

b) The high speed camera method gives the dependence of the frequency on the arc current. Taking current values between 6 and 16 A the frequency changed from 100 to 600 Hz.

c) The measurement of the background intensity near the spectral line as a function of the arc current shows an increase with the current.

The previous measurements show that the intensity of the spectral line increases with the volume of the plasma and opposite. The increase of the plasma volume can be connected with the increase of the residence time of particles, which results in an increase of the spectral line intensity.

The decrease of the plasma volume can be connected with higher centrifugal force and with the increase of the background.

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3.14 Influence of iodine vapour on the radial temperature distribution of the arc burning in the atmosphere of nitrogen and argon

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In some earlier papers^{1, 2, 3, 4}) we have discussed the influence of the arc atmosphere components on the radial temperature distribution. Our considerations were made in terms of the Elenbaas-Heller equation for the energy balance of plasma

$$\sigma(T) E^2 = -\frac{1}{r} \frac{d}{dr} \left(r \kappa \frac{dT}{dr} \right), \quad (1)$$

where σ is the electrical conductivity, E the axial electrical field strength, r the radial coordinate, κ the heat conductivity, and T the temperature.

An essential fact in the energy balance of plasma is the effect of chemical reactions among the components of the arc atmosphere on the heat conductivity of the arc plasma. The total heat conductivity κ is made up of several parts, i. e.

$$\kappa = \kappa_n + \kappa_r + \kappa_t, \quad (2)$$

where κ_n is the classical heat conductivity, κ_r the heat conductivity due to the transport of reaction energy, and κ_t the heat conductivity due to the thermal diffusion. The contribution of κ_r to the total heat conductivity is by far the greatest one, and therefore, the radial distribution of temperature in the arc plasma depends essentially on the chemical reactions of the plasma components.

To bring out this statement more distinctly, we considered the effect of the reaction energy on the radial temperature distribution using a series of ideal theo-

retical cases. For the moment, let us suppose that the chemical reaction occurs in one temperature region of the arc. Due to the chemical reaction, i. e. reaction of dissociation or recombination, the heat conductivity of the system will be changed. The conditions of equilibrium and energy of reaction determine the shape of heat conductivity function $\kappa = \kappa(T)$ and the maximal value of the temperature $T_{\kappa \max}$. Let us assume that these temperatures $T_{\kappa \max}$ are in different cases at 2000, 4000, 6000 and 7000 K, and the temperature dependence of the corresponding heat conductivities are as those shown in Fig. 1. Then, by introducing the heat function

$$S(T) = \int_0^T \kappa(T) dT$$

into Elenbaas-Heller equation, we are able to solve this equation according to Maecker⁵⁾ and determine theoretically the radial temperature distribution in the arc. The corresponding S -functions for our assumed cases are represented in Fig. 2,

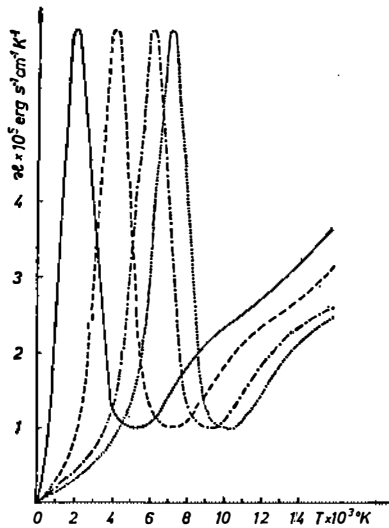


Fig. 1 Heat conductivity functions $\kappa = \kappa(T)$ in the case of κ_{\max} at 2000, 4000, 6000 and 7000 K.

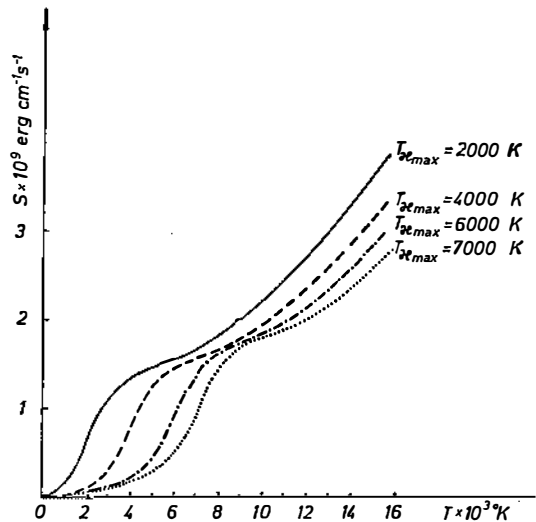


Fig. 2 Heat functions $S = S(T)$ of reactions at 2000, 4000, 6000 and 7000 K corresponding to functions given in Fig. 1.

and the results of theoretical calculations of radial temperature distributions in the arc plasma is represented in Fig. 3, for the case when the temperature in the arc axis is $T_0 = 8000$ K. We can notice that, if the temperature in the arc axis (T_0) is higher than the one ($T_{\kappa \max}$) where the heat conductivity has a maximal value, a core of high temperature will be produced in the arc center. This core becomes wider as T_0 is higher than $T_{\kappa \max}$.

