LONG-PULSE, HIGH-PERFORMANCE DISCHARGES IN DIII-D*

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Significant progress has been made in obtaining high performance discharges for many energy confinement times in the DIII-D tokamak. Normalized performance (measured by the product of $\beta_{N H 89}$ and indicative of the proximity to both conventional $\beta$ limits and energy confinement quality, respectively) $\sim 7.5$ has been sustained for $> 35 \tau_E$. In these ELMing H-mode discharges, $\beta \sim 3.1\%$ is maintained within 5% of the tearing mode $\beta$ limit (determined on separate discharges) for over 6 s through feedback control of the input power on plasma stored energy. The plasma density in these discharges is held nearly constant at $3.5 \times 10^{19}$ m$^{-3}$ through divertor exhaust and feedback control of external gas injection. Particle balance analysis shows that the total particle input rate is matched by the total exhaust rate throughout the high performance phase, indicating that the wall is not a primary agent in the overall particle balance. Of special interest in this class of discharges is that the current profile reaches a stationary state approximately 1.5 s into the high performance phase without any evidence of sawtooth oscillations or fishbones thereafter with $q_0 \gtrsim 1.0$. Analysis of the poloidal flux evolution indicates that the expected inward diffusion of current is being counteracted by non-diffusive current transport near the $q = 1.5$ surface, possibly due to a small, steady $m=3/n=2$ neoclassical tearing mode that appeared early in the discharge. These discharges are part of a larger set of discharges that exhibit high performance for extended durations in DIII-D. Over shorter durations ($\sim 10 \tau_E$), $\beta_{N H 89} \sim 10$ has been sustained for $> 10 \tau_E$. These discharges have $\beta \sim 5\%$, which is limited by the onset of resistive wall modes slightly above the ideal no-wall $n=1$ limit, with approximately 75% of the current driven non-inductively. The remaining Ohmic current is localized near the half radius. The DIII-D electron cyclotron heating system is being upgraded to replace this inductively driven current with localized ECCD in hopes of demonstrating steady-state, high performance advanced tokamak operation.

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