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TFTR Begins New Run

by Diane Carroll

Vacuum vessel conditioning has been completed and initial experiments are now underway in a new TFTR run that will last through December.

After a thorough technical review in 1987, the Department of Energy reaffirmed the deuterium-tritium (D-T) objective for TFTR. Research activities are now clearly focused on preparations for TFTR's Q=1 experiments with D-T to be conducted in 1990. The success of these experiments depends heavily on the results of the present run. The engineering and physics goals of this run provide the most ambitious experimental challenge TFTR has faced.

Supershots

Physics experiments will focus on extending the supershots to higher plasma currents so that higher pressure plasmas can be confined, allowing more fusion reactions to take place. This is a critical step in moving TFTR toward its Q=1 objective. (Q is the ratio of the fusion power output to plasma heating power input. Q=1 is termed "energy breakeven.")

Barring the unexpected, supershots represent TFTR's best chance of reaching Q=1. Supershots are low-current plasma discharges that are produced when high-power neutral beams are fired into a tokamak where the walls have been scrupulously conditioned to remove adsorbed deuterium. These conditions provide a plasma that is much denser at its center than at its edge, and one that enters an "enhanced confinement regime."

Plans for the present run call for gradually increasing the plasma current from 1 MA to 1.8 MA over the course of four or five months. Balanced neutral-beam power will be increased from 12 MW to about 27 MW by July. Physicists hope that these conditions will yield a D–T equivalent Q=1 in deuterium plasmas by late summer or early fall.

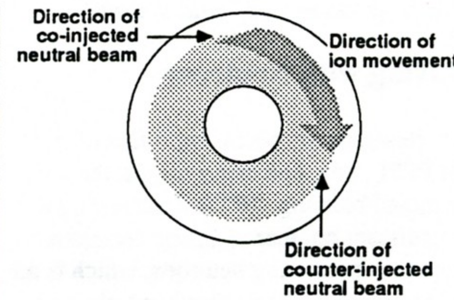
"This will be a major milestone in the TFTR program," said TFTR Project Head Dale Meade, "and it will give us a great deal of insight about our hopes for Q=1 in D-T plasmas in 1990."

Beams are Key

At present all four beamlines are under vacuum and all twelve long-pulse ion sources are operational. The reorientation of one beamline was accomplished this winter at a cost of about $3 million and will allow the first full-power test of balanced injection in TFTR.

Up until now, three beams injected in the same direction as the plasma current (co-injection) and one injected in the opposite direction (counter-injection). Co-beamline No. 3 was moved to counter position 1, so that now there are two co-injection beams and two counter-injection beams, providing essentially balanced beam particle momentum. In the first series of experiments, the neutral beams have been operational up to 20 MW.

"We have known for a while that supershots work better with balanced injection, and now we are anxious to find out just how much better TFTR will perform under these conditions," said Mike Williams, Heating Systems Division Head.



ICRF Studies Begin

For the first time Ion Cyclotron Radio Frequency (ICRF) heating will be used in TFTR. Six megawatts of heating power capability previously used on PLT and two wave launching antennas, one built at PPPL and one at Oak Ridge National Laboratory, were installed during the last opening.

Operating at 47 MHz, the ICRF system will be used to heat a small amount of helium-3 or hydrogen that is added to the deuterium plasma. This minority species then transfers its energy to the deuterium plasma.

"We need to learn if it is better to heat ions or electrons," said physicist Randy Wilson. By varying the percentage of helium or hydrogen in the plasma, researchers can focus the ICRF heating on either ions or electrons. With one percent concentrations of helium or hydrogen, the particles move faster so the ICRF waves tend to heat electrons, while at ten percent concentrations, ions are heated.

Electron heating may be the more useful in supershots. It has been found that at lower electron temperatures some of the neutral-beam energy goes to heat the electrons, limiting what is available for ion heating. "If we can heat electrons with ICRF, more beam-target fusions will occur since electrons won't add 'drag' to the beams," said Wilson.

