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Section: Energy for Buildings

Modern solutions to improve the efficiency of air treatment in HVAC Systems

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Abstract

Based on theoretical and experimental tests it was determined, that thermodynamic balance condition in the working space of contacting units of ventilation and air conditioning systems (HVAC systems) is entirely defined as the same values of humidity potential of finite parameters of air and water – Θ = const.
This makes it possible to put forward a new method of the analysis and calculation of heat and moisture exchange in contacting units HVAC systems.
It was established, that condition Θ = const of finite parameters of contacting environments is an index of the optimal mode of operation of the contacting unit, where in high thermodynamic efficiency of processes of heat and moisture exchange in it's working space is achieved.
The data received made it possible to work out a new approach to the implementation of energy-efficient processes in the contact units, and a new method of control their parameters.
The features of the progress of processes of heat and moisture exchange in contacting units are considered viewed in the article, and also the results of the offered method of moisture content of incoming air regulation in use are presented.

Keywords: humidity potential; heat and moisture exchange; contacting units.

Nomenclature

I	enthalpy (kJ/kg)
P	partial pressure (Pa)
t_1	initial temperature of air (°C)
d_1	initial absolute humidity of air (g/kg)
t_2	nitial temperature of water (°C)
B	sprying factor (kg/kg)
G_1	air flow rate (m^3/h)
G_2	water flow rate (m^3/h)
Greek symbols	
φ	relative humidity (%)
Θ_1	initial humidity potential of air (°B)
Θ_2	initial humidity potential of water (°B)
c_p	specific heat capacity, J/(kg·K

1. Introduction

Improving the efficiency of HVAC systems connected with optimization of energy consumption and reduction of energy expenditure for heat and primary air humidity handling in contacting units is widely discussed [1, 2].

In the theory of contacting units for efficiency characteristics of heat and moisture exchange ratio is often used Lewis number (Le), and the number of transfer units (NTU) [3, 4].

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Deviation ratio of Lewis number from the theoretical value (Cp) is explained by the dual nature of the process of transfer of moisture, and is an indirect characteristic intensity simultaneous processes of heat and moisture exchange in the workspace of the contacting units [5].

The main criterion of optimal performance contacting units is to create conditions (hydrodynamic and hygrothermic) of heat and moisture exchange processes, which provide the achievement of thermodynamic balance final parameters interacting media [6].

The application of the humidity potential theory enabled to define the condition of thermodynamic balance for interacting media in contacting units. In particular, it was found that implementation of cooling and dehumidification final parameters of air and water tend to achieve a state Θ = const in the range humid air of φ = 80–100% on the I-d-Θ- diagram (Fig. 2) [7].

It should be noted that complex character the interaction of air and water takes place in the workspace contacting units. It does not allow an unambiguous assessment of the effectiveness of heat and moisture exchange processes and requires additional research.

In modern conditions, the solution of this problem is the basis for determining ways of improving contact units and increase their thermodynamic efficiency.

2. Subject of study

Energy efficiency of treatment of air in HVAC systems can be achieved through optimization the operating modes to ensure most rational sequence of their implementation.

The most widely used method of optimal modes, based on thermodynamic approaches for assessing excellence different sequences of air treatment in terms of energy consumption. This method has been developed in the papers of prof. Rymkevich A.A. [2].

Required parameters of the supply air can be achieved by varying the sequence of treatment processes in the conditioner

As a criterion of efficiency any sequence modes elements in HVAC systems is usually accepted the inevitable minimum energy consumption in these conditions

Also, the efficient use of energy in HVAC systems can be achieved through controlling and regulating of heat and moisture exchange in contacting units.

Control the processes of heat and moisture exchange can be realized by changing the surface the interaction of air and water in the workspace contacting units.

Basic provisions on the thermodynamic essence of control processes an adiabatic humidification, as well as their particular automation schemes are given in [8].

