В ході дослідження було визначено умови раціонального використання переривчастого теплопостачання для будівель громадського призначення різних типів: адміністративні та навчальні заклади та інші будинки громадського призначення. Відомі результати теоретичних та експериментальних досліджень не враховують динаміку остигання будівлі та доцільність використання чергового режиму опалення. А це вкрай важливо для моделі управління системою теплопостачання. Проведено математичне моделювання зміни температури в приміщенні для різних типів будівель при змінних кліматичних параметрах, рівня термомодернізації та експлуатаційних параметрів будівель, що визначає доцільність використання чергового режиму. Відмова від чергового режиму дозволяє досягти додаткового енергозберігаючого ефекту.

Показано вплив огороджувальних конструкцій будівель на динаміку нагріву та остигання приміщень при змінних кліматичних умовах для різних режимів експлуатації. Запропоновано математичну модель основних режимів роботи при використанні переривчастого теплопостачання. Структура математичної моделі складається з двох інерційних ланок: мало інерційної та високоінерційної. Перша ланка відображає процес нагріву повітря в приміщенні. Друга ланка відображає процес нагріву огороджувальних конструкцій приміщення. Параметрами запропонованої моделі є коефіцієнти передачі об'єкта по каналу «потужність нагріву – зміна температури повітря», а також постійні часу для кожної із ланок. Вхідними змінними для даної моделі є температура навколишнього середовища та режим експлуатації приміщень (час перемикання з режиму на режим). Вихідною зміною є температура в приміщенні відповідно до діючого режиму. Визначено крайові умови застосування чергового режиму роботи системи переривчастого опалення для різних типів будівель при різних ступенях термомодернізації.

Результати дослідження можуть бути використанні при проектування нових будівель громадського призначення та реконструкції систем теплопостачання існуючих адміністративних та навчальних закладів. При цьому необхідно враховувати ступінь термомодернізації будівлі, тип систем опалення та режими експлуатації

Ключові слова: система переривчастого теплопостачання, форсування режиму, черговий режим, запас потужності, акумулятор теплоти

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CONSTRUCTION OF METHODS TO IMPROVE OPERATIONAL EFFICIENCY OF AN INTERMITTENT HEAT SUPPLY SYSTEM BY DETERMINING CONDITIONS TO EMPLOY A STANDBY HEATING MODE

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1. Introduction

It is known that the housing and communal services (HCS) are the most important social sector involving operations by thousands of enterprises and organizations, accounting for nearly 25 % of assets in the country, employing about 7 % of working population, and consuming about 26 % of Ukraine's fuel and energy resources. Housing and communal services utilize about 30 % of gaseous fuel to supply heating, and in most cities a share of gaseous fuel used for heating amounts to 80 %.

The above facts explain why reducing the consumption of fuel and energy resources has recently been given much attention to. In this case, a great potential for energy efficiency lies in the municipal sector. It is worth noting that the main energy saving measures in this sector are the thermal modernization and the reconstruction of heat supply system (installation of heat meters and weather-dependent controllers). However, measures aimed to align modes of energy consumption and operational modes of a building are almost not involved. Such activity is gaining momentum mainly in a private sector (installation of programmable thermostats). In addition, most of facilities for public use are characterized by a two-period regime of operation (working and standby), which makes it possible to implement a system of intermittent heat supply. It should be noted that the implementation of the specified system necessitates additional research into operational modes of a heating system in order to properly set an automation system during reconstruction of a heat supply system.

2. Literature review and problem statement

The issue of efficient use of energy resources is given much attention to [1]. Resolving a task on saving energy is relevant both at the local [2] and European level [3]. An essential role in this aspect belongs to the operational modes of heat supply systems at premises for different purposes. There are several major studies that address modes of control over a heat supply system. Thus, paper [4] tackles a task of optimal control over thermal regime of a building in general. In this case, the authors established a region of permissible values for the functional of control system for buildings with different thermotechnical characteristics; it is not clear, however, whether the variable climatic factors and operational modes of individual premises were taken into consideration.

