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SAVING ENERGY IN VENTILATION AND AIR CONDITIONING SYSTEMS

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ABSTRACT--*The peculiarity of microclimate support systems is that they consume a large number of energy resources, including thermal and electric energy and tap water. The problem of reducing energy consumption by ventilation (HV) and air conditioning (SLE) systems, as part of the general problem of efficient energy use, is especially relevant in the highly continental conditions of the Republic of Uzbekistan.A quantitative assessment of the energy efficiency of microclimate facilities is based on the total annual energy consumption of the systems. Annual energy consumption appears to be the most objective energy indicator, since it is in the annual cycle that all energy consumption modes are fully manifested.With SK equipment, the determination of the annual heat or cold consumption of SV or SCR is reduced to the integration of the power consumption of the equipment depending on the season. The latter value is a function of the heat content of the outdoor air, because heat and artificial cold are only used to process the outdoor air. Among the variety of models representing the annual change in the parameters of the outdoor air, we distinguish two groups. The first type of models is based on a description of the annual course of monthly average parameters. Models are presented in tabular form or described analytically. A variation of this model of the external climate is the so-called representative year, the use of which has become widespread abroad.*

Keywords*-- saving energy in ventilation and air conditioning systems*

I. INTRODUCTION

The second type of presentation of climate information uses the processing of urgent measurements in the form of parameter distribution functions. Distribution functions are set in tabular form, in the form of graphs, or are approximated by analytical dependencies. This type of representation of the climate meets certain difficulties. Firstly, complex meteorological data processing is required, and secondly, a fundamental difficulty arises, which consists in the need to operate with a two-dimensional distribution of parameters. In this case, the inevitable attraction of a cumbersome mathematical apparatus, which is also based on significant assumptions in the formulation of the problem, is inevitable. At the same time, the second type of climate model has an undoubted advantage over the first, consisting in the fact that the entire range of its change is included in the parameter information.

When averaging the parameters of the outdoor air, the existing range of parameter changes is reduced, which is a drawback of the first model. However, averaging eliminates all kinds of interference and allows us to highlight the main regularity of the parameter change over time, resulting from the physical nature of the processes that form the parameter. This is a definite advantage of the first model. But its main advantage is the simplicity of the representation of the time functions of the parameters, as well as the large amount of available data.

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The reduced range of parameters specified by average values is not an obstacle to their use in the analysis of the annual operating regime of SW and SCR, since the transition from mode to mode occurs, as a rule, at "moderate" parameter values. Only some modes of operation of the systems, which are not indicative from the point of view of energy consumption, occur at climate parameters close to the calculated ones.

It should be noted that when calculating the annual energy costs of systems, there is no need to involve parameters close to extreme in the analysis. This circumstance was rightly pointed out by A. M. Sizov [1]. If we keep in mind that the middle part of the distribution function coincides with the monthly average values, then the noted advantage of the completeness of the representation of the parameter by the distribution function is significantly reduced. Studies conducted by Yu. Mazukh [2] showed a slight discrepancy between the results of calculating the annual energy consumption for the two models, which confirms the legitimacy of using averaged climate parameters.

The foregoing considerations allowed us to develop fairly simple formulas for calculating the annual consumption of heat, cold, and electric energy of NE and SCR, which are given below. The accompanying database of annual changes in the parameters of the outdoor air allows calculation for a large number of settlements.

II. CALCULATION OF ANNUAL HEAT CONSUMPTION FOR VENTILATION, AIR CONDITIONING.

Calculation of annual heat and electric energy expenditures for a ventilation, air conditioning and cold system for hard currency is done separately for each work shift or part of a day (hereinafter referred to as shift), followed by summing up when the systems operate in two or more shifts.

The calculation uses the average outside air parameters during the system operation (per shift):

a) temperature of the hottest and coldest month, ° C:

$$t_{m,h} = t_h + A_h K_1 K_2, \quad (1)$$

$$t_{m,c} = t_c + A_c K_1 K_2, \quad (2)$$

where t_h, t_c – is the average temperature of the hottest and coldest month in ° C, determined by the table. 3 SNiP 23–01–99 "Construction climatology"; KMK 2.01.04.97

A_h, A_c – the amplitude of the temperature in ° C, equal to half the average amplitude of the hottest (Table 2) and cold (Table 1 KMK 2.01.04.97) months;

K1 is the coefficient determined by the table. 1 depending on the duration of the shift;

K_2 – coefficient determined by the table. 1 depending on the time in the middle of the shift.

