

ABSTRACTS OF DEPOSITED ARTICLES

THE MECHANISM OF BOILING

V. F. Stepanchuk and M. L. Guris

UDC 621.1.016.4

Models of bubble boiling and crisis boiling are considered, which are developed on the basis of the classical theory of boiling and the theory of polymolecular absorption films.

Since the vapors of polar liquids on a solid surface form extremely thick adsorption layers and vapor nuclei, which appear on the solid surface as a result of density fluctuations, a liquid microfilm is separated on it. The pressure of the vapor in the nuclei becomes equalized, on the one hand, by the capillary pressure on the spherical surface $\Delta P = 2\sigma/R$ and, on the other hand, by the disjoining pressure of the microlayer $\Delta P = P(h) = -\partial\omega/\partial h$, where ω is the free energy of the layer.

The thickness of the film must obviously be the same over the whole base of the bubble.

An analysis of the metastable system which ensures that a critical nucleus is produced enables one to determine the relation between the temperature of overheating of the generating layer, its thickness, and the dimensions of the bubble. As the bubble increases the vapor pressure in it rises and the thickness of the adsorbed film in equilibrium with it increases.

The bubble of vapor during the separation period has a somewhat greater radius than the capillary pressure on its surface and the disjoining pressure of the microlayer is negligibly small.

Fusion of these bubbles and of bubbles of greater size with the formation of even entire vapor cavities does not disturb the equilibrium of the system.

We now consider a bubble of vapor which does not reach the breakaway size and is in equilibrium with its adsorption film. When two or more of such bubbles merge a new bubble is obtained, the pressure of which is much less than the initial value.

The film is overheated with respect to the new pressure and evaporates. The equilibrium of the system is disturbed, and the reduction in pressure is accompanied by a thinning of the film, i.e., $\partial P/\partial h > 0$, which is a characteristic of the lability of the film. The β -film bursts open, changing the stable α -modification.

Consequently, the mechanism of bubble boiling and the boiling crisis can be explained on the basis of the common behavior of the instability of liquid microlayers.

Deposited at the All-Union Institute of Scientific and Technical Information, Reg. No. 2926-78 Dep. (Article submitted April 18, 1977; abstract submitted April 16, 1978).

A METHOD OF SIMULATING THE TURBULENT MOTIONS OF A VISCOUS INCOMPRESSIBLE LIQUID

F. N. Yasinskii and S. G. Ushakov

UDC 532.526.4

To simulate plane stationary flows of a viscous incompressible liquid, a system is proposed based on the following assumptions.

1. The motion of the medium is described by nonstationary Reynold's equations.
2. The stress tensor is a linear function of the rate of deformation tensor. The phenomenological turbulent viscosity is added to the molecular viscosity.

Translated from *Inzhenerno-Fizicheskii Zhurnal*, Vol. 36, No. 2, pp. 367-371, February, 1979.

3. The distribution of the turbulent viscosity in space is described by the differential equation [1]

$$\frac{\partial E}{\partial \tau} = - \sum_{s=1}^2 u_s \frac{\partial E}{\partial x_s} + \sum_{s=1}^2 \frac{\partial}{\partial x_s} \left((W + \alpha E) \frac{\partial E}{\partial x_s} \right) +$$

$$+ 0.2 E \frac{(E/8W)^2 + 1.4 (E/8W) + 0.2}{(E/8W)^2 - 1.4 (E/8W) + 1} \sqrt{\sum_{k=1}^2 \sum_{s=1}^2 \left(\frac{\partial u_k}{\partial x_s} + \frac{\partial u_s}{\partial x_k} \right)} - br^2 (W + lE) E.$$

Here E and W are the turbulent and molecular viscosities; τ , time; x_s , coordinates; u_s , velocity components; and α , b, and l, empirical constants.

4. The continuity equation is replaced by the artificial equation

$$\frac{\partial p}{\partial \tau} = -c^2 \sum_{k=1}^2 \frac{\partial u_k}{\partial x_k},$$

where p is the pressure and c^2 is a constant.

When the field becomes stationary this equation reduces to the usual continuity equation. By applying the build-up method and an explicit difference scheme to this system, we obtain a simple and comparatively rapid algorithm for searching for stationary turbulent fields. Numerical experiments showed that the accuracy is sufficient for practical applications.

An explicit difference scheme was used. The flow of air in industrial rooms was studied. The computational process was begun with a certain extremely arbitrary velocity field and was completed when the field practically ceased changing.

