Pedestal Structure Model Tests*

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Background. Predictions have been developed [1] for the structure of plasma parameter profiles of H-mode pedestals in transport quasi-equilibrium in tokamak plasmas. They are based on assuming paleoclassical radial plasma transport processes dominate throughout the pedestal. The pedestal density profile is determined mainly by what is needed for the outward paleoclassical diffusive flux to be nearly balanced by inward paleoclassical pinch flow — i.e., not by edge fueling.

Pedestal Structure Model Predictions. The key parameter of this pedestal structure model is the poloidal magnetic flux diffusivity $D_\eta \equiv \eta_\parallel^{\rm nc}/\mu_0$, in which $\eta_\parallel^{\rm nc}$ is the parallel neoclassical resistivity. Fundamental model predictions within the pedestal region are [1]:

$$n_e \text{ profile:} \qquad n_e(\rho) = \frac{n_e(\rho_{\rm REF})\,D_\eta(\rho_{\rm REF})}{D_\eta(\rho)} \propto \frac{T_e^{3/2}}{Z_{\rm eff}}\,\frac{\eta_\perp}{\eta_\parallel^{\rm nc}}, \tag{1}$$

$$T_e \text{ gradient:} \qquad -\frac{dT_e}{d\rho} = \frac{\text{electron power flow}}{(3/2)(V'\bar{D}_\eta n_e)} \sim \text{constant} \quad\Longrightarrow\quad \chi_e \simeq 1.2\,D_\eta, \tag{2}$$

$$\text{toroidal rotation:} \qquad \frac{d\Omega_t}{d\rho} \simeq 0 \quad\Longrightarrow\quad \Omega_t(\rho) \simeq \text{constant} = \Omega_t(a) \text{ on separatrix.} \tag{3}$$

Here, ρ is a toroidal-flux-surface-based radial coordinate, $\rho_{\rm REF}$ is a reference radius within the pedestal (e.g., at the separatrix $\rho = a$) and $V' \equiv dV(\rho)/d\rho = S(\rho)/\langle|\boldsymbol{\nabla}\rho|\rangle$ where $V(\rho)$ and $S(\rho)$ are the volume and area of the ρ flux surface. When neutral fueling effects are significant (e.g., for high density and high main chamber recycling cases) they are predicted [1] to add to the pedestal density, displace the density profile outward from the electron temperature profile and cause the plasma toroidal rotation Ω_t to decrease about linearly from the separatrix inward through the pedestal. The transition into electron-temperature-gradient (ETG) driven anomalous radial electron heat transport (assumed to be $\chi_e^{\rm ETG} \simeq f_\# \chi_e^{\rm gB}$, with $\chi_e^{\rm gB} = (\varrho_e/L_{T_e})(T_e/eB)$, $f_\# \sim 1.4$–3) in the core plasma determines the initial, transport-limited height of the electron pressure pedestal [1]:

$$\beta_e^{\rm ped} \equiv \frac{n_e^{\rm ped} T_e^{\rm ped}}{B_0^2/2\mu_0} \sim \frac{3\sqrt{2}}{\pi f_\#}\,\frac{\eta_\parallel^{\rm nc}}{\eta_\perp}\,\frac{L_{T_e}}{R_0 q} \tag{4}$$

Tests Of Pedestal Structure Model. These model predictions for the n_e, χ_e and Ω_t profile shapes and magnitudes, and the pedestal height $\beta_e^{\rm ped}$ are found to agree quantitatively (< factor of 2) with properties of the recently studied DIII-D pedestal 98889 [2]. In addition, these predictions for the χ_e and n_e profiles are found to capture the pedestal region variations in the SOLPS interpretive pedestal modeling results for recent NSTX experiments with and without lithium wall coatings [3].

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[2] J.D. Callen, R.J. Groebner, T.H. Osborne, J.M. Canik, L.W. Owen, A.Y. Pankin, T. Rafiq, T.D. Rognlien and W.M. Stacey, "Analysis of pedestal transport," Nuclear Fusion **50**, 064004 (2010).

[3] J.M. Canik et al., "Edge transport and turbulence reduction with lithium coated plasma facing components in the National Spherical Torus Experiment," invited paper JI2 1 at the 2010 Chicago APS-DPP meeting (to be published in Phys. Plasmas).