

Gas Puff Fueled H-Mode Discharges With Good Energy Confinement Above The Greenwald Density Limit on DIII-D*

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Tokamak reactors will require operation with good energy confinement at high density in order to maximize the ratio of fusion power to auxiliary heating power, Q . Because of the large size, high temperatures, and high densities required, direct particle fueling of the plasma core, as with neutral beams or pellets, becomes problematic, and fueling via an edge particle source, such as gas puffing, may still be required. Gas puff fueling of H-mode plasmas typically leads to loss of energy confinement when the electron density, n_e , approaches the Greenwald density, $n_G = I_P/(\pi a^2)$. In recent experiments on DIII-D discharges with $n_e/n_G = 1.4$, and energy confinement enhancement over L-mode scaling, $H_{ITER89P} = \tau_E/\tau_{ITER89P} = 1.9$ were obtained with gas puffing in combination with divertor pumping.

Obtaining good energy confinement at high density required divertor pumping during the gas puff fueling. Divertor pumping acts to maintain the temperature in the X-point region as high as possible while the H-mode pedestal temperature, T^{PED} , decreases and the pedestal density, n^{PED} , increases with gas puffing at roughly constant p^{PED} , in the Type I ELM regime. Maintaining high X-point temperature may avoid a transition from the Type I ELM regime to L-mode or to the Type III ELM regime in which confinement is reduced.

The high density good confinement discharges on DIII-D show spontaneous reappearing of the density profile in the Type I ELM regime which, in the highest density cases, compensates for a reduction in p^{PED} . The usual decrease in energy confinement in the Type I ELM regime with gas puffing is associated with a reduction in p^{PED} and a broadening of the density. The reduction in p^{PED} begins in the range $0.6 < n_e^{PED}/n_G < 0.8$ and is a result of the decrease in edge pressure gradient at low temperature. The pressure gradient decrease is consistent with what would be expected for a transition from ideal to resistive tearing modes. The effect of the reduction in p^{PED} is through stiffness of the temperature profile which is apparent in the high density regime on DIII-D. The energy confinement is also reduced in discharges with stiff temperature profiles when the density profile broadens at fixed p^{PED} . The density profile peaking occurs under conditions that reduce the central temperature suggesting the neoclassical Ware pinch.

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