The authors of paper [5] set the aim to improve the statement of a task about optimal control over an intermittent heat supply based on a simplified mathematical model of thermal processes in a building. They applied a quasi-static approach based on the representation of enclosing structures in a building in the form of thermal resistance without taking into consideration the accumulation of heat and dynamic approach that takes into consideration the transient processes. However, paper [5] failed to show the impact of different types of heating systems on the dynamics of a heating-up mode.

Using renewable sources of energy [6, 7], on the one hand, improves the efficiency of energy resources utilization, while, on the other hand, has a number of climatic constraints. That typically means the need for a reserve energy source. In other cases [8, 9], the example of an educational building employs a combined heating system; however, there is no information about the dynamics of heating modes.

The effect of different types of heating systems in a combined heating system is described in papers [10, 11] using an educational building as an example. The authors provided a chart of applying various sources of energy over a heating season. They also presented experimental data on the heating-up process dynamics for different heating systems. However, papers [10, 11] failed to consider the dynamics of cooling off a building and the current mode of operation. And it is extremely important for a model of control over a heat supply system.

Much attention is paid to the choice of equipment for heating various types of premises [12]. However, the specified paper, when calculating and selecting heating appliances, misses the influence of materials that the enclosing structures are made of under intermittent mode of operation.

The above indicates that the intermittent operational mode of a heat supply system is paid much attention to, but known recommendations on the features of employing an interrupting heat supply mode do not consider the level of thermal modernization and operating parameters of the facilities that receive heat. In addition, theoretical results are not confirmed experimentally.

Buildings for public use, in contrast to residential buildings, have a wide range of thermal loads. In this case, heat supply to buildings is affected by their designation. Buildings for public use are typically divided into the following categories:

1) administrative buildings and business centers;
2) commercial complexes;
3) entertainment establishments;
4) catering enterprises;
5) sports facilities;
6) educational institutions.

The specified categories differ by the ratio of share of heat consumption, the kinds of thermal load, and the organizational and operational modes of buildings, specifically:

– administrative buildings and business centers usually have a uniform schedule of heat consumption for hot water supply over a working day, while the percentage for the specified load is relatively small. Ventilation systems function only during working days and are typically equipped with heat recovery units, which makes it possible to significantly reduce the share of heat for heating outside air. A heating system works 24 hours and its thermal capacity depends on the temperature of the external air;

– commercial complexes in many cases work on a weekly and daily basis, which is why there is no any non-uniformity observed over a specified period. Ventilation systems are not always equipped with heat recovery units, which is why there is an increase in the share of heat for heating outside air. Hot water systems have a peak in consumption in the morning and there is an increased consumption mode in the evening. A heating system works 24 hours a day. In shopping malls one can utilize the heat of condensation of refrigerating machines in order to heat premises and prepare hot water;

– entertainment establishments include theatres, cinemas, discotheques, night clubs, children's centers, etc. In these establishments, there is a substantial daily non-uniformity in heat consumption. For example, movie theaters ventilate premises during a break between sessions; this dramatically increases the amount of heat consumed. The large density of movie-goers, as well as heat from equipment, lead to a certain reduction in the load on a heating system during session. If a movie theater has no any catering establishments, consumption for the preparation of hot water is insignificant;

– at nightclubs and in discotheques, a load peak for the type of heat supply occurs at night, when there is a sharp increase in the heat load for ventilation, hot water, and technological needs. In this case, there is almost no change, and sometimes even a decrease, in the load on heating [13];

– at food establishments, depending on the direction of functioning (cafes, canteens, restaurants, etc.), the irregularity is observed throughout the day and week. A peak of load on ventilation and hot water supply is during the time when halls are full (for cafes and diners, it is a lunch break, and for restaurants and cafes, at evening). When a dining hall is filled to capacity, the load on heating reduces significantly. Inside technological areas, the load on ventilation in daytime dramatically increases while the load on heating significantly reduces;

