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High Internal Inductance for High β_N Steady-State Tokamak Operation[1]

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An attractive scenario for steady-state tokamak operation at relatively high values of the internal inductance, $l_i > 1$, has been demonstrated at DIII-D. The more peaked current density profile leads to reduced core energy transport and higher ideal stability limits that could eliminate the need for n$\geq$ 1 active stabilization coils at $\beta_N \approx 4$, or enable $\beta_N \approx 5$ with wall stabilization. The scenario's potential is shown by discharges at $l_i \approx 1.3$ with high bootstrap current fraction $f_{BS} \approx 0.8$, high plasma pressure $\beta_N \approx 5$ and excellent confinement $H_{98(y,2)} \approx 1.8$. This very high β_N discharge with q_{95} =7.5 has noninductive current fraction $f_{NI} > 1$ and too much bootstrap current in the H-mode pedestal, so l_i decreases with time. To achieve a stationary current profile, the key is to maximize β_N and f_{BS} while maintaining l_i high enough for stability through choice of q_{95} or by reduced pedestal current. DIII-D modeling shows that with q_{95} reduced to lower f_{BS} to ≈ 0.5, a self-consistent equilibrium has $l_i \approx 1.07$ and $\beta_N \approx 4$ (below the n=1 no-wall limit) with $q_{95} \approx 6$. The remainder of the current can be externally-driven near the axis where the efficiency is high. Discharge tests with similar l_i in the ITER shape at q_{95}=4.8 have reached f_{NI}=0.7, f_{BS}=0.4 at $\beta_N \approx 3.5$ with performance appropriate for the ITER Q=5 mission, $H_{89}\beta_N/q_{95}^2 \approx 0.3$. The l_i was shown to increase further above 1, to enable higher self-consistent f_{BS} and β_N, by reducing pedestal pressure and bootstrap current density through application of n = 3 resonant magnetic fields. With similar fields for ELM mitigation, and neutral beam and electron cyclotron current drive sources for near-axis current drive, the high l_i scenario is a potential option for ITER. The increased core confinement can help mitigate the effect of reduced pedestal pressure.

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