Large Scale Poloidal Circulation in the Scrape-Off-Layer of Alcator C-Mod

C. S. Pitcher, X. Bonnin, C. J. Boswell, B. LaBombard, B. Lipschultz, R. Schneider and J. L. Terry

It is generally assumed in divertor tokamaks that neutrals created in the divertor via recombination on surfaces or in the volume are reionized some distance upstream but still relatively close to where they are born. Once ionized it follows that they travel only a short distance as ions downstream along field lines back to the recombination region. In this scenario the recycling circuit is restricted to the divertor region and does not extend into the main chamber. However, experimental and modeling results from Alcator C-Mod suggest that this picture is simplistic and that there are at least two other major recycling circuits active in the boundary of a divertor tokamak. In the first, direct plasma contact with the main chamber mechanical structures, results in a closed main chamber recycling circuit [1]. In the second, a circuit can arise due to the imbalance in neutral and ion sources between the low field and high field scrape-off-layers (SOLs). This can result in large scale plasma circulation around the poloidal circumference, usually flowing from the low field side to the high field side. It is this second main chamber circuit that is the subject of the present paper. The root cause of this poloidal circulation is the fact that ions are constrained to flow primarily along field lines whilst neutrals are able to freely cross field lines. This means that any mechanism that results in ions being preferentially inserted into the low field SOL over the high field SOL in comparison to their respective neutral sources, would naturally give rise to a poloidal circulation to complete the recycling circuit, since the single-null magnetic topology precludes a short path from outer fan to inner fan.

We identify three mechanisms that can give rise to ions being preferentially inserted into the SOL on the low field side. In the first, some fraction of neutrals generated in the divertor can penetrate to the X-point and above, where they are ionized on closed magnetic field lines. In this case, cross-field transport back into the SOL occurs most likely on the low field side, which means that the return path, for those particles originating as neutrals at the inner fan, carries them around the poloidal circumference back to the inner divertor. In the second mechanism, neutral creation in the divertor may generally favor the inner fan, whilst neutral ionization favors the outer fan. What results is a net flux of neutrals through the private flux region from inner to outer divertor fans, again with the return path for the resulting ions taking the long way around the SOL [2]. In the third, neutral leakage from the divertor through the mechanical baffle structure is primarily on the low field side, resulting in preferential ionization on the low field side. Again, the flux of leaking neutrals that originated on the high field side must complete their recycling circuit by circumnavigating the entire poloidal cross-section.

These scenarios are supported by a number of measurements in C-Mod, including the observation of strong flow in the SOL towards the divertor at the inner wall [3,4], the inference of high levels of neutral leakage on the low field side [5], strong impurity screening for impurities injected at the inside midplane but not the outside midplane [4] and a divertor gas pressure which appears to be determined primarily by the inner fan. In addition to these measurements, we present B2-Eirene modeling to help interpret the experimental findings.

[1] B LaBombard et al, Nucl Fusion 40 (2000) 2041
[2] B LaBombard et al, PSI96
[3] D Jablonski et al, J Nucl Mat 241-243 (1997) 782
[4] G M McCracken et al, Phys Plas 4 (1997), 1681
[5] C S Pitcher, PSI2000