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IMPROVING THE DESIGN OF WATER SPRAY NOZZLES IN COOLING TOWERS

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Abstract: The operation of enterprises in the industrial complex is accompanied by the release of a large amount of heat from technological processes in the operating equipment, which must be removed to maintain the operating mode and the given rate of production. In industry and energy, recycled water cooled in cooling towers is used to condense exhaust steam and gaseous products, cool liquid products, as well as equipment and mechanisms in order to protect them from rapid destruction under the influence of high temperatures. The performance of technological equipment, the quality and cost of manufactured products, and the specific consumption of raw materials, fuel and electricity depend on the efficiency of cooling towers. Today, removing low-grade heat from industrial devices using cooling towers is the cheapest way, allowing you to save at least 95% of fresh water from the network. As can be seen from the above, in water cooling devices it is mainly related to the improvement and development of new types of irrigation nozzles and the general design of cooling towers.

Keywords: Gradirnia, steam, gaseous, temperature, spray, efficiency, energy, air, water, nozzle.

Introduction. Hand compressors in the circulating (recycling) water supply systems of various industries to reduce the water temperature during the day, and the resulting nutrients and heat help food products. Cooling occurs mainly due to the evaporation of the circulating water flowing from the gravity sprayer (1% evaporation of the circulating water increases its temperature by 6 °C) [1] .

The performance of cooling towers depends on the water spray density, which means the relative consumption of cooled circulating water per 1 m2 of spray area. The types and parameters of cooling radiators determined during the design process, as well as its main elements, are based on technical and economic calculations - books depending on the temperature and amount of cooled water [2,9].

In the circulating water supply system, the cooling efficiency of the compressor largely depends on the operation of the cooling tower, where recycled water is taken for cooling from the refrigerators of the compressor unit [3,13]. Most of the cooling towers built according to the projects of the last century are in bad condition, and the technical and economic solutions of these projects are outdated. As a result, circulating water cools less, mainly in the hot season, which leads to excessive consumption of energy resources and other negative consequences.

Materials and Methods. Today, in the mining enterprises of Navoi region, mainly reciprocating compressor stations with cooling radiators work. Since the atmospheric temperature reaches high values in the summer, the efficiency of the cooling radiators decreases significantly, and in the hot days of the year, the cooling radiators cannot cool the cooling circulating water to the specified values. As a result, the efficiency of the compressor unit generally decreases, as the useful performance decreases due to the expansion of the volume of compressed air at high temperatures.

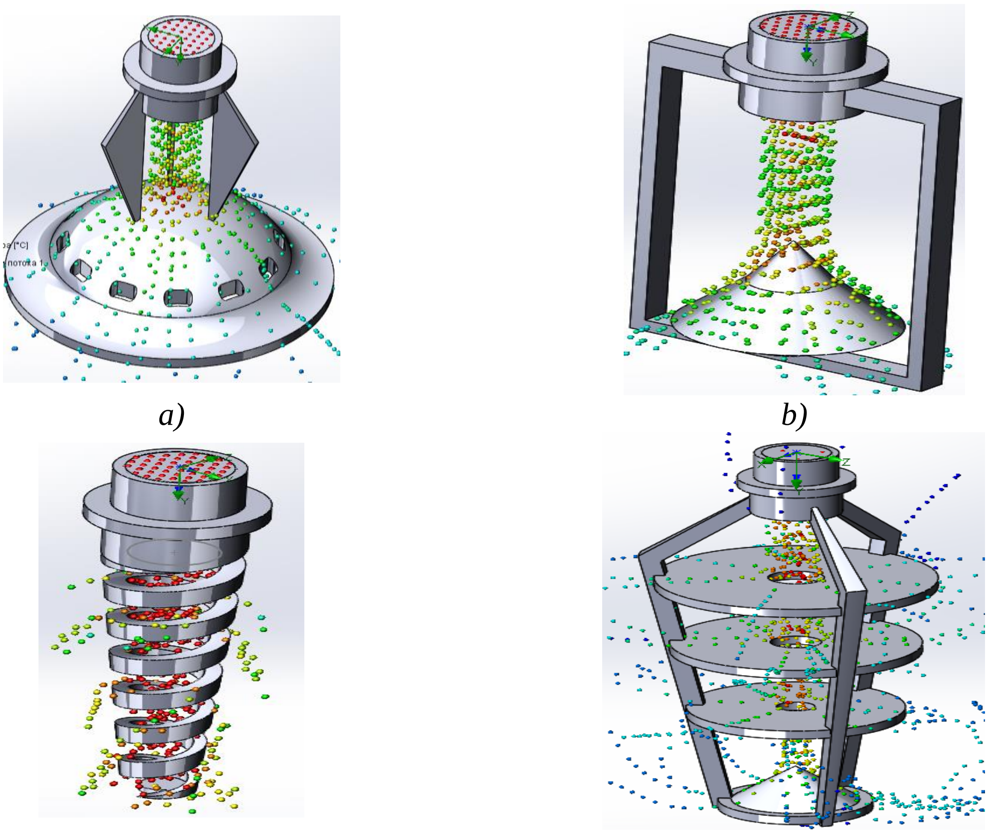
Discussion. The cooling problem can be solved by installing additional heat exchangers. But today's existing heat exchangers are mostly tubular, which creates additional resistance to air movement, which in turn puts additional stress on the compressor drive, resulting in excessive energy costs.

