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**Transport Analysis of TFTR
Experiments Final Report**

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Transport Analysis of TFTR Experiments

Introduction

The purpose of this investigation was to complete the analysis of TFTR data which was under progress. The main emphasis was to study the effects of heating profile and resulting density and temperature profiles on transport through the comparison between beam heated plasmas with hollow and centrally peaked heating profiles (edge vs. center heating). The analysis has been completed and a manuscript has been prepared for publication in Nuclear Fusion.

A proposal to perform a similar experiment using ICRF heating to decouple heating profile effects from density profile effects was submitted and was approved by the TFTR. ICRF heating enables the heating profile and the power partition between ions and electrons to be controlled. The experiment was scheduled twice, but it had to be postponed both times.

The main collaborators were R. Goldston, D. McCune, M. Zarnstorff, G. Hammett, and S. Scott of the TFTR Group.

Data Analysis of the Neutral Beam Edge vs. Center Experiment

The objective of this investigation was to carry out a more detailed analysis of the edge vs. center heating data than what was reported in past conference proceedings.¹⁻⁴ The main analysis tool used in this work was TRANSP, used in both analysis and predictive modes. In addition, various other techniques were used to study sawtooth, heat pulse propagation, and angular momentum transport. The analysis methods and the results of these analyses are detailed in the manuscript⁵ entitled "Effects of Heating Profile on Energy Transport in Neutral Beam Heated TFTR Plasmas" which has been prepared for

publication in Nuclear Fusion. Recent analysis results have also been and will be reported in conference papers.^{6,7}

The main highlights of the analyses carried out under this contract are summarized below:

- Both the ion temperature profile and the density profile were altered substantially by controlling the beam heating profile (centrally peaked vs. hollow heating profile), but little change was observed on the electron temperature profile.
- The lengthening of the sawtooth period correlated with the reduction of toroidal loop voltage inside the $q = 1$ surface.
- The electron thermal diffusivity obtained from the heat pulse propagation time-to-peak analysis was significantly larger than the diffusivity obtained from a power balance analysis. The heat pulse propagation diffusivity showed a decreasing trend with density in the low density unsaturated ohmic confinement regime but became independent of density at higher densities. The heat pulse propagation diffusivity was relatively insensitive to the form of heating (ohmic, center heating, edge heating) at both high and low densities.
- Generally, the magnitude and profile shape of the angular momentum diffusivity $\chi_\phi(r)$ and the ion thermal diffusivity $\chi_i(r)$ are similar. The profile shape of the electron thermal diffusivity $\chi_e(r)$ is also similar to $\chi_i(r)$, especially in center heated plasmas. For center heating both χ_ϕ and χ_i are enhanced over their ohmic values across the whole profile, but for edge heating they are enhanced only in the outer half radius where the beam power is deposited. In all cases the change in χ_e is smaller than the change in χ_i . Except in low density ohmic plasmas, χ_i is larger than χ_e in magnitude.
- The profile of $\eta_{i,e} \equiv d \ln T_i / d \ln n_e$ corresponding to the measured ion temperature and electron density profiles is slightly above the threshold value for ion temperature gradient (ITG) driven instability in the confinement region, but the ion temperature

profile shape is not close to the marginally stable profile in the edge region or within the $q = 1$ surface where other mechanisms are expected to play a more important role than the ITG mode turbulence.

- The evolution of the angular momentum profile for the low density edge heating case was consistent with the angular momentum transport being predominantly diffusive.

ICRF Edge vs. Center Heating Experiment

A TFTR experimental proposal entitled "Edge vs. Central ICRF Heating" (XP 227)⁸ was submitted as a proposal from the Transport Task Force, and was approved by the TFTR Task Force Council. A bounce-averaged Fokker-Planck code coupled with a full-wave code (FPPRF/SPRUCE) was used to predict the power deposition profile and the power partition between electrons and ions. The power deposition profile can be controlled by the location of the minority ion resonance layer in the plasma (which is controlled by the magnetic field for fixed transmitter frequency). The power partition between ions and electrons is controlled by the minority concentration or the density, which determines how energetic the minority ion distribution function can get for a given input power. It is more desirable to change the density at fixed density to control the power partition. Although the experiment was scheduled twice, it had to be delayed both times due to technical difficulties with the tokamak and scheduling difficulties of ICRF personnel to operate the RF system.

Summary

The investigation has been completed successfully. The results of the analyses performed on the neutral beam edge vs. center heating experiment have been documented in the manuscript⁵ entitled "Effects of Heating Profile on Energy Transport in Neutral Beam Heated TFTR Plasmas," which will be submitted for publication in Nuclear Fusion.

The ICRF edge vs. center heating (and electron vs. ion heating) experiment was proposed and was accepted. However, the actual experiment had to be postponed due to technical difficulties on part of the TFTR Group which was not under our control. Discussions on analysis methods and interpretation of data have been productive and useful for both MIT and PPPL personnel.

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