for the American Public Power Association, says that if there were no import quotas on any petroleum products, oil companies would have to compete with foreign oil across the whole spectrum of petroleum products; thus prices generally would be reduced and the domestic refinery capacity for resid would exist.

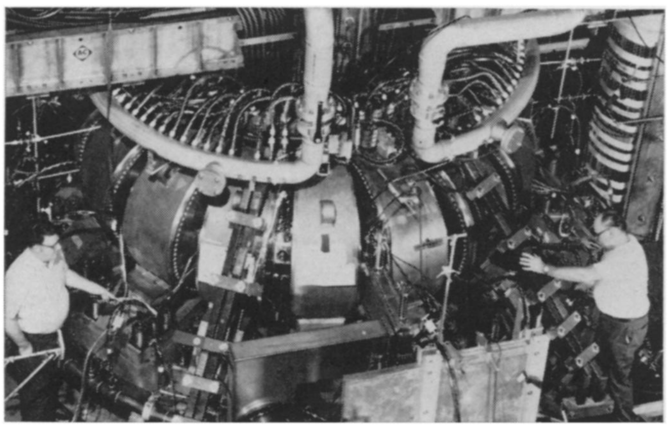
And Dr. Bruce C. Netschert of National Economic Research Associates Inc. says there is little doubt of growing monopoly control by the oil companies of all forms of energy. A succession of mergers during the past few years has given oil companies control of 26 percent of the coal industry, he says. Oil companies have long controlled most natural gas supplies, and oil companies also are rapidly diversifying into uranium production. Fry sees alleged natural gas shortages as a "natural gas strike" by the oil companies for higher rates from the FPC, a strike made possible by the fortuitous shortages of foreign resid and of the coal, whatever their cause.

Industry spokesmen, on the other hand, insist the energy industries are doing their best to provide needed fuels and that shortages are due to escalating costs, environmentalist pressures and inefficient regulation. Willard F. Rockwell, chairman of the board of North American Rockwell, recently suggested, for example, that more liberal antitrust laws governing energy industries—instead of more stringent ones as suggested by Dr. Netschert—are the answer.

The debate will not end soon. And some combatants are arguing that ways be sought to conserve energy resources by minimizing new demand. □

FUSION

Practice leads theory



Princeton Tokamak: As good as the Russian one, maybe a little better.

Princeton Univ.

From the basic principles of the behavior of electrically charged bodies in electric and magnetic fields, a theory can be derived that predicts the behavior of the plasmas of ions and electrons used in experiments aiming at controlled thermonuclear fusion. The only problem is that when experimenters made plasmas and tried to confine them in magnetic fields, this so-called classical plasma theory didn't work—the predicted and observed behaviors were different.

The result was a serious disappointment for theorists and experimenters alike, since the classical theory predicts an easier approach to the conditions of temperature, density and length of confinement necessary for a sustained fusion reaction than the experiments were showing.

From the experimental results theorists began to try to understand the behavior of the actual plasmas and to determine how the classical theory should be modified to make it work. Meanwhile experimenters went on trying to improve their experiments. In the last two or three years experimenters have achieved a number of significant improvements in confinement, but theorists are having as much trouble understanding the successes as they had understanding the earlier failures.

"I used to say," Dr. Harold P. Furth of Princeton University told the meeting of the Plasma Physics Division of the American Physical Society in Washington last week, "that when we understood it, we could make it better. But nature has foxed us and made it better before we understood it."

One of the most celebrated ways that nature has made it better is in a machine called Tokamak that was developed in the Soviet Union (SN: 10/17, p. 321). A Tokamak has a toroidal or doughnut-shaped chamber in which the plasma is held. A large electric coil is built around the toroid in such a way that a current flowing in the coil induces a current in the plasma just as a current in one coil of a transformer induces a current in the other coil. The plasma current both heats the plasma and generates a magnetic field to confine it.

The Tokamak not only held plasma for an unusually long time, but also produced a plasma that was exceptionally stable, lacking many of the disturbances that contribute to loss of plasma in other experiments. The Russian results started the U.S. Atomic Energy Commission on the construction of five Tokamaks. The first of these, at Princeton, has been operating since July.

The Princeton Tokamak is doing about as well as its Russian prototype and maybe a little better, says Dr. Edward Meservey, one of those who has been working with it. When the electric current in the plasma is 40,000 amperes, a plasma of 10^{13} particles per cubic centimeter can be contained for 3 milliseconds at temperatures up to 10 million degrees K. That is what the Russians get with the same current. The Russians claim 7 milliseconds confinement when they use a 100,000-ampere plasma current. So far the Princeton Tokamak is limited to currents under 50,000 amperes; improvements are under way to bring it to 80,000 amperes.

In the absence of a complete theoretical understanding of plasma behavior no particular approach is preferred in principle, and the current successes of the Tokamaks have not made the others roll over and play dead. Heating of plasmas by turbulence, by radial shock (theta pinch), by longitudinal shock (z-pinch) and by laser light are among those under study. Magnetic fields of many different shapes are being used in attempts to confine the plasmas.

Plasmas created and heated by lasers are considered by many a particularly hopeful approach, but says Dr. J. L. Bobin of the Centre d'Etudes de Limeil in France, "Laser-created plasma is about as far from the Lawson criterion (a rule of thumb for self-sustaining fusion) as others."

Says Dr. Lev A. Artsimovich, who led the development of the Tokamak, "Nobody can say right now what kind of closed system is more promising. It may be Tokamaks; it may be Stellarators (a magnetically different kind of toroid). This ingenious idea (the Stellarator), which was created in the United States, should be studied further." □

STRAIGHT WING VS. DELTA

Choosing shuttle options

The National Aeronautics and Space Administration has placed high stakes—its future for the next two decades—on the reusable shuttle (SN: 8/22, p. 178). Its argument is that to maintain