Gas Fueling (Gas Puff) System

J. Miyazawa, K. Yasui, K. Nagahara, G. Motojima, H. Kasahara, and H. Funaba
e-mail: miyazawa@nifs.ac.jp

1. Objective

(1) Supply hydrogen (H_2, D_2) and impurity gasses (He, N_2, Ne, Ar, Kr, Xe, *etc*.) into the LHD vacuum vessel for the plasma experiment.

(2) Supply hydrogen (H_2, D_2) and impurity gasses (He, N_2, Ne, Ar, Kr, Xe, *etc*.) into the LHD vacuum vessel for the discharge cleaning.

(3) Supply a large amount of H_2, He, and Ar, at an emergency, *e.g*, quench of superconducting magnet coils or earthquakes, to stop or prevent the plasma discharge.

(4) Serve low-pressure (0.1 MPa in gauge) gasses of H_2, D_2, He, N_2, Ne, Ar, Kr, Xe, *etc*., and high-pressure (8 MPa in gauge, at the maximum) gasses of H_2, D_2, He, N_2, Ne, Ar, as a gas utility system in the LHD hall for users.

2. Apparatus

2.1. Piezo-valves

- Three types of piezo-valves with the maximum flow rate of ~100 Pa·m^3/s, ~50 Pa·m^3/s, and ~5 Pa·m^3/s, in

