High Power Density Advanced Divertor Test Facility – Alcator DX

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Alcator C-Mod

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Notes on $q_{||}$ scalings in tokamak device table:

$q_{//}$ is computed from $q_{||} = \dfrac{B}{B_p} \dfrac{P_{tot} R}{2\pi (R+a)^2 \lambda_q}$

a – minor radius (meters)
R – major radius (meters)
κ – vertical elongation
B – magnetic field (tesla) on axis (R)
λ_q – scrape off layer heat flux channel width at outer midplane (meters)

B_p- poloidal magnetic field (tesla) $B_p = \dfrac{0.2 I_p}{a\sqrt{(1+\kappa^2)/2}}$

I_p – plasma current (MA)

Important note on source power

P_{tot} – total input power (MW). For all tokamaks, this is taken to be the total *installed source power* according to the above publications. While $q_{//}$ is quantitatively determined by the *net* power crossing the last-closed flux surface (as well as λ_q), we are using total source power as a simple means to *scale* the magnitude of $q_{//}$ that could be available across different devices. All else being the same (e.g., inefficiencies in auxiliary power systems, fraction of radiated power in core region,..), this is a reasonable first approximation.

Two models for the scaling of the heat flux width at the outer midplace (λ_q) are considered:

(1) Heatflux width given by $\lambda_q = 1.35 \varepsilon^{0.42} B_p^{-0.92} R^{0.04}$ (mm). This empirical relationship is based on a multi-machine database, looking at the divertor heat flux 'footprint' for attached divertor conditions in H-mode (between ELMs).
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(2) Heatflux width proportional to $\lambda_q \sim a$ ('pedestal scaling, critical-gradient model'). This is a simple scaling argument based on the observation that the width of the H-mode pedestal scales with machine size. The pedestal width in turn is thought to be controlled by 'critical gradient' transport physics.
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$q_{//}$ (1) / (2) values in the table are the result of applying the above formulas, normalized to the values obtained for Alcator C-Mod under the conditions shown (B = 5.4, I_p = 1.3). Since Alcator C-Mod has $q_{//}$ ~1 GW/m^2, the $q_{//}$ values in the table are shown with units of 1 GW/m^2 – a rough estimate of the maximum values that might be obtained in these devices.

Notes on 'divertor opacity scaling' (3) in tokamak device table:

The mean-free-path for neutrals and hydrogen radiation in a cold divertor depends on the local plasma density, going like $L_{MFP} \sim 1/n$. Thus the relevant parameter to judge how 'opaque' the divertor fan is to these atomic processes is simply *nL*, with *L* being a characteristic width of the divertor fan. The highest density that can be achieved in a tokamak is the Greenwald density (n_{20G}, in units of 10^{20} m^{-3}), $n_{20G} = \frac{I_p}{\pi a^2}$. Assuming that the size of the divertor 'fan' is maximized in all devices, its overall size will scale like major radius. Thus a good scale parameter to compare among devices how 'opaque' a given device's divertor can be is $n_{20G} R$.

I-mode

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QH mode

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Quiescent plasma in high-field side SOL

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Tokamak operation must be demonstrated with hot tungsten plasma-facing surfaces.
Alcator DX will use the experience of developing hot tungsten divertor targets (~ 600C) for Alcator C-Mod.

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Alcator DX will utilize DoE's investment in the high-performance tokamak support facility at the MIT PSFC

Alcator DX will make use of the extensive infrastructure presently supporting Alcator C-Mod – a facility evaluated at $200M: power supplies and control system for magnets, high power switching gear, a 225 MVA motor-generator and flywheel, advanced computing and data acquisition network, 8 MW source power ICRF system, 4 MW source power lower hybrid system and extensive plasma diagnostic systems.

Key engineers and technical support staff personnel involved in the original design and construction of Alcator C-Mod are available at the MIT PSFC.