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IMPROVING THE EFFICIENCY OF THE HYDROCARBON VAPOR COOLING PROCESS

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Abstract. The article presents experimental results and analysis of the effectiveness of air cooling of hydrocarbon vapors. The description and principle of operation of the experimental device is explained. It is established that the cooling efficiency when using dry and wet air differs by 9-13 percent when the volume flow rate of the product varies from 3 to 11 l/min. Gasoline fraction of grade Ai 80 was used in the experiments.

Keywords: air cooling, cooling efficiency, dry air, humid air, volume flow, heat capacity, hydrocarbon vapor

I. INTRODUCTION

Air cooling of raw materials, finished products and semi-finished products is important in oil and gas refineries. At the same time, several types of air cooling devices and their features are used [1–3, 5, 6]. The main parts of the air-cooled unit are the section and blade, and the vapors of the gasoline fraction move through the thin tubes of the section. The air flow through the blade passes through the gaps between the pipes and carries some heat. But the efficiency of these types of devices is less than that of others. One of the main reasons for this is the low heat capacity of air [4, 8]. According to the literature [3, 4, 7] [3, 4, 7], at a temperature of 20 ºC the heat capacity of air is 1008 J/(kg ºC), the heat capacity of water is 4200 J/(kg ºC). This value fluctuates in the around of 3-5 percent when the temperature changes. Considering this, we can say that the search for ways to improve the efficiency of the cooling process is one of the urgent problems facing scientists around the world [5, 7, 8].

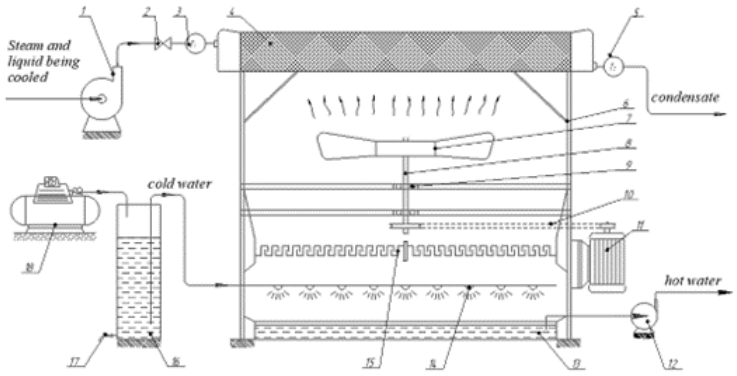


FIG. 1. The construction scheme of the air-cooling experimental device: 1.12 – pump; 2.17 – valve, 3 – thermometer-1 (input); 4 – heat exchange section; 5 – thermometer-2 (output); 6 – frame; 7 – fan, 8 – shaft; 9 – bearing; 10 – belt transmission; 11 – electric motor; 13 - water collection tank; 14 – nozzle; 15 – drop holder; 16 – hydro tank; 18 – compressor.

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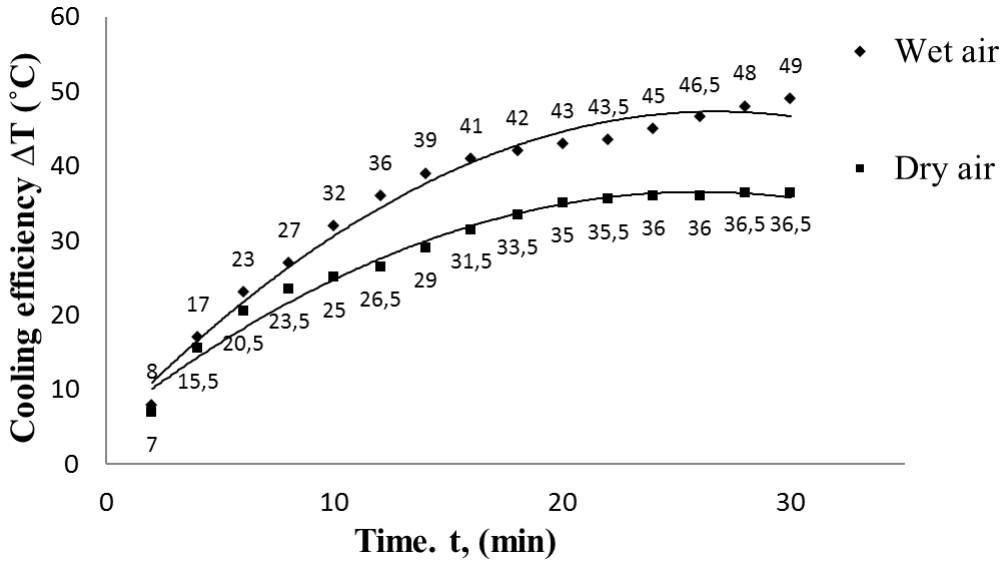


