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STUDY OF THE INFLUENCE OF HYDRODYNAMIC AND STRUCTURAL PARAMETERS OF THE EXISTING HEATING SYSTEM OF THE BUILDING OF THE FIRST EDUCATIONAL BUILDING OF NULES OF UKRAINE ON INDICATORS OF COMFORT OF PREMISES

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Abstract. *When assessing the thermal condition of the building and the parameters of the microclimate of the premises, the main factors influencing its thermal inertia were identified and taken into account. An assessment of the influence of the resistance of enclosing structures on the efficiency of the heating system, taking into account the influence of external and internal climatic parameters in the dynamic mode. It is shown that the time factor and depth of regulation, as well as the outdoor air temperature are important factors. Researches are carried out and the expediency of introduction of a duty mode of heating of buildings of HIGH SCHOOLS is estimated. The given algorithm of control of process of heat release (especially in the presence of a point of "breaking" - average (them) on the schedule) in addition increases accuracy of the decisions of the specified problems and reduces a temperature deviation by 4 ÷ 6 ° C in comparison with usual ("linear") dependence that allows to correct more precisely release of the heat carrier in system of heating of a structure at introduction of a standby mode. It was found that it took about 6.5 hours to achieve normalized air temperature and space heating in the forced (after a long stay on duty). It is shown that the heat consumption of the system in such conditions of its operation compared to the nominal mode increased by 25% (taking into account the limit value of the specific allowance from table H1 DBN B.2.5-67: 2013 "Heating, ventilation and air conditioning"), but for the entire period the action of the standby mode savings amounted to about 6-8% of energy consumed.*

Taking into account the design of the outer walls of the object of study, the temperature graph of the heating system was adjusted taking into account the value of the internal heat capacity of the building when implementing on-duty heating, which, according to preliminary estimates, will: improve comfort in the room; to reduce heating *costs of the educational and administrative building of NULES of Ukraine by 10-12% for the heating period.*

Key words*: microclimate, internal heat capacity of a building, standby mode, heating system, heat loss*

Relevance of research. Reducing the cost of utility payments for the operation of higher education institutions (HEIs) for our country is a promising step on the way to energy saving. The most important among them are the costs of heating to ensure the appropriate parameters of the microclimate and the thermal regime of buildings, which is determined by the arrival or loss of heat through external enclosing structures, the operation of heating, cooling and ventilation systems, domestic and technological heat emissions, as well as the thermophysical properties of the materials of building structures.

The calculated parameters of the microclimate of a particular room are determined depending on its functional purpose and sanitary and hygienic requirements that must be met during the heating period. The duration of preservation of the microclimate parameters in the premises of the building during the period, for example, the emergency shutdown of the heating system or the transition of its operation to the regular mode (non-working period of the HEI), is determined by a time constant that characterizes the internal thermal inertia (heat capacity) of the building [1].

The latter is significantly influenced by the heat-shielding properties of the enclosing structures, the calculated thermal power of the heating system, and the calculated parameters of the climatic region (temperature zone) of the location of the object under study. It is interesting that as the thermal insulation characteristics of buildings improve, the nature of heat loss by individual components also changes. Table 1 shows the data characterizing the qualitative changes in heat loss in the building that occur during the insulation of its external enclosing structures.

1. The structure of heat consumption of public buildings with different levels of heat transfer resistance of enclosing structures

Characteristics of the house	Heat consumption due to building elements in % of total heat consumption				
	opaque walls	transparent designs	roof	basement floor	air exchange
Built before 1995	39	21	15	8	17
$R_{іпр} \geq 1{,}6$ m²K/W	27	24	15	8	26
$R_{іпр} \geq 2{,}1$ m²K/W	23	26	14	7	30
$R_{іпр} \geq 2{,}5$ m²K/W	19	27	12	6	36
$R_{іпр} \geq 2{,}8$ m²K/W	18	25	12	6	39
$R_{іпр} \geq 3{,}3$ m²K/W	17	23	10	5	45

The analysis of the table shows that with an increase in the thermal resistance of heat transfer of the enclosing structures of buildings, the share of transmission heat losses decreases, and the share of losses with air exchange increases, since the need for heat consumption for ventilation of premises remains unchanged (provided there are no energy-saving measures implemented in ventilation systems) and even slightly increases due to a decrease in the share of infiltration losses. In view of the above, the issue of increasing the efficiency of energy use while maintaining the comfort level of the premises remains relevant. This result can be achieved, among other things, due to the use of the optimal mode of alternative heating, i.e. optimal management of the thermal mode of the building during the non-working period. It is advisable to use alternate heating mode for budgetary objects and buildings that are used according to the schedule, which also includes the buildings of HEI.

