DPP11-2011-001321
Abstract for an Invited Paper
for the DPP11 Meeting of
the American Physical Society

Developing the Core Physics Scenarios For Next Step STs[1]

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Steady-state spherical torus devices for nuclear component testing, or possibly fusion power generation, will need high-beta, excellent confinement and non-inductive current drive. In pursuit of these goals, the National Spherical Torus Experiment (NSTX) has, in recent years, developed lithium conditioning of the plasma facing components, improved control of strongly shaped equilibria, and implemented routine feedback control of n=1 error fields and resistive wall modes. The synergistic combination of these techniques has produced non-inductive current fractions of 65-70%, sustained for multiple current relaxation times, as well as the highest sustained values of toroidal beta, poloidal beta, and stored energy in NSTX. The confinement scaling with plasma current in these discharges is somewhat stronger than the previous NSTX scaling, and the toroidal field dependence is nearly absent. Intrinsic n=1 stability is improved by strong shaping and a broad pressure profile. Active n=1 control further improves reliability at high beta, although core n=1 kink/tearing instabilities often end the high-performance phase. Assessments of stability with the PEST-1, NOVA-K, M3D, and M3D-C1 codes show that these modes can be avoided by maintaining an elevated central q. The relaxed current profile in MHD-quiescent phases is well modeled by TRANSP with (neo)classical physics only. The effect of large TAE avalanches in elevating the central q has been simulated by including a transient fast ion diffusion; this produces a good match to the observed neutron emission drops and toroidal current profile. Using this overall physics basis, simulations with free-boundary TRANSP and DCON show that the higher toroidal field and off-axis beam current drive in NSTX-Upgrade can support a wide range of ideally stable non-inductive scenarios, and partially inductive operation with central safety factor >1 and toroidal beta>25%.

[1]This work is supported by US DOE contract DE-AC02-09CH11466.