FIG. 2. Graph of changes in cooling efficiency when using dry and wet air per unit of time.

II. METHODS AND MATERIALS

The research work is based on the analysis of indicators determined by practical experience. An experimental setup has been prepared for the organization of experiments related to the study of air cooling in laboratory conditions (Fig. 1)

With the help of this experimental device, it is possible to study the influence of temperature, pressure, flow rate of the hydrocarbon fraction, as well as the speed, temperature and humidity of the cooling air on the efficiency of the cooling process. hydrocarbon fractions using air. The experimental air cooling unit mainly consists of a heat exchange section 4, a fan, water spray nozzles 6 and a drop catcher 8 and is equipped with means for measuring and regulating pressure, temperature and flow of heat carriers. The centrifugal pump type 1 is used to move the cooled hydrocarbon product inside the pipe. The air flow is transmitted through the fan device. The fan consists of a shaft 10 and an attached fan 7 and an electric motor 8. The rotational motion from the electric motor 8 to the fan is transmitted through a belt drive 9. With the help of a compressor 18 and a hydraulic tank 16, water spray nozzles spray water under a certain pressure in order to humidify and cool the air. The nozzles of the water sprayer are installed on a special ring at an angle of 45 against the direction of the air flow, and their number is 4 or 6. The humidified air passes through the drop catcher 15, and the trapped water droplets through a special pipe (channel) fall into the water collector 14. When using an experimental setup, the determination and adjustment of the process parameters is carried out using a monometer, valve and thermometers.

A. Results and discussions

In order to improve the process of cooling the gasoline fraction in air-cooled apparatuses and increase the cooling efficiency, a number of experiments were conducted in the laboratory. The cooling process using dry and wet air was compared with each other (Fig. 2). The gasoline fraction was used as a refrigerant during the experiment. Over time, the temperature of the gasoline fraction gradually increased. First of all, the gasoline fraction cooled by dry air was cooled to ΔT_{dry} = 25 ℃ in the first 10 minutes, then to ΔT_{dry} = 35 ℃ in the 20th minute, and then to ΔT_{dry} = 36.5℃ in the 30th minute. We can see it from the fig 1. The graph also shows that as the temperature of the gasoline fraction increases and over time, the cooling efficiency also increases rapidly, and towards the end of the experiment, the acceleration disappears and reaches equilibrium. At the next stage of the experiment, the properties of the refrigerant were changed by humidifying the air. To humidify the air, water droplets were sprayed using nozzles installed at an angle of 45º against the direction of the air flow transmitted by the fan. The scattered tiny water droplets quickly mixed together as a result of the turbulent air movement, forming a mist. In the same case, the experiment was repeated as before, and the results were recorded.

The results showed that the process of cooling the gasoline fraction with wet air is more efficient than with dry air. The graph shows that the cooling efficiency of the gasoline fraction at 10, 20 and 30 minutes was 32 ℃, 43℃ and 49 ℃. Although the above-mentioned changes in cooling efficiency using dry and wet air per unit time have been studied, it is also necessary to study the effect of changes in the volume flow rate and temperature at the inlet of the gasoline fraction on cooling efficiency.

