RECENT H–MODE DENSITY LIMIT EXPERIMENTS ON DIII–D*

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An overwhelming body of tokamak data support the Greenwald density limit scaling law: $n_{GW} \approx I_p / \pi a^2$ ($10^{14}\,\mathrm{m}^{-3}$). Several machines; notably TFTR, ASDEX -Upgrade, JET and DIII–D, under restrictive conditions, have operated at densities above this scaling, albeit at varying degrees of confinement degradation relative to the H–mode. Although the Greenwald limit is not fundamental, it is apparently very difficult to surpass. Motivated by ITER's requirement of H–mode operation at $\bar{n}_e \geq 1.5(n_{GW})$, we have conducted a series of experiments designed to isolate and independently investigate several physical effects suspected to be directly or indirectly responsible for the density limit. The experimental knowledge gained was used to simultaneously achieve $\tau_e \approx \tau_{\mathrm{ITER-93H}}$ and $\bar{n}_e \cong 1.5(n_{GW})$.

Normally, in DIII–D, with either gas or pellet fueling, depending on divertor geometry and heating power, a density limit in the range 0.7–1.1 n_{GW} is observed. This limit is seen following divertor detachment when the most prominent radiation zone reaches the X-point. We have bypassed this limit by lowering the divertor density relative to the line average density by simultaneous divertor pumping and pellet injection (D = 2.7 mm, $\delta N/N \approx 30\%$).

The MARFE condensation instability is a density dependent phenomenon which is normally incompatible with the H–mode confinement. In low powered, high safety factor (q) plasmas, MARFEs were observed at densities below n_{GW}, whereas at low q and at a similar power no MARFE activity was observed. In the latter case, the line average density was increased to the symmetric radiative power balance limit at twice the Greenwald limit. Our results are in semi-quantitative agreement with theory.

Several deleterious effects of pellet fueling were observed which reduced the parameter window for high density plasmas. First, near the H–mode power threshold, pellets caused transient H-L transitions, which caused unacceptable particle loss. This problem was avoided by lowering B_T since the power threshold scales inversely with B_T. Secondly, spontaneous or pellet triggered ELMs expelled a large fraction of the plasma density which frequently increased the fueling demand beyond the available injection rate. This problem was alleviated by lowering ELM frequency through lowering P_{INJ}/I_p^2. Finally, pellets invariably triggered low number MHD modes which at times continued to grow and lock long after the pellet density perturbation had decayed away. Analysis shows these plasmas to be stable to classical and neoclassical tearing modes. Additional physics is needed to explain these observations. A phenomena similar to “snakes”, observed on JET, is suspected and is the subject of continuing investigation.

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