Modeling of Thermal Comfort Parameters in Residential Buildings

Radu-Cristian Dinu*, Daniela Popescu*, Ioana-Gabriela Sîrbu*, Dan Gabriel Stănescu*
* University of Craiova / Faculty of Electrical Engineering, Craiova, Romania, e-mail: rcdinu@elth.ucv.ro

***Abstract* – At the level of residential buildings, current studies and research are focused on issues that have as a main priority, the energy of buildings. Energy efficiency of buildings involves, in addition to technical regulations and energy rehabilitation works, an economic optimization of energy in buildings. This optimization must not be done at random, but we must ensure that the conditions of thermal comfort inside the building are met at all times. In this paper, the object of the study is a room located in the middle of a condominium building in Craiova. The building of which the studied room is part is located inside the locality and has constructive structure of the tire elements, characterized by specific thermal resistances of the construction materials used. The mathematical model involves determining the values of thermal comfort parameters (indoor temperature, average radiation temperature, etc.) and their implementation in the calculation of the thermal comfort index, B. The results obtained for the three categories of rooms, allow the feeling of comfort to be included in one of the seven levels. Between the three types of studied rooms there are differences of the calculated interior temperatures, due to the temperature differences on the faces of the construction elements.**

Cuvinte cheie: *clădire, camera, confort termic, indice de confort, temperature interioară.*

Keywords: *building, room, thermal comfort, comfort index, indoor temperature.*

I. INTRODUCTION

The concept of energy is closely related to the building and the system of installations related to the building, the energy saving problems implicitly referring to the latter category. The building is a set of spaces delimited by a series of surfaces that make up the building envelope and through which heat loss occurs. The envelope of a building separates the heated volume of a building from the outside air, floor, adjoining rooms not heated or much less heated, delimited by the volume of the building through walls and / or floors, properly insulated, and other buildings with adjacent walls, delimited by the building considered by joints [1].

For condominium buildings (residential blocks), the supervision and management of the endowment facilities is a necessary and complex problem. By using energy management systems, buildings become safer, consume less energy, ensure better operation of facilities and have a high level of comfort [2].

An efficient method of reducing the consumption of thermal energy for heating, and therefore of heating costs, is the intermittent operation of the set of heating installations (source - distribution network - heating elements). Through the intermittent (discontinuous) operation of the heating system, in addition to the benefits obtained from the source of thermal energy production (reduction of primary energy consumption and impact on the environment) there are a number of disadvantages regarding the degree of satisfaction of thermal comfort [1], [3].

The interruption of thermal agent supply leads to the decrease, in time, of the air temperature inside a room (of an enclosed space) which has the effect of worsening the thermal comfort index [3].

II. GENERAL PRESENTATION OF THE PROBLEM

As most people spend (80 ... 90)% of their lives in buildings, enclosed spaces must ensure: the possibility of performing both physical and intellectual work with maximum efficiency and the possibility of performing recreational, rest and sleep activities in optimal conditions [4], [5]. Achieving these conditions depends on many factors, which influence the feeling of comfort, work capacity and human regeneration.

The design of enclosed spaces taking into account these conditions is a complex issue that must take into account the current trends of rationalization of energy consumption, which decisively influence the optimal or allowed values of comfort parameters [4]. In most cases these influences have negative effects because this criterion leads to inadequate values in terms of comfort.

The notion of technical comfort includes all the parameters achieved and controlled with installations, which directly influence a person's mood and act on his senses. It includes thermal, acoustic, olfactory and visual comfort. Corresponding to the following percentages of dissatisfaction with the comfort provided: 10%, 20%, 30%, enclosed spaces are classified into three categories: A, B and C [1], [3], [5].

The perception and appreciation of the basic elements of comfort a person is influenced by some psychological factors, but at the same time the evolution and psychological balance of man are closely related to the environment. So there is a mutual relationship between psychological and technical comfort. However, the human psyche also depends on independent factors such as age, sex, etc., which also influence the assessment of the level of technical comfort. Thus, the sensation of pleasure may appear as the optimal result of the parameters of technical and psychological comfort (Fig. 1).

