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Review of Recent D-T Experiments from TFTR*

The TFTR Group presented by R.J. Hawryluk
Princeton Plasma Physics Laboratory, Princeton, NJ, USA

The TFTR device has begun an extensive series of deuterium-tritium (D-T) experiments. The initial high power deuterium-tritium experiments were performed in December 1993 by injecting 29.5 MW of neutral beams into discharges with $I_p = 2$ MA. The maximum fusion power obtained was 6.2 MW. The observed neutron flux was in good agreement with the calculated value based on the electron and ion temperature and density profiles. The loss of alpha particles was consistent with calculations of first orbit loss. In these high power D-T experiments, collective instabilities induced by the presence of alpha particles were not observed as expected from theoretical analysis using the measured plasma profile. The stored plasma energy, electron and ion temperature increased in deuterium-tritium plasmas compared with similar deuterium plasmas, corresponding to an increase in τ_E from 150 ms to 180 ms and in the parameter $n_i(0) \tau_E T_i(0)$ from 2.4×10^{20} to $3.8 \times 10^{20} \text{ m}^{-3} \cdot \text{s} \cdot \text{keV}$. For $r/a < 0.5$, the deduced ion thermal diffusivity is a factor of ~ 1.5 lower in the D-T plasma compared to the D plasma used as a baseline for the discharges shown in Fig. 1. This suggests a strong sensitivity of ion heat conduction to isotopic composition in supershot plasmas. The observed increase in electron temperature appears to be due to a combination of alpha heating as well as isotopic effects. The energy confinement time in these supershot discharges increases with the mass of the hydrogenic species as shown in Fig. 2.

A regime of enhanced confinement, with higher values of β_N than those in supershots, has been obtained in TFTR by tailoring the current profile using current rampdown. High values of β_N and τ_E/τ_E^L has been obtained in deuterium and deuterium-tritium experiments. In 1.2 MA discharges, values of β_N of 2.7 and fusion power of 4.2 MW have been achieved with 23 MW of neutral beam power. This fusion power is comparable to that obtained in supershot experiments at 1.8 MA. In these current rampdown experiments, a transition to a limiter H-mode occurred in both deuterium and deuterium-tritium experiments. However, the improvement in the value of confinement time was substantially greater in the deuterium-tritium discharge and values of τ_E/τ_E^L -mode > 4 were achieved.

In addition to neutral beam heated discharges, experiments have been performed utilizing ICRF heating together with neutral beam injection in deuterium-tritium plasmas. The initial experiments have focused on the RF physics associated with a deuterium-tritium plasmas. Second harmonic tritium heating with ~ 6 MW has resulted in increasing the ion temperature from 26 to 35 keV. The electron temperature increased from 8 to 10 keV due to direct electron damping as well as ^3He minority heating.

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*Work supported by U.S. DOE Contract No. DE-AC02-76-CHO-3073

To study differences in particle transport between deuterium and tritium, experiments were performed with small quantities of tritium prior to the walls becoming loaded with tritium. The initial series of experiments entailed the use of trace tritium concentration ($\leq 2\%$) or tritium gas puffing into a deuterium beam heated discharge. These experiments showed relatively rapid radial tritium transport such that $\tau_p \sim \tau_E$ and that the tritium particle transport coefficients are comparable to He particle transport coefficients in similar plasma.

The experimental physics program on TFTR will continue to concentrate on the study of alpha-particle physics and transport in deuterium-tritium plasmas. Fusion power optimization will be performed using Li pellet conditioning which has been demonstrated to increase the energy confinement time in supershots and high- β_p plasmas, increasing the neutral beam power and combining high power NBI with ICRF. The studies of confinement in D-T plasmas will be extended to different operating regimes to further document the isotope effect and alpha heating. The confinement and stability of alpha particles will be studied in operating ranges for which the collective instability threshold is predicted to be exceeded. The RF physics of a D-T plasma will be explored to provide the technical information for the design of the ITER and the TPX devices.

Figure 1.
Charge exchange spectroscopy measurements of the ion temperature profile in a D-T discharge (solid curve) compared with a D-D discharge (dashed curve).

Figure 2
Energy confinement time improves as the average ion mass is changed going from deuterium to tritium plasmas.

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