Analysis of recent research and publications. The analysis of literary sources proves that the issue of using alternate heating mode has not been studied enough. The conducted studies do not fully reveal all aspects of the use of alternative heating, but study only certain aspects of this issue. The alternate heating system is most fully described in the article [2]. However, this paper did not conduct an experimental study of the thermal inertia of the room. The results of the study of the influence of the thermal inertia of the room are given in the article [3], according to which neglecting the heat capacity of the elements of the heating system leads to an error in the simulation results at the level of about 10%. Therefore, it is important to determine the cooling time of the room after reducing the volume of heat supply and to determine the time to warm up the room. The authors of works [4-8] previously conducted a number of studies, in particular, on the analysis of the state of energy consumption at the facilities of the National University of Life and Environmental Sciences of Ukraine (NULES of Ukraine) in recent years, monitoring of microclimate parameters in the premises of educational buildings and in university dormitories. Indoor air temperature profiles were measured both on the floors and on the facades of the buildings before and after the thermal modernization works, which consisted in the insulation of external enclosing structures and the modernization of individual heating points in individual buildings.

According to DBN V.2.5-67:2013 "Heating, ventilation and air conditioning" [9] in the cold period of the year in public, administrative and domestic and industrial premises of heated buildings during the period of their non-use (non-working hours) the air temperature should be taken below the norm, but not less than 12 ºC, ensuring the restoration of normalized temperature before starting to use the room or before starting work. That is, it is possible to reduce the temperature by 6-10 ºC, which is quite a significant saving of thermal energy. That is, taking into account the above factors, it can be stated that the adjustment of the heating mode depends on many factors that must be taken into account when implementing the regular heating mode.

Setting the problem. In order to identify the reasons for the increase in the level of consumption by the building of one of the buildings of NULES of Ukraine, as well as to assess the feasibility of implementing a regular heating regime, an analysis of the efficiency of the heating system was carried out using an ITP with the possibility of weather-dependent heat release and a controller that, through a three-way valve with an electric drive (M), provides hourly change of system operation mode (Fig. 1).

