The device of heat pipes and their design

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ABSTRACT

The main goal set for the new Uzbekistan is the development of alternative energy production, the active introduction of technology. In the country, alternative and renewable types of energy should account for at least half of the total energy consumption. Heat exchangers are designed to carry out heat exchange processes when it is necessary to heat or cool the process medium in order to process it or utilize heat.

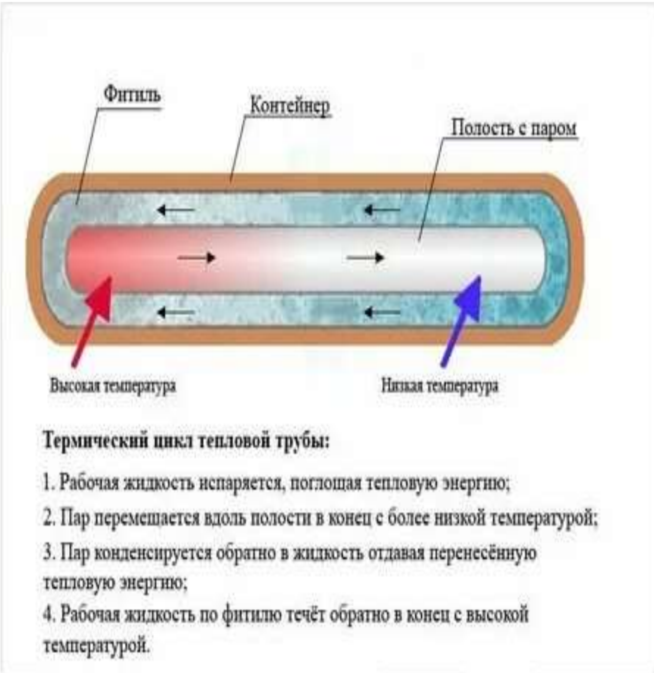
Keywords: energy production,

A heat pipe is a heat transfer device that uses a phase transition to transfer heat between two solid-state surfaces.

At the hot interface of the heat pipe, a volatile liquid in contact with a heat-conducting solid surface turns into steam, absorbing heat from this surface. The steam then passes through the heat pipe to the cold interface and condenses back into the liquid, releasing latent heat. The liquid then returns to the hot interface under the action of capillaries, centrifugal force or gravity, and the cycle repeats.

Due to the very high heat transfer coefficients during boiling and condensation, heat pipes are highly efficient heat conductors. The effective thermal conductivity depends on the length of the heat pipe and can reach 100 kW/ (m· K) for long heat pipes, compared to about 0.4 kW/ (m· K) for copper.

A typical heat pipe consists of a sealed pipe made of a material compatible with the working fluid, such as copper for water heat pipes or aluminum for ammonia heat pipes. As a rule, a vacuum pump is used to remove air from an empty heat pipe. The heat pipe is partially filled with working fluid, and then sealed.



The mass of the working fluid is selected in such a way that the heat pipe contains both steam and liquid in the operating temperature range.

The recommended operating temperature of this heat pipe system is critically important. Below the operating temperature, the liquid is too cold and cannot evaporate into gas. When the operating temperature is exceeded, the entire liquid turns into gas, and the ambient temperature is too high for any gas to condense

Thermal conductivity is still possible through the walls of the heat pipe, but with a significantly reduced heat transfer rate. In addition, for a given heat supply, it is necessary that the minimum temperature of the working fluid is reached; while on the other hand, any additional increase (deviation) in the heat transfer coefficient from the original design will tend to hinder the operation of the heat pipe.

The advantage of heat pipes over many other heat dissipation mechanisms is their high efficiency in heat transfer. A pipe with a diameter of one inch and a length of two feet can transmit 3.7 kW (12,500 BTU per hour) at a temperature of 1800 °F (980°C) with a difference of only 18°F (10°C) from end to end. Some heat pipes have demonstrated a heat flow of more than 23 kW/cm2, which is about four times the heat flow through the surface of the Sun.

