

ANALYSIS OF THE YEAR POWER CONSUMPTION BY CENTRAL AIR CONDITIONING SYSTEMS (USING THE CLIMATIC DATA STOCHASTIC STATISTICS MODEL)

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Abstract. The purpose of offered research is creation of a method of an estimation of annual power consumption by the central systems of air-conditioning (SAC), taking into account possibility of modern computers. The developed method is directed on definition of expenses of thermal and electric energy, and water during a year by the SAC taking into account their work at various period of day and optimization of the scheme of treatment of reveal air on the basis of minimization of power inputs. On chair Heating and Ventilation MSUCE the universal program for calculation on the computer of power and water consumption, spending by SAC, was worked out. The algorithm of calculation is made on the basis of search of combinations of temperature and relative humidity of air from minimum to the maximum values, in which process the zone including this combination is defined. For the decision of the put tasks the climatic base, intended for the analysis of operating modes and calculations of power consumption by SAC, working in various time of days, was created. Program realization on the computer allows to carry out multiple calculations of power consumption by direct-flow SAC for premises of different function: a premise of a dining room, billiard, sports hall and office premise.

Keywords: air conditioning systems, power consumption, method, climatic basis, heat and humidity area combinations, bypass, secondary preheating.

1. The Method Climatic Basis

This investigation has being aimed at developing the analysis methods of the year power consumed by central air conditioning systems (ACS), which operate according to different air treatment models. As the climatic basis of this method provision has been made of the stochastic statistics model represented in a Recurrence Period Table according to different average multi-year combinations of the outdoor air temperature, relative humidity and atmospheric pressure. The last parameter is important for the temperature and relative humidity conversion into the air enthalpy. Actual computing utility progress enables a quick and sound weather data statistic analysis, and urgent observations on magnetic media handed by the meteorology experts make this analysis faster without any accuracy losses.

The main advantage of the stochastic statistics model is that it can reflect the air state parameter combination recurrence for any period of time: the whole year, by seasons, by months, 24 hours, as well as any time interval in 24 hours. We have developed the recurrence period Tables of the above mentioned outdoor air parameters for the city of Moscow (*CHuII 23-01-99**) for the year as a whole and each month separately. The Tables cover 24 hours and

seven intervals within 24 hours, which represent the most typical working hours in various establishments: from 9 a.m. to 18 p.m., from 18 p.m. to 9 a.m., from 8 a.m. to 20 p.m., from 20 p.m. to 8 a.m., from 7 a.m. to 15 p.m., from 15 p.m. to 23 p.m. and from 23 p.m. to 7 a.m.

Absence of the time factor shall be considered as a shortcoming of the of the stochastic statistics model (Малыгина and Паенк 1984), since the climate parameter distribution surfaces include combinations for any time period within the given 24 hours. For this reason it is difficult to make a direct analysis of the non-stationary heating mode of the building and its systems. This non-stationarity, which we would like to take into account in the task under examination, means the ray time modification of the air heat and humidity treatment process in a premise. For most of different purpose premises the air treatment process ray direction does not change greatly.

That is why, this model as the fixed time recurrence period values of temperature, outdoor air relative humidity and atmospheric pressure seems to be very progressive, because it enables a rather exact and quick ACS comparative power and water consumption analysis according to different air treatment modes.

2. Appointment of the climate parameter combination zones having a definite outdoor air treatment sequence

Provision has been made for a PC universal software of ACS power and water consumption analysis. The calculation algorithm has been done on the basis of the air temperature and relative humidity combination trials from minimal to maximal ones, which lead to determination of a zone having this combination.

