Performance of High Triangularity Plasmas as the Volume of the Secondary Divertor is Varied in DIII–D*

M.E. Fenstermacher,[a] T.W. Petrie, T.H. Osborne, R.J. Groebner, R.J. LaHaye, C.J. Lasnier,[a] A.W. Leonard, G.D. Porter,[a] J.G. Watkins,[b] and The DIII–D Team

General Atomics, P.O. Box 85608, San Diego, CA 92186-5608
[a]*Lawrence Livermore National Laboratory, Livermore, California.*
[b]*Sandia National Laboratories, Albuquerque, New Mexico.*

The design of any future tokamak begins with a decision on the shape of the core and divertor plasmas. The desire is to achieve the performance advantages of high triangularity (high–δ) operation with the core plasma volume maximized and the divertor volume minimized. At low δ in single-null divertor configurations, only the primary X–point is present inside the vacuum vessel. As δ is increased the location of the secondary X–point, which maps at the midplane to a flux surface radially outboard of the primary, moves from outside the vacuum vessel to inside and divertor physics (recycling, target heat flux etc.) becomes important in this secondary divertor. This paper reports on a series of high–δ H–mode discharges in DIII–D in which the effect of variation in the secondary divertor volume on edge pedestal and divertor performance was examined. Since the secondary divertor takes up volume that could be used for the burning core plasma, the focus of the study was to determine the minimum secondary divertor volume consistent with good core, pedestal and divertor performance.

The sensitivity of edge pedestal and divertor performance parameters to reduction in secondary divertor volume was examined by varying the vertical distance of the secondary X-point from the target plate, 1 cm < Z_s < 16 cm, while holding the primary X–point height, Z_p = 16 cm, fixed. For these discharges the ion ∇B drift was in the direction of the primary divertor. Discharges with and without active primary divertor cryopumping were examined. The effective rate of rise of the core density at the L-H transition increased 60% as Z_s was reduced from 16 to 1 cm. At high density achieved by gas injection, the core line averaged density at the H-L back transition decreased 25% as Z_s was reduced. Both of these results indicate that performance may be affected when core plasma screening of neutrals in the secondary divertor is reduced as Z_s decreases. The peak heat flux in the secondary divertor $\left(P_{div}^{s}\right)$ was nearly constant for high Z_s. However, when Z_s was reduced from 3 cm to 1 cm, P_{div}^{s} increased a factor of 3 indicating that the secondary divertor target was beginning to act as a heat flux limiter as Z_s became comparable to the power scale length in the scrape-off-layer mapped to the secondary X–point location. Finally, for unpumped discharges the dependence of the maximum achieved edge pedestal temperature and pressure during the ELM-free period was nonlinear with Z_s. The dependence on Z_s was very weak for discharges with active pumping. Boundaries between Type-I ELMing and Type-III ELMing regimes in edge pedestal operating space also seemed to depend weakly on Z_s for unpumped plasmas. Although we attempted to hold as many control parameters fixed as possible, data will be presented showing that variation in wall conditions may also have affected the edge and divertor performance somewhat. These data will be presented in combination with core transport and SOL/divertor fluid simulations to identify the mechanisms connecting secondary divertor volume variation to changes in performance.

*Work supported by the U.S. Department of Energy under Contract Nos. DE-AC03-99ER54463, W-7405-ENG-48, and DE-AC04-94AL85000.