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Progress Towards Sustainment of Advanced Tokamak Plasmas on DIII-D[1]

M.R. WADE, General Atomics

Significant progress has been made in extending the duration of high normalized performance (high $\beta_N H_{89}$) plasma conditions in DIII-D. In the best discharge, $\beta_N H_{89} \sim 9$ with $\beta \sim 4.5\%$ has been sustained at $B_t = 1.6$ T, $I_p = 1.2$ MA with steady kinetic profiles for 2.1 s ($\sim 15\tau_E$). This is achieved with a nearly flat q profile, $q_{min} > 1.5$, and without the formation of a strong internal transport barrier. Performance is limited as β_N rises above the no-wall ideal MHD limit by the onset of intermittent resistive wall modes (RWMs) – not by neoclassical tearing modes, which were the limiting factor previously. The distinguishing characteristic appears to be stronger magnetic shear at the edge. These discharges also do not suffer a dramatic drop in β at the first ELM, as often observed in DIII-D high performance plasmas. This is ascribed to the onset of Alfven modes during the ELM-free period and to higher q_{95}, which typically results in smaller amplitude ELMs. Although the kinetic profiles are stationary, the high performance phase ends due to the continuing diffusion of current, indicating the need for noninductive sustainment of the q profile. Measurements indicate that $\sim$50% of the plasma current is self-generated via the bootstrap current and $\sim$25% via neutral beam current drive. To provide the remainder, a four-gyrotron system with flexible steering is now being commissioned to provide $\sim$2.5 MW of off-axis electron cyclotron current drive (ECCD). Improved density control, key to achieving optimum ECCD, has been provided by two new cryopumps in the upper divertor. Modeling using profiles obtained in pumped, high performance plasmas indicates that 3 MW of ECCD will be sufficient to maintain high normalized performance with $q_{min} > 1$ for up to 10 s.

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