Conf-910968-31

THE TFTR RF LIMITER UPGRADE DESIGN
AND INSTALLATION
G. W. Barnes, H. M. Fan, and M. Ulrickson
Princeton University, Plasma Physics Laboratory,
PO Box 451, Princeton, NJ 08543

ABSTRACT

The RF Limiters originally installed at Bays K-L and N-O[1] were upgraded to a new configuration and six new limiters of similar design were added. The RF Limiter upgrade protects the (2) existing RF Launchers and with a minor addition will protect the (2) RF Launchers to be installed in FY92 and will permit 50 Megawatts of auxiliary input power for two seconds during plasma operation. Each of the new RF Limiters are comprised of 18 tiles for a total of 108. The design provides for revised and strengthened supporting mounts because of additional forces induced in the tiles. Tile material is a 2D carbon-carbon composite identical to the original tile material. The channel shaped tile is geometrically the same as the original design. Subassembly of the panels took place outside the vessel in order to minimize exposure levels to the workers. Tooling was designed to replicate the vessel hardpoints and ease the subassembly tasks. Installation of the entire system occurred during the FY 91 opening. Integrated into the design are provisions to eliminate plasma damage to the insulators at the mounts. Detail design philosophy and an overview of the project are addressed by this paper.

GENERAL ARRANGEMENT

The "RF Limiters" are poloidal limiters which are located toroidally about the inside of TFTR approximately equally spaced about the vessel. The RF Limiters are located at toroidal position 9° (A-B), 63° (D-E), 117° (G-H), 153° (I-J), 189° (K-L), 243° (N-O), 279° (P-Q), and 315° (R-S) where the centerline of Bay A is at 0°. Ideally the limiters would be equally spaced however geometry constraints did not allow for this ideal configuration.

Each new limiter is made up of 18 carbon-carbon channel shaped tiles with 9 tiles above and 9 tiles below the vessel midplane. The outer midplane at each ring is not tiled through an included angle of $\pm 30^\circ$ except at locations 189° and 243°. The 189° and 243° locations are fully tiled (24) because of the close proximity of the RF Launchers at Bays L and M.

Each tile spans 10° in the poloidal direction so that a new Limiter ring of 9 tiles above or below midplane has a poloidal extent of 90° . Rings start at the interface of the Bumper Limiter at $\pm 60^\circ$ on the inner wall and terminate on the outer wall with either a protective plate or a large bellows cover plate at $\pm 30^\circ$ above or below the vessel midplane. Special considerations had to be given to the design at toroidal position 63° (D-E) because it is a stiffening ring rather than a vacuum bellows and the mounting surface for the clips did not exist and thus had to be designed and erected. Closure tiles were added at the outer end of all rings to protect the Vacuum Vessel bellows and internal mounting hardware from plasma strikes.

The RF Limiters at location 189° and 243° were installed during the Vessel opening in 1988 [1]. During plasma operation the tile segments translated and rotated on their support mounts. It was observed that the mounts required fixed supports at the vessel interface to prevent movement of the tiles. The tile supports were redesigned to prevent this motion and is one of the subjects of this paper. It was also observed that the Limiters of this early configuration were getting higher heat loads than anticipated. It was shown that the high heat loads could be minimized by sharing the heat with more rings and thus optimize the heat sharing between rings.

In addition, the mica-mat di-electric sheets were externally mounted and faced the plasma at the tile interface. Some of these were found to be severely damaged from the heat, however their di-electric capabilities were intact.

With this knowledge of how the design behaved during plasma operation a conceptual design was proposed that would add six rings of RF Limiters, to prevent excessive movement of the tiles, and protect the mica-mat di-electric from plasma strikes.

THE DESIGN

The previous mounts were supported directly off the vacuum vessel wall. In order to prevent the excessive movement of the tiles the mounts were located to either

PPPL-CFP--2470

DE92 001836

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

MASTER

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

• a Surface Pumping Panel (SPP) or a Bellows Cover Plate (BCP) and the effective spring rates increased. This was permitted by extensive engineering analysis of the effect of tile support stiffness on Limiter tile stresses. The primary support clips were welded to the BCP and mechanically fastened to the SPP. These supports were designed as moment connections. In order to prevent Eddy current loops one side of this mount was insulated while the other was grounded to the vessel. See Figure 1.

Figure 1. Typical RF Limiter Tile Mounting Arrangement

The mica mat di-electric was well protected from the plasma. Tile attachment to the supports was with the use of floating type self locking anchor nuts riveted to the support clips. External spherical washers compensated for angular misalignments up to 5° of the tile legs with respect to the plasma contoured surface.

Materials for the mounting clips was Inconel 625 because of its high structural strength after welding. The mechanical fasteners were made out of A-286 Stainless Steel. A-286 was selected for its high strength and high temperature characteristics. Rivets and floating anchor nuts were also A-286 material for the same reasons. Spherical washers were fabricated from Inconel 625.