b) Enthalpy of the hottest and coldest month, kJ / kg:

$$I_{m,h} = I_h + A_{i,h} K_1 K_2, \quad (3)$$

$$I_{m,c} = I_c + A_{i,c} K_1 K_2, \quad (4)$$

where I_h , I_c – average enthalpy of the hottest and coldest month, determined by the table. 3;

$A_{i,h}$, $A_{i,c}$ – the amplitude of the enthalpy of the hottest and coldest month, determined by the table. 3.

c) average annual temperature, taking into account the operating time of the system:

$$t_{m,a} = t_a + 0{,}5\,(A_h + A_c)\, K_1 K_2, \quad (5)$$

где t_a – the average annual temperature, determined by the table. 3 KMK 2.01.04.97;

A_h, A_c – temperature amplitudes determined by "a".

d) average annual enthalpy, taking into account the operating time of the system:

$$I_{m,a} = I_a + 0,5\ (A_{i,h} + A_{i,c})\ K_1K_2 \tag{6}$$

where I_a – the average annual enthalpy, determined by the table. 3;

$A_{i,h,}$ $A_{i,c}$ – the enthalpy amplitudes determined by "B".

III. ANNUAL HEAT CONSUMPTION FOR HEATING THE SUPPLY AIR IN THE NE

The annual heat consumption for heating the supply air for one shift in the direct-flow unit, in kJ / kg, is:

$$Q = 0,143\ nmGc(t_{ex} – t_{m,c})\ MK_3K_4, \tag{7}$$

Where n – number of working days per week;

m – shift duration, h;

c – specific heat of air equal to 1.005 kJ / kg • ° C;

G – maximum flow rate of supply (outdoor) air, kg / h;

T_{ex} – supply air temperature in the cold season, ° C;

$t_{m,c}$ – the outdoor temperature of the coldest month, determined by the formula (3);

M – the duration of the period of heat consumption by the SV air heater, in days;

K_3, K_4 – the coefficients determined by the table. 2 depending on the value of M.

Heat consumption by the CB air heater in the once-through system continues as long as the outdoor temperature is lower than the supply air temperature t_{ex}:

$t_{m,a}$ – the average annual outdoor temperature, according to the formula (5).

The annual heat consumption for SW working with air recirculation is calculated according to formula (7), in which instead of the outside temperature tm, x, the temperature of the mixture of outside and inside air should be taken:

$$t_{m,см} = t_{in,c}\ (1 – G / G_o) + t_{m,c}\ G / G_o\ . \tag{9}$$

In the formula (9),G и G_o – are the consumption of external and supply air, kg / h;

$T_{in,c}$ – internal air temperature in the cold season, ° C.

Heat consumption by the SV air heater in the recirculation system takes place while the temperature of the mixture of outdoor and indoor air is lower than the supply air temperature in the cold season. In this case, in the formula (8), instead of $t_{m,c}$ instead of $t_{m,см}$ according to the formula (9), and instead of $t_{m,a}$ – the average annual temperature of the mixture, which must be determined by the formula (9) at the average annual outdoor temperature.

The number of hours of operation of the heater during the year is determined by the formula:

M_a = 0,143 Mn m K_3. (10)=0,143*2*1,04*5*225=25,168=47,9=0,143*2*0,97*1295=178,9=179

IV. THE ANNUAL CONSUMPTION OF COLD HARD CURRENCY

The annual cold consumption of direct-flow SCR is equal to in kJ / g:

$$Q_c = 0{,}143 \text{ n m G } (I_{m,h} - I_o) \text{ M } K_3 K_4, \tag{11}$$

Where M – the duration of the period of cold consumption in days, determined by the formula (12)

$I_{m,h}$ – the enthalpy of the outside air of the hottest month, determined by the formula (3);

$I_{m,a}$ – the average annual enthalpy of outdoor air, determined by the formula (6);

I_o – enthalpy of air at the outlet of the nozzle chamber or surface air cooler in the warm season, kJ / kg;

K_3, K_4 – the coefficients determined by the table. 2 depending on the length of the cold consumption period M.

The number of hours of cold consumption per year is:

$M_c = 0{,}143 \text{ M n m } K_3$. (13)

The annual cold consumption for SCR with the first recirculation is:

$Q_{c,1} = Q_c - □Q_1$, (14)

Where Q_c – annual cold consumption according to formula (11);

$□Q_{c,1}$ – annual cold savings due to the use of the first recirculation, kJ / g

$□Q_{c,1} = 0{,}143 \text{ n m } (G_o - G_{r,1}) \cdot (I_{m,h} - I_{r,h}) M_1 K_3 K_4$, (15)

$I_{r,h}$ – enthalpy of air leaving for recirculation in the warm season, kJ / kg;

G, $G_{h,1}$ – supply and recirculation air consumption, kg / h;

K_3, K_4 – the coefficients determined by the table. 2 depending on the duration of M_1.