– at sports facilities, one observes uneven consumption of heat over a day and a week. During operation (training or competitions), all the life-support systems (heating, ventilation, hot water supply) are enabled. In between the events, there is a dramatic increase in heat load, which is why even during a working day there are characteristic fluctuations in thermal loads. Sports facilities, as well as small hotels with swimming pools, are attractive candidates for using renewable sources of energy based on systems that could supply heat and cold (absorption, refrigerating machines, or steam compressor refrigeration machines that utilize condensation heat for technological needs and hot water supply;

– educational establishments differ the most in special features and requirements to heat supply, because, in addition to a daily and weekly non-uniformity, there is an irregularity in the need for heat over a calendar year, due to winter and summer vacations. In this case, the daily irregularity depends on the schedule of an educational process and the occurrence of additional educational and cultural activities; the peak in heat load is during a heating period's working days from 8:00 to 15:00. The load on the need for hot water is also maximal within the specified period. In addition, at maximal presence of people in training premises and classrooms there is a possible partial reduction in the load on heating as a result of significant heat release and the increased load on ventilation systems (when they exist), respectively [14].

It should be noted that for the above categories of buildings for public use, the appropriateness of employing a mode of intermittent heat supply is undeniable and obvious. During operation, these heat supply systems are characterized by their capacity to naturally redistribute and compensate for certain types of heating needs.

For example, for the period of the maximal presence of visitors at a nightclub, the need for heating reduces at the expense of excessive heat transfer (from electrical appliances, people, etc.). In this case, the need for ventilation, on the contrary, dramatically increases, at certain periods, an increase in the need for heat in order to heat fresh air in ventilation systems is compensated for by reducing the load on heating systems.

As regards buildings for public use, there is no necessity to calculate a heating system with maximum capacity as there is a natural redistribution of some types of thermal needs into others (self-balance).

In order to transfer buildings to a mode intermittent heat supply, it is necessary to substantiate the patterns and duration of the four operational modes of the system: working; transitional; standby; heating-up. In this case, it is necessary to take into consideration the level of thermal modernization of buildings and the types of heating systems.

It should be noted that the transfer of buildings to the intermittent operational mode of a heat supply system will reduce the consumption of energy for the generation of heat. On the other hand, it is necessary to provide for a sufficient reserve of capacity so that a heating system is boosted to enter a working regime during a heating-up mode. For the efficient implementation of an intermittent heat supply mode in the above types of buildings, it is necessary to align the results of theoretical and experimental studies, capable to ensure the optimal operational modes of the system.

3. The aim and objectives of the study

The aim of this study is to determine a rational range of operational modes for intermittent heat supply and to define limits in the application of a standby regime for various types of buildings for public use.

To accomplish the aim, the following tasks have been set:

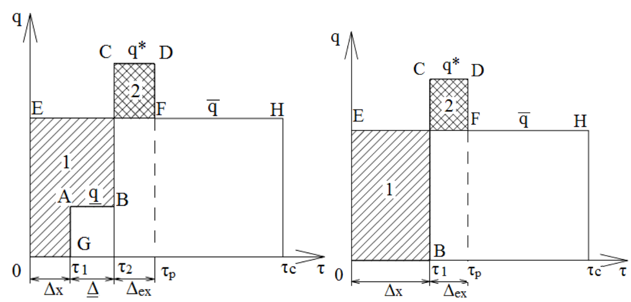
– to model operational modes of an intermittent heat supply system for various types of buildings under variable climatic factors;

– to analyze the results of modelling and to define conditions for the application of a standby heating mode for various types of buildings for public use.

4. Materials and methods to study operational modes of intermittent heat supply

When employing an intermittent heat supply, a very important energy saving contribution is due to the duration of two modes: standby (maintaining the minimum permissible temperature indoors) and heating-up (a period when the system is boosted to enter a working mode) [15].

