RADIATIVE AND SOL EXPERIMENTS IN OPEN AND BAFFLED DIVERTORS ON DIII–D*

S.L. Allen,[a] N.H. Brooks, R. Bastasz,[b] J.A. Boedo,[c] J.N. Brooks,[d]
J.W. Cuthbertson,[c] T.E. Evans, M.E. Fenstermacher,[a] D.N. Hill,[a] D.L. Hillis,[e]
J. Hogan,[e] R.C. Isler,[e] G.L. Jackson, T. Jernigan,[e] A.W. Hyatt, C.J. Lasnier,[a]
R. Lehmer,[c] A.W. Leonard, R. Maingi,[e] W. H. Meyer, P.K. Mioduszewski,[e]
R.A. Moyer,[c] D.G. Nilson, L.W. Owen,[e] T.W. Petrie, G.D. Porter,[a] M.E. Rensink,[a]
M.J. Schaffer, J.P. Smith, G.M. Staebler, R.D. Stambaugh, D.M. Thomas,
M.R. Wade,[e] W.R. Wampler,[b] J.G. Watkins,[b] W.P. West, D.G. Whyte,[c]
N. Wolf,[f] C.P.C. Wong, R.D. Wood,[a] and The DIII–D Physics and Operations Teams

General Atomics, P.O. Box 85608, San Diego, California 92186-9784

In 1997, a new divertor baffle and cryopump were installed in the upper divertor of the DIII–D tokamak. This configuration has allowed the comparison of recycling and impurity transport in open and closed divertors in a single tokamak device and provides density control for high-δ (triangularity) experiments. We also recently added new physics measurements in the lower open divertor, including: 1) direct absolutely-calibrated measurements of the principal line-emissions of carbon in the divertor, 2) line-integrated and 2-D measurements of recombination with visible and ultraviolet spectroscopy, and 3) plasma ion and impurity flow measurements from divertor Mach probes and tangential views of Doppler shifts of line emission in the divertor. This paper presents experimental results of divertor and SOL experiments to control the exhaust power along two major lines of research: partially-detached divertor (PDD) operation by deuterium gas puffing and intrinsic carbon divertor radiation at high core density ($n/n_{gw} \sim 0.75$), and reduction of divertor heat flux with impurity radiation with the goal of operation at moderate core density ($n_e \sim 0.4 \times 10^{20}$ m^{-3} in DIII–D). The PDD operation is consistent with ITER operation, as $Z_{eff} \sim$ 1.8 and H(ITER-89P) ~ 1.8. The lower density, higher electron temperature solution can serve as a target plasma for ECH current drive with the near-term available rf power on DIII–D.

In the research of the PDD regime, our new diagnostics have enabled more detailed examination of the relevant physical processes. 2-D Divertor Thomson Scattering measurements have shown an extended region of 1–2 eV in the divertor below the X-point during detachment. The radial profile of the plasma density and therefore pressure at the divertor plate peaks away from the separatrix; hence the nomenclature “partially detached divertor” (i.e., detached at the separatrix, but reattached outboard of the separatrix). The distance of the density peak from the separatrix becomes greater as one moves from the X-point to the divertor plate, suggesting the influence of neutrals which do not follow the field lines. Comparison of the radiated power in the divertor and the heat flux to the plate with the measured temperature profile indicate that the SOL power cannot be carried by classical conduction, a convective term with flow less than M=1 can explain the energy flow. Most of the divertor radiation is due to carbon emissions; we measure the principal

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[a]Lawrence Livermore National Laboratory, Livermore, California.
[b]Sandia National Laboratory, Livermore, California.
[d]Argonne National Laboratory, Argonne, Illinois.
[c]University of California at San Diego, San Diego, California.
[e]Oak Ridge National Laboratory, Oak Ridge, Tennessee.
[f]Dickinson College.

transition in CIV at 1550 Å. Initial estimates of plasma flow and temperature from probes near the divertor plate indicate semi-quantitative agreement with the required convected heat flux. Line-ratio measurements of neutral deuterium radiation in the visible (Ba_{α}/Ba_{γ} from both line-average measurements and 2-D inverted tangential images) and the ultraviolet (Ly_{α}/Ly_{β}) have shown that there is a recombination zone near the inner strike point before the PDD, which then moves to the outer strike point during the PDD. Operation with pure He plasmas with a PDD and comparison with UEDGE calculations has indicated that chemical sputtering of carbon in the private flux region is an important impurity generation source. The overall behavior of He-detached plasmas is similar to deuterium, even though the principal radiator changes from carbon to helium, and very different atomic physics processes are involved. An insertable sample probe, DiMES, has been used to measure erosion in PDD discharges and has shown that there is little if any net erosion (and perhaps net deposition) at the separatrix in these discharges.

Flow measurements of plasma ions and impurities from probes and spectroscopy have been compared with 2-D computations from UEDGE. A general trend of the measurements is that there is a plasma flow away from the divertor plate on field lines near the separatrix in attached plasmas, while the flows are towards the plate on field lines outboard of the separatrix. The UEDGE results up to this point have predicted similar qualitative behavior in attached plasmas. In the model, the flow is unidirectional towards the plate when the plasma detaches at the outer strike point. Further details of these measurements and modeling will be presented.

The design of the new upper baffle was guided by UEDGE and DEGAS modeling which predicted a reduction in the core ionization of a factor of 3 in single null. Measurements of edge H_{α} and a transport calculation using the measured n_e profiles have estimated 2 times lower ionization in the closed upper divertor compared to the open lower divertor, in rough agreement with the model predictions. UEDGE modeling has also shown changes in the plasma flow patterns as the separatrix is moved closer to the baffle, thus we may be able to use divertor geometry as a tool to control plasma and impurity flows and thereby concentrate impurity radiation in the divertor at modest densities. Preliminary indications of the usefulness of flows in closed divertors has been shown in an experiment with a forced SOL flow obtained by midplane deuterium puffing and divertor pumping. Argon impurity injection in the closed divertor resulted in enhanced divertor and SOL radiation. (For more details of impurity transport studies, see Ref. [1].)

Density control with the closed divertor (high-δ SN plasmas) has been used to reduce the "natural" ELMing H–mode density from $n_e/n_{gw} \sim 0.6$ to about 0.3. These results are similar to those obtained with the lower (open) pump. The core impurity density in these discharges is primarily due to carbon, and remains constant as the electron density decreases. The resulting Z_{eff} at 4×10^{19} m^{-3} is about 2.5. The exhaust rate can be increased(decreased) by moving the separatrix towards (away) from the pump aperture. the up/down magnetic balance is important in determining the sharing of the heat and particle flux between the upper closed and lower open divertor.

[1] WADE, M.R., et al., this conference.