magnitude less at the same temperatures. Physically, this means that, in periodic heating even at low frequencies, temperature differences are produced close to the sensor surface at small distances, which are difficult to realize in the steady method (this requires too narrow a gap: for toluene at 30°C and 20 Hz, $l = 27\ \mu$). Therefore, the heat flux is much larger with respect to the radiant flux in the nonsteady method than in the steady-state method, and increases with frequency.

As already noted, in steady methods to determine the fraction of the energy transferred by radiation, it is necessary to vary the gap between the plates producing the heat flux through the sample material, which involves very great complication both of the apparatus and of the experiment itself in the case of experiments at high temperatures. In the nonsteady method, the fraction of radiant energy may be determined, in principle, by varying the frequency. This is only possible in practice in the low-IR region, where the fraction of radiant energy is of a measurable size. Special measuring equipment must be developed for such an experiment. In the available apparatus at frequencies above 20 Hz, radiation may only be detected at high temperatures.

NOTATION

λ, heat conduction of the medium; ρ, density of the medium; c_p, specific heat at constant pressure; $b = \sqrt{\lambda c_p \rho}$, coefficient of thermal activity of medium; c, specific heat of foil material; m, foil—sensor mass; s, foil surface area (one side); W, power input to foil by electrical heating; ω, angular frequency of a current heating foil; x, y, z, rectangular coordinates; T(x), temperature of medium; $\bar{\bar{T}}$, mean temperature of medium; $\tilde{T}(x)$, complex amplitude of temperature pulsations of medium; T_1, foil temperature; $\bar{T}_1$, mean foil temperature; $\tilde{T}_1$, complex amplitude of temperature pulsations of foil; q(x), radiant energy flux in medium; Q, radiative—conductive energy flux from foil surface; l, damping length of temperature wave; σ, Stefan—Boltzmann constant; n, refractive index of medium; α, absorption coefficient of medium; $Bi = 4\sigma n^2 \bar{T}_1^3 l/\lambda$, Biot number; i, imaginary unity; R, reflective index of foil surface; $d = cm\sqrt{\omega}/s$, parameter characterizing heat-inertia properties of foil.

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EXPERIMENTAL STUDY OF SPECIAL FEATURES OF HEAT AND MASS TRANSFER IN A TWO-COMPONENT LOW-TEMPERATURE HEAT PIPE

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This paper presents results of an experimental investigation of the characteristics of a two-component heat pipe, operating with a mixture of water and ethanol.

A number of reports [1-7] have been published dealing with theoretical and experimental investigations of heat pipes in which a liquid mixture is used as the heat-transfer agent. Interest in two-component heat pipes arises mainly from the following causes:

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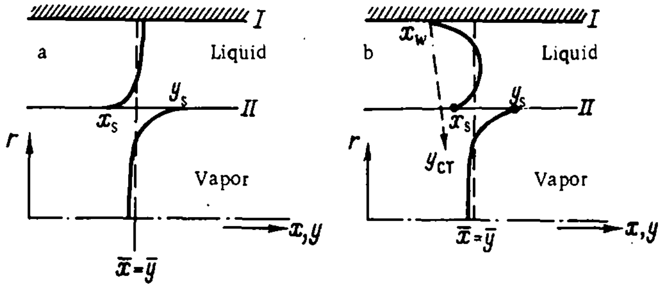

Fig. 1. Schematic variation of low-boiling component concentration x, y with heat pipe radius r, according to the diffusion model (a), and in the heat pipe evaporator (b). I) Wall; II) interface surface.

two-component heat pipes have a considerably wider range of operating temperatures than pipes using one of the chosen components;

the addition to a heat-transfer agent of even a small amount of a second component with a higher boiling temperature and better capillary properties considerably increases the heat pipe maximum power;

two-component liquid metal heat-transfer agents with a composition close to eutectic, having a comparatively low melting temperature, can appreciably simplify the start-up from a state with frozen heat-transfer agent.

For the heat-transfer agent in two-component heat pipes, one can use any liquids that do not chemically interact and for which the temperature ranges between the critical and the triple points partially overlap. A detailed analysis of the various types of binary mixtures has been given in [4].