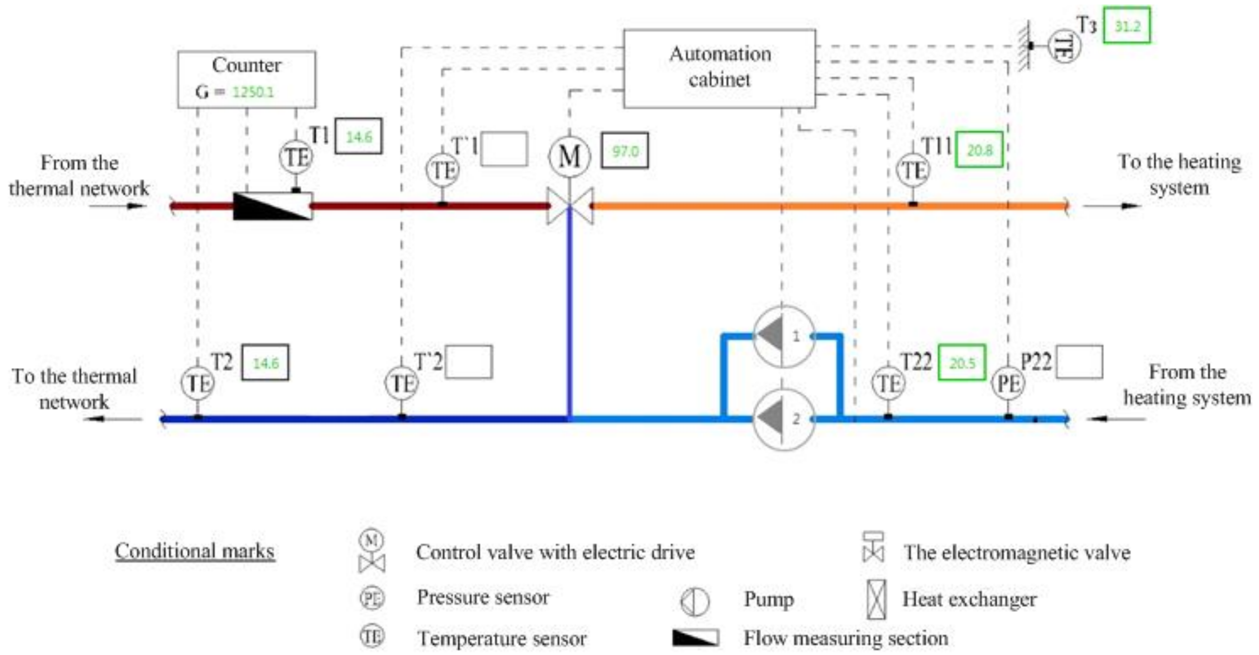

Fig. 1. ITP mnemonic scheme

The principle of the proposed work algorithm is as follows: during the absence of people in the room, the temperature of the supply coolant (T11) decreases to a value that will ensure a decrease in the temperature of the air in the room no lower than 12 ºC. At this time, the inflow of thermal energy into the room decreases taking into account the temperature of the outside air (Tz). The start of heating the room takes place a few hours before the start of the working day by increasing the volume of coolant supply in the forced mode (rapid increase of heat release).

Determining the main control parameters (the depth of the coolant temperature drop, the dynamics of indoor air temperature changes) associated with the simultaneous change in ambient air temperature is a task that needs to be solved taking into account the dynamics of the heat supply process.

Research materials and methods. The object of the study is the administrative and educational building of the National University of Life and Environmental Sciences of Ukraine.

The external walls are brick, 510-640 mm thick, insulated with mineral wool, 100 mm thick. The exterior is decorated with plaster and decorative relief stucco. There is a basement floor under the entire area of the building. The roof is gable, the attic is unheated, insulated. The windows are metal-plastic with two-chamber glazing and gas filling and energy-saving coating. The doors are wooden and metal, insulated and closed.

The building is connected to the central heat supply system according to a scheme dependent on the central heating point, where the ITP is installed with the regulation of the heat carrier depending on the weather conditions without preparation of water for the needs of domestic hot water. The indoor heating system is two-pipe. Heating devices - steel panel radiators with thermostatic heads. There are no heat-reflecting screens. Stairwells are heated. There are two heat meters for each "wing" of the building's heating system. Counters on commercial accounting. The ventilation system is mechanical (exhaust) and naturally inspired.

The schedule of staff and students stay is always on working days, except for weekends and holidays.

Experimental studies were conducted over 5 days, including weekends. Measurements were made with the help of temperature and air humidity data loggers - Trotec BL30. Measurement accuracy (at an ambient temperature of 20 °C) ±2%, but not less: ±2ºC in the range - 1...50 ºC, ±3 ºC in the range -18...-1 ºC.

It was established that the temperature of the external environment significantly affects the thermal regime of the room. Thus, at an outside air temperature of 0...5 °C, the temperature of the heating device was 32 °C, at an external air temperature of -5...0 °C, the radiator heated up to 35 °C, and at a temperature of -8...-15 °C, the temperature of the device was 38...40 °C. When changing the specified parameters, the air temperature in the premises fluctuated within ±2 °C.

Operation of the system is in standby mode. It has been experimentally confirmed that an important factor in the implementation of the regular heating mode is the time interval and the depth of adjustment. The average temperature drop of the heat carrier during the measurement period (from 18:00 to 04:00) was 8-10 °C at an outside air temperature of -3 °C. At the same time, the air temperature in the room did not change significantly, but remained at the level of more than 16 °C with the permitted 12 °C. Significantly different values were obtained when the heating system was operating in regular mode on weekends. Thus, when switching to work from 6:00 p.m. Friday to 11:59

p.m. Sunday, the temperature in the premises of the building dropped to the normalized 12 °C. At the same time, it took about 6.5 hours to reach the normalized air temperature and warm up the room in the forced mode. Heat consumption by the system under such conditions of its operation, compared to the nominal mode, increased by 25% (taking into account the limit value of the specific allowance from table H1 DBN V.2.5-67:2013 "Heating, ventilation and air conditioning") but for the entire period of operation of the alternate mode savings amounted to about 6-8% of the consumed energy.

A comparison of the actual consumption of thermal energy with the estimated actual number of degree-days for the month of November 2018 and the internal temperature in the premises of the building (Table 2) showed the level of average deviation of the indicators of the actual temperatures in the premises of the building (-0.8 °C) from the accepted values (16±2 °C) and, as a result, a decrease in the level of actual heat energy consumption from the calculated value reduced to the actual number of degree-days by -0.011 Gcal.

The given algorithm for controlling the process of heat release (especially if there is a "break" point - the middle point(s) on the graph) additionally increases the accuracy of solutions to the specified problems and reduces the temperature deviation by 4÷6 °C (see Fig. 2) compared to the usual ("linear") dependence (typical for buildings in column "A" in Table 3). This allows for a more accurate adjustment of the release of the heat carrier into the building's heating system when implementing an alternate mode.

