theoretical values, especially remarkable for He and air, is perhaps due to admixtures beyond our control. The values for N_2 and CO_2 are within 5% of their theoretical predictions. The experimentally obtained relative cross section for CO_2 was multiplied by the cross section of Ar [2], yielding thus an absolute scattering cross section of CO_2.

The scattering cross sections of Ar and CO_2 and the experimental values of I_r, I_r' were substituted in (4) and (5). The magnitude of I_s for jets inundated in the atmosphere is negligibly small. This was concluded on the basis of proximity of the values of σ_i, obtained in the vacuum chamber and in the one-component CO_2 jet at atmospheric pressure. The injector nozzle was moving in the horizontal plane in two mutually perpendicular directions making possible scanning of the jet. The intensity of the scattered light was measured at the angle 90° to the incident ray.

In Fig. 2 we show the distribution of the concentration of CO_2 in the inundated two-component gaseous jet as found by means of the described method. The cut of the nozzle is in the plane x = 10 mm, the measurements were carried out in the central plane of the jet.

On the coordinate plane the circles indicate the points of measurement of partial concentrations of gases in the jet, the curves (isobars) are identified by the partial pressure of CO_2 in percentage of the atmospheric pressure.

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LAWS OF COLORING OF PHOTOCHROMIC SOLUTIONS USED IN EXPERIMENTAL HYDRODYNAMICS

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It is known that the introduction of small quantities of photochromic compounds into a liquid flow makes it possible to obtain colored tracks in the solution by directional irradiation at a certain wavelength. Recording the positions of the tracks at subsequent moments of time makes it possible to study the structure of the flow and the phenomenon of flow about bodies of different shapes [1-6].

In using the method of photochromic visualization of flows, it is very important to know the optical characteristics of the tracks in the solution. These properties depend on the type of photochromic compound used, its concentration in the liquid, the wavelength and intensity of the activating radiation, and other parameters.

Here we study the photochromic characteristics of an aqueous solution of spiropyran 11. We determined the length of the colored track in relation to the energy of the activating laser radiation and the concentration of photochromic substance in the solvent. We established the range of concentration of the photochromic substance and of other parameters necessary to reliably record a colored track.

1. Experimental Unit. Photochromic substances (PCS) may have molecules with different chemical structures and may be capable of changing color under the influence of laser radiation of a certain wavelength in different types of solvents, such as water, alcohol, acetone, benzene, etc. [7, 8]. Here we study the properties of an aqueous solution of spiropyran (one of the most promising photochromic compounds). The color of spiropyran in solution changed under the influence of laser radiation with a wavelength λ = 347.4 nm.

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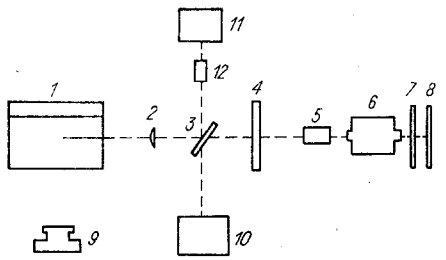

