Discharges in chambers with continuous (solid) electrodes are considered. It is shown that if the one-dimensional MHD approximation may be applied to these, then the far simpler electrotechnical approximation is applicable to the same accuracy. Calculations relating to exploding wires are described.

1. By passing a heavy current through a dense plasma it is not difficult to heat this to several electron volts and produce intense light emission. Such light sources have high electrical energy/radiation conversion efficiencies — sometimes over 50%; this explains why these devices have evoked major interest in the last few years. The corresponding problems are characterized by natural cylindrical symmetry. In the theoretical analysis and numerical simulation of such discharges, the one-dimensional MHD approximation is usually employed [1]. If, however, the MHD effects are slight, for calculating the electromagnetic field a simpler electrotechnical approximation may be used; this we shall now describe.

As in the earlier paper [1], we shall consider a discharge in the one-dimensional approximation, regarding it as cylindrically symmetrical. The motion of the plasma is described by the Euler equations with due allowance for the Lorentz forces:

\[
\frac{dr}{dt} = v, \quad \rho r \frac{dr}{dt} = dm,
\]

\[
\frac{dv}{dt} = -r \frac{\partial}{\partial m} \left( \rho \frac{v}{p} + w \right) + \frac{F}{p},
\]

Here \( t \) is the time; \( \rho \) is the density, \( v \) is the velocity; \( r, m \) are the space and mass coordinates; \( p \) is the pressure; \( w \) is the pressure corresponding to artificial viscosity; and \( F \) is the Lorentz force.

The energy equation includes the Joule heating and the terms characterizing radiative heat transfer (the time derivative in both equations is Lagrangian):

\[
\frac{\partial \varepsilon}{\partial t} = -\frac{\partial}{\partial m} \left( W + W_1 \right) - (p + w) \frac{\partial}{\partial t} \left( \frac{1}{p} \right) + \frac{q}{p},
\]

where \( \varepsilon \) is the internal energy of unit mass, \( q \) is the Joule heat, and \( W \) is the flow of energy due to electron-heat conduction:

\[
W = -\chi_e \rho T \frac{\partial T}{\partial m},
\]

where \( T \) is the temperature; \( \chi_e \) is the electron contribution to the thermal conductivity.

The radiation is assumed to be nonequilibrium. Radiative transfer is described by the multigroup kinetic equation

\[
\frac{dI_n}{d\tau} + \chi_h I_n = \frac{1}{\tau} \chi_n \sigma_k T^4,
\]

\[
\sigma_k = \frac{\chi_{eq}}{I_0} \frac{(\nu)}{\tau^4},
\]

where \( \kappa \) is the average absorption coefficient for the group allowing for reradiation; \( I_{eq}(T, \nu) \) is the spectral intensity of the equilibrium radiation.

Methods of calculating radiative transfer were given earlier [2]. The equations of gasdynamics were approximated by a purely implicit scheme, the gasdynamic terms of which were written in conservative form and the magnetic terms, in nonconservative form. Since the magnetic field is everywhere continuous, even in the shock waves, the conservative recording of the magnetic terms is optional. The energy balance was closely maintained in our calculations.

In the electrotechnical approximation the plasma column is a simple conductor, having a conductivity which varies over the cross section and characteristic proper values of the resistance, inductance, and capacity (the latter is negligibly small). The magnetic field at a specified point in the plasma is equal to

\[
H(r) = \frac{I(r)}{r}; I(r) = 2\pi \int_0^r j(r') \, dr'.
\]

Here \( I(r) \) is the current flowing inside the specified radius.

The calculation for the resistance of the plasma column is obvious. The inductance is determined from

\[
\frac{1}{2} LI^2 = \int \frac{1}{8\pi} H^2 dV,
\]

where the integration is carried out over the whole region in which a field exists, i.e., in problems involving an outer return conductor, up to the return conductor, and in problems involving an inner return conductor, up to the outer boundary of the plasma column.

Using Eq. (1) we may express the inductance in terms of the distribution of the conductivity over the cross section. Here we must consider that the electric field strength is constant in the laboratory coordinate system and is related to the current density by

\[
J = \sigma \left( E + v \times H \right).
\]

In the majority of problems the term \( v \times H \) is a small correction. If we neglect this term, we obtain the following equation for the inductance of the plasma in a construction with an outer return conductor:

\[
L_{pl} = 2 \cdot 10^{-9} \mu_{cm} \left[ \int_0^\infty \left( \frac{\sigma (\xi)}{\xi} d\xi \right)^2 \right] \cdot \left[ \int_0^{r_{lim}} \frac{\sigma (\xi)}{\xi} d\xi \right]^{-2}.
\]

The total current in the circuit and the voltage on the electrodes are here determined from the solution of the electrotechnical equation

\[
\frac{d}{dt} [I_c + L_{pl} I] + (R_c + R_{pl}) I + U_0 - \frac{1}{C_0} \int_0^t I dt = 0.
\]

In experimental work the action is usually initiated with the aid of a spark discharge or the explosion of wires or foils. This creates a thin layer of plasma with a temperature of the order of several thousands of degrees. The exact values of the layer parameters are not determined in the experiments. In our present calculations the initiation is simulated by specifying the initial temperature in a layer 0.5 mm thick.

In order to discover the influence of the initiation conditions we executed several numerical calculations differing as regards the parameters of the heated layer. The calculations showed that for too low an initial temperature no discharge developed. Starting from a certain critical temperature \( \sim 0.3 \) eV the discharge develops normally, the progress of the action only depending on the initiation temperature at the very beginning. Ever after 0.2 \( \mu \)sec the difference between the various versions is erased. This is not hard to understand. On reducing the initial temperature the resistance of the layer increases. This leads to a great evolution of Joule heat and more rapid heating of the plasma; however, if the resistance is excessive, it actually opens the circuit and extinguishes the discharge. We note that an ignition temperature of around 3000-5000° is physically most reasonable for a layer thickness of the order of tenths of a mil-