B. B. Kadomtsev. INTOR—*international tokamak reactor*. As a result of the initiative taken by Soviet scientists in 1979, the International Atomic Energy Agency (IAEA) has set up an international group to evaluate the possibility of producing a thermonulcear reactor based on the tokamak system. More precisely, the group was charged to (1) determine the programmatic and technical goals, (2) define parameters of a device and (3) evaluate the current scientific-technical basis for an international-scale thermonuclear reactor. The latter would be used to demonstrate the technical feasibility of producing fusion energy and it would constitute the most reasonable next step in the development of large-scale devices currently under construction: T-15 (USSR), UT-60 (Japan), JET (Europe) and TFTR (USA).

Relying on support from their national organizations, group members from the USSR, USA, Japan, and the European Community have prepared a detailed report which evaluates the scientific-technical level and deems the latter to be sufficient to design and build the International Tokamak-Reactor during a ten-year period.

The group have also defined the basic characteristics of the INTOR. It is proposed that the INTOR shall attain the conditions of ignition and prolonged burn of the self-sustaining thermonuclear $D-T$ reaction. The size of the plasma (large radius $R=5.2$ m, small radius $a=1.3$ m, cross section ellipticity parameter $b/a=1.6$), magnetic field strength $H\approx 5.5$ T, plasma current $I\approx 6$ MA, density $n=1.4\times 10^{14}$ cm^{-3} and temperature $T=10$ keV were selected by optimizing the parameters under the condition of attained ignition (with a small margin). The burn time is greater than 100 s for a thermonuclear power yield of nearly 600 MW and the first wall loading of 1.3 MW/m^2. To control the level of contaminants and the reaction product, helium, in the deuterium-tritium plasma, a diverter will be used and the heating of the plasma to ignition temperature may be accomplished by injecting a beam of 175-keV, 75-MW neutrals during a period of 5–6 sec.

The INTOR installation may accommodate experimental blanket modules for developing the technology of tritium recovery and for generating electricity (at the 5–10 MW level).

The preliminary design of the INTOR reactor began in 1980, concurrently with the formulation of a research and development program to form the project baseline of the large-scale thermonuclear INTOR reactor.

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.

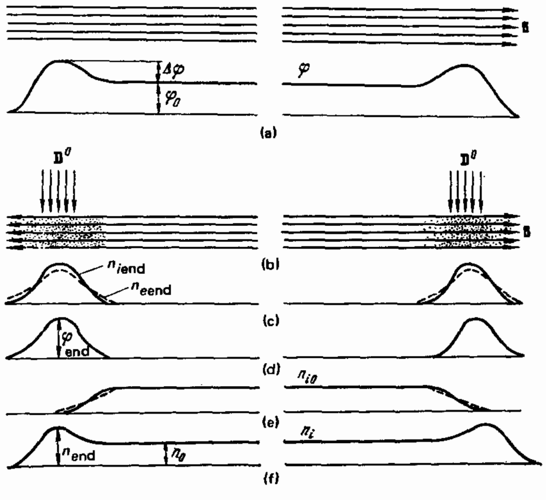

FIG. 1.

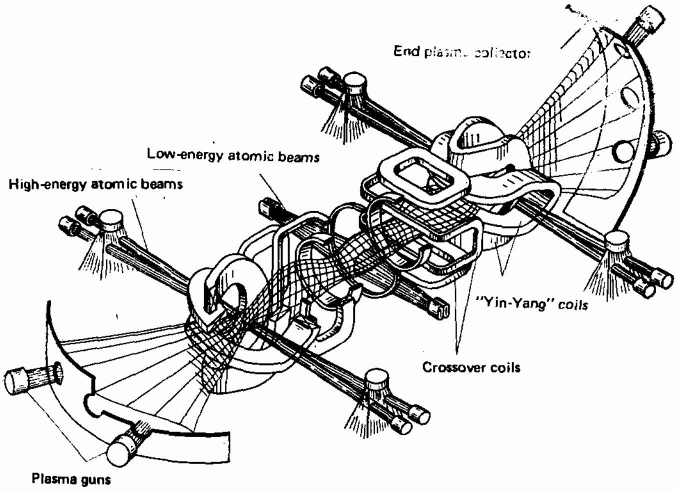

FIG. 2.

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