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ELECTRON TEMPERATURE DIFFERENCE IN FLOW CORE OF AN MHD ACCELERATOR CHANNEL

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The operating characteristics of MHD devices depend on the electrical conductivity of the plasma. Accordingly, it is important to know how it can be increased, taking into account the design properties of the materials used.

Generally speaking, as a result of the interaction of the plasma with the electric field the electron temperature is different from that of the ions and neutrals, and since the electrical conductivity of the plasma depends on the electron temperature, the question of nonequilibrium ionization has aroused considerable interest. In [1-3] an attempt was made to demonstrate, theoretically and experimentally, the presence of nonequilibrium ionization in an argon plasma seeded with potassium. The nonequilibrium ionization of noble gases seeded with alkali metal was also investigated in [4, 5].

In [6, 7] the effect of an elevated electron temperature near the surface of an insulator wall was investigated on the assumption of equilibrium electron concentration across the boundary layer. The equilibrium concentration was determined from the Saha equation. A similar assumption can be made in relation to the flow core, i.e., in the undisturbed region of the plasma.

We have investigated the undisturbed region of the plasma with allowance for diffusion and ionization of the charged particles at various concentrations of the potassium seed in nitrogen. We considered a dense plasma at a pressure p ~0.1 tech. atm, so that the ion temperature and the temperature of the basic gas may be taken to be the same.

The following assumptions are made: 1) The plasma is quasineutral; 2) all the plasma components, except for the electrons, are in thermal equilibrium; 3) there is no magnetic field; the electron temperature depends on the electric field strength and the current density.

Under these assumptions, the electric field strength, the particle fluxes, and the electron temperature are related as follows:

$$j = (D_e/\tau_e + D_i/\tau_i)G, \quad G = -j_e\tau_e/D_e, \; j_i = -j_e\tau_e D_i/\tau_i D_e, \; j = j_i - j_e, \qquad (1)$$
$$\tau_e = \tau_i + c\sigma_0 G^2/\nu,$$

where τ_e, τ_i, j_e, j_i, D_e, D_i are the temperatures, fluxes, and diffusion coefficients of the electrons and ions, respectively,

$$D_e = \frac{\tau_e^{1/2}}{\sum\limits_{s\neq e} N_s Q_{es}}\left(\frac{m_i}{m_e}\right)^{1/2}, \quad D_i = \frac{\tau_i^{1/2}}{\sum\limits_{s\neq i} N_s Q_{is}}$$

and G, σ_0, and ν are the electric field strength, the electrical conductivity, and the electron collision frequency [8].

We will use the collision cross sections obtained for nitrogen seeded with potassium [9]. The charged particle concentration is found from the Saha equation using the electron temperature:

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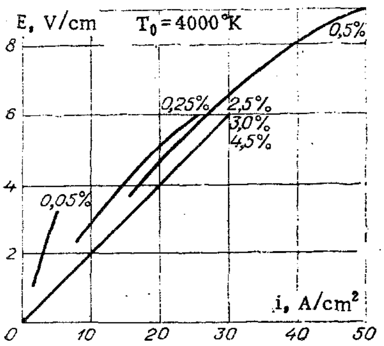

Fig. 1

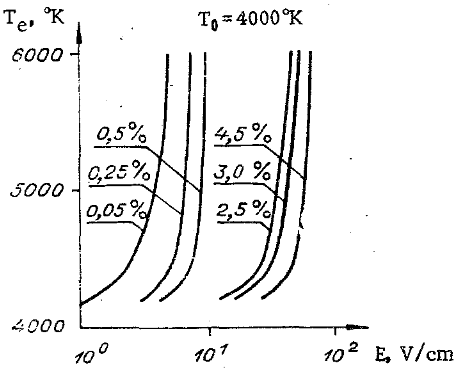

Fig. 2

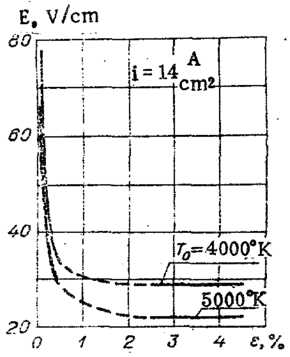

Fig. 3

$$\frac{n_e^2}{n_k} = \left(\frac{g_{0e} g_{0i}}{g_0}\right) \left(\frac{2\pi m_e k T_e}{h^2}\right)^{3/2} \exp\left(-\frac{I_i}{kT_e}\right). \tag{2}$$

Using (2), we solved relations (1) on a BÉSM-6 computer. The computation procedure reduced to the following: We specified the electron flux and selected the electron temperature satisfying the electron energy balance. The results are presented in Figs. 1-3 (T is the static nitrogen temperature, ε is the seed percentage). As may be seen from the graphs, the electric field strength in the undisturbed region of the plasma is small even at current densities ~50 A/cm². It follows that in MHD devices with an electrode spacing on the order of 1 cm the potential drop in the layers adjacent to the electrodes considerably exceeds the potential drop in the undisturbed region.

From the electric field strength versus current density relations it follows that at constant current density as the seed percentage decreases the electric field strength first remains constant and then begins to increase, whereas the electron temperature steadily increases with decrease in seed percentage. It is reasonable to assume that the optimum seed concentration lies between 0.5 and 2.5%.

As follows from the graphs, on the current density range considered (up to 50 A/cm²) at a near-optimal seed concentration the breakaway of the electron temperature from the temperature of the basic gas does not exceed 2000°K.

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