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Overview of the Radiated Fraction and Radiation Asymmetries Following Shattered Pellet Injection

During shattered pellet injection (SPI) shutdowns in ITER, a high fraction of the plasma thermal energy must be radiated with a moderate degree of uniformity to avoid damages to the divertor and the first wall such as melting. DIII-D, J-TEXT, JET, and KSTAR now operate SPI systems and studies have begun to assess these requirements. For studies of gross dependencies of the radiation efficiency, the radiation is often assumed axisymmetric and is measured in one toroidal location by approximately calibrated fast diodes, or by metal foil bolometers that integrate over the entire disruption and require subtraction of the radiated magnetic energy. Both approaches find increasing radiation as the injected neon quantity is increased until a saturation is observed at ˜10 Pa·m^3 in DIII-D [D. Shiraki et al., Phys. Plasmas 23 (2016)] and ˜50 Pa·m^3 in JET, in approximate agreement with the scaling $N_{\mathrm{Ne}} \propto (W_{\mathrm{th}}V/a)^{0.5}$. Unfortunately, the assumed axisymmetric radiated fraction $\langle f_{\mathrm{rad}}\rangle$ in JET decreases as the plasma thermal fraction f_{th} increases, similar to massive gas injection [M. Lehnen et al., NF 53 (2013)], and suggests that the ITER divertor will melt even with mitigation [$\langle f_{\mathrm{rad}}\rangle = \langle W_{\mathrm{rad}}\rangle/(W_{\mathrm{th}}+W_{\mathrm{mag}}–W_{\mathrm{coupled}})$ where $\langle W_{\mathrm{rad}}\rangle$ is the assumed axisymmetric radiated energy, W_{th} and W_{mag} are the thermal and magnetic energies, and W_{coupled} is the magnetic energy coupled to the vessel]. However, an asymmetry in the radiation is measured that shows positive correlations with f_{th} and the injected neon quantity, invalidating the axisymmetric assumption at high f_{th}, and possibly resolving the radiation shortfall. Work towards a full 3D treatment of the radiated power is ongoing. Asymmetries are explored further by varying the toroidal phase of an applied $n = 1$ field and measurements show that the radiation asymmetries at least partially track the phase-locked magnetohydrodynamic (MHD) modes. Localized wall heating near the SPI port in DIII-D is measured with infrared cameras, and work continues to quantify the radiation peaking consistent with this hot spot. The JOREK, M3D-C1, and NIMROD nonlinear MHD codes can be used to better understand the asymmetries, and present simulations show qualitative agreement with experiment.

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