Methods for improving energy efficiency of air handling unit using factor analysis of data

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Abstract. The article is devoted to ways of increasing industrial air conditioners efficiency. The current problem of increasing the energy efficiency of the supply and installation is considered in the article. A comparative analysis of the energy saving installation with and without a recuperator for the assembly hall was carried out. Installations of this type can be used for productions of various types, including at enterprises of the energy sector and mineral and raw materials complex. Ways to improve the existing equipment are considered. The possibilities of using factor analysis in determining the location of the installation and selecting the number and type of air conditioners are shown. The coolants properties are different depending on the required room temperature and the type of production. The issue of application expediency of trigeneration schemes for micro-gas turbine and gas-piston power units is also considered.

1. Introduction

To maintain a comfortable indoor microclimate, various systems of building engineering equipment are used. These systems include systems of heating, ventilation and air conditioning. Countries with a long-term winter period have a high potential in the field of energy conservation, including Russia. For example, it is used in such industries as power engineering and fuel-energy to raise the efficiency of equipment. It is necessary to be treated with a high degree of responsibility, since the equipment used here is the most energy-consuming in comparison with other spheres of production.

Heat-recovery devices of various types are used to improve energy efficiency. Most popular heaters are a regenerator, a recuperator and a heat recovery unit with an intermediate heat-transfer agent [1, 2, 3]. The properties of the coolants are different depending on the required room temperature and room appointment. It becomes important at the constant or temporary presence of people in the room. In addition, attention to heat generation equipment should be paid.

Recuperative ventilation systems are the most energy efficient compared to other available systems [3]. The currently used industrial air conditioning systems mostly have a low coefficient of secondary energy use. Also, these systems are not always sufficiently equipped with instrumentation and automation.

Within the framework of this article, a comparative analysis of existing energy saving installations and calculation of the thermal energy of units with and without the recuperator is presented. Based on the calculation, the most optimal system for this assembly hall is chosen.

2. Equipment analysis

According to the terms of reference, it was planned to install a supply and exhaust system with an estimated air consumption of L = 1600, m^3/h.

Technical characteristics of supply and exhaust units AHU – 1 with a recuperator and without it in Table 1 are considered, fig.1. To warm the outside air to a set temperature of 18 ° C, different methods were used in the calculated five-day period.

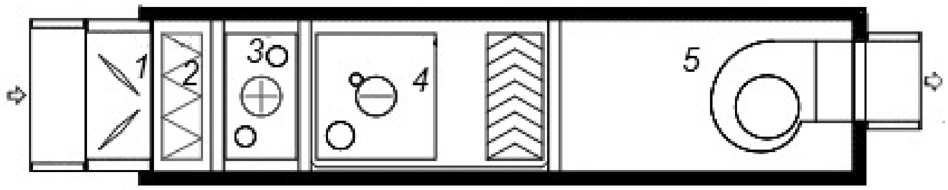

Figure 1. Standard setting of AHU-1 (CCFP-1.6-U3): 1 – front panel with valve, 2 – panel filter, 3 – hot-air heater, 4 – direct cooling air cooler, 5 – fan.

In the AHU-1 with the recuperator, fig. 2, the outside air was heated by means of electric heaters built into the unit. Using the installation with a rotary recuperator allowed saving about 60% of electricity. The tubular electric heater with a power of only 13 kW is installed after the recuperator to reheat the outside air [4, 5]. Used air, having passed through the recuperator, giving heat to the outside air was discharged outside at the temperature of -16.3 ° C. The calculated outdoor temperature is -35 ° C.