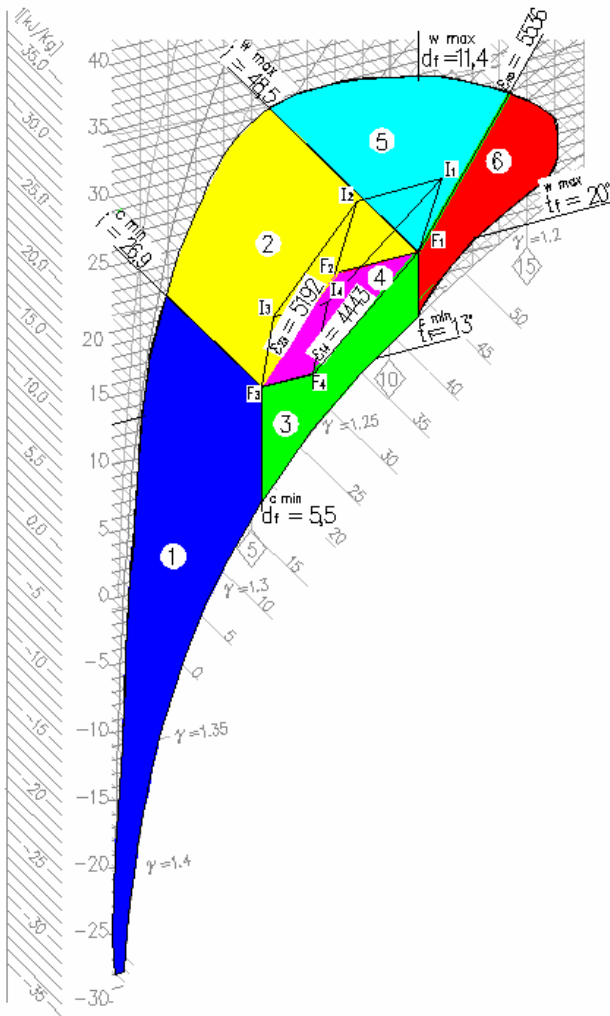


Fig 1. Inflow air treatment zones for maintenance of the interior air optimal parameters at the bypass pattern through a humidification chamber (for cold season)

In the 1st zone – outdoor air heating in a 1st stage air heater, adiabatic humidification and heating in a 2nd stage air heater, adiabatic humidification and mixing of heated and humidified air.

In the 2nd zone – mixing of the outdoor air non-treated part with an outdoor air part, which has been humidified in the adiabatic humidification block.

In the 3rd zone – heating up to the inflow air state in the 1st stage air heater.

In the 4th F1F2F3F4zone – absence of the outdoor air treatment in ACS devices.

In the 5th zone – refrigeration in a surface air cooler.

In the 6th zone- heating in the 1st stage air heater to enable the air state conformity to the points on ϵ row line, refrigeration in a surface air cooler.

Any outdoor climate zone corresponds to an exact air treatment sequence, and the zone borders determine the outdoor air parameter values, which demand a transfer from one treatment mode to another. To build the outdoor climate zones having a definite ACS air treatment sequence provision shall be made of the room indoor optimal parameter zones shown on the i-d diagram.