Comfort is the subjective sensation that occurs in the human body based on the complex action of physical and mental parameters. The subjective comfort of people in an enclosed space depends on many factors, which can be grouped, according to G. Blanchere, as follows: temperature, humidity and air circulation; smell and breath, touch and touch, acoustic factors; sight and color effects; vibrations and movements of the building, special factors (solar inputs, ionisation); safety factors; factors related to the daily schedule; unforeseen dangers; economic factors [4].

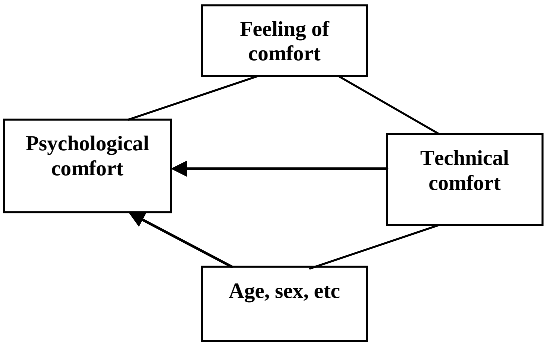

Fig.1. Getting the feeling of comfort [4]

By listing the comfort factors we can see a group related to the thermal environment, called thermal comfort factors. The appearance of the subjective sensation of thermal comfort is decisively determined by the following parameters: indoor air temperature, t_i [°C], average radiation temperature of the delimiting surfaces, θ_{mr} [°C], relative humidity of the indoor air, φ_i [%] and the partial pressure of water vapors in the air, p_s [bar], the speed of the indoor air,v_i, [m/s], the heat production of the human body (labor intensity), i_M [met], the heat released, thermoregulation, thermal resistance of clothing and its influence on evaporation, R_{clo} [clo] [4].

The first four are physical parameters, and the other two are related to the human body's ability to adjust in order to maintain thermal balance. The basic factors that influence the thermal balance of the human body are: the heat produced by the body, which depends primarily on the level of activity, but is also influenced by age, sex, etc. respectively, the heat given off by the body, which depends on the clothing, but also on the other parameters listed above [5], [6].

The sensation of thermal comfort is defined as that conscious state that expresses satisfaction with the thermal environment and whose evaluation is performed using the subjective seven-level comfort scale (relation 1): +3 (very warm); +2 (hot); +1 (slightly warm); 0 (neutral); -1 (coolness); -2 (cold); -3 (cold) [4], [6], [7]:

$$\begin{gathered} B = C + 0{,}25 \cdot (t_i + \theta_{mr}) + 0{,}1 \cdot x - \\ - 0{,}1 \cdot (37{,}8 - t_i) \cdot \sqrt{v_i} \end{gathered}, \qquad (1)$$

where C is a constant that has the value –9.2 in the cold period and –10.6 in the hot period and x is the absolute humidity of the air inside the room, [$g_{apă}/kg_{aer}$] [7].

The average radiation temperature, θ_{mr} represents the weighted average temperature of the delimiting surfaces (horizontal and vertical walls, doors, windows, heating elements) of the studied room. From a mathematical point of view, the average radiation temperature represents a weighted average of the products of the specific surfaces S_j [m^2] and their specific temperatures, θ_j [°C], being in fact a result of the radiation effect on a body inside the room, on hot surfaces (heating bodies) and cold surfaces (relation 2) [8]:

$$\theta_{mr} = \frac{\sum_{j=1}^{n} S_j \cdot \theta_j}{\sum_{j=1}^{n} S_j}. \qquad (2)$$

The average temperature of the interior surfaces of the construction elements (their specific temperatures) is determined by the relation 3 [5]:

$$\theta_j = t_i - R_i \cdot \frac{t_i - t_e}{R'_j}, \qquad (3)$$

where R_i is the thermal resistance at the surface of the construction elements, [m^{2}K/W], t_e is the temperature of the air outside the considered space, [°C] and is the corrected thermal resistance of the construction elements delimiting the examined space, [m^{2}K/W]. The value of the thermal resistance at the surface of the construction elements R_i, is considered 0,125 m^{2}K/W for all categories of vertical construction elements and respective ceilings, 0,172 m^{2}K/W for floors [5], [7].

