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High Performance Double-null Plasmas Under Radiating Divertor and Mantle Scenarios on DIII-D

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Enhanced radiation has been used to reduce divertor heat flux in high power, high performance (AT) double null divertor (DND) and near-DND plasmas in DIII-D, while at the same time maintaining acceptable energy confinement and particle control. Effective radiating mantle operation in high power AT plasma depended strongly on the location of electron cyclotron (EC) heating deposition, on impurity selection and its effect on triggering inimical MHD activity, and on the location where seed impurities are injected. Predictions by ELITE for ways to improve confinement and fueling in these high performance plasmas have been experimentally verified. The plasmas discussed here are characterized by: H98 = 1.4-1.7, betaN = 3-4, q95 ≈ 6, neutral beam plus EC power input P_in up to 15 MW, with EC providing up to 3.5 MW, dRsep = 6-25 mm. When the radial location of the ECH deposition was near the magnetic axis (e.g., rho_ech = 0.20), the radial profiles of both the injected impurity (e.g., neon) and carbon were mostly flat, while ECH deposition farther out (i.e., rho_ech = 0.45) produced profiles that were peaked. Analysis with the STRAHL transport code indicates a stronger inwardly-directed pinch for neon in the rho_ech = 0.45 case, while analysis for rho_ech = 0.20 indicates screening of neon from the central plasma. Using higher-Z seed impurities to form a radiating mantle increases deleterious MHD activity when applied to these AT DND plasmas. For example, when argon seeds were injected into these AT plasmas, the argon seeds triggered more deleterious MHD activity than the neon seed injection. Impurity selection, injection location, the ion grad-B drift direction, and details of scrape-off layer shaping strongly are shown to dictate where injected impurities can be most effectively pumped in DND and near-DND configurations. Finally, we show that conditions leading to improved performance in high power high performance regimes, which were predicted by ELITE code analysis, are largely supported by recent DIII-D experiments.
These studies represent a continuing effort to experimentally identify potential issues related to adapting radiating mantle/divertor methods to high-powered AT DND plasmas.
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