6. V. D. Seleznev, P. E. Suetin, and N. A. Smirnov, "Separation of a binary gas mixture throughout the Knudsen number range," Zh. Tekh. Fiz., 45, No. 7, 1499-1502 (1975).
7. V. Zhdanov, Yu. Kagan, and A. Sazykin, "Effect of viscous momemtum transfer on diffusion in a gas mixture," Zh. Eksp. Teor. Fiz., 42, No. 3, 857-866 (1962).
8. A. A. Tarin, "Investigation of the diffusion separation and conductivity of gas mixtures in a capillary tube with their efflux into a vacuum," Author's Abstract of Candidate's Dissertation, Physical-Mathematical Sciences, Sverdlovsk (1978).
9. N. D. Pochuev, V. D. Seleznev, and P. E. Suetin, "Flow of a binary gas mixture with arbitrary accommodation of a tangential impulse," Zh. Prikl. Mekh. Tekh. Fiz., No. 5, 37-41 (1974).
10. V. D. Akin'shin, S. F. Borisov, B. T. Porodnov, and P. E. Suetin, "Experimental study of the flow of low-density gases in a capillary sieve at different temperatures," Zh. Prikl. Mekh. Tekh. Fiz., No. 2, 45-49 (1974).

HYDRODYNAMIC CHARACTERISTICS OF A FLAT-FLAME INJECTOR TORCH WITH A VORTEX INJECTOR

R. K. Narkhodzhaev and E. R. Kasparov

UDC 662.951.23/27:532.5

The optimum twist of an injected flow is established through studies of a function describing the hydrodynamic characteristics of a flat-flame burner.

Existing designs of torches do not meet the requirements of flame decontamination technology. We have developed a new design of flat-flame injector torch with a vortex injector [1, 2]. Presented below are the results of studies of the hydrodynamic characteristics of the proposed torch, which consists of a cylindrical mixing chamber and a slit diffuser. The mixing chamber is equipped with rotary nozzles which allow the twist parameter to be changed from 0 to 2.84.

It is well known that the width of the jet increases more rapidly in the case of swirled flow [3]. Allowing for this, we investigated the velocity distribution in the outlet section of the mixing chamber diffusion nozzle in relation to the twist parameter n for values of n equal to 0, 1, and 2. Velocity curves recorded at these parameter values were compared with the curves obtained with axial location of a nozzle of the same capacity (Fig. 1). Analysis of the curves shows that the velocity of the mixture leaving the diffuser is extremely nonuniform in the case of axial location of the nozzle. Here, the velocity distribution in the outlet section of the mixing chamber is uneven, with the maximum occurring on the torch axis. The existence of this maximum leads to deformation of the flow by the diffuser walls a considerable distance from the outlet section of the mixing chamber and results in a velocity maximum in the axial region of the diffuser outlet section.

The character of the velocity nonuniformity changes little for a slightly twisted flow ($0 < n < 1$), but there is an increase in velocity in the peripheral zones of the slit, with a maximum on the axis. The velocity field smooths out at $n = 1$, and at $n = 2$ the flow may be considered uniform at the slit outlet, although it has a certain axial trough in the mixing chamber. This can be explained by the fact that the rate of development of the cylindrical flow increases with an increase in n. It begins to be deformed by the walls of the diffuser at the outlet of the mixing chamber and gradually degenerates into a plane flow with a uniform velocity distribution. A further increase in the parameter n leads to an increase in the size of the velocity trough in the mixing chamber section, and a nonuniform flow — with the velocity maximum in its peripheral zones — is produced at the slit outlet.

It follows from the results of the experiment that the optimum value of the twist parameter for the model being examined, ensuring uniform flow of the mixture from the slit, should be found within the range $n = 2 \pm 0.1$. The uniformity of the flow in the outlet sec-

Mid-Asian Branch of the All-Union Scientific-Research Institute of Gas Utilization in the National Economy and of Underground Storage of Petroleum, Petroleum Products, and Liquefied Gas (VNIIpromgaz). Translated from Inzhenerno-Fizicheskii Zhurnal, Vol. 41, No. 4, pp. 708-711, October, 1981. Original article submitted September 16, 1980.