SLE operation in recirculation mode is advisable during the year when the enthalpy of the outside air is higher than the enthalpy of the recirculated air; the duration of this period in days is The annual cold consumption for SCR with a second recirculation in kJ / g is

$$Q_{c,2} = (1 - G_{r,2}/G_o)Q, \tag{17}$$

Where Q – annual consumption of cold hard currency without a second recirculation, kJ / year;

$G_{r,2}$, G_o – the consumption of internal air entering the second recirculation and the total flow rate of the supply air, kg / h

V. ANNUAL HEAT CONSUMPTION FOR FIRST HEATING

The annual heat consumption for the first heating is determined in kJ / g according to the formula:

$Q_1 = 0{,}143 \text{ n m G } (I_k - I_{m,c}) \text{ M } K_3 K_4$, (18)

Where G – maximum flow rate of external air passing through the air heater, kg / h; before mixing with recirculating air;

M – the duration of the first heating operation when the outside air enthalpy is lower than the air enthalpy at the outlet of the air heaters, expressed in days:

$$M = 182{,}5\sqrt{(I_к - I_{вх,x}) / \ (I_{вх,г} - I_{вх,x})}, \tag{19}$$

I_c – enthalpy of air at the outlet of the heater in the cold season in kJ / kg;

$I_{ah,c}$ – enthalpy of air at the inlet to the heater in kJ / kg, determined for the coldest month;

$J_{ah,y}$ – enthalpy of air at the inlet of the heater in kJ / kg, average for the year;

K3, K4 **-** coefficients determined by the table. 2 depending on the duration of the first heating operation M.

When calculating the annual heat consumption for the first heating by a direct-flow system, in the formulas (20) and (21) should be substituted the value of Iin x equal to Im, x, which is calculated by the formula (4), and value $I_{ah,y}$ equal $I_{m,y}$, calculated by the formula (6). In calculating the annual heat consumption by the system with the first recirculation, when the external and internal air are mixed after heating the external air in the air heater, the value G equal to the external air flow should be substituted into formula (20).

When calculating the annual heat consumption for the first heating of SCR with the first recirculation and mixing of the external and internal air before heating, the values are substituted into formulas (20) and (21):

$$I_k = I_{r,c}\,(1 - G / G_o) + I_{m,c}\,G / G_o\,, \tag{20}$$

$$I_{k,y} = I_{r,c}\,(1 - G / G_{in}) + I_{m,y}\,G / G_{in}\,, \tag{21}$$

где $I_{m,c}$ – the enthalpy of outdoor air calculated by the formula (4);

$I_{m,y}$ – the enthalpy of outdoor air calculated by the formula (6);

$I_{r,c}$ – enthalpy of recirculated air in the cold season, kJ / kg;

G, G_{in} – external and supply air costs, kg / h.

The number of operating hours of the first heating per year is determined by the formula

My = 0,143 n m M K3, (22)

Where M – the duration of the first heating operation;

K_3 – coefficient determined by the table. 2 with the corresponding value of M determined by the formula (19).

VI. ANNUAL HEAT CONSUMPTION FOR THE SECOND HEATING OF HARD CURRENCY

The annual heat consumption for the second heating for both direct-flow and SCR with the second recirculation is:

$$Q = 0{,}143\ n\ m\ 365\ [(G_o - G_{r,2})\Delta I_r - 3{,}6\ Q_{m,y}], \tag{23}$$

Where G_o – supply air flow, kg / h;

$G_{r,2}$ – consumption of internal air entering the second recirculation, kg / h; in direct-flow system $G_{r,2} = 0$;

$Q_{m,y}$ – average annual, average per change of heat surplus (in full heat) of the served premises, W;

ΔI_y – the average annual enthalpy difference of internal air and air at the outlet of the nozzle chamber or surface cooler in kJ / kg, determined by the formula:

$\Delta I_y = 0{,}5\ (I_{a,h} + I_{a,c} - I_{o,h} - I_{o,c})$, (24)

Where $I_{a,h}$, $I_{a,c}$ – enthalpy of internal air, respectively, for warm and cold periods, kJ / kg;

$I_{o,h}$, $I_{o,c}$ – enthalpy of air at the outlet of the irrigation chamber or surface cooler, respectively, for the warm and cold period, kJ / kg.