Let us also consider the case when the heat conductivity as a function of temperature shows two maxima. Such example is in the case of two parallel chemical reactions occurring in the arc plasma, i. e. $A_2B \rightleftharpoons AB + A$, and $AB \rightleftharpoons A + B$, or in the case of the mixture of two gases when one gas dissociates in the lower,

and the second in the higher temperature region, i. e. $A_2 \rightleftharpoons A + A$, and $B_2 \rightleftharpoons B + B$. Theoretically supposed shape of heat conductivity function with two maxima is shown in Fig. 4. The corresponding radial temperature distribution, when the temperature in the arc axis has the value $T_0 = 8000$ K, is given in Fig. 5. Now, we can notice that, if the temperature corresponding to one maximum is below the one in the arc axis, than a core of high temperature is again formed in the arc center.

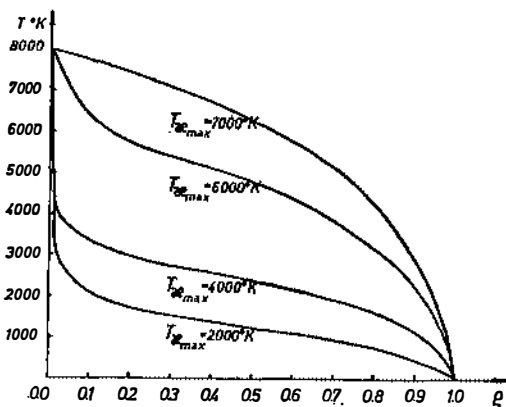


Fig. 3 Theoretical curves of radial temperature distribution in the case of κ_{\max} at 2000, 4000, 6000 and 7000 K and the temperature in the arc axis $T = 8000$ K.

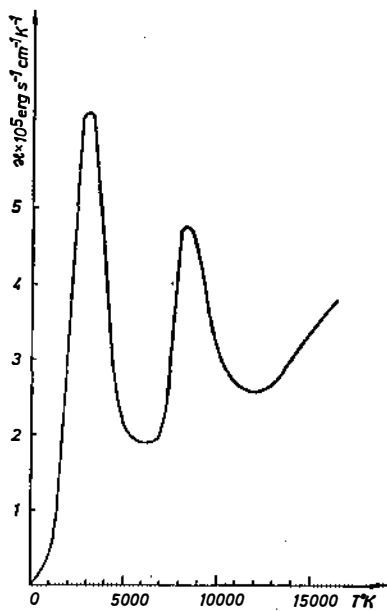


Fig. 4. Heat conductivity function in the case of two reactions with κ_{\max} at 3000 and 8000 K.

To prove these theoretical considerations, we observed experimentally the influence of the iodine vapour addition on the radial temperature distribution in the arc burning in argon, respectively in nitrogen atmosphere. The heat conductivity curve of iodine vapour as a function of temperature, reaches the maximum at about 1500 K. Likewise, the heat conductivity function of the mixture of iodine and argon must possess the maximum in the same temperature region. Here, we have theoretical case of the heat conductivity function possessing one maximum where the temperature (T_0) in the arc axis is considerably higher from that one ($T_{\kappa_{\max}}$) at which iodine molecules dissociate, i. e. recombine. Therefore, according to our theoretical considerations it can be expected that the zone of high temperature will be formed in the arc axis. The temperature in the arc plasma will decrease abruptly towards the peripheral zones of the arc. This is confirmed experimentally and can be seen in Fig. 6 (curve Ar + J_2).

In the case of nitrogen in mixture with iodine, we have the theoretical case where the curve of heat conductivity possesses two maxima. The first one corresponds to the recombination of iodine atoms, and the second, corresponding to the recombination of nitrogen atoms is placed in the temperature region of about 7000 K. As a consequence of these two maxima, corresponding to reactions of dissociation, i. e. recombination, according to theoretical considerations, the core of higher temperature will be formed too. And indeed, the expected radial temperature dis-

tribution in the arc burning in mixture of nitrogen and iodine is obtained (Fig. 7). From the zone of high temperature the curve of radial temperature distribution will decrease abruptly towards the peripheral zones in which the iodine atoms recombine.

