Development features of the plasma flow in the gas discharge with the liquid electrolyte cathode

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Abstract. The plasma flows in the form of a flat vertical wall were obtained and investigated. The discharge was ignited in an open air atmosphere in the range of currents of 2-15 A. The possibility of forming the plasma flow with parameters acceptable for energy-intensive technologies is shown.

1. Introduction
The plasma flows are formed from the liquid-phase electrolytes possess great potential practical applications [1-8]. High-power plasma flows can be created by the gas discharge in the current range in the tens of amperes [9-11]. In the traditional embodiment, the gas discharge is ignited in the vertical discharge gap between the liquid electrolyte cathode and the metal anode. In this case, the metal anode is located in the plasma flow and a significant part of the thermal energy of the plasma flow is conducted away to it. Heat losses at the anode average about 20% of the power input to the discharge [12]. In this paper, with the aim of reducing heat loss at the metal anode, studies have been conducted.

2. Experiment
In experimental practice, the gas discharge with a liquid electrolyte cathode is created by using various liquid systems. In the open air at atmospheric pressure, as a rule, the electrolyte is either poured into a container with a large geometric volume and circulates through it, or expires from the tube. In such cases, the discharge is formed in the form of a cylindrical form. In this paper, the electrolyte flows out of the slot gap. In this case, the discharge was formed in the form of a vertical luminous wall of relatively small thickness.

The experimental device used to create and study the gas discharge is schematically shown in Figure 1. There is also a photograph of the device. The housing of the cathode assembly was made of fiberglass. A copper rod was mounted inside it. Negative potential from the power supply was applied to this rod. The liquid electrolyte was fed into the internal cavity of the cathode assembly through the opening, and it flowed out of the narrow gap. The gap length was 22 cm, and width – 3 mm. At the edges of the gap, there were projections with a height of 5 mm. Anode 5 was located above the cathode assembly. It was made of a copper pipe with a diameter of 14 mm. Anode was cooled with water flowing through the pipe. Experiments were conducted at different locations of the anode. The height h varied from 2 to 10 cm. The horizontal displacement x reached up to 3.5 cm.
Sodium chloride solutions in distilled water with various concentrations were used as electrolyte. Electrical conductivity of electrolytes was in the range of 5 to 12 mSm/cm. Mass flow rate of the electrolyte through the gap was 5-30 g/s. The power source was a three-phase, full-wave rectifier. The voltage ripple was smoothed by the C-L-C-filter.

Photographing was done with a high-speed camera ВИДЕОСКАН-415, which made it possible to take photographs with a minimum exposure time of up to 1 μs.

The heat loss at the electrodes (at the cathode and anode) was determined by the calorimetric method.

3. Results of the experiment and their analysis
On figure 2 and 3 shows photographs of the gas discharge at a non-zero horizontal shift of anode. When photographing the camera lens was directed along the gap at the cathode. The exposure was 200 μs. As can be seen, at low currents the plasma column is positioned vertically above the gap. The anode is almost completely outside the plasma column. A discharge channel in the form of a filament is formed near the anode. Under the influence of Archimedes principle the filament bends, taking the form of an arc. Discharge filament during of burning discharge was continuously varied. The plasma column also continuously changed its shape.

As the current increases, the plasma column becomes thicker and touches the edge of the anode (Figure 3). Thin spark channels appear near the anode.
Experiments have shown that the gas discharge burns at small displacements of the anode $x$ from the central position. In the studied range of parameters, the maximum displacement was within 3.0 - 3.5 cm.

**Figure 3.** Plasma column at discharge current 6A. $x = 3.0$ cm; $h = 5.0$ cm.

Fig. 4 shows instant photographs of the plasma column obtained when the camera lens is directed perpendicularly to a narrow gap on the cathode (respectively, perpendicular to the anode).

**Figure 4.** Plasma flow in the form of a vertical wall. The anode is in the background. Its outlines are indicated by white lines. The discharge current: (a) – $I = 5$ A; (b) – 12 A; (c) – 15 A. $x = 2.5$ cm; $h = 4.0$ cm.

As can be seen, with the current increases, the binding zone of the discharge to the water-soluble cathode expands along gap. On the surface of the aqueous solution point support spots are formed. The glow of support spots increases with increasing current. At the same time, the number of visible spots decreases markedly. In addition, the spatial structure of the plasma column in the cathode region is changing. The plasma column in this area becomes clearly non-uniform. Luminous columns appear in it, which rest against the supporting spots. A further increase in current in the experiments led to extinguishing of the gas discharge. In this case, the aqueous solution used as the cathode was heat to
boiling. As an example, table 1 shows the temperature of the aqueous solution at the outlet of the cathode assembly at different discharge currents.

| Discharge current (A) | Temperature of aqueous solution (°C) |
|-----------------------|--------------------------------------|
| 5                     | 69                                   |
| 11                    | 82                                   |
| 14                    | 93                                   |

In fig. 5 shows the heat loss at the anode QA. It is seen that the displacement of the anode from the central position contributes to a significant reduction in heat loss.

4. Conclusions
It is necessary to ensure the outflow of the water-soluble cathode from the long narrow gap upwards to generate the plasma flow in form of vertical wall. In this case, the aqueous solution shouldn't be heat to boiling.

The displacement of the anode from the central position contributes to the reduction of heat losses.

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