Energy Efficiency Analysis of Central Air Conditioning Systems

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Abstract. The article considers the ways of reducing heat and cold loads in air conditioning systems of public buildings both by air recirculation and by using these loads in recuperative ventilation systems. Energy efficiency is studied by analyzing thermody–namic processes of air treatment on the I-d diagram. The construction of thermodynamic air purification processes in recirculation and recuperative ventilation systems on the I-d diagram is considered.

Keywords: ventilation, air conditioning, recirculation, recuperation, utilization, thermo-dynamic treatment, heating and cooling loads, energy saving, energy efficiency.

Introduction

In modern society, more and more attention is paid to the economy of natural resources, among which energy resources are of particular importance. One of the largest con-sumers of energy resources is construction, which consumes 40-42% of the generated energy. Therefore, energy saving in const–ruction and increasing its energy efficiency is one of the current areas of modern construc–tion. Many countries around the world have a law on the energy efficiency of buildings, the main goal of which is to reduce the energy consumed by buildings to almost zero. Georgia also has such a law [ ], according to which all new buildings in Georgia must have almost zero energy consumption from 2030. For public buildings, this date is September 30, 2027. Increasing the energy efficiency of buildings and bringing them to a state of zero energy consumption is possible with the correct choice of thermophysical characteris–tics of enclosing structures and the installation of energy-efficient engineering systems for buildings. If it is relatively easy to achieve zero energy consumption in residential buildings with the correct selection of energy-efficient restrictive structures and recuperative venti-lation devices, then in public buildings (offic-es, theaters and cinemas, sports halls, etc.) achieving zero energy consumption is relatively simple. It is complicated by the thermodynamic processing of large quantities of air in the ventilation systems of these buildings (heating, cooling, drying, humidifi–cation, etc.). Air exchange rate in a number of public buildings n=5÷20, this means that in these buildings the amount of ventilation air must be $L=(5\div20)\cdot V$ m^3/hour(1) where V is the volume of the building in m^3.

Main part

Microclimate systems of buildings (heating, ventilation, air conditioning) must ensure the creation and maintenance of temperature and humidity conditions stipulated by standards in warehouse premises. For residential and public buildings, these standards are determined by the current standard [1], and for industrial buildings - according to the relevant industry standards. For atmospheric air, parameters A or B are taken into account depending on the construction area [2]. The climatic conditions of Georgia in summer are characterized by a conditional air temperature of up to +34ºC, relative air humidity φ=(40÷60)% within Humidity is relatively high in coastal and mountainous areas. At the specified humidity and high temperature, the humidity of the outside air reaches (18-30) g / kg of dry air, and in winter the outside air temperature is zero or lower, despite the high relative humidity (φ = 60 ÷ 80%), the air is dry enough. At this time, the humidity of the outside air is (1 ÷ 3) g / kg of dry air. Thus, according to climatological data of the outside air, in summer the outside air is hot and humid, and in winter it is cold and dry. Neither in winter nor in summer are the parameters of the outside air satisfactory. For normal physiological functioning of a person. For this purpose, we carry out preliminary thermodynamic treatment of air in the central air conditioner and then supply it to the conditioned rooms so that the conditions of thermal comfort stipulated by the standards are established in these rooms [1]. These conditions are graphically presented in the so-called comfort diagram (Fig. 1).