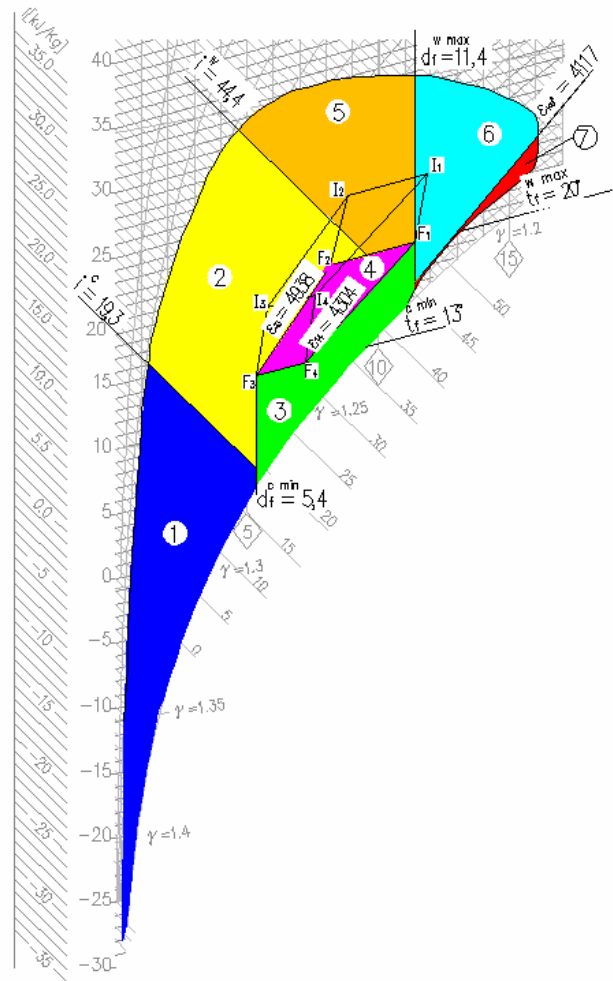


Fig 2. Inflow air treatment zones for maintenance of the interior air optimal parameters using the direct flow pattern with secondary preheating

In the 1st zone – outdoor air heating in a 1st stage air heater, adiabatic humidification and heating in a 2nd stage air heater.

In the 2nd zone – adiabatic humidification and heating in a 2nd stage air heater.

In the 3rd zone – heating up to the inflow air state in the 2nd stage air heater.

In the 4th F1F2F3F4zone – absence of the outdoor air treatment in ACS devices.

In the 5th zone – «dry» refrigeration in a surface air cooler, adiabatic humidification and heating in a 2nd stage air heater.

In the 6th zone- «wet» refrigeration in a surface air cooler and heating in a 2nd stage air heater.

In the 7th zone- heating in the 1st stage air heater to enable the air state conformity to the points on ϵ kw line, refrigeration in a surface air cooler and heating in a 2nd stage air heater.

The power consumption analysis has been done for four different rooms: an office, a billiards room, a dining room and a fitness room. Air consumption in the air conditioning systems, which serve these premises, has been taken the same and equal to 5475 m³/h. The air treatment rays in the premises are taken as equal ones to satisfy the investigation purpose, i.e. $\epsilon^c=8800$ KJ/kg for the cold season and $\epsilon^w=14500$ KJ/kg for the warm season. The required indoor conditions for the premises differ as follows: $19 < t_{in} < 25$ °C; $30 < \phi_{in} < 60$ % in the office, $18 < t_{in} < 25$ °C; $45 < \phi_{in} < 60$ % in the billiards room, $20 < t_{in} < 25$ °C; $30 < \phi_{in} < 60$ % in the dining room; $17 < t_{in} < 25$ °C; $30 < \phi_{in} < 60$ % in the fitness room. In the general case the premise design air state will be represented by $I_1 I_2 I_3 I_4$ (Figs 1, 2) zone. The lines of the ϵ^w warm season process ray angle coefficient cross I_1 and I_2 points. On fig. 1,2 the points I_3 and I_4 of the room air optimal parameter area are crossed by the lines which show the air state modification ray inclination in the ϵ^c cold season. These lines have indication of the corresponding operation temperature differences as well as the $F_1 F_2 F_3 F_4$ inflow air parameters. The ϵ^w and ϵ^c process rays fix location of the zone, which determines creation of all the other external climate zones on the i-d diagram.

Attention shall be focused on the fact, that actually during the year the micro-climate indoor parameters change within the oblique-angled quadrangles, which are limited from the bottom by the minimal possible temperature in the cold season of the year, and from the top – by the maximum allowable temperature in the warm season of the year.

The minimum relative humidity corresponds to a minimum one, which is required in the cold season, and

the maximum relative humidity – to the maximum one in the warm season.

Since the normative documents (*ГОСТ 30494-96*) require, that the same $t_{in}=25$ °C temperature shall not be exceeded in warm season of the year, the quadrangles have the same upper limit for all the premises under examination.

A rather high minimal humidity in the billiards room is explained by the need to avoid a longer drying of the glued wood.

Different outdoor air treatment devices operate during the year. The fig.1 shows the outdoor air heat and humidity area combinations when different devices operate under the direct inflow air pattern with secondary heating, and the fig.2 gives a bypass pattern (curving the humidification chamber in the winter season) in the billiards room.

