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# DISTRIBUTION OF THE HEAT FLUX TO THE CALORIMETRIC PROBE IN A MULTIARC PLASMA REACTOR

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The article presents the distribution of the heat flux to the calorimetric probe in a multiarc plasma reactor.

The quality of treatment of materials in multiarc plasma reactors is decisively influenced by the speed with which the plasma jets mix [1, 2]. It is known that the heat flux from the gas to the calorimetric probe is a function of the temperature and of the speed of the gas. Therefore the nature of its distribution gives some indication of the speed with which the plasma jets mix.

The present work represents an investigation of the distribution of the heat flux from the gas to the calorimetric probe in a widely used plasma reactor [3, 4] in dependence on the flow rate of the plasma-forming gas and the power supplied to the plasmatrons.

The experimental device (Fig. 1) consists of the plasma reactor 1 with three plasmatrons 2 and linear calorimetric probe (LCP) 3 mounted in the upper part of the plasma reactor. In the lateral wall of the reactor along its generatrix at an angle of 0, 30, and 60° there are three rows of holes with dielectric inserts 4. The plasmatrons are of the electric-arc type, with linear arrangement and self-adjusting arc length, and their channel diameter is $8 \cdot 10^{-3}$ m. The overall electric power used for the electric discharge varied between 40 and 60 kW. The overall flow rate of plasma-forming gas – air was varied within the limits $1.5 \cdot 10^{-3}$ to $4.5 \cdot 10^{-3}$ kg/sec. Raw material was not charged into the reactor. The arrangement of the LCP and the method of measuring the heat flux were described in detail in [5, 6].

Figure 2 shows the distribution of the heat flux in the diametral section of the reactor $3 \cdot 10^{-2}$ and $7 \cdot 10^{-2}$ m from the point of intersection of the longitudinal axes of the plasmatrons. The LCP entered the reactor at the angle $\alpha = 60°$ (Fig. 1). Analogous distributions of the heat flux were obtained with $\alpha$ equal to 0 and 30°.

An analysis of the obtained data showed that in the cross section of the reactor at a distance of 0.3 of the bore from the imaginary point of intersection of the axes of the plasmatrons (point A) the distribution of the heat fluxes is very nonuniform. With decreasing power supplied as well as with decreasing flow rate of plasma-forming gas the gradient of the heat flux over the radius decreases. However, this also entails a decrease of the fraction of the longitudinal section of the reactor occupied by flux with high enthalpy. With increasing distance from the place of collision of the plasma jets the heat fluxes are further equalized in the cross sections of the reactor.

It follows from the oscillograms that at a distance of $3 \cdot 10^{-2}$ m from point A there are one-dimensional flows directed toward the periphery of the reactor. It may be assumed that these flows originate in conse-

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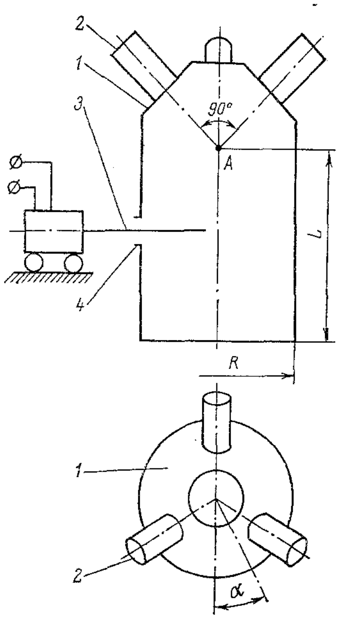

Fig. 1

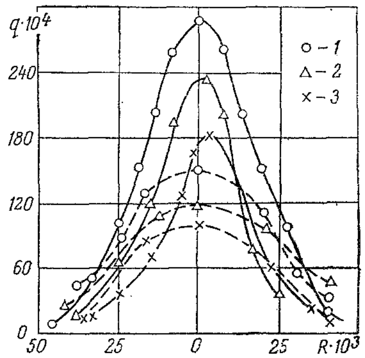


Fig. 2

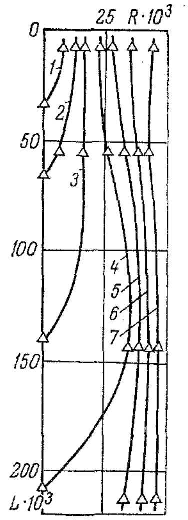


Fig. 3

Fig. 1. Diagram of the experimental device.

