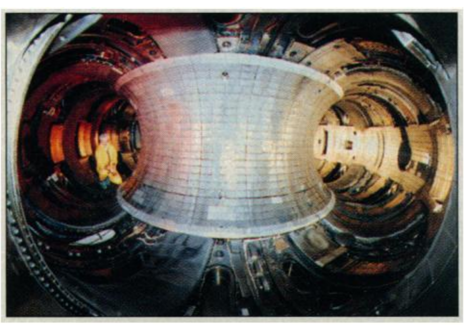
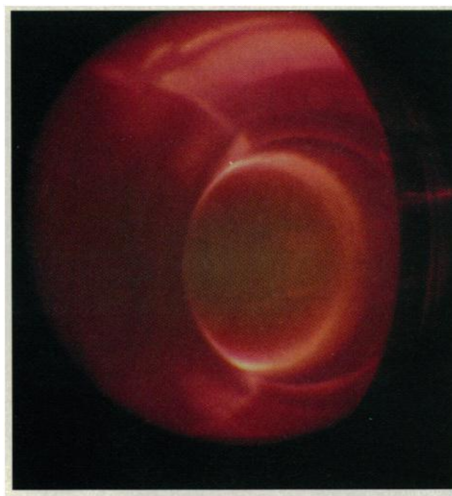
# Will Tritium Give Magnetic Fusion a Shot in the Arm?

"Exhilarating" is the way Ronald Davidson, head of the Princeton Plasma Physics Laboratory, describes the moment 2 weeks ago when diagnostic screens lit up with data from the first fusion experiments ever performed with the same mixture of hydrogen isotopes likely to fuel a working reactor. Much of the ensuing attention focused on the record power levels generated by the magnetically confined mixture of deuterium and tritium: about 6 megawatts, comparable to the output of a medium-sized jet engine.





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**A tokamak's hot breath.** Inside the 5-meter-wide Tokamak Fusion Test Reactor *(above)*, a plasma trapped in the spiraling magnetic fields is heated to incandescence.

But more important in the long run, say Davidson and other physicists, is what will follow from these first shots: a year-long series of experiments that will explore the behavior of plasmas in which fusion is taking place on a large scale. "It's the start of a new stage of [fusion] physics—the physics of burning plasmas," says Michael Mauel, a fusion researcher at Columbia University.

After all, it has long been known that a hot, confined plasma consisting of a 50-50 deuterium-tritium mixture would yield the optimal fusion output. But researchers worried that the plasma, heated and stirred up by the byproducts of fusion, might prove unstable. "People always had a concern that there was something out there waiting to bite you," says John Willis, head of the Department of Energy's confinement systems division in the Office of Fusion Energy. The success at the Tokamak Fusion Test Reactor (TFTR), he says, "was like taking a big load off." It is also raising researchers' hopes of a reprieve for TFTR, which is now doomed by a funding cutoff to shut down in a year.

Until now, experimenters had held back from tritium shots because of the formidable difficulties they present. Some of those difficulties stem from the shower of high-energy neutrons thrown off by the reactions—the same neutrons whose energy would be harnessed to generate electric power in a practical reactor. These neutrons can blind diagnostic equipment, and they can also generate radioactive isotopes in a reactor's structural components. Even though much of this radioactivity has a half-life of only a year or two—much shorter than that of many byproducts created in present-generation fission reactors—it greatly limits access to the machine. And tritium itself is radioactive and must be handled carefully.

As a result, all earlier experiments at TFTR and other facilities had been done with plasmas of either pure deuterium or deuterium with a trace of tritium. Because deuterium doesn't fuse as efficiently as tritium at laboratory temperatures or produce as much energy per fusion, these experiments generated limited power: The previous record, set in 1991 at the Joint European Tokamak (JET) in the United Kingdom, was less than 2 megawatts, achieved in a plasma containing about 10% tritium. Such tests yielded insights into the behavior of hot, magnetically confined plasmas, but they couldn't fully reproduce the behavior of a 50-50 deuterium-tritium mixture, and efforts to extrapolate from the behavior of the deuterium plasmas have large uncertainties. The next step was to move on to real fusion fuel—and with time running short for TFTR, program officials decided to take the plunge.

The fusion reactions were sparked by heating the mixture with high-energy particle beams to a temperature of about 300 million degrees kelvin and confining it for roughly a second in TFTR's spiraling magnetic fields. The heating required about 30 megawatts of power, so the 6 megawatt yield—and even the 10 megawatts planned for next year—falls well short of break even. But the planned TFTR experiments will enable physicists for the first time to explore a process that could allow them to shut off the beams and other heat sources and rely on internal heating to sustain the reaction.

The internal heating would come from the energetic helium nuclei, or alpha particles, produced when deuterium and tritium nuclei fuse. In an "ignited" reaction, these particles should continuously supply energy to the plasma, keeping it hot enough for the reaction to sustain itself. Although alpha heating is expected to be small in the TFTR experiments, it should be easy to detect if present theories are right, and a major effort will be dedicated to observing the effect.

The researchers will also be exploring a predicted downside of alpha particles: their potential to generate instabilities that might shake the plasma out of TFTR's magnetic bottle and into the walls of the reactor, killing the reaction. That was what worried the waiting physicists during the first shots. "Plasmas are rich with waves," says Dale Meade, deputy director of the lab, "and alpha particles have a speed comparable to the speed" of a key wave type. The result is a resonant interaction that could drive the waves to large amplitudes, like wind gusting over the surface of a lake. The early results? "So far, so good," says Stewart Zweben, a physicist measuring alpha effects. Zweben stresses, however, that surprises may still turn up as the plasma conditions are varied in future experiments.

Those experiments will have to be done on a tight schedule. After TFTR shuts down in a year, the magnetic fusion program will be at a standstill until the machine is cannibalized for Princeton's next major initiative, the Tokamak Physics Experiment (TPX). Designed to approach steady-state operation, TPX would begin operation in the year 2000—if construction funds materialize. After TPX, the next major step would be the 1000-megawatt International Thermonuclear Experimental Reactor, scheduled to stoke up 5 years later at a site to be determined.

The death sentence facing TFTR added a somber note to the celebration for the 80 physicists working at the facility. "We're all extremely concerned with what happens one year from today," says Dennis Mansfield, a physicist studying plasma-wall interactions. "[After that], very few of us know what we're going to be doing."

**–James Glanz**

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*James Glanz is a science writer in Chicago.*