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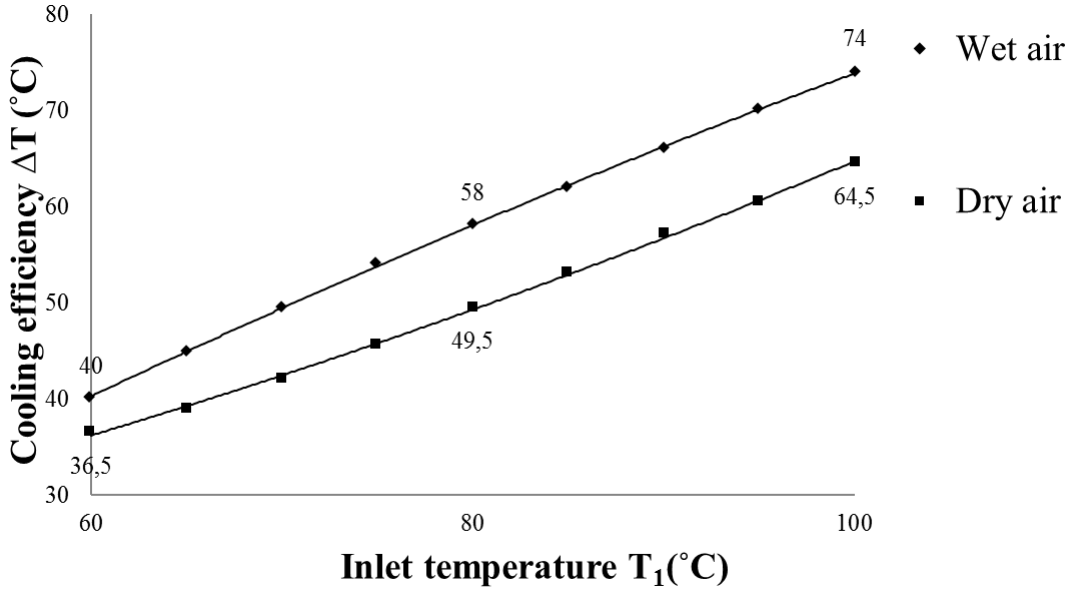


FIG. 3. Graph of the cooling efficiency of dry and wet air depending on the temperature change at the inlet of the cooling device. (At volume flow $V_1 = 3 \times 10^{-3}\,\mathrm{m}^3/\mathrm{min}$)

Accordingly, the volume flow rate of gasoline fraction during the experiments $V_1 = 3 \times 10^{-3}\,\mathrm{m}^3/\mathrm{min}$, $V_2 = 7 \times 10^{-3}\,\mathrm{m}^3/\mathrm{min}$ and $V_3 = 11 \times 10^{-3}\,\mathrm{m}^3/\mathrm{min}$ the dependence of the cooling efficiency of dry and wet air from the change of the inlet temperature cooling device (Fig. 3, 4 and 5). In addition, it was assumed that the experiment was conducted at a constant air temperature, since the temperature of dry and wet air during the experiments ranged from 23 to 25ºC. In experiments, the difference between the cooling of the gasoline fraction by dry and wet air can be calculated by the expression $\Delta t = \Delta T_{\text{wet}} - \Delta T_{\text{dry}}$ (ºC) In this case, the cooling efficiency with dry air ΔT_{dry} and the cooling efficiency with wet air ΔT_{wet} are determined by the temperature difference of the gasoline fraction at the inlet and outlet of the refrigerator during the day.

According to figure 3, the volume flow rate of the gasoline fraction $V_1 = 3 \times 10^{-3}\,\mathrm{m}^3/\mathrm{min}$ entering the apparatus and a temperature T_1=60 ºC, the dry air cooling efficiency was ΔT_{dry}=36,5 ºC and the wet air cooling efficiency ΔT_{wet}=40ºC. Then the difference between ΔT_{dry} and ΔT_{wet} turned out to be equal to Δt_1=3,5 ºC. During the experiment, when the temperature of the gasoline fraction entering the apparatus increased to T_2=80ºC, the cooling efficiency in dry air was ΔT_{dry} =49,5ºC, and the cooling efficiency in wet air was ΔT_{wet} =58ºC. Then the difference between the two methods was Δt_2 = 8.5 ºC. At the next stage of the experiment, when the temperature of the gasoline fraction reached T_3=100ºC, the cooling efficiency in dry air was ΔT_{dry} =64,5 ºC, and the cooling efficiency in wet air was ΔT_{wet} =74 ºC. Then the difference between the cooling efficiency using dry and wet air showed Δt_3=9,5 ºC. In general, with a volume flow rate $V_1 = 3 \times 10^{-3}\,\mathrm{m}^3/\mathrm{min}$, the difference between the cooling efficiency using dry and wet air was 3.5 ºC, 8,5 ºC and 9.5 ºC, respectively, at 60 ºC, 80 ºC and 100 ºC. Thus, the difference between cooling with dry and wet air increases sharply with an increase in temperature at the inlet to the refrigerant and immediately goes into an equilibrium state. Therefore, the best option for the experimental process is to use wet air when the temperature of the incoming gasoline fraction at low volume flow is 80 ºC.