To develop a technique for designing two-component heat pipes, and to clarify the possibility of reducing the temperature drop along the pipe typical of these, one must have a clear understanding of the heat- and mass-transfer processes in such heat pipes.

The authors of the first theoretical papers [1, 2] put forward a physical model where there is a complete separation of the two-component mixture into its constituents, in the heat pipe operating under steady conditions. The component with the higher boiling temperature (the high-boiling component) occupies part of the heat pipe on the evaporation zone side, while the second (the low-boiling) component occupies a region on the condensation zone side, and each component exists at its own saturation temperature, corresponding to the pressure in the pipe. It is assumed that the zones of the pure components are separated by a short transition section, along which there is a continuous variation in the composition and temperature of the heat-transfer agent.

However, experiments [3-7] have shown that no complete division of the components in a heat pipe is observed and a mixture of variable composition occupies practically the entire length. At present the physical model adopted to explain the mechanism of division in a two-component heat pipe is that of [4-6], which uses elements from the theory for rectification of binary mixtures. The model is based on two conditions. From the mass conservation law at any cross section of the pipe, the mass-mean composition of the phases are equal, $\bar{x} = \bar{y}$. Simultaneously, in thin layers, adjacent to the phase interface, thermodynamic equilibrium of the liquid and vapor is obtained. In fact, in heat pipes the rate of convective motion of the vapor because of phase transition is usually much less than the velocities of thermal motion of molecules of each component. Here the condition of thermodynamic equilibrium at the edge of the interface holds very rigorously [11], and the concentrations of the low-boiling component in the boundary layers x_s, y_s are determined by the equilibrium curve for the binary mixture. At the interface surface the vapor is enriched with low-boiling component. Thus, at each transverse heat pipe section there is a significant radial concentration gradient, which causes a diffusion flux M_d of low-boiling component from the liquid to the interface surface, and from the interface surface to the vapor. The distribution of low-boiling component concentration with heat pipe radius, satisfying both model conditions, is shown schematically in Fig. 1a. Since the main variation in the content of low-boiling component occurs in the very thin boundary layers adjacent to the interface surface, the concentration of low-boiling component is assumed constant in the remaining part of the pipe cross section, and coincides quite accurately with its mean-mass value $x = y = \bar{x} = \bar{y}$. The diffusion flux of low-boiling component per unit interface area per unit time is given by the expression

$$M_d = \beta_v(y_s - \bar{y}) = \beta_l(\bar{x} - x_s) = k(y^* - \bar{y}),$$

where

$$k = \frac{1}{\beta_l} + \frac{m}{\beta_v}.$$

To reach equilibrium at the interface there must be evaporation of low-boiling component from the liquid phase, and condensation of high-boiling component from the vapor phase. This process is adiabatic and equimolar. Thus, the division of the mixture results from radial adiabatic mass transfer in each heat pipe cross section, and the driving force is assumed to be the radial difference in component concentrations. The heat pipe contains a mixture of variable composition with a content of low-boiling component which increases from the evaporator to the condenser.

The degree of division Δx, which we shall take to be the difference in the mean-mass concentrations of components at opposite ends of the heat pipe, depends on the type of mixture used, its initial composition, the thermal conditions, and the total length of the heat pipe.

The diffusion model considered undoubtedly reflects more realistically the processes occurring in a two-component heat pipe than the above-mentioned complete separation model. However, even it is very much simplified, and does not take into account some of the actual general features of mass transfer during rectification of binary mixtures, nor the special features, determined by the specific heat pipe conditions. The objective of the present paper is to experimentally elucidate special features of the heat- and mass-transfer processes in the different zones of a two-component heat pipe, and, in particular, to determine the maximum thermal power of the pipe as a function of the initial composition of heat-transfer agent, the effects of heat-transfer agent composition, heat power transferred, and the intensity of evaporation and condensation processes on the degree of component division in the pipe.

Experimental Equipment and Experimental Technique. The experimental investigations were carried out in a heat pipe in which water and ethanol were used as the heat-transfer agent.

