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Improving the efficiency of the air cooling system of gas pumping compressor stations

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ABSTRACT: The article examines the factors affecting the performance of the cooling systems of gas pumping compressor stations. Studies have shown that these factors have an internal and external impact. The ways to improve the efficiency of operation of compressor stations are defined.

KEY WORDS: gas pumping compressor, cooling system, factors, temperature, electric motor, external environment, gas, gas pipeline.

I. INTRODUCTION

Each of the compressor stations located on main gas pipelines uses a wide range of cooling devices. The role of refrigeration equipment in the compressor station is of great importance. Compressing a gas at a compressor station leads to an increase in its temperature at the exit of the station. The numerical value of this temperature is determined by its initial value at the inlet of the compressor station and the degree of compression of the gas. Excessively high gas temperature at the outlet of the station, on the one hand, can lead to the destruction of the insulating coating of the pipeline, and on the other hand - to reduce the supply of process gas and increase energy consumption for its compression (due to an increase in its volumetric flow rate). In accordance with this, the mode of operation of the gas cooling system is determined, which allows to increase the efficiency of the compressor station.

II. WORKING CONDITIONS OF COMPRESSOR STATION COOLING SYSTEMS

The flow between the heat exchanger valves requires speeds of up to 5-15 m / s. The fan speed controller can be set to a range of 5-15 m / s by installing cooling equipment on gas. Taking into account the rules of thermal physics, the lowest coefficient of thermal conductivity α=30-90Вт/(м^2·K). Reducing the conveyor ratio from a given value can lead to an increase in energy consumption and a decrease in the effective ratio. In refrigeration equipment, heat treatment performs chemical cleaning. We can see that the utility ratio can vary, i.e. increase from 3% to 10% by cleaning tiny holes.

Since the compressor stations are located in gas pipelines with different climatic conditions, it is desirable to use an automatic air cooling system to cool the compiled gas.

To choose a heat exchanger for an air cooling device, it is necessary to fulfill the following process requirements:

- exclude additional water supply when using air cooling equipment;
- there is no possibility of additional consumption of energy resources;
- the cooling system should be simple and reliable;
- the influence of any factors on the automatic control system on the cooling process should be minimal;
- there should be no environmental impact.

The figure below (Fig. 1) shows the scheme of the air cooling device.Here, the gas inlet and outlet temperatures t_1 and t_2, the inlet and outlet pressure of the gas entering the devices P_1 and P_2, ΔP is the pressure reducing gas flowing through the device; R_a and T_a are the atmospheric pressure and temperature, N is the power consumption of the drive engine.

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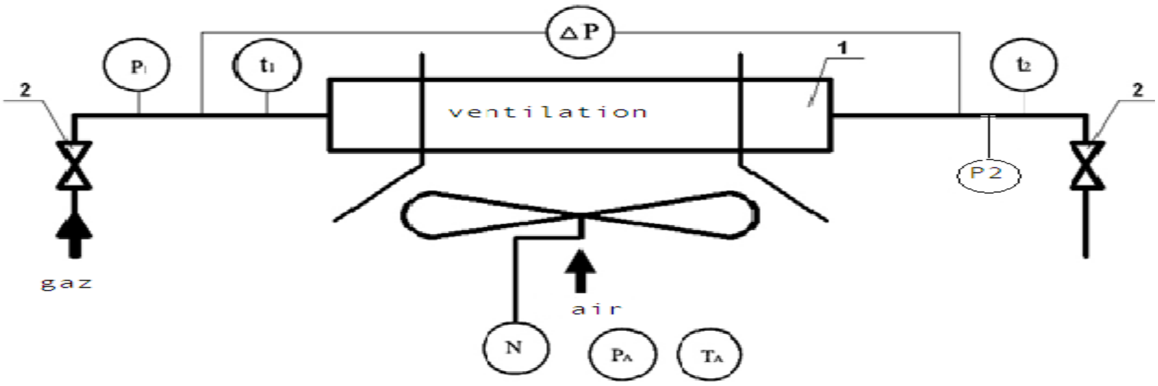

Fig. 1. Technical processing scheme of air cooling device

According to Figure 1, many factors affect the efficiency of a compressed gas air cooling system. The following are the main factors that significantly affect the energy performance of the integrated gas cooling system: [Ref 1].

- the outside temperature T_a;
- outside air humidity λ_a;
- gas flow humidity λ_g;
- compressed gas flow rate υ_g;
- average logarithmic temperature difference of the cooling device Θ_m;
- average density of gas ρ_g;
- heat transfer coefficient K;
- gas humidity λ_g.