Living with Neutrons

Neutrons are becoming a fact of life at PPPL, and, like many things, they are a mixed blessing. TFTR is achieving a significant number of fusion reactions and thus producing neutrons, which is all to the good. On the other hand, the neutrons cause the vacuum vessel and other components to become radioactive, which complicates work on hardware near the plasma, and makes diagnostic measurements more difficult.

Hans Hendel is responsible for the seven neutron detectors used on TFTR. The detectors use a thin layer of uranium to capture neutrons. When hit by a neutron, the uranium atom splits, and the fission products ionize a gas in the detector. These particles are collected and measured.

Measuring the neutrons produced is complicated by their scattering and absorption by TFTR structures. For this reason, careful calibration of this system is critical. "We want to be as precise as possible in these measurements," said Hendel.

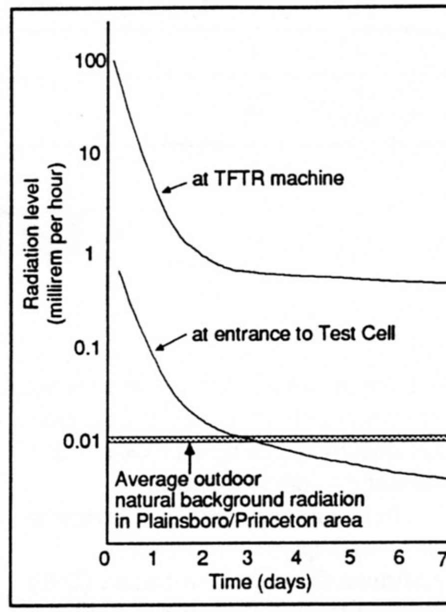
Between January and July 1987, a total of 4×10^{18} neutrons were produced. The peak production rate was 1.9×10^{16} neutrons per second, a new record for fusion devices. On the average, about 1.5×10^{17} neutrons per day were produced.

This neutron production resulted in induced radiation levels at the vacuum vessel of up to 600 millirem (mrem) per hour immediately following a series of supershots.

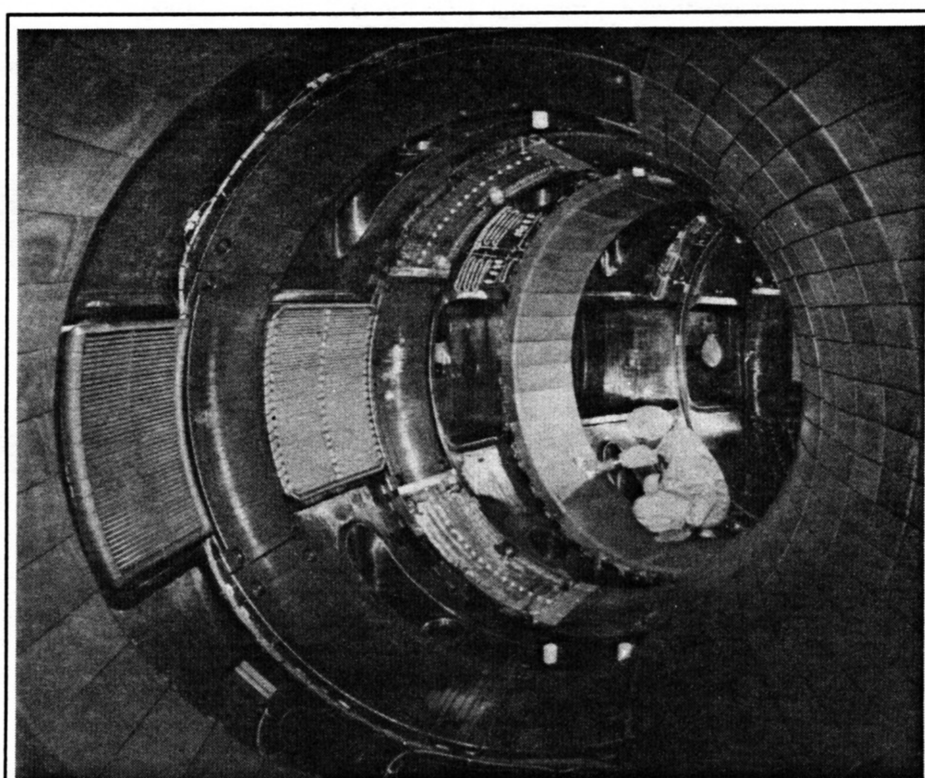
According to Jerry Gilbert, Head of Environmental and Operational Health Physics, most of this radiation dose is produced by the interaction of neutrons with the manganese-55 contained in the vacuum vessel's stainless steel. The manganese-56 that is produced has a 2-1/2 hour half-life, so that maintenance activities were not greatly affected. "Waiting a few hours or overnight greatly reduced the contact radiation levels," said Gilbert.