This heat-transfer agent was chosen so that one could qualitatively compare the results of these tests with the results of [3-6], where experiments were conducted on mixtures of water and alcohol. Five working mixtures with the following composition (in volume percent) were investigated: 100 of water; 75 of water—25 of ethanol; 50 of water—50 of ethanol; 25 of water—75 of ethanol; 100 of ethanol.

The tests were carried out on a single heat pipe. The cylindrical case, of type Kh18N10T stainless steel, had an outer diameter of 0.016 m, a wall thickness of 0.0015 m, and a length of 0.6 m. The wick was a perforated nickel mesh (TU16-538082-70), which was fitted closely to the inner surface of the heat pipe. One end of the case was closed off, and the other was attached to a vacuum valve of bellows type, which allowed the heat pipe to be charged repeatedly with heat-transfer agent. Three vacuum manometers were attached to the case, to measure pressure within the heat pipe cavity.

The wall temperatures were measured by means of 12 Chromel—Copel thermocouples. The thermocouples were attached in longitudinal slots on the outside wall of the case. The vapor channel temperature was measured by a movable thermocouple, which moved along the heat pipe axis. The thermocouple readings were recorded by means of a type PP-63 dc potentiometer (accuracy class 0.05) and a type ÉPP-09 potentiometric recorder. Heat was supplied to the heat pipe evaporator from an ohmic radiative heater, which was connected via a regulator and voltage stabilizer to single-phase mains (220 V, 50 Hz). The heater electrical parameters were measured by means of a type D-553 ammeter (accuracy class 0.2) and a type D-567 voltmeter (accuracy class (0.5). The heat was removed from the tube at the condenser by means of a controlled-length cooler. The thermal power of the pipe was determined from the heater and the mass flow of water in it. The increase in the water temperature was measured by means of a differential thermocouple and was regulated from the readings of two mercury thermometers (with subdivisions of 0.1°K). Mass flow rate was measured by means of a type RS mass flowmeter (accuracy class 2.5). An auxiliary heater was provided to maintain a given water temperature at the cooler entrance. The heat pipe transport zone was thermally insulated by a layer of foam plastic of thickness 70 mm.

After charging with the required amount of heat-transfer agent of each of the above compositions, the heat pipe was tested subsequently in three series of tests. In the first series of experiments we determined the effective initial heat-transfer agent composition on the maximum power transmitted by the heat pipe, and also on the level of separation of the components within it. To do this the mass flow and temperature of the

TABLE 1. Maximum Power Transmitted by the Heat Pipe

Ethanol content in the initial mixture, %	100	75	50	25	0
Max. power transmitted by the heat pipe, W	105	225	303	363	368

TABLE 2. Degree of Separation of Components in the Heat Pipe, and Mean-Mass Concentration of Ethanol in the Evaporator for the 75% Water—25% Ethanol Mixture

Max. vapor temp. in the evaporator, °K	351	357	360	378	390
Degree of separation of components, mole fraction	0,835	0,7	0,63	0,615	0,61
Mean-mass concn. in evaporator, mole fraction	0,16	0,14	0,1	0	0

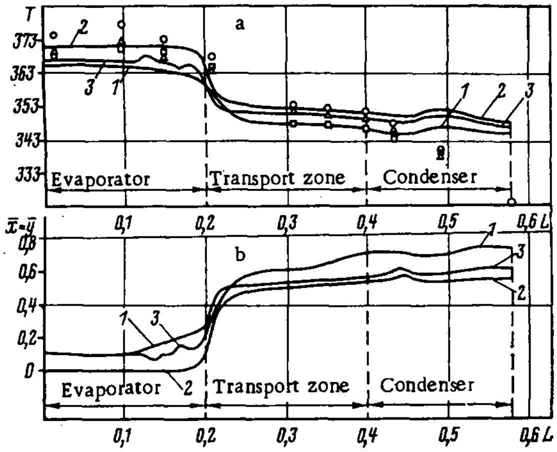

Fig. 2. Variation in vapor temperature T_V, °K (a) and of mean-mass ethanol concentration $\bar{x} = \bar{y}$, mole fraction (b) as a function of L, m, of the heat pipe, for a heater power of 300 W: 1) ethanol content in the initial mixture 25%; 2) 50; 3) 75. The heat pipe wall temperature: □) ethanol content in the initial mixture 25%; ○) 50; △) 75. L is in meters.