2. Analysis of the efficiency of the heating system using ITP. Comparison of the actual consumption of thermal energy with the estimated actual number of degree days for the month of November 2018 and the internal temperature in the premises of the building

Indicators	November 2018																														Total for the period (average)
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Actual consumption of thermal energy for the period, Gcal	0,377	0,376	0,144	0,143	0,373	0,409	0,439	0,473	0,447	0,222	0,342	0,617	0,649	0,369	0,382	0,629	0,464	0,491	0,679	0,729	0,596	0,602	0,622	0,494	0,519	0,564	0,577	0,628	0,654	0,667	14,676
Actual outside temperature, ^{o}C	11,50	10,50	10,10	11,40	10,50	8,10	8,00	8,30	8,50	8,50	5,40	5,90	2,60	3,30	6,30	1,60	0,00	2,00	1,80	0,80	2,00	1,75	1,00	2,00	1,00	3,00	2,50	0,50	0,00	-0,50	(4,61)
According to the hydrometeorological center (HMC), ^{o}C	10,20	9,00	8,60	9,30	8,90	6,70	5,70	4,40	4,50	4,50	1,70	2,00	0,00	1,90	3,20	-0,90	-2,40	-1,50	-1,20	-0,50	-1,25	-1,50	-2,25	-1,25	-2,25	0,00	-0,50	-2,50	-3,50	-4,00	(1,84)
Normalized internal temperature, ^{o}C	20,00	20,00	16,00	16,00	20,00	20,00	20,00	20,00	20,00	16,00	16,00	20,00	20,00	20,00	20,00	20,00	16,00	16,00	20,00	20,00	20,00	20,00	20,00	16,00	16,00	20,00	20,00	20,00	20,00	20,00	(18,93)
Estimated consumption (normative temperature - data of HMC), Gcal	0,303	0,333	0,241	0,223	0,336	0,392	0,418	0,451	0,449	0,346	0,418	0,513	0,564	0,515	0,482	0,587	0,523	0,500	0,595	0,577	0,596	0,602	0,622	0,494	0,519	0,564	0,577	0,628	0,654	0,667	14,687
Estimated consumption (actual internal temperature - HMC data), Gcal	0,251	0,282	0,241	0,223	0,285	0,341	0,367	0,400	0,397	0,346	0,418	0,461	0,513	0,490	0,456	0,587	0,523	0,500	0,543	0,526	0,596	0,602	0,622	0,494	0,519	0,564	0,577	0,628	0,654	0,667	14,072
Estimated consumption (actual internal-actual external temperature), Gcal	0,218	0,244	0,203	0,169	0,244	0,305	0,308	0,300	0,295	0,244	0,323	0,361	0,446	0,454	0,377	0,523	0,461	0,410	0,467	0,492	0,513	0,519	0,538	0,410	0,436	0,487	0,500	0,551	0,564	0,577	11,938
Deviation in internal temperatures, ^{o}C	-2,00	-2,00	0,00	0,00	-2,00	-2,00	-2,00	-2,00	-2,00	0,00	0,00	-2,00	-2,00	-1,00	-1,00	0,00	0,00	0,00	-2,00	-2,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	-0,8
Consumption excess, Gcal	0,074	0,043	-0,097	-0,080	0,037	0,017	0,021	0,022	-0,002	-0,124	-0,076	0,104	0,085	-0,146	-0,100	0,042	-0,059	-0,009	0,084	0,152	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	-0,011

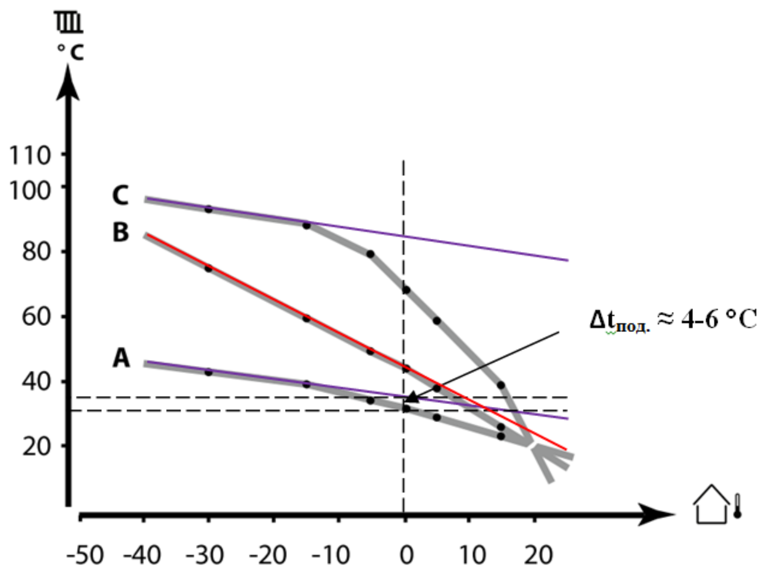

Fig. 2. The temperature schedule of the building's heating system depending on the indicator of its internal heat capacity

