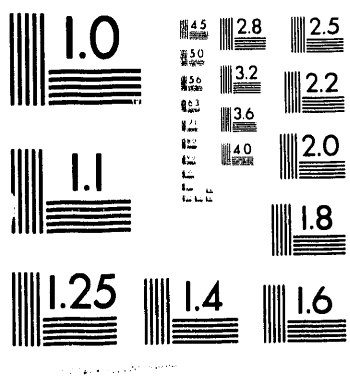
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TFTR DT Preparation Project Status

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ABSTRACT

The Tokamak Fusion Test Reactor (TFTR) research program is preparing to commence the first high power Deuterium-Tritium (DT) experiments of the U.S. Fusion Program. Hardware upgrades to TFTR required for DT operations have been completed. This paper discusses these hardware preparations.

INTRODUCTION

The objective of the DT Preparation Project on the Tokamak Fusion Test Reactor (TFTR) has been to provide the capability required to perform a sequence of deuterium-tritium experiments in a manner which is consistent with DOE orders and the Environmental, Safety and Health requirements of DOE and PPPL. These experiments will include the study of confinement and heating of DT plasmas, determining the effects of alpha particles, demonstration of DT technical capability and the demonstration of DT power production. The TFTR Research Plan summarizing these activities is shown in figure 1.

TRITIUM SYSTEMS

A significant portion of the work involved in this project related to the ability to provide full tritium handling capability to TFTR. This included the commissioning of the tritium handling equipment, upgrading the HVAC systems for tritium containment, the safety analysis and documentation necessary to implement tritium operations on TFTR, the training of tritium operators and the tritium monitoring capability for tritium operations.

In order to accomplish the goal of full tritium handling capability for TFTR several tritium systems have been employed. First, there is the Tritium Storage and Delivery System (TSDS), which receives, stores and delivers tritium to the the injection systems (torus gas injection and neutral beam gas injection). Secondly, the three Tritium Cleanup Systems which remove the tritium by oxidation from the various streams or room air: the Torus Cleanup System (TCS), the Tritium Storage and Delivery Cleanup System (TSDCS) and the Tritium Vault Cleanup System (TVCS). And finally, the Tritium Regeneration System (TRS) which regenerates the cleanup system drier beds and deposits the oxidized tritium on molecular sieve beds in shipping containers.

The TSDS is now fully operational. Deuterium, which behaves as tritium except for its radioactive properties, has been used as its transfer and performance testing medium. The TRS, TCS, TVCS and TSDCS are also fully operational. Final performance testing with trace tritium has been performed, confirming that the design requirements have been met.

The area and stack monitoring systems are also fully operational. They are used to detect any tritium that may be released to the atmosphere, either into a room or into the environment.

TRITIUM DELIVERY SYSTEMS

The delivery of tritium from the tritium vault systems to the tokamak involves two systems, the Torus Gas Injection System (TGIS) and the Neutral Beam Gas Injection System (NBGIS). These systems are now fully operational.

The scope of work for the Torus Gas Injection Systems included the modifications necessary for DT operations to the Torus Vacuum Pumping System (TVPS), the Non-Tritium Gas Injection System (NTGIS), the Glow Discharge System (GDC), and the Residual Gas Analyzer (RGA).

The modification of the Neutral Beam Gas Injection System concentrated on minimizing the amount of tritium required for each pulse, adding the required double containment and tritium compatible components. The feeding of tritium and deuterium gas to the sources is done downstream of the grids. This allows the tritium to be fed at ground potential through a stainless steel tube that does not pass through the SF6 surrounding the source.

The redesign of the existing Deuterium Pellet Injector (DPI) to a high speed Tritium Pellet Injector (TPI) was a task which was being done jointly with ORNL. Unfortunately this effort had to be suspended due to funding constraints and the injector will be used only as a deuterium injector during the DT experiments.

NEUTRAL BEAM MODIFICATIONS

Aside from the neutral beam gas injection modifications discussed above, the major task for the neutral beams was to develop a cryogenic cold trap to prevent halogens, such as the SF6 used for the neutral beams and the ICRF transmission lines, from contaminating the tritium recovery system during beamline regeneration. Tests at Los Alamos on the effects of various quantities of SF6 on the tritium cleanup system catalytic beds, however, proved that the cold trap was not required and the system was dropped from the project.

