Poloidal Pressure Gradients, Divertor Detachment and MARFEs*

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Plasma in the magnetically open tokamak scrape-off layer (SOL) and divertor obeys the equations of MHD equilibrium with flow. “Near-static” equilibria, in which only the parallel (to **B**) flow is rapid, require the presence of Pfirsch-Schlüter (P-S) currents to satisfy $\nabla \cdot \vec{J} = 0$. P-S currents are observed to close through the electrically conducting targets in present tokamaks when the divertor plasmas are attached [1]. When divertor plasmas detach in JET [1] and DIII–D, the P-S target currents become negligibly small (presumably due to increased target plasma impedance). Despite the blocked equilibrium currents, there are no experimental signs of a loss of the “near-static” MHD equilibrium, which would be appear as enhanced poloidal flow from the inner to the outer divertors. During detachment, MARFEs commonly occur in or near the X–point, and divertor Thomson scattering data from DIII–D show steep poloidal pressure gradients in the SOL near the magnetic X–point. Furthermore, some DIII–D data show locally increased p_e near the low-radius side of the X–point. This paper discusses edge-plasma MHD constraints in detached plasmas and their relations to the poloidal pressure distribution and to MARFEs

A recent analysis [2] shows that “near-static” detached equilibria exist in single-null divertors if there is at least one poloidal pressure gradient region in the SOL, at either a larger or smaller major radius than the radii of the main divertor pressure drops. The extra pressure gradient is necessary to satisfy $\nabla \cdot \vec{J} = 0$ in the blocked toroidal geometry. Near-static MHD equilibrium solutions also exist with local pressure extrema at the local major radius maxima and minima of a magnetic surface. Both single- and double-null divertor systems are studied. Common flux regions do not admit “near-static” detached equilibria, but closed magnetic surfaces do. Poloidal pressure gradients drive parallel plasma flows tending to relieve the gradient. Interesting solutions must be consistent with physically plausible particle and heat sources and sinks. For example, a local pressure maximum can build on the combination of electron parallel heat flux from a hotter region of the magnetic surface and local particle recycling, while the particle sink consists of the usual cross-field transport at the bad curvature region. It is noteworthy that if a MARFE has a locally higher pressure than the rest of a magnetic surface, then its radiated power density can be greater than if the pressure were constant or decreased toward the MARFE.

[1] M.J. Schaffer et al., Nuclear Fusion **37** (1997) 83.
[2] M.J. Schaffer, submitted to Comments on Plasma Physics.

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