 0022-0841/81/4104-1146$07.50

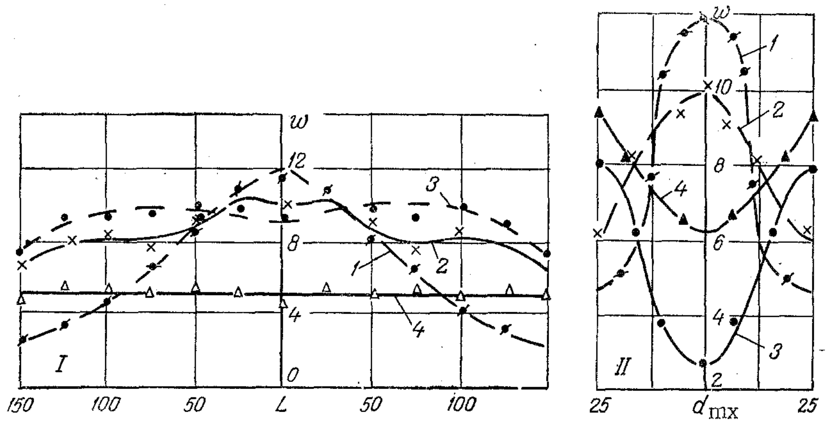

Fig. 1. Velocity field in the outlet section of the mixing chamber I and diffuser II at different values of n: 1) axial location of the nozzle; 2) n = 0; 3) 1; 4) 2. w, m/sec; L, mm.

tion of the burner is one of the main indices of the quality of the preparation of the mixture for combustion. However, this characteristic does not allow us to judge the hydrodynamic characteristics of the injector and torch as a whole. Such a characteristic would first of all be the fluid resistance of the torch. It is well known that the fluid resistance of aerodynamic systems depends on several factors: the roughness of the walls bounding the flow, convergence or divergence of the channel, any deformation of the flow resulting from a change in its direction. The burner model being examined is an aerodynamic system, and all of these factors also affect the fluid resistance in this case.

We experimentally determined the relation between the flow twist parameter and the coefficient of fluid resistance, which was calculated from the formula

$$\xi = \frac{2g\Delta P_{st}}{\rho w_2^2}\left(\frac{f_1}{f_2}\right)^2 - \left(\frac{f_1}{f_2}\right)^2 + 1. \tag{1}$$

Several studies of the effect of the parameters of a swirled flow on the fluid resistance of a burner [3-5] have noted that fluid resistance increases with an increase in the rate of swirling. However, these studies were concerned with burners in which air was forced through special swirlers. In the model being examined here, the flow is twisted as a result of the energy of the active gases of a stream introduced in a certain manner into a mixing chamber, with the vortical gas—air flow subsequently degenerating into a plane flow as a result of the installation of a slit diffuser. It is also assumed that such a combination of system elements should introduce certain changes into the character of the hydraulic-characteristic functions and that these changes will be reflected first of all in a change in the fluid resistance and, hence, a change in the injecting capacity of the mixer.

The results of study of the functions $w_2 = f(n)$, $\xi = f(n)$, $\alpha' = f(n)$ are shown in Fig. 2. The tests were conducted under isothermal conditions. The gas was simulated by air at a constant excess pressure of 50 kPa. We measured the velocity of the gas—air mixture at the burner orifice, the consumption of the air simulating the gas, and the static pressure gradients in the inlet section and the orifice. The air—fuel ratio was determined from the measured velocity in the outlet section of the diffuser, the consumption of air simulating the gas, and the quantity of air theoretically required to burn 1 m^3 of the gas ($A_t = 27.35$ for a propane—butane mixture) from the formula