The most important unit of a cooling tower is the nozzle or spray unit, whose aerodynamic, mass and heat transfer characteristics determine the efficiency of the cooling tower, i.e. affect the size or cooling capacity of the new cooling tower.

Analysis of the performance of cooling towers shows that the main reason for the decrease in cooling efficiency is the poor performance of water spray devices. Thus, there is a need to modernize cooling towers by improving the construction of water sprinklers.

Results . Water sprinklers are designed to break up water droplets and disperse them into the air.

The exchange of moisture and heat between air and water occurs more strongly when air interacts with small droplets of water than with a flat surface, which determines the use of water spray nozzles in cooling towers. During spraying, the surface area of water droplets exposed to air increases significantly [4,15].



a) *b)* *v)* *g)*

a) plate-shaped nozzle; b) conical nozzle; c) spiral nozzle; g) cascade nozzle

Figure 1. Water spray nozzles in the cooling tower.

In order to determine the optimal geometric parameters of the water spray device and the best conditions for liquid spraying, we designed several nozzle designs in SolidWorks Flow Simulation software. Figure 1 shows pictures of nozzle structures tested in SolidWorks Flow Simulation.

Test results in SolidWorks Flow Simulation showed that the use of a cascade nozzle (Figure 1d) provides the best spray of the liquid, which increases the exposure of water to air.

The processes that occur when air interacts with liquid in spray chambers can be expressed by the following dimensionless quantities [17,20]:

in the case of complete heat exchange:

$\Delta J = A \cdot (1 + M_1 R) \cdot R^p \cdot B^m$; (1)

in the case of heat exchange:

$\Delta T_c = (C + K \cdot M_1) \cdot B^n$, (2)

here

A, C, K - are conditional proportionality coefficients;

p, m, n - conditional level indicators;

$\Delta J = \frac{J_1 - J_2}{J_1 - J_p}$ – relative change of heat content in the air;

$\Delta T_c = \frac{t_{c1} - t_{c2}}{t_{c1} - t_p}$ – air temperature change indicator;

J_1 и J_2 – the amount of heat in the air before and after spraying, respectively, $kkal/_{kg}$;

t_{c1} и t_{c2} – air temperature before and after spraying, respectively, grad;

t_p и J_p – temperature and heat content of the water droplet before spraying, $kkal/_{kg}$ and grad;

$\Delta t = t_{c1} - t_p$ – the difference in air temperature values, $grad$;

$J_1 - J_2 = c_p(t_{c1} - t_p)$ – the value of the amount of heat in the air, $kkal/_{kg}$;

$t_{вн}$ – water temperature entering the cooling tower, $grad$;

$M_1 = \frac{t_p - t_{вн}}{tc_1 - tp}$ – a temperature criterion that takes into account the initial parameters of water and air;

$B = \frac{W}{G}$ – drip coefficient;

W – amount of water sprayed in one hour, $kg/soat$;

G – air mass processed in one hour, $kg/soat$;

C_p – heat capacity of air, $kkal/kg \cdot grad$.

The effect of moisture exchange on heat exchange is taken into account by the R criterion and is determined by the following formula [5,7]:

$R = 1 + \frac{r_{BC}}{б} \cdot a = 1 + 2.34 \cdot a$, (3)

Here $a = \frac{P_n - P_{вн}}{t_p - t_{вн}}$ – proportionality coefficient, $mm.rt.st./_{grad}$;

P_n и $P_{вн}$ – in line t_p va $t_{вн}$ saturated vapor pressure at temperatures, $mm.rt.st.$;

б – heat exchange coefficient;

в_c − moisture exchange coefficient;

r – amount of heat of steam formation, $^{kkal}/_{kg}$.