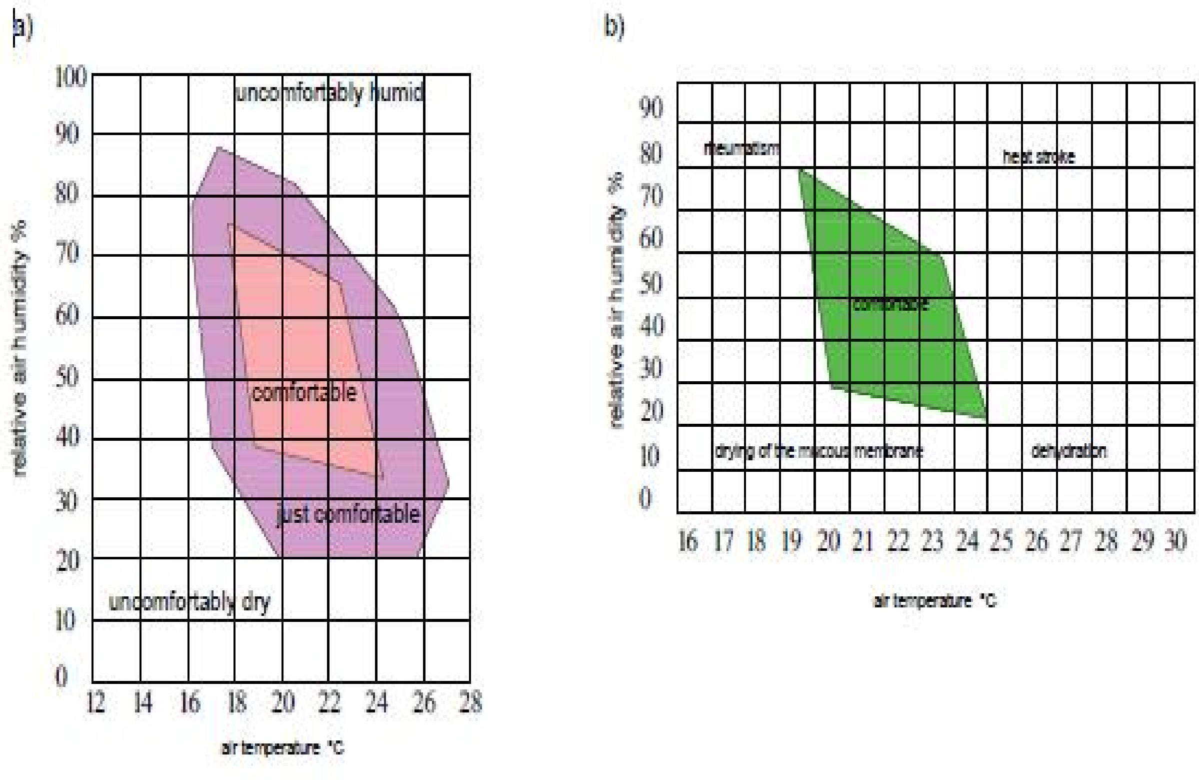

Fig. 1 comfort diagrams
a) values of temperatures and relative humidity of acceptable and comfortable microclimate zones.
b) harmful effects of uncomfortable zones on the human body.

The diagram a) shows the values of temperature and relative humidity that the air conditioning system must provide, and diagram b) shows what harmful effect the combined effect of temperature and relative humidity can have on the human body when these parameters remain outside at the comfort zone.

Fig. 2a shows the process of thermodynamic treatment of air in a central ventilation unit (air conditioner), depicted in the I-d diagram, for both summer and winter climatic conditions for the simplest direct diagram. This is a diagram where the outside air with parameter 1 (Fig. 2) is cooled and dried in summer, and heated and humidified to parameter 3 in winter. Thus, the purified air is supplied to the room to provide comfortable conditions in room 2. Section 2-3 is known in ventilation engineering as the process beam in the conditioned room and represents the ratio of the amount of heat released in the room and the released moisture.

$$\varepsilon=\pm(\Sigma Q/\Sigma W) \quad kJ/kg \tag{2}$$

where ΣQ- The total amount of heat released in the storage is kJ/h

ΣW - The amount of moisture released in the storage kg/h.

The plus sign shows an excess of heat in the compartment, and the minus sign shows a deficit (lack of heat).