According to figure 4, the volume flow rate of the gasoline fraction $V_1 = 7 \times 10^{-3}\,\mathrm{m}^3/\mathrm{min}$ entering the apparatus and a temperature T_1=60 ºC, the dry air cooling efficiency was ΔT_{dry}=29 ºC and the wet air cooling efficiency ΔT_{wet}=36.5ºC. Then the difference between ΔT_{dry} and ΔT_{wet} turned out to be equal to Δt_1=7,5 ºC. During the experiment, when the temperature of the gasoline fraction entering the apparatus increased to T_2=80ºC, the cooling efficiency in dry air was ΔT_{dry} =40,5ºC, and the cooling efficiency in wet air was ΔT_{wet} =48.5ºC. Then the difference between the two methods was Δt_2 = 8 ºC. At the next stage of the experiment, when the temperature of the gasoline fraction reached T_3=100ºC, the cooling efficiency in dry air was ΔT_{dry} =50,5 ºC, and the cooling efficiency in wet air was ΔT_{wet} =61 ºC. Then the difference between the cooling efficiency using dry and wet air showed Δt_3=10,5 ºC. In general, with a volume flow rate $V_1 = 7 \times 10^{-3}\,\mathrm{m}^3/\mathrm{min}$, the difference between the cooling efficiency using dry and wet air was 7.5 ºC, 8 ºC and 10.5 ºC, respectively, at 60 ºC, 80 ºC and 100 ºC. Thus, the difference between cooling with dry and wet air with an increase in temperature at the inlet to the refrigerant at first maintained an equilibrium state for some time, and then sharply increased. In this case, we can say that the best option for the experimental process is the use of wet air at a temperature of 100 ºC or higher gasoline fraction entering the refrigerant.

According to figure 5, the volume flow rate of the gasoline fraction $V_1 = 11 \times 10^{-3}\,\mathrm{m}^3/\mathrm{min}$ entering the apparatus and a temperature T_1=60 ºC, the dry air cooling efficiency was ΔT_{dry}=23.5 ºC and the wet air cooling efficiency ΔT_{wet}=28ºC. Then the

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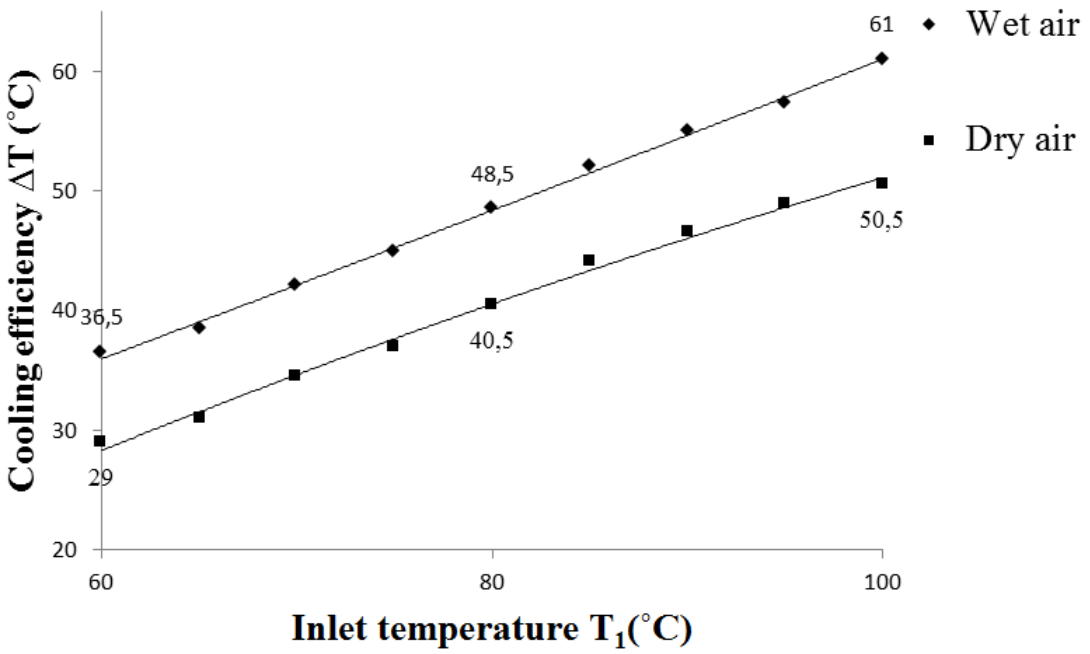