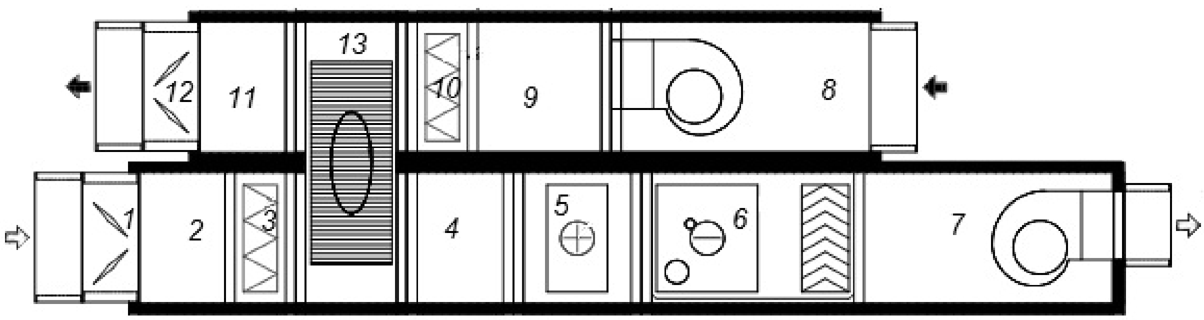

Figure 2. Setting of AHU-1 (CCFP-1.6-U3 with the recuperator): 1 – front panel with valve, 2 – intermediate chamber, 3 – filter, 4 – intermediate chamber, 5 – electric air cooler, 6 – direct cooling air cooler, 7 – fan, 8 – fan, 9 – intermediate chamber, 10 – filter, 11 – intermediate chamber, 12 – front panel with a valve, 13 – rotary heat exchanger (recuperator)

It was suggested to install the AHU-1 installation without a recuperator because the conference hall is rarely used. Such solution could possibly be more effective [6, 7].

A heat-transfer agent for heating the outside cold air was a water.

3. Methodology of research investigation

The methodology is based on the data of measurements and reference data for air, water and refrigerants.

The formula for calculating the consumption of heat for heating outdoor air is:

$$Q = L \cdot c \cdot p \cdot (t_{in} - t_{en}) / 3600, \quad (1)$$

where L is the rate of supply of air to the space, m^3/h;

t_{in} is the temperature of the heated air supplied to the room, °C. This temperature is determined by the regulatory documentation

t_{en} is temperature of outside air , °C;

c is heat storage capacity of air, kJ/(kg·K).
p is density of air, kg/ m^3 (1.2 kg/ m^3 at 20 °C [5]).
t_{en} is selected for the minimum five-day period to calculate the installation without a recuperator.
The calculations are summarized in Table 1.

The air that enters the unit with a recuperator is first heated by the air leaving the room from the outside temperature (t_{en}) to the temperature that is embedded in the characteristics of the product (-16.9 in this case). The technical characteristics depend on the design features. It is indicated in the product passport.

In the unit with the recuperator, the outside cold air is heated. So the temperature difference is assumed to be (t_{in}-t_{en}) = 18 - (-16.9) °C.

Table 1. The technical characteristics of air-conditioning units

Type of AHU	Heat carrying agent	t_{en}, °C	t_{in}, °C	Air consumption, L, m^3/h	Heat consumption, Q, kW/h
CCFP-1,6-U3 without recuperator	Water	-35	-18	1600	28
CCFP-1,6-U3 with recuperator	Electricity power	-16,9	-18	1600	18.7

Economically, it is possible to justify the use of more modern control systems for industrial air-conditioning [4, 8]

4. Application of the factor analysis

A researcher is guided by certain hypotheses when collecting data, and the information obtained in the course of the research relates to the selected subject and topic of the study, but often it is a material in which it is necessary to study the structure of indicators characterizing objects, and also to identify homogeneous groups of objects. Information should be better represented in a geometric space, laconically reflect its features in the classification of objects and variables. Such work creates prerequisites for the identification of objects typologies and the formulation of a space in which the distances between objects of observation are designated, allows us to visualize objects properties. The meaning of the factor analysis model is that the measured empirical indicators, variables are considered the consequence of other, deep, hidden from the direct measurement characteristics - latent variables. A schematic model of factor analysis can be represented as follows:

