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H-mode and Non-Solenoidal Startup in the Pegasus Ultralow-A Tokamak

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Studies at near-unity aspect ratio offer unique insights into the high confinement (H-mode) regime and support development of novel startup scenarios. Ohmic H-mode operation has been attained at A < 1.3. Edge plasma parameters permit probe measurements of the edge pedestal, including the local current density profile, with high spatial and temporal resolution. H-mode plasmas have standard L-H transition phenomena: a drop in D_alpha radiation; the formation of pressure and current pedestals; field-aligned filament ejection during ELMs; and a doubling of energy confinement time from H_98 ˜ 0.5 to ˜1. The L-H power threshold P_LH increases monotonically with n_e, consistent with the ITPA08 empirical scaling used for ITER and the theoretical FM3 model. Unlike at high A, P_LH is comparable in limited and single-null diverted topologies at A ˜ 1.2, consistent with FM3 predictions. The magnitude of P_LH exceeds ITPA scalings by an order of magnitude, with P_LH/P_ITPA08 increasing as A approaches 1. Multiple n modes are observed during two classes of ELMs, consistent with excitation of multiple peeling-ballooning modes. Small, Type III-like ELMs occur at P_OH ˜ P_LH with n <= 4. Large, Type-I-like ELMs occur with P_OH > P_LH and intermediate 5 < n < 15. Helical edge current injection appears to suppress Type III ELM activity. J_edge(R,t) measurements across single ELMs show the nonlinear generation and expulsion of current-carrying filaments during the ELM crash. Local Helicity Injection (LHI) offers a nonsolenoidal tokamak startup technique. Helicity is injected via current sources at the plasma edge. A circuit model that treats the plasma as a resistive element with time-varying inductance reasonably predicts I_p(t). The electron confinement governs the power balance. Initial measurements show peaked T_e and pressure profiles, which are comparable to Ohmic-like transport or moderately stochastic confinement. Extrapolation suggests I_p ˜ 1 MA may be achievable in NSTX-U. Resistive MHD simulations suggest I_p is built from current rings injected during reconnection between unstable helical current streams. Several experimental observations support this model: imaging of the merging current streams; n=1 MHD activity and discrete current stream localized in the plasma edge; and anomalously high impurity ion heating in the edge region.

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