change in the heat exchange coefficient is taken into account because of the increase in the gas volume and velocity. The integral obtained here has no exact analytic solution and is determined by numerical methods. Also superposed on Fig. 1 is a curve which is the solution of the equation obtained with the variability of α taken into account. As is seen, taking account of the variability of α substantially smooths the nature of the dependence in the second stage of the process by approximating it to that available during heat exchange through a surface.

Therefore, the change in gas temperature during adiabatic evaporation is characterized by two zones: the temperature is reduced more abruptly compared to the case of heat exchange through a surface in the first stage, while, on the other hand, the gas temperature is raised during evaporation in the second stage.

NOTATION

α, β, heat and mass exchange coefficients; t, t_f, gas and fluid temperatures; x, x_f, moisture content of the gas and saturation at t_f; c_{gf}, c_{vf}, specific heats of the dry gas and the vapor at t_f''; G_g, G_v, gas and vapor consumptions; F, heat exchange surface; r, latent heat of vapor formation; $\Delta_c = (c_g - c_{gf})/(t - t_f)$, $\Delta_m = (c_v - c_{vf})/(t - t_f)$, temperature coefficients of the specific heat.

LITERATURE CITED

1. T. Hobler, Mass Transfer and Absorbers, Pergamon (1966).
2. Heat Engineering Handbook [in Russian], Vol. 2, Énergiya, Moscow (1976).

HEATING CHARACTERISTIC OF IMPERFECT DIELECTRICS IN A TRAVELING ELECTROMAGNETIC WAVE FIELD

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UDC 536.24:538.312

A new characteristic of a dielectric in an electromagnetic field, the rate of adiabatic heating of the boundary of a semiinfinite dielectric bulk under normal incidence by an electromagnetic wave, is proposed to describe the heating of dielectrics whose parameters are temperature dependent.

At this time, heating of dielectrics in a traveling electromagnetic microwave field is used more and more often in addition to the traditional method of heating imperfect dielectrics in the field of a high-frequency capacitor in order to change some physical or chemical characteristics of the material.

Performing the experiments and producing the appropriate apparatus required a preliminary estimation of the rate of dielectric heating. As a rule, the tangent of the dielectric loss angle ($\tan\delta$) or the loss factor ($\varepsilon'' = \varepsilon'\tan\delta$) is used as the main characteristic of the influence of the electromagnetic field on the dielectric. Meanwhile it is still impossible to determine the rate of dielectric heating in an electormagnetic field by means of these quantities. The fact is that the electrical and thermophysical characteristics depend on the temperature for the majority of the materials and therefore they vary during action. This latter results in the appearance of a number of competing processes during the heating, which makes estimation of the magnitude of the heating rate difficult. Thus, for instance, ε', $\tan\delta$, and the specific heat c grow during heating in a number of materials. The increase in ε' and $\tan\delta$ results in a diminution in the depth of electromagnetic field penetration h into the material and an increase in the heating rate of the dielectric layer adjacent to the air–dielectric interface. On the other hand, as ε' increases, the coefficient of reflection from this boundary increases, i.e., the quantity of electro-

G. V. Plekhanov Leningrad Mining Institute. Translated from Inzhenerno-Fizicheskii Zhurnal, Vol. 37, No. 6, pp. 1101-1103, December, 1979. Original article submitted October 23, 1978.

 0022-0841/79/3706-1480$07.50

magnetic energy incident on the material diminishes, and, consequently, the heating rate is reduced. The rise in the specific heat with temperature also results in a reduction of the heating rate. All this shows that the heating characteristic cannot be based on only the temperature dependences of ε' and ε'', but should be a more complex combination of these and the thermophysical quantities, which also depend on the temperature.

The single combination having the dimensionality of the heating rate which can be composed from dimensional considerations is the quantity $S/hc\rho$, where S is the energy flux density, and ρ is the density of the substance.

Let us call

$$V_T = 2N_e S/hc\rho \tag{1}$$

the characteristic rate of dielectric heating in an electromagnetic field. Here $N_e = 1 - |(1-\sqrt{\varepsilon})/(1+\sqrt{\varepsilon})|^2$ is the transfer factor of the electromagnetic energy in a semiinfinite dielectric under normal incidence of an electromagnetic wave. In the limit case of normal electromagnetic wave incidence on a semiinfinite dielectric, this quantity will agree with the heating rate of the boundary of a dielectric possessing constant electrical and thermophysical properties, as well as with the heating rate of a dielectric for which the electrical and thermophysical characteristics are arbitrary functions of the temperature, which allows the use of the WKB method to compute the electromagnetic field in a medium [1-3].

The use of the quantity V_T is especially convenient for analyzing the heating of dielectrics whose parameters depend on the temperature in the electromagnetic field since the determination of the electromagnetic field is related to solving an extremely complex system of interrelated nonlinear integrodifferential equations of the electrical and temperature fields. Let us illustrate this by the example of heating such media as frozen rock in an electromagnetic field. At a temperature from -10 to $-0°C$, $\tan\delta$ grows by almost an order in frozen rock, while ε' increases 2-3 times and the specific heat increases also by almost an order because of the ice-bound water phase transitions occurring in this range. Substitution of the experimental dependences of these quantities in (1) shows that the heating rate does not increase with the temperature rise as should have been expected from an analysis of the temperature dependence of the loss factor, but decreases. An exact computation of the behavior of the temperature at the boundary, as well as the experiments performed, verifies this.

Taking into account that there is no variance in the many practically interesting cases in the microwave range, it is convenient to use a proportional quantity dependent only on the dielectric parameters in place of the quantity V_T:

$$V_{T,\mathrm{sp}} = V_T/Sk_0 = 2N_e/k_0 hc\rho \tag{2}$$

(where k_0 is the wave number of the electromagnetic wave in a vacuum), which we designate the specific rate of dielectric heating in an electromagnetic field. The quantity $V_{T,sp}$ is especially useful for comparing the heating of media with different electrical and thermophysical properties in an electromagnetic field.

In the case of heating of dielectrics with small losses ($\tan\delta \ll 1$), which is of practical importance, the expression for $V_{T,sp}$ can be simplified. Taking into account that

$$N_e \approx \frac{4\sqrt{\varepsilon'}}{(1+\sqrt{\varepsilon'})^2}, \quad h = \frac{2\sqrt{\varepsilon'}}{k_0\varepsilon''},$$

we obtain

$$V_{T,\mathrm{sp}} \approx \frac{\varepsilon''(T)}{c(T)\rho(T)[1+\sqrt{\varepsilon'(T)}]^2}. \tag{3}$$

LITERATURE CITED

1. L. É. Rikenglaz and L. B. Nekrasov, Zh. Tekh. Fiz., 43, 694 (1973).
2. L. É. Rikenglaz, Zh. Tekh. Fiz., 44, 1125 (1974).
3. L. É. Rikenglaz, Inzh.-Fiz. Zh., 27, No. 6 (1974).