LITERATURE CITED

1. G. N. Abramovich, S. Yu. Krasheninnikov, and A. N. Sekundov, "Features of turbulent flows in the presence of volume forces and nonautosimulation," in: Turbulent Flows [in Russian], Nauka, Moscow (1974).

Deposited at the All-Union Institute of Scientific and Technical Information, Reg. No. 2923-78 Dep. (Article submitted January 9, 1978; abstract submitted May 3, 1978).

SOLUTION OF NONIDEAL CONTACT PROBLEMS OF NONSTATIONARY HEAT CONDUCTION

I. A. Zhvaniya and A. V. Kazakov

UDC 536.2

The one-dimensional problem of nonstationary heat conduction is studied when there are nonideal thermal contacts between the neighboring layers. The conjugation conditions take into account the reduced heat capacity and thermal resistance of the contact [1]. The solution is obtained by Datsev's method [2]. To determine the temperatures of the contacting surfaces, a system of Volterra integral equations of the second kind is obtained.

For a double-layer system, accurate solutions are obtained using the Laplace integral transform. The problem of the heat exchange between two semibounded bodies is analyzed as a special case. A table of the roots of the characteristic equations as a function of the nonidealness is given.

LITERATURE CITED

1. Ya. S. Podstrigach, Inzh.-Fiz. Zh., 6, 129 (1963).

2. A. Datsev, Dokl. Akad. Nauk SSSR, 101, 1019 (1955).

Deposited at the All-Union Institute of Scientific and Technical Information, Reg. No. 2922-78 Dep. (Article submitted October 25, 1977; abstract submitted May 16, 1978).

DETERMINATION OF THE EFFECTIVE DRYING MODES OF LIGHT MALT USING MATHEMATICAL SIMULATION

A. N. Kashurin, V. A. Domaretskii, and A. S. Zelepuga

UDC 66.047.7.001.57

The process of convective drying of granular material, (e.g., light malt) is described by the following set of differential equations:

$$Q \frac{\partial u_h}{\partial y} + \epsilon \rho_h \frac{\partial u_h}{\partial \tau} - (1 - \epsilon) \rho_g \frac{\partial W_g}{\partial \tau} = 0, \quad (1)$$

$$\frac{\partial u_g}{\partial \tau} = -k (u_g - u_{gs}), \quad (2)$$

$$c_h Q \frac{\partial T}{\partial y} + \epsilon \rho_h c_h \frac{\partial T}{\partial \tau} + c_g \rho_g (1 - \epsilon) \frac{\partial T}{\partial \tau} - r (1 - \epsilon) \rho_g \frac{\partial W}{\partial \tau} = 0, \quad (3)$$

where Q is the flow rate of the heat carrier, $\text{kg}/\text{sec} \cdot \text{m}^2$; u_h , u_g , and u_{gs} , moisture content of the heat carrier, the average grain of malt, and the surface of a grain, respectively, kg moisture/ kg dried material; W , average moisture content of a grain of malt per total weight, %; c_h and c_g , heat capacity of the heat carrier and a grain, $\text{J}/\text{kg} \cdot \text{deg}$; T , temperature of the heat carrier, $^{\circ}\text{K}$; τ , time, sec ; r , heat of vaporization, J/kg ; ϵ , porosity; y , a coordinate (the height of the layer), m ; and k , drying factor, sec^{-1} . For the boundary conditions we have $T(\tau, 0) = f(\tau)$, $u_h(\tau, 0) = u_h^0$, $T(0, y) = T_0$, $W_g(0, y) = W_0$, $u_T(0, y)$, and on the basis of the experimental empirical relations

$$k = k_0 (i - \varphi) \exp [m (T - T_1)], \quad u_{gs} = [u_g^0 - b (T - T_1)] \varphi,$$

where φ is the relative moisture content of the heat carrier, the set of equations (1)-(3) was solved numerically on the Minsk-32 computer. The purpose of the solution was to obtain the minimum flow rate of the heat carrier x , which occurs in the drying agent flow equation

$$Q = x \rho_g (1 - \epsilon) \int_0^{y_0} \frac{\partial W(y, \tau)}{\partial \tau} dy + Q_0, \quad \text{starting from the conditions for the optimum electrical energy cost,}$$

expended on blowing the layer of material with the heat carrier, the heat for heating the latter, and the payment for the working time.

