Divertor Operation Scenarios in Helical Devices

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The basic concepts of the Wendelstein 7-X (W7-X) island divertor and of the closed helical divertor (CHD) of LHD, will be explained. Within the framework of both divertor concepts routes have been found, which allow producing stable, high density detached divertor plasmas using carbon as plasma facing material. On both devices, up to a factor of 10 reduction in peak heat loads and simultaneous efficient neutral particle exhaust have been accomplished - a pre-requisite of any high power quasi-continuous plasma operation in these superconducting devices. The development of efficient and lasting wall conditioning procedures are essential for such discharges. The strategies followed on both devices, within their individual technical boundaries, will be compared, and the efficiencies of operation techniques applicable without running down the magnetic field, like ECRH and ICRH, as well as cryo-desorption-pump-assisted ECRH conditioning (LHD), will be discussed. Efficient and sufficient divertor pumping capabilities are essential for sustaining long-pulse high-power discharges. In LHD with the CHD supported by integrated cryo-sorption pumps, a $10 - 15$ times higher neutral compression than in the open helical divertor (HD) was achieved and thereby a significantly improved neutral particle exhaust. The W7-X island divertor also provides good neutral pressure build up, such that its 30 turbo molecular pumps alone were sufficient to maintain stationary constant densities in a 25 s discharge with 5.0 MW O2-mode ECRH heating in a high-density ($n_e l \sim 1\ 10^{20}$ m^{-2}) detached plasma state. In qualitative agreement with EMC3-Eirene predictions, high divertor neutral pressures (0.8Pa) were achieved with radiated power fractions from carbon of up to f_{rad}=70-80%. For higher f_{rad} the achievable neutral pressures dropped. Stable, completely detached, high-density discharges were achieved at constant, low Z_{eff} of $\sim$1.5, demonstrating good impurity retention of the W7-X divertor. The impurity screening in W7-X was predicted by EMC3-Eirene and experimentally verified. CIII-flows measured with Coherence Imaging Spectroscopy were well aligned with the island structure and directed towards the targets. Very similar low ionized impurity ion flow behavior was also seen in LHD in hydrogen as well as deuterium plasmas. In W7-X divertor performance optimisation experiments were performed with hydrogen and impurity (N, Ne) divertor gas fuelling. Feedback control was done on density, total radiation, divertor impurity radiation and radiation front location. Controlled impurity seeding allowed driving plasmas into detachment in W7-X and LHD and allows finding optimal radiation distributions between confined plasma edge and SOL/divertor radiation.