ORIGINAL ARTICLE

INTERNATIONAL JOURNAL OF ARTIFICIAL INTELLIGENCE

ISSN: 2692-5206, Impact Factor: 12,23

American Academic publishers, volume 05, issue 03,2025

Journal: https://www.academicpublishers.org/journals/index.php/ijai

ANALYSIS OF THE EFFECTIVENESS OF HYDROCARBON VAPOR CONDENSATION

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Annotation: This article analyzes the heat transfer process during the condensation of hydrocarbon vapors. The study focuses on determining the heat transfer coefficient in both vertical and horizontal condensers. Experimental research was conducted under specific conditions, including a pressure of 200-250 kPa and a vapor flow rate of 0.000122-0.000367 kg/s. The results demonstrate that the heat transfer coefficient increases with rising temperature and that horizontal condensers exhibit 1.5 times higher efficiency than vertical ones. The findings highlight the advantages of using horizontal condensers for improved energy efficiency in industrial applications.

Keywords: Heat transfer, condensation, hydrocarbon vapors, heat exchangers, cooling process, vertical condenser, horizontal condenser, energy efficiency.

This article discusses the analysis of heat transfer during the condensation of hydrocarbon vapors. The study calculated the heat transfer coefficient during the condensation process and examined how this process occurs in horizontal and vertical types of equipment.

The temperature distribution between the gas condensate vapors and the coolant over time and distance was studied using an experimental setup. This process was conducted at a pressure of 200-250 kPa and a vapor flow rate of 0.000122-0.000367 kg/s. In the experiments, the cooling water flow rate was 5 liters per minute. The properties of water were determined based on its temperature using data obtained from scientific sources.

When calculating the heat transfer coefficient, the physicochemical properties of water and gas condensate were measured based on the experimental results, including density, dynamic viscosity, and thermal conductivity. Additionally, appropriate equations using the Reynolds number were applied to calculate the heat transfer process in heat exchange equipment:

$$Re = \frac{AV}{\pi d^2 n} \cdot \frac{\rho}{\mu} \qquad (1)$$

Here

V - volumetric flow rate of water in m^3/s;

d_{vn} - inner diameter of the condenser tubes in m;

n - number of tubes in the device, units

ρ - density of water, kg/m^3;

μ - dynamic viscosity of water, Pa·s.

According to the research results, it was determined that when the water flow rate changes, its movement undergoes a transformation process. In this case, specific equations were selected for the vertical and horizontal types of heat exchangers:

$$Nu = 0.008 \cdot Re^{0.9} \cdot Pr^{0.43} \qquad (2)$$

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The heat transfer coefficient of cooling water is determined using the Nusselt number:

$$a_2 = \frac{Nu\lambda}{d_{вн}} \quad (3)$$

The heat release coefficient of gas condensate vapors for vertical and horizontal condensers was found using the following equations:
For a vertical condenser:

$$a_1 = 378\lambda_{кн} \cdot \left(\frac{\rho_{кн}^2 d_{нр} n_T}{\mu_{кн} G_p}\right)^{0.33} \quad (4)$$

For a horizontal condenser:

$$a_1 = 202 \cdot (p) \cdot \lambda_{кн} \cdot \left(\frac{\rho_{кн}^2 L_T n_T}{\mu_{кн} G_p}\right)^{0.33} \quad (5)$$

Using these equations, the overall heat transfer coefficient is determined by the following formula:

$$K = \frac{a_1 a_2}{a_1 + a_2} \quad (6)$$

The calculation results show the heat transfer coefficients at different temperatures. The obtained values for vertical and horizontal condensers are presented in the tables.
Table 1

Gas condensate temperature, °C		Thermal conductivity coefficient 1, W/ (m2·K)	Cooling water temperature, °C		Heat transfer coefficient 2, W/ (m2·K)	Heat transfer coefficient to the device K, W/ (m2·K)
$t_{н1}$	$t_{к1}$		$t_{н2}$	$t_{к2}$		
174	24	2146	18	34	293	257
180	24	2155	18	25	302	264
186	24	2163	18	27	311	271
192	24	2172	18	24	319	278
198	24	2238	18	24	335	291

