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Some Features of Heat and Moisture Exchange in Direct Contact of Air with a Surface of a Heated Liquid

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Abstract: The article examines and analyzes the temperature conditions of possible cases of evaporation of water and liquid vapors entering the surrounding air, and liquid vapors, being a carrier of heat, together with them transfer their heat to the surrounding air. As a result, the heat content of the air increases and as a result of the ongoing process of heat and mass transfer, the temperature, heat content and moisture content of the air will increase.

Keywords: evaporation, heat content, liquid, heat, steam, environment, moisture content.

The liquid vapors formed in the process of evaporation enter the surrounding air, increasing its moisture content. The sensible heat arriving at the surface of the liquid is completely spent on evaporation, while transforming into latent heat. Since liquid vapors are a carrier of heat, they together with them transfer their heat to the surrounding air, as a result of which the heat content of the air increases. The heat spent on evaporation, as well as the apparent heat given off by the surface of the liquid, in this case will enter the liquid from the specified special heater and be transferred to its surface due to the thermal conductivity of the liquid itself. As a result of the ongoing process of heat and mass transfer, the temperature, heat content and moisture content of the air will increase. The article discusses and analyzes the temperature conditions of possible cases of evaporation of water, and liquid vapors entering the surrounding air, increasing its moisture content.

1st case. Isothermal evaporation process ($t_c = t_{\text{п}} > t_m$). This process is characterized by the equality of the temperatures of the surface of the liquid and the ambient air. If there are no bodies in the room with a temperature that differs from the temperature of the surface of the liquid (or air), then the evaporation process will be determined by the final value of the difference in partial pressures ($p_{\text{пп}}$ - $p_{\text{по}}$)>0 (where $p_{\text{пп}}$ and $p_{\text{по}}$ are the partial pressures of vapor on the surface of the liquid and in ambient air). In this case, the heat spent on the evaporation of the liquid $Q_{\text{в}}=G_{\text{п}}\,r$ (where $G_{\text{п}}$ - is the amount of the evaporated liquid; r - is the heat of evaporation) will be supplied to the surface due to the thermal conductivity of the liquid. It is assumed that the liquid receives this heat from some kind of heater that maintains a constant surface temperature $t_n = t_c$ during evaporation.

Thus, the stationary evaporation process occurs under isothermal conditions. Since $t_n - t_c = 0$, the amount of exchangeable heat $Q_я$ between the surface of the liquid and the environment is also equal to 0. In Fig. 1, a shows a diagram of the flows of heat and matter in relation to the surface of the liquid. As a result of the ongoing process of heat and mass transfer, Q_n kg of steam and $Q_c = G_n i$ kcal of heat enter the air (where i - is the heat content of the steam), as a result of which the heat and moisture content of the air will increase at a constant temperature.

2nd case. Adiabatic process (tc> tp = tm). From the previous one, it is known that at tp = tm, an adiabatic evaporation process will occur, which is characterized by the equality between the amount of heat received by the liquid surface from the surrounding air and the amount of heat spent on evaporation.

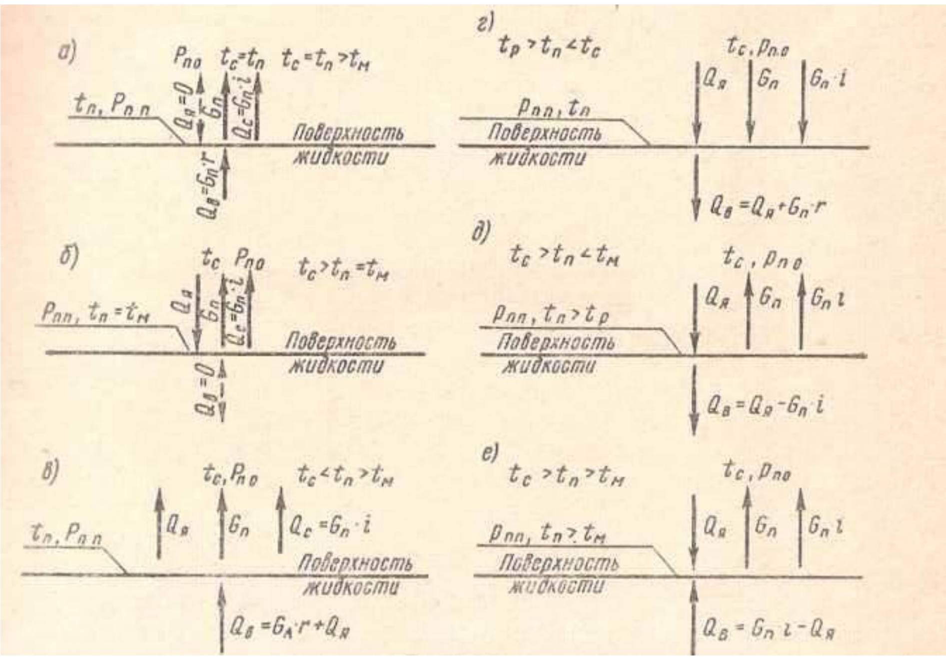

Fig. 1. Diagrams of the direction of flows of heat and mass of vapor relative to the surface of the liquid