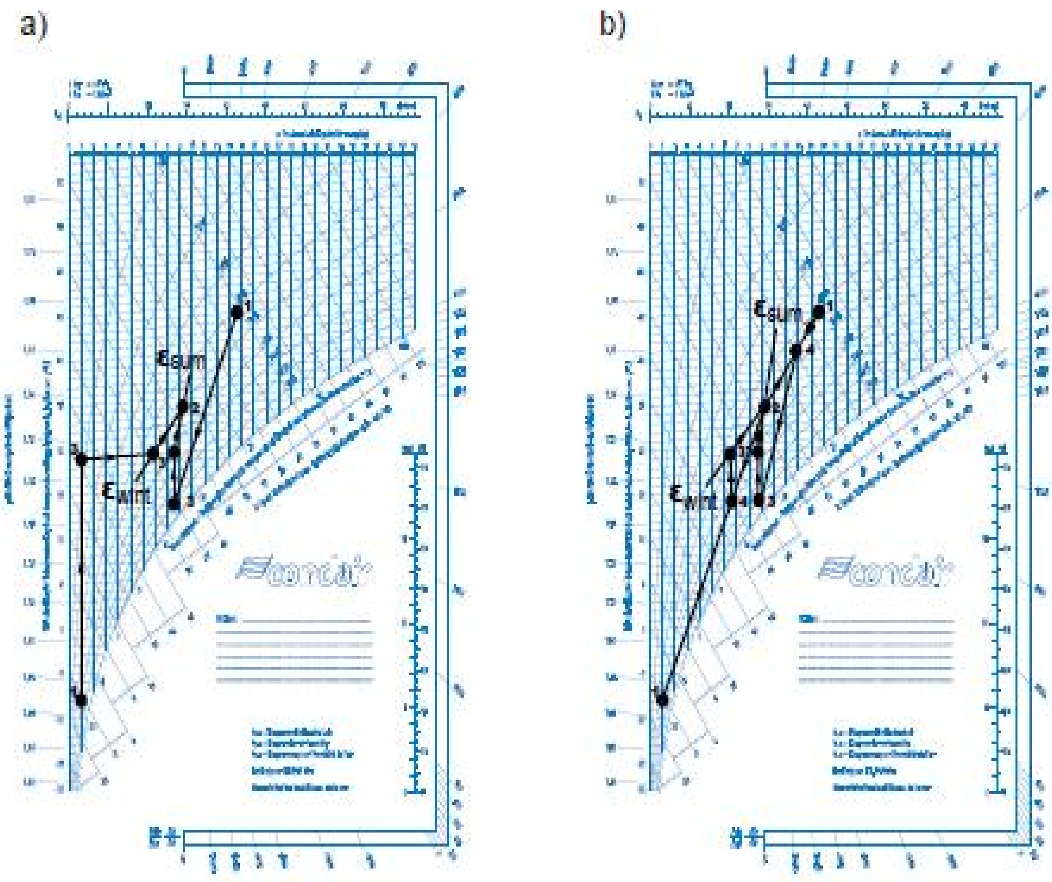

Fig. 2. Schemes of thermodynamic air treatment on the I-d diagram:
a) with a direct scheme, b) with air recirculation.

b) In Fig. 2a it is evident that in summer during the process of cooling and drying the air in the air conditioner its temperature is so low that it is necessary to additionally heat the air to an acceptable temperature of the supplied air (point 31). The temperature of the supplied air depends on the height to which we supply air to the compartment. If the air from the storage room is supplied to the working area, its temperature will be 5 degrees lower than the air temperature in the storage room. In winter, when the air in the air conditioner is heated, which occurs at a constant air humidity, the relative humidity of the air decreases to 10%, i.e. the air is almost completely dry. Therefore, before supplying the air to the storage room, it is necessary to humidify it to the required parameters of the supplied air (pos. 31). The presented I-d diagram displays the process of isothermal air humidification (t=const). With thermodynamic air treatment, it is possible to humidify it adiabatically (I=const). With such humidification, the air again becomes so cold that it is necessary to heat it. (d=const) so as to ensure that the required parameters of the supply air are achieved (pos. 31).

The scheme shown in Fig. 2a is the best from the point of view of hygiene, since at this time outside air, purified to the appropriate state, is supplied to the room, and the contaminated working air is discharged into the environment. From the point of view of energy efficiency, the scheme under consideration is unacceptable, since a large amount of air blown into the environment brings with it a large amount of heat in the winter and cold in the summer.

In order to save thermal energy, air recirculation is used in the air preparation process (Fig. 2b). In this case, only the amount of air stipulated by sanitary standards is supplied from the environment to the warehouse, which is mixed with recirculated air (returned from the exhaust air), again supplied to the warehouse.

