PPPL HOTLINE
PRINCETON PLASMA PHYSICS LABORATORY

Volume 11, No. 20 September 4, 1990

Hard Work during Shutdown Pays Off

Early shutdown completion, new limiter, and high-power beams leads to record deuterium-deuterium fusion power

by Carol Phillips

TFTR Project Head Dale Meade likes to tell the following story about Chairman of the Fusion Policy Advisory Committee Guy Stever's visit to PPPL:

Dr. Stever was overheard talking with a companion during his visit. He said that he had visited a lot of laboratories and had been on a lot of tours, but he was really impressed with the things he had seen at PPPL — both TFTR and PBX-M. His companion agreed, saying that it had taken many years, a lot of money, and very hard work by lots of people. Turning, Stever answered emphatically, It shows!

"... very hard work by lots of people" are indeed accurate words to describe employees' efforts during TFTR shutdown activities earlier this year. In fact, because of these intense efforts, TFTR shutdown work was completed 16 days ahead of schedule — the first-time this has ever been achieved!

It couldn't have happened at a better time according to Dale Meade. "We're in competition with JET [the European tokamak equivalent to TFTR] to reach breakeven and we'd like to surpass their [most recent] reported results by the time of the International Atomic Energy Agency Conference in October. The quick startup will help us do this," he said.

Erik Perry, TFTR Shutdown Manager, was responsible for planning and overseeing all shutdown activities, which included more than 720 scheduled jobs and 60 unanticipated ones. He was supported by George Barnes and Doug Loesser who directed in-vessel activities and by Rusty Walton, Geoff Gettelfinger, and Harry Bush who directed activities outside the vessel.

In-Vessel Work

Major in-vessel activities included: replacing nearly 40% of the bumper limiter protective tiles, improving mechanical alignment of the limiter to the plasma, and locking the middle limiter plates in place; designing, fabricating, and replacing several radio-frequency (rf) limiter mounts; and feather-edging protective tiles at the organ pipes.

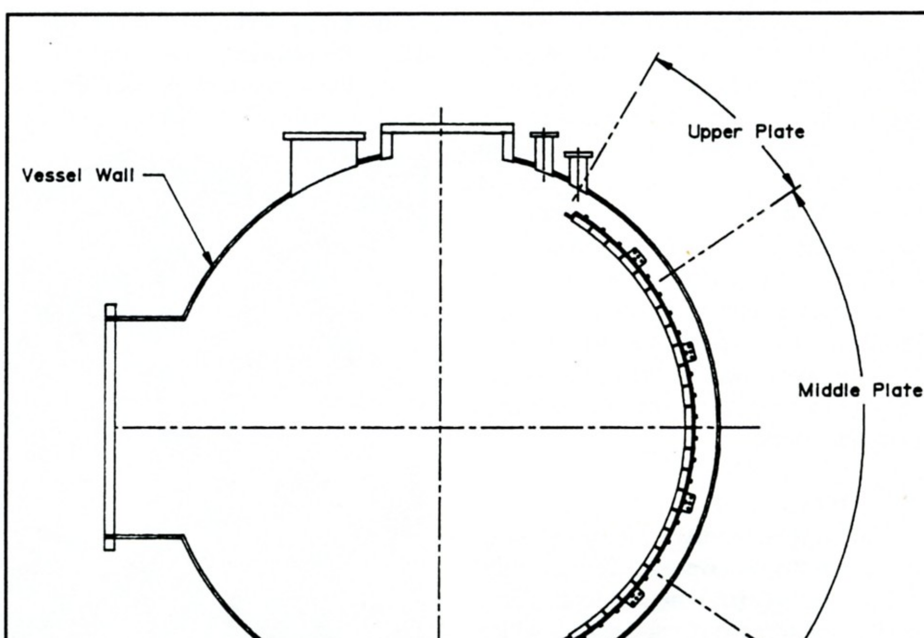
Bumper Limiter

The water-cooled bumper limiter, which protects the inner vacuum vessel wall from the plasma, consists of three plates — upper, middle, lower — that form an 120° arc around the center of the inside vacuum vessel wall (see Fig 1). The front is made of tiles and the back of Inconel plates.