Work of the system under an intermittent mode of operation can be represented graphically (Fig. 1), specifically a change in thermal capacity.



a *b*

Fig. 1. Operational modes of ISAIHS: *a* — standby mode; *b* — no standby mode; OGA — transitional mode; AB — standby mode; BCD — heating-up mode; FH — working mode; 1 — heat saving at ISAIHS; 2 — excess heat when boosting a heating-up mode

In Fig. 1, heat flows $\bar{q}$ and q correspond to the stable values for temperatures under working and standby operational mode, respectively: $T_{\min}$, $T_{\max}$ i T_{am}. Heat flow q^*, which defines the *length* of a heating-up period Δ_{ex}, is taken with respect to the following condition:

$$q_{\max} \geq q^{*} > \bar{q}.$$

To define the dynamic properties of buildings, it is necessary to construct a model of thermal regime. A model of the building's thermal mode [16] is built based on a thermal balance using quasi-stationary approximations. It is proposed to determine in the model the average temperature of the outer wall of a building as a half the sum of temperatures of internal and external air in order to organize the modes of an intermittent heat supply system.

It should be noted that the temperature of the outer wall of a building could be defined more precisely when considering the distribution of temperature along the thickness of the wall. Using a similar quasi-stationary approach, the average temperature of the outer wall of a building is equal to [16]:

$$\bar{t} = (t_{in} - t_{am})\left(\frac{\delta}{2\cdot R\cdot\lambda} - \frac{1}{\alpha_{ex}\cdot R}\right) + t_{am}, \qquad (1)$$

where $t_{\rm in}$, $t_{\rm am}$ is the temperature of the internal and external air, respectively, °C; δ is the thickness of the external wall of a building, m; R is the thermal resistance of heat transfer from the environment to the internal air through the outer wall of a building (m^2·K)/W; λ is the thermal conductivity of a material of the wall, W/(m·K); α_{ex} is the coefficient of heat transfer from the environment to the outer wall of a building, W/(m^2·K).

We obtain from formula (1):

$$\bar{d}t=\left(\frac{\delta}{2\cdot R\cdot\lambda}+\frac{1}{\alpha_{in}\cdot R}\right)dt_{am}-$$
$$-\left(\frac{\delta}{2\cdot R\cdot\lambda}+\frac{1}{\alpha_{H}\cdot R}\right)dt_{am}+dt_{am}, \qquad (2)$$

where α_{in} is the coefficient of heat transfer from the outer wall of a building to the internal air W/(m^2·K).

The equation of thermal balance for a small period [17]:

$$[W_0-q_0V(\bar{t}_{in}-t_{am})]d\tau=$$
$$=c\rho F\delta\left[\left(\frac{\delta}{2R\lambda}+\frac{1}{\alpha_i R}\right)dt_i-\left(\frac{\delta}{2R\lambda}+\frac{1}{\alpha_{\rm H} R}\right)dt_{am}\right], \qquad (3)$$

where W_o is the power of an intermittent heat supply system, kW; $q_{\rm o}$ is the specific heat characteristics of a building for public use, KJ/(m^3·h·K); V is the volume of premises at an object to which heat is supplied, m^3; F is the area of external enclosures of a building, m^2; c is the heat capacity of a material of the outer fencing, kJ/(kg·K); ρ is the density of a material of the outer fencing, kg/m^3.

The differential equation for the internal air temperature indoors is then [17]:

$$\frac{c\rho F\delta}{q_0V}\left(\frac{\delta}{2R\lambda}+\frac{1}{\alpha_i R}\right)\frac{dt_i}{d\tau}+t_i=$$
$$=\frac{W_0}{q_0V}\frac{c\rho F\delta}{q_0V}\left(\frac{\delta}{2R\lambda}+\frac{1}{\alpha_{\rm H}R}\right)\frac{dt_{am}}{d\tau}+t_{am}. \qquad (4)$$

Taking into consideration the adopted notation, inherent in the theory of automatic control, based on formula (4), we obtain the following equation [15]:

$$T_B\frac{dt_i}{d\tau}+t_i=kW_0+T_{am}\frac{dt_{am}}{d\tau}+t_{am}, \qquad (5)$$

where T_{am} is the time constant of differentiation for the outdoor temperature, taken to be $T_{in}=T_{am}$; $k=1/q_oV$ is the coefficient of transmission along the channel "capacity of a heating system – temperature of internal air". With respect to equation (4), the coefficient of transmission along the channel "temperature of external air – temperature of internal air" is equal to 1.

