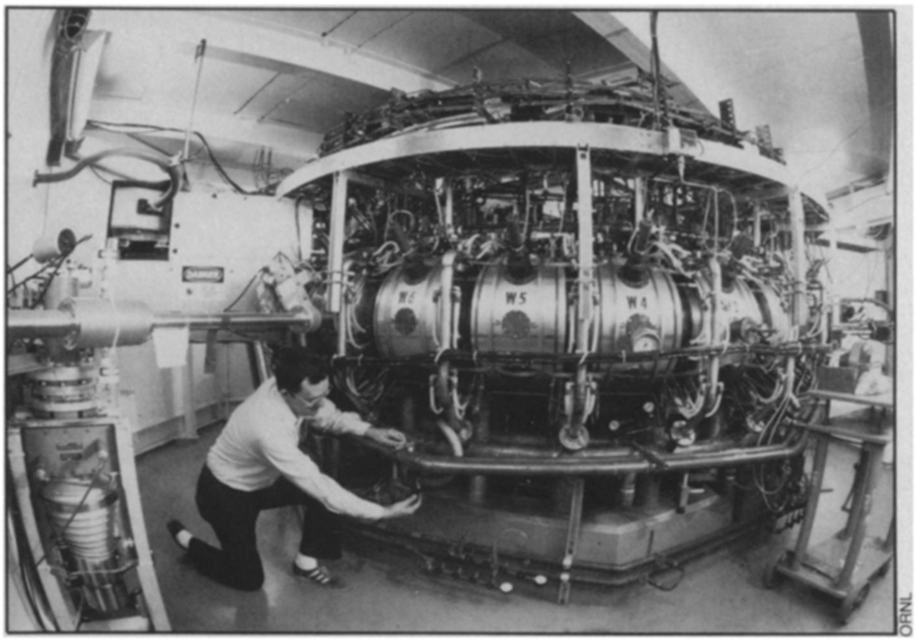
BUMPS IN THE TORUS

The ELMO Bumpy Torus may someday yield controlled fusion —in a magnetic field shaped like link sausage

BY DIETRICK E. THOMSEN



Present state of the EBT *results from about a decade of planning and experiment.*

"If at first you don't succeed, try it again a different way." Such could be the thinking of the scientists working on controlled thermonuclear fusion. They are continually altering and refining their basic approaches. Sometimes they mix them together. An example of such mixing is an experiment, or rather a series of experiments, that has been going on for about the past eight years at Oak Ridge National Laboratory. It is called the ELMO Bumpy Torus, and it combines elements of one basic approach, the magnetic mirror, in the shape of another, the torus, and adds to it some things drawn from experiments on so-called collective accelerators or relativistic electron rings.

To obtain fusions a hot plasma (an ionized gas, that is) must be confined against its normal tendency to expand without limit. In principle that can be done in a magnetic field, but the shape of that field has been the bedeviling question for 30 years. The plain magnetic mirror is one possible solution: a cylindrically shaped magnetic field with constrictions at the end. The constrictions are intended to hold the charged particles of the plasma in the field by bouncing them back toward the middle. But many escape out the ends. Another solution is confinement in a toroidal shape. That eliminates the ends, but it produces problems of its own, one of them being that the curviness of the toroid induces particles to drift away from the center of the plasma and get lost.

The solution, some people think, is the bumpy torus: A toroid-shaped field with periodic mirror-like constrictions. This way, some of the advantages of both shapes might be gained and some of the disadvantages of both suppressed. As Gareth Guest of the General Atomic Co. reminded the Plasma Physics Division of the American Physical Society as it met recently in San Diego, the Russian physicist Boris Borisovich Kadomtsev proposed that "charged particles can be confined in a bumpy torus if the bumpiness is sufficient to balance toroidal drift." (Before he moved from Oak Ridge to General Atomic not long ago, Guest was one of the leaders of the bumpy torus work.)

But how to provide the bumpiness? Kadomtsev had suggested metal coils. Coils on the outside of the vacuum chamber in which the plasma is held did not provide the requisite amount of constriction. Metal rings on the inside of the chamber seemed impractical. "Later we realized that relativistic electron rings could be used," Guest says. That is, rings of hot electrons circulating at relativistic speeds. They make electric currents and generate magnetic fields. Such electron rings have been the subject of a number of experiments. The particular technology adopted by the bumpy torus experimenters came from a project called ELMO, and so the device and its name were assembled: the ELMO Bumpy Torus.

It works. The first version, which went into operation in 1973, showed that the relativistic electron rings do provide the requisite magnetic bumps and protect against certain magnetic instabilities in the plasma. They also contribute an ambipolar electric field that helps confine the ions in the plasma. The runs of EBT-1 showed that there is a stable and quiescent mode of existence for the EBT plasma corresponding to a certain range of energies in the relativistic electron rings. In this mode the plasma will sit for a while in the field. Instabilities are less disruptive. Furthermore, the time during which the electrons of this plasma will confine energy increases as the temperature increases (by the 5/2 power of the temperature). This means that the more you heat it, the more efficiently it holds heat, a good property if you want to concentrate heat in it to ignite fusion.

All of this suggests extrapolation, Guest says. And so they are doing it. One way is to heat it more. Heating is by broadcasting high-frequency radio waves into the plasma. The electrons absorb energy from the waves that resonate with the orbits they are performing in the magnetic field (electron cyclotron heating). EBT-1 uses 18 gigahertz rf waves. The current version, EPS, is designed for 28 Ghz. When that has been tested out, the experimenters plan to go for 60 Ghz or higher.

"If we could get collisionless ions," says Guest, "we could make a marvelous change in the economic utility of the device." Collisionless ions move along the magnetic field without colliding and knocking each other out of the arena. (The other kind make a loss problem.) He suggests that the ambipolar electric potential could be manipulated to get the ions into collisionless behavior patterns if a way of controlling the ambipolar potential can be developed.

Another desirable thing is to extend the plasma's quiescent behavior mode to higher temperatures and lower pressures and longer confinement times. This may require altering the present heating method, which depends on the electrons to transfer heat to everything else. Negative ions might be introduced, say hydrogen molecular ions, to take heat from the rf waves by *ion* cyclotron heating.

Other changes, too, may become desirable to optimize the bumpy torus concept, but its advantages as a potential reactor are that: It runs continuously ("steady state"). It operates "with marvelous purity." It is modular. Its magnets are noninterlocking, (which means fewer engineering problems). But Guest stresses that "as a reactor it loses its attraction if we cannot get the collisionless ion mode." □