Test Results for Ventilation Units

A S Mozgova¹ and T V Shchennikova¹
¹Construction Faculty, I. Ulianov Chuvash State University, 15, Moskovskiy pr., Cheboksary, Chuvash Republic, 428015, Russia

E-mail: mozgova-energo@yandex.ru

Abstract. The article presents the findings of the tests conducted for the forced air heating unit of a supply ventilation system. The supply air system is designed to feed clean air into the industrial facility of the oil-gas field of the Yamalo-Nenets Autonomous District. The tests were performed in five modes at the ambient air temperatures of -5, -10, -15, -20, -25 °C. The mode throughout the tests was steady, i.e. the temperatures of water and air remained unchanged within 30 minutes before the tests. Since the capacity of the heater unit was proved to be 24 - 41.5% according to the test results, recommendations were made to improve the capacity. With the said measures having been taken, control measurements of test parameters were carried out, the actual U-value was calculated and the capacity of the heater unit was determined. The performed work is relevant in view of theoretical and practical significance for engineers and employees of industrial enterprises servicing the ventilation systems.

1. Introduction
The energy efficiency of industrial enterprises is a burning problem. [1] – [11] The legislation obliges to take measures to reduce the consumption level of energy resources and to ensure the gradual achievement of economic benefits through the use of resources belonging to both buildings and structures and industrial facilities. Determination of the level of losses in engineering structures is considered in papers [12] – [17].
In article [18], comprehensive test findings of the ventilation units in operation mode are stated.
The supply ventilation unit P-2 was inspected at the industrial oil and gas enterprise: blower C14-70 №12.5, capacity 46000 m³/h, type of the heater unit ТРВВ-8, thermal capacity of the blower heater unit 0.7316 Gcal/h.
Measurements of the following indicators were performed throughout the tests:
- Air consumption L through the heater unit, m³/h;
- Coolant flow through the heater unit G, m³/h;
- Air temperature before the heater unit t₁ and behind the heater unit t₂, °C;
- Coolant temperature at the ingress T₁ of the heater unit and at the exit T₂.
All the said measurements were performed in the steady thermal conditions. The temperatures of water and air remained unchanged within 30 minutes before the tests.

2. Methods
The actual thermal capacity is required to be determined during the heater unit tests.
The heat amount that actually goes to warm up the air is calculated by the formula:
\[ Q' = G \cdot c \cdot (T_{i'}^f - T_{f'}^f), \text{W} \] (1)

In this and other formulae, the "ф" index indicates the values that have actually been obtained in the testing process.

The actual U-factor definition is presented in the paper [19]:

\[ \kappa' = \frac{2Q}{F \cdot n \cdot (T_{i'}^f + T_{e'}^f - t_{e'}^f - t_{e'}^f)} \] (2)

where \( Q \) is the heater thermal performance, W; \( F \) - area of the heater surface being warmed up, m\(^2\); \( n \) - number of air heaters; \( T_{i'}^f \) - water temperature at the inlet to the air heater, °C; \( T_{e'}^f \) - water temperature at the outlet from the air heater, °C; \( t_{e'}^f \) - air temperature at the inlet to the heater, °C; \( t_{e'}^f \) - air temperature at the outlet from the air heater, °C.

The reference U-value of air heaters is determined according to formulae considering the mass air flow and water flow rate in heater tubes. [20]

\[ \kappa = 25.5 \cdot (\nu \rho)^{0.06} \cdot \omega^{0.16}, \text{W/m}^2\circ\text{C} \] (3),

where \( \nu \rho \) - the mass air flow rate through the heater unit, kg/(m\(^2\)·s); \( \omega \) - water flow rate in heater tubes, m/s.

The air heater effectiveness is defined according to the formula:

\[ \eta = \frac{\kappa'}{\kappa} \cdot 100\% \] (4)

3. Results
The inspection of the supply unit was performed in five modes at the ambient air temperatures of -5, -10, -15, -20, -25 °C.

The measurement findings and heater U-value calculations are stated in Table 1.

| Table 1. Measurement findings and heater U-value calculations. |
|---------------------------------------------------------------|
| **Ventilation unit parametering #** | 1 | 2 | 3 | 4 | 5 |
| \( G' \) | 5200 | 5250 | 5100 | 5200 | 5150 |
| \( T_{i'}^f \) | 63.1 | 64.3 | 67.9 | 76.1 | 83.2 |
| \( T_{e'}^f \) | 45.2 | 44.1 | 45.3 | 46.2 | 46.0 |
| \( Q' \) | 108252 | 123336 | 134047 | 180823 | 222808 |
| \( t_{e'}^f \) | 16.8 | 17.2 | 17.0 | 19.0 | 19.1 |
| \( t_{e'}^f \) | 30.0 | 33.1 | 34.9 | 37.2 | 38.0 |
| \( L \) | 39790 | 39880 | 38765 | 39990 | 41000 |
| \( F \) | 282.4 | 282.4 | 282.4 | 282.4 | 282.4 |
| \( \kappa' \) | 12.5 | 15.0 | 15.5 | 19.3 | 21.9 |
| \( f_{\nu} \) | 1.58 | 1.58 | 1.58 | 1.58 | 1.58 |
| \( f_{\nu} \) | 0.007 | 0.007 | 0.007 | 0.007 | 0.007 |
| \( \nu p \) | 7.0 | 7.0 | 6.8 | 7.0 | 7.2 |
| \( \omega \) | 0.21 | 0.21 | 0.20 | 0.21 | 0.21 |
| \( \kappa \) | 52.0 | 52.2 | 51.2 | 52.2 | 52.7 |
4. Discussion
The calculation results to determine the efficiency of the supply ventilation heater unit are demonstrated in Fig. 1.