water at the cooler entrance were kept constant, and the heater power was increased in steps. Correspondingly, the thermal power transmitted by the pipe was increased up to its limiting value. At each of the steady-state conditions measurements were made of the temperature drop and the pressure in the vapor volume. These values were then used to determine the degree of separation in the heat pipe, using the phase equilibrium diagram. In the second series of tests we determined the influence of the power transferred by the pipe on the degree of separation of the components within it. The heat pipe pressure was kept constant by controlling the heater power and the flow rate of water through the cooler, and the power transferred was increased by steps. In each of the steady-state conditions we determined the degree of separation. The objective of the third series of tests was to determine the influence of the intensity of the evaporation and condensation processes on the degree of separation. During the tests the pressure and the power transferred by the heat pipe were kept constant. The intensity of evaporation and condensation were varied by varying the areas of the heat pipe evaporator and condenser.

Experimental Results and Discussion. The tests to determine the maximum power transferred as a function of the initial mixture composition confirmed the suggestion of the authors of [2, 4] that even small additions of high-boiling component with better capillary properties to the heat-transfer agent appreciably increased the maximum power transferred by the heat pipe. As can be seen from Table 1, this parameter increases with increase of water content.

The maximum power for the mixture of 25% water—75% ethanol was greater by a factor of two than for pure ethanol. This can be explained by the fact that water, having a higher surface tension coefficient, is predominant in the evaporator, as a result of mass transfer and division of components. The available capillary head, and, correspondingly, the maximum thermal power both increase. It should be noted that the relative increase in power with increase in water content decreases. The values obtained for the 75% water—25% ethanol mixture and for pure water are practically equal.

TABLE 3. Measured Drop in Vapor Temperature and Pressure in the Heat Pipe for the 75% Water—25% Ethanol Mixture

Power, W, transferred by the heat pipe	196	260	312	350
Pressure, N/m^2	$1{,}71 \cdot 10^5$	$1{,}71 \cdot 10^5$	$1{,}72 \cdot 10^5$	$1{,}71 \cdot 10^5$
Temp. drop in vapor space, °K	20,5	20,5	21	20,5

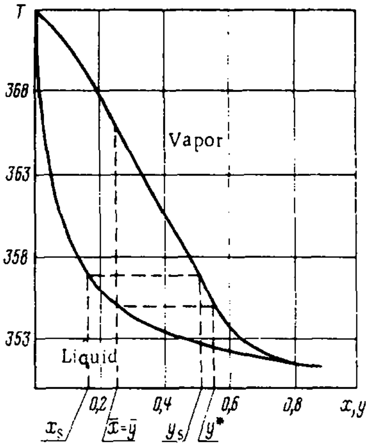

Fig. 3

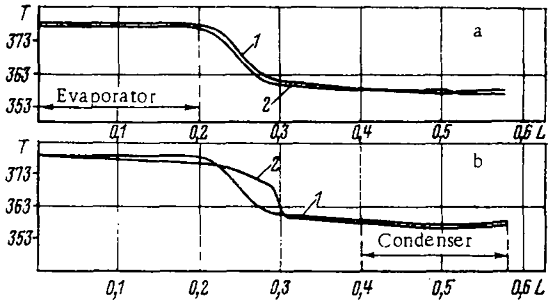

Fig. 4

Fig. 3. Phase equilibrium diagram, temperature T,°K, versus composition x, y, mole fraction, of a binary water—ethanol system, for pressure $P = 9.81 \cdot 10^4$ N/m^2.

Fig. 4. Distribution of vapor temperature T_V, °K, along the length L, m, of a heat pipe, with variation in intensity of the surface of evaporation (a) and condensation (b): 1) condenser 0.2 m; 2) 0.37 m; b) 1) evaporator length 0.2 m; 2) 0.3 m.

