Dependence of transport, bootstrap current, and stability on the safety factor profile in DIII-D steady-state scenarios*

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A high beta, high gain steady state tokamak scenario with large bootstrap current fraction will have strong coupling between the current density and the pressure gradient through turbulent transport and the bootstrap current. To address this coupling experimentally, a scan of the safety factor minimum (q_{min}, from 1.1 to over 2) and edge value (q_{95}, from 4.5 to 6.8) was performed. The variation of measured turbulent density fluctuation and calculated drift wave growth rate with measured q profile have been compared. As an example, at q_{95}=6.8 and β_N=2.8, a higher measured fluctuation amplitude over a wide spectrum is correlated with a higher calculated ion temperature gradient (ITG) mode growth rate at mid-radius in a discharge at $q_{\min}$ near 2 than a discharge with $q_{\min}$ just above 1. The measured density and temperature profiles show systematic variation with both $q_{\min}$ and q_{95}. At fixed β_N, lower q_{95} tends to result in higher n_e, T_e, and T_i, and lower $q_{\min}$ tends to result in more peaked n_e and T_e, but lower T_i. The bootstrap current fraction f_{BS} is expected to scale as $q\beta_N$. In these scans, f_{BS} did increase with q_{95}, but it did not continue to increase with $q_{\min}$ above about 1.5. This is primarily caused by lower n_e and lower ∇T_e at the highest $q_{\min}$ in the scans. Testing each q profile at the highest achievable β_N resulted in lower achieved β_N at the highest $q_{\min}$, usually limited by tearing modes. All discharges achieved β_N ~10-20% above the calculated ideal n=1 no-wall limit, and all were within 10%-20% of the ideal n=1 with-wall limit. Calculated stability limits generally decrease with $q_{\min}$. An extrapolation of these data suggests that $q_{\min}$ near 1.5 optimizes f_{BS} if the calculated ideal wall n=1 limit can be reached.

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