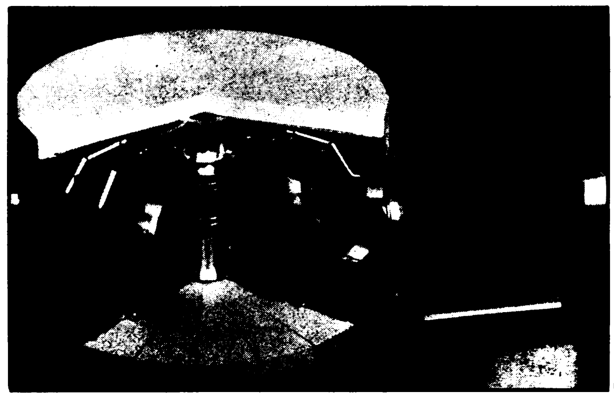
Tokamak Makes Hot News



Department of Energy

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,

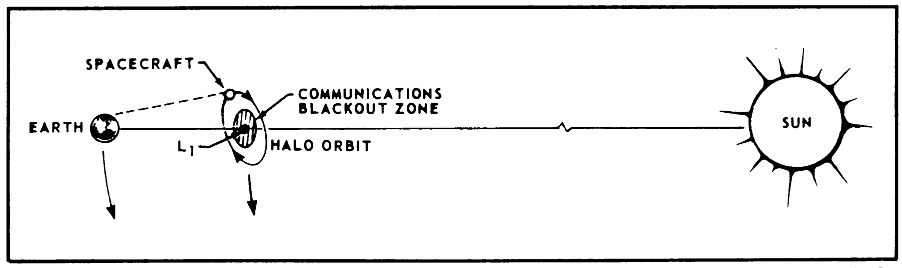
V. Yu. Petrumcin and V. A. Podlevskiy (Soviet Technical Physics Letters, Vol. 2, p. 296). Sixty meters is a conceivable length over which one might want to transport an electron beam for fusion purposes, but still maybe the Soviet government knows what it is being nervous about. The whole subject of particle beam weapons (SN: 7/23/77, p. 60; SN: 10/29/77, p. 281) is fraught with noninformation, deliberate misstatement, horror tales and spy-spook mystification. Still, it seems evident that the United States and the Soviet governments and possible others are thinking about them.

The idea of a particle-beam weapon is to produce a copious burst of energetic particles, be they electrons, protons, ions (or, as the Soviets now seem to be suggesting, neutral [?] particles), send them X kilometers through the atmosphere and zap! there goes your capital city ("biological target") or, more likely, zap! there goes your incoming cruise missile. Those in authority who call the idea a fairy tale usually stress the difficulties of inventing an engine to produce the particles in sufficient density and with sufficient energy and the difficulties of propagating the beam (some voices with the unassailable assurance that comes from years of giving commands have said "impossibility"). Yet there is ongoing research that can be brought to bear on these questions. Incidentally, the background gas through which the laser makes the path in the NRL experiments is air. □

Unusual orbit for sun-earth satellite

Around an invisible point, on an imaginary line, there is "the halo." It is not a definition in abstract topology, but the calculated path for a satellite whose planned orbit, according to the National Aeronautics and Space Administration, is "the most unusual ever proposed for a NASA space mission." The probe that on August 12 was launched toward the halo, furthermore, has an unusual job to go with its unique location: early warning system for two other satellites. Their paths too, in fact, are hardly conventional.

The goal of all this complexity is the coordinated study of the earth's complex responses to the equally complex outpourings of the sun. With emphasis on the "coordinated." Numerous satellites over the years have monitored various aspects of the sun-earth system, but they have done so for the most part "independently." How does the tail region of the earth's magnetic field, for example, respond to a burst of charged particles from the sun, compared with the response at the "bow shock" where the burst is striking the geomagnetic field head-on? To get data from their desired locations, researchers have often had to combine measurements from completely different solar outbursts, perhaps months or years apart.



NASA

One attempt to deal with this problem is a series of satellites known as the International Sun-Earth Explorers. Last October 22, NASA launched ISEE 1 and 2 aboard a single rocket that placed them in what amounts to a common orbit, chasing each other around the planet. Because the orbit is a radically stretched ellipse, varying from about 480 to 144,800 kilometers above the planet, the distance between the satellites changes—sometimes hundreds, sometimes thousands of kilometers. In addition, flight controllers at the NASA Goddard Space Flight Center in Maryland sometimes raise or lower the orbit a bit, so that the whole pattern of catching up and dropping back changes. A single solar burst reaching the earth can thus be monitored at two known — and adjustable — locations.

In order to best take advantage of such a system, it would be useful to have data on what is actually coming from the sun, before it is affected by the earth's presence at all. And so, last Saturday, NASA launched ISEE 3, bound for "the halo."

About one percent of the way along a line from the earth toward the sun is a so-called "libration point," where the gravitational influences of the two bodies (with slight corrections for other factors) are balanced. It is about 1.5 million km from earth, well sunward of the geomagnetic bow shock, and it is where ISEE 3 is heading for its sunwatch. The probe will arrive around Thanksgiving, but it will not settle right at the libration point, since that would put the probe in line with solar interference that would drown out the data being radioed to earth. Instead, ISEE 3 will be placed in the "halo" orbit *around* the line, so that it clears the line by about 120,000 km to the (ecliptic) north and south and about 640,000 km to either side. The halo orbit's inertia would normally cause the plane of the orbit to drift so that it was no longer perpendicular to the sun-earth line, so thrusters on the satellite will be used to make periodic corrections. There is fuel for about three years. Once on station, ISEE 3 will provide data to "calibrate" the responses reported by ISEE 1 and 2, and in some cases will even give scientists time to modify certain experiments aboard the earth-orbiting probes in preparation for whatever is coming from the sun.

The ISEE probes are part of the large, multi-year project known as the International Magnetospheric Study, which also includes other satellites and ground-based sensors. In addition, says U.S. IMS coordinator Robert Manka of NOAA, data from NASA Goddard are being used to alert IMS scientists in advance of useful alignments of as many as a dozen satellites (as if several will be strung out down the geomagnetic tail on a given date), enabling widely spaced, "timed" looks at the earth-sun system. □

Sherman to Austin: Pass the bananas

It has been clearly demonstrated that Washoe and other chimpanzees can use sign language to communicate with human beings (SN: 7/29/78, p. 72). Now psychologists at the Yerkes Regional Primate Research Center and Georgia State University report "the first instance of ... symbolic communication between nonhuman primates."

"This simply shows that these [symbolic communication] processes are accessible to their intelligence," E. Sue Savage-Rumbaugh of Yerkes told Sience News. Prior to the experiments, "I didn't know whether they would pay any attention to one another's behavior," she said. But the results—reported with colleagues Duane M. Rumbaugh and Sally Boysen in the August 18 Science — illustrate that chimps can indeed communicate symbolically with each other.

The chimps — four-and-a-half-year-old Sherman and three-and-a-half-year-old Austin — first learned to identify symbols for individual foods. Each geometric symbol was embossed on individual keys of a keyboard. Depressing a key caused that symbol to appear on a screen above the keyboard.

Austin and Sherman then learned to ask for certain foods by pressing the corresponding keys. This was achieved by one of the researchers symbolically asking a chimp which food was in a certain container, and then giving him that food after correct identification was mastered. The second chimp learned the process from watching the first.

In a final progression of steps, Sherman and Austin learned to ask for, give and receive food from each other by using the keyboard system. In the last phase, the