Fig. 1

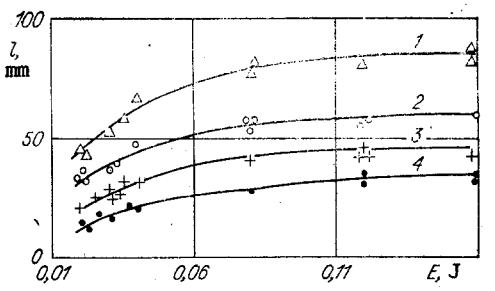

Fig. 2

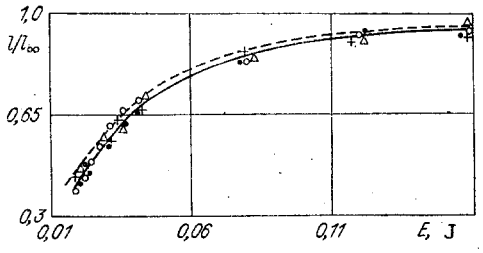

Fig. 3

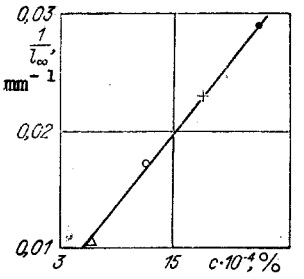

Fig. 4

With the absorption of radiation, the molecules of the initially colorless (initial) form A of spiropyran change to the excited state A^*. The molecules then pass through several intermediate states to the colored (red) form B. As a result of either heating or the absorption of radiation of the same wavelength, the molecules B may either return to the initial state A or change into some nonphotochromic product. Accumulation of the colored form B leads to the formation of a colored track in the liquid. The lifetime of the track after the radiation is cut off is 0.1-0.5 h [9].

The nearly inertialess appearance of color – occurring in 10^{-8}-10^{-18} sec – the long lifetime, and the fairly high photochromic sensitivity of spiropyrans make them promising for use in the visualization of liquid flows.

Our goal here is to experimentally study the quantitative laws of photochromic coloring of a working liquid so as to permit calculation of the length of the colored track ℓ as a function of the energy E of the pulsed laser radiation and the concentration c of the photochromic substance in solution.

Experiments were conducted on the unit depicted in Fig. 1. The source of laser radiation was a ruby laser 6. The laser was used without an outlet reflector, which allowed us to increase the quality factor of the resonator formed by the ends of a rod and 99% reflecting mirror 8. In the giant-pulse generation regime, this made it possible to significantly reduce the heating of nonlinear crystal CDP 5 with the conversion of radiation at λ = 694.7 nm to the second harmonic at λ = 347.3 nm. The second harmonic is necessary to effect the photochromic reaction. We used a passive gate of the KS-19 type as the Q-factor modulator.

The form, duration, and number of peaks in the laser pulse were monitored with a high-speed S8-17 recording oscillograph 11. The oscillograph was fed signals from a photodiode 12 through a beam-splitting plate 3. The signals arriving from the photodiode were calibrated according to radiant energy E by IKT-1N and IMO-2 meters 10.

The maximum energy of the laser pulse with one-peak generation was 0.04 J at λ = 347.3 nm. The number of peaks in one pulse ranged from 1 to 6, which increased the total energy of the UV radiation from 0.04 to 0.24 J.

The energy of the UV radiation of the laser was reduced (E < 0.04 J) with one-peak generation by changing the orientation of the CDP crystal relative to the radiation. An FS-6 filter 4 was installed after the crystal to prevent radiation with λ = 694.7 nm from affecting the solution of photochromic substance.

Power density in the interaction region was increased by focusing the multimode beam with a spherical quartz lens having a focal length of 400 mm, a neck diameter of 1.2 mm, and a caustic length of 50 mm. The radiation then entered a quartz dish 1 with the test solution, forming a colored cylindrical trace which was recorded by a camera 9. The pictures were taken on "Mikrat-200" film, while the negatives were analyzed on a microdensitometer.

2. Dependence of the Length of the Colored Track on the Energy of the Laser Pulse with Different Concentrations of PCS. The laser was operated in regimes generating one pulse or a series of pulses. The time between the pulses in one series was 10^{-6} sec, which was considerably shorter than the time of the thermal transition of the substance from the colored to the colorless form after cutoff of the radiation.

Figure 2 shows the experimental dependence of ℓ on E of the laser pulses for concentrations $c = 6 \cdot 10^{-4}$, $12 \cdot 10^{-4}$, $18 \cdot 10^{-4}$, and $24 \cdot 10^{-4}$% (lines 1-4). The concentration was determined by the ratio of the weight of PCS to the weight of the solvent. In analyzing the negatives, as ℓ we took the distance from the wall of the dish to the point at which the density of the track was twice as great as the noise level of the rest of the negative. Films with the same sensitivity, contrast, and spectral characteristics were used in all of the experiments. The sensitivity of the densitometer also remained constant. With a change in radiant energy ($0 < E \leq E_{max}$, $E_{max} = 0.04$ J), the resulting values of ℓ correspond to one-pulse activation of the solution. At $E > E_{max}$, the experimental points correspond to multiple-pulse action with $E = nE_{max}$ ($n = 2, 3, 4$).

