WHITE PAPER

RACER (Ring ACElerated Reactor)

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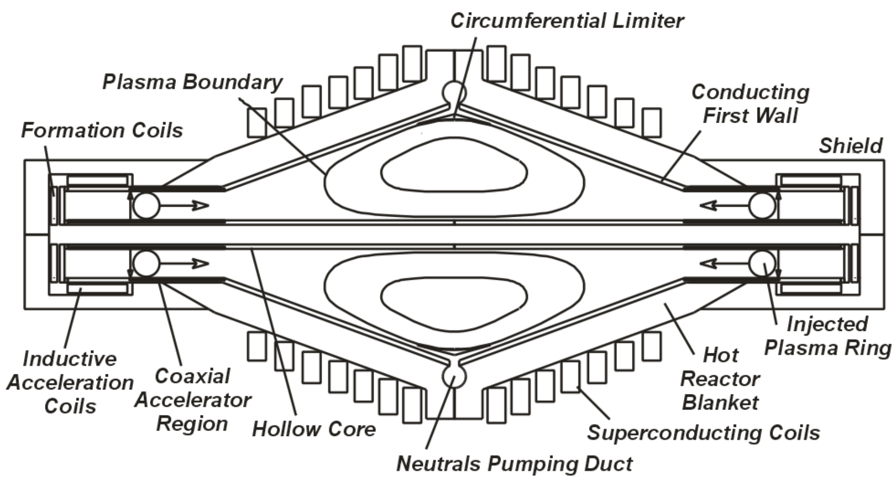
This White Paper is in response to the USDOE Fusion Energy Sciences Advisory Committee (FESAC) panel request for community input. It is offered in an effort to persuade the DOE to support other fusion concepts besides ITER, concepts that may be high-risk, but also have high commercial potential.

The Field-Reversed Mirror (FRM) was studied extensively in the late 1970's and 1980's as an improvement over the standard mirror [1]. By supplying an internal plasma current, which closed the field lines around the plasma, mirror end losses are reduced and energy confinement increased. Considerable work was done, primarily at LLNL, on injection of high-speed plasma rings into FRMs for fuel, heating, and plasma current. Experiments showed that dense plasma rings can indeed be created and efficiently (25%) accelerated to over 2000 km/sec [2].

This work builds on that impressive early work and attempts to show that the FRM remains an attractive fusion reactor concept. This author has pursued this concept in the past [3], and the current work also draws from that effort.



The reactor concept is shown in the figure below. The central plasma region is surrounded by conical first walls and blankets. Outside the blankets are superconducting coils with conical vacuum fields that increase in both directions from the center to the edges. These field gradients keep the plasma centered. A hollow, actively-cooled, passive conducting central core inhibits plasma radial shifts and tilting. Plasma ring injectors at each end consist of a formation region, an inductive acceleration region, and a coaxial accelerator. The inductive acceleration gets the plasma rings up to ~100 km/sec. Then, when the coaxial arc strikes, the plasma is moving so fast that electrode erosion should hopefully be minimal. The final injection velocities of ~1600 km/sec correspond, when thermalized, to ~33 keV D-T ion temperature.

As a starting point, an EES (Engineering Equation Solver) program was written to evaluate reactor parametrics. An example reactor was sized for 1400 MW neutron power, 2.4 MW_n/m^2 neutron wall loading, and $\beta_{pol} \approx 0.1$. These parameters give a major radius R = 4 m, minor radius a = 2.7 m, I_p = 65 MA, a reasonable 170 W/cm^2 limiter heat flux (limiters can be used with this geometry), 750 MW(e) gross, and 500 MW(e) for sale. The large plasma current is built up, assuming 99.5% ohmic dissipation, in ~14 hours using plasma rings with 560 kA internal current injected at 14 Hz. The ability to use modest hardware to create such a large plasma current is a major feature of this concept.

Clearly, the spheromak configuration is just as attractive as the FRM, although there would be some changes in geometry.

Having a steady-state main plasma is attractive because overall energy balance is likely to be more favorable. A pulsed system requires that a certain fuel burnup be achieved before the plasma expands away, not an easy task.

The original RACE experiment had issues with impurities being sputtered into the plasma ring due to the high axial velocity. In this present concept residual magnetic fields in the accelerator from the main coils would be compressed between the conducting accelerator electrodes and the high-speed plasma, hopefully reducing impurity input.

There is a natural tendency for plasma currents to concentrate in the hot center of the plasma. In this concept the current is being injected from both ends. It is expected that this would maintain the preferred flatter current profile, thereby increasing the volume of plasma available for fusion reactions without exceeding local plasma pressure limits.

1. C. Hartman et al, "Production of Field-Reversed Mirror Plasma with a Coaxial Plasma Gun", US Patent 4,314,879 (Feb. 9, 1982).

2. J. Hammer, et al, "Experimental Demonstration of Acceleration and Focusing of Magnetically Confined Plasma Rings", Phys. Rev. Letters, **61**, No 25, 2843 (19 Dec 1988).

3. R. Bourque, "The Colliding Compact Torus: A Steady State Fusion Reactor with Pulsed Heating, Fueling, and Current Drives", J. Fusion Energy, **17** No. 3, 207 (1988).