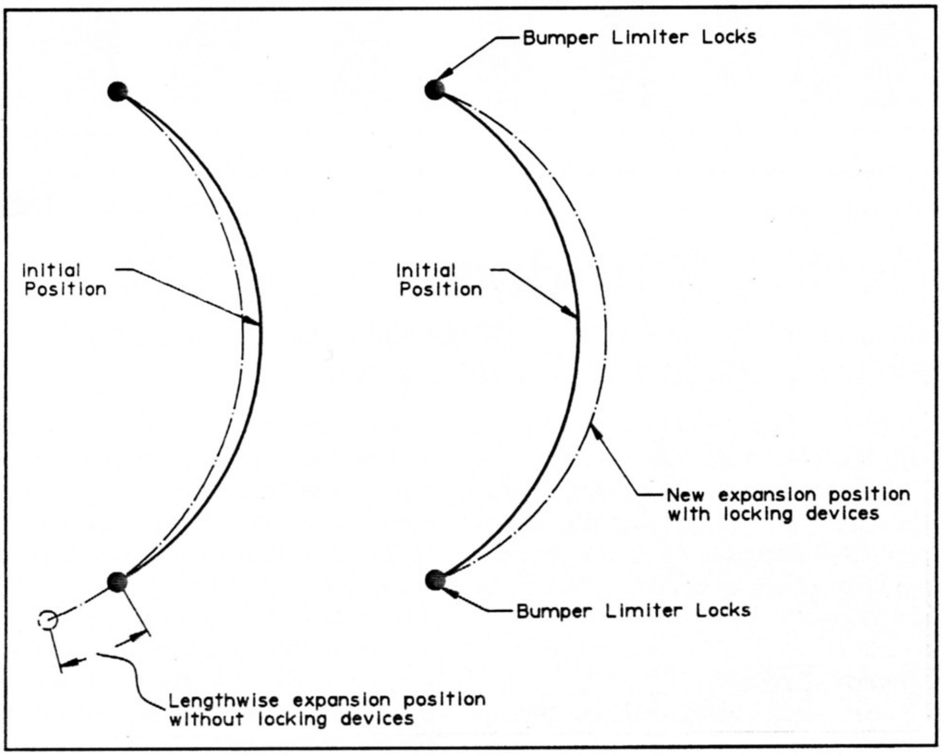
Poco-graphite tiles protecting the middle limiter plates were damaged by high plasma heat loads. During the shutdown, these were replaced with carbon-carbon tiles which are mechanically much stronger and can take higher heat loads. This should allow for better plasma performance. "With poco-graphite tiles you can get 'carbon blooms' — a type of plasma impurity that severely limits plasma performance," explained George Barnes. "With the carbon-carbon tiles you have to try to get the carbon blooms — they don't limit performance anymore — and you can go into the supershot regime at high power," he said.

Tiles on the middle limiter plates were

continued on page 2



Cross section of the TFTR bumper limiter.



Cross section of the bumper limiter locking system. The "locks" hold the limiter plate in position, keeping the tiles away from the plasma.

also being damaged because they were being hit by the plasma. The plates had become misaligned and the tiles were being "pushed" into the plasma. During the shutdown, the middle limiter plates were realigned and locked into position.

Physicist Kingston Owens devised the unique bumper limiter locking system — a set of custom-made shims inserted into the thermal expansion grooves of each plate to hold it in place. These shims force the plates to bend away from the plasma instead of "growing" lengthwise into it (see Fig. 2). In-vessel technicians took the measurements and installed the locking systems. Jack Mount and the Machine Shop personnel along with Vinny Smith and the Vacuum Shop personnel custom-made the shims.

RF Limiter

The biggest surprise during the shutdown was the discovery of damage to the radio-frequency (rf) limiter mounts. These limiters protect the rf antennas — which provide auxiliary heating to the plasma — from contact with the plasma. "We weren't expecting this [the damage]," said Erik Perry. He explained that a month earlier the vacuum vessel interior, including the rf limiter, had been checked with periscopes and cameras and everything was fine.