FIG. 4. Graph of the cooling efficiency of dry and wet air depending on the temperature change at the inlet of the cooling device. (At volume flow $V_1 = 7 \times 10^{-3}$ m^3/min)

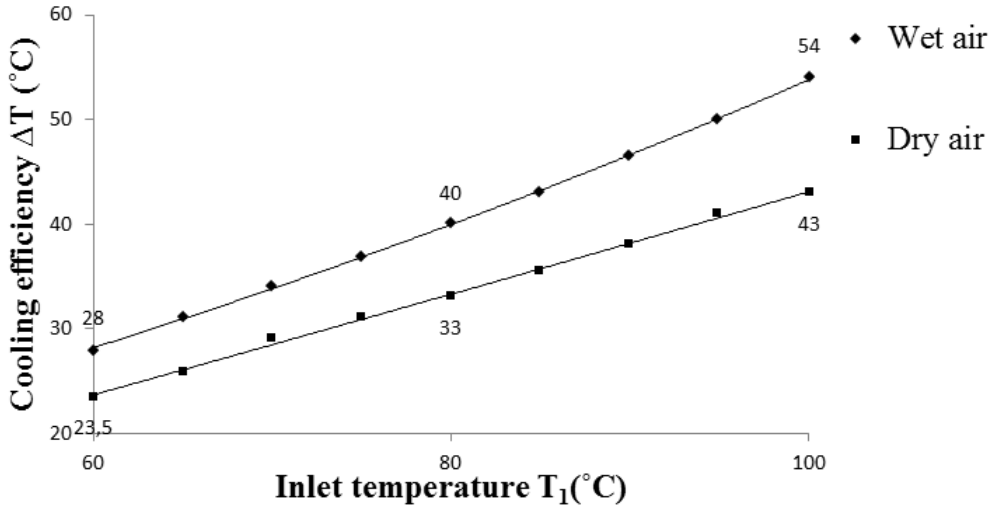


FIG. 5. Graph of the cooling efficiency of dry and wet air depending on the temperature change at the inlet of the cooling device. (At volume flow $V_1 = 11 \times 10^{-3}$ m^3/min)

difference between ΔT_{dry} and ΔT_{wet} turned out to be equal to $Deltat_1$=4,5 ℃. During the experiment, when the temperature of the gasoline fraction entering the apparatus increased to T_2=80℃, the cooling efficiency in dry air was ΔT_{dry} =33℃, and the cooling efficiency in wet air was ΔT_{wet} =40℃. Then the difference between the two methods was Δt_2 = 7 ℃. At the next stage of the experiment, when the temperature of the gasoline fraction reached T_3=100℃, the cooling efficiency in dry air was ΔT_{dry} =43 ℃, and the cooling efficiency in wet air was ΔT_{wet} =54 ℃. Then the difference between the cooling efficiency using dry and wet air showed Δt_3=11 ℃. In general, with a volume flow rate $V_1 = 11 \times 10^{-3}$ m^3/min, the difference between the cooling efficiency using dry and wet air was 4.5 ℃, 7 ℃ and 11 ℃, respectively, at 60 ℃, 80 ℃ and 100 ℃. Thus, the difference between cooling with dry and wet air increases in parabolic dimensions with an increase in the temperature at the inlet to the refrigerant.

