Compatibility of divertor heat flux control with detachment and core plasma performance

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A review of the compatibility of high core plasma confinement and divertor detachment finds the most critical issue for predictive capability to be that of plasma transport in the pedestal and near SOL region. In existing devices achieving highly dissipative divertor conditions, or detachment, is often associated with a degradation of the core plasma energy confinement. This degradation is most often mediated through the edge H-mode pedestal. Increased electron and/or impurity density required for divertor detachment can lead to pedestal degradation through several processes. The MHD stability limit of the pedestal may be reduced at higher density due to reduced bootstrap current at higher collisionality. An outward shift of the pedestal density profile due to the increased fueling can also lower the pedestal stability limit. Additionally, increased radiative and charge-exchange losses inside the separatrix may lower the power flowing though the separatrix below that necessary to maintain a robust edge transport barrier. The role of poloidally asymmetric power losses in this degradation, particularly through the X-point region, is an open issue in need of further investigation. To scale these effects of dissipative divertor conditions to reactor-scale tokamaks requires prediction of the boundary conditions at the pedestal–SOL separatrix interface, particularly the electron and impurity densities as well as the neutral ion flux. In turn, assessing this compatibility relies on improved understanding of pedestal energy and density transport in response to these boundary conditions. In future large tokamaks the pedestal particle flux will no longer be driven by edge recycling neutral flux, but rather by core sources. A model of pedestal particle transport will be necessary to predict the ratio of separatrix to pedestal top density in these conditions. This ratio can have a profound effect on the divertor solution for a given core plasma scenario. Similarly, limits to seeded impurity density may be very different than in existing devices due to changes in the pedestal density profile, and resulting neoclassical impurity transport. For the divertor solution, one of the greatest uncertainties is accurate prediction of the width of the SOL exhaust heat flux. While plasma drift models accurately predict this width in existing devices, computational models suggest turbulent transport originating in the pedestal near separatrix region may expand the heat flux width beyond the drift width in future larger devices. The need for an advanced divertor will depend upon this SOL heat flux width and the sensitivity of a given reactor scenario to X-point region dissipation. Prospects for scenarios with improved compatibility between dissipative divertors and high performance core scenarios will also be discussed.

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