physical sciences

Gathered at the 4th International Conference on Plasma Physics and Controlled Nuclear Fusion Research last week at Madison, Wis.

Heating plasma with electrons

Various methods of heating plasmas to or nearly to temperatures at which controlled thermonuclear fusion can take place are under consideration. Electric resistance, shockwaves and turbulence in the plasma are used singly or in combination by many of the experiments now under way in various parts of the world.

To heat a small amount of plasma quickly, the delivery of large amounts of concentrated energy to a small solid pellet of the appropriate substance, either deuterium or a deuterium-tritium mixture, is also being tried. In current experiments the energy is delivered by a beam of laser light.

A group of Russians, Drs. M. V. Babykin, E. K. Zavoisky, A. A. Ivanov and L. I. Rubakov of the Kurchatov Institute in Moscow, present a theoretical calculation to show that it can also be done by beams of electrons moving at relativistic speeds. Dr. Zavoisky had suggested this in 1968, noting that it might be more promising than lasers since the efficiency of transmitting electrical energy from power sources to such an electron beam is 35 percent; for lasers it is only 0.1 percent.

The calculation shows that plasma of the density of a solid deuterium-tritium pellet can ultimately be heated to thermonuclear temperatures starting with an electron beam.

Automatic correction of plasma drift

A tokamak device for containing plasma of the sort used in experiments in controlled thermonuclear fusion is much like an electric transformer. The plasma of ions and electrons is to be confined in a torus-shaped tube. The magnetic field that confines the plasma is generated by an electric current running through the plasma itself around the loop of the torus. This plasma current is induced by a current in a coil that loops through the plasma torus like the primary coil of a transformer.

Tokamak plasmas can become unstable if the current drifts from the center of the torus or becomes twisted. An experiment aimed at automatic self-correction of these problems has been done by a group of Soviet physicists, Drs. L. I. Artemenkov, I. N. Golovin, P. I. Kozlov, V. N. Lukyanchuk and L. I. Melikhov of the Kurchatov Institute in Moscow and V. K. Butenko, Yu. P. Ladikov-Roev, A. N. Kukhtenko and Yu. I. Samoilenko of the Institute of Cybernetics of the Ukranian Academy of Sciences.

They decided to start with the simplest case, that of a plasma current drifting off-center. They built a tokamak, TO-1, in which they placed special sensing coils at various locations around the torus. If the plasma current drifts, the magnetic field at the sensing coils changes and the change induces a voltage in the sensing coils. The induced voltage tells the main induction coil how much of an adjustment to make and the main coil brings the plasma current back on center.

They say the system works well in keeping the plasma current on center. Now they want to try to develop systems for more complicated cases such as twisted plasma currents.

Ormak begins operation

The Ormak machine at Oak Ridge National Laboratory, the second American tokamak to be completed, is ready to begin experiments. Dr. G. G. Kelley had hoped to be able to give the first experimental results at the meeting, but problems involving a breakdown of insulation in the winding that induces the plasma current delayed the start.

Dr. Kelley reported that the first toroidal plasma discharge in Ormak took place on June 15. After some testing and tuning experimentation will begin. Meanwhile, the Oak Ridge group has done a theoretical computer simulation of the plasma conditions they can expect. In this they find they have to include a suggestion by Dr. Lev A. Artsimovich of the Kurchatov Institute in Moscow that plasma electrons dissipate energy by means of an anomalously high thermoconductivity. Other tokamak experimenters and theorists are engaged in a lively debate over whether Dr. Artsimovich's suggestion is correct or necessary (SN: 6/26/71, p. 434).

Ormak is one of five American tokamaks that were started last year after the Russian successes were confirmed. The first one to operate was the ST tokamak at Princeton University. The other three are still under construction.

Classical diffusion in the spherator

For a year physicists of Princeton University have been experimenting with a spherator, a plasma-confinement device in which a current in a superconducting ring helps form the confining magnetic field. The ring carries a current of 85 kiloamperes and can be levitated for up to two hours by magnets.

Dr. R. Freeman told the meeting that the Princeton spherator has fairly well solved a serious problem that has long plagued controlled fusion research, fast diffusion of the plasma particles across the magnetic field to the wall of the chamber. The classical theory of plasma predicts a relatively slow rate of diffusion. This would be acceptable in a fusion reactor, but for years experiments found much higher rates, usually designated Bohm diffusion. Gradually in various devices there has been improvement tending toward classical diffusion.

The Princeton spherator, Dr. Freeman says, can hold a plasma with a density ranging between 10^{10} and 10^{11} particles per cubic centimeter and a temperature that decays from 10 electron-volts to 0.2 electron-volts during the experiment for times between 100 and 200 milliseconds. This is only about a fourth to a half the length of time the plasma should be confined under these conditions of density and temperature.

The Princeton group says these figures indicate that a loss mechanism contributing to anomalous diffusion may still persist in the spherator. But at least one other observer believes that the factor of two or four can be attributed to uncertainties in the measurement and that the spherator may indeed have achieved classical diffusion.

This and similar successes lead some to suggest that it may be time to do away with the term Bohm diffusion.