In operation of the contacting units (when initial parameters of environments or modes of their work are being changed), there is a necessity of regulation one of the parameters (for example, moisture content of supply air) for the purpose of preservation of its constant value.

Resolving this issue should be considered with respect to the direction of air parameters change as a result of heat and moisture in the workspace contacting unit.

Known that reduction in energy consumption for processing the supply air is primarily determined by the rates of intensity the flow of exchange processes, which is estimated the following value [9]:

$$\Lambda = \alpha_t \cdot F_{жс} \tag{6}$$

where α_t – the heat transfer coefficient, W/m^2; $F_{жс}$ – contact surface, m^2.

The value Λ is determined on the basis of experimental results in the mode isenthalpic humidification. In order to determine the relative temperature settings should be used the expression:

$$\theta_t = 1 - \exp(-F_0') \tag{7}$$

$$Fo' = \frac{\alpha_t \cdot F_{жс}}{c_в \cdot G_в} = \frac{\Lambda}{c_в \cdot G_в} \tag{8}$$

where Fo' – modified criterion Fourier; $c_в$ – heat capacity of air, J/kg·K; $G_в$ – mass flow rate of the treated air, kg/h.

3. Methodology

Realization of process in the workspace contacting units goes on a complicated curve, consisting of sections with different orientation processes of heat and moisture transfer [10, 11].

To analyze the progress of heat and moisture exchange processes the model of workspace of the contacting unit (Fig. 1) was used including distinctive zones (L_I, L_{II}, L_{III}) of air parameters change lengthwise of contacting unit.

The progress of heat and moisture exchange processes is characterized by hygrothermic and hydrodynamic conditions of interaction in a working space of contacting units [12, 13].

Hygrothermic conditions are determined by combination of initial parameters of air (t_1, d_1, Θ_1) and water (t_2, Θ_2), and hydrodynamic ones – are determined by a ratio of air flows (G_1) and water (G_2), i.e. by value of a spraying factor (B).

The combination of conditions determines an operational mode of the contacting unit, including the direction of change for parameters of air lengthwise of contacting unit (Fig. 2).

In Fig. 2 the possible directions of processes of air processing (lines A and D) are shown, ensuring achievement of required values of finite parameters of air (t_1', d_1', Θ_1') in a mode of cooling and drying of air. Thus finite parameters of air and water are on a line Θ = const.

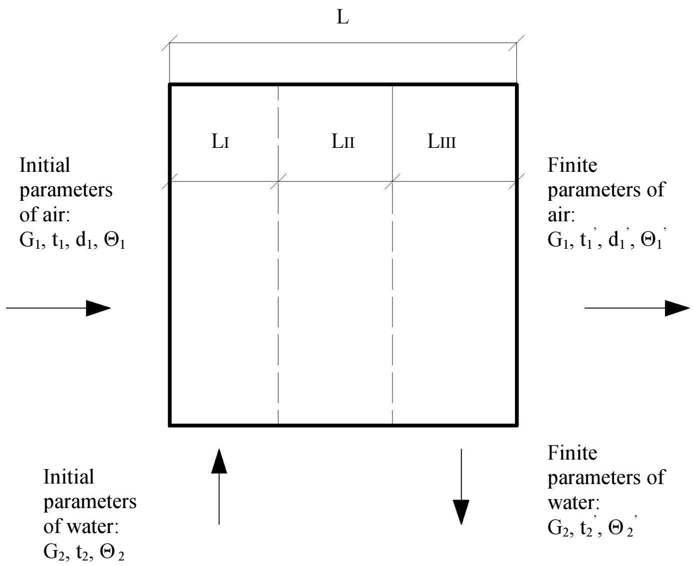

Fig. 1. Model of contacting unit of HVAC systems

When process goes along the line A (Fig. 2), a calculated regime of air processing takes place lengthwise (or surface heat and moisture exchange)of contacting unit – cooling and drying. This mode of contact unit can be called "ideal", its implementation presents some difficulties associated with significant costs of energy to create required a contact surface, provide the required hydrodynamic interaction conditions, etc.

