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A convective divertor utilizing a 2nd-order magnetic field null[1]

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New results motivate a detailed study of a magnetic divertor concept characterized by strong plasma convection near a poloidal magnetic field ($\mathrm{B_p}$) null region. The configuration is that of a near-2nd-order $\mathrm{B_p}$ null ($\mathrm{B_p} \propto \Delta \mathrm{r}^2$), as in a snowflake divertor [1,2]. The concept has 2 key features: (A) Convection spreads the heat flux between multiple divertor legs and further broadens the heat-flux profile within each leg, thereby greatly reducing target-plate heat loads [2]. (B) The heat flux is further reduced by line radiation in each leg in detachment-like ionization zones. Theory indicates that convective turbulence arises when the poloidal plasma beta, $\beta_{\mathrm{p}} = 2\mu_0 \mathrm{nT}/\mathrm{B_p^2} >> 1$. Measurements in TCV [4] now more fully quantify earlier NSTX and TCV observations of plasma mixing [5.6], and related modeling of TCV indicates that strongly enhanced null-region transport is present [7]. Convective mixing provides a stabilizing mechanism to prevent the ionization fronts (hydrogenic and impurity) from collapsing to a highly radiating core MARFE. Also, the radiating zone maps to a very small region at the midplane owing to the very weak $\mathrm{B_p}$ in the convective region, thus minimizing its impact on the core plasma. Detailed calculations are reported that combine features A and B noted above. The plasma mixing mechanisms are described together with the corresponding transport model implemented in the 2D UEDGE edge transport code [2]. UEDGE calculations are presented that quantify the roles of mixing, impurity radiation, and detachment stability for a realistic snowflake configuration. Work in collaboration with D.D. Ryutov, S.I. Krasheninnikov, and M.V. Umansky.

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