In any section of a heat pipe, the difference in static pressures at the interface between the liquid and the vapor phase (on the surface of the wick) must be balanced by the pressure difference in the capillaries. The maximum pressure difference occurs at the beginning of the evaporation zone, where all the liquid leaves the wick. The operation of the heat pipe is possible under the condition that the total pressure losses in the steam and liquid path are equal to or less than the driving forces (capillary, gravitational-mass):

$$\Delta P_{п} + \Delta P_{ж} \leq 2\sigma \frac{\cos\Theta}{r_0} + \rho g L \cdot \sin\gamma \qquad (1)$$

σ – surface tension coefficient;

Θ - marginal angle of wetting with capillary fluid;

r_0 – capillary pore radius;

γ – the angle of inclination of the axis of the heat pipe to the horizon.

For a vertical pipe, γ = 90 and sin γ = 1; for a horizontal pipe, γ = 0 and sin γ = 0, therefore, there is no second term, movement occurs only under the action of capillary forces.

With a stationary process, a constant specific heat flow on the walls of the active zones of the heat pipe (qw= const), laminar flows of the liquid and steam flow mode, the total resistance of the wick (DRl) and the steam channel (DRp) can be represented by the following expression:

$$\Delta P_{ж} + \Delta P_{п} = \frac{(L + L_T)Q}{r_{\Phi}} \cdot \left(\frac{\mu_{ж}}{2\rho_{ж} K_{КС} f_{\Phi}} + \frac{16\mu_{п}}{\rho_{п} d_{п}^2 f_{п}} \right) \qquad (2)$$

L - heat pipe length, m

L_T - length of the transport zone, m

Q - transmitted heat flow of steam, W

r_{Φ} - latent heat of the phase transition, J/kg

f_{Φ} - wick cross-section, m²

$K_{КС}$ - capillary permeability of the capillary-porous structure of the wick

$d_{п}$ - diameter of the steam channel

$f_{п}$ - steam channel cross section.

The joint solution of equations 1 and 2 allows us to determine the maximum heat flow transmitted by a heat pipe limited by the capillary properties of the heat pipe.

$$Q_{к} = \frac{2\frac{\sigma}{r_c} + gP_{ж} L \sin\gamma}{\frac{L + L_{ж}}{r_{\Phi}} \left(\frac{\mu}{2\rho_{ж} \kappa_{кс} f_{ж}} + \frac{16\mu_{п}}{\rho_{п} d_{п}^2 f_{п}} \right)} \qquad (3)$$

To analyze the resulting expression, consider a special case (γ=0⁰C, sin γ=0 – horizontal pipe), $\Delta P_x > \Delta P_\eta$, then the maximum heat flow:

$$Q_{к} = 2\left[\frac{f_{\phi} \kappa_{кс}}{(L + L_T) r_0} \right] \cdot \left[\frac{r_{\phi} \rho_{ж} \sigma}{\mu_{ж}} \right] = 2\Phi_{Г} \cdot \Phi_{Т} \qquad (4)$$

$\Phi_г$ – reflects the geometric characteristics of the heat pipe;

Φ_m – characterizes the thermos-physical properties of the coolant.

The maximum heat flow can be changed either by the geometry of the pipe, or by changing the coolant (replacement).

Dependences 3 and 4 characterize only the heat transfer capacity limited by the capillary properties of the heat pipe.

In general, it is necessary to take into account the compatibility of the coolant with the body and wick of the heat pipe. This is due to the fact that as a result of chemical reactions or decomposition of the coolant, corrosion and erosion of the housing and wick, the heat transfer properties of the heat pipe may deteriorate, therefore, for water as an intermediate coolant, the use of aluminum or iron is not possible, it is necessary to use copper, nickel, titanium. The coolant must be pre-degassed.

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