The air-plasma units produced currently have the following specifications: no-load voltage of the power source \( U_{nl} = 300 \) V, working voltage \( U_w = 150-200 \) V, working current \( I_w = 100-300 \) A, and water cooling. According to the existing safety standards such units can be used only for mechanized cutting.

There is considerable scope for using air in plasma cutting units intended for manual work. However, in this case it is necessary to restrict the no-load voltage to 180 V, which creates problems in exciting and maintaining a stable arc.

In units of the PPD-1-65, PRP-1, KDP-1, KDP-2, OPR-6, and ÊDR-60 types, the arc is excited in nitrogen with \( U_{nl} = 180 \) V. When a mixture of gases with different ionization potentials \( \varepsilon_i \) is used, the gas with the lowest value of \( \varepsilon_i \) is ionized to the greatest extent. Thus, in order that the effective potential of the mixture be close to the potential of the component having the lowest value of \( \varepsilon_i \), it is necessary to have about 5-50% of the component gas in the mixture [1]. Therefore, under identical conditions it should be somewhat easier to strike an arc in air (mixture of \( N_2 \) and \( O_2 \)) than in \( N_2 \) alone.

Stability of the arc and cutting process is ensured if there is a particular relationship between the angles of inclination of the static volt-ampere characteristics of the arc and power source [2]:

\[
K_s = \frac{\partial U_a}{\partial I_a} - \frac{\partial U_p}{\partial I_p} = \rho_a - \rho_p > 0, \tag{1}
\]

where \( K_s \) is the coefficient of stability of the power source—arc system; \( U_a, U_p \) are the voltages of the arc and power source, respectively; \( I_a \) is the arc current; \( \rho_a, \rho_p \) are the dynamic resistances of the arc and power source, respectively.

Power sources with flat (types VKS-500-1, VD-301, PSO-500) or drooping (same types but connected in blocks of two or more in series) external volt-ampere characteristics always have \( \rho_p < 0 \). Therefore, in order to fulfill condition (1) it is necessary that \( \rho_a > 0 \), i.e., the working zone of the arc volt-ampere characteristic should be either horizontal or slope upwards.

With a view to developing manual plasma cutting units, a prototype has been made with a special plasma-tron at the All-Union Scientific-Research Institute of Autogenous Welding Equipment. Two VDG-501 rectifiers with a total \( U_{nl} = 180 \) V are used as the power source. The resistance in the idling arc circuit is regulated by means of ballast rheostats, and the arc is excited with the help of an OSPZ-2M-1 oscillator. Air is supplied at a pressure of 1.5–2.5 kgf/cm\(^2\) for stabilizing the working arc after exciting the intermediate arc. The air consumption is 60–120 liters/min.

**TABLE 1**

<table>
<thead>
<tr>
<th>Idling arc current, A</th>
<th>Air consumption, liter/min</th>
<th>No. of failures in exciting the arc, %</th>
<th>Excitation stability rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>75–80</td>
<td>25–35</td>
<td>&gt;60</td>
<td>Unstable</td>
</tr>
<tr>
<td>60–60</td>
<td>10–15</td>
<td>&lt;1.5</td>
<td>Stable</td>
</tr>
<tr>
<td>45–60</td>
<td>5–10</td>
<td>Her</td>
<td></td>
</tr>
</tbody>
</table>

Studies have shown that the idling arc can be excited with ease in the air stream. The consumption of air in this case is somewhat less than when the main arc is in operation. It was noticed that the air flow rate has a great effect on the stability of the excitation process (Table 1).

Excitation stability depends to a great extent on the gap \( h \) between the copper ring (which has a zirconium insert) and the internal surface of the nozzle. The magnitude of the gap determines the speed, nature of flow, and direction of the gas stream and causes variation in the resistance of the idling arc \( \Delta R_{id} \). An increase in \( \Delta R_{id} \) raises the idling arc voltage, and if \( U_{nl} \) is limited, leads initially to instability and finally to disruption of the idling arc.

The transition of the arc from the idling through an intermediate to a working condition is sometimes accompanied by dual arcing. It was found that this effect is more pronounced when the idling arc current \( I_{id} \) is higher and the gap \( h \) is smaller. This can be avoided if the arc is excited when the unit is located directly above the edge of the metal to be cut. In this case the factors which cause bending of the arc and contact with the nozzle walls are eliminated. Dual arcing can also be avoided at the transition stage by reducing the idling arc current to 25-30 A. However, stable excitation of the arc with such low values of current is possible only in an argon atmosphere. The consumption of argon is not affected when the no-load voltage \( U_{nl} \) of the power source is lowered to 180 V.

If the air flow is increased, it is possible to somewhat reduce the radius of the conducting zone of the idling arc and also prevent curving of the arc at the moment when the cutting head approaches the metal edge. However, this rate of flow is so high that it is impossible to excite the idling arc.

Based on the successful introduction of various manually operated plasma cutting units (types KDP-2, KPM-1 and "Vikhr") which have air cooling and current ratings of 150–300 A, the problem of developing manually operated air-cooled air-plasma cutting units can be reduced to one of ensuring the reliability of zirconium cathodes under the given operating conditions.

The life of zirconium cathodes is determined by their thermochemical interaction with the plasma-forming medium (consisting of \( O_2 \) and \( N_2 \)), as well as the intensity of cooling. Cooling is necessary to ensure that the temperature of the cathode spot does not exceed the level at which the refractory \( ZrO_2 \) and \( ZrN \) compounds begin to dissociate [3]. In view of the facts that the specific heat of air is only 13–24\% lower than that of water over the temperature range of 0 to 2200°C [4], the velocity of the cooling air stream is one order of magnitude higher than with water, and a reduction in the arc current lowers the intensity of cathode heating [1], it is clear that stable operation of an air-cooled cathode is definitely feasible.

Two designs of the cathode unit (Fig. 1) were tested on the prototype plasmatron. The first design had a hollow copper ring of the type used in conventional water-cooled plasmatrons, while the second design had a solid copper ring. As was to be expected [5], the cathode with a massive solid ring worked three to five times longer than the cathode with a hollow thin-walled ring. However, the total working duration of the cathode insert was small and did not exceed 20–22 minutes with 15 excitations. This is evidently insufficient under manual operating conditions where interruptions are inevitable because of the physical limitations of workers.

The permissible current density for air-cooled zirconium cathodes was calculated from the known value for water-cooled zirconium cathodes [2] taking into consideration the specific heats of air and water. The permissible current density was found to be \( i_{per} = 20-25 \, A/mm^2 \). The actual current density during