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Experiments in DIII-D Toward Achieving Rapid Shutdown with Runaway Electron Suppression[1]

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For safe discharge shutdown in future large tokamaks in the event of an unavoidable disruption, it is important to develop rapid ($\sim$ several ms)shutdown methods to avoid large runaway electron currents, which pose a serious threat to plasma facing components. Prevention of runaway current formation has been proposed by either increasing electron-electron collisionality with massive particle injection, or magnetically by using externally applied non-axisymmetric fields to increase radial diffusive losses of a runaway seed population. Experiments studying both approaches have been pursued in the DIII-D tokamak. For collisional suppression, three different rapid shutdown methods are being investigated: massive gas injection, massive shattered cryogenic pellet injection, and polystyrene shell pellet injection. First-of-kind demonstrations of fast shutdowns were produced by 3000 Torr-l (0.8-g) shattered D_2 pellets and large, 10-mm diameter, 0.3-g polystyrene shell pellets filled with boron powder. The application of external magnetic perturbations shows promising preliminary results in suppressing seed runaway electrons, although lack of repeatability in the runaway seed term made these results challenging to interpret. Experiments have been performed to help understand how runaways form and are transported during rapid shutdown. These experiments confirm that the commonly used 0D loop voltage + Dreicer evaporation picture of runaway seed formation is not applicable here, with relativistic $E > 0.5\,\mathrm{MeV}$ electrons forming before any external loop voltage appears. Present applications of 0D, 1D, and 2D models to the rapid shutdown and runaway confinement experiments, as well as preliminary extrapolations to ITER, will be discussed.

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