Several modifications to neutral beam auxiliary systems were necessary to accommodate the nuclear

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environment of the Test Cell. Modifications were required to the deuterium and auxiliary gas systems, the helium gas system (for cryopanel regeneration), the SF6 system, the cryogenic system and the beamline water system. All gas bottles and control electronics which require personnel interface have been relocated to the Test Cell Basement. Dose measurements during the last TFTR run period proved that the liquid helium refrigeration control station did not need to be relocated to the TFTR control room as originally thought.

The problems which were addressed for the neutral beam water systems were twofold. First, a water stoppage, although of low probability, has the consequence of extensive damage to beamline components. Restarting water flow within one hour is required to prevent frozen and possibly ruptured water lines. More reliable flow switches and remotely operated control valves were installed to ensure that the restarting of water flow occurs in a timely fashion. The second problem involved the removal of water from a beamline should an internal water leak occur. Piping has been added to allow the draining of potentially tritiated water into containers rather than into the floor drains as has been done in the past.

In the area of Neutral beam instrumentation there were several upgrades performed. First there was the installation of a remote Programmable Logic Controller (PLC) to control the air operated water loop solenoids. Next there was the upgrade of an existing PLC from an Allen Bradley PLC2 to an Allen Bradley PLC5 since more memory is required for DT operations. Finally, aremote PLC in the Cryogenic Compressor room, along with TV cameras for general area monitoring, were installed so that cryogenic compressor operations could be monitored from the operating station.

Finally, as part of the beamline upgrade, th3e replacement of all existing elastomer seals with either a metallic seal or by a differentially pumped pair of elastomer seals was investigated. These seals were reviewed for failure modes and compliance with TFTR safety requirements. The existing metal seals were found to be adequate, while radiation tests (at Henry Diamond Lab) conducted on similar O-ring seal material showed no significant degradation in their vacuum retention characteristics. By analysis, tritium permeation rates through the O-rings were within aceptable levels. Laboratory modeling experiments with pressure rise in a vacuum enclosure due to cryogenic failure showed that overpressure levels were low enough that the Neutral Beam enclosure lid would retain its vacum integrity. The overall assessment based on these investigations indicated that upgrade of the Neutral Beam seals was not required.

TOKAMAK/FACILITY MODIFICATIONS

Decon Facility

Fluorinert

TF coil case bolt tightening

Buswork

One area of work involved the sealing of over 2000 wall and floor penetrations in the Test Cell, Test Cell Basement and Tritium areas. This sealing is required for various combinations of fire seals, gas seals and radiation shielding, depending on the location and size of the penetration. In addition, a one foot thick shielding wall along the north side of the Test Cell has been installed to permit a greater number of shots without exceeding the boundary limit.

Another major facility activity was the seismic verification of systems within the Test Cell, Test Cell Basement, Tritium Areas and Mechanical Equipment Room. This task was performed by having an company which is recognized as an expert in this field evaluate the seismic adequacy of systems and components in these areas.Modifications were then made as required so that a letter of seismic verification could be issued by this company.

DIAGNOSTICS

The scope of work for the diagnostic systems included the installation of a new diagnostic, the Alpha Particle CHERS diagnostic. The Alpha Particle CHERS diagnostic is designed for the measurement of the thermalizing confined alpha particles. This instrument was developed in collaboration with the University of Wisconsin.

Another new diagnostic, the Gyrotron Scattering diagnostic, was being developed in collaboration with MIT for the measurement of the energy distribution of the confined high energy fusion-generated alpha particles. Unfortunately, budgetary and technical difficulties forced the cancellation of this effort.

• **Thomson Scattering** - There were two important upgrades to this system. The first involved shielding of the CCD detectors in the Test Cell Basement. Based on noise levels observed in DD operation and shielding calculations, a shield consisting of an inner shield of 10 cm of lead and an outer shield of 10 cm of borated polyethylene was installed around the spectrometer/detectors. In addition, the drive for the internal cover plates which protect the vacuum window from coating was modified to provide for remote operation. Previously, moving these cover plates required personnel access directly beneath the vacuum vessel.

• **Vacuum Vessel Illumination/Inspection** - This system was completely changed in preparation for DT operation. In place of the previously used, long bellows probe drives, three fixed illumination systems were installed following successful prototype testing during the '91-'92 run. Each illuminator in the DT configuration uses four 250 watt quartz halogen bulbs operated in pairs. They are located at the top of the machine at a minor radius

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location corresponding to that of the main vacuum vessel. Each has an integral shutter to protect it during plasma operation. In addition, to increase the dynamic range of the torus inspection system, cooled integrating cameras were added prior to the DT run to allow inspection of dimly lit areas by using long exposure times for the cameras.