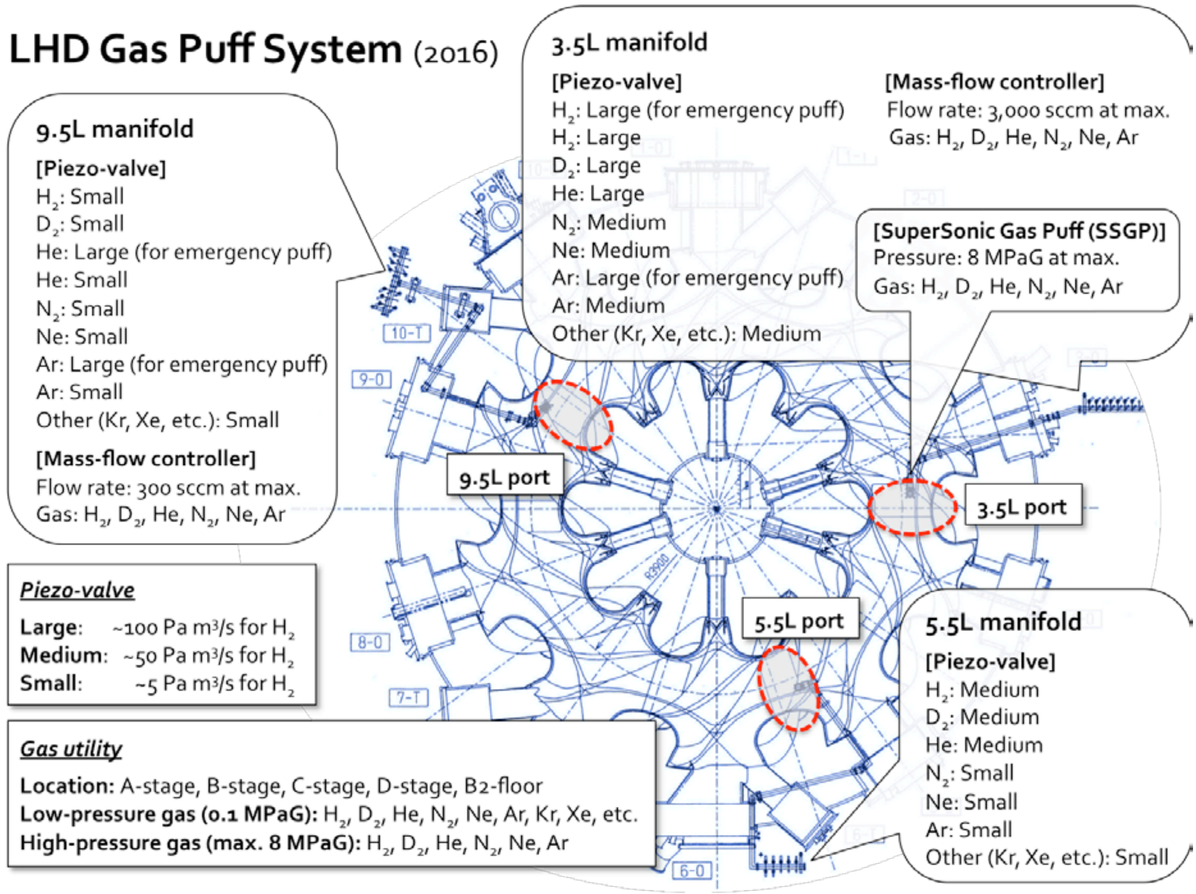

Fig. 1. Distribution of piezo-valves, mass-flow controllers, and supersonic gas puff (SSGP) in the LHD.

the case of H_2, are distributed at 3.5L, 5.5L, and 9.5L ports (see Fig. 1) [1].

- The gas species are basically fixed for each piezo-valve, since 2014FY.
- The working gasses of H_2, D_2, He, N_2, Ne, Ar are always available, while other impurity gasses as Kr, Xe, are available according to the request from users.
- The working gas pressure is basically set to 0.1 MPa in gauge, for all of the gas species.

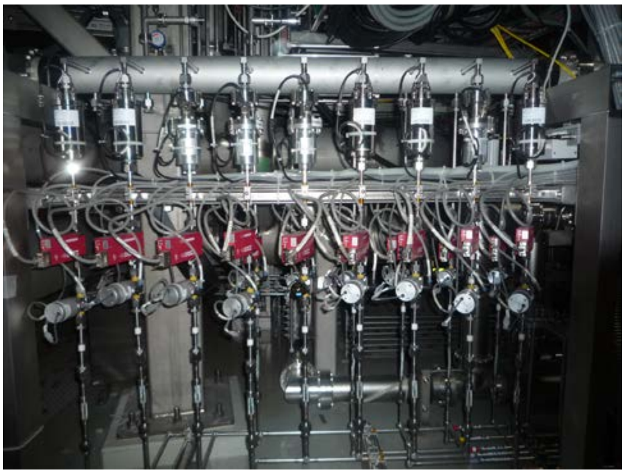

Fig. 2. A photo of the manifold at 3.5L.

- The flow rate of each piezo-valves has been calibrated in situ, *i.e.*, by measuring the pressure decrease in the reservoir tank after puffing the corresponding gas into the LHD vacuum vessel. Examples of calibrated flow rate are shown in Fig. 3. Note that not necessarily all of the piezo-valves are calibrated yet, at this moment.
- At an emergency, H_2 and Ar are puffed from the 3.5L port, while He and Ar are puffed from the 9.5L port, through large piezo-valves, to increase the pressure in the LHD vacuum vessel to a few to ~10 Pa. This emergency gas puff is triggered by the signal from the LHD central control system and/or the manual switch on the gas puff control desk.