A model of the dynamics of heating the premises is a parallel connection of two aperiodic inertial links of the first order W_1 (low-inertial) and W_2 (highly-inertial) (Fig. 2).

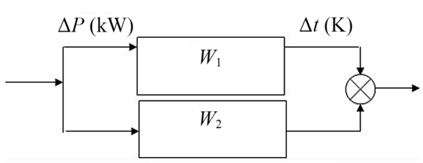


Fig. 2. Structure of a mathematical model of the dynamics of change in the air temperature indoors

By applying the Laplace transform, transfer functions of the model's links can be recorded, accordingly, in the form:

$$W_1(s)=\frac{k_1}{1+T_1\cdot s};$$
$$W_2(s)=\frac{k_2}{1+T_2\cdot s}, \qquad (6)$$

where k_1, k_2 are, respectively, the coefficients of the transfer of an object along the channel "power of heating – change in air temperature" for low and highly-inertial links, K/kW; T_1, T_2 are, respectively, the time constants of low- and highly-inertial links, h.

Transfer coefficient k_1;

$$k_1=\frac{R_{B-C}}{\Sigma S_{BH}}+\frac{R_{IS}^{BH}}{\Sigma S_{BH}}=\frac{R_{B-C}+R_{IS}^{BH}}{\Sigma S_{BH}}\ \text{K/W}, \qquad (7)$$

where $R_{B\text{-}C}$ is the thermal resistance of "air–wall"

$$R_{B\text{-}C}=1/K_{B\text{-}C},\ (\text{m}^2\cdot\text{K})/\text{W}, \qquad (8)$$

where $K_{B\text{-}C}$ is the coefficient of heat transfer of "air-wall", W/(m^2·K); ΣS_{BH} is the total area of thermal insulation of an inner surface (wall, floor, ceiling), m^2; $R_{:S}^{BH}$ is the average thermal resistance of the inner layer of thermal insulation, (m^2·K) W.

A time constant of the low-inertial link T_1 is:

$$T_1\frac{C_{ai}m_{ai}+C_f\cdot m_f+C_{eg}\cdot m_{eg}+C_{is}\cdot m_{is}}{K_{B-C}\cdot\Sigma S_{BH}},\ \text{K}, \qquad (9)$$

where $m_{\rm ai}$, $m_{\rm a}$, m_{eg}, $m_{\rm is}$ are, respectively, the mass of air, furniture, equipment and thermal insulation inside a premise under a heating-up mode, kg; $C_{\rm ai}$, $C_{\rm f}$, $C_{\rm eg}$, $C_{\rm is}$ are, respectively, the heat capacity of air, furniture, equipment and thermal insulation, KJ/(kg·K).

A transfer coefficient is:

$$k_2=\frac{R_w+R_{:S}^{ou}}{\Sigma S_{BH}}\ \text{K/W}, \qquad (10)$$

where $R_{\rm w}$, $R_{:S}^{w}$ are, respectively, the thermal resistance of walls and the outer thermal insulation, (m^2·K)/W.

A time constant of the highly-inertial link T_2 is:

$$T_2=\frac{R_w\cdot C_w\cdot m_w}{\Sigma S_{BH}}=\frac{\rho_w\cdot c_w\cdot l^2}{\lambda},\ \text{K}, \qquad (11)$$

where C_w is the heat capacity of the wall, kJ/(m^2·K); R_w is the thermal resistance of the wall, (m^2·K)/W; l is the depth of warming a wall under a boosted heating-up mode, which is determined by methods of nonstationary thermal conductivity, m.