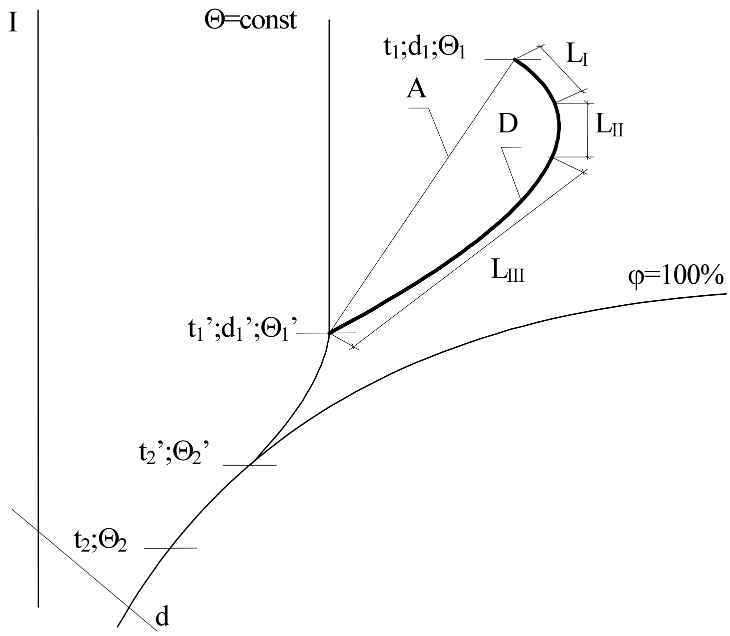

Fig. 2. Changing parameters of air and water in contacting unit at the I-d-Θ diagram

In real conditions the progress of processes takes place along the curve D (Fig. 2), where one can see, that the calculated regime of processing of air takes place only in the third zone (L_{III}). Thus in the first zone (L_I) the process is close to I = const, and in the second zone (L_{II}) it is close to d = const.

That is estimated processing mode of air (cooling and drying) will be observed only part of the length (or the surface of the heat and moisture exchange) of the contacting units, which reduces the resulting values of the coefficients of heat and moisture exchange, and therefore average indicators intensity of proceedings of processes of heat and moisture exchange will have lower values relative to an "ideal" mode.

Thus the direction of proceedings of processes determines an efficiency of work of the contacting units, and increasing the efficiency can be achieved by reducing the areas of L_I and L_{II}, while maintaining optimal conditions for interaction defined achievement condition Θ = const final parameters of air and water.

4. Results

Taking into account features of the progress of processes of heat and moisture exchange in contacting units in Fig. 3 curves (a, b and c) of changing of air parameters along a contacting unit are presented at realizing regulation of moisture content (d_1) of air at the outlet from the contacting unit. Direction of the air parameters change in curve A takes place at some value of spraying factor $B_1=G_2/G_1$ and constant values of initial parameters of air (t_1, d_1, Θ_1) and water (t_2, Θ_2).