It follows from Fig. 2 that with an increase in the concentration of PCS at a constant energy of activating radiation, the length of the colored track decreases. This occurs because an increase in the number of radiation-absorbing photochromic molecules leads to an increase in the absorption of radiant energy. It should be noted that at $c < 6 \cdot 10^{-4}$%, the density of the colored track on the resulting photographs becomes low enough to possibly cause difficulties in analyzing the results of hydrodynamic experiments. Thus, to obtain colored tracks with sufficient density on the photographs and to obtain the required length in setting up hydrodynamic experiments in water, the range of PCS concentration should be $5 \cdot 10^{-4}$% $< c < 30 \cdot 10^{-4}$%. An increase in activation energy to values >0.12 J does not appreciably increase the length of the track, while with an increase in E for each value of c the length of the colored track approaches a certain limiting value ℓ_∞. Thus, when analyzing experimental data, it is best to change over to the dimensionless track length ℓ/ℓ_∞ [10, 11].

The solid line in Fig. 3 shows the dependence of ℓ/ℓ_∞ on E constructed from the data in Fig. 2. It is evident that all of the experimental points lie satisfactorily on a single universal curve, regardless of the PCS concentration. In Fig. 3, the values E = 0.08, 0.12, and 0.16 J correspond to two-, three-, and four-pulse irradiation of the solution.

Figure 4 gives the dependence of the change in the quantity $1/\ell_\infty$, determined from the tests, on the concentration c. This dependence is represented in the form

$$1/l_\infty = \alpha c + \beta,$$

where $\alpha = 10$ mm^{-1}, $\beta = 0.005$ mm^{-1}.

The experimentally obtained curve in Fig. 3 (solid line) can be approximated well by the relation

$$l/l_\infty = (E - E^*)/E$$

shown by the dashed line in Fig. 3, where $E^* = 0.011$ J.

Thus, the following formula can be used to calculate the length of the colored track in hydrodynamic experiments employing photochromic visualization of a flow of an aqueous solution of spiropyran with a PCS concentration $5 \cdot 10^{-4}$% $< c < 30 \cdot 10^{-4}$% and a UV laser-pulse activation energy 0.01 J $< E <$ 0.12 J,

$$l = (\alpha c + \beta)^{-1}(E - E^*)/E. \qquad (2.1)$$

Here, $\alpha = 10$ mm^{-1}, $\beta = 0.005$ mm^{-1}, $E^* = 0.011$ J.

It should be expected that Eq. (2.1), with different values for the constants α, β, and E^*, will also be valid for calculation of the length of the colored track in liquids composed of different photochromic compounds in different solvents.

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THREE-DIMENSIONAL FLOW OF A HYPERSONIC DUSTY GAS OVER A WING

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The atmosphere always contains an impurity of fine solid particles (dust) in some concentration. This generates interest in investigating what happens when bodies fly through clouds of such particles, and also the possible change of aerodynamic characteristics. By using approximate theories of hypersonic flow [1] and the usual simplifications of the theory of two-phase flow [2], we can investigate the problem analytically.

A number of papers (e.g., [3, 4]) have examined hypersonic flow of a dusty gas over bodies of simple shape under the assumption that the presence of the impurity does not influence the gas flow. Flow over a thin wedge allowing for the mutual influence of the phases was investigated in [5].

In passing through the bow shock the gas parameters change sharply, but the parameters of the impurity particles remain continuous [5, 6]. According to the degree of accommodation of their velocity and temperature to the corresponding values of the carrier phase, we distinguish two limiting regimes of two-phase flow: "frozen," when the accommodation proceeds only slowly and the changes of particle parameters are negligible, and "equilibrium," where accommodation proceeds very rapidly in a narrow relaxation zone near the shock [6], and the phase parameters are the same in the main part of the field.

The present paper uses the thin-shock-layer method [1, 7] to study three-dimensional hypersonic flow over a short wing at finite angle of attack in the intermediate regime when the relaxation zone occupies the entire shock layer adjoining the windward surface of the wing. The particle velocity, temperature, and concentration change markedly across the shock layer. However, in reality, because of the high gas density in the layer, the influence of

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