The resulting solution takes the form: $\Delta t=f(\tau)$, where τ is the duration of the process over which there is a change in temperature indoors, h,

$$\Delta t=\Delta t_1(\tau)+\Delta t_2(\tau), \qquad (12)$$

where $\Delta t_1(\tau)$, $\Delta t_2(\tau)$ is a change in the temperature indoors during heating-up for W_1 and W_2, respectively.

$$\Delta t_1 = \Delta Q \cdot k_1 \cdot \left(1 - e^{-\frac{\tau}{T_1}}\right),$$

$$\Delta t_2 = \Delta Q \cdot k_2 \cdot \left(1 - e^{-\frac{\tau}{T_2}}\right), \quad (13)$$

$$\Delta t_1(\tau) = \Delta Q\left(k \cdot \left(1 - e^{-\frac{\tau}{T_1}}\right) + k_2\left(1 - e^{-\frac{\tau}{T_2}}\right)\right),$$

where ΔQ is a change in heat release indoors, kW.

A procedure for determining the depth of warming a wall over time τ is based on the theory of nonstationary thermal conductivity using a Fourier number (Fo) [18].

The depth of warming a wall over τ (a period of heating-up) is equal to:

$$l = \sqrt{\frac{a \cdot \tau}{Fo}}, \quad (14)$$

where a is the temperature conduction of a material of the wall, m^2/s;

$$Fo = \frac{\ln\left(\frac{4}{\pi}\right) - \ln(\theta)}{\frac{\pi^2}{4}}$$ – a Fourier criterion;

$\Theta = \frac{t_w^\tau - t_{cn}^0}{t_w^{BH} - t_{cn}^0}$, Θ is the relative temperature of the wall; t_w^τ is the wall temperature at depth l at the time of starting the heating-up τ, °C; t_w^0 is the temperature of the wall before starting the heating-up (τ=0), °C; t_w^{BH} is the temperature of the inner surface of the wall under the inner layer of thermal insulation at the time of starting the heating-up, °C.

$$t_w^\tau = t_w^\tau + \frac{\left(t_w^{BH} - t_w^0\right)}{2}, \ ^\circ\text{C}. \quad (17)$$

Thus, the temperature of the wall at a great depth at the end of the heating-up period depends on the starting temperature of the section and temperature of the inner surface of the wall. That shows the absence of influence of temperature of the external surface of the wall at the high level of thermal modernization on the temperature of the specified section at intermittent heat supply.

5. Results of numerical simulation

We have obtained, for two types of buildings with a high accumulating capacity (HAC) T_2=200 h, and a low accumulating capacity (LAC) T_2=30 h, the distribution of temperatures at intermittent heat supply within 24 hours at the same temperature of outside air for the conditions of operation of an educational building (Fig. 3, 4).

An analysis of modelling results (Fig. 3, 4) leads to the conclusion that the large amplitude of fluctuations in the temperature of air indoors characterizes buildings of the LAC-type (to 30 % at T_2=30 h) in comparison with buildings of the HAC-type (T_2=200 h), that is, one can draw a conclusion about the greater effectiveness of an intermittent heat supply mode for a given class of buildings for public use (business center). In addition, an analysis of graphs reveals that the HAC buildings that operate under an intermittent heat supply mode can do without a standby heating over 24 hours if air temperature indoors does not decrease below +12 °C, which leads to the useful energy-saving effect.

In order to reduce a peak load on the source of heat generation by using a night tariff for electricity, we generalized and analyzed results of numerical simulation of processes in ISA-IHS that operates under an intermittent mode applying a heat accumulator (Fig. 5).

An analysis of the results of numerical simulation demonstrates the need to employ a standby mode of heating for buildings of the HAC type at outside air temperatures below minus 10 °C for different modes of operation. As regards buildings of the LAC type, it is necessary to employ a standby mode at outside air temperatures below minus 5 °C.

