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ON MEDICAL RESTRICTIONS TO COOLING MODES OF THERMOELECTRIC AIR CONDITIONERS

The paper provides a detailed description of the temperature restrictions imposed on the conditioned environment. The considered medical aspects of the impact of sharp temperature changes on the human body make it possible to create and operate air conditioners that will meet the necessary conditions for their safe use. The main advantages and disadvantages of using thermoelectric air conditioners in comparison with compression air conditioners from the standpoint of medical restrictions are identified.

Key words: thermoelectric air conditioner, medical restrictions, temperature difference, compression air conditioner.

Introduction

General characterization of the problem. Using an air conditioner is today the most common method of reducing the temperature in an office, apartment or vehicle. This is mainly due to the fact that air conditioners allow people to survive the summer heat more easily. This is especially important for those who suffer from cardiovascular diseases and are at risk of suffering from a hypertensive crisis or heart attack due to the heat and the excessive load it causes on the heart and blood vessels.

Despite their obvious benefits in providing comfortable conditions, air conditioners have a number of significant drawbacks. For example, the accumulation of carbon dioxide, viral and infectious microorganisms in the absence of any ventilation, which quickly evaporate with normal ventilation. Also, cooled, overdried air, which is harmful to the skin and mucous membranes of the respiratory tract. But the main and most common disadvantage is associated with a sharp change in temperature between the ambient and conditioned environment, which causes a number of negative consequences for human health. This problem is increasingly becoming the subject of various studies, but, unfortunately, only as a component of a broader problem, which consists in the general study of human thermal comfort.

To create an effective air conditioner, it is necessary to take into account and, if possible, minimize all its negative effects on the human body. To do this, it is necessary to study the available information in this area and draw the necessary conclusions on the medical restrictions of air conditioners in cooling mode. At the same time, special interest will be focused on thermoelectric air conditioners, and their comparison with compression air conditioners from the standpoint of medical restrictions will allow us to determine rational ways of their safe and effective use.

The purpose of this work is to determine the necessary medical restrictions on the cooling modes of thermoelectric air conditioners and compare them with compression air conditioners.

Temperature requirements for air conditioning of premises and vehicles

Requirements for air conditioning of premises.

According to GOST 30494-2011 “Residential and public buildings. Microclimate parameters in premises”, the following optimal and permissible temperature norms for residential, public, and administrative premises are determined [1].

Table 1

Optimal and permissible microclimate parameters

Time of year	Air temperature, °C		General temperature, °C		Relative humidity, %		Air speed, m/s	
	Optimal	Permissible	Optimal	Permissible	Optimal	Permissible	Optimal	Permissible
Warm	22-25	20-28	22-24	18-27	30-60	65	0.2	0.3

In general, the optimal air conditioning temperature for cooling air is 22 – 25 °C (Table 1). The acceptable comfort standard is considered to be the range from 20 °C to 28 °C. But this is provided that the temperature difference between the air-conditioned room and the outdoor environment is no more than ~ 7 °C [1]. Otherwise, when the environment changes, the additional load on the human body will increase dramatically. For some, such a difference is equal to a slight feeling of discomfort, and for others – the threat of getting sick. The negative consequences of a sharp temperature drop were studied in the most detail in [2]. The aforementioned work states that when the air temperature changes by more than 5 °C, negative consequences for the respiratory system are already possible and for the human body there is a serious risk of exacerbation of symptoms of respiratory disease (asthma and chronic obstructive pulmonary disease). This is because the respiratory tract is lined with a thin layer of fluid. Cool air causes this fluid to evaporate more quickly, which in turn causes it to dry out [3, 4]. But even in people without serious respiratory diseases, cool air causes changes in the respiratory tract. The action of cooled air increases the number of granulocytes and macrophages (their role is to phagocytosis (envelopment and digestion) of cell debris and pathogens, both stationary and mobile cells, as well as to stimulate lymphocytes and other immune cells to respond to pathogen penetration) in the lower respiratory tract [5]. Nasal breathing of cooled air causes submucosal venous sinus dilation [6], leading to coughing, congestion, and sneezing in both healthy subjects and patients with rhinitis [7]. However, these effects are greater in subjects with rhinitis than in healthy volunteers [8] and greater in subjects with asthma and rhinitis than in subjects with rhinitis alone [9]. In the short term, cold air causes bronchial constriction in asthmatics [10], especially in children and young adults. Long-term responses to temperature changes include airway changes, and some are anatomical, including increased bronchoalveolar lavage fluid granulocytes in healthy subjects [5], loss of ciliated epithelium, increased inflammatory cell counts, hypersensitivity, and airway obstruction [11]. But it should be noted that all of the above mainly applies to a sharp temperature drop of more than 5 °C. With a gradual decrease in temperature with a certain step, the recommended range may be higher than 5 °C.

