A Novel Concept for Prompt Gas Delivery During Mitigated Plasma Disruptions: Burst Membrane Gas Injection, and Comparison with Conventional Gas Delivery Tubes

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Abstract

Modeling high-pressure gas flows through long extended delivery tubes used for massive particle fueling of tokamaks during a major disruptive instability or a preemptive fast plasma shutdown is presented using analytical theory and simulation. Expressions were derived and compared with experiments for the transition diameter and inlet Mach number of a straight tube (pipe) attached to a “nozzle-like” inlet valve, such that increases in pipe diameter have no effect on the flow rate (valve-limited flow), and decreases below the transition diameter cause decreasing flow rates (friction-limited flow). Analytical expressions for the exit outflow rate and other gas dynamic variables during the initial transient phase were developed from the classical 1-D centered rarefaction wave problem and compared with 2-D axisymmetric FLUENT simulations with wall friction, and good agreement was found for sufficiently high conductance pipes. The intrinsic time delay before steady-state outflow is reached can seriously limit plasma density increases during the disruption, as the disruption time scale is similar to the delay time or “rise time” of the outflow. Thus, conditions required for strong collisional dissipation of destructive runaway electron currents can be compromised. A new gas injection scheme “Burst Membrane Gas Injection” is also presented in which a steady-state outflow can be established promptly (zero rise time).

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