USE OF A HEAVY-CURRENT STABILIZED ARC TO PRODUCE AN AIR PLASMA WITH A TEMPERATURE OF UP TO 35,000°K

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We consider two versions of heavy-current arc discharge chambers with vortex stabilization, making possible the production of an air plasma to a temperature of 35,000°K, without contamination by electrode material. We study the space-time stability of the plasma formations that are produced.

We have recently seen descriptions of several continuous-action and pulse-regime discharge installations which made it possible to reduce stable axisymmetric plasma formations without contamination by electrode material [1-3]. Such installations exhibit a number of advantages relative to the unit currently in use in connection with quantitative studies of the thermophysical and optical properties of exceedingly hot gases and their mixtures. In a discharge chamber operating in a low-current regime (I ~ 10 A), a temperature of 20,000°K was obtained [2] at the axis of the arc filament, and this corresponds to the maximum regimes of the best contemporary adiabatic compression tubes. Transition to higher-current regimes opens the way for further elevation of temperature. However, this problem has been dealt with exclusively in connection with the case of pulse discharge [3].

In this article we discuss the results obtained in a study on the use of heavy-current stabilized arc discharges to produce a long-lasting air plasma with a temperature of tens of thousands of degrees. We apply the principles of the heavy-current plasma-jet generators in the development of this discharge chamber. The initial version of the chamber (Fig. 1a) was reminiscent of a bilateral plasma generator [4] in which the gas streamlining the arc is discharged from the vortex chamber through two tubular electrodes. The jets which were formed as a result, in our case, represented secondary plasma formations. The object of our research was the central segment of the discharge channel. We undertook the task of designing a unit to provide for the maximum possible space stabilization of this channel segment and to eliminate its contamination with the products of electrode erosion. To reduce the level of erosion, the electrodes were cooled with running water at a pressure of 6 atm. The movement of the products of erosion in the direction of the central zone of the chamber was restricted by means of a gas flow and through the insertion of special diaphragms which serve also to provide for the spatial stabilization of the central segment of the discharge channel.

The inside diameters of the chamber of the stabilization diaphragms were 90 and 5 mm, respectively. The gas flow rate was ~1 g/sec. The arc was powered by an RMV-500 mercury rectifier. A high-frequency generator was used to ignite the discharge. At currents of up to 500 A it was possible to produce an arc filament in the discharge chamber that produced virtually no destruction of the electrodes and diaphragms.

Two quartz windows in the housing of the chamber were used to keep the central segment of the arc filament under observation. The purity of the plasma was monitored and the temperature profile was determined by spectroscopic methods. The emission spectra of the plasma filament were photographed along the lateral cross section. One of the characteristic sections of the spectrogram obtained with an ISP-30
Fig. 1. Basic diagrams of the two types of chambers to produce a pure air plasma by means of heavy-current arc discharge, the oscillograms of the current (solid lines) and the lateral displacements of the plasma filament with the passage of time (dotted lines): 1) cylindrical chamber; 2) stabilizing diaphragms; 3) electrodes; I, A; Ar, mm; t, sec.

Fig. 2. A portion of the emission spectrogram for the air plasma (p = 1 atm, I = 300 A).

The spectrogram is shown in Fig. 2. Spectral analysis shows that the spectra include only the lines of nitrogen and oxygen atoms and ions, i.e., the products of the thermal decomposition and ionization of the air. The lines for the material of the stabilization diaphragms and electrodes are entirely absent in the spectra, which indicates the high degree of purity for the plasma produced.

The space-time stability of the arc filament was monitored by means of an SKS-1 M high-speed camera, converted for operation on a continuous basis. The arc filament was projected with an F = 150 mm condenser onto the plane of an intermediate slit cutting a thin plasma disk which was projected by means of another condenser onto the moving film of the high-speed camera (Fig. 3a). The time sweep of the luminescence of the plasma disk was parallel to the axis of the arc filament. The time resolution of the sweep, determined by the width of the slit and the speed of film motion, amounted to \( \sim 3 \times 10^{-5} \) sec (for a slit width of 0.7 mm). The space connection of the plasma-filament cross section on the film was achieved by positioning a thin wire on the slit, perpendicular to the latter. A typical segment of the time sweep for the discharge chamber under consideration is shown in Fig. 3b.

Examination of the time sweeps demonstrates that the stability of the arc filament produced here is substantially better than the stability of conventional arc discharges, as well as of the Maeker arc with similar current regimes [5], although the latter does show slight pulsations in brightness. The frequency of filament brightness pulsation is \( \sim 3 \) kHz, and its diameter in this case varies from 4 to 5 mm. We also noted slight displacement of the filament axis at a frequency of about 1 kHz. Investigations have demonstrated that the observed fluctuations in brightness and in the position of the filament axis are primarily associated with the circular motion of the electrode spot over the inside surface of the tubular electrodes, setting into rotation the plane in which the distorted arc channel is located. The shunting of the arc [4] may also exert some influence on filament stability.

In this paper we have considered the possibility of a further rise in the stability of the arc filament. With this purpose in mind, we altered the design of the electrode units so that the arc bases were fixed in position at the electrodes. In this new version of the chamber (Fig. 1b) intensively cooled flat tungsten rods served as the electrodes, and these were placed within the tubular electrodes. The "connection" of the arc