III. FACTORS THAT AFFECT THE EFFICIENCY OF COOLING SYSTEMS

Analysis of the ratio of the velocity of the compressed gas shows that the efficiency of the cooling system of the compiled gas depends on the state of the device [Ref 1].

$$\omega_1 = \frac{M_1}{\rho_{gaz} \cdot F_s}, \text{ m/s} \quad (1)$$

here F_s-cross section of gas conductive intermediate pipes m^2, ρ_{gaz}-gas density m^3/kg. From the formula, we can conclude that with a narrowing of the walls of the pipeline and its reduction of the surface F_s, an increase in the density of the gas is observed. Layers accumulated on the inner and outer surfaces of the pipeline cause a decrease in heat transfer ability. As a result, the cooling system will reduce its effectiveness.

Another important factor causing the cooling unit to fall is the appearance of the outer surface of the heat exchange bubbles and the appearance of a fibrous layer. Figure 2 shows that the energy consumption of a heat exchanger at a certain level of cooling can be up to 12%.

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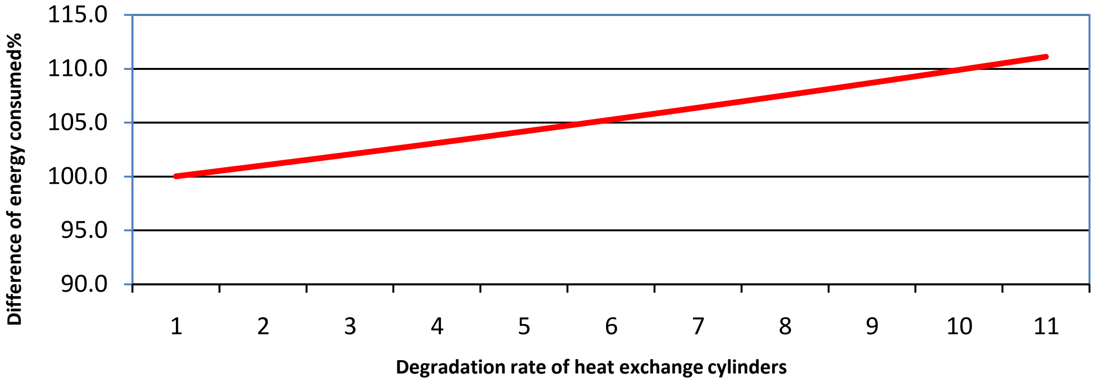

Fig. 2. Expressed the rate of increase in energy consumption as a result of contamination of heat exchangers

The following formula is used to control the outer surface of the heat transfer conductor.

$$F = D \cdot S_p + \frac{D^2-(D-2\cdot H)^2}{2}, \quad (\text{м}^2) \tag{2}$$

where D is the external measurement of the costal tube, m;
H is the pipe length, m;
S_p is pipe width, m;
The cooling efficiency is determined by the following expression

$$\eta_\text{в} = \frac{M_2 \cdot C_{p2} \cdot (\tau_2-\tau_1)}{M_1 \cdot C_{p1} \cdot (t_1-t_2)} = \frac{W_2 \cdot (\tau_2-\tau_1)}{W_1 \cdot (t_1-t_2)} \tag{3}$$

where $M_1$and M_2 are heat transfer weight and cold consumption, kg/h; C_{p1} and C_{p2} are average heat content of heat transfer conductor, kJ/ kg · K, t_1 and t_2 temperature at the inlet and outlet of the cooler,°C; $\tau_1$andτ_2 are level of the inlet and outlet chiller temperature, °C, $W_1$and $W_2$are the moisture content in the coolant during cold and hot conditions. As can be seen from this expression at a low temperature at the output increases the efficiency [Ref2].

The formula for calculating the average thermal conductivity of a gas is given below [3].

$$C_u = 4.604 - 2.11 \cdot t \cdot 10^{-2} + 0.57 \cdot P_u^e - 0.17 \cdot t \cdot 10^{-2} \cdot P_u^e + \\ +0.4584 \cdot t^2 \cdot 10^{-4}. \tag{4}$$

The connection diagram of the cooling device to the compressor station is shown in Fig. 3 [Ref 3]. The diagrams of DY 1000 in the figure are compressed air supply tubes for cooling devices. The number of refrigeration units at the compressor station is 24. The number of used cooling devices depends on the amount of flowing gas. The correct choice of the number of coolers will reduce the pressure on the cooling device ΔP.

