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Optimization of Massive Impurity Injection Techniques for Thermal Quench Mitigation and Current Quench Control on DIII-D[1]

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Recent DIII-D experiments demonstrate the ability of massive impurity injection techniques to effectively control current quench (CQ) timescales and thermal quench (TQ) radiation fractions, which are essential design requirements for the ITER disruption mitigation system (DMS). Allowable CQ timescales for ITER are constrained by both a lower bound due to eddy current forces as well as an upper bound due to halo currents, and this must be achieved while maintaining sufficiently high radiated powers to minimize thermal loads. The DIII-D shattered pellet injection system has been modified to allow formation of mixed species pellets with variable quantities of high-Z radiating impurities (Ne) and main ions (D_2), which is shown to provide control of TQ radiation fractions and the resulting post-TQ plasma resistivity which determines the CQ rate. By varying the pellet composition ranging from pure D_2 to pure Ne, TQ radiation fractions are observed to saturate with modest quantities of Ne, indicating that relatively small quantities of the radiating impurity provide effective thermal mitigation. Resulting CQ durations are found to remain within scaled eddy and halo current limits predicted for ITER, demonstrating that integrated control of TQ and CQ properties during disruption mitigation can be achieved. The effectiveness of these mitigation techniques in disruptive plasma scenarios with large MHD instabilities is also crucial for ITER. Such effects are observed to lead to increased assimilation of injected impurities during the TQ, implying the importance of MHD mixing during the initial assimilation. Longer timescale CQ metrics are relatively unaffected by the pre-existing MHD activity, allowing effective mitigation of electromagnetic loads. These results provide further confidence in the implementation of these injection techniques in the final design of the ITER DMS.

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