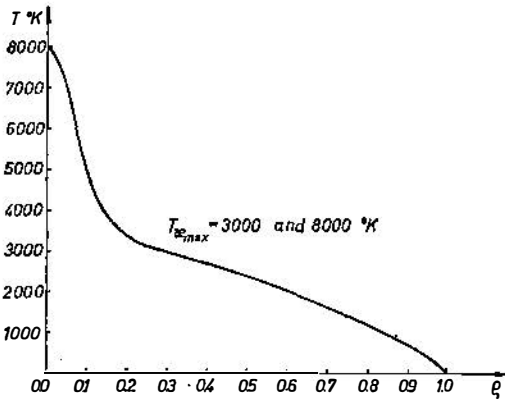


Fig. 5 Theoretical curves of radial temperature distribution in the case of two reactions corresponding to Fig. 4 and the temperature in the arc axis $T=8000$ K.

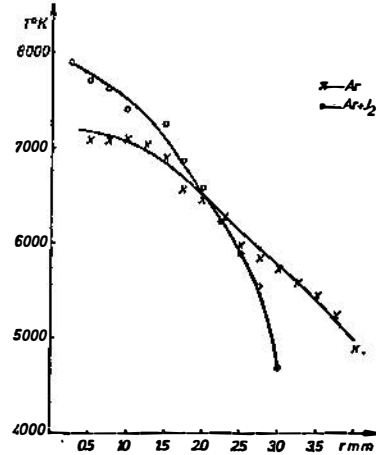


Fig. 6 Experimental curves of radial temperature distribution of d. c. arc burning in argon, respectively, argon-iodine mixture.

The core of higher temperature in the arc axis is broader in the mixture of nitrogen and iodine vapour than in mixture of argon and iodine vapour (Fig. 8). This is the consequence of the existing maximum in the heat conductivity function

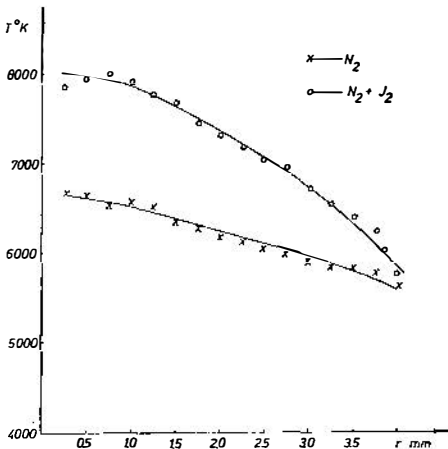


Fig. 7 Experimental curves of radial temperature distribution of d. c. arc burning in nitrogen, respectively, nitrogen-iodine mixture.

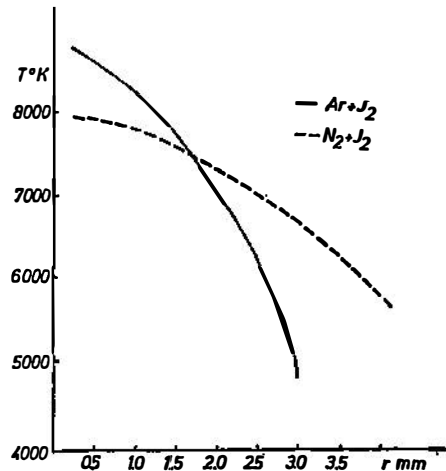


Fig. 8 Comparison of radial temperature distributions of d. c. arc burning in the argon-iodine, respectively, nitrogen-iodine mixture.

due to recombination of nitrogen atoms in molecules in the arc axis temperature. In the case of argon, which is a monoatomic gas, such maximum does not exist in the arc axis temperature.

We can notice that the experimental results of radial temperature distribution in the zone from the arc axis to the periphery are not quite identical with those obtained according to Maecker theory⁵⁾. Nevertheless, the theory informs us about the shape of the curve of radial temperature distribution in the freely burning arc, so that we can obtain an insight into the effect of the atmosphere components on the arc characteristics.

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3.15 Measurement of temperature and metal vapour density in a welding arc

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1. Introduction

The measurement of temperature and metal vapour density is necessary in order to understand the physical processes in the welding arcs which is important for industrial applications. Very few measurements of that kind have been published.

A metal inert gas welding arc (MIG) in the range 200 — 300 A was observed burning vertically between a 1.2 mm iron wire as anode and metal plate as cathode as shown in Fig. 1. The arc length was about 1 cm. The wire was consumed at the rate of 10 — 20 cm/s and fed continuously into the arc. The cathode plate was