A Fusion Nuclear Science Facility for a Fast-Track Path to DEMO*

A.M. Garofalo[1], M. Abdou[2], J.M. Canik[3], V.S. Chan[1], N.B. Morley[2], M.E. Sawan[4], T.S. Taylor[1], C.P.C. Wong[1], and A. Ying[2]

[1]General Atomics, PO Box 85608, San Diego, California 92186-5608, USA
[2]University of California Los Angeles, Los Angeles, California 90095-7099, USA
[3]Oak Ridge National Laboratory, Oak Ridge Tennessee 37830, USA
[4]University of Wisconsin-Madison, Madison, Wisconsin 53706, USA

An accelerated fusion energy development program, a "fast-track" approach, requires proceeding with a nuclear and materials testing program in parallel with research on burning plasmas, ITER. Proceeding with a Nuclear Fusion Science Facility (FNSF) in parallel with ITER provides a strong basis to begin construction of DEMO upon the achievement of $Q \sim 10$ in ITER.

A FNSF would address many of the key issues that need to be addressed prior to DEMO including breeding tritium and completing the fuel cycle, qualifying nuclear materials for high fluence, developing suitable materials for the plasma-boundary interface, and demonstrating power extraction. The Advanced Tokamak (AT) is a strong candidate for an FNSF as a consequence of its mature physics base, capability to address the key issues, and the direct relevance to an attractive target power plant.

Key features of AT are fully noninductive current drive, strong plasma cross section shaping, internal profiles consistent with high bootstrap fraction, and operation at high beta, typically above the free boundary limit, $\beta_N > 3$. Recent research shows that full noninductive and high β_N scenarios are obtained and sustained for many energy confinement times. Key remaining challenges are to sustain these AT scenarios for several current redistribution times, τ_R, and develop high fluence boundary solutions consistent with high plasma performance.

A moderate sized FNSF-AT has an advantage of limited tritium consumption, robust tritium self-sufficiency (achievable TBR > ~1.1), and sufficient neutron flux (2 MW/m^2) to test components. An example design point gives a Cu-coil device with $R/a =$ 2.7 m/0.77 m, k = 2.3, $B_T = 5.4$ T, $I_p = 6.6$ MA, $\beta_N = 3.7$, $P_{FUS} = 230$ MW, and $P_{COILS} = 400$ MW. The finite aspect ratio provides space for a solenoid and robust plasma current initiation. The modest bootstrap fraction of $f_{BS} \sim 0.75$ provides an opportunity to develop steady state with sufficient current drive for adequate control.

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