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Expanding the Physics Basis of the Baseline Q=10 Scenario toward ITER Conditions

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Results obtained recently in DIII-D provide critical information for ITER baseline scenario operation. Much of the physics basis for ITER baseline scenario operation has been obtained in plasmas with significant fueling and applied torque from neutral beam injection (NBI). DIII-D has unique capabilities to extend this physics basis toward ITER conditions by applying neutral beam injection (NBI) with combinations of co- and counter-injection to reduce torque input, applying electron cyclotron heating (ECH) to reduce fueling and torque and to equilibrate the electron and ion temperatures, and exploring the effects of steady-state and transient divertor heat flux reduction with radiative divertor operation. All of these tools have been applied to plasmas with a boundary shape close to that of ITER to minimize systematic effects in projection of the results to ITER. The existence of stationary plasmas at nearly zero applied torque in
DIII-D with sufficient normalized pressure and confinement for Q=10 in ITER at 15 MA is a key validation of the baseline scenario. Sustained operation with normalized parameters sufficient for Q=10 operation in ITER (βN=1.9, H_98=1.05, I_N=1.41) has been achieved with nearly zero external torque input from NBI (TNB=0.3 Nm) for more than four resistive relaxation times (4τR). Similar conditions with PEC>PNB and TNB=0.5 Nm have been sustained for >3τR. Confinement at low torque is reduced relative to the standard co-NBI, but there is sufficient confinement margin in DIII-D so that the reduction brings the plasmas to H98~1. Application of ECH does not reduce the confinement quality of the plasmas relative to those with NBI only as long as plasmas at the same applied torque are compared. Radiative divertor operation is successful in reducing steady-state and transient heat flux to the divertor in DIII-D at low q95 and reduced torque without enhanced accumulation of the seed impurity used for radiation. The studies of the flux usage indicate sufficient flux should be available in ITER to meet the >300 s operational requirement. However, the operational difficulties encountered with tearing mode stability at low applied torque suggest that a more diverse set of plasmas should be considered for the Q=10 mission, due to the sensitivity of ITER to disruptions.

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