All of the metallic material was tested for magnetic permeability prior to machining, after machining and after welding. Magnetic permeability was specified at not greater than 1.02 for raw material, 1.05 for machined parts, and 1.2 for welded joints. All of the material met these requirements.

Tile material selected was a 2D Carbon-Carbon fiber composite manufactured by BFG, Santa Ana, CA. Carbon-Carbon composite was selected for its excellent strength characteristics, low coefficient of expansion, and capability to withstand temperatures in excess of 2400°C. The tiles were identical in shape to the existing tiles at 189° and 243°. This existing tile configuration was channel shaped .40 inches constant thickness through web and legs, 21.30 inches wide from outer leg to outer leg. Leg lengths varied from 3.2 inches to 5.1 inches depending on tile location in the vessel. The leg length of the raw billet was 7.00 inches and each tile was final machined and drilled after tile fabrication. Each tile was serialized during the manufacturing process for identification and traceability.

Vacuum bakeout of the tiles after final machining was a necessary part of the design process. All 108 tiles were baked out in one lot. Test coupons to verify oven cleanliness were examined for impurities prior to the actual tile bakeout run. After the test coupon run the oven was not allowed for use by others until coupon evaluation was completed and the actual tile bakeout initiated and completed satisfactorily. Bakeout of the tiles was specified for 1150°C for 8 hours at 2×10^{-5} torr. The vendor selected for this task was Solar Atmospheres, Souderton, PA.

THE SUBASSEMBLY

The subassembly of the tiles with its support frames was accomplished outside the vessel rather than in-situ. The reason for making maximum use of subassembly work outside the vessel was to minimize worker exposure and abide by the ALARA (As Low As Reasonably Achievable) concept for radiation workers. A radiation work area was constructed in the test cell in order to proceed with the subassembly tasks. This area was large enough to work on four sub-assemblies at any one time. Four fixtures allowed for two Bays worth of assemblies. The tooling fixtures were designed to be universal such that they would account for geometry differences in the various bays. See Figure 2.

The activated and contaminated panels were removed from the vessel and installed on the fixtures. The panels could then be worked on by a team of technicians

for the rework. Panels had to be cut, welded and ground flush at the faying surface of the clips.

The tiles were then prelocated on the panels by utilizing C-Clamps in order to locate the mounting clips to the panels. Tiles were measured to ensure that they met the plasma radius of 99cm. This radius was not concentric with the vessel radius and each tile position was unique from its neighbor. Once the holes were spotted, they were drilled. The SPP rails are Inconel X750 and thus the drilling operation was difficult. Special drilling fixtures were used for the drilling operation. The BCP utilized welded clips to the BCP slats. Premachined seats in the slats aided the tile position however some shimming was allowed for in the clip seat to allow for differences in the BCP locations in the vessel. The tiles were re-assembled to the panels and rechecked for plasma radius.

Figure 2. Tile Sub-Assembly Area

After the tiles were installed on the panels, the entire panel assembly was checked for possible eddy current loops. After the panels were successfully checked the tiles were removed from the panel and prepared for installation in the vessel

THE INSTALLATION

The panels were transported from the radiation work area to the machine, hoisted up to the vessel platform and positioned in the vessel. Vessel mounting and torquing of the hardware was accomplished and tile installation on the panels completed. Tiles near the upper Bumper Limiter required a custom fit due to the presence of Bumper Limiter water lines. Interfaces with the protective plates and bellows cover plates were established and the closure pieces trimmed to fit. At this point the RF Limiter was remeasured for the plasma radius utilizing the mechanical measuring arm [2]. The 99cm radius was verified and the actual measurement came out to ± 2 mm which was within the physics tolerance band.

CONCLUSIONS

The RF Limiters Upgrade was one of the largest tasks of in-vessel design and installation for TFTR. Many subcontracts were executed in order to coincide with the Fall 90 opening. However despite the enormity of this installation the job was completed and the true test will be the performance of TFTR during the coming run period.

The next vessel opening in the fall of 91 will require two more RF Launchers installed in TFTR at Bats K and N. These launchers will also need protection from plasma strikes and therefore one more RF Limiter ring of six tiles will be added to the vessel at 171° (J-K).

[1] G.W. Labik et al, "TFTR Carbon-Carbon Composite RF Limiters Design, Selection, Fabrication, and Installation" presented at the 13th IEEE Symposium on Fusion Engineering, Knoxville, TN, October 2, 1989

[2] G.D. Loesser et al, "Five degree of freedom measuring arm for resolving spatial relationships within TFTR vacuum vessel" presented at the 14th IEEE Symposium on Fusion Engineering, San Diego, CA, September 30, 1991

END

**DATE
FILMED**

12102191