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Development of a 3-m HTS FNSF Device and the Qualifying Design and Engineering R&D needed to meet the Low AR Design Point

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A Fusion Nuclear Science Facility (FNSF) study based on the Spherical Tokamak (ST) confinement option has progressed through a number of stages of development to understand the requirements to establish a self-consistent conceptual design of an ST-FNSF device. The objective has been to establish sufficient physics and engineering details needed to meet mission objectives centered on achieving tritium self-sufficiency and TF shielding protection within a configuration arrangement develop with a viable maintenance strategy that fosters high availability in the maintenance of the in-vessel components.

The ST physics is centered on lower aspect ratio designs that offer higher confinement times, improved stability and higher beta operation when compared with the conventional high aspect ratio advanced tokamak. One disadvantage of the small major radius ST device is the machine geometry offers limited space on the plasma inboard side for shielding to protect the TF coils from neutron heating and material damage and space to locate inboard tritium breeding blankets. This is especially the case when working to define a small size FNSF device; greater inboard space is expected when an ST design is scaled to a larger DEMO device. The earlier copper ST-FNSF designs incorporated a copper center stack of wedged TF plates with joints to the outer return legs and a maintenance approach that involved dismantling horizontal return legs of the TF coils to gain access to plasma components and replacing the TF coil center stack after a few years of operation, due to neutron damage. In defining a superconducting ST-FNSF device sufficient inboard shielding is needed to protect against neutron heating and material damage condition for 6 FPY operations and a thin inboard breeding blanket is desired to augment the outboard blanket system. To accomplish this two design features were pursued: incorporating HTS TF coils with a winding designed for high current density (reducing the dimensional build of the TF inboard leg) and reducing the size of the plasma by moving to a device with a slightly higher aspect ratio. This paper will provide the design details of the 3-m HTS ST-FNSF device - defining engineering R&D qualifying requirements, structural analysis results and any engineering defined limitations that may be imposed within a low aspect ratio tokamak environment.

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