Taking into account the structure of the external walls of the research object, adjusting the temperature schedule of the heating system taking into account the value of the internal heat capacity of the building, when implementing the alternate heating mode, according to a preliminary assessment, will allow: to improve the comfortable conditions in the room when the heating system is operating in alternate mode; to reduce heating costs of the educational and administrative building of NULES of Ukraine by 10-12% during the heating period.

3. Numerical values of coolant temperatures in the supply pipeline of the building's heating system depending on the indicator of its internal heat capacity

$t_{external}$, °C	Supply temperature, t_{supply}, °C		
	A*	B	C
-30 °C	45 °C	75 °C	95 °C
-15 °C	40 °C	60 °C	90 °C
-5 °C	35 °C	50 °C	80 °C
0 °C	32 °C	45 °C	70 °C
5 °C	30 °C	40 °C	60 °C
15 °C	25 °C	28 °C	35 °C

* Column "A" of the table corresponds especially to capital buildings with stone or brick walls (thickness of 2.5 - 3.5 bricks), with a reinforced concrete or metal frame, with a reinforced concrete floor and a layer of mineral wool insulation on the walls; column "B" - capital buildings with brick walls thick (1.5-2 bricks) without insulation, with reinforced concrete floors; column "C" - a large-panel, large-block building with brick walls in one brick without insulation, with reinforced concrete or wooden floors [1].

System operation in nominal mode. A comparison of the actual consumption of thermal energy with the estimated degree-days for the month of March 2019 (Table 4) and the internal temperature in the premises of the building showed that with a slight (+1.3 °C) level of deviation of the actual temperatures in the premises building from the normalized values (18±2 °C), an excess of the level of actual consumption of thermal energy from the calculated value reduced to the actual number of degree-days by 3.73 Gcal was recorded. One of the reasons for which is considered to be the difference between the readings of the outdoor air temperature sensor (≈ +3 °C) and the values of the actual operating temperatures, which is caused by the wrong choice of location of the sensor (from the north-west side on the outer wall of the building in place of constant action of drafts).

In addition, the absence of a heat-reflecting screen between the outer wall of the building and the wall of the heating radiator somewhat affects both the temperature regime in the room (on average by 0.5-1.0 °C) and the overall efficiency of the heat transfer system as a whole.

Research results and their discussion. The analysis of data on the comparison of actual and normative degree-days taking into account the actual number of days of the heating period (Table 5) under the conditions of operation of the building's heating system in the nominal mode, showed that the actual number of them did not comply with the standard for the entire heating period of 2018/2019 by 7, 4%. Bringing the calculated consumption of thermal energy to the actual number of degree-days of the heating period (Table 6) showed its decrease by the same percentage. A comparison of the actual consumption of heat energy (Table 7) with the estimated heating period reduced to the actual number of degree-days (Table 8) shows that it was exceeded by 4.4% for the same period. At the same time, a comparison of the actual consumption of thermal energy with the estimated one reduced to the actual number of degree-days of the heating period and the internal temperature in the premises of the building (Table 9) indicates that it was exceeded by 16.5% for the same period, which indicates probable deviation (increasing) in compliance with the values of the average actual temperature in the premises of the facility with the established sanitary standards.

4. Analysis of the efficiency of the heating system using ITP. Comparison of the actual consumption of thermal energy with the estimated actual number of degree days for the month of March 2019 and the internal temperature in the premises of the building

