Magnetoreaction Confinement of Plasmas.

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Summary. – When energy is injected into a multicomponent magnetoplasma momentum balance may lead to the radial expulsion of one component and the simultaneous reaction confinement of the others.

It is useful to consider energy and momentum balance in a multicomponent magnetically confined plasma. Such a plasma might, for instance, consist of tritium, and deuterium ions, alpha-particle « ash », and electrons; all with different velocity distributions. When energy is injected (by RF fields for instance) one of the plasma components (preferably the fusion ash in this example) can be forcibly driven out of the system across the magnetic field. In reaction to this outgoing radial momentum the remaining plasma components may be forcefully confined (against the usual diffusive and anomalous losses). If we consider just two ion species a simple radial force balance is [1]

$$n_i z_i v_{ir} = -n_I Z_I V_{Ir}\,, \tag{1}$$

where n_i, n_I, z_i, Z_I, v_{ir}, and V_{Ir} are the densities, charges, and radial velocities of the plasma fuel ions and ash, respectively.

In order to attempt to demonstrate such magnetoreaction confinement, the present experiments were performed in the device [2] illustrated in fig. 1. A list of fundamental machine parameters is given as table I. The torus consists of a set of 8 field coils mounted in a circular frame. A rotational transform can be supplied by energizing a stellarator two-pass helical winding (not shown). Discharges are sustained by RF power electrostatically coupled into the plasma column through a surrounding pair of copper rings.

The principal diagnostic for plasma density and temperature is the Langmuir probe (single, double, and triple) scanned in 3 dimensions. Density and temperature profiles are also measured by noninvasive (and hence nonperturbing) spectroscopic means. An energy analyser [3] is available for ion temperature measurements and calorimeters and thermocouple probes are proved to measure radial particle and heat flux.

(1) R. JONES: *J. Ind. Inst. Sci. B*, **61**, 187 (1979) and *South Afr. J. Sci.*, **74**, 470 (1978).
(2) R. JONES: *Lett. Nuovo Cimento*, **41**, 107 (1984).
(3) R. JONES: *Rev. Sci. Instrum.*, **49**, 21 (1978); **50**, 392 (1979).

TABLE I.

Neutral pressure	$\sim 10^{-4}$ mm
Steady-state electron temperature	$(5 \div 10)$ eV
Electron temperature in the afterglow	$(0.3 \div 0.5)$ eV
Steady-state density	few$\cdot 10^{12}$ cm^{-3}
Steady-state ion temperature	$(0.5 \div 2)$ eV
Ion temperature in the afterglow	$(0.2 \div 0.3)$ eV
Plasma minor radius	1.5 cm
Plasma major radius	20 cm
Toroidal-magnetic-field strength	$(0 \div 1000)$ G

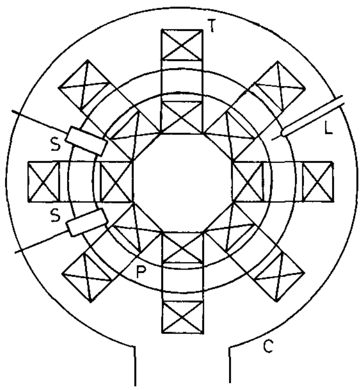

Fig. 1. – Toroidal plasma device consisting of RF plasma source S, toroidal field coils T, vacuum chamber C, plasma column P, and auxiliary heating antenna L. (Stellarator windings are not shown.)

The variation of the plasma density with time in the decaying afterglow plasma is measured by probe (ion saturation) current and spectroscopy. The confinement times computed from the slopes of the density decay curves are plotted *vs.* confining magnetic-

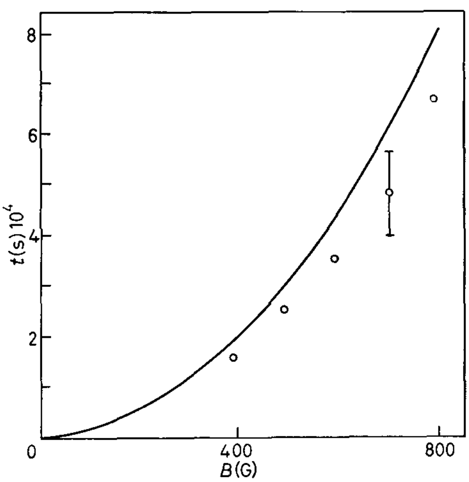

Fig. 2. – Particle confinement time *vs.* toroidal-magnetic-field strength (in hydrogen). Points: experiment, solid curve: eq. (2).

field strength in fig. 2. The confinement times observed in the absence of magnetoreaction experimentation are in reasonable agreement with the Pfirsch-Schluter formula

$$\tau = \frac{r^2}{4\nu_{ei} r_{Le}^2 (q^2+1)}\,, \tag{2}$$

which is appropriate in the present regime where

$$\nu_{ei} \gtrsim \frac{v_e}{Rq}\,. \tag{3}$$

Here r is the minor radius (1.5 cm), ν_{ei} is the electron-ion Coulomb collision frequency (typically $\sim 10^7\,s^{-1}$), v_e is the electron thermal velocity ($\sim 10^8$ cm/s), R is the major radius (20 cm) and q is the safety factor (typically 1 to 2).