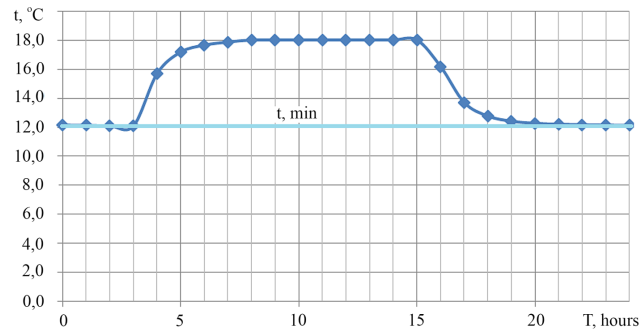


Fig. 3. Graph of a temperature change indoors over 24 hours at intermittent heat supply when t_{am}=–10 °C, T_2=200 hours

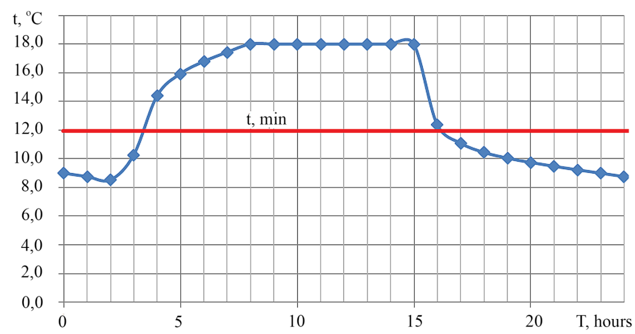


Fig. 4. Graph of a temperature change indoors over 24 hours at intermittent heat supply when t_{am}=–10 °C, T_2=30 hours

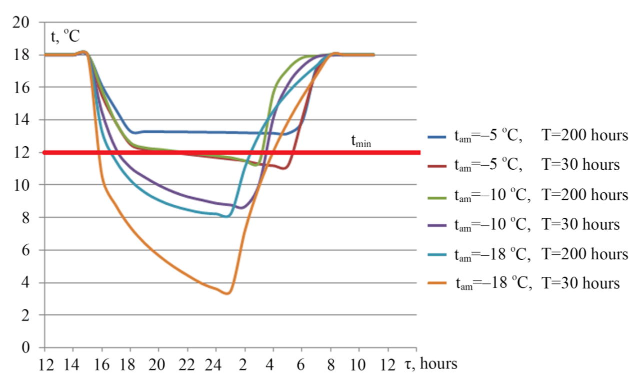


Fig. 5. Generalizing charts of temperature change indoors over 24 hours under an intermittent heat supply mode for conditions of an educational building

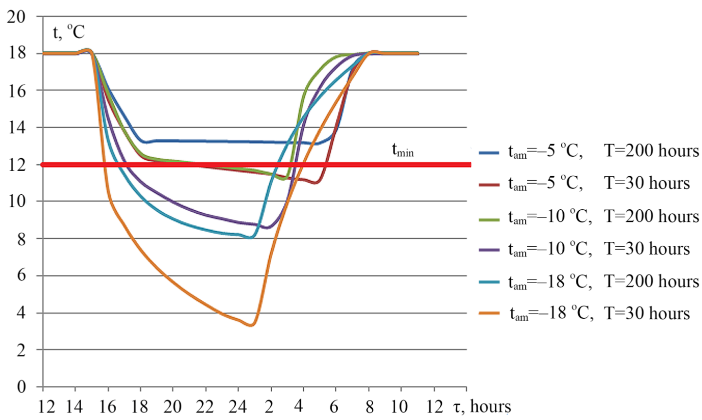


Fig. 6. Generalizing charts of temperature change indoors over 24 hours under an intermittent heat supply mode for conditions of an administrative institution

