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Mathematical model of the processes of heat and mass transfer in the volume of the flat fills with a horizontally located polymeric pipe of the expiratory cooling tower

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ABSTRACT:This article discusses a new mathematical model of the heat exchange process in a flat fills of an evaporative cooling tower in order to describe the process of heat and mass transfer between water and air and determine the effective irrigation area in the flat fills, taking into account the uneven distribution of the air flow.

KEY WORDS: Cooling tower, thermal power plant, flat fills, circulating water supply systems, evaporative cooling, heat and mass transfer.

I.INTRODUCTION

The share of thermal power plants (TPPs) accounts for the bulk of the generating capacity of the power industry in the Republic of Uzbekistan. In the structure of the production of electric energy, thermal power plants are represented by thermal power plants, combined heat and power plants and combined thermal power plants with combined-cycle plants. Important in the work of power plants performs technical water supply, which can be direct, circulating or mixed. The purpose of this system is cooling the power unit condensers.

With a direct-flow water supply, the spent warm water is discharged into a river, reservoir, lake or sea at such a distance from the intake structure in order to exclude the possibility of warm water entering into it. At low temperatures of river water, power from the river can be supplied by the system with admixed river water during low-water periods of the year when warm water is spent at the power plant.

The use of a direct-flow water supply system does not require large capital investments for construction, and low and stable cooling water temperatures are ensured [1].

The technical water supply system is a complex natural-technical complex, the main technological node of a low potential part of a thermal power plant.The main function of a low potential part of a thermal power plant is to provide cooling water for turbine units with an installed capacity and to maintain an economic vacuum in condensers, regardless of the change in their operating modes. The effective operation of a low potential part of a thermal power plant depends on the balance of the parameters of turbine condensers, circulating pumps, and coolers in various combinations with the meteorological parameters of the power plant area [2].

The system of technical water supply of power plants provides thermodynamic processes of a power plant by transferring and dissipating thermal energy in the surrounding atmosphere.

Basically, evaporative tower cooling towers are installed in the technical water supply systems of power plants.

Analysis of the results of surveys and technological tests of cooling towers and water supply systems revealed that the cooling of water in the systems is 2–10 ° C below the standard, and the lack of water for cooling the calculated steam volumes in turbine condensers is 30–40% [3].

II. SIGNIFICANCE OF THE SYSTEM

The object of the study is a flat fills, as the main technological element of the heat mass transfer apparatus - evaporative cooling tower. The subject of research is the basic laws of hydro-mechanical and heat-mass transfer processes occurring in the volume of the flat fills. Based on the analysis of existing methods, develop a mathematical model in a

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flat fills to intensify the processes of heat and mass transfer during evaporative cooling of circulating water in cooling towers.

III. LITERATURE SURVEY

It should be noted research related to the improvement of individual elements or the development of new types of cooling towers in order to improve heat and mass transfer processes. In most of the works, the analysis of the data of the operation of industrial cooling towers with different types of contact devices – the fills. It has been established that under equal technological and meteorological conditions, the type and location of contact devices affects the efficiency of the cooling tower.

The greatest contribution to the study of hydrodynamic and heat and mass transfer characteristics of fills was made by the following scientists and experts: Berman L.D., Ramm V.M., Lewis V.K., Merkel F., Poppe M., Zhavoronkov N.M., Aerov M. E., Levich V.G., Olevsky V.M., Ponomarenko V.S. and other.

IV. METHODOLOGY

The surface of a horizontal flat fills with a pipe is irrigated with water supplied in the form of droplets from a water distribution device (Fig. 1). A film flow is formed on the surface of a flat fill with a pipe (1st stage). From the lower end of the flat fill with a pipe, the water flows in the form of a jet (2nd stage). After passing the distance H_2 is converted into drip (3rd stage), etc. Thus, if we take into account the developed design of a flat fill with a pipe, the process will consist of N consecutive cycles. In turn, each cycle consists of the 3 above stages.

We conduct the ordinate Z with the beginning of the report Z = 0. The beginning of the 1-stage of the 1-cycle corresponds to the point Z = 0, and the end to the point Z = H. The beginning of the 2-stage corresponds to the point Z = H_1, and the end to the point Z = $H_1 + H_2$, etc. The direction of air movement from the bottom to the top and corresponds to the drawn line of the direction of air.

In order to simplify the solution of the problem, we will make the following assumptions based on the physics of the process.

1. The flow of water along the surface of a flat sprinkler with a pipe is film and inseparable.
2. The distance between the jets is small and equal to ΔĿ.
3. Water droplets are monodisperse with an average equivalent diameter d = 1 mm.
4. During the cycle, temperature and humidity do not change.
5. The flow of water and air laminar.

