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A conceptual design for a low aspect ratio liquid lithium tokamak for ST-FNSF, a fusion pilot plant, or a compact power reactor, R. Majeski, *PPPL*

This paper is intended as a brief reference document to provide a conceptual design for a low aspect ratio, compact, tokamak which employs low recycling flowing liquid lithium walls as the primary plasma-facing surface. A flowing lithium wall system, with a 1-10 m/sec flow rate – sufficient to provide self-cooling (convective heat removal with the flowing liquid metal), fronting an ST plasma, forms the design basis. The flowing lithium wall would be 0.5 to 1 cm thick, fully axisymmetric, and cover most (but not all) of the poloidal extent of the plasma. Lithium would flow over a guide wall; since the guide wall is not exposed to plasma, and is cooled by the flowing lithium layer, it can be constructed of low thermal conductivity material such as ferritic steel. The flowing wall system described here will incorporate an outflow region suited to lower single null divertor geometry. Liquid lithium would be recirculated within the toroidal field volume, and plasma heat removed via a heat exchanger incorporated into an internal lithium reservoir. Coolant from the heat exchanger would subsequently be routed through the breeding blanket, which can operate at significantly higher temperature than the wall. The overall thermodynamic efficiency for electricity generation is therefore set by the blanket operating temperature, rather than the lithium wall temperature. For the small scale (R_0~1.5 m, a~1 m, k~2-2.5) device considered here, the total lithium inventory (wall + circulation system + reservoir) would be less than 1.5 tonnes, or 3 m^3. This is very modest compared to the required blanket lithium inventory for breeding. Only low recycling, high confinement regimes are considered, with correspondingly long particle confinement times. Neutral beam injection at energies appropriate for positive ion beams provides fueling. The high tritium burnup fraction expected with efficient core fueling provided by NBI and good particle confinement, where here the relevant burnup fraction is given by (tritium burned)/(NB injected tritium), limits the tritium inventory captured by the liquid lithium wall. Therefore, the lithium inventory would only need to be processed on the order of once per 1-2 days, to limit the inventory of tritium stored in the lithium to 1-2 kg. A separate loop, with much lower flow rates than the wall recirculation system, would route lithium outside the toroidal field volume for tritium removal. Simple distillation of the lithium should be sufficient at the expected tritium concentrations (~0.2% atomic for a 1.5 kg dissolved tritium inventory in the lithium). Fusion power output would be in the range of a few hundred MW to < 1 GW. The study is intended to provide a design point which addresses issues such as the required lithium inventory, the necessary rate at which tritium must be removed from the lithium, and thermodynamic efficiency, as well as to provide a clarifying concept for a recirculating lithium wall. The primary ReNeW thrust to which this work is relevant is Thrust 16, Developing the spherical torus to advance fusion nuclear science.

This effort would represent a longer term/higher cost initiative, which is (I believe) outside the stated scope of the strategic planning panel.

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