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Divertor Heat Flux Reduction and Detachment in the National Spherical Torus eXperiment.[1]

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Steady-state handling of the heat flux is a critical divertor issue for both the International Thermonuclear Experimental Reactor and spherical torus (ST) devices. Because of an inherently compact divertor, it was thought that ST-based devices might not be able to fully utilize radiative and dissipative divertor techniques based on induced power and momentum loss. However, initial experiments conducted in the National Spherical Torus Experiment in an open geometry horizontal carbon plate divertor using 0.8 MA 2-6 MW NBI-heated lower single null H-mode plasmas at the lower end of elongations κ=1.8-2.4 and triangularities δ=0.45-0.75 demonstrated that high divertor peak heat fluxes, up to 6-10 MW/ m^2, could be reduced by 50-75% using a high-recycling radiative divertor regime with D_2 injection. Furthermore, similar reduction was obtained with a partially detached divertor (PDD) at high D_2 injection rates, however, it was accompanied by an X-point MARFE that quickly led to confinement degradation. Another approach takes advantage of the ST relation between strong shaping and high performance, and utilizes the poloidal magnetic flux expansion in the divertor region. Up to 60 % reduction in divertor peak heat flux was achieved at similar levels of scrape-off layer power by varying plasma shaping and thereby increasing the outer strike point (OSP) poloidal flux expansion from 4-6 to 18-22. In recent experiments conducted in highly-shaped 1.0-1.2 MA 6 MW NBI heated H-mode plasmas with divertor D_2 injection at rates up to 10^{22} s^{-1}, a PDD regime with OSP peak heat flux 0.5-1.5 MW/m^2 was obtained without noticeable confinement degradation. Calculations based on a two point scrape-off layer model with parameterized power and momentum losses show that the short parallel connection length at the OSP sets the upper limit on the radiative exhaust channel, and both the impurity radiation and large momentum sink achievable only at high divertor neutral pressures are required for detachment.

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