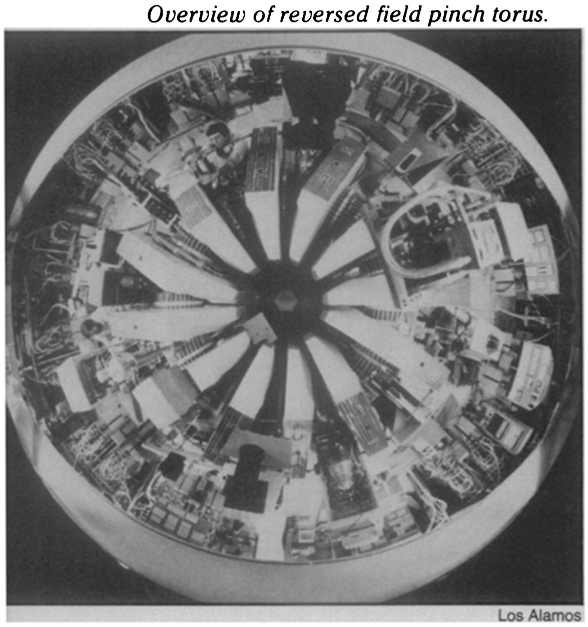
Reversed Pitch Pinch Pins Plasma

If anything is certain from the history of the attempt to achieve controlled thermonuclear fusion by magnetic means it is that the subject has had its twists and turns — and an occasional sharp kink. The purpose of the effort is to find a configuration in which a magnetic field will hold a hot plasma (ionized gas) for long enough to have nuclear fusions occur and so get energy out. A number of ingeniously twisted magnetic field configurations have been used to try to hold the plasma, while the plasma fights confinement with convolutions of its own.

One of the latest configurations to be applied is the so-called reversed field. A device incorporating it, the reversed field pinch ZT-40 at the Los Alamos National Laboratory, has recently registered an 80-fold gain in confinement time (from 0.1 millisecond to 8 milliseconds) after certain changes were made in some of its components. There have been times in the history of magnetic fusion research when experimenters would have signed contracts in blood to get that kind of an increase in a short time. The managers of the Los Alamos magnetic fusion program say that in future the reversed field pinch may be scaled up more toward a possible reactor.

The present ZT-40 is a small device. It is part of an advanced concepts program intended to investigate possible alternate methods of plasma confinement. The numbers should not be compared directly with those achieved in the much bigger tokamak devices because confinement time tends to scale upwards with the size of the device, all other things being equal. What is important here is that the reversed field condition has been achieved, and, as theorists predicted, the plasma in that configuration tends to cooperate with its own confinement and lie in a natural quiescent state.

Overview of reversed field pinch torus.



Los Alamos

The reversed field pinch is like a tokamak in that both are toroidal or doughnut-shaped chambers. The magnetic field lines in both spiral around the body of the torus through the hole in the middle. But there the difference begins. The field lines of the tokamak have a low pitch to the midline of the doughnut; they may loop through the hole once or twice in a complete circuit. The lines of the reversed field pinch are highly pitched. They loop many times through the hole while making one circuit around the doughnut. This high pitch design has a further feature. Going inward from the shell of the doughnut to the center of the plasma inside it, the pitch gradually turns over and reverses so that the pitch of the field lines is opposite that of the lines on the outside with a 90° angle between them. This is the reversed field condition that helps hold the plasma so well. Another bonus of this high-pitched field configuration is that it allows a very strong electric current to circulate through the plasma. It is desirable to heat the plasma with a current of this kind, and if the plasma can be heated all the way to ignition temperature in this way, a reactor based on the reversed field pinch might be able to forgo the auxiliary heating devices being designed for other approaches to magnetically controlled fusion.

What gave the ZT-40 its sudden large jump in confinement time was the substitution of a metal walled vacuum chamber (the shell of the doughnut) for a ceramic one, and changes in circuitry that permitted the magnetic field at the beginning of an experimental shot to rise from zero to its maximum value more slowly. Why this combination did it is not clear. Says Ken Freese, one of the physicists involved, "We're investigating those reasons." Another thing they want is "to understand the physics of termination [what happens to the plasma at the end of the 8 milliseconds] and to extend it."

The ZT-40 is designed to pass a maximum electric current of 600,000 amperes through the plasma. With the ceramic container it took 500,000 amperes to produce a plasma temperature of a million degrees. With the metal container it took only 190,000 amperes. The temperature in the present experiments came to a maximum of nearly 2 million degrees. Presumably it could go still higher.

Enlargement of the reversed field pinch type of experiment is planned to be an international effort. The United States, Italy and Great Britain are planning a 2-million-ampere reversed field pinch, the RFX. It will be built at Great Britain's Culham Laboratory in the next five years. Later there may be a 6-million-ampere device built at Los Alamos. □

Protons go the way of all flesh

Once a proton always a proton. That used to be the rule in physics. From the big bang (or shortly thereafter) to the final consummation, be that entropy death, recollapse or parousia, if a thing was a proton, it stayed a proton. People could sleep at night knowing that their atoms were firmly grounded on so trustworthy an object.

Not any more. In their desire to explain everything in physics (or in particle physics at least) in one mathematical framework, physicists have been deriving what they call grand unified field theories — GUTS for short. According to these theories protons can decay, and experimenters have been looking for evidence of such decay. Now a group of physicists from India and Japan say they think they may have found it in three events recorded in their detector.

Back when physicists had no GUTS, the class of particles called baryons was supposed to have an inviolate character: If any baryon decayed radioactively, another baryon (at least) had to be in the decay products. Baryonness must be conserved. The proton as lightest baryon had no other baryon into which it could decay and so was believed to be absolutely stable. With GUTS more things are possible. Baryonness is no longer conserved, and the proton can decay into non-baryon particles, several of which are lighter than it.

The prediction is that the proton's lifetime is something like 10^{30} years. (The universe is only about 10^{10} years old so this means nothing cataclysmic will happen at the expected rate of decay. Tall buildings will not fall nor speeding locomotives leave the track — at least not for proton failure.) With such rare expectations of decay, physicists set up detectors deep underground. The one that seems to have seen something is in a mine in the Kolar gold fields in India. It is operated by a group from the Tata Institute in Bombay and the University of Osaka. There had been talk for months that they had candidates for proton decay. According to a report in the June CERN COURIER representatives of the group came to a workshop held recently at the University of Michigan and put their results forward formally. □

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