Thus, according to [12], in order to prevent possible diseases, the temperature difference can be higher than 5 °C, depending on the ambient temperature and reach 13 °C (Table 2).

Table 2

The value of the temperature difference depending on the ambient temperature

Ambient air temperature (°C)	Temperature difference (°C)
< 32	5
34	7
36	9
38	11
40	13

A room cooling system installed to ensure comfort can cause various ailments. Respiratory illness from air conditioning that cools the air is a common phenomenon of our time. A sharp temperature drop, for example from 32 °C to 18 °C, becomes a stress for the body A condition occurs that resembles a cold in the autumn-winter period. In the first days, the malaise is accompanied by muscle aches, headache, general weakness, a slight increase in body temperature, sneezing. If treatment is not started, the situation is complicated by sore throat and cough. In a neglected state, the disease leads to chronic diseases of the respiratory system [13].

Requirements for vehicle air conditioning.

Air conditioning equipment does not have a strictly set temperature for cooled air. Conclusions about cooling efficiency should be drawn not from the air temperature, but from the difference between the ambient and cooled air. It is accepted that the air conditioner works effectively if it manages to provide a difference with the outside temperature of 15 – 20 °C. That is, the temperature of the air stream coming out of the interior deflector should be approximately 20 °C lower than the outside air temperature.

Car engineers are researching air conditioning modes to create systems that provide maximum comfort for the driver and passengers. It has been found that the optimum temperature for a car interior is 22 °C. Depending on their own preferences, drivers can adjust it within 2 °C. Studies have shown that it is this microclimate that allows maximum concentration on the road [14]. When the temperature drops to 18 °C, there is a risk of colds. If the temperature is higher than 24 °C, this significantly affects the driver's fatigue, making him fall asleep, which is especially dangerous when driving at night.

If the air conditioner is turned on in a garage where the thermometer shows + 25 °C, the air temperature coming out of the deflector should be no lower than + 5 °C. At an outside temperature of (+ 30 ÷ + 32) °C, cooling the air to (+ 12 ÷ + 14) °C is considered a completely normal indicator. At the same time, it is not recommended to make the temperature in the cabin too low, the optimal value is 5 °C lower than outside. That is, at an outside air temperature of + 30 °C, the cabin should be about + 25 °C in order not to provoke a cold, sore throat or pneumonia [2]. But according to [15], a difference of 5 °C mainly applies to short-term trips. That is, when the driver or passengers often leave the car.

During long trips (or simply a long stay in a car), it is recommended to gradually lower the temperature. According to [16], the temperature difference can reach 10 – 12 °C. However, the step of transition to a larger difference should not exceed 5 °C. That is, if you need to cool the car interior by 10 °C, for example from 35 °C to 25 °C, then this must be done in at least two steps: first to 30 °C, and after a while to 25 °C. Also, when using the air conditioner in a vehicle, it is necessary to direct the flow of cold air up, to the side or down. Thanks to this, you can also significantly reduce the likelihood of various diseases.

A significant disadvantage of compression air conditioners is the need to use freon. Freon is a refrigerant used in most modern air conditioners. Freon is heavier than air, so if it leaks, it can displace air from the room. Some types of freon release dangerous toxins when decomposed and can cause poisoning.

Medical aspects of the impact of high temperature drops on the human body

When air temperature drops rapidly without any gradual adaptation, even with small changes of up to 2 – 3 °C, but especially with changes of more than 5 °C, negative consequences for the human body are possible. For example, such changes can cause the risk of serious exacerbation of symptoms of obstructive respiratory diseases (asthma and chronic obstructive pulmonary disease) [2].

