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TITLE: ⁽⁶⁾ Design of semiconductor coolers and heaters for liquid flows.

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ABSTRACT: Formulas are derived for calculation of semiconductor thermopiles with variable size thermoelements for heaters and coolers with liquid heat carriers. The symbols Alpha, Lambda, and Rho are respectively the reduced values of the coefficients of thermal e.m.f., heat conductivity, and electrical resistance of the semiconducting materials employed; l and S are the length and area of the thermoelements; I the current passing through thermoelements; T and T**0 are temperatures of the hot and cold junctions; I**p is the current under design conditions; (l:S)**n and (l:S)**1 are geometric dimensions of thermoelements of the n-th and first thermocouple, respectively; m is the number of rows (lines) parallel to the liquid flow. To calculate the cooling of a liquid with a heat capacity c and initial temperature T**01, flowing at an hourly rate G, it is

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assumed that the heat transfer coefficients of the hot and cold junctions of thermoelements are equal to infinity, the heat conductivity of the protective insulation $KF = 0$, and the ambient temperature $T = \text{const}$. Geometric dimensions of thermoelements of the cooling thermopile vary according to the law see enclosure 1. The temperature of the cooled liquid flowing consecutively through a thermopile section with dn thermoelements is T^{**0} at the inlet and $T^{**0} - dT^{**0}$ at the outlet. From the heat balance of the cooled liquid and cold junctions of the thermopile we have Enclosure 2. By solution of equation 4 (Enclosure 2) with a boundary condition $n=0$, $T^{**0} = T^{**0} 1$ we have enclosure 3, from which the temperature of the cooled liquid T^{**0} and the number of thermocouples required n can be determined. Energy consumption W and the amount of heat Q liberated at the hot junctions of the thermopile are then determined see enclosure 4. With cooling of the liquid from $T^{**0} 1$ to T^{**0} , the thermopile cooling capacity $Q^{**0} = Gc (T^{**0} 1 - T^{**0})$ (Formula 16), and $Q - Q^{**0} = W$ (Formula 17). The thermopile energetic efficiency is expressed by the cooling and heating coefficients $\text{Epsilon} = Q^{**0} / W$, and $\text{Phi} = Q / W$ (Formula 18). In this case (Enclosure 5), it should be emphasized that $\text{Epsilon} = \text{Phi} - 1$ (Formula 21). Formulas (5) to (21) make it possible to determine the indices of the thermopile under conditions of maximum energy efficiency. Formulas for calculation of parameters of a thermopile for heating are derived in a similar manner, except that the constant temperature, equal to the ambient, is T^{**0} , and a variable - the temperature T of the hot junctions.

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where

$$\frac{t}{S} = \epsilon(T - T_0) \left\{ \rho l \left[\left(1 + \frac{T + T_0}{2} Z \right)^n - 1 \right] \right\}^{-1}, \quad (1)$$

$$Z = \frac{e^2}{\rho \lambda}. \quad (2)$$

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$$-GcdT_0 = \left[aT_0 l - \frac{1}{2} \rho \frac{l}{S} - \lambda \frac{S}{l} (T - T_0) \right] dn. \quad (3)$$

Substituting (1), we obtain

$$-\frac{Gc}{\rho l} \frac{dT_0}{dn} = T_0 - \frac{1}{2} \frac{T - T_0}{M-1} - \frac{M-1}{Z}, \quad (4)$$

$$\text{where } M = \left(1 + \frac{T + T_0}{2} Z \right)^{1/2} = \text{const.}$$

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$$n = \frac{Gc}{B \rho l} \ln \frac{\psi_0}{\psi}, \quad (5)$$

$$B = \frac{2M-1}{2(M-1)},$$

$$\psi_0 = T - B(T - T_{01}) - \frac{1}{Z}(M-1), \quad (6)$$

$$\psi = T - B(T - T_0) - \frac{1}{Z}(M-1). \quad (7)$$

$$T_0 = T_{01} - \frac{\psi_0}{B} \left[1 - \exp \left(-\frac{\rho l n B}{Gc} \right) \right]. \quad (8)$$

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$$W = \int_0^n dW, \quad Q = \int_0^n dQ. \quad (9)$$

where

$$dW = \left[I^2 p \frac{l}{S} + \alpha I (T - T_0) \right] dn, \quad (10)$$

$$dQ = \left[\alpha T l + \frac{1}{2} I^2 p \frac{l}{S} - \lambda \frac{S}{l} (T - T_0) \right] dn. \quad (11)$$

Taking (1)
into account

$$dW = \alpha I (T - T_0) \frac{M}{M-1} dn, \quad (12)$$

$$dQ = \alpha I \left[T + \frac{1}{2} \frac{T - T_0}{M-1} - \frac{M-1}{Z} \right] dn. \quad (13)$$

Substituting (8)

$$W = \frac{2MGc(T_{01} - T_0)}{2M-1} \left[\frac{TZ - M + 1}{Z(\psi_0 - \psi)} \ln \frac{\psi_0}{\psi} - 1 \right], \quad (14)$$

$$Q = \frac{Gc(T_{01} - T_0)}{2M-1} \left[\frac{2M(TZ - M + 1)}{Z(\psi_0 - \psi)} \ln \frac{\psi_0}{\psi} - 1 \right]. \quad (15)$$

$$Q_0 = Gc(T_{01} - T_0). \quad (16)$$

$$Q - Q_0 = W. \quad (17)$$

$$s = \frac{Q_0}{W}, \quad \varphi = \frac{Q}{W}. \quad (18)$$

In this case

$$\frac{1}{s_{\max}} = \frac{2M}{2M-1} \left[\frac{TZ - M + 1}{Z(\psi_0 - \psi)} \ln \frac{\psi_0}{\psi} - 1 \right], \quad (19)$$

$$\varphi_{\max} = \frac{(TZ - M + 1) \ln \frac{\psi_0}{\psi} - \frac{\psi_0 - \psi}{2M} Z}{(TZ - M + 1) \ln \frac{\psi_0}{\psi} - (\psi_0 - \psi) Z}. \quad (20)$$

$$s = \varphi - 1. \quad (21)$$