Indicators	March 2019																															Total for the period (average)
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	
Actual consumption of thermal energy for the period, Gcal	1,236	1,256	0,932	0,900	0,769	0,640	0,475	0,329	0,326	0,356	0,369	0,572	0,574	0,661	0,596	0,698	0,728	0,932	0,924	0,951	0,888	0,820	0,884	0,459	0,427	0,701	0,626	0,592	0,635	0,563	0,686	21,505
Actual outside temperature, °C	-10,00	-7,40	-6,00	-5,60	-1,30	0,00	2,60	4,70	4,60	6,90	6,60	4,80	4,40	3,50	5,20	1,60	-2,80	-4,90	0,10	-2,10	2,10	2,30	0,70	3,20	4,40	3,00	5,00	3,90	3,20	4,90	9,10	(1,51)
According to the hydrometeorological center (HMC), °C	-13,30	-12,10	-9,40	-8,60	-5,60	-2,70	0,50	2,30	2,50	3,50	2,80	2,90	2,90	1,30	3,00	-0,90	-5,60	-8,10	-5,60	-5,50	-2,70	-1,90	-2,90	-1,00	0,70	1,10	2,80	0,90	0,60	3,40	7,40	(-1,53)
Normalized internal temperature, °C	20,00	20,00	16,00	16,00	20,00	20,00	20,00	20,00	20,00	16,00	16,00	20,00	20,00	20,00	20,00	20,00	16,00	16,00	20,00	20,00	20,00	20,00	20,00	16,00	16,00	20,00	20,00	20,00	20,00	20,00	16,00	(18,84)
Estimated consumption (normative temperature - data of HMC), Gcal	0,905	0,874	0,702	0,682	0,708	0,633	0,551	0,505	0,500	0,372	0,390	0,490	0,490	0,531	0,487	0,587	0,605	0,669	0,708	0,705	0,633	0,613	0,638	0,487	0,444	0,536	0,492	0,541	0,549	0,477	0,272	17,774
Estimated consumption (actual internal temperature - HMC data), Gcal	0,905	0,874	0,779	0,759	0,708	0,633	0,551	0,454	0,449	0,423	0,441	0,490	0,413	0,479	0,436	0,536	0,631	0,695	0,656	0,705	0,633	0,613	0,638	0,564	0,520	0,536	0,492	0,490	0,497	0,451	0,349	17,799
Estimated consumption (actual internal-actual external temperature), Gcal	0,820	0,754	0,692	0,682	0,597	0,564	0,497	0,392	0,395	0,336	0,344	0,441	0,374	0,423	0,379	0,472	0,559	0,613	0,510	0,618	0,510	0,505	0,546	0,456	0,426	0,487	0,436	0,413	0,431	0,413	0,305	15,390
Deviation in internal temperatures, °C	0,00	0,00	3,00	3,00	0,00	0,00	0,00	-2,00	-2,00	2,00	2,00	0,00	-3,00	-2,00	-2,00	-2,00	1,00	1,00	-2,00	0,00	0,00	0,00	0,00	3,00	3,00	0,00	0,00	-2,00	-2,00	-1,00	3,00	1,3
Consumption excess, Gcal	0,331	0,382	0,230	0,218	0,061	0,007	-0,076	-0,176	-0,174	-0,016	-0,021	0,082	0,084	0,130	0,109	0,111	0,123	0,263	0,216	0,246	0,255	0,207	0,246	-0,028	-0,017	0,165	0,134	0,051	0,086	0,086	0,414	3,731

5. Comparison of actual and normative degree-days taking into account the actual number of days of the heating period

No n/n	Name of the institution (facility)/name of the building	The actual number of degree units / Normative number of degree units														Total for the period, degree units	Ratio, %
		2018						2019									
		October		November		December		January		February		March		April			
1	Educational building No. 3 of NULES of Ukraine	261,44	94,2%	551,70	90,6%	624,65	81,3%	750,51	89,3%	728,84	100,1%	729,43	108,9%	108,90	77,2%	3755,47	93,1%
		277,40		609,00		768,80		840,10		728,00		669,60		141,00		4033,90	

6. Bringing the estimated consumption of thermal energy to the actual number of degree-days of the heating period

No n/n	Name of the institution (facility)/name of the building	Estimated heat energy consumption, Gcal / Reduced thermal energy consumption, Gcal														Total for the period, degree units	Ratio, %
		2018						2019									
		October		November		December		January		February		March		April			
1	Educational building No. 3 of NULES of Ukraine	7,18	106,2%	15,77	110,4%	19,91	123,0%	21,76	112,0%	18,85	99,9%	17,34	91,8%	3,65	129,5%	104,47	107,4 %
		6,77		14,29		16,19		19,43		18,87		18,88		2,82		97,25	

7. Analysis of the actual consumption of thermal energy for the heating period of 2018/2019.

No s/p	Name of the institution (facility)/name of the building	Thermal energy, Gcal							Total for the period, Gcal	Specific heat consumption, kWh/m³
		2018			2019					
		October	November	December	January	February	March	April		
1	Educational building No. 3 of NULES of Ukraine	0,00	14,68	14,53	16,52	22,97	21,51	15,18	101,53	32,38