Fig. 2. Distribution of the heat flux in the diametral section of the reactor: 1) N = 60 kW, G = 4.5 · $10^{-3}$ kg/sec; 2) 50 and 3 · $10^{-3}$; 3) 50 and 1.5 · $10^{-3}$. Solid curves: L = 3 · $10^{-2}$ m; dashed curves: L = 7 · $10^{-2}$ m. q · $10^4$, W/$m^2$; R · $10^3$ m.

Fig. 3. Heat flux distribution in the longitudinal reactor section with N = 50 kW and G = 3 · $10^{-3}$ kg/sec: 1) 1600; 2) 1200; 3) 1000; 4) 800; 5) 600; 6) 400; 7) 200 kW/$m^2$ · L, m.

quence of the fact that the range of the plasma jets under the conditions of the experiment exceeds the radius of the reactor. In fact, the range of the plasma jets, calculated by the equation [7] $h = kd(v_2/v_1)(\rho_2/\rho_1)^{1/2}$ for the conditions of the experiment, confirms the assumption.

With increasing distance from point A, with decreasing power of the plasmatrons and decreasing flow rate of plasma-forming gas, the transverse one-dimensional flows are attenuated. At a distance of 7 · $10^{-2}$ m with N = 40 kW and G = 1.5 · $10^{-3}$ kg/sec no one-dimensional flows to the periphery of the reactor were detected. This is probably due to the fact that at this distance the plasma jets manage already to expand in the direction parallel to the reactor axis. The heat flux in the cross section of the reactor becomes more uniform. The ratio of the maximum heat flux at the center to the minimum heat flux at the reactor wall decreases by a factor of three. The area in the central part of the reactor occupied by uniform heat flux density increases considerably.

The heat flux distribution in the longitudinal axial sections of the reactor is also of complex nature (Fig. 3). At first the isolines of the heat flux approach the reactor axis, then they recede from it toward the wall, and again approach the axis. Such a nature of the isolines at the initial reactor section may be due to one-dimensional flows which make an angle of 45° with the reactor axis. The return of the isolines to the axis in the lower part of the reactor is due to the removal of heat through the wall to the environment.

Figures 2 and 3 present the static distribution of the mean heat flux densities over the radius and the length of the reactor. However, numerous oscillographic records indicate that there are large-scale pulsations of the heat flux with a frequency of 0.2-1 Hz at a length of one to two bore diameters. The amplitude of such pulsations attains 70% of its mean value. This is probably caused on the one hand by the gasdynamic pulsation of the plasma jets in consequence of the shunting of the electric arc in the plasmatron channels, and on the other hand by random fluctuations of the speed when the plasma jets collide on the reactor axis.

Thus, the experimental investigations showed that the heat flux density from the gas to the calorimetric probe at the initial section of a multiarc plasma reactor is considerably nonuniform at least up to 0.7 bore diameter. One-dimensional flows directed toward the periphery of the reactor were discovered.

Reduced flow rate of plasma-forming gas and reduced power of the electric arc cause more rapid equalization of the heat flux in the cross sections of the reactor. However, in that case the absolute value of the heat flux density and the fraction of the reactor filled with high-enthalpy gas are reduced.

## NOTATION

N, electric power of the plasmatrons, kW; G, flow rate of the plasma-forming gas, kg/sec; q, heat flux density from the gas to the probe, $W/m^2$; L, length of the reactor, m; $\alpha$, angle of insertion of the probe in the cross section of the reactor, deg; h, range of the plasma jet, m; d, diameter of the anode channel, m; K, experimental coefficient equal to 2.2; $v_1$, $v_2$, linear velocity of the total flux and of the plasma jet, respectively, m/sec; $\rho_1$, $\rho_2$, gas density in the total flux and in the plasma jet, respectively, $kg/m^3$.

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# THERMODYNAMIC PROPERTIES OF NORMAL PROPYL ALCOHOL AT ATMOSPHERIC PRESSURE

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Data from the literature on density, speed of sound, and isobaric specific heat are analyzed and approximated. Isochoric specific heat and adiabatic and isothermal compression coefficients are calculated for normal propyl alcohol at atmospheric pressure for the temperature range 146.95-370.35°K.

The systematization and compact presentation of information (compression of experimental data) on experimental studies of the thermodynamic properties of aliphatic alcohols over wide temperature and pressure ranges, and especially at atmospheric pressure, is a task of great practical importance.

There exist only a few review articles and handbooks [1-4] containing collections of experimental data on the density and isobaric specific heat of normal propyl alcohol at atmospheric pressure, encompassing the temperature range 253-363°K. The most complete is handbook [3]. But it should be noted first, that not all properties are presented in those studies, and second, the collected results encompass only the time period up to 1970. Practically no one had reported data on the speed of sound previously. The literature contains no in-

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