The value of the average annual excess heat should be determined by calculation at the average annual values of the parameters of the external climate. In the absence of relevant data, it is permissible to take $Q_{m,y}$ average between calculated excesses of total heat in the warm and cold periods of the yearIf the air heaters of the second or zone heating of hard currency serve several rooms, then the value $Q_{m,y}$ defined as the sum for all serviced premises.

VII. ANNUAL ENERGY CONSUMPTION FOR THE MOVEMENT OF AIR NE AND SCR

The annual energy consumption for the movement of air NE and SCR is equal to the sum of the products of the power consumption of electric motors N, kW installed in the system, for the duration of their work M_y, ч/г

$$N_y = N\ M_y. \tag{25}$$

The duration of the fans of CB and SCR in h / g is

M_y = 0,143 n m M, (26)

Where m – number of fan hours per shift;

n – number of working days per week;

M – the duration of the periods of work in days.

If the system operates with a variable air flow rate, then the duration of the periods of operation with a different flow rate is defined as the duration of the characteristic modes of heat and cold consumption, which are discussed above.

VIII. EXAMPLE

Determine the annual heat consumption for the supply air in two shifts (5 days a week in Uzbekistan without recirculation and with recirculation. The duration of each shift is m = 9 hours, the first shift from 7 to 15 hours, the second from 15 to 23 hours (true time)). Total air consumption - 28,000 m / g, including outdoor air - 12,000 m / g, air temperature in the cold season $t_{a,c}$ = -14 °C, supply air temperature for the cold season t_a = 20 °C.

IX. DECISION

According to KMK 2.01.99 for Tashkent, the average outdoor temperature for the year (Table 3 of SNiP) t_y = 13,6 °C; for the coldest month (tab. 1 SNiP) t_c= –4,2 °C, the amplitude of the temperature fluctuation of the hottest month (tab. 2 SNiP) A_h= 0,5 • 23,7 = 11,9 °C; for the coldest month (tab. 1 SNiP) A_c = 0,5 • 19,9 = 9,95=10 °C.

When the shift duration is m = 8 hours and the average time for the first shift is 7 + 15/2 = 11 hours, the second shift is 15 + 23/2 = 19 hours, according to the table. 1 find for the first shift K_1 = 0,83; K_2 = 0,5; for the second shift K_1 = 0,83, K_2 = 0,5, i.e., the coefficient values for the first for the first and second shifts coincide. This means that the values of the outdoor temperature for shifts coincide and the annual heat consumption for the first and second shifts will be the same.

The average temperature per shift of the coldest month according to the formula (2):

$$t_{m,c} = –4,2 + 3,9 \cdot 0,83 \cdot 0,5 = 3\ °C,$$

average annual change per temperature according to the formula (5)

$$t_{m,y} = 3,6 + 0,5\ (11,9 + 10)\ 0,83 \cdot 0,5 = 9\ °C.$$

The duration of the period of heat consumption according to the formula (8)

M = 182,5 • [(20 + 3) /(9 + 3)] 0,5 = 175

For M = 175 days. according to the table 2, we get K_3 = 0,97; K_4 = 0,67. The annual heat consumption according to formula (7) for a once-through system is

Q = 0,143 • 5 • 8 • 28 000 • 1,005 (20 + 3) 175 • 0,97 • 0,67 = 101,11 GJ / g

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The annual number of hours of operation of the heater according to the formula (10)

Му = 0,143 • 5 • 8 • 175 • 1,06 = 600,6 ч/г.

When working with air recirculation, the average temperature per shift of the mixture of external and internal air in the coldest month of the year according to formula (9) is

tm,c = 18 (1 – 12 000 / 28 000) – 3 – 12 000 / 28 000 = 6,54 °C,

and the average annual mixture according to the formula (9)

$t_{m,y}$ = 18 (1 – 12 000 / 28 000) + 9 – 12 000 / 28 000 = 7,71+8,57=16,28 °C.

The duration of the heat consumption period according to formula (8) when using recirculation is

M = 182,5 [(20 – 6,54)/(16,28 – 6,54)] 0,5 =2456,4/487=51

When M = 197 days. according to the table 2, we get K_3 = 0,91, K_4 = 0,65.

The annual heat consumption according to the formula (7)

Q = 0,143 • 5 • 8 • 28 000 (20 – 6,54) 51 • 0,91 • 0,65 = 4,8 GJ / g

The number of hours of operation of air heaters per year according to the formula (10)

My = 0,143 • 5 • 8 • 51 • 0,91 = 291,72 h / g.

The annual heat consumption of the system for two shifts will be respectively:

– for a direct-flow system 101.11 • 2 = 202.22 GJ / g;

– for a system with recirculation 4.8 • 2 = 9.6 GJ / g.

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