Science & Technology

Princeton fusion device to achieve energy breakeven

by Charles B. Stevens

At 3:06 AM on Dec. 24, 1982, scientists at the Princeton Plasma Physics Laboratory (PPPL) began operation of the world's largest fusion energy experiment, the Tokamak Fusion Test Reactor (TFTR). The TFTR will be the first device to control the energy released by the fusing together of two hydrogen atoms to generate a net output of usable energy—a condition known as "energy breakeven." And, while full-scale operation is still many months away, these first test runs of the Princeton device constitute a technological achievement as significant as the first landing of men on the Moon. The TFTR will provide a proof of the magnetic fusion energy's feasibility and go a long way toward making fusion—which uses the almost unlimited supply of heavy hydrogen found in seawater as its fuel—into an economical and practical electricity source.

At a press conference announcing the start-up of TFTR, the Director of Information for Princeton Labs, Anthony DeMaio, reported that the first "shot", or injection of a hydrogen test plasma into TFTR had been more successful than anticipated, achieving plasma containment and energy flux on its first attempt. More than 400 shots are planned to be done by April in a heavy test schedule of components and behavior of the reactor under many different conditions, prior to the first compression and full Ohmic heating experiments to bring the plasma up to high temperatures, which will begin that month.

By September a neutral heating beam device will be used for the first time to reach plasma temperatures on the order of 100,000,000°C, well in the range for power-producing fusion plasmas. DeMaio said that breakeven experiments with DT (deuterium-tritium) fuel are planned for 1986, though the conditions needed for breakeven will be demonstrated by 1985 with all deuterium plasmas.

Only constraints are political

What the enormous success of the TFTR already demonstrates is that the only constraints to development of this limitless energy source are political ones.

As mandated by the Magnetic Fusion Engineering Act of 1980, and proven by scores of government reports, magnetic fusion power plants could be commercially demonstrated before the end of this century, if sufficient resources are devoted to development.

The TFTR's success thereby reconfirms the argument advanced by this reporter, and two organizations with which he is associated, the *Executive Intelligence Review* and the Fusion Energy Foundation, which have campaigned for fusion by the 1990s since 1974.

But current administration policy was reflected in the statement of Presidential Science Adviser Dr. George Keyworth that while the TFTR start-up "means a tremendous amount of hope for fusion power," it "will be well into the 21st century" before any commercial fusion applications are attempted.

What proponents of fusion energy hope is that the TFTR success can provide the spark to reignite the United States' commitment to fusion development.
throughs made at Princeton will not be wasted. If not incorporated into a U.S. R & D program, they will nonetheless be used by the nation emerging as the world's leader in fusion energy development—Japan.

Birth of a reactor

The TFTR was born in 1973 as an idea of Dr. Robert Hirsch who was at that time director of the U.S. controlled fusion program. The initial breakthroughs which had been accomplished by the Soviets in the late 1960s with their tokamak magnetic confinement concept had been confirmed on a number of U.S. experiments together with significant advances involving the heating and control of tokamak fusion plasmas. Until that time all existing and planned magnetic fusion experiments used unreactive hydrogen and deuterium fueled plasmas. This avoided having to deal with the engineering and technical difficulties of plasmas generating intense fusion energy outputs. Most of the significant scientific questions concerning the problem of generating the conditions needed to ignite nuclear fusion could still be addressed while keeping the experimental facilities readily accessible and unencumbered with energy removal and shielding equipment.

But as fusion director Hirsch pointed out at the time, if the goal of practical fusion power plants is to be attained in a timely fashion, the program must meet and address the problems of fully reactive deuterium-tritium fusion plasmas as soon as scientifically feasible. Hirsch therefore took the bold step of mandating that the next major magnetic fusion facility would have to be designed to run with deuterium-tritium fueling.

Hirsch's idea was that the TFTR would mark the beginning of the engineering phase for the development of the first fusion electric power reactor prototypes. At the time, given the many basic scientific questions which remained unresolved, this Hirsch initiative appeared to be bold and quite ambitious.

The tokamak and fusion

When Hirsch conceived of the TFTR, the chief problem up to that point in magnetic confinement fusion research had been that of successfully designing a "magnetic bottle" or "trap" which would confine and insulate hydrogen fusion fuel while it was heated up to the enormous temperatures needed to spark significant numbers of fusion reactions.

The easiest fusion reaction to ignite is that between the two heavy isotopes of hydrogen, deuterium and tritium. At temperatures above 50,000,000° Celsius, this D-T reaction becomes sufficiently vigorous such that more fusion energy can be generated than the energy it takes to heat the fuel to these temperatures. But in order to achieve this energy breakeven or net energy producing situation, the fusion fuel must be maintained at a sufficient density for significant amounts of reactions to take place. And the fuel must be sufficiently insulated that it does not lose its heat content faster than the rate at which fusion energy is being generated. This is measured as an energy confinement time.

The conditions of density and energy confinement are combined to form a product which must be greater than one hundred trillion seconds-nuclei per cubic centimeter.

When a material is heated to anywhere near fusion temperatures, its atoms become ionized and it forms an "electrified" gas called a plasma. The problem for magnetic confinement fusion is to find a configuration of magnetic fields which stably interacts with the hydrogen plasma to keep its energy confined in the plasma itself. The tokamak magnetic confinement system has the shape of a donut. The tokamak was the first magnetic configuration to achieve stable confinement of hydrogen plasmas.

In 1978 the Princeton PLT tokamak showed for the first time that temperatures in excess of 80,000,000°C could be stably attained. This was achieved through utilizing neutral beam heaters supplied by Oak Ridge National Lab. And as pointed out by Dr. Stephen O. Dean, who was then the director of confinement systems research in the U.S. magnetic fusion program, this meant that there were no scientific barriers to the construction of prototype fusion reactors within the next 10 to 15 years.

Malthusian attempted sabotage

But to the mind of the Malthusian Carter administration, the near-term prospect of abundant, cheap and clean fusion energy was anathema. Thanks to the efforts of Dr. Dean and the Fusion Energy Foundation, the PLT breakthrough received the international attention it deserved in print and broadcast media, including a front page article in the *Washington Post*. Energy Secretary James Schlesinger thereupon mounted extraordinary efforts to blunt the impact of his own department's achievement, belittling the PLT results and insisting that news reports had been greatly exaggerated. Dr. Robert Hirsch was driven out of government in 1976. When Dr. Dean refused to suppress the news of the 1978 breakthrough, he too was forced out. Many attempts to cut the fusion research budget, amd the TFTR in particular, were mounted by the Carter administration. But even Carter appointed review panels were forced to admit the great progress and promise shown by the U.S. magnetic fusion program. And the program was able to at least maintain 1976 funding levels.

As a result of the efforts of the Fusion Energy Foundation and Rep. Mike McCormack, Congress was persuaded to recognize the progress of fusion research through the passage of the 1980 Magnetic Fusion Engineering Act which called for the realization of demonstration commercial electric fusion power reactors by the year 2000.

The FEF carried out a nationwide postcard campaign that demonstrated to Congressmen and Senators that their constituents understood and felt strongly about this supposedly abstract and technical issue.

But the Reagan administration so far has proved to be only a little more willing than its predecessor to move ahead with fusion development. The director of the magnetic fusion program in the Department of Energy, Dr. Edwin Kintner, was forced to resign in despair a year ago.

The successful inauguration of the TFTR at Princeton Labs can function as a powerful reminder of the feasibility and necessity of the nation's still unfulfilled commitment to fusion energy development.