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Fusion Nuclear Science Facility Overview, Physics Assumptions and Operating Space

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The conventional aspect ratio Fusion Nuclear Science Facility (FNSF) is being studied to identify its requirements and characteristics, as a device between ITER and the routine electricity production demonstration power plant (DEMO). This facility provides the break-in to the fusion nuclear regime while simultaneously accessing the ultra long duration high performance plasma regime. The facility requires an extensive pre-requisite R&D program to provide the needed database for its design and operation. Apart from plasma science advances, high priority areas include 1) fusion neutron materials science, 2) tritium behavior science, 3) liquid metal breeder science, 4) plasma material interaction science, and 5) enabling technologies. Meanwhile it provides the critical database to move to a DEMO of the fully integrated fusion environment and fully integrated fusion components that cannot be accessed in any other way. The program on the FNSF is laid out with He/H, DD, and DT phases, with the later moving progressively to higher neutron fluence (and dpa), higher operating temperature, and most advanced radiation resistant RAFM alloy structural material. The primary goal of the DD phase is to access the ultra long plasma pulses for the first time, albeit without the DT alpha power. The plasma strategy on the facility focuses on operating at or near the no wall beta-limit, 100% non-inductive plasma current, below the Greenwald density, at high magnetic field, with high elongation, and with a peak divertor heat flux $\leq$ 10 MW/m^2. The blanket concept is the full "banana" Dual Coolant Lead Lithium design. Backup blankets (HCLL and HCPB/CB, modular) are included to accommodate the possibility of a serious flaw in the primary blanket, associated with the PbLi liquid metal breeder. The divertor component is tentatively defined to be a tungsten structure with He coolant, until an improved material for the plasma and nuclear loading can be established. The maintenance scheme is full sector radial removal through large ports in the vacuum vessel, using casks to transport to the Hot Cell. A major aspect of the FNSF program is to examine the blanket, divertor, and plasma heating and current drive system components to identify the material behaviors in the actual environmental service conditions. This requires extensive Hot Cell capabilities to clean, disassemble, inspect, cut and examine materials that are highly activated, which provides a database well beyond the pre-FNSF nuclear and non-nuclear R&D, needed for the DEMO and beyond. The operating point used for design will be described, along with the flexible operating space that surrounds this point. A wide range of engineering and physics analysis including nuclear analysis, magnets, maintenance, PbLi thermofluids, steady and transient thermo-mechanic and electromagnetic, tritium, safety, plasma scrape-off layer and divertor, time dependent core plasma, plasma ideal MHD and heating and current drive has been completed to examine the features and priority needs for an FNSF. The critical aspects of taking such a first step into the fusion nuclear regime will be reviewed.

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