MAGNETIC CONFINEMENT FUSION

Will the alphas abscend?

Richard D. Petrasco

WHEN Princeton University’s Tokamak Fusion Test Reactor (TFTR) began burning a 50:50 deuterium–tritium mix last December, a key question was what would become of the energetic alpha particles (helium nuclei) generated in the fusion reaction. For a future reactor, losses of even a few per cent of the energetic alphas could have serious consequences. With losses of more than 15 per cent, the temperature needed for fusion ignition, about 250 million kelvin, would be difficult to sustain unless the thermal confinement was good. And the heat load of even 5 per cent of these particles could damage the vessel walls, especially if the heating was unevenly distributed over the surface. With the completion of an extensive sequence of deuterium–tritium (D–T) experiments, including one in which a record 6.2 MW of fusion power was achieved, an international workshop* gave researchers the chance to consider what had been learned.

As I described in a News and Views report three years ago, when the first such workshop was held, future fusion reactors are expected to run on a 50:50 D–T mix, as D–T fusion has a much higher reaction rate and requires a far lower temperature than other fuel combinations. The TFTR experiments are the first to try this mix, although the Joint European Torus (JET) ran two discharges using 13 per cent tritium in November 1991, setting the previous record of 1.8 MW fusion power. The end product of the D–T reaction is a 14.1-MeV neutron and a 3.5-MeV α. The neutrons, unlike the α, are uncharged and therefore unconfined by the magnetic field of the tokamak (about 50 kG). In principle, these would be the heat source driving electric power generators.

When deuterium and tritium operations first started at TFTR, two scientific issues were paramount. First, would a large fraction of the αs unexpectedly abscend from the plasma without depositing their kinetic energy into the plasma? And second, would the plasma be able to store and retain its thermal energy as effectively as it did when running in pure deuterium? At TFTR, because fusion power was found to scale as the square of the stored plasma energy content, any diminution in the plasma’s ability to hold its thermal energy, the efficiency of which is measured by the energy confinement time $\tau_E$, would be directly reflected in a low level of fusion reactions.

Encouragingly, the main message from the TFTR workshop was that unexpected losses of energetic alphas did not occur, and $\tau_E$ actually improved by 20 per cent to 0.18 s (R. Hawryluk, Princeton Plasma Physics Laboratory (PPPL)). At present, the reasons for the improvement are not understood, but are being actively investigated (K. Itoh, National Institute for Fusion Science).

Figure 1 shows the fusion power generated when three different mixes of deuterium and tritium ions were injected into the plasma. These beam ions, with an energy of about 100 keV, both heat and fuse with the background plasma ions. In the top trace, representing 30 MW of beam power injected for 0.75 s, the fusion power was seen to peak at the new record of 6.2 MW. 0.4 s after beam heating was initiated (J. Strachan, PPPL). About 75 per cent of this power results from the heating beams fusing with background ions and with energetic, unthermalized ions originating from the beams. After the peak, the fusion power then smoothly declined by 30 per cent over the remaining duration of the beam heating (0.35 s). For other discharges (lower two traces of Fig. 1), the fractional de-


FIG. 1 Fusion power emitted from the burning of deuterium–tritium, for three discharges in which different proportions of tritium were injected via energetic heating beams into the plasma. Top trace, seven tritium sources (this set the record of 6.2 MW fusion power); middle, four sources; bottom, one source. NBI (neutral beam injection) indicates the duration of the heating beams. (From J. Strachan.)

FIG. 2 Imaging of the 14.1-MeV neutrons produced in deuterium–tritium fusion allows mapping of the inflow and transport of trace amounts of tritium, injected at time $t = 3.50$ s into a deuterium plasma. The transport of both tritium and deuterium is crucial to sustaining the fusion burn. (From L. Johnson.)
DAEDALUS

Dilute pleasure

Addictive drugs owe their market not to the pleasure of using them, but to the pain of giving them up. Their withdrawal symptoms are so unpleasant that addicts will commit any crime to get more drug. So Daedalus wants to alleviate withdrawal. He recalls the traditional French alcoholic, who sips wine all day and much of the night. His blood-alcohol never drops to zero, so he never has a sober moment. If cocaine and heroin could be sustained like this, instead of giving a brief rush of pleasure followed by hideous withdrawal pains, they would be less of a menace.

Many modern pharmaceuticals can be injected as a subcutaneous fatty 'depot', from which they leach out slowly into the patient's bloodstream. DREADCO's biochemists are now devising a blanket, rechargeable depot. It will act as an internal buffer for addictive drugs. Most of them, such as amphetamines, cocaine and heroin, are nitrogen bases; they can combine reversibly with acids. So the new drug buffer is an inert fatty polymer with many acidic groupings. It will seize any drug that gets into the user's bloodstream, and slowly release it again. This equilibrium will need careful tuning. The buffer must absorb drug from the blood in levels much above the desired value, and feed out again to stop the level dropping much below.

When perfected, DREADCO's 'Drugstat' will simply be injected into the addict — either as treatment or as part of the punishment for drug-related crime. His next dose will be a strangely muted experience. There will be no sudden rush of pleasure; as fast as he takes in the drug, the Drugstat depot inside him will seize it. The low equilibrium dose in his bloodstream will give him only a mild mental alleviation. Yet this alleviation will persist wonderfully. Drugstat will maintain the defined concentration in his blood, leaking out just enough drug to avoid withdrawal symptoms. Many days may pass before he has to repeat the dose.

Drugstat will calm the wild roller coaster of the addict's life. It will meter his drug so efficiently that he will need far less of it. His new mental stability may even let him hold down a job and buy his reduced dose without resorting to crime. Furthermore, the pallid, dilute pleasure of Drugstatted addiction will no longer antagonize the respectable masses. Their puritanical envy and outrage at people who get pleasure without working for it, is the basic reason why drugs are illegal in the first place. Once Drugstat is in wide use, public opinion may at last permit drugs to be legalized, thus solving the whole problem.

Richard D. Petraso is at the Plasma Fusion Center, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139, USA.