Having depicted the processes of thermodynamic air treatment on the I-d diagram, we can already determine the cooling and heating loads of the air conditioning systems using the formulas:

$$Q=G_{del}\,(I_{St}-I_{sab})\ vt \qquad (3)$$

Where G_{del} - Air consumption supplied to the warehouse, kg/h;

I_{st} და I_{sab} Accordingly, in the air conditioner or air conditioner Initial and final enthalpies of the processed air (thermal changes) kJ/kg.

The parameters determining the cooling loads on the I-d diagram correspond to points 1 and 3 and 4 and 3 according to the corresponding direct and recirculation schemes, and the heating loads are determined according to the winter air preparation schemes, according to points 1 and 3 and 4 and 31.

The schemes considered above were widely used in a number of public buildings in the last century. Today, the use of these schemes is more appropriate in buildings whose microclimate parameters do not have strict requirements for comfort. These are: a number of industrial buildings, warehouses, wagon depots, garages and others, or those air-conditioned warehouses where people are less frequent.

In modern construction, recuperation systems of ventilation and air conditioning are widely used to improve energy efficiency. Recuperation systems allow heating the air supplied to the warehouse during the cold period of the year by extracting heat from the taken warm air, and cooling the hot air supplied from outside in the summer by cold air taken from the room. warehouse. Regenerative ventilation systems are used in all types of buildings and are a prerequisite for creating buildings with zero energy consumption. The main characteristic of ventilation recuperators is their efficiency.

$$\eta=t_{del}-t_g/t_{sh}-t_g \qquad (4)$$

where t_{del} supply air temperature in the compartment

After the recuperator ºC;

T_g - outside air temperature;

T_{sh} - room air temperature;

Today, ventilation recuperators have been created with an efficiency of up to 97%. Using a heat pump with a recuperator allows increasing the efficiency to 140%. In addition to heat recovery, some types of recuperators (especially rotary ones) provide the ability to utilize moisture. The efficiency values for different types of recuperators are:

Glycol recuperators----- 55%-მდე
plate-------------------------- 70%
rotor------------------------------ 85%
with resistance (including enthalpy) —92-94%
Two-stage (recuperator + heat pump) ---140%

The temperature of the ventilation air after the recuperator is calculated from condition (4) if its efficiency is known in advance.

$$T_{del}=t_g+(t_{sh}-t_g)\eta \qquad (5)$$

The heat transfer of air after the recuperator is calculated in the same way.

$$I_{del}=I_g+(I_{sh}-I_g)\eta \qquad (6)$$

T_{del} and I_{del} Based on the parameters, we determine whether additional thermodynamic processing processes are needed to bring the air up to the parameters.

The table below shows the values of supply air temperature (t) and relative humidity (φ) after the recuperator.

t_g	34	30	20	10	0	-5	-10
T_{del}	25	24,6	23,6	22,6	21,6	21,1	20,6
φ_g	40	50	60	70	80	%	
Φ_{del}	49	50	51	52	53	%	