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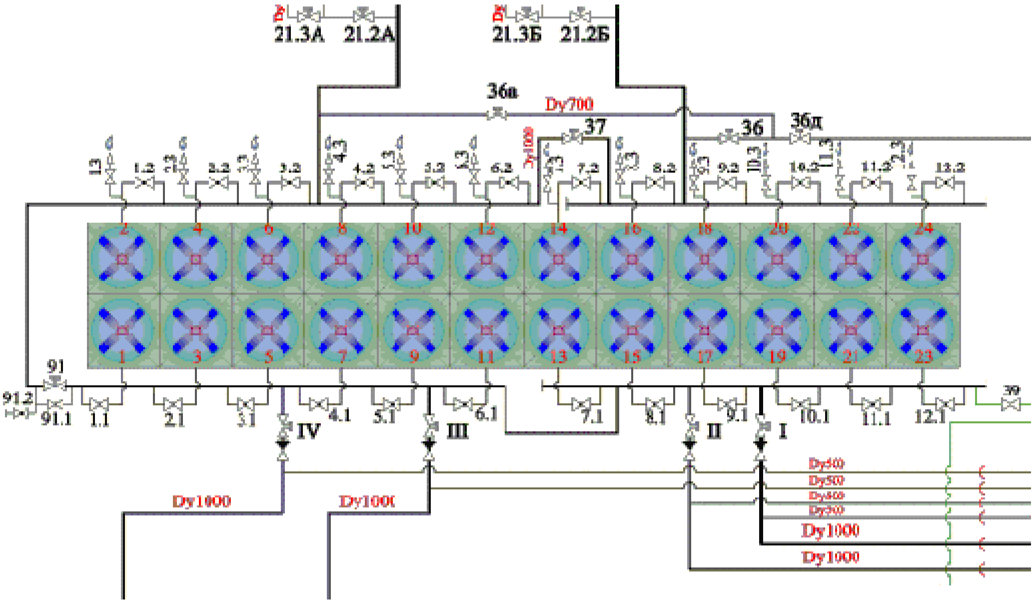

Fig. 3. Connection of a compressor station to a cooling device

When the compressor station is equipped with cooling devices for refrigeration units, we can see a number of effective operating conditions:

- the gas velocity in the cooling tubes is controlled
- reduced gas pressure loss in cooling devices
- reduced energy consumption
- increases efficiency
- avoid high starting currents.
- the life of equipment will increase.

We can see the degree of heat transfer of the cooling device to the external surface of the heat transfer device in the following formula[Ref 4]

$$Q_g = \alpha \cdot F \cdot (T_g - T_a), \quad (5)$$

here α is heat transfer coefficient, F is external surface of the heat exchanger, T_g is gas flow temperature, $T_a$is outdoor air temperature.

As is known, the heat transfer coefficient (α) is directly proportional to the speed and power consumption of the engine i.e. α~ v ~ N.

The change in the optimal flow rate of air from the fan depends on the change in the external surface of the heat transfer bubbles. This suggests that the cooling device is directly related to the efficiency.

Finding the outer surface of the heat exchanger cooling device can be determined by the following formula

$$F = \frac{8 \cdot W_1 \cdot W_2 \cdot [(t_1 - \mathcal{T}_1) - \Theta_m] \cdot L}{(W_1 + W_2) \cdot C_p \cdot (t_1 - t_2) \cdot \rho \cdot \omega \cdot d}. \quad (6)$$

Finding Θ_m ia an average logrifmit thermal conductivity in this formula is expressed as follows [Ref 5].

$$\Theta_m = \mathcal{E} \cdot \left(\frac{\Theta_1 - \Theta_2}{\ln \frac{\Theta_1}{\Theta_2}} \right), \quad (7)$$

here $\Theta_1$and Θ_2 are logarithmic thermal conductivity at the inlet and outlet [Ref 6].

The formula for the correction coefficient$\mathcal{E}$ of the heat transfer coefficient is expressed as [Ref 6]

$$\mathcal{E} = 1 - 0.022 \cdot 2.72^{\left(\frac{\Delta t}{t_1 - \tau_1}\right)} \quad (8)$$

The dependence of efficiency on the external temperature is determined by the formula

$$\eta = \frac{t_1 - T_a}{t_2 - T_a}, \quad (9)$$

Where t_1 is the outside air temperature, t_2 is the outlet temperature and T_a is the inlet temperature. Formula (9) shows that the main factor affecting the efficiency is air temperature [Ref 7].

As the operating experience of gas pumping compressor stations shows, it is very difficult to develop a balancing factor of a compressor station on a cooling device. The influence of external factors is due to the fact that the year has seasonal variations, but at the same time, internal factors differ from the degree of external and internal penetration.

IV. CONCLUSION AND FUTURE WORK

In conclusion, we can say that the factors affecting the efficiency of the air cooling device can be divided into two interdependent categories. The division of these categories into internal and external factors facilitates the process of learning. It can be seen that the technological factors affecting the slowdown of the cooling system are determined by the internal and external heat exchangers of the main cooling device. External factors include temperature, humidity, the fall of the ray of the sun and other factors. It is difficult to balance the impact factors in a balanced manner for each technology and compressor station.

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