# Physics basis of a Fusion Development Facility utilizing the tokamak approach

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**Abstract.** The objective of the Fusion Development Facility (FDF) under consideration is to carry forward advanced tokamak physics for optimization of fusion reactors and enable development of fusion's energy applications. A concept of FDF based on the tokamak approach with conservative expressions of advanced physics and non-superconducting magnet technology is presented. It is envisioned to nominally provide $2\ \mathrm{MW/m^2}$ of neutron wall loading and operate continuously for up to 2 weeks as required for fusion nuclear component research and development. FDF will have tritium breeding capability with a goal of addressing the tritium self-sufficiency issue for fusion energy. A zero-dimensional system study using extrapolations of current physics and technology is used to optimize FDF for reasonable power consumption and moderate size. It projects a device that is between the DIII-D tokamak (major radius 1.8 m) [J.L. Luxon, Nucl. Fusion **42**, 614 (2002)] and the Joint European Torus (major radius 3 m) [P.H. Rebut, R.J. Bickerton, and B.E. Keen, Nucl. Fusion **25**, 1011 (1985)] in size, with an aspect ratio A of 3.5 and a fusion gain Q of 2-5. Theory based stability and transport modeling is used to complement the system study and to address physics issues related to specific design points. It is demonstrated that the FDF MHD stability limits can be readily met with conservative stabilizing conducting wall placement. Transport analysis using a drift-wave based model with an edge boundary condition consistent with the pedestal stability limit indicates that the FDF confinement requirement can also be readily satisfied. A surprising finding is that the toroidal Alfvén eigenmodes are stabilized by strong ion Landau damping. Analysis of vertical stability control indicates that the basis configuration with an elongation $\kappa_x \sim 2.35$ can be controlled using a power supply technology similar to that used in DIII-D. Peak heat fluxes to the divertor are somewhat lower than those of ITER [R. Aymar, P. Barabaschi, and Y. Shimomura, Plasma Phys. Control. Fusion **44**, 519 (2002)] but FDF will operate with a higher duty factor.