$$\alpha' = \frac{f_2 w_2 - v_{ag}}{A_t V_{ag}}. \tag{2}$$

Analysis of the results of the tests, shown in Fig. 2, indicates that, in the case of diffuser system, a change in the parameters of the vortex in the mixing chamber leads to a change in the fluid resistance along the gas—air channel in the burner. An increase in the twist parameter n increases the fluid resistance of the model, with the increase in ξ being slight (within the range 0.6-1.2) at n = 0-2. Thus, the change in the injection coefficient for torches with an open flame operating under atmospheric conditions remains within the

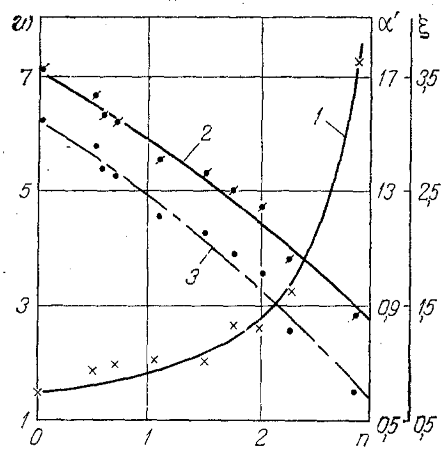

Fig. 2. Hydraulic characteristics of the burner at different swirling rates: 1) $\xi = f(n)$; 2) $w = f(n)$; 3) $\alpha' = f(n)$.

norm. Despite the fact that the increase in fluid resistance is accompanied by a decrease in the air—fuel ratio, $\alpha' > 1$ at values close to $n = 2$. For this twist parameter, the angles of inclination of the nozzles α and β are 55 and 30°, respectively. At $n > 2$, the value of ξ approaches the extremum, while α' becomes much less than 1. This does not satisfy the requirements established for full-premixing burners. In the tests, the twise parameter $n = 2.84$ corresponded to nozzle inclinations $\alpha = 70°$ and $\beta = 30°$. The extremum of the function $\xi = f(n)$ at these values indicates that a further increase in the twist will lead to a sharp decrease in the longitudinal velocity component, and $w \to 0$ as $\alpha \to 90°$.

Methods of determining the hydraulic characteristics of vortex gas burners were the subject of [6-9], in which analytical formulas were presented for calculating the coefficient of fluid resistance from a known twist parameter. Since these formulas were obtained by the authors for swirlers of a special geometry used in blast burners (tangential, spiral, axial, etc.), we thought it would be useful to mathematically analyze the results of the tests. The analysis yielding the following empirical relations for the functions $\xi = f(n)$ and $\alpha' = f(n)$: $\xi = 0.06n^{3.6} + 0.8$; $\alpha' = (2.5 - 0.5n - 0.1n^2)^{1/2}$. These formulas are valid at values of $n = 0$–2.84.

NOTATION

n, twist parameter of gas—air flow; f_1, inlet section of diffuser (section of mixing chamber), mm^2; f_2, outlet section of diffuser (section of slit), mm^2; w, flow velocity, m/sec; ΔP_{st}, difference in static pressures in the sections, Pa; ξ, coefficient of fluid resistance; α', air—fuel ratio; A_t, injection coefficient (amount of air theoretically required for combustion of 1 m^3 of gas), m^3/m^3; V_{ag}, consumption of air simulating the gas, m^3/h; α, projection of angle of inclination of nozzles onto a transverse plane, deg; β, projection of angle of inclination of nozzles onto a frontal plane, deg; d_{mx}, diameter of mixing chamber; ρ, flow density.

