Divertor and SOL Optimization for Advanced Tokamak Operation in DIII–D: Experiments and Computational Modeling*

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We present an overview of recent DIII–D experiments and computational modeling for an "Advanced Tokamak" (AT). The present AT concept relies heavily on: a) plasma shaping (high-δ, use of ∇-B drift direction for H-mode control), b) profile control with rf current drive (with cryopumping for n_e control), and c) divertor operation over a wide range of core conditions (e.g., radiative divertor operation at modest n_e and low Z_{eff} using divertor flow control). Shape experiments showed that the measured up/down peak divertor heat flux sharing was a sensitive function of the magnetic balance, and could be explained by mapping the measured midplane n_e and T_e profiles to the divertor plate; profile during ELMs showed a similar sensitivity. However, the profiles of particle flux and pumping exhaust vs. magnetic balance were broader, indicating that divertor effects were important. We found that fueling efficiency and edge pedestal parameters could also be varied in special high-δ single-null plasmas (with a second X-point inside the vessel). To develop flow control, we have measured 2-D flow patterns of deuterons (Mach probe) and carbon (spectroscopy) and compared these with UEDGE models (with drifts). The UEDGE models reproduce the main features of the flow data, particularly the disappearance of a flow-reversal region in the Mach Probe data near the outer separatrix after the plasma detaches. Puff and pump experiments, particularly at modest core densities, are in progress to study radiative divertor operation and impurity control. Comprehensive 2-D measurements of n_e, T_e, n_o, and carbon emissions near the X-point highlight the importance of this region and the private flux region in determining divertor conditions and the H–mode transition. Significant progress has been made in understanding impurity sources and transport, particularly for carbon. While many conditioning cycles over several years has reduced the measured carbon source, we have not measured a corresponding decrease in the plasma concentration. Spectroscopic measurements and UEDGE modeling indicates that >90% of the carbon generated in the divertor is a source to the core plasma in attached plasmas. In detached plasmas, we do not measure net erosion in the divertor. All these observations point to the importance of sources outside the divertor and plasma transport in determining impurity content. A summary of comparisons with codes, including the UEDGE, CORSICA and ONETWO (scenario development), BOUT (edge fluctuations), and core-edge coupling with CORSICA-II will be presented.

*Work supported by the U.S. Department of Energy under Contract Nos. DE-AC03-99ER54463, W-7405-ENG-48, DE-AC05-96OR22464, DE-AC02-76CH03073, DE-AC04-95AL85000, and Grant Nos. DE-FG03-95ER54299 and DE-FG02-92ER54139.