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Efforts toward Steady State Operation in Long Duration Discharges with the Control of Hot Wall Temperature on QUEST

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Achievement of steady state operation (SSO) of magnetic fusion devices is one of important issues for fusion research. Fully non-inductive plasma start-up and its maintenance up to 1h55min was successfully achieved on QUEST with a microwave of 8.2GHz, 40kW and well-controlled gas fueling and plasma-facing wall (PFW) temperature of 373K. The gas fueling is feedback controlled to keep constant in Hα signal, which can be an indicator of in-coming H flux to plasma facing materials (PFMs). On QUEST, the hot wall, which can be actively heated by electrical heater, was installed inside the vacuum vessel in 2014 autumn/winter (A/W) campaign, and the plasma can be sustained with high temperature PFW to investigate particle balance such as fuel recycling and wall pumping properties. Thermal insulators are installed between hot wall and vacuum vessel wall to keep the temperature of vacuum vessel wall below 423K for the protection of various diagnostics and plasma-heating devices. The function of active cooling of hot wall with cooling water channels will be installed in 2017 spring/summer (S/S) campaign.

The plasma-wall interaction (PWI) is an important subject when considering SSO, and is a wide-range issue because the matters such as material science and the plasma science are linked each other complicatedly. In these matters, especially, power balance and particle balance play important roles against SSO. The power balance in long duration discharges was sufficiently investigated in TRIAM-1M, which has the world record of plasma duration on tokamaks for more than 5h16min [1]. During the long plasma discharge, all of the temperatures of PFMs are saturated and kept constant on TRIAM-1M. The power balance on QUEST is also investigated before 2014, in which the hot wall had been installed. Approximately 70%-90% of the injected power could be detected by calorimetric measurements of PFMs, and about half of the injected power was deposited on the vessel wall [2].

The total particle balance on QUEST is estimated experimentally [3]. The time evolution of wall-pumping rate is evaluated as the difference between injected and evacuated H_2 flux, which are derived from the flowmeter installed on gas fueling system and a quadrupole mass analyzer (QMS) installed on the bottom of the vessel, respectively. Absolute values of them are calibrated with consideration of the pressure and volume of gas fueling line and the relationship between flowmeter and QMS signal with the situation of no plasma. The wall-stored H can be obtained by time-integration of wall-pumping rate with setting the initial integrated value at zero. On the QUEST, the wall kept at higher temperature is rather active, and almost all stored H particles are released from the wall during the intervals of plasma discharges.

In the long duration discharges, the wall pumping occurs in the initial phase, and its rate gradually decrease. Finally, the wall-pumping rate becomes zero, and the wall saturation occurs. This tendency is likely to occur faster when its wall temperature is higher. To express this tendency, a wall model with hydrogen barrier (HB) which is formed around boundary between the deposition layer and the substrate was proposed [4]. In this model, the time derivative of the number of H dissolved in wall (dH_W/dt) is proportional to the square of H_W, when the number of H trapped in defects (H_T) can be negligible. The parabolic relation between dH_W/dt and H_W is clearly observed in low H_W experimentally, and the given curves with this model is well-fitted to the experimental observation.

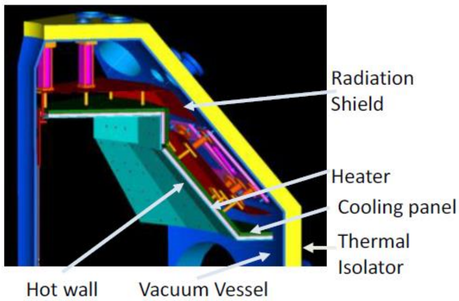

Fig. 1 Cross-sectional view of the hot walls, which include heaters, cooling panels, and radiation shields.

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