THE SPHERICAL TOKAMAK PATH TO FUSION POWER

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The low aspect ratio tokamak or spherical torus (ST) approach offers the two key elements needed to enable magnetic confinement fusion to make the transition from a government-funded research program to the commercial marketplace: a low cost, low power, small size market entry vehicle and a strong economy of scale in larger devices. Within the ST concept, a very small device (A = 1.4, major radius about 1m, similar size to the DIII–D tokamak) could be built that would produce ~800 MW thermal, 250 MW net electric, and would have a gain, defined as Q_{PLANT} = (gross electric power/recirculating power), of about 2. Such a device would have all the operating systems and features of a power plant and would therefore be acceptable as a pilot plant, even though the cost of electricity would not be competitive. The ratio of fusion power to copper TF coil dissipation rises quickly with device size (like R^3 – R^4, depending on what is held constant) and can lead to 3 GW thermal power plants with Q_{PLANT} = 4–5 but which remain a factor 3 smaller than superconducting tokamak power plants. Power plants of the scale of ITER might be able to burn the advanced fuel D-He^3. These elements of a commercialization strategy are of particular importance to the U.S. fusion program in which any initial non-government financial participation demands a low cost entry vehicle.

The ability to pursue this line of fusion development requires certain advances and demonstrations which are probable. Stability calculations support a specific advantage of low aspect ratio in high beta which would allow simultaneously β_T ~ 60% and 90% bootstrap current fraction (I_p ~ 16 MA, $\kappa = 3$). Steady state current drive requirements are then manageable. The high beta capability means the fusion power density can be so high that neutron wall loading at the blanket, rather than plasma physics, becomes the critical design restriction.