PROBE MEASUREMENTS IN THE CHANNEL OF A MAGNETIC ANNULAR ARC

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The profiles of the electron temperature and density in the channel of a magnetic annular arc have been measured with the help of an electrical circuit developed for large probe currents.

The magnetic annular arc, described in [1, 2], is used in various types of experiments, but the phenomena involved have received little study: the processes occurring in the arc channel have not been studied, and the profiles of the electron density and temperature near the electrodes are unknown. This information must be obtained if a physical model is to be developed for an arc of this geometry.

In our experiments the arc exists between a hollow anode and a cathode. The tungsten anode has an inside diameter of 18 mm, while the cathode is a loop of tungsten wire 1.5 mm in diameter. The cathode is held 5 mm from the end of the anode. The magnetic field is produced by a solenoid which is coaxial with the coaxial electrodes. The working gas is admitted into the region between the anode and cathode, i.e., the arc channel, through slits in the anode. The gas flows in the direction perpendicular to the anode as it enters the channel. The electrode system is held in a vacuum chamber, evacuated by an N-8T pump.

The arc is ignited by preheating the cathode with a voltage applied to the anode. After the arc is established, the cathode heater current is cut off; thereafter, the cathode is heated by the heat from the discharge. Under the particular experimental conditions the discharge is homogeneous in the azimuthal direction (along φ), carrying plasma out of the electrode system.

The electron temperature and density are measured by an electrostatic-probe method; this method reveals local values of the parameters without the need for complicated special equipment. The probe measurements consist of determining two quantities: the probe current and potential. When probes are used in intense arcs, a modified procedure must be used to obtain the I-V characteristics. The modification is necessary because of the high current densities drawn by the probe and because of the limited time the probe spends in the arc. Various types of electronic devices can be used to measure the probe potential at the necessary rate [3], but these devices cannot handle the power required for measurements of high probe currents.

To measure the profiles of the electron temperature and density in our experiments we use the transformer circuit shown in Fig. 1.

The circuit includes a dividing transformer (1), from which the voltage is fed to the probe; an oscillographic recorder (2), used to record the probe voltage and current; an electromagnetic relay (3) with an RC circuit, necessary for turning the circuit on briefly (~ 0.06 sec); a semiconductor diode (4), used to cut off the electronic part of the probe current; and an electrostatic probe (5).

When push-button switch 6 is pushed, capacitor C (previously charged through resistor R; $R > R_1$, where R_1 is the relay resistance) is discharged into the winding of relay 3. At this time an alternating voltage (50 Hz) is fed to the probe, and the recorder is turned on. The time at which the relay contacts close is chosen on the basis of the following considerations: in each measurement, three to five probe characteristics are recorded in order to reduce the experimental error. Since the frequency of the probe voltage

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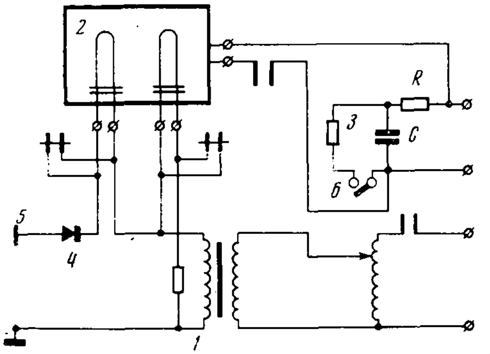

Fig. 1

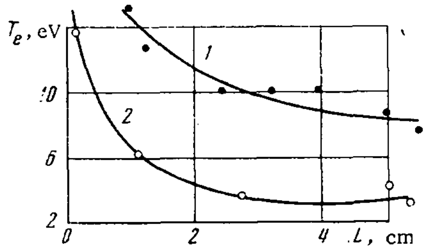

Fig. 2

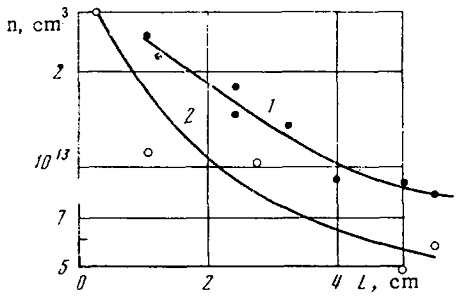

Fig. 3

is 50 Hz, the recording time for the probe characteristics is 0.06-0.1 sec. At this probe-voltage frequency, the photographic paper in the oscillograph must travel at high speed (10^3 mm/sec) for adequate resolution of the recording; the oscillograph is accordingly turned on by the contacts of relay 3 for a time of 0.06-0.1 sec in order to reduce the length of the recording frame. Since the probe characteristics are analyzed on the basis of the current drawn by the negatively charged probe, a semiconducting diode is placed in the circuit of this probe.

Using semiconducting diode 4 to cut off the electronic component of the probe current makes it possible to avoid severe overheating of the probe when it is held at a positive potential and makes it possible to increase the accuracy with which the ion current drawn by the probe can be measured, since it is not necessary to use a galvanometer to measure the electronic part of the probe current, which is much higher than the saturation ion current. With this circuit it is possible to record the probe characteristic in 0.02 sec at probe currents up to 2 A. The I-V characteristics obtained from the oscillograms are replotted in semilogarithmic scale: the electron temperature is calculated from the slope of the linear dependence of the logarithm of the current on the voltage, and the electron density is calculated from the saturation ion current.

Experiments were carried out for an arc current of 50 A, a magnetic induction in the channel of 4×10^{-2} T, and an air flow rate through the anode of 1 mg/sec. The pressure in the chamber was held at 10^{-4} torr. The working element of the probe was a tungsten wire 0.1 mm in diameter and 2 mm long. The axis of the probe was parallel to the axis of the electrode system. The probe was mounted on translation stage so it could be moved in the direction perpendicular to the arc channel.

The experimental results are displayed in Figs. 2 and 3; the distance L is measured from the end of the anode. Figure 2 shows profiles of the electron temperature along the axis of the system (curve 1) and at a distance of 5 mm from the anode (curve 2). We see that the electron temperature falls off with distance from the electrodes, and the decrease is less pronounced at the axis than at the periphery of the system. This behavior results from the existence of a central cathode stream, i.e., a stream of electrons emitted by the cathode along magnetic lines of force perpendicular to the end of the anode. Under our experimental conditions the electrons are "magnetized" ($\omega_e \tau_e > 1$) and do not participate in the current transport in the arc channel as they move along the magnetic lines of force. Figure 3 shows the profile of the electron density; the density falls off with distance from the arc channel, due to the expansion of the arc into vacuum and its acceleration. The density in the arc channel is lower than near the cathode, perhaps because of the existence of the cathode stream.

The profile of the density of all charged particles is consistent with our understanding of the typical processes occurring in a magnetic annular arc. The decrease in the electron temperature along the axis is not due to collisions and requires further study.

LITERATURE CITED

1. W. E. Powers and R. M. Patrick, "Magnetic annular arc," Phys. Fluids, 5, No. 10 (1962).
2. G. B. Dautov and M. F. Zhukov, "Some generalizations based on study of electric arcs," Zh. Prikl. Mekhan. Tekh. Fiz., No. 2, 97 (1965).
3. O. V. Kozlov, Electric Probes in Plasmas [in Russian], Atomizdat, Moscow (1969).