Away from the vessel, dose rates were even lower. At the entrance to the Test Cell, radiation levels were about 1 mrem per hour right after a run, about 0.1 mrem per hour after one day, and below the naturally occurring background radiation levels in the area after about three days. "The thick concrete walls shield cosmic rays to produce a below-background level in the Test Cell," Gilbert said.

"During this run," said Gilbert, "we estimate that levels of 600 to 1,000 mrem per hour at the vessel might be reached immediately after a long series of experiments." This will affect maintenance schedules and procedures.



Typical falloff of radiation following TFTR operation.



(E. FARRIS)

Engineer George Barnes is shown inside the TFTR vacuum vessel. The radio-frequency antennas are at left.

"At PPPL we limit a person's quarterly exposure to 600 mrem, which is one fifth of the USDOE limit," Gilbert continued. "If it is necessary to work near the vessel, Health Physics will evaluate the radiation dose expected from each job. If necessary, we will limit the amount of time a person can spend there to keep him or her within these limits."

Three new area radiation monitors were added to the machine at bays Q, C, and L, and one within the Test Cell at the north-west entrance near the guard's desk. The new monitors will provide a constant measure of Test Cell radiation and can be read from within the control room or outside the Test Cell entrance. "These will make the job of checking radiation levels vastly easier," said Gilbert.

Tritium Systems Readied for Operation

Modifications and refinements to the tritium storage and delivery systems were completed in May by the contractor, Burns and Roe, and turned over to PPPL for cleaning, calibration, and preliminary testing. Work on the cleanup systems will be completed this month.

Very small amounts of tritium will begin arriving at PPPL next fall. An initial shipment of 100 Curies (0.01 gram) will be used to check out and test tritium-handling equipment and monitors. The PPPL inventory of tritium will be increased over the course of six months to 1,000 Curies (0.1 gram) to complete equipment testing and operator training.