Highlighting the thermal comfort in an enclosed space (room) involves, in addition to establishing the thermal comfort index, the determination of groups of comfort indexes established in the order of their evolutions, as follows [4]: thermal stress evaluation indexes under extreme environmental conditions, which include the effect of several environmental parameters and the discomfort of ICA airflow.

A. Thermal stress assessment indexes in extreme environmental conditions.

With the help of thermal stress evaluation indexes, the safety limits and the tolerance time for industries where the activity takes place in environments with high temperatures can be established. This category includes: P4SR index (McArdl); ITS thermal stress index; physiological effect index (Robinson); thermal acceptability ratio (lonodes); the WBGT index (Yaglou and Missenard); the nomograms of Vogt and Metz etc.

The thermal stress index is standardized internationally by ISO-7243, coded WBGT (Wet Bulb Globe Temperature - wet bulb temperature of a special construction thermometer) and defined using relation 4 [9]:

$$WBGT = 0{,}7 \cdot t_u + 0{,}2 \cdot t_g + 0{,}1 \cdot t_{as}. \qquad (4)$$

where t_u is the temperature of the wet thermometer, [°C], t_g is the temperature of the black globe, [°C] and t_{as} is the temperature of the air under solar thermal charge, [°C].

B. Indexes that include the effect of several parameters of the environment.

1. **The effective temperature,** established by Yaglou, is defined as the index that includes the effect of the temperature measured with the dry bulb thermometer, humidity and air movement in a single value and which

produces the sensation of heat or cold felt by the human body. For low air currents (vi<0,15 m/s) the effective temperature is calculated with the relation (McIntyre) [6]:

$$t_E = 0{,}492 \cdot t_i + 0{,}19 \cdot p_S + 6{,}47\ , \qquad (5)$$

2. **The resulting temperature,** established by Missenard, represents the temperature of an uniform environment, with calm air in which the air temperature is equal to the average radiation temperature and which produces a sensation equivalent to the existing environment (rel. 6) [7]. The resulting dry temperature is less sensitive to the radiation temperature and does not consider the humidity:

$$t_R = \frac{\theta_{mr} + 3{,}17 \cdot t_i \cdot \sqrt{v_i}}{1 + 3.17 \cdot v_i}\ , \qquad (6)$$

3. **The equivalent temperature** is defined as the air temperature in a room in which v_i=0 and $t_i=\theta_{mr}$ and where a black cylinder 558 mm high and 390 mm wide loses the same quantity of heat as in the surrounding environment. The surface of the cylinder is maintained at a temperature equal to the temperature of the human body by recording and compensating the energy consumed during the heat exchange with the environment [2]. This index of thermal comfort indoors can be determined by the relationship [6]:

$$t_{ech} = 0{,}522 \cdot t_i + 0{,}478 \cdot \theta_{mr} - 0{,}21 \cdot (37{,}8 - t_i) \cdot \sqrt{v_i}\ , \qquad (7)$$

C. ICA airflow discomfort

According to Mayer and Fanger, the discomfort of the air current, ICA, can be determined according to the degree of turbulence of the indoor air, T_u [%], the speed of movement of the indoor air, v_i [m/s] and the temperature of indoor air, t_i [°C], according to relation [4]:

$$ICA = (34 - t_i) \cdot (v_i - 0{,}05)^{0{,}62} \cdot (0{,}37 \cdot T_u \cdot v_i + 3{,}14)[\%] \qquad (8)$$

III. Results

The applicative part of this article consists in determining the thermal comfort indicators for a room located in a residential building, in the middle (a single exterior wall - Fig. 2), based on mathematical calculation models.

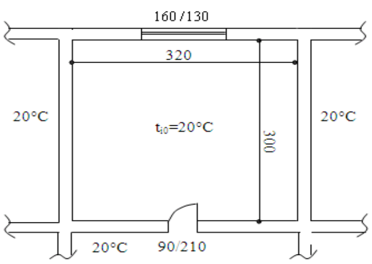

Fig. 2. Constructive Dimensions and parameters measured for the studied room.

