On the basis of results of preliminary tests, described earlier, the authors have constructed a physical model of the channel evaporator.

Physical Model of the Evaporator. This model is based on the following conditions: 1) the channels have a regular geometric form; 2) the liquid moves in the channel only because of surface tension forces; 3) the capillary pressure in the channel is equal to the difference in the equivalent minisci of the liquid; 4) the working liquid practically fully wets the channel material; 5) the transverse meniscus is replaced by the nominal width of the liquid layer; 6) in a triangular channel with maximum heat removal at the initial section the nominal width of the liquid layer is equal to the channel width, and tends to zero at the end section; 7) in a rectangular channel with maximum heat removal at the initial section the equivalent miniscus is flat, and is equal to half the channel width at the end section; 8) the heat removal is hyperbolic along the channel; 9) the liquid flow is laminar; 10) the vapor pressure above the liquid is constant; 11) there is no heat transfer between the dry walls of the evaporator and the vapor; 12) at any cross section of the liquid flow in the channel the capillary pressure increment is equal to the increment of hydraulic resistance.

Theoretical Formula for the Maximum Heat Flux. Triangular Channel

Constant Channel Width. The derivation of the formula is based on the variation of capillary pressure being equal to the hydraulic drag at any cross section of the liquid flow in the channel

\[
\frac{dP_{\text{cap}}}{dx} = -\frac{dP_h}{dx}.
\]

The capillary pressure in a triangular channel is

\[
dP_{\text{cap}} = aM = -\sigma \cos \theta \frac{dR(x)}{R^2(x)} = -\frac{\sigma \cos \theta dx}{R^2(x) C_1(x)}.
\]

According to the Hagen–Poiseuille law, the hydraulic resistance is

\[
dP_h = \int m(x) \frac{\rho_1}{A(x) D_h^2(x)} dx.
\]

The mass flux of liquid in the channel at any section can be represented as the difference between the flux of all the liquid vaporized and the flux vaporized in the section from \( x = x_0 \) to \( x = x_0 + x \):

\[
m(x) = Q_0' \frac{r^*}{x_0} \ln \frac{x_0 + x_{\text{max}}}{x_0 + x}.
\]

At the same time, we have

\[
\frac{Q_0'}{r^*} x_0 \ln \frac{x_0 + x_{\text{max}}}{x_0} = \frac{q_{\text{max}} x_{\text{max}}}{r^*}.
\]
Then the variation in resistance along the channel is

$$dP_h = \frac{q_{\text{max}} \gamma_{\text{max}} \mu_4}{r \rho_1 t^4(x) C_2(\alpha) C_3 (\alpha)} \ln \frac{x_0 + x_{\text{max}}}{x_0 + x} dx. \quad (6)$$

We equate Eqs. (2) and (6) and integrate

$$\frac{\sigma \cos \theta}{C_1(\alpha)} \int_0^t t^2(x) dt = \frac{q_{\text{max}} \gamma_{\text{max}} \mu_4}{r \rho_1 C_2(\alpha) C_3 (\alpha)} \int_0^{x_{\text{max}}} \ln \frac{x_0 + x_{\text{max}}}{x_0 + x} dx. \quad (7)$$

After integrating we have

$$q_{\text{max}} = \frac{\frac{\sigma r \rho_1 \cos \theta C_2(\alpha) C_3 (\alpha)}{3/C_1(\alpha) \mu_4 x_{\text{max}}} \left[ \ln \frac{(x_0 + x_{\text{max}})}{x_0 + x} - x_0 \right]}{x_0} \quad (8)$$

Since, for a given channel shape, the friction factor depends mainly on the angle $\alpha$, we introduce the following coefficient:

$$K(\alpha) = \frac{1}{3f}. \quad (9)$$

In addition, we designate

$$N_1 = \frac{r \rho_1 \sigma}{\mu_4}, \quad (10)$$

$$C(\alpha) = \frac{C_2(\alpha) C_3 (\alpha)}{C_1(\alpha)} \quad (11)$$

Finally, Eq. (8) takes the form

$$q_{\text{max}} = \frac{t^2 N_1 \cos \theta C(\alpha) K(\alpha)}{x_{\text{max}}} \left[ \ln \frac{(x_0 + x_{\text{max}})}{x_0 + x} - x_0 \right] \quad (12)$$

Constant Channel Depth. In this case we determine the optimal angle $\alpha$ for which maximum heat removal is achieved. With $d = \text{const}$ we write Eq. (12) as

$$q_{\text{max}} = \frac{d^2 N_1 \cos \theta (1 - \sin \alpha) \sin \alpha K(\alpha)}{x_{\text{max}}} \left[ \ln \frac{(x_0 + x_{\text{max}})}{x_0 + x} - x_0 \right] (1 + \sin \alpha)^2 \quad (13)$$

The function $q_{\text{max}} = \varphi(\alpha)$ has a maximum at the point $\alpha = 19^\circ$ ($2\alpha = 38^\circ$).

Rectangular Channel. As in the previous case, derivation of the theoretical formula is based on equality of the variation of capillary pressure and hydraulic drag:

$$dP_{\text{cap}} = \sigma d \left(2 \frac{\cos \theta}{t}\right) = -\frac{2\sigma}{t} \sin \theta d\theta, \quad (14)$$

$$P_{\text{cap}} = -\frac{2\sigma}{t} \int_{\theta=0^\circ}^{\theta=90^\circ} \sin \theta d\theta = \frac{2\sigma}{t} \quad (15)$$

$$P_h = \frac{\int q_{\text{max}} x_{\text{max}} \mu_4}{4r^2 \rho_1} \int_0^{x_{\text{max}}} \left[ t + b(x) \right]^2 \ln \frac{x_0 + x_{\text{max}}}{x_0 + x} - \frac{x_0 + x}{x_0 + x_{\text{max}}} \ln \frac{x_0 + x}{x_0} dx \quad (16)$$

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