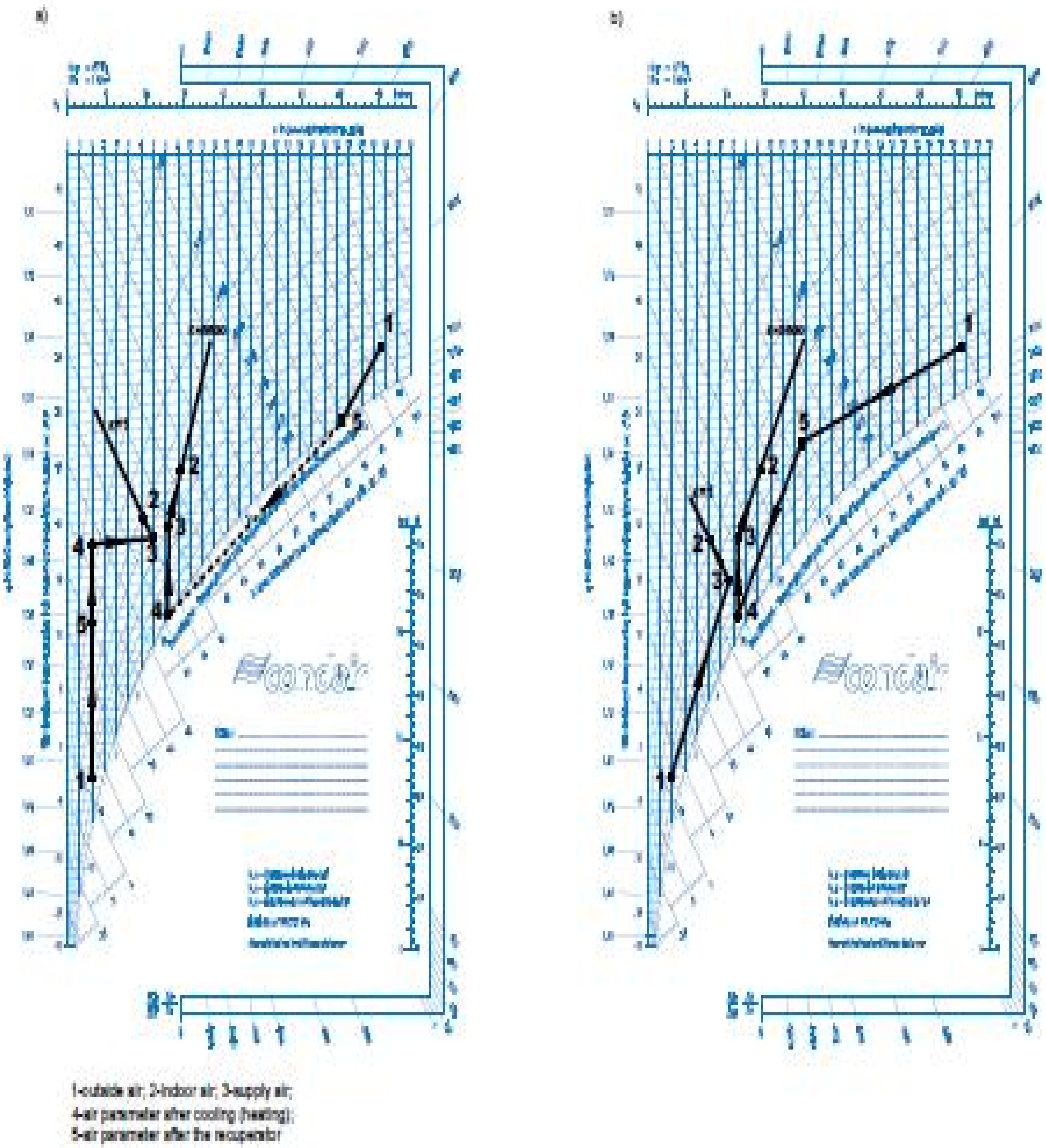

Fig. 3. Schemes of thermodynamic air treatment on the I-d diagram in recuperative ventilation systems:

a) plate recuperators
b) in the case of rotary recuperators.

As we can see from this table, when the outside air temperature changes from 34ºC to -10ºC and the relative humidity values (40-80)% after the recuperator, the required parameters of air supplied to the warehouse are achieved, due to which there is no need for additional heating or cooling of air in the recuperator. Using a recuperator for buildings with low energy consumption (passive, active, zero houses, etc.), we can refuse expensive heating and cooling systems.

For public buildings in case of high excess heat and moisture or high heat losses, if the amount of heat and moisture utilized in the recuperator cannot provide the required parameters of air supplied to the warehouse, then additional measures must be taken. However, at this time, cooling and heating loads are reduced to a minimum.

The scheme of thermodynamic air treatment for public buildings, when additional cooling and dehumidification of air is required in summer, is presented in Fig. 3 for both plate and rotary recuperation.