The actual condition of the heater unit was satisfactory. With the tests having been performed, the intertubular and interfin space was cleaned and control measurements were taken at the ambient air temperature of -15°C. The heater unit capacity amounted to 67.3%.

5. Conclusions
The tests conducted at the heater unit in five ambient temperature modes of -5, -10, -15, -20, -25°C resulted in the heating capacity amounting to 24.0-41.5%, which is below the optimal value (75-80%). By the testing period, the condition of the heater unit was satisfactory, with the last flushing of the heater unit being performed 1.5 years ago. After external flushing of the heater unit, the measurements were taken repeatedly, and the capacity increased by 37% (the measurements were taken at the external air temperature of -15°C). In the future, the personnel operating the ventilation equipment will take measurements and perform heater flushing not on the annual basis, but basing on its pollution and with the capacity decrease. The performed work is relevant in view of theoretical and practical significance for engineers of industrial enterprises servicing the ventilation systems.

6. References
[1] Bakulina A A, Karpukhin D V, Lapina M A 2018 Lighting products: problems of technical and legal regulation of saving and energy efficiency Light & engineering 4 pp 93-98
[2] Borshcheniuk V, Semeryanova N, Filatova U, Nikolaeva D and Frolova E 2019 Issues of implementing the state program of energy saving and energy efficiency E3S Web of Conferences 110 02080 DOI: 10.1051/e3sconf/201911002080
[3] Alabugin A, Aliukov S and Osintiev K 2017 Management models of efficiency of development of resource and energy saving systems using methods of approximation of step functions Proceedings of the World Congress on Engineering 1 pp 102-106
[4] Meshcheryakova T 2019 Assessment of energy saving and energy efficiency development in Russia and abroad E3S Web of Conferences 110 01076 DOI: 10.1051/e3sconf/201911001076

Figure 1. Calculation results.
[5] Borshcheniuk V, Semeryanova N, Filatova U, Nikolaeva D and Frolova E 2019 Issues of implementing the state program of energy saving and energy efficiency E3S Web of Conferences 110 02080 DOI: 10.1051/e3sconf/201911002080

[6] Ermolaev K A, Dyrdonova A N and Kamaev B N 2017 Methods of modelling in the context of energy saving management and increase of energy efficiency of industrial enterprises 2nd International conference on Energy and Development (Vienna: Premier Publishing s.r.o) pp 58-64

[7] Alabugin A, Aliukov S and Osintsev K 2017 Management models of efficiency of development of resource and energy saving systems using methods of approximation of step functions Proceedings of the World Congress on Engineering 1 pp 102-106

[8] Kluczek A and Olszewski P 2017 Energy audits in industrial processes Journal of Cleaner Production 142 pp 3437-53

[9] Belussi L, Danza L, Salamone F, Meroni I, Galli S and Svaldi S D 2017 Integrated smart system for energy audit: Methodology and application Energy Procedia 140 pp 231-239 DOI: 10.1016/j.egypro.2017.11.138

[10] Nizovtsev M I, Borodulin V Yu and Letushko V N 2017 Influence of condensation on the efficiency of regenerative heat exchanger for ventilation Applied Thermal Engineering 111 pp 997-1007 DOI: 10.1016/j.applthermaleng.2016.10.016

[11] Lyalkina G, Nikolaev A and Makarychev N 2018 Creation of the Information System Based on Experimental Data for Control of the MMF Operating Modes to Improve the Efficiency of Ventilation in Mines Journal of Physics: Conf. Series 1059 012013 DOI: 10.1088/1742-6596/1059/1/012013

[12] Nemirovsky Y V and Mozgova A S 2020 Thermal conductivity of gasholders during gas storage J. Phys.: Conf. Ser. 1565 012057 DOI: 10.1088/1742-6596/1565/1/012057

[13] Nemirovsky Y V and Mozgova A S 2019 Two-dimensional steady-state heat conduction problem for heat networks J. Phys.: Conf. Ser. 1359 012138 DOI: 10.1088/1742-6596/1359/1/012138

[14] Nemirovsky Y V and Mozgova A S 2019 Thermal conductivity of cylindrical tanks for backup fuel of boiler rooms J. Phys.: Conf. Ser. 1382 012139 DOI: 10.1088/1742-6596/1382/1/012139

[15] Nemirovsky Y V and Mozgova A S 2018 Problems of thermal conductivity for storage tanks of liquefied gases and oil products Journal of Physics: Conf. Series 1128 012131 DOI: 10.1088/1742-6596/1128/1/012131

[16] Nemirovsky Y V and Mozgova A S 2018 Proceedings of the XI all-Russian scientific and technical conference “Topical issues of architecture and construction” (Novosibirsk: Novosibirsk state University of architecture and civil engineering) pp 9-15

[17] Nemirovsky Y V and Mozgova A S 2017 Bulletin of the Yakovlev Chuvash State Pedagogical University Series: Mechanics of Limit State 2 pp 23-32

[18] Mozgova A S and Shennikova T V 2020 Determination of the real energy efficiency of the inlet ventilation air heater and air curtain J. Phys.: Conf. Ser. 890 012147 DOI:10.1088/1757-899X/890/1/012147

[19] Agafonov E 1978 Adjustment of industrial ventilation systems (Moscow: Stroizdat)

[20] Shilyaev M 2019 Heating, ventilation and air conditioning (Moscow: Yurayt)