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COMPACT DT FUSION SPHERICAL TORI AT MODEST FIELDS*

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A spherical torus is obtained by retaining only the indispensible components on the inboard side of a tokamak plasma, such as a cooled, normal conductor that carries current to produce a toroidal magnetic field. The resulting device features an exceptionally small aspect ratio (typically 2-to-1 elongation), and ramp-up and maintenance of the plasma current primarily by noninductive means. The tokamak plasma takes on the spherical shape with a modest hole through the center, suggesting the name of spherical torus.[1] This paper reviews the initial assessments of near-term DT fusion devices based on the spherical torus concept.

A spherical torus plasma is characterized by comparable currents in the plasma, the toroidal field coils, and the poloidal field coils; comparable toroidal and poloidal beta; comparable toroidal and poloidal magnetic fields; and strong self-generated toroidal field (paramagnetism). None of these can be attributed to a tokamak with aspect ratios above 2.5. As a result of the favorable dependence of the tokamak plasma behavior to decreasing aspect ratio and increasing plasma current, a spherical torus is projected to have high beta, small size, and modest field. In the case of toroidal field coils of normal conductors and inorganic insulators, inboard nuclear shield can be eliminated while losing only a few percent of the fusion neutrons to the center conductor. This permits dramatic simplifications in the configuration of a fusion spherical torus. A schematic elevation view of a DT spherical torus is

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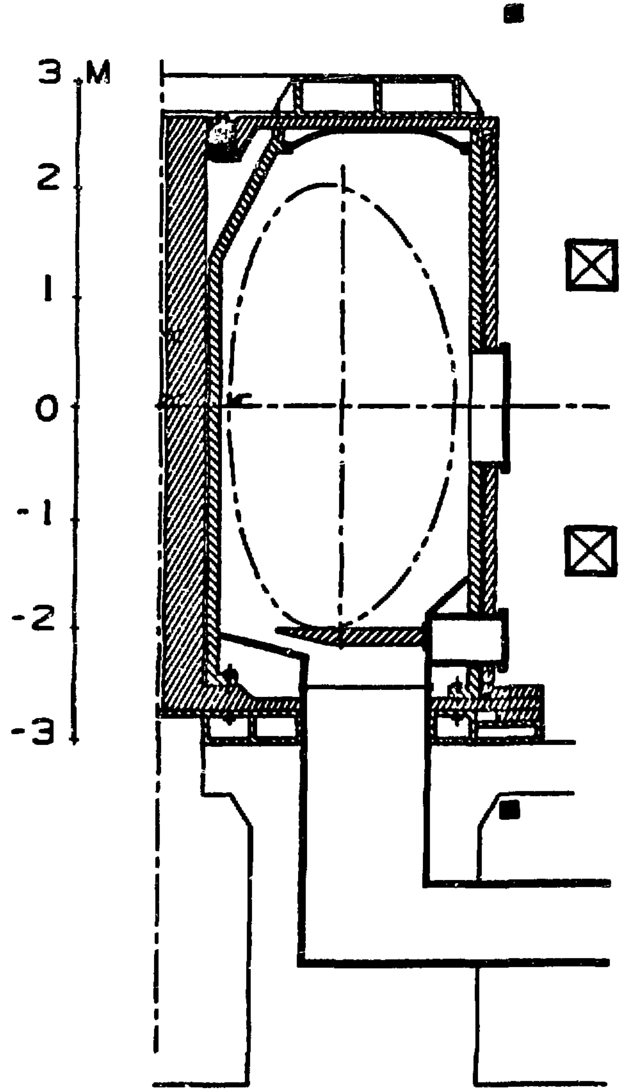
given in the Figure.

Assuming confinement and beta scalings with favorable dependencies on the plasma current, an ignition spherical torus at a field of 2 T features a major radius of 1.5 m, a minor radius of 1 m, a plasma current of 14 MA at a safety factor (inverse rotational transform of the magnetic field) of 2.4, an average toroidal beta of 24% (with respect to the externally applied toroidal field at the major radius), and a fusion power of 50 MW. At 2 T, a scientific break-even (Q = 1) spherical torus will have a major radius of 0.8 m, a minor radius of 0.5 m, and a fusion power of a few megawatts. Assuming a high technology copper coil that permits tripling of the conductor current density up to 10 kA/cm^2, a spherical torus suitable for fusion engineering and technology development would have a field of 3 T, a major radius of 0.7 m, a minor radius of 0.45 m, a DT fusion power of 40 MW, and a neutron wall load of 2 MW/m^2. Because of the nuclear shielding required for super-conducting coils leading to large aspect ratio plasmas, compact DT spherical torus appears to be limited to copper devices. Features and the cost benefits of these applications of the spherical torus concept will be discussed.

Although the plasma properties projected for the spherical torus are consistent with present-day tokamak data base having aspect ratios ranging from 2.5 to 5, its unique properties identify a new and unexplored tokamak physics regime. The prevailing scaling laws give widely divergent predictions in a spherical torus but not in a conventional tokamak. A small spherical torus experiment (STX) is being defined to resolve these major physics scaling questions of the conventional tokamaks and to provide concrete data in this regime.

Reference:

1. Y-K. M. Peng, "Spherical Torus, Compact Fusion at Low Field," ORNL/FEDC-84/7 (December 1984).



SPHERICAL TORUS ELEVATION