The Table 1 shows water, electric power and heat consumption within the year to enable the device operation. The Table 1 makes evident, that the billiards room requires the biggest power consumption either in cold and warm seasons. It occurs, because the outdoor air heat and humidity parameter combination zone, which coincides with the inflow air optimum, is the smallest one. The largest coincidence zone of the outdoor and the inflow air is in the fitness room.

Separation into zones is determined by examination of possible outdoor air treatment procedures to make the air reach the required state within the $F_1 F_2 F_3 F_4$ area by the most economical power saving way using the existing device facilities.

3. Summarized results

The developed PC software enables power and water consumption estimation for the design period (year, season, month) by each air treatment device in every climatic zone. For example, the above mentioned room, if it functions 24 hours a day and respects the room optimal conditions, may be subject to heat, cold, power and water calculations for the ACS air treatment (see Table 1).

Table 1. The year consumption of heat, power and water by inflow air treatment devices up to the optimum parameters in an office room (a bypass pattern) for a 24- hour operating ACS

Control zone number	1st step pump air heater		Cellular pump humidifier		Cooling machine	Main fan	Operation hours in control zone, h
	Heat consumption MJ	Power consumption KW·h	Water consumption kg	Power consumption KW·h			
zone 1	546137	185	38146	49		8416,7	3845
zone 2			4305	50		1241,2	567
zone 3	144703	146				6676,5	3050
zone 4						1834,4	838
zone 5					2053	468,4	214
zone 6	7356	12			2419	551,6	252
Total	698196	343	42452	99	4472	19188,8	8766

Table 2. Comparison of the year heat, power and water consumption for the inflow air treatment

Room	1st step pump air heater		secondary air heater	Cellular pump humidifier		Cooling machine	Total consumption		
	Heat consumption MJ	Power consumption KW-h	Heat consumption MJ	Water consumption kg	Power consumption KW-h		Heat consumption MJ	Power consumption KW-h	Heat consumption MJ
Direct flow pattern with secondary pre-heating									
Office	224252	219	508403	51744	120	17194	732655	7216,6	51744
Billiards	472897	313	337559	106950	120	17194	810456	7310,6	106950
Dining room	166085	173	465641	40678	121	17194	631726	7171,6	40678
Fitness room	166085	173	465641	40678	121	17194	631726	7171,6	40678
Bypass pattern									
Office	698196	343	-	42452	99	4472	698196	4914	42452
Billiards	773341	346	-	96470	100	4472	773341	4918	96470
Dining room	755668	357	-	49293	99	4472	755668	4928	49293
Fitness room	597322	330	-	31487	99	4472	597322	4901	31487

Data of the Table 1 let us conclude, that in Moscow ACS operate nearly the half of the year in the 1st zone, i.e. at the first pre-heating of the outdoor air. Cold consumption in the 5th and the 6th zones shall be required when the outdoor air temperature is higher than 20 °C (see Fig. 2). So, for the room under analysis all necessary cold is produced by a refrigerating machine and there is no need in any heat exchanger to enable free cooling. The results, which are similar to these ones of the Table 1, make possible calculation of the summarized year consumption of each power and water type to maintain optimal conditions in different premises (see Table 2).

The Table 2 estimates power consumption of each device, which provides the air treatment to get the optimum parameters in different purpose rooms under two options of the inflow air treatment patterns.

It is important to note, that heat and power consumption values estimated according to the existing simplified methods (Самарин 2007) are 1.7 times higher than those, which have been calculated according to the year climate parameter combination distribution and definition of some device operation zones.

Importance of the air conditioning becomes greater due to the permanently increasing heat excess in the rooms and the climate trend to getting warmer. So the method, which enables a justified choice of the most power economical air treatment way, as well as the choice of the interior condition level, is quite actual.

4. Conclusions

1. The climatic data stochastic statistics model, which has been developed for the city of Moscow, as well as the PC software program, enable multi-variant power consumption calculations in the air conditioning direct flow systems with secondary preheating and humidification chamber bypass systems in the cold season of the year.
2. During investigation of the required interior condition influence on power consumption of the air conditioning

systems it has been found out, that the power consumption increases, if this zone becomes smaller.

3. Possible calculation of each device operation time in a central air conditioning system enables removal of any device, if it operates shortly during the year.

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