8. Actual consumption of thermal energy to the calculated reduced to the actual number of degree-days

No s/p	Name of the institution (facility)/name of the building	Actual consumption of thermal energy, Gcal / Estimated reduced consumption of thermal energy, Gcal														Total for the period, Gcal	Ratio, %
		2018						2019									
		October		November		December		January		February		March		April			
1	Educational building No. 3 of NULES of Ukraine	0,00	0,0%	14,68	102,7%	14,53	89,8%	16,52	85,0%	22,97	121,7%	21,51	113,9%	15,18	538,5%	101,53	104,4%
		6,77		14,29		16,19		19,43		18,87		18,88		2,82		97,25	

9. Comparison of the actual consumption of thermal energy with the calculated reduced to the actual number of degree-days of the heating period and internal temperature in the premises of the building

No s/p	Name of the institution (facility)/name of the building	Actual consumption of thermal energy, Gcal / Estimated reduced consumption of thermal energy, Gcal														Total for the period, Gcal	Ratio, %
		2018						2019									
		October		November		December		January		February		March		April			
1	Educational building No. 3 of NULES of Ukraine	0,00	0,0%	14,68	120,2%	14,53	105,2%	16,52	92,3%	22,97	128,5%	21,51	119,6%	15,18	698,7%	101,53	116,5%
		5,22		12,21		13,82		17,91		17,87		17,98		2,17		87,17	

In view of the above, the main reason for the deviations is considered to be the excess of the actual indoor air temperatures in the premises of the object in the transitional stage of the heating period from the value accepted in the calculations. It is proposed to change the adopted temperature schedule of heat release (the curve of the first temperature break) in the direction of lowering its initial position, which will allow to reduce the level of resource consumption in the transitional stage (spring-autumn) of the heating period.

In order to improve the efficiency of the heating system, the following is additionally offered:

1. Adjust the operation of the ITP controller to ensure a change (decrease by 6-8 °C) of the temperature regime of the system during non-working (night) hours and weekends and holidays.

2. To eliminate the difference between the readings of the outdoor air temperature sensor (≈ +3 °C) and the values of real operating temperatures, protect it from direct or reflected solar radiation/draughts, carry out its calibration.

3. Install a heat-reflecting screen between the outer wall of the building and the wall of the heating radiator, which will increase both the useful heat transfer coefficient of the latter and the temperature regime in the room by 0.5-1.0 °C.

Conclusions and perspectives. When assessing the thermal condition of the building and the microclimate parameters of the premises, the main factors affecting its thermal inertia were determined and taken into account. It is shown that an important factor is the period of time and depth of regulation, as well as the temperature of the outside air. A study was conducted and an evaluation of the expediency of introducing a regular regime of heating of buildings of the HEI was given. In particular, the following was obtained:

1. It was established that the temperature of the external environment significantly affects the thermal regime of the room. Thus, at an outside air temperature of 0...5 °C, the temperature of the heating device was 32 °C, at an external air temperature of -5...0 °C, the radiator heated up to 35 °C, and at a temperature of -8...-15 °C, the temperature of the device was 38...40 °C. When changing the specified parameters, the air temperature in the premises fluctuated within ±2 °C.

2. The average temperature drop of the coolant during the measurement period (from 18:00 to 04:00) was 8-10 °C at an outside air temperature of -3 °C. At the same time, the air temperature in the room did not change significantly, but remained at the

level of more than 16 °C with the permitted 12 °C. Significantly different values were obtained when the heating system was operating in regular mode on weekends. Thus, when switching to work from 6:00 p.m. Friday to 11:59 p.m. Sunday, the temperature in the premises of the building dropped to the normalized 12 °C.

3. It took about 6.5 hours to reach the normal air temperature and heat the room in the forced mode. Heat consumption by the system under such conditions of its operation, compared to the nominal mode, increased by 25% (taking into account the limit value of the specific allowance from table H1 DBN V.2.5-67:2013 "Heating, ventilation and air conditioning") but for the entire period of operation of the alternate mode savings amounted to about 6-8% of the consumed energy.

4. The given algorithm for controlling the process of heat release (especially if there is a "break" point - the middle point(s) on the graph) additionally increases the accuracy of solutions to the specified problems and reduces the temperature deviation by 4÷6 °C compared to the usual ("linear") dependence , which makes it possible to more accurately adjust the release of the heat carrier into the heating system of the building when implementing the next mode.

Taking into account the structure of the external walls of the research object, adjusting the temperature schedule of the heating system taking into account the value of the internal heat capacity of the building, when implementing the alternate heating mode, according to a preliminary assessment, will allow: to improve the comfortable conditions in the room when the heating system is operating in alternate mode; to reduce heating costs of the educational and administrative building of NULES of Ukraine by 10-12% during the heating period.