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Based on this, it can be concluded that the higher the temperature of the incoming gasoline fraction at high volume consumption in this case, the more productive the use of wet air will be for the experimental process. The results of the experiment were carefully analyzed and proved that cooling with wet air is better than with dry air. In the scientific explanation of the process, the difference in the efficiency of cooling the gasoline fraction with dry and wet air is due to the difference in the heat capacities of the two media, i.e., the heat capacity of air is 1008 J/(kg ℃) , and the heat capacity of water is 4200 J/(kg ℃) . Tiny droplets of water in wet air touch the heat exchange surface of the device, absorbing more heat than dry air and increasing heat transfer. The gasoline fraction transfers its heat to the wall of the device, and then through the wall to the external environment. The more heat the device emits through the heat exchanger, the higher the cooling efficiency. In the course of experiments, it was studied that the efficiency of cooling using dry and wet air differs from each other even in cases of different volume flow of the gasoline fraction, and sufficient scientific knowledge was obtained.

III. CONCLUSIONS

Thus, the influence of dry and wet air on the cooling efficiency of an air cooling device used for cooling the gasoline fraction in oil and gas processing plants was studied. As a result, cooling the gasoline fraction with wet air proved to be more effective than with dry air. It is established that the key factor for changing the efficiency is the change in the heat capacity of the cooling medium. In addition, the efficiency of cooling with dry and wet air was experimentally determined at the volume flow rate of the gasoline fraction $V_1 = 3 \times 10^{-3}\,\mathrm{m}^3/\mathrm{min}$, $V_1 = 7 \times 10^{-3}\,\mathrm{m}^3/\mathrm{min}$ and $V_1 = 11 \times 10^{-3}\,\mathrm{m}^3/\mathrm{min}$. Based on the results, graphs were constructed and indicators were compared with each other. For each value of the volume flow of the gasoline fraction, separate conclusions are given and it is recommended at which stage of the process dry or wet air can be used.

REFERENCES

[1] A. Ç Yunus, Heat and Mass Transfer: A Practical Approach, Third Edition, McGraw-Hill, New York, 2007.
[2] Kryukov N.P. Apparaty vozdushnogo okhlazhdeniya. M.: Khimiya, 1983. 168 p.
[3] Vladimirov A.I., Shchelkunov V.A., Kruglov S.A. Osnovnyye protsessy i apparaty neftegazopererabotki (kratkiy spravochnik). – M.: Neft' i gaz, 1996. – 155 p
[4] V. B. Kuntysh, A. N. Bessonniy. Osnovy rascheta i proyektirovaniya teploobmennikov vozdushnogo okhlazhdeniya: spravochnik. SPb.: Nedra, 1996. 512 p.
[5] Xurmamatov, A.M., Mo'minov, J.A. Benzin fraksiyasini havo yordamida sovitish jarayonining tadqiqot natijalari. Oriental renaissance: Innovative, educational, natural and social sciences, (2021), 1 (9), 619-624.
[6] B.V. Kuntysh, A.N. Bessonnyy, A.A. Bril'. Osnovnyye sposoby sovershenstvovaniya apparatov vozdushnogo okhlazhdeniya. Khimicheskoye i neftekhimicheskoye mashinostroyeniye. 1997. № 4.pp. 41-44.
[7] Muminov, J. A. "Uglevodorod xom ashyosini havo yordamida sovitish jarayonlarining asosiy kursatkichlari." Kimyo va oziq-ovqat maxsulotlarining sifati va khavfsizligini ta'minlashda innovatsion texnologiyalar (2021): 314-315.
[8] Ye.V. Chitrov, V.Z. Kanter, S.B. Pokhodyayev, YU.I. Anoshkin. Povysheniye effektivnosti i nadezhnosti apparatov vozdushnogo okhlazhdeniya dlya neftekhimicheskoy promyshlennosti. Mir nefteproduktov. 2007. № 2. pp. 22–25.

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