Measurements of Injected Impurity Assimilation During Fast Shutdown Initiated by Multiple Gas Valves in DIII-D*

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Massive gas injection (MGI) is a promising technique for reducing tokamak wall damage during disruptions, with reductions observed in both conducted wall heat loads and in halo currents, when compared with unmitigated disruptions [1]. However, it is unknown at present if MGI can prevent the formation and amplification of runaway electrons (RE) in future high-current tokamaks, so RE formation during MGI remains an outstanding concern. To avoid RE during MGI shutdowns, efficient delivery of injected impurities into the plasma core is desirable.

Here, up to six fast-acting gas valves are fired simultaneously into initially quiescent (non-disrupting) DIII-D H-mode discharges. The experiments demonstrate that rapid gas delivery is crucial for achieving large core impurity densities. The initial early arrivals of injected gas cause the rapid (~ 1 ms) core thermal quench (TQ). Mixing efficiencies of injected impurities into the plasma core during the TQ are measured to be of order 0.05 – 0.2 for H_2, Ne, or Ar injection and of order 0.2 – 0.4 for He injection. By using narrow (~ 2 ms) pulses of H_2 so that the bulk of the gas is delivered during the TQ, DIII-D record free electron densities of $n_e \approx 2 \times 10^{15}\ \mathrm{cm}^3$ are achieved. During the subsequent slower (~ 5 ms) current quench (CQ) phase, mixing appears to be significantly less efficient, and gas delivered to the plasma edge during this phase appears to have minor effect on the core impurity density.

To begin efforts to extrapolate DIII-D MGI results to larger tokamaks, 0D modeling is used [2]. The 0D modeling is found to reproduce the observed TQ and CQ durations reasonably well (typically within ±25% or so), although shutdown onset times are underestimated (by around $2\times$), possibly because profile effects are ignored. Preliminary 0D modeling of ITER suggests that MGI will work well with regards to disruption heat load and vessel force mitigation, but may not collisionally suppress REs with a realistic number of gas valves (ten or less D = 2 cm valves with L = 5 m delivery tubes).

[1] D.G. Whyte, et al., J. Nucl. Mater. **313**, 1239 (2003).

[2] E.M. Hollmann, et al., to be published in Contrib. Plasma Phys. (2008).

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