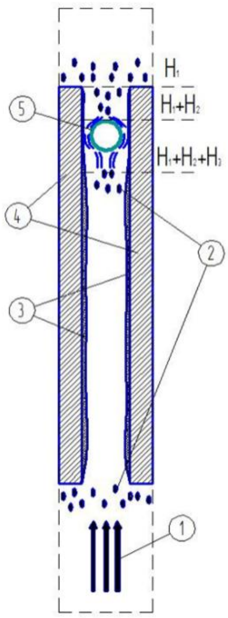

Fig1. Scheme of a flat irrigators (fills) (1- air, 2- water drops, 3- water film, 4- flat fills, 5- tube).

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V. EXPERIMENTAL RESULTS

To describe this process, we use the methods described in the works [4, 5] where water flows in the form of a thin film over the surface of vertical shields are considered.
Before us we will consider the task in a circular coordinate system. The elementary area of the film is determined by:

$$dl = R_0 \cdot d\varphi, \tag{1}$$

Were, $R_0 = H_1/2$- the outer radius of the pipe located between the flat fills, m.
The thickness of the water film can be determined by the following:

$$h(\varphi) = const = h_0 \tag{2}$$

Were, h_0 - water film thickness, m.
From equation (2) comes the following statement:

$$\langle v_f(\varphi) \rangle = v_f = const \tag{3}$$

Were, v_f- water drop speed.
The <> sign means averaging over the radial value.
Equations (2) and (3) characterize the conservation of the mass of water flow without taking into account its evaporation, since, in [1], it is stated that in the case of laminar flow of water, the mass flow rate of evaporated water in cooling towers is about 1% of the total mass flow rate. Therefore, it will be possible to consider equations (2) and (3) as correctly formulated.
Based on the results of research work for the 1-stage cycle evaporative cooling, we write a system of equations in a circular coordinate system:

$$\frac{dh(\varphi)}{d\varphi} = \frac{R_0 j_f (\rho_{sv} - \rho_v)}{\rho_w \langle v_f \rangle} \tag{4}$$

$$\frac{dT_f(\varphi)}{d\varphi} = \frac{R_0 (T_a - T_f(\varphi)) - R_0 r j_f (\rho_{sv} - \rho_v)}{C_w \rho_w h_0 \langle v_f \rangle} \tag{5}$$

$$\frac{dT_a}{d\varphi} = 0 \tag{6}$$

$$\frac{d\rho_v}{d\varphi} = 0 \text{ for } -\frac{\pi}{2} \le \varphi \le \frac{\pi}{2} \tag{7}$$

$$h(\varphi) = h_0;\ T_f(\varphi)\Big|_{\varphi=-\frac{\pi}{2}} = T_{f0};\ T_a(\varphi) = T_{a0};\ \rho_v(\varphi) = \rho_{vo} \tag{8}$$

where: V_a - air velocity; T_a- is the air temperature; T_f - water temperature; ρ_a - is the air density; ρ_w- is the density of water; H- is the height of the cooling tower; ρ_{sv}- is the density of saturated water vapour; C_w- is the specific heat of water; ρ_v- is the density of water vapour;
$j_f = \frac{0{,}324 \mathrm{Re}_{af}^{0,5} \mathrm{Pr}^{0,33} D}{H - z}$ - mass transfer coefficient; $\alpha_f = \frac{0{,}324 \mathrm{Re}_{af}^{0,5} \mathrm{Pr}^{0,33} \lambda_a}{H - z}$ - heat transfer coefficient, where $\mathrm{Re}_{af} = \frac{(H - z)\rho_a (V_a + V_f)}{\mu_a}$.
Where: λ_a - the coefficient of thermal conductivity of air; D- is the diffusion coefficient of water vapour in the air; μ_a - coefficient of dynamic air viscosity; Pr- is the Prandtl number, V_f - is the water velocity.
The coefficients and the Reynolds number for the problem in question are:

$$j_f = \frac{0{,}324 \mathrm{Re}_{af}^{0,5} \mathrm{Pr}^{0,33} D}{H R_0 (1 + \sin\varphi)}; \tag{9}$$

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$$d_f = \frac{0{,}324 \mathrm{Re}_{af}^{0,5} \mathrm{Pr}^{0,33} \lambda_a}{HR_0(1+\sin\varphi)}; \qquad (10)$$

$$\mathrm{Re}_{af} = \frac{(H - R_0(1+\sin\varphi))\rho_a(\nu_a + \nu_f)}{\mu_a}. \qquad (11)$$

Equation (9, 10) is solved analytically as simple integration over. However, such a solution is not of interest, since, for the 1st stage, the thickness of water h decreases slightly. In our opinion, it is more interesting to obtain a solution to equation (11), which characterizes the change in water temperature and is solved analytically.

VI.CONCLUSION AND FUTURE WORK

In this article, the theoretical aspects of evaporative cooling of water in the form of a film, droplets, and a jet of water in a cooling tower with a polymer tubular flat fill were considered. A mathematical model of the processes of transfer, mass and heat in a flat fills tubular has been compiled.

The theoretical dependence of the temperature of the cooled water depending on the flat fills with their spatial arrangement is determined. The developed mathematical model is used to select the calculation options for cooling tower flat fills.

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