In addition, the value of R can be determined using the following formula [5,8]:

$$R = 1.795 + 0.022(t_p + t_{\text{вс}}) + 0{,}00077(t_p^2 + t_p \cdot t_{\text{вн}} + t_{\text{вн}}^2). \qquad (4)$$

Equation (1) describes the total heat transfer between water and air in the sprinkler nozzles, while Equation (2) describes the net heat transfer.

The value of ΔJ shows the change in the amount of heat in the air during direct contact with water. The value of ΔT_c shows the increase in air temperature in the spray chamber.

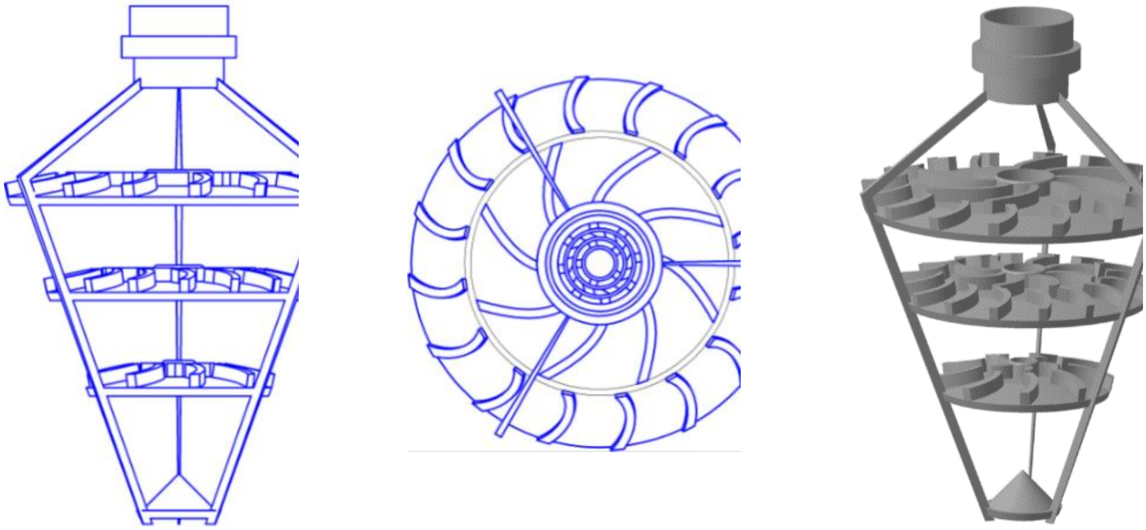
The driving force of moisture exchange, as well as the initial hygrometric difference of air temperature for cooling, is represented by $M_1 \cdot R$, so these quantities are used to represent the complete heat exchange (1). The expression $M_1 \cdot R$ also shows the ratio of the values of the actual driving force of moisture exchange and the driving force of heat exchange.

Drip coefficient B is the ratio of the weight speed of air $v_\text{г}$ to the weight speed of water $v_\text{в}$ and indicates the hydrodynamic conditions of moisture and heat exchange.

Accordingly, moisture and heat exchange in spray chambers are estimated by ΔJ va ΔT_c values and characterized by hydrodynamic and temperature exchange conditions [6].

The secondary droplet breaking effect affects the spray quality of the liquid, and effective liquid spray ensures the best interaction of water with air, resulting in water cooling efficiency. Disintegration of the water coming out of the nozzle hole is achieved by giving the water rotation and advance movements at the same time.

A cascade nozzle design has been developed to create the desired dispersion and spray angle. The nozzles are equipped with deflector blades, which ensure the circular movement of water droplets and their effective fragmentation. Figure 2 shows the general view of the developed nozzle construction.

