Title
TORMAC CONCEPT

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TORMAC CONCEPT*

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The containment of a hot ionized gas for a fusion reactor by a magnetic field remains a difficult and frustrating problem. With all the research, there is still divided opinion on the best solution. The choice is between open and closed magnetic field lines. The Tokamak and Surmac devices rely on closed field lines. On the other hand, the mirror machine and the laser heated solenoid would use open magnetic field lines.

Both of these approaches have their advantages and their problems. Closed magnetic field surfaces have a beta limit. Beta is a measure of the amount of plasma that can be held for a given magnetic field. For instance, in the Tokamak, the beta limit is thought to be such that the maximum plasma energy must be less than 8% of the magnetic field energy.

Configurations with open magnetic field lines, such as the mirror device, have a different problem. Particle containment on open magnetic field lines is relatively poor; so that, the ratio of particles burned to particles lost is low.

Tormac is a concept for magnetic containment of ionized gasses for fusion which combines the use of open magnetic field lines with the closed line. The advantages of this combination is that Tormac can contain a high beta plasma, near 85%, as in a mirror, and still have the low loss characteristics of a Tokamak.

The magnetic fields shape to do this is shown in Fig. 1. The gas itself is held in a doughnut shape or torus, which looks very much like a Tokamak. What is different is that the magnetic field lines on the surface of the ionized gas or plasma are open and penetrate the walls of the system.

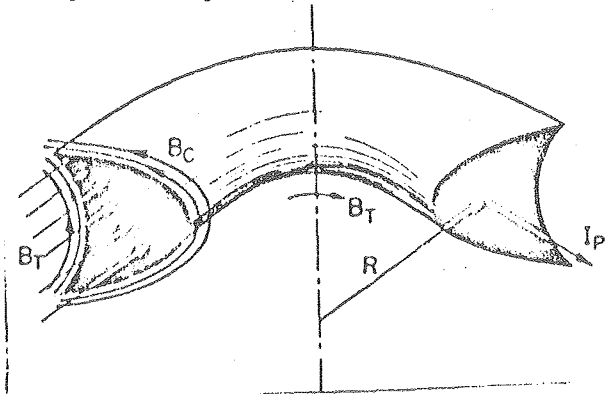

Fig. 1. Plasma shape in a Tormac bicusp.

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By combining the mirror device with a Tokamak, it is hoped to obtain the best features of both. On the other hand, there is also the danger of combining the difficulties of both. On the positive side, it should be noted that Tormac makes very effective use of magnetic fields as in a mirror. It is not predicted to have impurity problems as in a mirror. Because of the low magnetic field intensities, radiation problems, which prevent some devices from going to advanced fuels, are not a problem in Tormac. Also on the good side is the containment time. The theoretical containment time for Tormac is even better than that for a Tokamak.

While Tormac does combine many of the best features of the Tokamak and mirror devices, it also has some of the problems. Tormac is a toroidal device with a doughnut-like shape; so that the mechanical construction of the vessel is complicated.

Another problem common to Tokamaks is the problem of start-up and the associated problem of maintaining a steady state reactor. Start-up in Tormac is a special problem because the magnetic field necessary to contain the plasma in Tormac is in part generated by the plasma. This also implies a problem with long time, steady state operation, since plasma currents tend to dump out.

To solve this problem, a special gun is being developed. This gun is designed to shoot both plasma and magnetic field into a reactor region. The experiment has been nicknamed the "Puffer" experiment because what it does is create a puff of plasma shaped very much like a smoke ring. In this device, the gun is designed to both create the smoke ring and to shoot it at a very high velocity. In fact, the directed velocity of the particles in the smoke ring is high enough so the particles will be at reactor temperatures when stopped.

This high velocity expanding smoke ring is in fact a Tokamak-like structure. It has within it the same magnetic field and current that a Tokamak has. Thus, when this plasma is stopped in the reactor region, it creates the Tokamak like central region necessary for a Tormac plasma.

In Fig. 2 is a sketch of the puffer experiment.

