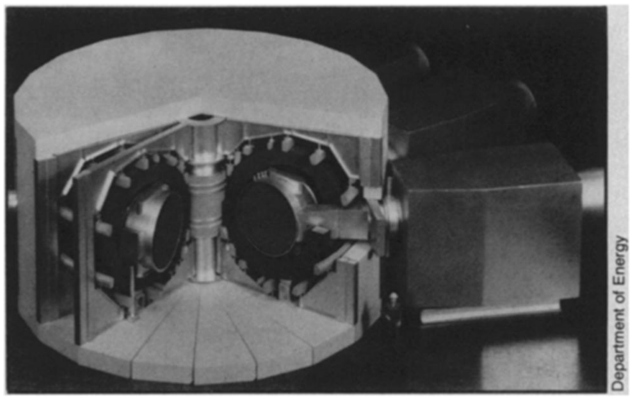
Tokamak Makes Hot News



The next generation tokamak, the TFTR, is being built at Princeton and should be operating in 1981. Recent experiments suggest that TFTR may produce as much energy as it consumes.

A significant step was recently taken by a group of Princeton scientists toward the realization someday of extracting usable power from a nuclear fusion reactor. Using a two-megawatt beam of deuterium atoms, the physicists heated a hydrogen plasma within the Princeton Large Torus to a record (for tokamak-like reactors) 60 million degrees centigrade, which is four times as hot as the solar interior. The highest temperature achieved previously was 25 million by the same Princeton group last December.

Plasma is confined in the donut-shaped PLT by invisible walls of magnetic force. Light elemental particles rattling around inside the edible portion of the donut collide and fuse with a frequency that increases with the crowdedness of the particles (number density), the longevity of the plasma (confinement time) and its temperature. Among the more than thirty known nuclear reactions that peculiarly release more energy than they consume, the deuterium-tritium one is exceptionally energetically profitable and will probably be used in the first commercial reactors now expected during the first decades of the next century. In the D-T reaction, a helium nucleus is created together with a neutron that carries away most of the energy.

There are several reasons why the recent Princeton achievement is notable.

First, at this temperature, a D-T plasma could sustain its fusion reactions and thereby produce about one percent of the energy it uses. Although this is far shy of ultimate commercial expectations, it is nonetheless a great improvement over machines of the recent past that typically produced only one part in tens of thousands of the energy they took in. In fact, the landmark PLT experiment involved hydrogen-deuterium (not D-T) reactions because at the elevated temperature even this less efficient fusion mixture produces a quantity of neutrons that threatened to be a radioactive nuisance to the researchers. Anyway, the experimental results are no less significant with regard to our understanding of the commercially important D-T reaction because, in both cases, the underlying physical principles are identical.

Second, the PLT experiment was important because it largely dispelled the anxiety caused by preliminary theoretical calculations that indicated the possible appearance of a new plasma instability at the higher temperatures. Physicists worried that beginning at about 30 million degrees, the plasma would convulse in a so-called "trapped particle instability," wherein the particles slosh around collectively, causing local colonies and voids that disrupt the efficient progression of the fusion process.

Future plans by the Princeton group, which includes Wolfgang Stodiek, Harold Eubank, Harold P. Furth and Princeton Plasma Physics Laboratory Director Melvin B. Gottlieb, are attempts at still higher temperatures using the PLT. These efforts are made with the realization that a commercial reactor will have to operate at temperatures of about 100 million degrees centigrade. During the early 1980s, a new tokamak with twice the PLT's capacity will very likely, according to Gottlieb, produce as much energy as it consumes. This potentially remarkable facility is currently being built at Princeton and is known as the Tokamak Fusion Test Reactor. Until that significant achievement is manifest, however, plasma physicists right now have reason to be aglow. □

A way for electrons through the air

One way that physicists hope to produce useful amounts of nuclear fusion someday is by imploding a pellet of fuel composed of deuterium or deuterium and tritium. Implosion should compress and heat the pellet to the point where billions and trillions of fusions take place inside it, releasing a puff of usable energy.

To implode such a pellet requires delivering some triggering energy, shortly and sharply, simultaneously from all sides. Experimenters first considered using laser beams to deliver the energy, and arrangements of this sort are fairly well advanced. Later on it was suggested that beams of electrons or even of light ions could deliver the energy more efficiently — if they can be gotten to the target.

One method of getting an electron beam to the target has recently been demonstrated by a group of physicists working at the Naval Research Laboratory: J. R. Greig, D. W. Koopman (of the University of Maryland), R. F. Fernsler, R. E. Pechacek, I. M. Vitkovitsky and A. W. Ali. It involves preparing a way for the electron beam by using the light beam from a carbon dioxide laser. Coincidentally, the Carter administration placed before Congress arms control impact statements that indicate that the government is exploring the possibility of a particle-beam weapon that would use a laser beam to make a way through the atmosphere for a beam of charged particles that might do some destruction. A Navy project called Chair Heritage seems to have been the biggest part of the exploration. The Soviet government is also concerned: It has proposed banning development of charged and neutral beam weapons intended for destruction of "biological" targets.

Coincidences are only coincidences. The published work of Greig and collaborators in the July 17 PHYSICAL REVIEW LETTERS has only to do with imploded-pellet fusion, a topic of sufficiently widespread interest in itself. The problem here is to get a beam of electrons over a short distance from the diode that produces them to the fusion target. The thing cannot be done by shooting the electrons through a vacuum tube as is done at electron accelerators. There are too many electrons in this beam, and the beam would just turn back on itself, says Pechacek. The space charge, the mutual repulsion of the electrons for each other, is too much.

So experimenters try to move the electrons through some kind of background gas, establishing a path in which there is a magnetic field to guide them. One way that has been used in the past is an exploding wire, a wire laid along the path of the electrons that explodes when hit with a certain current. It had been suggested that a laser beam might induce electrical breakdown in the background gas providing an electric current and the guiding magnetic field. Greig and collaborators have shown that it will indeed do this for distances up to two meters. The present system may not be optimum for application to relativistic-electron-beam fusion apparatus, but further development could make it so. In addition, "Other laser systems have reportedly achieved chains of aerosol-induced breakdowns up to 60 m long so that much longer guided discharges may be feasible," Greig et al. conclude.

The reference for the claim of 60 meters is to work of V. A. Parfenov, L. N. Pachomov,