The studied room is of the living room type, with a height of 2.5 m, and the air temperature inside the room, to satisfy the conditions of thermal comfort, being t_i=+20°C. The absolute air humidity for this category of rooms is x_i=7 kg_{water}/kg_{air}, the air speed inside the room is 0.15 m/s and the air turbulence coefficient T_u=40% [9]. The room is heated by a radiator type heater with 10 elements KALOR 600/160 series, with a thermal power of 136.7 W/ element, each element having a heating surface of 0 de 0,306 m^2, the heating agent being hot water with a temperature of 65/45°C.

The room is part of a building located inside the Municipality of Craiova, included in the second climatic zone, for which the average external temperature of calculation is considered to be θ_e=-15°C.

The corrected thermal resistances of the perimeter construction elements were established according to the constructive structure of each type of element and the thermal characteristics of the constructive materials, resulting: exterior walls (PE), R_{PE}=0,255 m^2K/W; interior walls (PI), R_{PI}= 0,393 m^2K/W; ceilling (Tv), R_{Tv}=0,433 m^2K/W; terraces over the top floor (Tr), R_{Tr}=0,269 m^2K/W; floor (Pd) R_{Pd}=0,433 m^2K/W; exterior window FE), R_{FE}=0,390 m^2K/W; interior door (UI), R_{UI}= 0,348 m^2K/W [10].

The heat supply regime is intermittent, a regime that implies that both during the night and during the day, the supply of the heating agent will turned off [11]. During the day, we will consider an interruption of the heat supply for 7 hours. During the interruption of the heat supply, the outside air temperature is considered to remain constant (θ_e=-15°C – Table I).

TABLE I.
INDOOR AIR TEMPERATURE VARIATION WHEN INTERRUPTING THERMAL ENERGY SUPPLY [9]

hour	Indoor air temperature, [°C] (Measured values)		
	Ground floor	Intermediate floor	Top floor
0	20	20	20
1	19,796	19,798	19,781
2	19,694	19,698	19,672
3	19,593	19,598	19,563
4	19,492	19,498	19,455
5	19,391	19,398	19,347
6	19,291	19,299	19,239

Based on the mathematical models presented in the second part of the article (rel. 1-8), for the studied room, located at different levels, different values are obtained for the specific temperatures on the inner faces of the perimeter construction elements (table II for the located room on the ground floor, tab. III for the room located on the intermediate floor and tab. IV for the room located on the top floor), and different values of the thermal comfort index.

The hourly variation of the thermal comfort indicators is presented in figures 3 - 5, highlighting the variation curves for the thermal comfort index (Fig. 3), of the effective temperature (Fig. 4) and of the air current discomfort (Fig. 5).

TABLE II VARIATION OF THERMAL COMFORT INDICES INSIDE THE ROOMS LOCATED ON THE GROUND FLOOR, WHEN NO HEAT IS SUPPLIED

Parameter/ symbol/U.M.	Heat supply shutdown time, [h]						
	0	1	2	3	4	5	6
	Variation of indoor air temperature as a function of the heat supply shutdown time , [°C]						
	20	19,796	19,694	19,593	19,492	19,391	19,291
Temperature on the inside of the FE, θ_{FE}, [°C] (rel. 3)	8,78	8,64	8,57	8,51	8,44	8,37	8,30
Temperature on the inside of the PE, θ_{PE}, [°C] (rel.3)	2,82	2,72	2,67	2,62	2,57	2,51	2,46
Temperature on the inner faces of the interior construction elements, [°C] (rel. 3)	20	19,796	19,694	19,593	19,492	19,391	19,291
The temperature on the inside of the floor, θ_{Pd}, [°C] (rel. 3)	17,18	17,05	16,98	16,92	16,85	16,79	16,72
Temperature on the inside of the ceiling,θ_{Tv}, [°C] (rel. 3)	20	19,855	19,782	19,710	19,638	19,567	19,495
Temperature on the heater $\theta_{C,î}$, [°C]	55	19,796	19,694	19,593	19,492	19,391	19,291
Average radiation temperature, θ_{mr}, [°C] (rel. 2)	19,16	16,98	16,89	16,81	16,73	16,65	16,57
Thermal comfort index, B (rel. 1)	0,60	0,00	-0,05	-0,10	-0,15	-0,20	-0,25
The sensation felt	Neutral/slightly warm	neutral	neutral	neutral	neutral	neutral	neutral
Equivalent temperature, t_{ech}, [°C] (rel. 7)	18,15	16,98	16,88	16,78	16,68	16,58	16,48
The resulting temperature, $t_{R,}$ [°C] (rel. 6)	29,62	27,98	27,84	27,70	27,56	27,42	27,28
Effective temperature,, t_E, [°C] (rel. 5)	16,31	16,21	16,16	16,11	16,06	16,01	15,96
The discomfort of the air current, ICA, [%] (rel. 8)	10,62	10,77	10,85	10,93	11,01	11,08	11,16

