Candidates for a Fusion Nuclear Science Facility (FDF and ST-CTF)

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A Fusion Nuclear Science Facility (FNSF) is needed to make possible a DEMO of the ARIES-AT type after ITER. One candidate, a conventional aspect ratio Fusion Development Facility (FDF), should have neutron flux of 1-2 MW/m^2, continuous operation for periods up to two weeks, a duty factor goal of 0.3 on a year and fluences of 3-6 MW-yr/m^2 in 10 years to enable development of blankets suitable for tritium, electricity, and hydrogen production. A second candidate is the Spherical Tokamak-Component Test Facility (ST-CTF).

FDF and ST-CTF share many aspects of mission scope. FDF will develop fusion's energy applications and the operating modes needed in DEMO. FDF should be used to learn how to close the fusion fuel cycle and make electricity and hydrogen from fusion. FDF will have a goal of producing its own tritium and building a supply to start up DEMO. The size of FDF (R = 2.7 m) and the significant level of fusion power produced (290 MW) require that FDF be self-sufficient in tritium. The ST-CTF's small size (R = 1.3 m) and lower fusion power (110 MW) mean the provision of 20% of its tritium from external supply may be feasible.

In port blanket modules, the development of blankets suitable for both tritium production and electricity production will be made. Both FDF and ST-CTF will provide the necessary facility to test perhaps ten different blanket concepts or variants in 2-3 ports over a 10 year time period. Actual demonstrations of electricity production (100-300 kW) should be made on the most successful port blankets.

With neutron fluence of 3-6 MW-yr/m^2 (30-60 dpa in 10 years) onto complete blanket structures and port material sample exposure stations (1 m^3), FDF and ST-CTF can enable irradiation qualification of materials to qualify the first years of DEMO operation.

FDF will demonstrate advanced physics operation of a tokamak in steady state with burn. FDF will be designed using conservative implementations of all elements of Advanced Tokamak physics to produce 100-300 MW fusion power with modest energy gain ($Q<8$) in a modest sized device. Conservative AT physics will enable full non-inductive, high bootstrap operation to demonstrate continuous operation of a tokamak for periods up to two weeks, a necessary step before DEMO and essential to a blanket development mission. The ST-CTF will also operate steady state, but with very conventional physics and the majority of the plasma current driven by auxiliary power.

FDF must be capable of further developing all elements of AT physics, qualifying them for an advanced performance DEMO. The extent to which the ST-CTF may enable Advanced Tokamak physics toward DEMO is examined in this paper.