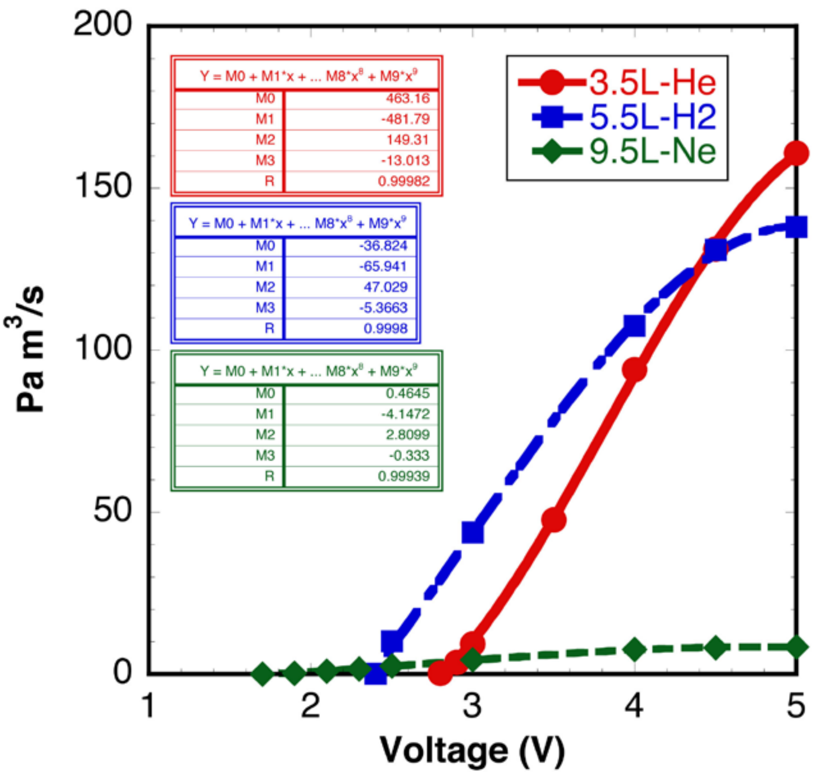

Fig. 3. Calibrated flow rates of typical piezo-valves. Calibration has been done in situ in LHD, using the corresponding gas. Horizontal axis is the control voltage, which is applied to the piezo-valve after amplification for 30 times.

2.2. Mass-flow controllers

- Two types of mass-flow controllers with the maximum flow rate of 3,000 sccm (standard cubic centimeter per minutes) and 300 sccm, in the case of H_2, are distributed at 3.5L and 9.5L ports, respectively (see Fig. 1). At each port, gas species of H_2, D_2, He, N_2, Ne, and Ar, are available.
- The gas species are fixed for each mass-flow controllers, since 2014FY.
- These mass-flow controllers are also available in the plasma experiment.

2.3. Supersonic gas puff (SSGP)

- For supersonic gas puff (SSGP [2]), a large Laval nozzle is installed inside the 3.5L port (Fig. 4).
- A solenoid-valve is connected to the Laval nozzle (Fig. 5).
- The working gas can be chosen from H_2, D_2, He, N_2, Ne, and Ar.
- The working gas pressure is adjustable in the range of 0.5 – 8 MPa in gauge.

2.4. Gas utility

- Low-pressure (0.1 MPa in gauge) gasses of H_2, D_2, He, N_2, Ne, Ar, Kr, Xe, *etc*., and high-pressure (8 MPa in gauge, at the maximum) gasses of H_2, D_2, He, N_2, Ne, Ar, are available at A-stage, B-stage, C-stage, D-stage, and B2-floor.

