4. R. E. Powe, C. T. Carley, and E. H. Bishop, Trans. ASME, Ser. C: J. Heat Transfer, 91, No. 3, 310 (1969).
5. R. E. Powe, C. T. Carley, and S. L. Carruth, Trans. ASME, Ser. C: J. Heat Transfer, 93, No. 2, 210 (1971).
6. J. R. Custer and E. J. Shaughnessy, Trans. ASME, Ser. C: J. Heat Transfer, 99, No. 4, 596 (1977).
7. T. H. Kuehn and R. J. Goldstein, Trans. ASME, Ser. C: J. Heat Transfer, 102, No. 4, 768 (1980).
8. C. H. Cho, K. S. Chang, and K. H. Park, Trans. ASME, Ser. C: J. Heat Transfer, 104, No. 4, 624 (1982).
9. B. Farouk and S. I. Güceri, Trans. ASME, Ser. C: J. Heat Transfer, 104, No. 4, 631 (1982).
10. Y. T. Tsui and B. Tremblay, Int. J. Heat Mass Transfer, 27, No. 1, 103-111 (1984).
11. M. C. Charrier-Mojtabi, A. Mojtabi, and J. P. Caltagironi, Trans. ASME, Ser. C: J. Heat Transfer, 101, No. 1, 171 (1979).
12. B. É. Vasilik, B. B. Petrazhitskii, M. A. Rozanov, and L. N. Shchukin, Tr. Mosk. Énerg. Inst., No. 588, 24-30 (1982).
13. B. Tremblay and Y. T. Tsui, IEEE Trans. Power Appar. Syst., TPAS-103, No. 3, 668-672 (1984).
14. Z. Rotem, Int. J. Heat Mass Transfer, 15, 1679-1693 (1972).
15. O. G. Martynenko and Yu. A. Sokovishin, Natural-Convection Heat and Mass Transfer: Bibliographic Index [in Russian], Parts 1 and 2, Minsk (1982, 1983).
16. V. M. Paskonov, V. I. Polezhev, and L. A. Chudov, Numerical Simulation of Heat- and Mass-Transfer Processes [in Russian], Moscow (1984).

EXPERIMENTAL STUDY OF THE PROCESS OF ESTABLISHMENT OF PHOTOABSORPTION-INDUCED CONVECTION

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The times required for establishing photoabsorption-induced convection in a cell containing an absorbing liquid by a vertically propagating laser beam are measured. The results obtained are compared with available theoretical estimates.

1. The absorption of powerful laser radiation in an absorbing medium causes photoabsorption-induced convection (PAC) to appear near the region of heating [1, 2]. The low threshold of PAC distinguishes it from other types of free convection. The laser beam is a unique, stationary, continuous, volume, penetrable source of heat. It has the characteristic feature that as a result of the thermal self-action in the absorbing medium the characteristics of the beam itself change.

The thermalization time of the laser radiation, determined by the molecular absorption time of a radiation quantum in the medium (in this case a liquid) and by the collision time of the molecules, is obviously much shorter than the times characteristic for the appearance of PAC. The times for establishing different states of PAC in a liquid were determined in [3, 4] ($Pr \gg 1$): 1) $t_v = D^2/\chi$ for the case of weak ($Pe \ll 1$, $Re \ll 1$) and moderate ($Pe \gg 1$, $Re \ll 1$) convection; 2) $t_v = D/v$ for developed convection ($Pe \gg 1$, $Re \gg 1$).

It was noted that as the intensity of the beam of heating radiation increases the process of establishing convective motion can acquire an oscillatory character.

Experiments on photoabsorption-induced convection, induced by horizontal [3] and vertical [5] beams of laser radiation in a gas, have been performed. In so doing, however, the velocities of the convective flows were not measured, and the establishment of motion was judged from indirect data.

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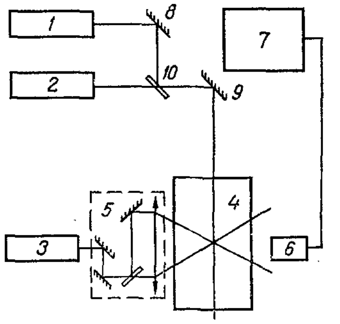

Fig. 1

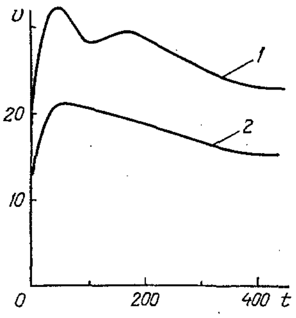

Fig. 2

Fig. 1. Layout of the experimental setup: 1, 3) He−Ne laser; 2) YAG laser; 4) cell with liquid; 5, 6, 7) components of the laser Doppler anemometer manufactured by the DISA company; 5) beam former, 6) photomultiplier; 7) signal-processing block; 8, 9) mirrors; 10) beam splitting plate.

Fig. 2. Establishment of the velocity of photoabsorption-induced convection (mm/sec) as a function of the time (sec) for different powers of the heating radiation: 1) 80 W; 2) 25 W.

2. In this work, the flow velocities of photoabsorption-induced convection, arising as a result of absorption of a vertically propagating laser beam by the liquid, were measured with the help of a laser Doppler anemometer. The times for establishing motion were measured, and the transient processes were recorded.

PÉS-4 silicone liquid was used ($\rho = 1100$ kg/m^3, $\nu = 4.5\cdot$m^2/sec, $\alpha = 5.94$ m^{-1}, $C_p = 1863$ J/(kg•°K), $k = 0.147$ W(m•°K), Pr = 627). This liquid was chosen because of its low coefficient of absorption at the wavelength of the radiation 1.06 μm and low chemical activity.