After initial inspection it was found that, in some cases, the damage to the mounts was so severe they had to be replaced. "We had to redesign the mounts, get the design reviewed and verified, and then fabricate and install the mounts within the scheduled shutdown period," Erik said. He stressed that this work was in addition to the planned tasks. This activity was overseen by George Barnes, with help from Kingston Owens and Paul Kivler.

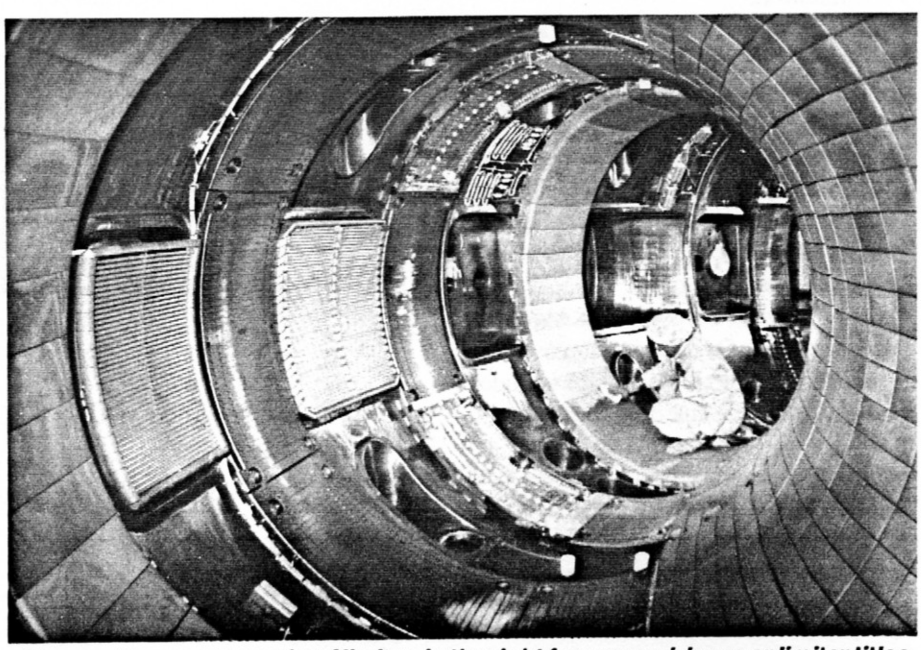
Organ Pipes

An organ pipe is a long tube that connects a diagnostic device to the vacuum vessel. Where the pipe attaches to the vessel, there's a tile that has a hole in it. Sometimes these tiles have sharp edges that the plasma hits and heats up. During this shutdown period, the sharp edges of the organ pipe tiles were "chamfered" or rounded. The work to correct this problem was delicate because it had to be done within glove boxes to protect the workers against contamination. The technique for machining the tiles was designed and worked out by Russ Walton and Jack Mount.