References

1. Energy efficiency of buildings. Method of calculating energy consumption for heating, cooling, ventilation, lighting and hot water supply: DSTU B A.2.2-12: 2015 (2015). 140.
2. Akhmetov, E. R. (2014). Analysis of the model of duty heating as an energy-saving measure. Energy safety and energy saving, 5, 25-29.
3. Boyko, V.S. (2016). Transient process in the electric circuit as an analogue of heat transfer and thermal inertia of the room. Electromechanical and energy saving systems, 3/2016 (35), 10-16.

4. Radko, I.P., Lut, M.T., Nalyvaiko, V.A, Okushko, O.V. (2018). Design of a heat point for the main building of NULES Of Ukraine. Power engineering and automation, 1, 86 – 94. Retrieved from http://journals.nubip.edu.ua/index.php/Energiya/article/viewFile/10596/9329

5. Radko, I.P., Nalyvaiko, V.A., Okushko, O.V., Mishchenko, A.V., Antypov, Ye. O. (2018). Pidvyshchennia zakhodiv z enerhoefektyvnosti ta enerhozberezhennia u vyshchykh navchalnykh zakladakh [Enhancing energy efficiency and energy efficiency measures at higher education institutions]. Scientific herald of the NULES of Ukraine, 283, 275 – 280.

6. Mishchenko, A.V., Shelimanova, O. V., Antypov, I. O. (2014). Analiz teplovoho komfortu u prymishchennyakh navchalʹnoho korpusu №8 NUBiP Ukrayiny pislya termomodernizatsiyi budivli [Analysis of thermal comfort in premises of educational building number 8 of NULES of Ukraine after thermo-modernization of the building]. Scientific herald of the NULES of Ukraine, 194 (1), 119–123.

7. Radko, I.P. (2018). Metodyka ta obladnannya dlya provedennya enerhetychnoho audytu [Methods and equipment for energy audit]. Energy and automation, 1, 123–134.

8. Kozyrsky, V.V. (2012). Rezulʹtaty sproshchenoho enerhoaudytu obʺyektiv NUBiP Ukrayiny [Results of simplified energy audit of NULES of Ukraine]. Power engineering and automation, 1 (11), 55–63.

9. Heating, ventilation and air conditioning: DBN B.2.5-67 (2013), 147.

ДОСЛІДЖЕННЯ ВПЛИВУ ГІДРОДИНАМІЧНИХ ТА КОНСТРУКТИВНИХ ПАРАМЕТРІВ ІСНУЮЧОЇ СИСТЕМИ ОПАЛЕННЯ БУДІВЛІ ПЕРШОГО НАВЧАЛЬНОГО КОРПУСУ НУБіП УКРАЇНИ НА ПОКАЗНИКИ КОМФОРТНОСТІ ПРИМІЩЕНЬ

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Анотація. *При оцінці теплового стану будівлі та параметрів мікроклімату приміщень встановлені та враховані основні фактори, що впливають на її теплову інерційність. Проведено оцінку впливу опору огороджувальних конструкцій на ефективність системи опалення з урахуванням впливу зовнішніх і внутрішніх кліматичних параметрів у динамічному режимі. Показано, що важливими факторами є фактор часу та глибина регулювання, а також температура зовнішнього повітря. Проведено дослідження та оцінено доцільність впровадження чергового режиму опалення будівель ВНЗ. Наведений алгоритм керування процесом тепловиділення (особливо за наявності точки «обриву» – середньої за графіком), який додатково підвищує точність розв'язків зазначених задач і зменшує відхилення температури на 4 ÷. 6 ° С порівняно зі звичайною («лінійною») залежністю, що дозволяє точніше коригувати виділення теплоносія в системі опалення будови при введенні режиму очікування. Встановлено, що для досягнення нормалізації температури повітря та обігрівання приміщень у примусовому режимі потрібно близько 6,5 годин. Показано, що теплоспоживання системи в таких умовах її експлуатації порівняно з номінальним режимом збільшилось на 25 % (з урахуванням граничного значення питомої надбавки з таблиці Н1 ДБН В.2.5-67: 2013 «Опалення,* *вентиляції та кондиціонування»), але за весь період дії режиму очікування економія склала близько 6-8 % спожитої енергії.*

Враховуючи конструкцію зовнішніх стін об'єкта дослідження, температурний графік системи опалення було скориговано з урахуванням значення внутрішньої теплоємності будівлі при здійсненні чергового опалення, яке за попередніми оцінками, дозволить: покращити комфорт у приміщенні; зменшити витрати на опалення першого корпусу НУБіП України на 10-12 % на опалювальний період.

Ключові слова: ***мікроклімат, внутрішня теплоємність будівлі, режим очікування, система опалення, втрати тепла***