G.I. Dimov. *Ambipolar traps.* One possible method of increasing the confinement time of a plasma in open traps with respect to its drift along the magnetic field is to set up twin electrical barriers at the open ends of a trap, as shown in Fig. 1(a). The ions are confined by the positive barriers $\Delta\varphi$ and electrons, by the negative barriers φ_0. It is understood that in this case the plasma must obey the quasi-neutrality condition over the entire length of the trap, including the end sections with the electrical fields, where the required ion density must be maintained by other means (inertial confinement, confinement).

Production of the electric fields in the end sections is made possible as a result of plasma polarization. Let the plasma bunches be sustained in these sections as a result of ionization of the fast deuterium atoms injected across the field [Fig. 1(b)]. The longitudinal distribution of the plasma bunches will be determined in this case by the spreading of ions. In order to confine the faster electrons near the ions, the plasma bunches are polarized, as shown in Fig. 1(c); a potential well for the ions is formed between the ends of a solenoid field [Fig. 1(d)]. If into this well we introduce plasma with a density sufficiently low that it exerts only a weak effect on the polarization of the end bunches, and with an ion temperature $T_{i0} \ll \varphi_{\text{end}}$, the well potential will rise to a certain value $\varphi_0 < \varphi_{\text{end}}$ but will not exceed the end bunch potential φ_{end} (Fig. 1a). Moreover, the plasma introduced into the potential well is polarized only at its ends (Fig. 1e). The relation between $\Delta\varphi$ and φ_0 is derived from the equality of times during which ions and electrons in the plasma are confined by the barriers $\Delta\varphi$ and φ_0, respectively.

The electrons corresponding to both the ambipolar barrier-confined plasma (the central plasma) and the end bunches, are in a common potential well. They are in equilibrium at the electron temperature $T_e \ll \varphi_0$ and follow the Boltzmann distribution $n_e = n_0 \exp[(\varphi - \varphi_0)/T_e]$. As a result of the quasi-neutrality condition, the potential is given by $\varphi = \varphi_0 + T_e \ln(n_i/n_0)$, where n_i is the total ion density [Fig. 1(f)]. Correspondingly, $\Delta\varphi = T_e \ln(n_{\text{end}}/n_0)$, and the ion confinement time in the central plasma is

$$\tau_{i0} \sim \tau_i \frac{\Delta\varphi}{T_{i0}} \exp \frac{\Delta\varphi}{T_{i0}} = \tau_i \ln \frac{n_{\text{end}}}{n_0} \frac{T_e}{T_{i0}} \left(\frac{n_{\text{end}}}{n_0}\right)^{T_e/T_{i0}},$$

where τ_i is the ion relaxation time. For $n_{\text{end}} \gg n_0$ and $T_e > T_{i0}$, the confinement time of the central plasma is considerably greater than the confinement time in the classical open traps where it is of the order of τ_i.

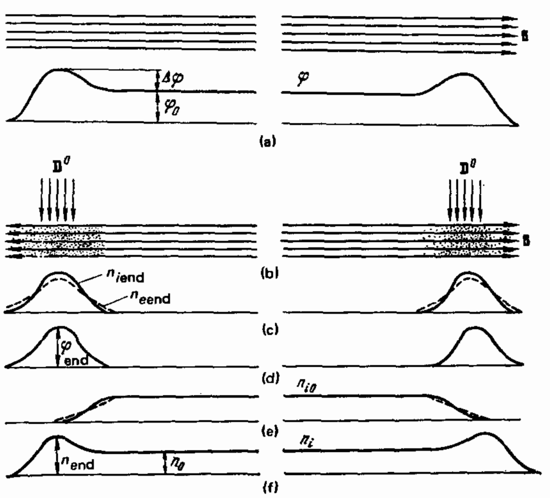

FIG. 1.

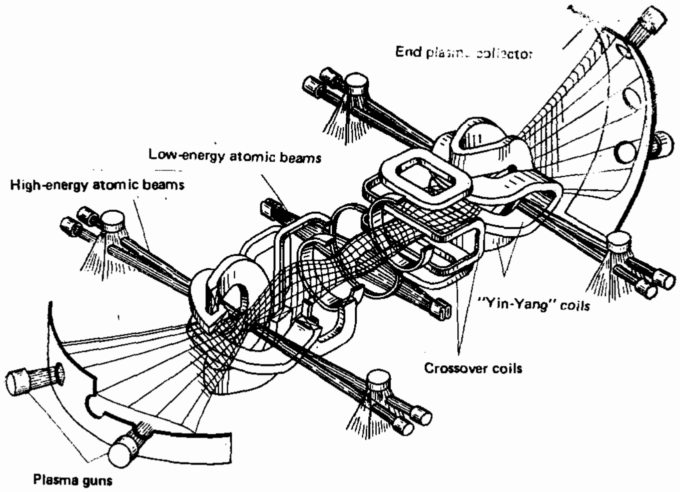

FIG. 2.

The energy losses due to confinement of the end plasma bunches, which may be reduced by forming the solenoid ends in the shape of "probkotron" traps, are independent of the solenoid length. The thermonuclear energy yield in the central plasma may, in the case of a relatively large trap length, considerably exceed these losses.

In the classical approximation, the energy balance calculations show that a thermonuclear reactor with a high power gain can, in principle, be constructed on the basis of a trap with ambipolar barriers-mirrors. In order to hold the reactor length down (100–200 m), high energy (of the order of 1 MeV) deuterium ions must be sustained in the end bunches. The highly energetic atomic deuterium beams required for this may be obtained with high efficiency from accelerated negative ions. A sufficiently strong magnetic field is also required in the end probkotrons (120–160 kG). But the required magnetic field in the main solenoid portion of the reactor amounts to tens of kilogauss, and the construction of this portion, in which fusion should occur, is relatively simple.

The theory and results of experimental investigations over many years of the classical open trap underscore a hope that the hydrodynamic and kinetic plasma instabilities may be surmounted in an ambipolar trap. It is estimated that the transverse losses in a plasma may be comparable to longitudinal ones, however there are ways of reducing them.

Currently, there are four experimental ambipolar traps in operation or under construction: AMBAL at the Institute of Nuclear Physics at the Siberian Branch of the Academy of Sciences of the USSR, TMX and

FEDR in the USA and Gamma-6 in Japan. The new experimental probkotrons OGRA-4 at the I. V. Kurchatov Institute of Atomic Energy and the MFTF under construction in the USA, are also capable of providing solutions to a number of questions which are important to the development of ambipolar traps. Figure 2 shows a diagram of the AMBAL installation. It appears to be quite complicated because its simplest solenoid part is reduced to a minimum. The TMX installation was operated in the summer of 1979; it produced a quasi-stationary plasma with near-design parameters. The confinement time of the central plasma along the device axis was considerably in excess of the value calculated for confinement without the ambipolar barriers. Experiments with the end probkotrons switched off have shown fairly conclusively that the ambipolar barriers work. The main task of future experiments is to increase the temperature of the central plasma while preserving its stability and increasing the energy-producing lifetime.

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