Figure 2a, by way of example, shows the vapor temperature along the heat pipe, measured under steady-state conditions at a heater power of 300 W, for various initial heat-transfer agent compositions. From these measurements, carried out using the movable thermocouple, one can elucidate some special features on the temperature distribution along the pipe, which were not noted in [1-7]. As can be seen from Fig. 2a, one can single out three basic zones in the heat pipe under steady conditions (apart from the dependence on heat-transfer agent composition): there is an almost isothermal zone, occupying the major part of the evaporator; a zone characterized by a slight nonisothermal state, which occupies part of the transport section and the heat pipe condenser, and joining these two there is a short zone with a temperature characteristic varying sharply along the length. For each regime the variation in heat-transfer agent composition along the pipe was determined by means of the phase equilibrium diagram. Figure 2b, by way of example, shows the variation in mean-mass concentration of the low-boiling component along the heat pipe, for various initial compositions of the heat-transfer agent. It can be seen that the composition of the heat-transfer agent affects the degree of separation of components. Its greatest value was obtained for the 75% water-25% ethanol mixture ($\Delta x = 0.66$ mole fraction), and its least value was obtained for the 25% water—75% ethanol mixture ($\Delta x = 0.53$ mole fraction).

From the test results it also follows that, with increase of evaporator temperature, and therefore, of pressure in the heat pipe, the degree of separation Δx decreases to a value which is quite definite for a given heat-transfer agent composition, and then remains roughly constant. Table 2 shows the values for the degree of separation of components, for various evaporator temperatures, for the 75% water—25% ethanol mixture.

For all the heat-transfer agent compositions investigated, the heat pipe evaporator is occupied by a mixture with an appreciable preponderance of water, or by pure water. With increase of temperature and pressure the content of ethanol in the evaporator diminishes. Table 2 shows values of mean-mass ethanol concentration in the heat pipe evaporator for the 75% water—25% ethanol mixture. Part of the transport section and the condenser of the heat pipe are occupied by a mixture with a preponderance of ethanol. In this zone the mass-transfer process occurs, and as a result the ethanol content somewhat increases along the zone, and the temperature falls. The mean-mass ethanol concentration here varies in the range $\bar{x} = \bar{y} = 0.5$–0.7 mole fraction. The maximum local heat-transfer efficiency, and correspondingly, the main division of the mixture is observed in a short intermediate zone (roughly 1/6-th part of the heat pipe), occupying the beginning of the transport section. The mean-mass ethanol concentration in this zone varies in the range $\bar{x} = \bar{y} = 0.05$–0.4 mole fraction. Such an extreme character in the dependence of mass-transfer efficiency on the mean mixture composition cannot be explained by the diffusion model for mass transfer suggested by the authors of [4-6]. The motive force for mass transfer in the diffusion model is assumed to be difference in concentrations of the components, as was mentioned. Here mass transfer between phases, which has an appreciable influence on the mass-transfer process, is completely neglected. In actual fact, it follows from the phase equilibrium diagram (Fig. 3) that with equality of mean-mass compositions of liquid and vapor $\bar{x} = \bar{y}$ between the phases at each transverse section of the heat pipe, there is a temperature gradient. This gradient determines the heat transfer between the vapor and the liquid. For the flow conditions of streams meeting in a heat pipe, one can assume that the heat transfer causes condensation of vapor and evaporation of liquid from the boundary layers adjacent to the phase interface surface, which are in thermodynamic equilibrium. As was noted in [8, 9], where aspects of rectification theory were described, the simultaneous occurrence of evaporation and condensation processes leads to the appearance of an additional convective mass flux of low-boiling component (in our case ethanol) from the liquid to the vapor. An expression for this, under conditions where the molar heat of evaporation is the same for the two components, can be written in the form

$$M_c = \frac{\alpha_l}{l}(y_s - x_s)(T_s - \bar{T}_l) = \frac{\alpha_v}{l}(y_s - x_s)(\bar{T}_v - T_s)$$

$$= \frac{k_T}{l}(y_s - x_s)(\bar{T}_v - \bar{T}_l).$$

Therefore, transfer of low-boiling components in the process of separation of the mixture in a two-component heat pipe should be computed as the sum of a diffusion flux M_d and a convective flux M_c:

$$M = M_d + M_c.$$

It can be seen from the phase equilibrium diagram that the temperature gradient between the phases, and correspondingly, the additional flux of material from thermal rectification are particularly significant in the range of concentration of low-boiling component $\bar{x} = \bar{y} = 0.05$–0.4 mole fraction. This explains the extremal nature of mass transfer in the two-component heat pipe, for which the greatest efficiency was observed in the zone of main separation of components. In addition, there is one more factor which, in our opinion, may promote additional improvement of mass transfer in the zone of main component separation. Since there is no external heat transfer in the transport zone of a heat pipe, and the thermal resistance to internal heat transfer in the liquid phase is appreciably less than in the vapor phase, one can suggest that the entire radial temperature drop occurs in the vapor, and the liquid temperature is constant with pipe radius, and equal to the phase interface surface temperature. Here the liquid at the wall and in the mean layers is heated, as a result of which it may boil. The vapor bubbles formed cause the liquid to move, and the mass transfer in the liquid is increased.

Measurements conducted in the heat pipe evaporator show that for the 75% water—25% ethanol and the 50% water—50% ethanol mixtures the temperature and the vapor composition are constant or vary very little along the pipe. This kind of variation of these quantities was noted even for conditions when the mean-mass concentration of ethanol here lies in the range offering the greatest mass transfer efficiency $\bar{x} = \bar{y} = 0.05$–0.4 mole fraction. The temperature curve of the heat pipe evaporator, for an initial mixture composition of 25% water—75% ethanol, is not smooth everywhere, but has several small peaks (of 1-2°K), and valleys (Fig. 2a, curve 3). However, even here the heat-transfer agent, temperature and composition are roughly constant along the length. Thus, the degree of component separation in the evaporator of a two-component heat pipe is very small for all initial compositions of heat-transfer agent.

This feature can be explained in terms of the simple qualitative model for the mass-transfer mechanism that we have proposed. If there is no mixture of components in the evaporator, then, for the reasons described above, mass transfer there will occur between the opposing streams of liquid and vapor. The layer of liquid adjacent to the phase interface surface generates vapor whose concentration of low-boiling component y_s is above the mean-mass value $\bar{x} = \bar{y}$. At the same time, the heat supply from the external heater causes vapor formation from the wall liquid layer. The possibility of such operating conditions was confirmed experimentally in [10]. This regime is normal for heat pipes with a nonmetallic heat-transfer agent at the heat fluxes and pressures of our tests. The temperature of the wall layer is above the average liquid temperature, and therefore the concentration of low-boiling component x_w there, and also in the vapor formed y_w are below the mean-mass value (see Fig. 1b). The mean-mass concentration $\bar{x} = \bar{y}$ in a given section of the evaporator is determined by the ratio of the amount of vapor, and also by the content of low-boiling component, in the fluxes arriving from the wall layer and the surface layers of liquid. With the flux from the wall layer predominant, the mean-mass concentration of low-boiling component remains almost constant along the evaporator length. And if this quantity of vapor with low content of low-boiling component is insufficient to compensate for the increase in concentration of the latter due to mass transfer from the surface layer of liquid, then the mean-mass concentration of low-boiling component increases along the evaporator length. However, this process will be considerably less intense than in the zone where the main separation of components occurs.

Table 3 shows the temperature drop along the entire pipe length, measured in a test to determine the influence of power transferred by the heat pipe on the degree of separation in it. The initial concentration of heat-transfer agent in this case was 75% water—25% ethanol, and the pressure in the pipe was $1.71 \cdot 10^5$ N/m^2. The vapor temperature in the evaporator was 389°K.

As can be seen, the total temperature drop in the vapor state is practically constant over the whole range of variation of power transmitted. For constant pressure in the heat pipe this indicates that the degree of separation of components is constant there. Similar results were obtained also for the other initial heat transfer agent compositions.