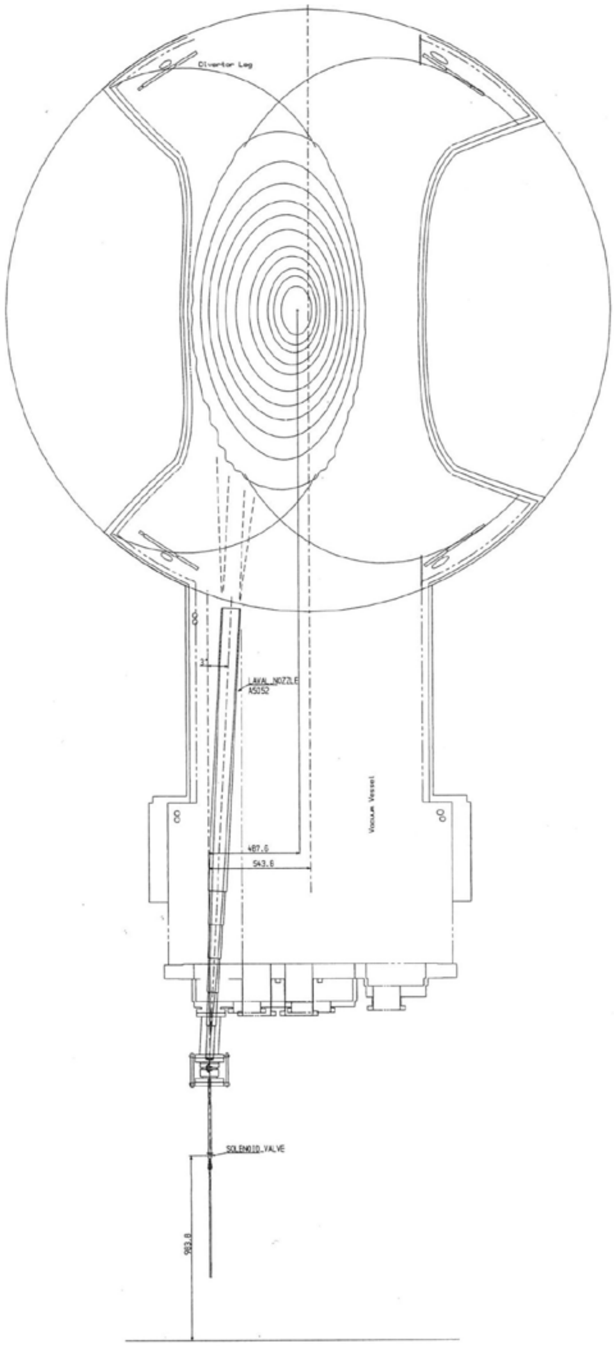

Fig. 4. A schematic view of the large Laval nozzle for SSGP installed inside the 3.5L port.

3. Operation

3.1. Normal gas puff for plasma experiment

- All of the piezo-valves and mass-flow controllers are operated in the pre-programmed mode or various feedback modes [1].
- In the pre-programmed mode, the control voltage is applied to a selected piezo-valve or mass-flow controller, according to the arbitrary waveform programmed in advance. Several piezo-valves can be used at the same time with different waveforms.
- In the feedback mode, which starts at a pre-programmed timing, the control voltage is basically

determined from the difference between the arbitrary pre-programmed target density signal and the measured real-time density signal. Both of the proportional control and PID control are available.

3.2. SSGP

- The solenoid-valve for SSGP is also operated in the pre-programmed mode or the feedback mode.
- In the pre-programmed mode, the solenoid-valve is operated with the programmed pulses, where the start timing, the pulse width, the frequency, and the number of pulses can be arbitrarily determined.
- In the feedback mode, which starts at a given timing, the solenoid valve becomes open when the density signal is lower than the target value.

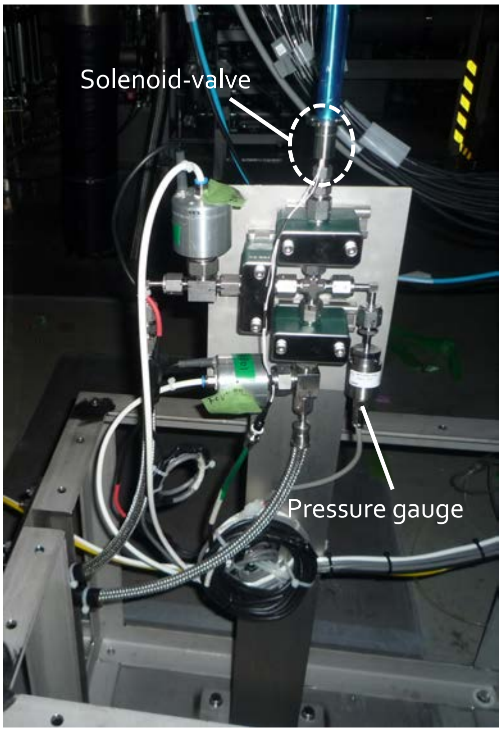

Fig. 5. A photo of the solenoid-valve for SSGP set just below the 3.5L port. Both of the magnetic shield and the neutron shield are not installed yet.

4. Available data by "Retrieve"

4.1. LABCOM

The gas puff data can be retrieved with the signal names of "GASPUFF" and "DGASPUFF".

4.2. Kaiseki-data server

The gas puff data can be obtained with the signal names of "gas_puf" and "gas_ssgp".

5. Remarks

- To protect the piezo-valves from the neutron and/or gamma ray irradiation during deuterium experiments, the manifolds at 3.5L (Fig. 2), 5.5L, and 9.5L are moved from just below the ports, *i.e*, R ~ 4 m, where R is the major radius from the LHD center, to R ~ 8 m, since 2014FY. Because of the additional conductance between the manifolds and the ports, the response of the plasma after gas puffing tend to be slower compered with that before 2014FY.

References

[1] J. Miyazawa, K. Yasui, H. Yamada, LHD Experimental Group, Fusion Engineering and Design **83** (2008) 265.

[2] A. Murakami, J. Miyazawa, *et al.*, Plasma Physics and Controlled Fusion **54** (2012) 055006.