Progress on Advanced Tokamak and Steady-State Scenario Development on DIII-D and NSTX*

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Steady-state operation would substantially enhance the attractiveness of the tokamak as a fusion powerplant, and such operation at $Q \geq 5$ is one of two key ITER performance objectives. Steady-state operation implies 100% noninductive operation, which requires a simultaneous combination of high q_{min} to maximize self-driven bootstrap current (f_{BS}), and high beta and confinement to maximize fusion power with reduced I_p (as compared with conventional H-mode operation). Advanced Tokamak (*AT)* research seeks to develop steady-state operating scenarios for ITER and other future devices from a demonstrated scientific basis, and is a major component of the DIII-D tokamak and NSTX spherical torus (ST) research programs. Approximate target parameters for *AT* operation are f_{BS}~55%-75%, with $q_{min} \geq 1.5$ and normalized beta (β_N) of ~3.5-5. Progress in realizing such plasmas can be considered in terms of expanding *AT* operating space, development of plasma control capabilities, and scientific understanding: The credibility of *AT* operation has been strengthened by recent DIII-D experiments in which $\beta_N \sim 4$ operation was sustained for ~2 s at 50% above the no-wall stability limit. These plasmas have a broad current profile with $\rho_{qmin} \sim 0.6$ and an ion thermal internal transport barrier (ITB), providing a first experimental demonstration that ITBs are consistent with high beta operation, but are to-date non-stationary. In separate DIII-D experiments, 90-100% noninductive plasmas with $1.5 < q_{min} < 2.0$ and weak negative magnetic shear have been maintained for $\sim 1\tau_R$ with $\beta_N \leq 3.5$, using electron cyclotron (ECCD) and neutral beam current drive. On NSTX, passive resistive wall mode (RWM) stabilized, high performance (β_N~5-6, H_{98}~0.9-1.3), MHD quiescent plasmas have been sustained for 300 ms, $\sim 7\tau_E$, opening a path to *AT* research in the ST configuration, but to-date with $1 \leq q_{min} \leq 1.5$. *AT* plasmas will require active control of the current profile and MHD stability; DIII-D routinely operates at up to 50% above the no-wall beta limit using active control of internal and external non-axisymmetric coil sets to obtain RWM stabilization, while ECCD provides a flexible tool for current profile control and sustainment. Progress has also been made in understanding both transport and stability limits in advanced regimes. For example, new experimental observations and GYRO simulations indicate that ITB formation at rational-*q* surfaces may be due to equilibrium zonal flow generation. Overall, consistent progress is being made towards achieving *AT* performance goals, and modeling projections based on these results indicate that steady-state *Q*=5 operation should be possible on ITER.

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