TABLE III VARIATION OF THERMAL COMFORT INDICES INSIDE THE ROOMS LOCATED ON THE INTERMEDIATE FLOOR, WHEN NO HEAT IS SUPPLIED

Parameter/ symbol/U.M.	Heat supply shutdown time, [h]						
	0	1	2	3	4	5	6
	Variation of indoor air temperature as a function of the heat supply shutdown time , [°C]						
	20	19,798	19,698	19,598	19,498	19,398	19,299
Temperature on the inside of the FE, θ_{FE}, [°C] (rel. 3)	8,78	8,64	8,58	8,51	8,44	8,37	8,31
Temperature on the inside of the PE, θ_{PE}, [°C] (rel. 3)	2,82	2,72	2,67	2,62	2,57	2,52	2,47
Temperature on the inner faces of the interior construction elements, [°C] (rel. 3)	20	19,798	19,698	19,598	19,498	19,398	19,299
The temperature on the inside of the floor, θ_{Pd}, [°C] (rel. 3)	20	19,869	19,804	19,740	19,675	19,610	19,546
Temperature on the inside of the ceiling,θ_{Tv}, [°C] (rel. 3)	20	19,850	19,775	19,701	19,627	19,552	19,478
Temperature on the heater $\theta_{C,î}$, [°C]	55	19,798	19,698	19,598	19,498	19,398	19,299
Average radiation temperature, θ_{mr}, [°C] (rel. 2)	19,99	19,80	19,71	19,61	19,52	19,43	19,34
Thermal comfort index, B (rel. 1)	0,81	0,70	0,65	0,60	0,55	0,49	0,44
The sensation felt	slightly warm	slightly *warm*	*Slightly warm*	*neutral/ slightly warm*	*neutral/ slightly warm*	*neutral*	*neutral*
Equivalent temperature, t_{ech}, [°C] (rel. 7)	18,55	18,34	18,23	18,13	18,02	17,92	17,81
The resulting temperature, $t_{R,}$ [°C] (rel. 6)	30,19	29,89	29,75	29,60	29,45	29,31	29,16
Effective temperature,, t_E, [°C] (rel. 5)	16,31	16,21	16,16	16,11	16,06	16,02	15,97
The discomfort of the air current, ICA, [%](rel. 8)	10,62	10,77	10,85	10,92	11,00	11,08	11,15

TABLE IV VARIATION OF THERMAL COMFORT INDICES INSIDE THE ROOMS LOCATED ON THE TOP FLOOR, WHEN NO HEAT IS SUPPLIED

Parameter/ symbol/U.M.	Heat supply shutdown time, [h]						
	0	1	2	3	4	5	6
	Variation of indoor air temperature as a function of the heat supply shutdown time , [°C]						
	20	19,781	19,672	19,563	19,455	19,347	19,239
Temperature on the inside of the FE, θ_{FE}, [°C] (rel. 3)	8,78	8,63	8,56	8,49	8,41	8,34	8,26
Temperature on the inside of the PE, θ_{PE}, [°C] (rel. 3)	2,82	2,71	2,66	2,60	2,55	2,49	2,44
Temperature on the inner faces of the interior construction elements, [°C] (rel. 3)	20	19,781	19,672	19,563	19,455	19,347	19,239
The temperature on the inside of the floor, θ_{Pd}, [°C] (rel. 3)	20	19,86	19,79	19,72	19,65	19,58	19,51