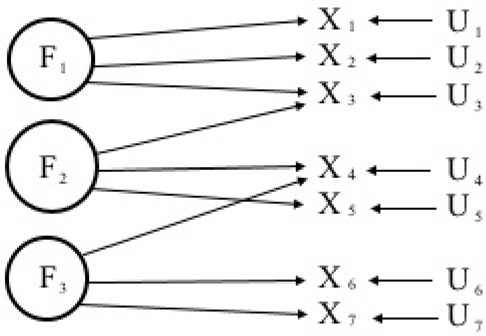

Figure 3. Conditional representation of the factor analysis model: F_1, F_2, F_3 - common factors, each of which affects a certain set of variables; X_1, X_2,...,X_7 - variables, formed on the basis of the answers of the respondents; U_1, U_2,..., U_7 - unique factors, each of which affects only one variable.

The factor analysis equation has the form:

$$X_i=\Sigma_{k=1}(a_{ik}F_k+U_i), \qquad (2)$$

where a_{ik} - factor loadings.

It is assumed that X are standardized, and factors F_1, F_2,..., F_n are independent and not related to specific factors U.

It is also assumed that factors F are standardized. Under these conditions, factor loads a_{ik} coincide with the correlation coefficients between the common factors and variables X. Dispersion X is decomposed into a sum of factor loads squares and the variance of a specific factor:

$$S_{Xi}^2=H_i^2+S_{Ui}^2, \quad (3)$$

$$H_i^2=\Sigma_k a_{ik}^2. \quad (4)$$

The value of H_i^2 is called commonality, S_{Ui}^2 is specificity.

In other words, commonality is a part of variance of variables, explained by common factors, specificity is a part not explained by common dispersion factors. In accordance with the formulation of the problem, it is necessary to look for factors in which the total community is maximal, and the specificity is minimal.

The application of formula (3) is possible when determining parameters that directly and indirectly affect the quality of air conditioning by the industrial air conditioning system [9, 10].

5. Conclusion

The cost of electricity is more than three times the cost of thermal energy, but despite this, the use of tubular electric heaters (TEH) is more economical.

At "zero" temperatures, there is practically no heating of the outside air, so there is almost no energy expenditure either.

The outside cold air is heated internally to a predetermined temperature.

As a result of consideration, a version of the supply and exhaust system AHU-1 with the recuperator was chosen.

6. Acknowledgments

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References

[1] Tikhomirov K and Sergeenko E 2009 Thermal engineering, heat and gas supply and ventilation Bastet Publishing 446-80

[2] Eremkin A, Coroleva T and Danilin G 2008 Energy saving in buildings with the utilization of exhaust air heat: textbook Publishing house of the Association of Construction Universities 167-84

[3] Gubina I and Gorshkov A 2015 Energy saving in buildings with utilization of exhaust air heat *Construction of unique buildings and structures* **31(4)** 12-19

[4] 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 *Lecture Notes in Engineering and Computer Science* **1** 102-12

[5] Stomakhin G 2003 *Heating, ventilation and air conditioning. Residential buildings with built-in public buildings and parking* (Pantori Publising)

[6] Building climatology. Rules 131.13330.2012. Updated version of rules 23-01-99 2012 Ministry of Regional Development of Russia Publising 35-67

[7] Sunil D Refrigeration and Air Conditioning 2018 Nirali Prakashan Publishing 46-84

[8] Szelitzky T, Dulf E 2010 Advantages of robust control for series load pulse amplitude modulation induction heating inverter *IEEE International Conference on Automation, Quality and Testing, Robotics (AQTR)* **2** 1-4

[9] Teruyuki S A New Concept for Air-Conditioning in Japan: An All-Air Supplied Induction Radiant Air-Conditioning System and Cool Room 2018 In book: Towards the Implementation of the New Urban Agenda 86-97

[10] Hundy G, Trott A, Welch T Air Conditioning Methods and Applications 2016 In book: Refrigeration, Air Conditioning and Heat Pumps 124-28