The heat transfer coefficient of gas condensate vapors (1), the heat transfer coefficient of cooling water (2), and the total heat transfer coefficient (K) of the device in a vertical tubular condenser:
Table 2

Gas condensate temperature, °C		Heat transfer coefficient 1, W/ (m^2·K)	Cooling water temperature, °C		Heat transfer coefficient 2, W/ (m^2·K)	Heat transfer coefficient K to the device, W/ (m^2·K)
$t_{н1}$	$t_{к1}$		$t_{н2}$	$t_{к2}$		

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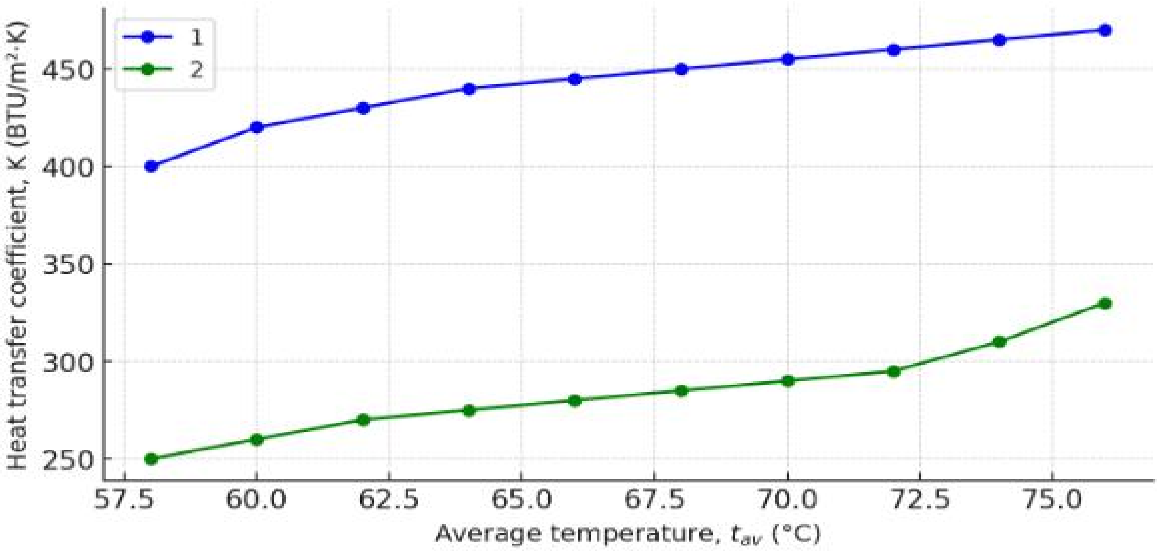
158	17	7820	20	66	428	405
160	19	8931	20	63	450	428
165	15	9460	20	61	459	437
168	14	9519	20	56	462	440
172	14	9687	20	50	468	446

Figure 1 - Dependence of the heat transfer coefficient of gas condensate vapors in horizontal (1) and vertical (2) tubular condensers on the average temperature:
The heat transfer coefficient of gas condensate vapors in a horizontal tubular condenser (1), the heat release coefficient of cooling water (2), and the total heat transfer coefficient (K) of the unit:



This figure shows the change in the heat transfer coefficient of gas condensate vapors depending on the average temperature.

With increasing temperature, the heat transfer coefficient in the horizontal capacitor increased by 41 W/ (m^2·K), and in the vertical - by 34 W/ (m^2·K).

The α1 coefficient (the heat transfer coefficient of gas condensate) increases easily with rising temperature. This enhances the efficiency of gas condensate.

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The coefficient α2 (the heat transfer coefficient of cooling water) is also directly related to temperature. Its values vary with temperature, but it remains lower than the α1 coefficient. An increase in temperature leads to a significant rise in the α1 coefficient. For example, when increasing from 158°C to 172°C, the coefficient α1 rises from 7820 W/ (m^2·K) to 9687 W/ (m^2·K).