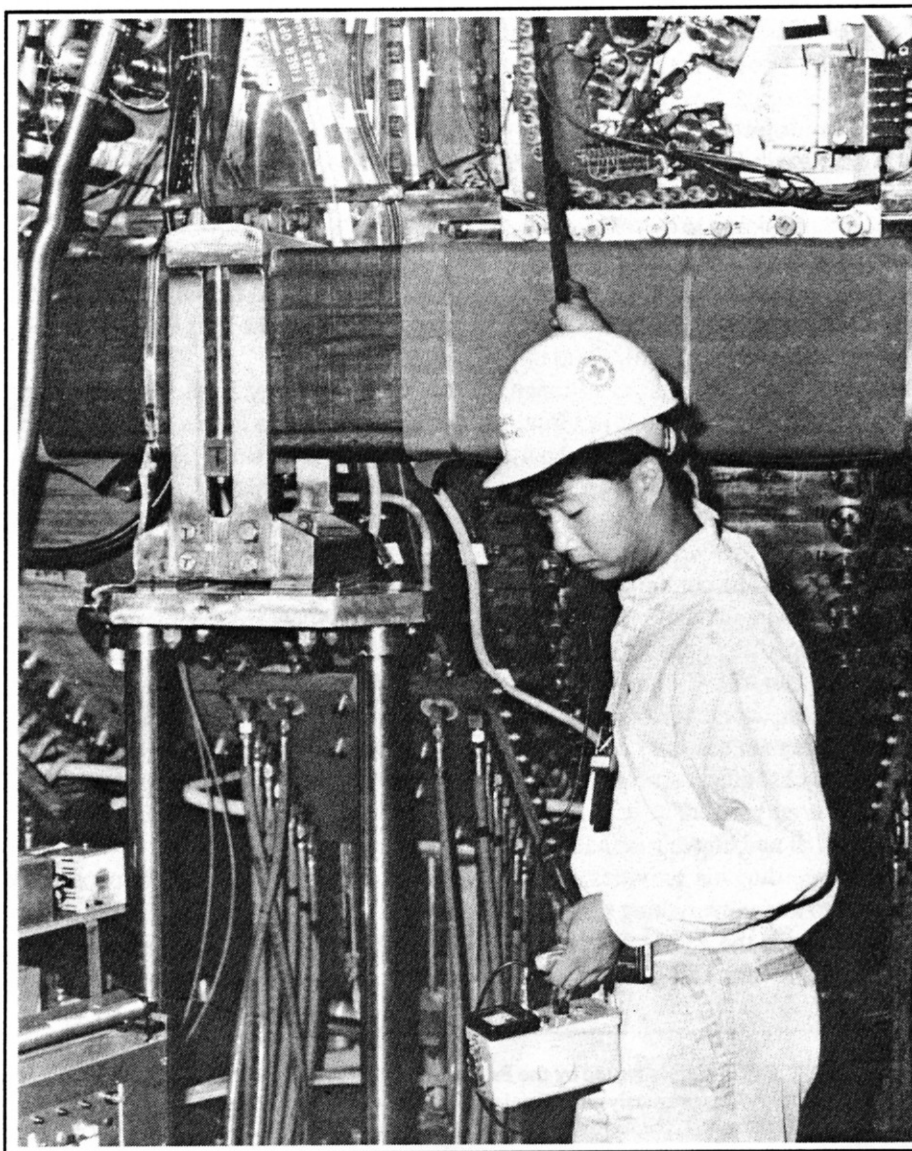
Nineteen technicians and engineers have taken the Tritium Technology Course developed and taught by PPPL staff. Those who will operate the tritium-handling equipment will go on to a "hands-on" equipment training program of several months duration here at the Laboratory and two to four weeks of instruction at another DOE tritium-handling facility. This will be supplemented with several other safety-related courses.

Reliability is an Issue

Preparation for D-T experiments is changing how work is being done on TFTR and focusing effort on new issues and problems.

"We have to improve the reliability of the machine in preparation for D-T operation," said TFTR Operations Head Rich Hawryluk. Next January, construction will start on a concrete-block igloo that will completely enclose TFTR, including the neutral-beam boxes, to absorb the high-energy neutrons D-T operation will produce. In so doing, the igloo will prevent access to almost all machine components and a host of diagnostics. "We need to be certain that all critical components can operate reliably during the six months of D-T operations," said Hawryluk, "because it will be extremely difficult and in some cases impossible to get in to do repairs, calibrations, and adjustments."

An engineering team headed by John Lowrance and Don Knutson is working



(DIETMAR KRAUSE)

Dave Wang, a Health Physics technician, takes a dose rate measurement near the TFTR vacuum vessel. Such measurements are taken each morning.

