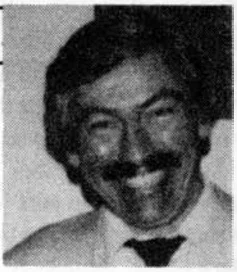
Interview: Dr. Dale Meade

Results that are exceeding the original TFTR design



Dr. Dale Meade is in charge of experiments on the Tokamak Fusion Test Reactor (TFTR) at the Princeton Plasma Physics Laboratory. He put the latest achievements of the TFTR in perspective in this Aug. 15 telephone interview with David Cherry of the Fusion Energy Foundation, for EIR.

EIR: The TFTR has set two new records that bring us closer to fusion as a practical energy source. What are they?
Meade: In mid-July we set a world record for the highest temperature achieved in a laboratory, 18-20 kiloelectron volts of ion temperature,* that is, roughly 200 million degrees Celsius. This is comfortably within the range in which a working fusion reactor will function, but achieved at a lower density than will be required.

In March, the TFTR set a new record for the Lawson product, $n\tau$, or quality of confinement. It is the product of density and confinement time. By enriching the fuel, with fuel pellet injection, and doing this at high plasma density, we achieved an $n\tau$ of 1.5×10^{14} nuclei-seconds per cubic centimeter. Our pellet injectors were developed at the Oak Ridge National Laboratory. The density itself was 3×10^{14} nuclei per cubic centimeter, confinement time was .5 seconds, and temperature was 1.2 kiloelectron volts. If our high temperature and $n\tau$ achievements can be combined, we will easily have break-even, where the power produced equals the power required to heat the plasma. Putting it another way, the ratio Q of power produced to power required equals 1 (Q or quality factor = 1). That is beyond the original TFTR design.

EIR: This is being done with deuterium alone?
Meade: Yes. These are D-D reactions. The combination of deuterium and tritium (D-T) is two hundred times more reactive. When we started our tokamak work in 1974, we had rather modest objectives. For example in 1976, people said we should produce 1-10 megajoules of fusion energy per pulse with temperatures of 5-10 kiloelectron volts and $n\tau$ of 10^{13}. Part of the significance of these latest results with deuterium plasmas is this: We believe that if we put tritium in now, we'd achieve the original objectives for the TFTR.

After 1976, we boosted the objectives. By 1979, we were saying the TFTR should reach real break-even. In the coming year, with deuterium plasmas, we expect to achieve the conditions for break-even once tritium is introduced.

EIR: How will that be done?
Meade: One-third to one half of the reactions are going to come from neutral beam ions hitting tritons [tritium nuclei]. To get break-even utilizing these beam-target reactions, you need 15-20 kiloelectron volts and $n\tau$ of $2\text{-}3 \times 10^{13}$. That's twice the $n\tau$ we now have at this temperature. Without these neutral beams of deuterium, we'd need $n\tau$ of 6×10^{13}. In 1983, the Alcator C got $n\tau$ of 6×10^{13}, without beams.

At present, the TFTR with tritium would produce a Q of 0.25. Within the next year, the four neutral beam heaters will go from half to full power, and we'll get longer pulses, pulses of two seconds instead of typically one-half second. Q will go to 0.5 as a result.

To get $Q = 1$, we face the following problem. We use the injection of fuel pellets to get high $n\tau$. The pellets will penetrate a dense plasma, *but not above a certain temperature*. We use neutral beams, beams of deuterium atoms, trained into the plasma to heat it, but neutral beams *will not penetrate a sufficiently dense plasma*.

EIR: So, it is the horns of a dilemma.
Meade: Yet, we must approach the objective from both directions. For the high temperature regime, we will perhaps improve the density with the injection of smaller fuel pellets. Working from the high density regime where we have a high $n\tau$, the ion cyclotron range of frequencies [ICRF, one form of radio frequency heating—ed.] becomes useful for increasing the temperature. We will be depositing 5 megawatts of ICRF right in the center of the plasma column. Neutral beams do not reach the center of the plasma.

Coming back to the latest results on the TFTR. The common thread in these two regimes—the very dense and the not so dense—is that they both have sharply peaked density profiles along the diameter of the plasma column. We weren't able to get high temperatures until we learned to get peaked profiles using only neutral beam heating. Now, we get them with neutral beams or pellet injection right to the center.