TABLE 1. Results of the Numerical Solution of the Problem

Theoretical quantities	Time, h									
	0	1	2	3	4	5	6	7	8	9
u_g , upper	0,754	0,71	0,67	0,63	0,56	0,48	0,382	0,28	0,778	0,084
u_g , lower	0,754	0,62	0,51	0,41	0,30	0,22	0,135	0,076	0,037	0,014
T , upper	303,0	303,7	305,4	307,5	310,0	314,0	318,0	324,0	328,2	332,0
T , lower	312,4	319,9	315,0	317,1	319,6	322,0	325,6	328,8	332,7	335,7
y_c , m	1,0	0,96	0,93	0,88	0,82	0,78	0,72	0,66	0,62	0,59
Q , $\text{kg}/\text{sec} \cdot \text{m}^2$	0,96	0,98	1,04	1,10	1,17	1,23	1,21	1,16	0,89	0,34
$E\varphi(\tau)$, $\text{kW} \cdot \text{h}$	0	0,28	0,516	0,905	1,58	2,47	3,91	5,43	6,86	7,4
$E\varphi(\tau)$, $\text{kJ} \cdot \text{h}$	0	0,25	0,49	1,01	1,29	1,84	2,66	3,54	4,57	5,29

We introduced limitations on the drying cycle time with respect to the initial temperature and the final relative moisture content of the drying agent on the basis of preliminary experiments.

As a result of calculations, by choosing values of the coefficient x we obtained $x_{opt} = 172$ kg heat carrier/kg moisture, and the corresponding temperature and moisture content of the layer of malt on the boundaries, the height of the layer, the operating parameters, and the energy cost in the process as a function of time (see Table 1).

Deposited at the All-Union Institute of Scientific and Technical Information, Reg. No. 2921-78 Dep. (Article submitted February 27, 1976; abstract submitted May 11, 1978.)

A GENERAL HEAT-CONDUCTION INTEGRODIFFERENTIAL EQUATION FOR SOLIDS

V. A. Makagonov

UDC 536.2

The thermal conditions of bodies when highly intense nonstationary processes are occurring is often calculated using a hyperbolic heat-conduction equation which is a special case of the integrodifferential heat-conduction equation [1].

However, in [1] when obtaining the integrodifferential equation, the fact that in bodies, together with an external highly intense action, there may also be internal additional heat dissipation connected either with chemical reactions or the absorptions of penetrating radiation, or due to other physical processes, was ignored.

In the present paper, in addition to [1] these phenomena are taken into account, and a general integrodifferential equation is obtained from which the hyperbolic and parabolic heat transfer equations are obtained as a special case taking into account and ignoring the internal sources.

When obtaining the equation it was assumed that the heat-transfer mechanism occurs by means of carriers emitted by some particles and absorbed by others. The body is considered to be isotropic consisting of particles of spherical shape. The structure of the body is assumed to be polydisperse. The equation is derived by considering the heat balance of the body. The final result is presented for the case of the one-dimensional problem in a rectangular system of coordinates.

LITERATURE CITED

1. N. I. Nikitenko, Investigation of Nonstationary Heat and Mass Transfer Processes by the Grid Method [in Russian], Naukova Dumka, Kiev (1971).

Deposited at the All-Union Institute of Scientific and Technical Information, Reg. No. 2925-78 (Article submitted February 16, 1978; abstract submitted February 16, 1978.)

DEVELOPMENT OF A MATHEMATICAL MODEL OF HEAT EXCHANGE IN A FLAME THERMAL OVEN

Yu. V. Neverov and S. A. Podosenov

UDC 536.245

To determine the effect of the constructional parameters of the oven and the choice of the form of controlling actions ensuring a specified heating uniformity and accuracy, an approximate method is proposed for calculating the heat exchange in the channel formed by the stacked and heated article.