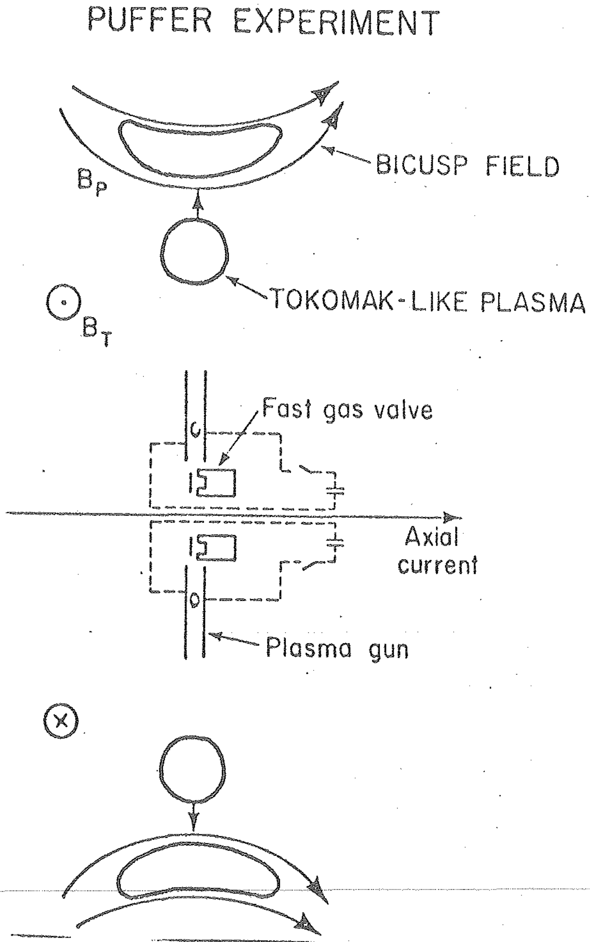

Fig. 2. Pulse filling system for Tormac designed to make a steady state plasma.

In the center of the device is a fast gas valve. The purpose of this valve is to inject a puff of gas in between the plates of the plasma gun. The gas is then driven radially outward by a high current which flows through the gas. This structure has the same magnetic field configuration of a Tokamak and laboratory experiments have indicated that it is highly stable and uniform.

The toroidal plasma once created is stopped in a Tormac shaped magnetic field. It is the intention of this system to have subsequent puffs of plasma created so that the reactor will be continually stoked and maintained with a reacting plasma.

In addition to the puffer experiment, there are, at Lawrence Berkeley Laboratory, two other small experiments exploring different facets of the Tormac configuration. These experiments are aimed at understanding such problems as the equilibrium, the stability of the sheath, and the behavior of the internal current. What is still needed with Tormac is a proof-of-principal experiment.

One of the problems with doing plasma research in this type of device is that the rate of power dissipated is very high. It is difficult to design an intermediate size experiment with a temperature high enough to carry the plasma into the scaling regime to be used in a reactor without actually having all the power necessary to run a reactor. For Tormac research the puffer experiment takes on particular significance because the plasma gun delivers to the plasma energy at the rate of 1000 megawatts. The aim of the current series of experiments being funded by the Department of Energy at Lawrence Berkeley Laboratory is to design a proof-of-principal experiment using Tormac which will enter into the range of temperature and density such that the next step could be a demonstration reactor.

In order to insure that this effort is worthwhile there have been two design studies based on Tormac, one at Lawrence Berkeley Laboratory and another at Los Alamos Laboratory. While these studies are very preliminary and are only meant to determine the range and size of components necessary to produce a reactor using Tormac, they do give very optimistic results. An ignition Tormac reactor using the deuterium tritium reaction in the 100-200 MW range look practical. On the other hand, a reactor to produce energy from the catalyzed deuterium reaction does not look too much more difficult. While this assessment is preliminary and based very heavily on an extension of the design studies carried for Tokamaks, they do indicate the strength of Tormac as a reactor concept. The indication is that a Tormac reactor could be built to reach ignition with 1/10 the magnetic pressure and 1/10 the plasma volume as would be required by a Tokamak reactor.

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