Gas balance and permeation probes for hydrogen retention analysis in QUEST

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Hydrogen (H) retention in long duration steady state tokamak operation (SSO) is studied in QUEST spherical tokamak. H plasma is started-up non-inductively with RF systems; plasma current is in range of 10 – 20 kA, maintained by electron-cyclotron waves [1, 2]. RF frequencies of 8.2 GHz and 2.45 GHz are used with total power ~ 100 kW. The plasma density is less than $\approx 10^{18}$ m^{-3}, T_e ~ 500 eV. The toroidal magnetic field B_T is 0.29 T at R = 0.3 m. The vacuum vessel consists of fully metallic (SS and W) plasma facing materials (PFM), vessel radius and height are 1.4 m and 2.8 m, respectively.

Reduction of the long-term retention rate of H isotopes by factor of 10 – 20 was confirmed when PFMs were changed from carbon to all metal ILW in JET [3]. In QUEST during SSO net wall retention, estimated with global gas balance, is ~ 70 – 80% of the fuelled H amount. To prolong SSO duration gas injection is feedback controlled to keep H_α radiation in a given range, SSO up to ~820 sec is achieved. In the second half of discharge no gas was fuelled, reducing possibility for discharge control. PdCu membrane probes are used for measurement of atomic and ion H fluxes Γ_{pdp} to PFMs. Four probes are located at different positions: top and bottom divertor plates and at the 'side' wall far from main plasma-wall interaction (PWI) regions. Incident H flux Γ_{inc} is numerically calculated to fit Γ_{pdp} [4]. H retention flux is estimated as $q_{ret} = A_i \Gamma_{inc} dt$, where A_i – surface area of PFMs surrounding corresponding probe. Spatial distribution of retention is studied for SSO. Atomic H irradiation of the 'side' SS wall leads to one order of magnitude higher retention than in main PWI areas.

[1] H. Zushi et al., 21st IAEA FEC (2012)

[2] H. Idei et al., 21st IAEA FEC (2012)

[3] S. Brezinsek, S. Brezinsek, T. Loarer, et al., Nuclear Fusion, 53-8 (2013), 083023

[4] A. Kuzmin et al., J. Nucl. Mater., in press, http://dx.doi.org/10.1016/j.jnucmat.2014.12.092