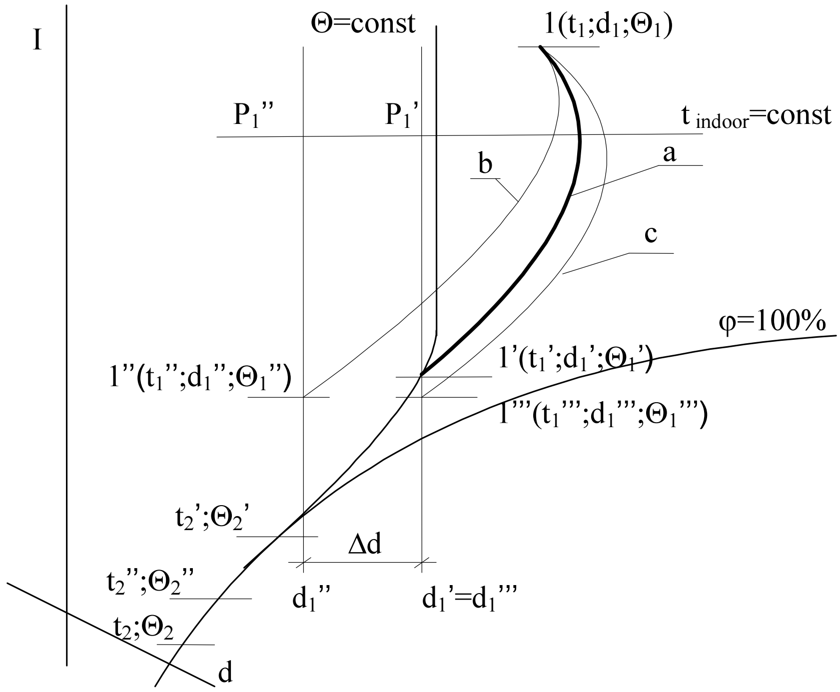

Fig. 3. Method of air parameters control on I-d-Θ diagram

When increasing a spraying factor to the value B_2 ($B_2>B_1$) under the same initial parameters of air and water a direction of process on curve b (Fig. 3) will take place but finite parameters of air will be moved to the point 1″ and will have values t_1'',d_1'', Θ_1''. The deviation of moisture content of inlet air from the calculated value d_1 to lower values – $\Delta d = d_1'' - d_1'$ will happen.

But if at the same time with increasing spraying factor to B_2 one increases an initial temperature of water to t_2'' ($t_2''> t_2$), as a result the air processing process will go along curve c (Fig. 3) to parameters t_1''',d_1''', Θ_1''' that will ensure an achievement of the required value of inlet air moisture content $d_1'''= d_1'$.

Thus, as a result of proportional increase of initial temperature of water and increase of a spraying factor the constancy of final moisture content of incoming air is ensured and precision of air parameters in a working space is increased.

The regulation of parameters of incoming air in case if its moisture content deviates to larger values is made in the same way.

To confirm the theoretical conclusions and the approve the offered method of regulation series of experiments were conducted in the injector spraying chamber. The results of one of the series are presented in Table 1.

The analysis of the experimental results demonstrates the fact that at the increase of a spraying factor up to 1,49 kg/kg (test 2) at constant initial parameters of air, the moisture content of final parameters of air decreases down to 8,7 g/kg.

To support the required value of moisture content d1 = 9,5 g/kg the initial temperature of water was increased up to 8,9°C (Table 1, test 3). Thus, the possibility of air moisture content regulation at the outlet of the injector chamber is achieved with a proportional change of initial parameters of water and factor of spraying.

Table 1. Results of tests of the spraying chamber

Test	Parameters of air, °C				Parameters of water, °C		B, kg/kg	Moisture content of finite parameters of air, d, g/kg
	initial		finite		initial	finite		
	t_1	t_m’	t_1’	t_{m1}’’	t_2	t_2’		
1	2	3	4	5	6	7	8	9
1	26.1	19.5	15.1	14.0	6.9	11.0	1.0	9.5
2	26.0	19.4	12.8	12.3	6.8	10.5	1.49	8.7
3	26.1	19.4	14.0	13.5	8.9	11.8	1.5	9.5

5. Conclusions

The article discusses the possibility of increasing the effectiveness of treatment of air in HVAC systems by using control processes heat and moisture exchange between air and water

The regulation method of air supply parameters (in particular, its moisture content) considering thermodynamic regularities of heat and moisture exchange in contact devices is offered.

The presented method allows to regulate parameters of air operating processes heat and moisture exchange, providing thus optimum conditions of interaction.

Thus a condition of preservation of optimum conditions in working space of the contacting units is the condition of Θ = const of parameters of air and water at the exit from the contacting units.

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