Low-current arc in plasma flow from discharge with liquid electrolyte cathode

K K Tazmeev\textsuperscript{1}, R N Tazmeeva\textsuperscript{1} and B K Tazmeev\textsuperscript{2}

\textsuperscript{1}Kazan Federal University, Naberezhnye Chelny Institute, Naberezhnye Chelny, Russian Federation

\textsuperscript{2}Kuban State Agrarian University named after I.T. Trubilin, Krasnodar, Russian Federation

\textsuperscript{1}tazmeevh@mail.ru

Abstract. The effect of plasma flow from a discharge with a solution cathode on the properties of a low-current electric arc has been experimentally studied. Electric power was supplied to the arc from a GORN-type inverter source. A rectifier served as a power source for the discharge with a solution cathode. The output voltage was 1700 V. Aqueous solutions of table salt were used in the experiments. The specific electrical conductivity of the solutions was in the range of 10–15 mS/cm. The electric arc was ignited between horizontally oriented rod electrodes. The interelectrode distance varied within 2–15 mm. The discharge current with a water cathode was established within 8–15 A. The arc burned in the current range of 1–8 A. The conditions under which stable burning of the electric arc is ensured are revealed.

1. Introduction
To solve a number of practical problems, a volumetric plasma of atmospheric pressure is required. In particular, this problem is relevant in the processes of air purification and sterilization in laboratory rooms for the study of nanomaterials. One of the sources of volumetric plasma is a gas discharge with a liquid electrolyte cathode \cite{1}. With the help of an electric arc, under certain conditions, it is also possible to obtain a volumetric plasma. Favorable conditions form in the so-called "sliding arc"\cite{2}. The purpose of this work was to study the possibility of forming a volumetric plasma when two sources are used together: discharge with a solution cathode and an electric arc.

2. Experiment
Two variants of electric arc excitation were investigated in experiments. In the first variant, the arc was ignited in the interelectrode space of a gas discharge with a discharge with a solution cathode (figure 1a) and in the second variant, outside this space (figure 1b). Metal electrodes 1 and 2 were used for the electric arc. They were copper rods with diameters of 25 and 16 mm, respectively. Electrodes 1 and 2 were horizontally oriented. They were cooled with water. The distance \( l \) between them was set within 2–15 mm. Electric power was supplied to the arc from inverter sources of the GORN type. The maximum output voltage was 3000 V. The discharge was ignited with a solution cathode electrolyte cathode between metal electrode 3 and electrode assembly 4, from which the electrolyte flowed. A detailed description of electrode assembly 4 is given in \cite{3}. Salt solutions were used as a liquid electrode. They were prepared with specific electrical conductivity \( \sigma \) in the range of 10–15 mS/cm. Electrode 3
was made of copper in the form of a rod. It was cooled with water. This electrode was placed horizontally
and was oriented perpendicular to the rod electrodes 1 and 2. The vertical distance \( h \) between the cathode
of the arc (electrode 1) and the discharge anode with a solution cathode (electrode 3) varied between 2–
7 cm. In both variants, the metal electrodes were located at a height of 2 cm above electrode assembly
4 (in the first version – electrodes 1 and 2, and in the second – electrode 3). The end of metal electrode
3 was moved away from the axial line of electrode assembly 4 by 1 cm. With this electrode
configuration, the plasma flow from the liquid electrode almost freely rose upward. The gas discharge
current with a liquid electrolyte cathode was regulated by the resistor 5. The power source was a rectifier.
A C-L-C filter was connected to it. The output voltage was 1700 V.

![Electrical diagram of the experimental setup. Options
for ignition of the arc: (a) – in the combustion zone of a gas
discharge with a liquid electrolyte cathode; (b) – in the afterglow
region.](image)

Electric arc current \( I_1 \) was set within 1–8 A. The discharge current with the solution cathode \( I_2 \) varied
in the range of 8–15 A. Currents \( I_1 \) and \( I_2 \) were measured with pointer instruments of precision class 0.2.

The value of \( \sigma \) was performed using an ANION 4150 conductometer before and after the
experiments. The measurement results showed that there is an increase in \( \sigma \). The aqueous solutions were
reused if their electrical conductivity \( \sigma \) did not exceed 15 mS/cm.

The photographing was carried out with a video camera VIDEOSKAN-415. It made it possible to
obtain frames with an exposure of 1 μs. The luminous flux was controlled by a diaphragm. Thus,
photographs of the arc channel against the background of the plasma column of the discharge with a
solution cathode were obtained.

### 3. Experimental results

Figure 2 shows photographs of the discharges obtained with the arrangement of the electrodes according
to option (a).
Figure 2. Pictures of discharges. White lines – contours of the electrodes. \( l = 5 \) mm. \( h = 2 \) cm. \( I_1 = 7 \) A, \( I_2 = 8.5 \) A.

As can be seen from the presented frames, in this variant there are some features of the burning of an electric arc. In the first two frames (figures 2a and b), the arc is not visible against the background of a discharge with a solution cathode. Here, the anode spot on the upper rod electrode stands out noticeably. In the next two frames, a contracted discharge channel was recorded. It is formed between the cathode of an electric arc and the anode of gas discharge with a liquid electrolyte cathode. The appearance of such a channel leads to some decrease in the radiating volume. In general, it can be noted that the ignition of an arc in the interelectrode space of a discharge with a solution cathode does not contribute to an increase in the plasma volume.

Figure 3 shows photographs of the discharges obtained with the arrangement of the electrodes according to option (b).

Figure 3. Instant photos of discharges in autonomous and joint combustion modes. (a) – electric arc; (b) – discharge with a solution cathode; (c) and (d) arc in the plasma flow from a discharge with a solution cathode. \( l = 5 \) mm. \( h = 3 \) cm. \( I_1 = 7 \) A, \( I_2 = 10 \) A.

In the first frame on the left (figure 3a), an electric arc was recorded in the variant of autonomous combustion. In this variant, the geometry of the discharge channel changed continuously. The processes of elongation and shortening of the discharge channel were repeated. Shunting phenomenon was observed. The mechanism of such processes is considered in more detail in [4-6]. In the second frame (figure 3b), autonomous combustion of a discharge with a solution cathode was recorded. It can be seen that the discharge forms a volumetric plasma column. In the third (figure 3c) and fourth (figure 3d) frames, different moments of electric arc burning in the gas discharge plasma flow with a discharge with a solution cathode were recorded: shunting (figure 3c) and upward blowing (figure 3d). The upward blowing of the electric arc was accompanied by the formation of a plasma cloud. At the moments of
shunting, the cloud disappeared (figure 3c). Note that blowing out the arc with a plasma flow did not lead to its breakage. With an increase in the current of gas discharge with a discharge with a solution cathode $I_2$, arc shunting occurred less frequently.

4. Conclusions

Thus, experiments have shown that an electric arc can be used to increase the plasma volume. The greatest effect is achieved when the electric arc burns in the region of the afterglow of the discharge with a solution cathode.

References

[1] Bruggeman P et al. 2008 Plasma Sources Science and Technology 17(2) 025012
[2] Korolev Y D 2013 Gaodianya Jishu/High Voltage Engineering 39(9) 2061-2076
[3] Tazmeev G K, Timerkaev B A and Tazmeev K K 2019 Journal of Physics: Conference Series 1328 012075
[4] Tazmeev K K and Tazmeev B K 2016 Plasma Physics Reports 42(1) 86-90
[5] Yunusov R F and Garipov M M 2020 Journal of Physics: Conference Series 1588 012064
[6] Yunusov R F and Yunusova E R 2020 Journal of Physics: Conference Series 1683 032006