• **Alpha Charge Exchange** - During testing of this relatively new diagnostic at the end of the '91-'92 run, significant noise contributions from neutrons and gammas as well as visible light were observed. There were effects in both the scintillators and the photomultipliers. Based on these noise sensitivity measurements, a shield consisting of an inner shield of 10 cm of lead surrounded by 10 cm of borated polyethylene was added to shield the scintillators. In addition, the photomultipliers were moved to a more shielded location in the Test Cell Basement and coupled to the scintillators with optical fibers. There is currently an effort to shield these fibers as well. The interior of the analyser was also blackened to reduce the visible light contribution.

• **Alpha Particle CHERS** - Even though this diagnostic was located 25 meters from the plasma with over a meter of concrete shielding it, gamma induced noise measured in the cooled CCD detectors during the DD phase indicated that without additional shielding, there would be significant radiation induced noise problems during DT. Thus, it was relocated to a position with more concrete between it and the plasma. It was also shielded with 10 cm of lead inside 10 cm of borated polyethylene.

• **Neutron Calibration** - Extensive calibration of the neutron systems were performed before the start of the '93 run. This involved several spatial scans of a Cf source and a DT generator (14 Mev source) around the inside of the vacuum vessel. Prior to this in vessel calibration, extensive lab work was needed to characterize the directionality and stability of the generator. As a result of these efforts, there are now three independently calibrated instruments with the following absolute accuracies:

system absolute accuracy	detector type
epithermal neutron detectors ± 15%	U^{235} fission
neutron collimator ± 20%	ZnS:Ag scintillators
neutron activation ± 10%	transportable foils

• **Escaping Alpha** - This system has undergone extensive modification since the '91-'92 run. The CCD cameras and photomultiplier detectors for this system were moved from an unshielded location in the Test Cell Basement into a prexisting shield structure which formerly shielded an array of X-ray PHA systems that were removed since it was clear they would not work during DT. This shield consists of 10 cm of lead and 20 cm of borated polyethylene. In addition, the scintillators in the four probes were changed from P31 (ZnS:Cu) which would saturate in DT to lower sensitivity P46 ($Y_3Al_5O_{12}$:Ce). The coherent fiber optic bundles relaying the scintillator image to the detectors were changed from plastic to quartz to minimize radiation induced effects in the fibers. Even so, a reference loop of identical fiber was inserted along the same path as the bundles and will be used with a chopped light source to evaluate transient opacity in the fibers. Fiber flourescence is also a serious problem, particularly in evaluating DD data with the new low sensitivity P46 scintillators. Effort is now underway to shield the ~ 1 meter of bundle between the bottom of the vacuum vessel and the thick floor under TFTR. This shield will consist of castings of lead shot, boron frit, and epoxy providing a 15 cm thick inner shield surrounded by 5 cm of borated polyethylene.

• **Neutron Collimator** - New 14 Mev neutron detectors were installed with associated electronics. The old detectors were NE 451 ZnS:Ag plastic scintillators. The new scintillators are custom made of the same material but of smaller volume to reduce sensitivity. They will be cross calibrated to the NE 451 detectors.

• **Neutron Activation System** - Modifications to this system centered primarily around the need to avoid activated air from being transported back through the pneumatic foil transport system into uncontrolled areas. This involved plumbing modifications along with software modifications to vent the activated air in the Test Cell after each shot before the foil is transported back to the area where the foils are analysed. In addition, photodiode sensors in the transport lines near the machine were replaced with sensors with remote illumination source and detectors coupled via fiber optics to the pneumatic lines near the machine.

The balance of the scope of work for the diagnostics involved the shielding of detectors and electronics as well as the remote operation of some aspects of other diagnostics.

SUMMARY

TFTR has moved rapidly toward performing Deuterium-Tritium (DT) experiments. A demonstration of tritium handling capabilities within the tritium vault has been successfully completed with trace tritium and the performance of similar trace tritium exercises involving the movement of tritium to the TFTR neutral beam lines and vacuum vessel should begin in the very near future. Once these have been completed TFTR will request permission from the Department of Energy to proceed with full DT operations.

This work has been performed under Department of Energy contract No. DE-AC02-76CH03073.

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5. "Design of the TFTR Coil Alternate Coolant System," G. R. Walton et al.

6. "Modification and Final Alignment of the TFTR Bumper Limiter," G. D. Loesser et al.

7. "Installation of Decon Facility in Preparation for TFTR D-T Operations," J. H. Chrzanowski et al.

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12/14/93

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