At t_c > $t_п$, the sensible heat flux $Q_я$ will have a direction from the ambient air to the surface of the liquid. The sensible heat arriving at the surface of the liquid is completely spent on evaporation, while transforming into latent heat (vapor of the evaporated liquid $G_п r$). The liquid vapors formed in the process of evaporation enter the surrounding air, increasing its moisture content. Since liquid vapors are a carrier of heat, together with them they transfer their heat, equal to $G_n i$, to the surrounding air, as a result of which the heat content of the air increases. However, this increase occurs only due to the initial heat content of the evaporated liquid, equal to $G_п t_м$ and usually representing a very insignificant fraction of the total heat content of water vapor, as a result of which it is practically assumed that $Q_c = G_n i \approx G_n r = Q_я$. Thus, this approximation allows the considered process to be considered adiabatic. A characteristic feature of this process is that $Q_в$=0. The scheme of heat fluxes and mass of matter for the considered case is shown in Fig. 1, b.

3rd case. Non-isothermal process ($t_с$<$t_п$>$t_м$). Under such temperature conditions, the flow of sensible heat $Q_я$0 will be directed from the surface of the liquid into the environment. It is assumed that the maintenance of a constant temperature of the liquid surface is ensured by means of a special heater. Since $p_{пп}$ – $p_{по}$>0, evaporation will occur simultaneously with the release of sensible heat from the surface of the liquid. The amount of heat supplied to the surface of the liquid from the heater, in this case, will be equal to $Q_в = G_n i + Q_я$. The scheme of heat and mass fluxes is shown in fig. 1, c.

4th case. Non-isothermal process ($t_р$>$t_п$<$t_с$). Due to the fact that the surface temperature is lower than the ambient temperature, the flow of sensible heat $Q_я$ will be directed from the environment to the liquid surface. The mass flow of the substance $G_п$ will also be directed from the ambient air to the surface of the liquid, since under the temperature conditions under consideration, the partial pressure of vapors in the air is higher than their partial pressure directly above the surface of the liquid (since $t_п$<$t_р$, where tp is the dew point temperature). When humid air comes into contact with the surface of the liquid, condensation of water vapor will occur, accompanied by the release of the heat of evaporation ($G_п$ r). Thus, heat from the environment will enter the liquid in the amount of $Q_в = Q_{я.} + G_n r$.

It is assumed that the maintenance of a constant temperature of the liquid surface in this case is ensured by means of a special cooler. As a result of this process, the temperature, heat content and moisture content of the air decrease. Processes like this are often found in air conditioning plants where cooling and dehumidification is required. The scheme of heat and mass fluxes for this case is shown in fig. 1, d.

5th case. Temperature conditions of the process ($t_с > t_п < t_м$) and $t_п > t_р$. Since $t_м > t_п$ and $t_п > t_р$, the value of $Q_я$ will be greater than the value of $G_n i$, as a result of which the difference $Q_я - G_n i$ will express the amount of heat entering the water.

The rays of the change in the state of air during such processes are located within the angle between the lines I = const and d = const. A diagram of the direction of heat and moisture fluxes is shown in fig. 1, d.

6th case. Temperature conditions of the process $t_с > t_п > t_м$. Changes in the state of air under such temperature conditions are depicted by rays lying within the angle formed by the lines t = const and I = const (with the exception of the purely adiabatic process considered in the 2nd case). In this case, the flow of sensible heat is directed from air to water, since $t_с > t_п$, and the flow of steam is from water to air. In this case, the heat transferred to the air by the steam $G_n i$ will be greater than the apparent heat given off by the air $Q_я$, as a result of which the amount of heat given off by the air $Q_я$ as a result of which the amount of heat equal to $G_n i - Q_я$ will come from a heat source that maintains constant temperature conditions water. A diagram of the direction of heat and moisture fluxes for this case is shown in fig. 1, e.

Thus, the temperature of the water, due to the influx of this heat, will increase, and the temperature and heat content of the air will decrease. This process of interaction between water and air makes it possible to cool the air with a simultaneous increase in its moisture content with a corresponding decrease in the heat content due to the sensible heat given off by the air to the water.

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