Figure 4a and b shows the vapor temperature distributions along the heat pipe, charged with a 75% water—25% ethanol mixture, obtained in the test to determine the influence of the intensity of evaporation and condensation processes on the degree of separation. The power transferred and the pressure in the pipe were, respectively, 275 W and $1.25 \cdot 10^5$ N/m^2. It can be seen that the variation in condensation intensity has practically no influence on the temperature distribution, and correspondingly, on the degree of component separation in the condenser, and also in the heat pipe as a whole. The increase in intensity of evaporation leads to some decrease in the measured temperature drop, which also means in the degree of separation in the heat pipe evaporator, and a decrease in intensity leads to an increase in the temperature drop and in the degree of separation in the evaporator. Here the total degree of separation in the heat pipe remains constant. Thus, variation in the intensity of evaporation causes only a redistribution in the efficiency of mass transfer, which determines the degree of separation, along the section in which this variation occurs. The total degree of separation of components in the heat pipe remains constant.

NOTATION

x, y, concentrations of low-boiling component in the liquid and vapor, respectively; $\bar{x}$, $\bar{y}$, mean-mass concentration of low-boiling component in the liquid and vapor, respectively; x_s, y_s, concentration of low-boiling component at the phase interface surface in the liquid and vapor, respectively; x_w, y_w, concentration of low-boiling component at the heat pipe wall in the liquid and vapor, respectively; y^*, concentration of low-boiling component in the vapor in equilibrium with $\bar{x}$; Δx, degree of separation of components; $\bar{T}_l$, mean liquid temperature; $\bar{T}_v$, mean vapor temperature; T_i, temperature of the phase interface surface; β_l, β_v, coefficient of mass-removal in the liquid and vapor, respectively; α_l, α_v, coefficient of heat-removal in the liquid and vapor, respectively; k, k_t, coefficient of mass transfer and heat transfer, respectively; l, molar heat of vaporization; m, tangent of the angle of inclination of the equilibrium line; M_d, diffusion flux of material; M_c, convective flux of material; M, total flux of material.

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BUBBLE MODE OF FLOW OF A GAS—LIQUID MIXTURE IN A VERTICAL PIPE

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V. P. Odnoral

UDC 532.529.5

The results of the measurement of the local frictional stress at the wall in an ascending two-phase stream using the electrochemical method are presented.

The need to determine the coefficients of friction and heat transfer in two-phase flows, caused by problems of nuclear power engineering and chemical technology, in particular, has led to the appearance of a large number of investigations of the integral parameters of such flows and the development of a number of semiempirical and empirical calculation methods based on them [1, 2]. The diversity of forms of flow of two-phase media, however, leads to the fact that there is presently an absence of sufficiently universal calculating methods yielding satisfactory results in the entire range of variation of the flow parameters. The problem of investigating the detailed structure of two-phase flows in order to create mathematical models which more adequately reflect the flow properties becomes urgent in this connection.

Recently, there have appeared a number of reports devoted to measuring the distributions over a channel cross section of the local velocities of the phases and the gas content, as well as the simplest pulsation characteristics of the flow [3-6]. To obtain fuller information about two-phase streams one must, in addition to expanding the range of variation of the parameters, supplement the results of the above-indicated work by the measurement of other important flow characteristics, one of which is the local frictional stress at the wall.

The goal of the present work is to determine the behavior of the coefficient of friction during the ascending flow of a gas—liquid mixture in the bubble mode and at the start of the plug mode using the electrochemical method, which allows one to determine the local shear stress at the pipe wall.

The experiments were carried out on an installation for which a diagram is presented in Fig. 1. The installation consists of a liquid-tight circulation loop having ascending and descending channels of round cross section with an inner diameter of 86.4 mm. All the measurements were made in the ascending section. The channel had transparent inserts of plastic for visual observation.

The liquid was pumped through the loop with a centrifugal pump having a maximum output of 50 m^3/h. The gas was supplied, as shown in Fig. 1c, through the cylindrical section of a porous pipe 40 mm in diameter and 80 mm long located at the entrance to the ascending channel. The liquid and gas were thermostatically controlled at a temperature of 24 ± 0.5°C ahead of the entrance to the working section. The flow rates of the liquid and gas were determined with flowmeter diaphragms. The measurements were made in the cross section lying at a distance of 4.750 m (55 diameters) from the point of gas supply. A constant pressure of 1.5 atm. abs. was maintained in the measurement cross section with the help of throttle devices at the outlet of the working section.

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