 Nm^3	16.7 Nm^3 [Maximum flow rate: 12.4 Nm^3/h]	-	~ 55.5 %
Regeneration of closed divertor cryopump [1 section]	-	~ 4.4 Nm^3/h	-	~ 7 %
Regeneration of 1 LHD cryopump	-	~ 4.2 Nm^3/h	-	~ 1.8 %
Normal exhaust gas from LHD and NBI	7.5 Nm^3/h	2~4 Nm^3/h	~ 1 % [Normally 0.2~0.4%]	-