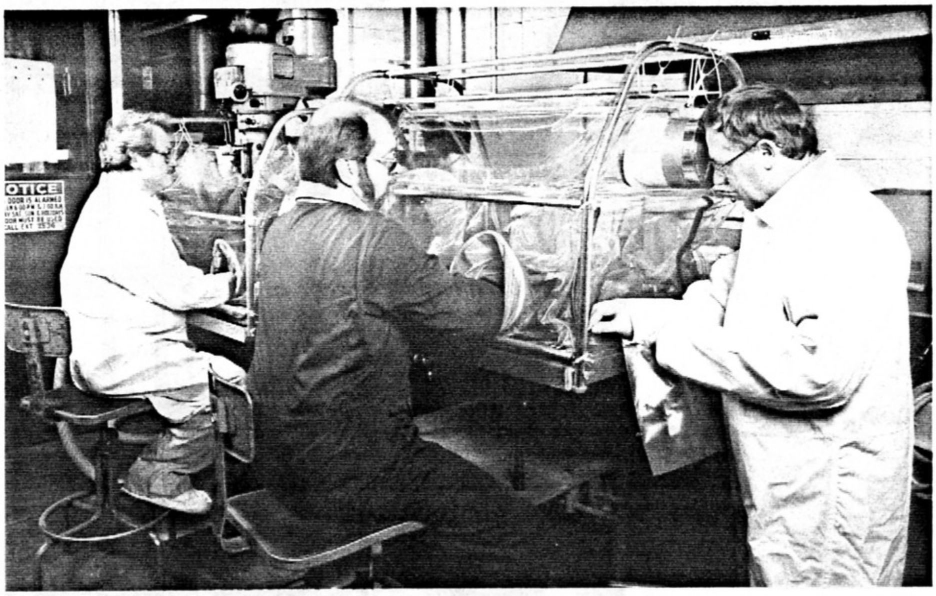
Out-Vessel Work

Major activities outside the vessel included: maintenance and repairs to elements of the neutral-beam heating system including the liquid helium refrigerator and two failed ion sources and the installation of improved cryogenic transfer lines; installation of a new diagnostic — the Beam Emission Spectroscopy (BES); and installation of the mechanical system for the multichannel reflectometer.

Jim Chrzanowski and TFTR technicians, with the help of personnel from the National Nuclear Corporation, also re-



George Barnes cleans the rf limiter. In the right foreground, bumper limiter titles can be seen.



Nick Dereka (left), Jim Benchoff (center), and Frank Polom (right) "chamfer" organ pipe tiles inside glove boxes.

paired water leaks on two toroidal-field coils. "A year ago there was great concern about getting water leaks repaired. Now we have a good system that can handle such activities without too much concern," Erik Perry said.

Neutral Beams

Awareness late in the last run period of two major unexpected and unscheduled repair jobs coupled with nonideal working conditions required a strong personal commitment by everyone to complete the neutral-beam work. Al von Halle, Head of the TFTR Neutral Beams Operations Branch, explained: "A lot of our technicians were already assigned to work on in-vessel activities when two ion sources failed without available replacements and it became apparent that the liquid helium refrigerator would require major overhauling."

The TFTR neutral-beam system is equipped with twelve Berkeley-type long-pulse ion sources which accelerate and focus high-energy deuterium atoms that provide the major component of plasma heating on TFTR. The helium refrigerator liquifies the helium required to cool cryogenic panels in the beamlines. The cryogenic panels are required to provide the high pumping speed necessary to support beam operations. The absence of two ion sources would greatly reduce the number of planned experiments that could be performed on TFTR, while poor operation of the helium refrigerator prevents any TFTR programs that require heating beams.

Ken Wright and his crew were responsible for repairing the failed ion sources. They were able to complete their repairs one week ahead of schedule despite the fact the ion source repair facility was being moved from the CAS building to D-Site, and they had to work in new surroundings where their tools and supplies weren't always readily accessible, using temporary lighting and water hookups.

Repairs to the liquid helium refrigerator, which had been running for 240 uninterrupted days before its shutdown, turned out to be far more extensive than expected. Completing the task was made more difficult because many members of the Cryogenic Operations Group under Mark Cropper had been assigned to in-vessel work. Still, the system was ready twelve days ahead of schedule.

Vic Garzotto spearheaded installation of new cryogenic transfer lines, which bring liquid helium from the refrigeration system to the beamlines. The lines were built and installed in-house and von Halle believes "they are superior to anything available commercially" and that "they will increase the efficiency of the [liquid helium] refrigerator."

Repairs and maintenance to the ion sources and the liquid helium refrigerator and installation of the new cryogenic transfer lines will make the neutral-beam auxiliary heating system more reliable. Other activities during the shutdown will help increase the energy delivered to the the plasma.

The new gas injection system that was installed during the shutdown should improve neutralization efficiency and this, coupled with modifications to the power supplies, should mean more energy delivered to the plasma without the need for addition input power. Additional power and more reliable power will help TFTR plasmas reach the supershot regime.

Talking about his group's efforts during the shutdown, von Halle said, "At one point we were looking at the worst side of things, where we thought we might have to resume operations with less power than we had planned. But, the guys really rose to the occasion. We had people who came back from previously arranged assignments to support our beam efforts every chance they could get."