The main negative impact of this temperature difference concerns the respiratory system. According to [17], the respiratory tract is lined with ciliated epithelium and secretory cells. The cilia interact with a thin layer of fluid that covers the outer surface of the epithelium in contact with the air, the airway surface layer (ASL). The ASL includes a low-viscosity periciliary layer (PCL), which lubricates airway surfaces and facilitates ciliary function, and an additional layer of mucus above it. The volume, pH, ion and nutrient content of the ASL are important for regulating antimicrobial activity and mucociliary transport. Antimicrobial factors found in the ASL participate in innate and adaptive defense mechanisms that protect the airways from internal pathogens [18].

In other words, airway surface layer (ASL) is a thin layer of fluid that covers the luminal surface for normal airway physiology. Inhaling chilled air can cause ASL to evaporate faster than it is replenished, leading to ASL drying out and a number of serious negative health consequences.

Medical research confirms that the human body needs time to acclimatize from heat to cold or from cold to high temperature [19]. Blood vessels accumulate heat in winter, and vice versa in summer. A sharp change in temperature affects their functioning and, as a result, the work of the heart. Whenever there is a change in air temperature, immunity weakens and the body becomes more susceptible to viral infections. A sudden change in temperature can cause severe discomfort in people with respiratory diseases. Patients with asthma, respiratory ailments, and heart problems can experience acute stress.

Optimal temperature conditions of a thermoelectric air conditioner in cooling mode

The use of thermoelectric air conditioners allows for precise and smooth temperature control in residential premises and vehicles. Unlike compression air conditioners, thermoelectric air conditioners do not require the presence of liquid coolants (for example, freon), which eliminates the possibility of air poisoning when hydraulic units are depressurized. In addition, thermoelectric air conditioners have a number of advantages: lower weight and dimensions, high reliability, ease of maintenance, independence from spatial orientation, the possibility of spatial dispersion according to operating conditions, and simple switching from cooling mode to heating mode [20 – 23]. It should also be noted that, unlike compression air conditioners, the efficiency of thermoelectric air conditioners increases with decreasing power, increasing air temperature, and decreasing the temperature difference between outside and inside the conditioned environment, which also creates additional advantages for them (Fig. 1).

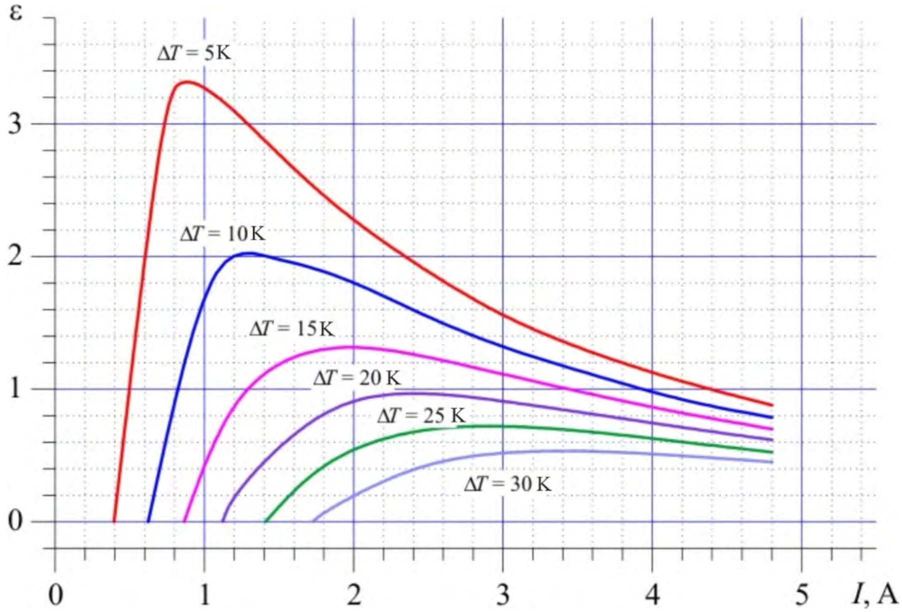

Fig. 1. Typical dependence of the coefficient of performance of a thermoelectric air conditioner on the supply current for different values of the temperature difference between its hot and cold sides.

As can be seen from Fig. 1, the efficiency of a thermoelectric air conditioner is maximum at temperature differences of about 5 °C, which is recommended by medical opinions and competes with compression air conditioners in many climatic zones (Fig. 2).

