Progress Toward Fully Noninductive Discharge Operation in DIII-D Using Off-axis Neutral Beam Injection*

J.R. Ferron, General Atomics

The new 5 MW off-axis neutral beam capability on DIII-D results in discharges with improved access to fully noninductive plasma regimes. Off-axis beam injection broadens the current density profile by changing the distribution of beam-driven current; broadens the pressure profile; and extends the tearing mode stable duration. In cases with the most off axis current, plasmas can now be sustained without q=2 resonances. The measured T_e is lower on axis, and the calculated fast ion pressure profile is less peaked, resulting in the broadened pressure profile. This plus the additional current near the conducting vacuum vessel wall results in an increase in the calculated ideal n=1 β_N limit to above 4, close to the β_N that must be achieved for fully noninductive operation in a reactor. With no q=2 surface, neither the most deleterious, low-order (2/1) tearing modes nor off-axis fishbone modes are observed; instead, if present, tearing modes are higher order (5/2 or 3/1). A decrease in the normalized confinement results from the off-axis injection, with a further decrease when the minimum in q is above 2. With more peaked current profiles so that the minimum in q is around 1.4, stability is also improved with off-axis injection, with pulse duration at β_N=3.5 increased to 2 current relaxation times, 3 s, in a discharge that projects to Q=5 in ITER. Modeling indicates that in DIII-D, solutions for fully noninductive operation have β_N above 4, making the increased ideal stability limit that results from off-axis beam injection a requirement, and the minimum in q is above 2 with about 50% of the input power from off-axis injection. This new approach to modification of the current profile in DIII-D, then, is providing crucial insight into the development of a fusion steady-state scenario.

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