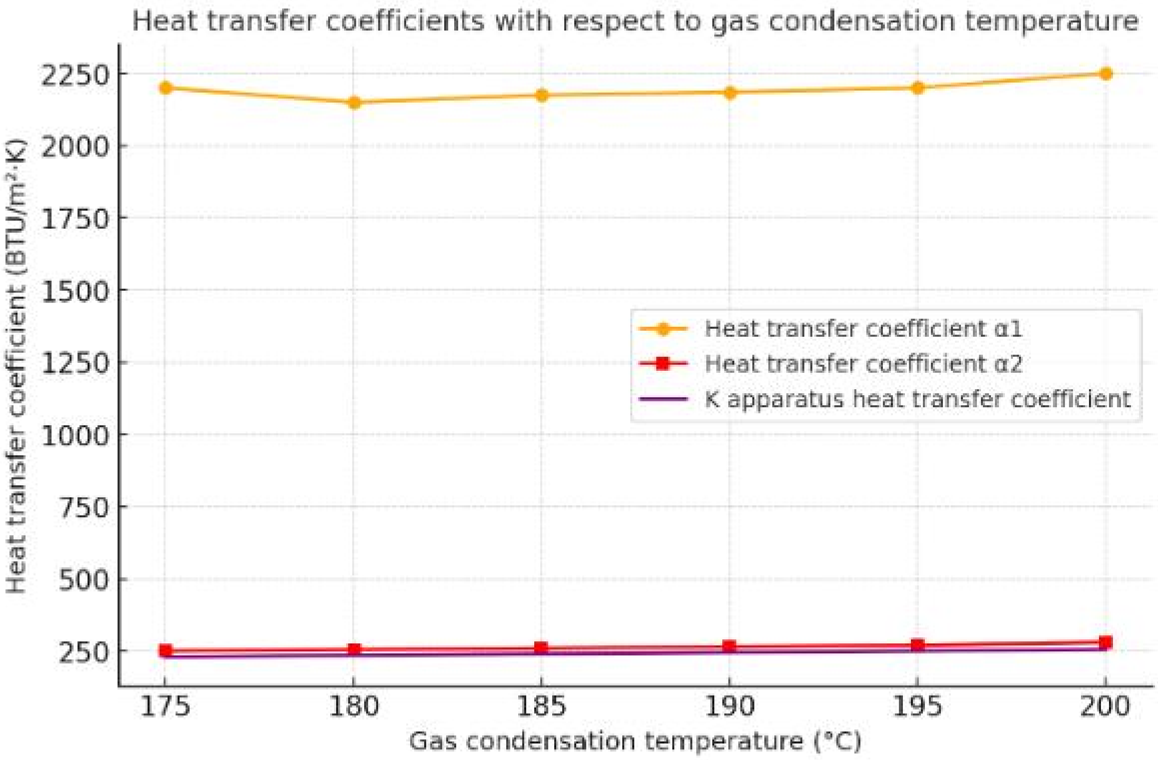

Figure 2. The values of the coefficients α1 and α2 for the gas condensate temperature (°C) are shown.

The coefficient α2 is also directly related to temperature, but its rate of increase is lower than α1. As evident from the calculations presented in the article, heat exchange in horizontal installations is 1.5 times more efficient than in vertical ones. Therefore, the use of horizontal devices for condensing vapors of hydrocarbon raw material fractions is advisable for efficient energy use.

In this new graph, different coefficients are shown with various line styles and symbols:

1. α_1 (Heat Release Coefficient) - with solid lines and square markers.
2. α_2 (Cooling Coefficient) - with dashed lines and triangular markers.
3. K (Total heat transfer coefficient) - with dash-dot lines and circular markers.

• As the gas condensate temperature increases, both the heat release coefficient (α_1) and cooling coefficient (α_2) gradually rise.

• The K-total heat transfer coefficient is influenced by both coefficients and steadily increases with rising temperature.

Conclusion

This study examined the heat transfer process during the condensation of hydrocarbon vapors. The results show that the efficiency of heat exchange differs between vertical and horizontal tube

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condensers. In both types of condensers, the heat transfer coefficient increases with rising gas condensate temperature, but this process is more effective in horizontal condensers.
According to the research results, the heat transfer coefficient in horizontal tubular condensers is 1.5 times higher than in vertical devices, which allows for a reduction in energy consumption. Additionally, the cooling process in such devices is considered optimal.
The research findings have significant practical importance for the design and modernization of industrial devices used in hydrocarbon vapor condensation processes. To reduce energy consumption and optimize the production process, the use of horizontal condensers is recommended.

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