The new high-temperature results over the past two months

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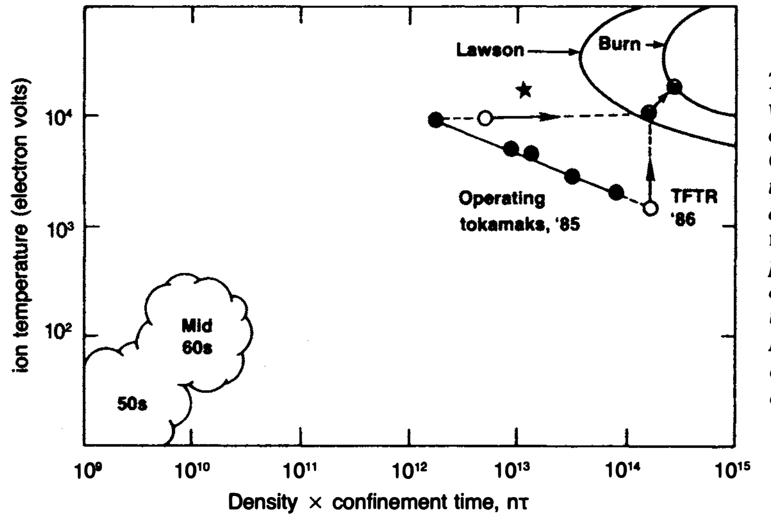
* The electron volt is the standard for measuring the temperature of both electrons and ions; one kiloelectron volt is 1,000 electron volts.

FIGURE 1

Progress in tokamak confinement



The new, mid-July high-temperature achievement is shown with a star. The latest achievements of Princeton's TFTR as of two months ago were represented by the two open dots. On the x-axis is the combined density and confinement time, the product $n\tau$*, where* n *is the nuclei per cubic centimeter and* τ *is confinement time in seconds. For fusion breakeven,* $n\tau$ *must be* 3×10^{13} *or better, as shown. Ion temperature is plotted on the y-axis in electron volts: breakeven requires 8,000 electron volts or better. Breakeven will occur in the upper right-hand region marked Lawson (fulfillment of the Lawson criteria). Arrows from the open circles point to convergence on this region. Self-sustaining fusion will occur in the region marked burn.*

have been achieved by first firing many shots at low density to clean impurities from the machine and condition the interior of the chamber. Then, we would get one good shot. Again, many shots at low density, then three good shots. Then, after the same routine, 10 good shots.

Concerning our March results in the high-density regime, density and temperature are now so good that hydrogenic bremsstrahlung accounts for 20% of energy loss at the center—it used to be negligible.

EIR: By that you mean that results are so good that the amount of energy being lost by radiation has now assumed significance, where previously it was a negligible proportion of the general energy losses?
Meade: Precisely.

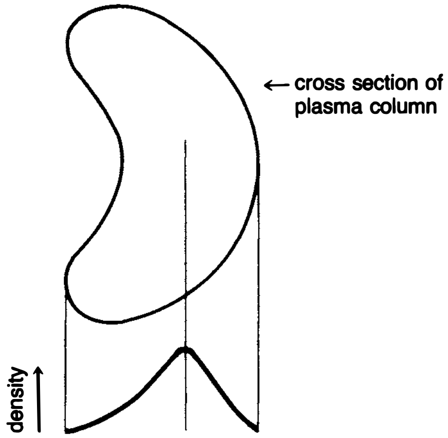
EIR: What is being accomplished with Princeton's other tokamaks?
Meade: The TFTR is on the main line of tokamak development. The Princeton Large Torus (PLT) and Princeton Beta Experiment (PBX), like the Doublet III in San Diego, are on the advanced tokamak line. The PBX is investigating ways of shaping the cross-section of the plasma column to achieve β [confinement quality] of 10%. The PBX has already achieved 5%. It is now being modified—it will be PBX-M—in order to achieve a theoretical β of 20%, but practically, the objective is 10%. PBX-M will start operation in April 1987.

The PLT is working on techniques for radio frequency heating to achieve steady-state operation, instead of pulses. It is achieving 5 kiloelectron volts of electron temperature now, using lower hybrid-current-drive of 2.5 gigaherz. Lower hybrid means intermediate in frequency between electron cyclotron and ion cyclotron frequencies. In the heating of ions, we have traditionally used ion cyclotron waves. Now, we are heating with Bernstein waves—the 5th, 6th or 7th harmonics of ion cyclotron waves, and looking at other forms of radio frequency current drive.

The PLT will shut down at the end of September, 1986. If we had the money, it would not!

FIGURE 2

Peaked plasma density



The highest temperatures are now being achieved in plasmas in which the center of the plasma column is very dense, with sharply decreasing density toward the circumference. (The curve shown is illustrative, not a laboratory result.)