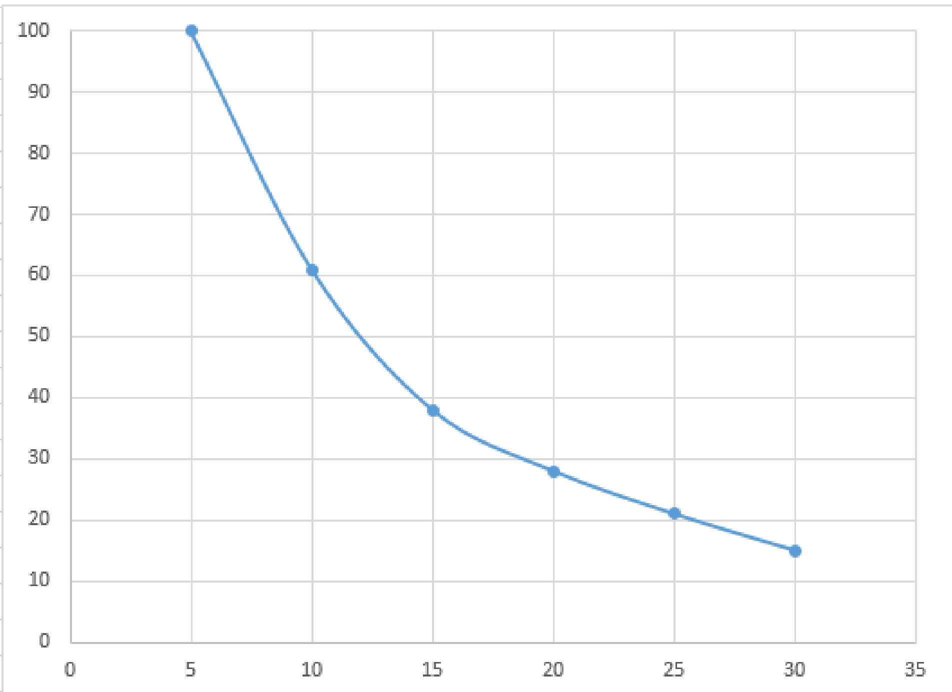

Fig. 2. Dependence of the efficiency of a thermoelectric air conditioner on the temperature difference.

As can be seen from Fig. 2, the efficiency of a thermoelectric air conditioner decreases with increasing temperature difference, while the electrical power consumption increases.