Magnetoreaction confinement is studied by the injection of auxiliary RF heating (at $(50\div 100)$ MHz(and a $(5\div 10)\%$ admixture of an argon contaminant. In the steady state the hydrogen plasma profiles of fig. 3*a*) are modified to those of fig. 3*b*). (Argon injection in the absence of auxiliary heating does not substantially modify the plasma profiles, fig. 4*a*). Neither does auxiliary heating significantly modify the plasma profiles in the absence of an argon ion component, fig. 4*b*).)

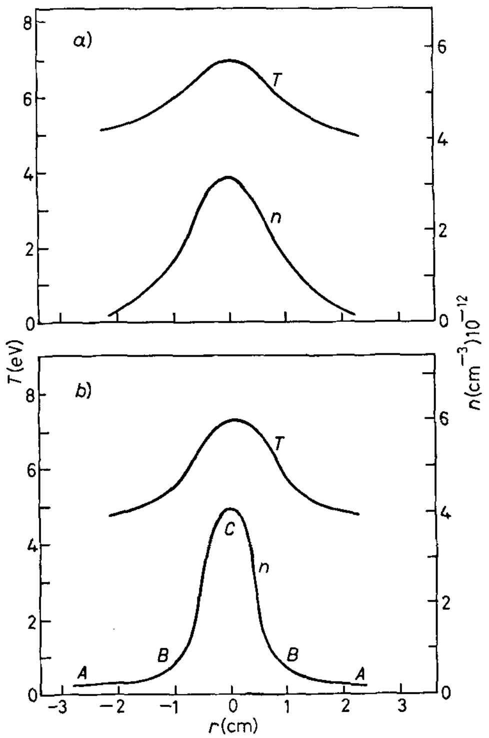

Fig. 3. – Radial profiles of plasma density, n, and temperature T. r is the minor radial co-ordinate. *a*) Hydrogen plasma without RF or argon injection. *b*) Hydrogen plasma with both RF and argon injection.

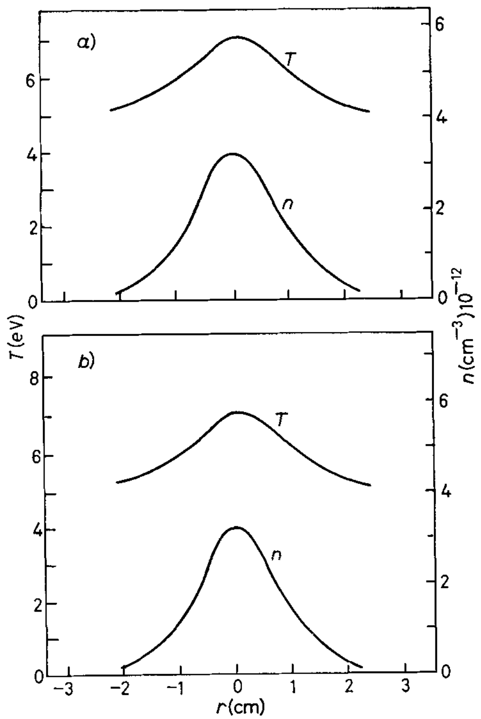

Fig. 4. – Radial profiles of plasma density and temperature. *a*) Hydrogen plasma with Argon injection alone. *b*) Hydrogen plasma with RF auxiliary injection alone.

Figure 3*b*) is taken as strong evidence for the existence of magnetoreaction confinement. In the peripheral region « *A* » a component of the plasma has been radially expelled across the magnetic field. (Compare with fig. 3*a*), 4*a*), and 4*b*).) In region « *B* » the plasma density has actually *decreased* as plasma has been confined *into* the core region « *C* ». These unique particle profiles are not explainable in terms of simple RF flux control (4), enhanced plasma production, or the like.

(4) K. ITOH and S. INOUE: *Comments Plasma Phys. Controlled Fusion*, **5**, 203 (1980).