A BILATERAL DISCHARGE PLASMATRON WITH VARIABLE ELECTRODE DIAMETER

A. I. Zhidovich, S. K. Kravchenko, and O. I. Yas'ko

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Increasing volt-ampere characteristics are obtained experimentally on a powerful nonsegmented bilateral-discharge plasmatron.

The use of various high-temperature industrial processes is associated to a great extent with the development and production of high-power plasmatrons (in thousands of kW) for the heating of working fluids and intermediate heat carriers. One of the difficulties hindering the production of such plasmatrons is the rapid wearing out of the electrodes and the need to provide for special sources of electrical energy to supply installations exhibiting declining static volt-ampere characteristics.

The operational service life of electric-arc installations is governed by electrode erosion which, all other conditions being equal, is the greater, the greater the current. For a specified power it is therefore advisable to strive toward an increase in the operational voltage at the arc.

The attainment of high voltages is most easily accomplished in linear plasmatrons with vortical stabilization [1–3]. In addition to this advantage, these plasmatrons exhibit descending characteristics, and it is therefore necessary to employ ballast resistances in their operation or special automatic current-stabilization circuits which will ensure steep descent for the outside characteristics of the electric power source.

This latter inconvenience can be eliminated by designing the plasmatrons with rising volt-ampere characteristics. To achieve rising characteristics, the resistance of the arc must remain constant or, at least, it must diminish more slowly than the current increases. This is achieved by stabilizing the geometric dimensions of the arc which tend to increase as the current is strengthened.

The literature describes various methods of achieving increasing characteristics [4–6]. Unfortunately, until now none of these methods has made it possible to develop a sufficiently simple and reliable plasmatron design for great power.

A simple and convenient method of establishing arc length was the method of altering the electrode diameter in a bilateral-discharge plasmatron, thus making it possible: a) to raise the voltage at the arc; b) to reduce the dimensions of the plasmatron; c) to reduce the operating current; d) to increase the efficiency; e) to work on the ascending segments of the volt-ampere characteristic; f) to increase the service life by employing large-diameter current-carrying electrodes.

A schematic diagram of a plasmatron is shown in Fig. 1. It is made symmetrically relative to gas ring 1 and consists of two identical electrodes with variable diameter. Each electrode has a small-diameter clamping section 2 (diaphragm) and a separate large-diameter electrode 3. The gas is introduced tangentially to the inside surface, it is heated in the diaphragms and in the electrodes by arc 4, and it is discharged from the plasmatron in both directions in the form of the plasma jets 5.

On discharge initiation, an ionized channel is formed within the clamping diaphragms. In connection with the fact that the velocity of the gas in the diaphragms is high, the support points of the arc are blown away in both directions and reach the current-carrying portions of the electrodes.

The variation of the current within certain limits affects only the position of the support points within the large-diameter electrodes and has little effect on the slope of the volt-ampere characteristics, which is governed by the strongly compressed portion of the arc column situated in the diaphragms. However, since the diaphragms are not insulated from the electrodes, a substantial increase in the current leads to a shift in the support points of the arc into the diaphragm and to conversion of the plasmatron into a conventional installation with descending volt-ampere characteristics.

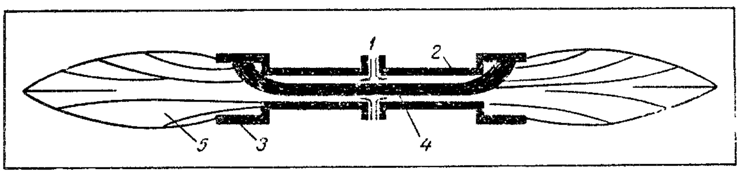

Fig. 1. Scheme of a plasma generator with ascending voltage-current characteristics obtained by changing of the electrode diameter: 1) gas inlet ring; 2) diaphragm; 3) electrode; 4) arc; 5) plasma jet.

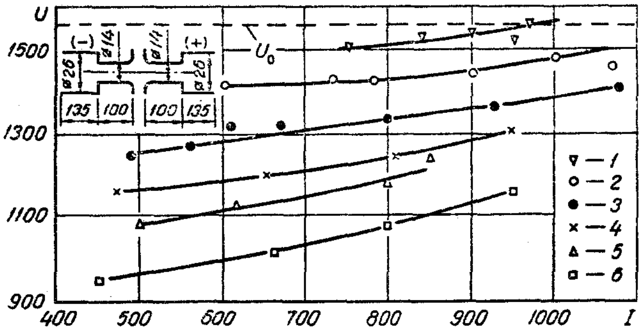

Fig. 2. Voltage-current characteristics of a plasma generator with the variable electrode diameter (gas–air. U_0 is the voltage of direct current source. U, V; I, A): 1) 356 g/sec; 2) 300; 3) 250; 4) 200; 5) 150; 6) 100.

Ascending characteristics make it possible to work from a source with an external rigid characteristic at nominal voltage without use of any current-stabilization systems.

On the basis of the above-described scheme, we developed a series of electrical arc heaters ranging in power from 200 to 3000 kW. The volt-ampere characteristics of one such plasmatron are given in Fig. 2. The figure shows the case of plasmatron operation in a nonrheostat regime at a voltage of 1650 V. The gas (air) flow rate is equal to 356 g/sec and the current is 960 A.

Regulation of the plasmatron parameters (current, power, temperatures) after entry into the nonrheostat regime is accomplished by varying the gas flow rate. An increase in the flow rate leads to a shift in the operating point to the left along the outside power-supply characteristic, while a reduction in the flow rate leads to a shift in the operating point to the right, all the way to the current magnitude at which the support points of the arc are drawn into the diaphragm.

A further reduction in the flow rate is undesirable, since it may lead to a loss of arc stability and short circuiting. Entry into the nonrheostat regime is possible in two ways: the first involves the gradual reduction of the ballast resistance during the process of starting the plasmatron, and the second involves the direct connection of the plasmatron without resistance to the voltage of the source. The first method is preferable, since it makes it possible to reduce the starting overloads.

In the study of the plasmatrons, we determined their thermal and electrical characteristics, established the material and energy balance of the discharge chamber, and found the mass-averaged enthalpy and the temperature of the heated gas.

The mass-averaged temperature of the heated gas is controlled within wide limits, and at low temperatures it is possible to pass the entire flow through the arc without dilution at the outlet. In these experiments we were able to achieve temperatures from 500 to 6000° K.

The efficiency of the discharge chamber is a function of the current strength and of the gas flow rate. With direct current an increase in the flow rate leads to increased efficiency. However, the higher the absolute value of the efficiency, the smaller the relative increase in efficiency with increasing flow rate. For example, an increase in the flow rate from 50 g/sec to 100 at a current of 800 A leads to a 7% increase in efficiency, while the subsequent increase in the flow rate to 200 g/sec increases efficiency by only 3%. A rise in current with a constant flow rate leads to a drop in efficiency as a result of the increased thermal losses. The efficiencies of the plasmatron designs under consideration, despite the presence of cooled electrodes, are rather high (for example, on a current of 900 A and an air flow rate of 250 g/sec, the efficiency amounts to 82% when T = 2500° K).

Thus these studies have demonstrated that a plasmatron—given a discharge chamber of small dimensions—can be produced to operate at high voltages, it exhibits a long service life of continuous operation, and its efficiency exhibits rising characteristics and a wide range of temperature regulation.

This type of plasmatron can be recommended for various industrial installations requiring the heating of a gas to 5000° K.

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Institute of Heat and Mass Transfer AS BSSR, Minsk