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Applying the Radiating Divertor Approach to Innovative Tokamak Divertor Concepts

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Results are reported and interpretation made of recent experiments on DIII-D that assess the effectiveness of three innovative tokamak divertor concepts under radiating divertor (RD) conditions: (1) high performance standard double-null divertor (DND) plasmas, (2) high performance double-null "snowflake"(SF-DN) plasmas, and (3) single-null H-mode plasmas with different parallel connection lengths between their X-points and outer divertor targets (L||-XPT). In general, all three concepts are attractive, with reduced heat flux and good H-mode confinement. Significant reductions in peak divertor heat flux (q⊥,P) of more than 50% and 85% at the outer and inner targets, respectively, were observed in DND plasmas under neon/deuterium-based RD conditions, and high performance metrics were maintained, e.g., βN ≅ 3.0 and H98(Y,2) ≅ 1.35. Under these RD conditions, <20% of the input power (≈10-13 MW) was radiated in the core, while >40% outside the main plasma. Impurity injection from poloidal locations other than the private flux region opposite the BxV̈B drift direction produced high levels of fuel dilution. High performance SF-DN plasmas mirrored the DND results under similar RD conditions. While the heat flux profiles at the inner target of the SF-DN and DND plasmas behaved similarly under comparable RD conditions, q⊥,P at its outer divertor target of the SF-DN cases was generally about a factor of two lower. Impurity build up in the main plasma, however, was 15%-20% higher in the SF-DN, due in part to difficulty in pumping the broad density profile under the outer divertor leg of the SF-DN. Plasmas with longer L||-XPT had lower q⊥,P than those with the shorter L||-XPT. SOLPS modeling has indicated that cross-field transport between the X-point and the divertor target resulted in broadened heat flux profiles and reduced q⊥,P. Under similar RD conditions, the longer L||,XPT cases maintained lower q⊥,P by at least 50%. Partial detachment at the outer divertor under RD conditions occurred at lower bar_ne in the longer L||,XPT cases. This study represents a first systematic step in examining three potential solutions to the excessive power loading expected in future generation high-powered tokamaks.

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