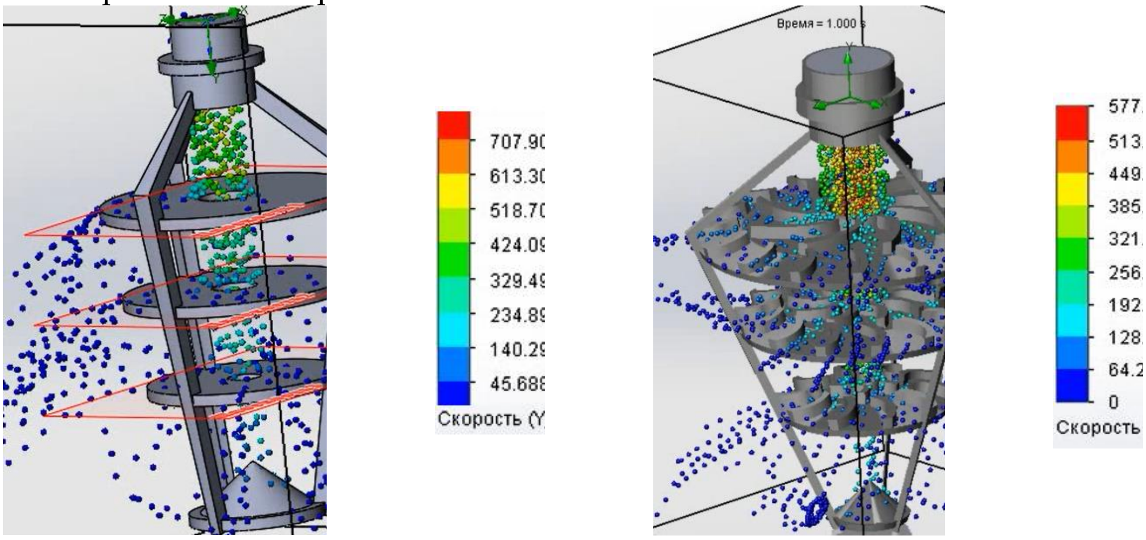


a) b) v)

a) side view; b) top view; v) 3D appearance

Figure 2. Overview of the developed cascade nozzle design.

The developed nozzle design was tested in the SolidWorks Flow Simulation program. Figures 3 and 4 show the results of the test obtained by software testing the speed and temperature of drops at the nozzle outlet.



a) b)

a) simple cascade nozzle; b) new cascade nozzle design

Figure 3. Test results for determining the speed of drops coming out of the nozzle.

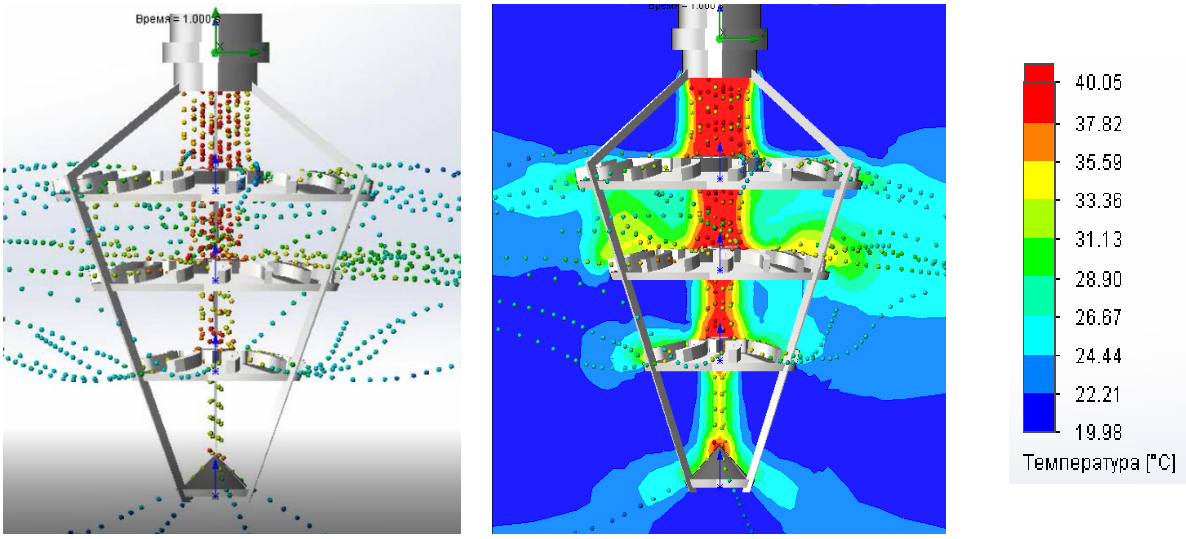


Figure 4. Test results for determining the temperature of droplets coming out of the nozzle.

Conclusion. The test results presented in Fig. 3a showed that the spray velocity of droplets at the exit from simple cascade nozzles (Fig. 3a) is 45.6 m/s. The developed cascade nozzle design has a droplet spray velocity of 64.2m/s, so our proposed nozzle design can increase the droplet spray speed to 18.6m/s (40%), resulting in efficient water causes cooling.

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