Performance of Discharges with High Elongation and β in NSTX and Near-Term Paths Toward Steady State.

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Spherical Torus configurations for plasma material studies, a nuclear component testing facility (CTF), and eventually fusion power generation, will need strong shaping, high-beta, excellent confinement and (possibly) external current drive, in order to operate in steady state. Recent experiments in the National Spherical Torus Experiment (NSTX) have demonstrated high-beta, high-elongation operation over a range of normalized currents in support of these needs. High poloidal-beta scenarios with non-inductive fractions $f_{NI} \approx 70\%$, elongation of 2.7, normalized betas of 5, and normalized currents $I_N=I_P/aB_T=2.4$, have been reliably demonstrate with minimal large-scale MHD activity, and have NSTX record low loop voltages (~130 mV). The density in these discharges ramps to a Greenwald fraction of ~1, such that the neutral beam current fraction f_{NBCD} drops from ~30% early in the discharge to 15% at later times; the bootstrap fraction ramps up as the density increases, achieving maximal values of $f_{BS}=60\%$. These scenarios were then extended to higher normalized current $I_N= 4.2$ and toroidal betas up to 30%. All of these scenarios benefited from lithium conditioning of the plasma facing components, and achieved confinement comparable to or better than ITER H-mode scaling. n=3 non-resonant error field correction, n=1 dynamic error field correct and resistive wall mode feedback were critical in maintaining stability and discharge-reliability at this high normalized beta.

Predictive modeling with the TRANSP code has been used to find near term means to increase f_{NI} beyond 70%, starting from the parameters of the high poloidal-beta discharges discussed above. A 25% decrease in the plasma density, as predicted to be possible with the recently installed liquid lithium divertor (LLD), coupled to a 18% increase in the temperature, increases the neutral beam current at the expense of the bootstrap current, and leaves the total non-inductive fraction unchanged. If, however, the temperatures vary inversely with the density, an increase in the non-inductive fraction to 83% may be anticipated for this density decrease. If the densities remain fixed, a 40% increase in T_e and T_i is sufficient to achieve $f_{NI}=1$; reducing Z_{eff} from three to two reduced the required temperature increase to 25%. This increase in temperature might be provided by increased confinement with LLD, or via core fast wave heating in addition to that from neutral beams.

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