The powerful laser radiation (Fig. 1) propagated vertically from top to bottom through a glass cell filled with the PÉS-4 liquid. The dimensions of the cell were 70 × 70 × 300 mm, and the column of liquid was 200 mm high.

The position of the heating beam was monitored with a He−Ne laser beam (0.63 μm, 0.4 mW) which was combined with the heating beam with the help of an optical system.

The source of powerful radiation was a continuous aluminum−yttrium garnet laser (YAG), lasing at a wavelength of 1.06 μm with a power of up to 80 W. The diameter of the beam, broadened as a result of the thermal self-action, equalled 10 mm.

The velocity was measured with the help of a laser Doppler anemometer manufactured by the DISA company.

3. The times for establishing photoabsorption-induced convective motion in the PÉS-4 liquid were measured in the experiment for different powers of the heating laser radiation.

As is evident from Fig. 2, the establishment of motion as the power of the heating radiation is increased acquires, in accordance with [3, 4], an oscillatory character. This is due to the inertial nature of the fluid flow, which desynchronizes the velocity on the axis of the beam and the temperature. As long as the velocity is low the convective flow does not have time to remove the heat, overheating appears at the center of the beam, and the temperature rises up to values exceeding the stationary value. The force pushing out the liquid increases, the liquid is accelerated up to velocities higher than in the stationary state, and this in its turn causes the temperature to drop and reduces the pushing force.

In the process of establishing PAC in this experiment two characteristic times which are independent of the power of the heating radiation can be identified. The first is the time for switching on the motion $t_{v1} \sim z/v$, whose measured value is ~ 20 sec, and the second is the time for a stationary value of the velocity to appear, determined by the establishment of thermal processes in the cell owing to heat conduction, $t_{v2} \sim 200$ sec.

The corresponding Peclet numbers lie in the range Pe = $(7\text{-}25)\cdot 10^2$, while Reynolds numbers Re = 1-4. This makes it possible to identify this case of convection as a transient state between moderate and developed PAC.

NOTATION

t_V, time for establishing the motion; D, a characteristic size; v, velocity of convective motion; ν, kinematic viscosity; μ, dynamic viscosity; c_p, heat capacity; k, coefficient of thermal conductivity; α, coefficient of absorption of radiation; $\chi = k/(\rho C_p)$, coefficient of thermal diffusivity; ρ, density; $Pe = vD/\chi$, Peclet's number; $Re = vD/\nu$, Reynolds number; $Pr = \mu C_p/k$, Prandtl's number; and z, height of the column of liquid.

LITERATURE CITED

1. B. M. Berkovskii and L. P. Ivanov, Izv. Akad. Nauk SSSR, Mekh Zhidk. Gaza, No. 5, 128-135 (1971).
2. N. E. Galich, Zh. Tekh. Fiz., 50, No. 6, 1196-1202 (1980).
3. B. P. Gerasimov, V. M. Gordienko, and A. P. Sukhorukov, Zh. Tekh. Fiz., 45, No. 12, 2485-2493 (1975).
4. B. P. Gerasimov, V. M. Gordienko, and A. P. Sukhorukov, Inzh.-Fiz. Zh., 36, No. 2, 331-336 (1979).
5. R. A. Chodzko and S. C. Lin, AIAA J., 9, No. 6, 1105-1112 (1971).

FLOW OF MONOTONIC RAREFIED GAS ALONG THE CLOSED PART OF THE CONTOUR OF A SLOT CHANNEL

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The asymptotic behavior of flows of strongly rarefied gas in a slot channel is constructed, and the region of applicability of the results obtained is determined for different cases of flows.

The asymptotic behavior of flows of the Heel-Shaw type constructed in [1] for a planar slot channel is unsuitable for describing he motion of rarefied gas near closed and open parts of the cylindrical surface S bounding the slot channel along the contour.

To analyze flows within the boundary layer formed near the open part of the contour of a slot channel, a dimensionless orthogonal coordinate system $\xi = x_1/H$, $\eta = x_2/H$, $\zeta = x_3/H$ is introduced, where x_1 is measured along the contour Γ, corresponding to the intersection of the surface S with the median plane S_0 of the channel, x_2 is the coordinate along the normal to the contour Γ in the plane S_0; x_3 determines the distance of this point from the plane S_0, and, H is the height of the slot channel. One can talk about the asymptotic behavior of the boundary-layer type if the effective width b of the layer in which the effect of the "special" characteristics is significant is much smaller than the scale L of the flows in the plane S_0, i.e., $b/L \ll 1$. It is evident that the curvature K of the contour Γ is of the order of L^{-1} (or less). Thus, $bK \ll 1$, while $\lambda K = O(Kn_L)$. For this reason, in order to obtain an idea of the characteristic features of flows in a boundary layer, only the first term of the expansion introduced in [1] with respect to the small parameter Kn_L need be retained, neglecting the curvature K, and therefore, the curvature of the coordinate lines $\eta = \text{const}$, i.e., the flow may be regarded as local, assuming that outside the boundary layer ($\eta \to \infty$) the flow along the ξ axis is uniform. In other words, the flow of a rarefied gas along the ξ axis is studied in the region $-\infty < \xi < \infty$, $0 < \eta < \infty$, $-0.5 < \zeta < 0.5$.

As will be shown below, flows of rarefied gas in a slot channel have the property that the long-range action, which consists of the fact that for $Kn_H \gg 1$ the effect of the boundary S extends to distances much greater than the height of the channel ($b \gg H$), while in the continuum limit $Kn_H \to 0$, $b = O(H)$. This makes it possible to restrict the analysis to states corresponding to values $\alpha = \sqrt{\pi}H/3\lambda \to 0$, when the behavior of the gas is described quite well by any model equation, including the simplest linearized Bathanger, Gross, Crook (BGC model) model [2]

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