Record Results

The success of the present experimental run has been due in large measure to the improved bumper limiter, which continues to show no evidence of damage, to the improved neutral-beam performance, and to the overall high availability of TFTR.

It is believed that the new boronization process developed by Fred Dylla and Paul LaMarche and designed and installed by Harry Bush, Geoff Gettelfinger, and Rusty Walton was responsible for significantly decreasing the time needed for pulse discharge cleaning. The number of pulses required was reduced from about 105,000 to about 25,000 and the time from two weeks to two days!

A new TFTR Q_{DD} power record of 1.85 $\times 10^{-3}$ was set only three weeks after resuming operation this spring. (Q_{DD} is the ratio of the power produced by the deuterium-deuterium fusion reaction to the heating power put into the plasma.) This represents an improvement of 8% over that achieved previously.

TFTR has been averaging more than 70 plasma shots per day since the beginning of this experimental run period as compared to the 46 shot per day average in the previous run. Twenty of these shots have been neutral-beam heated. This high availability has made it possible to do work on a variety of physics studies. The neutral

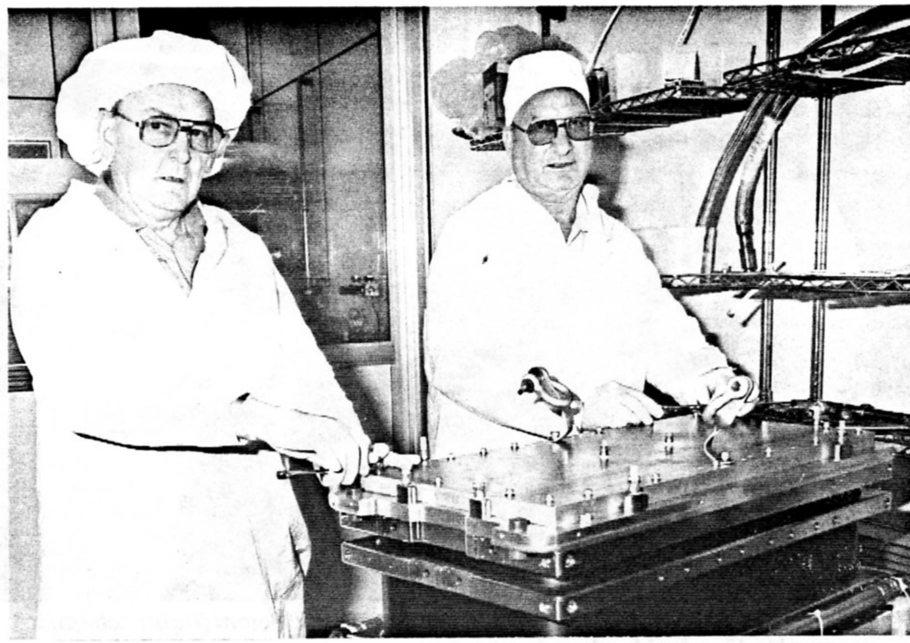
continued on page 4

beams have injected up to 32 MW of power—a world record. Ion Cyclotron Resonance Heating (ICRH) has recently operated up to 6.3 MW—a US record. Increased reliability has allowed routine exploration of significantly higher power operation than was possible in the past.

A Happening

Much has been said many times about PPPL employees' special efforts, but everyone connected with this shutdown sensed something quite "extraordinary" happening.

"I saw activity during this shutdown that I have not seen for a while in the Laboratory — kind of like the first plasma push we had a few years ago — people going all out, making very few mistakes, lots of teamwork and cooperation between groups, and very little wasted time. It was an impressive operation," von Halle said.



Don West (left) and Henry Swiderski (right) refurbish an ion source in the newly commissioned TFTR clean room at D-Site.

The PPPL HOTLINE is issued by the Princeton University Plasma Physics Laboratory, a research facility supported by the United States Department of Energy. It is primarily an internal publication. Correspondence and requests to reprint material should be directed to Carol Phillips, Editor, PPPL HOTLINE, P.O. Box 451, Princeton, NJ 08543 or telephone 609-243-2754; Interoffice correspondence should be addressed to Room B366, James Forrestal Campus, C-Site.