LITERATURE CITED

1. R. K. Narkhodzhaev, I. Kh. Irgashev, and E. R. Kasparov, "Use of a gas for flame treatment of livestock quarters against pathogens," in: Utilization of Gas in the National Economy [in Russian], Vol. 5, VNIIÉGAZPROM, Moscow (1976), pp. 31-35.
2. I. Kh. Irgashev, R. K. Narkhodzhaev, and E. R. Kasparov, "Injector torch," Inventor's Certificate No. 688773, Byull. Izobret., No. 36 (1979).
3. G. N. Abramovich and S. Yu. Krasheninnikov, Turbulent Mixing of Gas Streams [in Russian], Nauka, Moscow (1974).
4. R. B. Akhmedov, "Rate of swirling of a gas flame in vortex burners," Teploenergetika, No. 6, 17-22 (1962).
5. R. B. Akhmedov and F. K. Rashidov, "Effect of structural elements on the aerodynamic and hydraulic characteristics of the flow-through part of vortex burners," in: Utilization of Gas in the National Economy [in Russian], Vol. 5, Fan, Tashkent (1965), pp. 13-18.

6. V. P. Golubtsov, "Calculating the resistance of vortex burners," Gazov. Promst., No. 1, 52-54 (1975).
7. F. K. Rashidov, "Determining the coefficient of fluid resistance of vortex burners," Gazov. Prom., No. 3, 55-56 (1978).
8. S. N. Shagalova, "Determination of the swirl parameters and fluid resistance coefficients of different burner swirlers," Teploenergetika, No. 7, 88-89 (1970).
9. A. I. Shchelokov, "Design features of injector torches with a swirled air flow," in: Utilization of Gas in the National Economy [in Russian], Vol. 5, Fan, Tashkent (1969), pp. 171-178.

AUTOMATION OF THERMAL FLUX MEASUREMENTS WITH A LINEAR CALORIMETRIC PROBE

S. P. Polyakov and A. T. Neklesa

UDC 537.562.083

A system is developed to automate measurements of specific thermal flux in a plasma jet using a linear calorimetric probe. The effect of turbulence and gas flow rate on thermal flux is studied.

Contact methods are widely used to study thermal fluxes in plasma jets [1].

The linear calorimetric probe method was developed for measurement of local thermal flux values in a plasma of arbitrary configuration [2]. The essence of the method is that the probe (Fig. 1) is moved at constant velocity in the plasma jet in the direction in which the thermal flux distribution is being measured, and its local value at each point of the jet is given by

$$q = \frac{G_1 c}{\pi d_1} \frac{dt}{dx}. \tag{1}$$

In calculating q with Eq. (1), it is necessary to differentiate the experimentally obtained water temperature in the probe as a function of coordinate. As a rule, this operation is either performed manually using graphical methods or by using a computer, in which case the differentiation error can reach 30% [3]. This error can be decreased significantly by using analog differentiation circuitry. This reduces the error to 1% [3].

If we transform Eq. (1) to the form

$$q = \frac{G_1 c}{\pi d_1} \frac{1}{v_s} \frac{dt}{d\tau}, \tag{2}$$

then measurement of the thermal flux density distribution over coordinate can be reduced to differentiation of the signal recorded by the thermocouple with respect to time.

In calculating q with Eq. (2) significant dynamic error can develop in t(x) if the probe velocity is chosen incorrectly. After several mathematical operations, the condition [4]

$$\frac{t_1 - t}{T_1} = \frac{dt}{d\tau} \tag{3}$$

provides us with the value of v_m for the probe:

$$v_m \leqslant \frac{\eta_{q_1}}{1-\eta_{q_1}} \frac{t_m}{T_1 dt/dx}. \tag{4}$$

To calculate v_m with Eq. (4), we initially determine T_1 from a curve obtained by applying a П-shaped thermal pulse to the probe. The value of dt/dx is estimated experimentally by moving the probe through a plasma at the smallest possible rate.

Dnepropetrovsk Metallurgy Institute. Translated from Inzhenero-Fizicheskii Zhurnal, Vol. 41, No. 4, pp. 712-716, October, 1981. Original article submitted February 27, 1980.