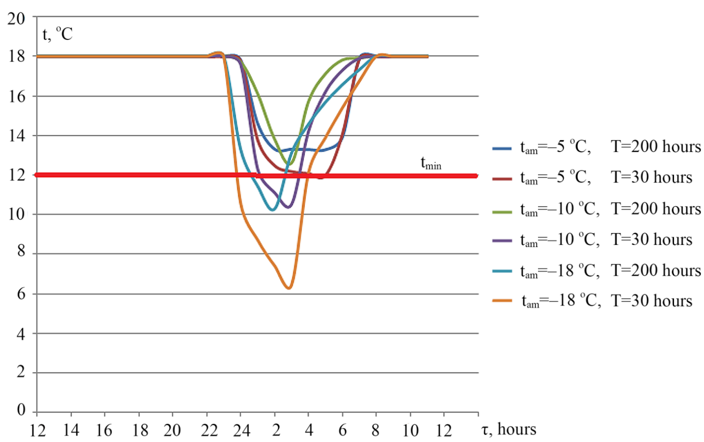


Fig. 7. Generalizing charts of temperature change indoors over 24 hours under an intermittent heat supply mode for conditions of entertainment and dining facilities

6. Discussion of results of studying the intermittent heat supply modes

The results of numerical simulations reveal that at optimal control over the system it is required to consider the following important factors:

– design features of external enclosures (type of a material that a fence is made of);

– modes of building operation (duration of operation);

– climatic patterns of the region (outside air temperature, wind speed, insolation, etc.) that make it possible to achieve additional energy saving only by canceling a standby mode of heating. In this case, a direct transition from the standby mode (Fig. 1) *OA* (no heating; the system is turned off) to the heating-up mode *BCD* (Fig. 1, *b*) is enabled. In this case, based on the results of numerical simulation, one achieves an *additional saving* (heat saving ~10 %), which must be confirmed experimentally.

It should be noted that cancelling a standby mode of heating is a pressing issue in terms of effective operation of the system, which makes it possible to more efficiently utilize saved energy under an intermittent mode. For example, for charging a heat accumulator during night, in order to subsequently use this heat for boosting the heating-up regime [19].

The above is important in accordance with the tasks of energy saving technologies, as it leads to a decrease in the maximum power of the system, which is dedined by the level of energy needs and the duration of a heating-up regime [20].

Special features of climatic limitations for different type are explained by a major influence of the accumulating capacity of a building on the mode of cooling off and the duration of a standby regime. In this case, it should be noted that the longer the working mode, the less the duration of a standby regime.

The obtained results make it possible to introduce the required climatic limitations to the models of optimal control over a heating system in a building, obtained in other studies [4, 5, 18]. In contrast to the models proposed earlier, the specified procedure makes it possible to determine the end of a standby regime and the beginning of heating-up, with respect to inertial character of both the enclosures and the heating systems of a building.

The above would significantly improve energy savings. In the present study, the cooling off regime and a standby mode are almost not affected by a factor defined by the type of a heating system. However, quite a significant contribution and the duration of a standby regime comes from the start of a heating-up mode, which is why in the further research it would be necessary to consider the impact on the duration of a standby exerted by the inertial character of heating systems.

In the practical implementation of the obtained research results it will be necessary to take into consideration the irregularity of cooling off and heating-up in different rooms within the same building. That necessitates determining the least inertial rooms in a building as those that "urge" the start of a heating system operation in order to meet heating needs.

7. Conclusions

1. Based on the results of numerical simulation, we have defined special features in the basic modes of ISAIHS operation: a heating-up regime, a working mode, a standby mode, a transition mode. In addition, we have determined the most important factors that affect the operational efficiency of an intermittent heat supply system, namely, the duration of operating modes, the time to switch modes, and cancelling a particular regime, which affect the energy efficiency of ISAIHS operation.

2. An analysis of the results of numerical simulation of daily schedules of thermal loads during ISAIHS operation under an intermittent mode of heat supply for building of the HAC-type and buildings of the LAC-type has revealed the most effective conditions of ISAIHS operation for the criterion of heat savings. We have also found that it is necessary to reasonably choose the moment of transition from a particular operating regime of an intermittent heat supply system to another (heating-up, work, transition, standby), as well as the rational duration of each mode in the operation of an intermittent heat supply system, which is determined by the level of thermal modernization and operating modes of a building, as well as by climatic factors, which makes it possible to achieve additional energy-saving effect without additional capital investment.

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