The above diagram corresponds to the humid climate zone in Fig. 3, where the humidity of the outside air is high, the temperature (t_g=33ºC) and the relative humidity (φ=80%) d=26g/kg of dry air. At such high humidity, the heat extracted from the air sucked into the recuperator is mainly used for cooling and drying the outside air (beam 1-5), since after cooling in the recuperator, the air parameters (item 3) cannot react to the parameters of the supplied air (item 3), additional air cooling and drying (beam 5-4) and further heating (beam 4-3) are necessary. In winter, the recuperator alone is sufficient to provide the parameters of the supply air.

The air from the recuperator to the environment has a fairly high temperature throughout the year (t_{del}=5÷25ºC), which provides the best conditions for using a heat pump to provide the building with hot water. The temperature of the air removed from the building (after the recuperator) is calculated using the formula:

$$t_{\delta del}=t_{sh}+(t_g-t_{sh})\eta \quad (7)$$

When using a heat pump, the recovery efficiency increases to 140%.

conclusion

To reduce heat and cold loads in central air conditioning systems, replacing recirculation ventilation systems with recuperative ones significantly improves the sanitary parameters of indoor air, and due to the utilization of heat and moisture, it allows removing heat and cold supply sources from the premises. systems. In this way, high energy efficiency of a public building is achieved, which reduces the costs of heating and cooling buildings by 80-90 percent.

Reference

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Aspects of designing shelters in Georgia

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Abstract: In the article is considered the importance of protecting the population in possible emergency situations and during hostilities in Georgia using collective defense means. Necessary recommendations for the reconstruction of the existing shelters in Georgia and the construction of new ones based on the analysis of the current war in Ukraine and the study of the weapons used by Russia against the civilian infrastructure.

Keywords: shelter, civil defense, civil safety, collective protection of the population.

1. Introduction

Due to the geopolitical location of the country, the existence of civilian shelters is a critically important issue to ensure safety and protection of the population in case of possible foreign aggression. In this context, it is appropriate to focus on the comprehensive study and analysis of possible threats, which is an integral part of the shelter construction process. A detailed study of different types of weapons systems used in military conflicts, their destructive potential, impact radius and destructive factors is a necessary prerequisite for the design and construction of shelters that fully respond to protection and safety requirements.

Analyzing the current war in Ukraine and studying the weapons used by Russia against civilian infrastructure is very important for Georgia. This gives us the opportunity to study in detail and understand the radius of impact and the destructive potential of the weapons that Russia is using extensively against the civilian population and infrastructure. Russian occupation forces widely use missile weapons in their military operations against Ukraine.

Georgia's strategic location in the Caucasus region and its propensity for regional conflicts create the need to develop solid civil protection measures. By understanding and adapting to these threats, Georgia will be able to strengthen national safety and ensure the safety of its citizens.

In modern history, Georgia, depending on its geo-political location, faced various types of aggression several times. The last military conflict with the direct participation of Georgia took place in 2008, between Russia and Georgia. In this war, 412 Georgian citizens died, including 228 civilians, 170 military personnel and 14 policemen (Arabuli, 2023). The war exposed significant weaknesses in Georgia's civilian infrastructure, including the failure of the early warning and evacuation system. This historical context creates a good basis to prove the need for shelters in Georgia, which will protect citizens during conflicts.

A study of today's Russia-Ukraine conflict reveals the impact of modern wars on civilian populations and infrastructure. Analyzing this conflict allows us to identify specific weapons systems and tactics that could be used against Georgia and accordingly plan to design shelters that can withstand such threats. This chapter aims to identify the basic design parameters of shelters that will effectively deal with these hazards. This includes structural strength, capacity, accessibility, life support systems and communication infrastructure.

2. **Existing regulation frameworc**

According to the Law of Georgia on Civil Safety, a shelter is a building or structure that can be used to protect people from various damaging factors during an emergency or war. The shelter can be a dual-purpose, civil or industrial building and/or a special hermetic protective structure, which is designed taking into account damaging factors;

According to the same law, it is the duty of executive authorities, self-governments and organizations to provide in the areas assigned to their governance in the manner established by the legislation of Georgia:

- during an emergency situation, if necessary, creating a shelter for people, mobilizing collective protection means and other material resources;
- providing assistance in organizing the evacuation of people and, if necessary, placing