It is shown that in the extraction (stationary) mode, in view of the irreversible thermal losses through the stack, it is impossible in principle to achieve uniformity of the heating of the metal along the motion of the heat carrier, although it is often assumed that in thermal ovens an unlimited increase in the extraction time should lead to equalization of the temperature of the heated article. The analytical expression for the temperature fields is given by the following equations: In the gas flow

$$T(x) = T_s + (T_0 - T_s) \exp \left[-\frac{1}{2} K \left(\sqrt{1 + \frac{4\delta}{K^2}} - 1 \right) \frac{1}{L} x \right],$$

$$K = \frac{Lv_0\rho c_v}{\alpha}, \quad \delta = \frac{\alpha L^2}{\kappa H} \frac{1}{\left(1 + \frac{\alpha}{\alpha_3} + \frac{H_K \alpha}{\lambda}\right)};$$

the temperature distribution in the metal

$$U(x) = \frac{A_{02} T(x) + A_{12} V_1(x)}{A_{02} + A_{12}}.$$

In the steady-state heat-exchange mode where we take as the initial state the steady-state temperature distribution, the temperature field in the metal is given by the following relation:

$$W(X, \tau) = \frac{1}{2} \varphi_1(X) \exp(-\mu, \tau) - \frac{1}{2} \varphi_1(0) \exp(aX - \mu, \tau) - J_0(\sqrt{4c_1(X-\tau)X}) + \exp(aX) f_1(\tau) + \frac{1}{2} \exp(aX - \mu, \tau) \times$$

$$\times \int_{-2X}^0 \left[J_0(\sqrt{c_1[(\tau-2X-\xi)^2 - \tau^2]}) \psi_1^*(\xi) + \frac{\sqrt{c_1} \tau J_1(\sqrt{c_1[(\tau-2X-\xi)^2 - \tau^2]})}{\sqrt{(\tau-2X-\xi)^2 - \tau^2}} \right.$$

$$\left. \varphi_1\left(-\frac{\xi}{2}\right) \exp\left(\frac{a}{2} \cdot \xi\right) \right] d\xi + \exp(aX - \mu, \tau) \times$$

$$\times \int_0^{\tau-X} \frac{2\sqrt{c_1} X J_1(\sqrt{c_1[(\tau-2X-\xi)^2 - (\tau-\xi)^2]}) \exp(\mu, \xi) f_1(\xi)}{\sqrt{(\tau-2X-\xi)^2 - (\tau-\xi)^2}} d\xi,$$

where $W = U - T_s$; $f(\tau) = W(0, \tau)$; $\varphi_1(X) = W(X, 0)$; $J_0 J_1$ is the Bessel function; $\tau = v_0 t/L$; $X = x/L$.

$$\mu_1 = \frac{L(A_{02} - A_{12})}{v_0 \gamma c h}; \quad \mu_2 = \frac{L \beta A_{12}}{v_0 \gamma c h}; \quad \beta = \frac{h_1}{l} = \frac{1}{\frac{\alpha}{\alpha} + \frac{H_K}{\lambda_K} + \frac{1}{\alpha_3}};$$

$$c_1 = \frac{1}{4} (4c^2 - a^2 + b^2); \quad a = \mu_1 - \varepsilon_1 - \varepsilon_2; \quad b = -(\mu_1 + \varepsilon_1 + \varepsilon_2);$$

$$c = -(\varepsilon_1 \mu_1 + \varepsilon_2 \mu_2); \quad \varepsilon_1 = \frac{L \beta A_{01}}{v_0 \rho c_v H}; \quad \varepsilon_2 = \frac{L A_{02}}{v_0 \rho c_v H};$$

$$\psi_1^*(\xi) = \left[\psi_1\left(-\frac{\xi}{2}\right) - \frac{\partial \psi_1\left(-\frac{\xi}{2}\right)}{\partial \xi} - \frac{b}{2} \varphi_1\left(-\frac{\xi}{2}\right) \right] \exp\left(\frac{a}{2} \xi\right); \quad \psi_1(x) = \frac{\partial W}{\partial \tau} \Big|_{\tau=0}.$$

NOTATION

T , T_s and U , temperature of the gas, of the surrounding medium, and of the metal; L , length of the channel; H and h , thickness of the channel and the metal; v_0 , velocity of the gas; c and c_v , heat capacity of the metal and the gas; λ_K , λ , and κ , thermal conductivity of the stack, the metal, and the gas; α , α_3 , A_{01} , A_{02} , A_{12} , heat-transfer coefficients inside the channel to the stack, from the stack to the air, from the gas to the stack, from the gas

to the metal and from the stack to the metal; ρ , γ , density of the gas and the metal; and α_1 and α_2 , thermal diffusivities of the stack and the metal.

Deposited at the All-Union Institute of Scientific and Technical Information, Reg. No. 2920-78 Dep. (Article submitted June 28, 1977; abstract submitted March 14, 1978.)