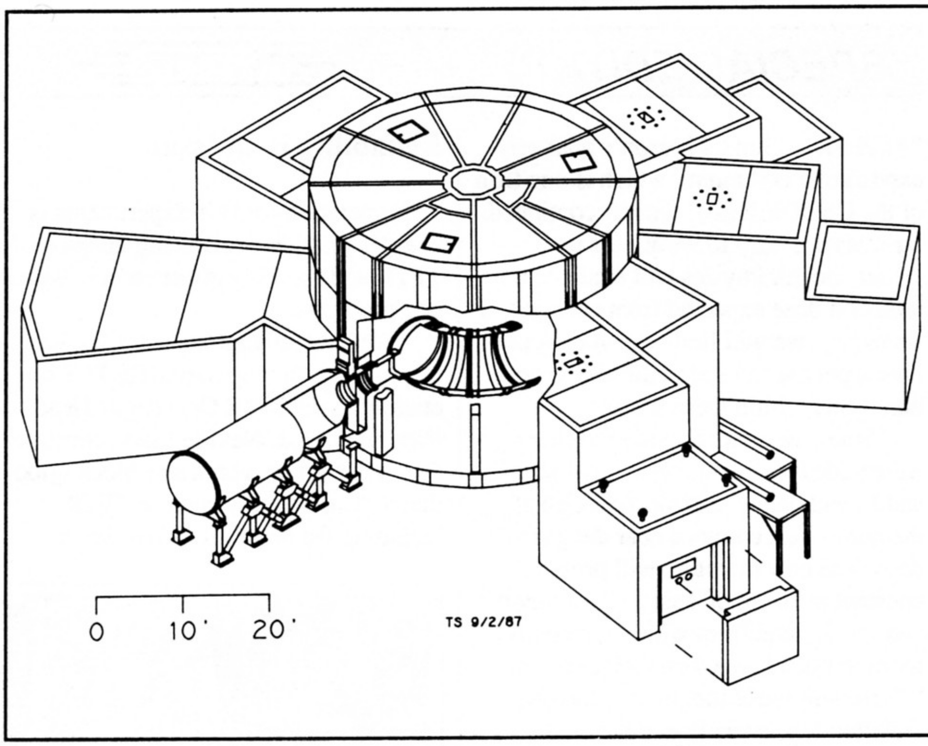
to identify potential reliability problems. They are interviewing cognizant engineers and physicists associated with every machine component and diagnostic that will be located within the igloo and reviewing TFTR Trouble Reports to obtain a history of each device. Their aim is to flush out reliability issues and to identify the work that has to be completed before D-T operations begin.

The engineering team and Quality Assurance are also preparing a Failure Modes Effect Analysis that analyzes critical components within the igloo (machine part, neutral beam, or diagnostic). The team looks at every possible way the component can fail, assesses the impact of such failure on D-T operation, and looks at the likelihood of the event. From this, a priority list of potential problems is being developed for engineering or project action.

In addition, a Failure Reporting System has been established, requiring engineers and physicists to report every failure that occurs, whether it affects machine operation or not. "We need to know where and why the failures are occurring," said Dave O'Neill, Head of the TFTR Engineering Operations Branch.

A new Operations Reliability Board (ORB) will review these failure reports. "The attention of the ORB is focused on critical failures in the igloo," said O'Neill. "The ORB will serve to identify the weak links," he continued, "and it will make recommendations to the project for modifications to improve reliability prior to D-T operations."

In the past, access for work within the Test Cell was not centrally controlled. This too is changing. "As long as an employee was authorized, he could enter the Test Cell and do what he had to do without recording his activities. Now, we need to know everything that is going on inside the Test Cell," said O'Neill. To record Test Cell access, a system was instituted on TFTR requiring each individual to obtain a Work Permit before entering the Test Cell for any type of work.



Schematic of TFTR showing the concrete igloo.

"With D-T operation, each system or diagnostic can no longer be treated as a separate entity," said O'Neill. "Each researcher and engineer has to understand the impact of the igloo on his operation," he continued.

The Quality Assurance (QA) group collects the data from the failure reports and work permits and uses it to track the mean time between failures and other variables. The QA trend analysis will provide indications of how large a task improving reliability will be, as well as chart how well TFTR is doing in this area.

"All of these steps require paperwork and extra effort," admits O'Neill. "They also represent a cultural change in the way we operate. But it must be stressed that TFTR's reliability needs to be improved. To accomplish this we must identify the weak points and repair or modify them. This improvement to TFTR's reliability is absolutely critical to the success of the TFTR mission," he continued.

Dale Meade is confident about TFTR's prospects. "Improving reliability is difficult, but it can be done," Meade said. "In the near term, the TFTR team expects to extend its world record for ion temperature and hopes to also extend the plasma confinement to record values by the end of this run," he continued. The International Atomic Energy Agency (IAEA) meeting in Nice, France is scheduled for October. This important international meeting is like the "Olympics of plasma physics," according to Meade, "And the TFTR team is confident it will have good results to report," he said. ✿

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