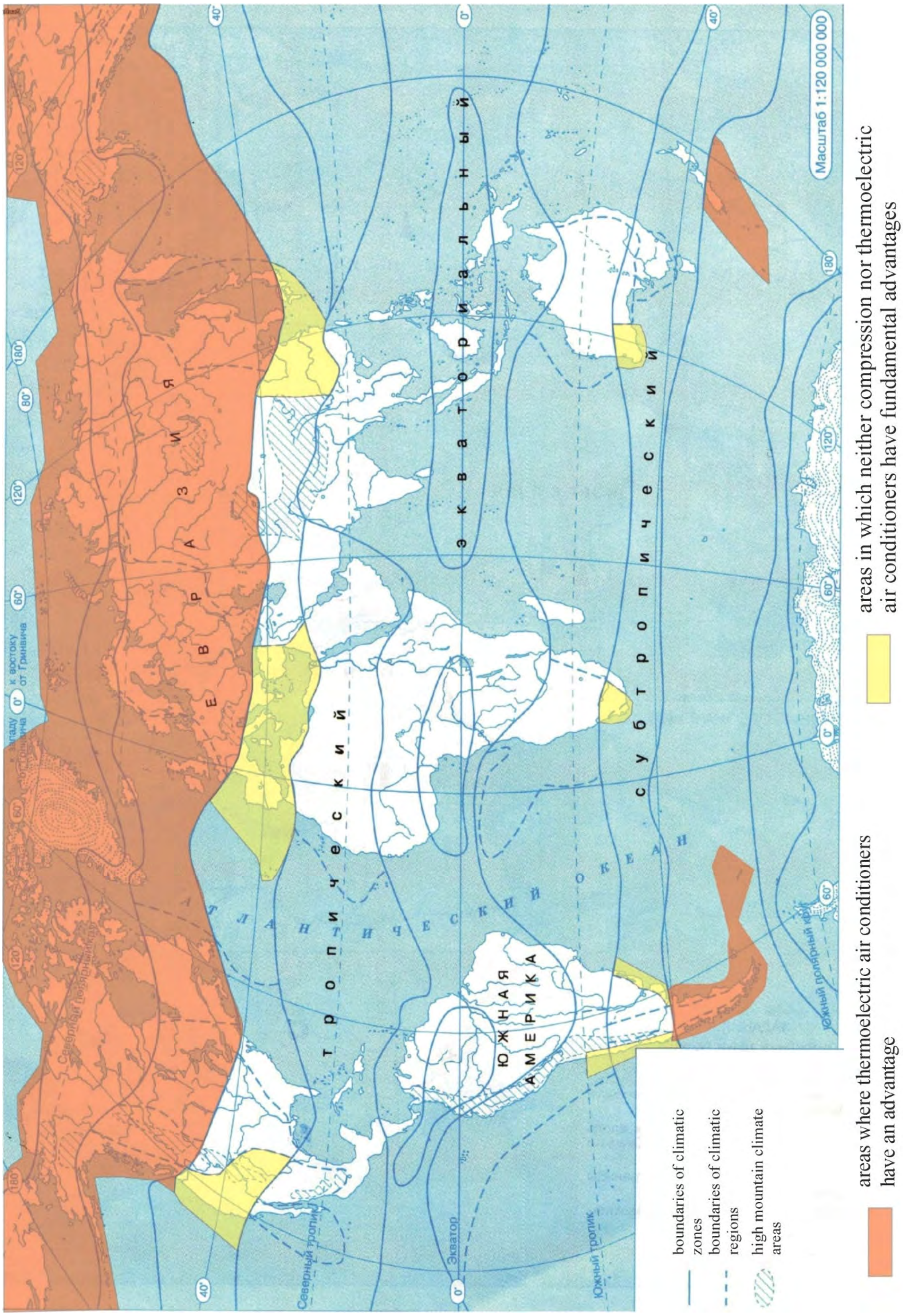

Fig. 3 Climatic zones for rational use of thermoelectric air conditioning.

The average statistical values of winter and summer air temperatures in areas of appropriate use of thermoelectric air conditioners are given in Table 3.

Table 3

Seasonal air temperature in the zones of thermoelectric air conditioning advantages

Name of the climate zone	Summer temperature, °C	Winter temperature, °C
Moderate maritime climate	14 ± 6	8 ± 3
Moderate continental climate	20 ± 5	– 5 ± 3
Moderate monsoon climate	23 ± 4	– 20 ± 6
Subarctic climate	8 ± 2	– 23 ± 4
Arctic climate	10 ± 6	– 40 ± 3

As can be seen from Table 3, the temperature range for the operation of a thermoelectric air conditioner covers extreme values from 10 °C to 27 °C in summer and from – 43 °C to 11 °C in winter.

Conclusions

1. The medical aspects of the impact of low temperatures on the human body when using air conditioners have been studied. It has been established that sharp temperature drops can cause diseases of the respiratory system and exacerbation of chronic lung diseases.
2. The optimal temperature difference between the ambient and conditioned environments was determined, which is $\Delta T \leq 5$ °C.
3. The advantages of the thermoelectric method of conditioning over the compression method are analyzed.
4. Temperature ranges for operation of thermoelectric air conditioning systems have been established for climatic zones in which the use of such systems is energy efficient.

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ПРО МЕДИЧНІ ОБМЕЖЕННЯ ДО РЕЖИМІВ ОХОЛОДЖЕННЯ ТЕРМОЕЛЕКТРИЧНИХ КОНДИЦІОНЕРІВ

У роботі проведено детальний опис температурних обмежень, що накладаються на кондиційоване середовище. Розглянуті медичні аспекти впливу різких перепадів температури на організм людини дають можливість створювати та експлуатувати кондиціонери, що будуть відповідати необхідним умовам їх безпечного використання. Визначено основні переваги та недоліки використання термоелектричних кондиціонерів у порівнянні із компресійними кондиціонерами з позиції медичних обмежень.
Ключові слова: термоелектричний кондиціонер, медичні обмеження, перепад температури, компресійний кондиціонер.

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