Parameter/ symbol/U.M.	Heat supply shutdown time, [h]						
	0	1	2	3	4	5	6
	Variation of indoor air temperature as a function of the heat supply shutdown time , [°C]						
	20	19,781	19,672	19,563	19,455	19,347	19,239
Temperature on the inside of the ceiling, θ_{Tv}, [°C] (rel. 3)	9,907	9,751	9,674	9,596	9,519	9,442	9,366
Temperature on the heater $\theta_{C,î}$, [°C]	55	19,781	19,672	19,563	19,455	19,347	19,239
Average radiation temperature, θ_{mr}, [°C] (rel. 2)	17,84	15,65	15,57	15,48	15,39	15,30	15,21
Thermal comfort index, B (rel. 1)	0,27	-0,34	-0,39	-0,45	-0,50	-0,55	-0,61
The sensation felt	neutral	neutral	neutral	neutral	neutral/ cool	neutral/ cool	neutral/cool
Equivalent temperature, t_{ech}, [°C] (rel. 7)	17,52	16,34	16,23	16,13	16,02	15,91	15,80
The resulting temperature, $t_{R,}$ [°C] (rel. 6)	28,74	27,07	26,92	26,77	26,62	26,47	26,32
Effective temperature, t_E, [°C] (rel. 5)	16,31	16,20	16,15	16,10	16,04	15,99	15,94
The discomfort of the air current, ICA, [%](rel. 8)	10,62	10,79	10,87	10,95	11,03	11,12	11,20

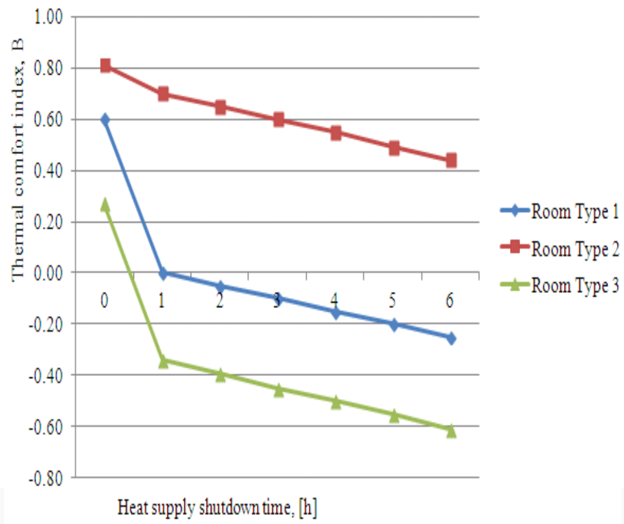

Fig. 3. Hourly variation of the thermal comfort index, B, during the interval of interruption of the heat supply, depending on the type of room, at outside temperature of -15°C: type 1 - room located on the ground floor; type 2 - room located on the intermediate floor; type 3 - room located on the top floor.

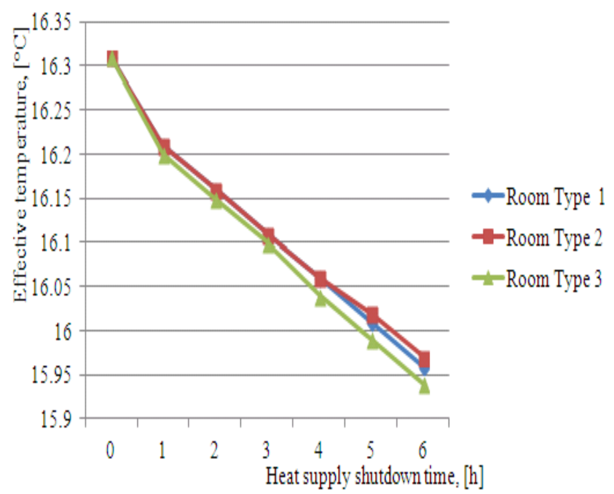

Fig. 4. Hourly variation of the effective temperature, tef, during the interval of interruption of heat supply, depending on the type of room: type 1 - room located on the ground floor; type 2 - room located on the intermediate floor; type 3 - room located on the top floor.

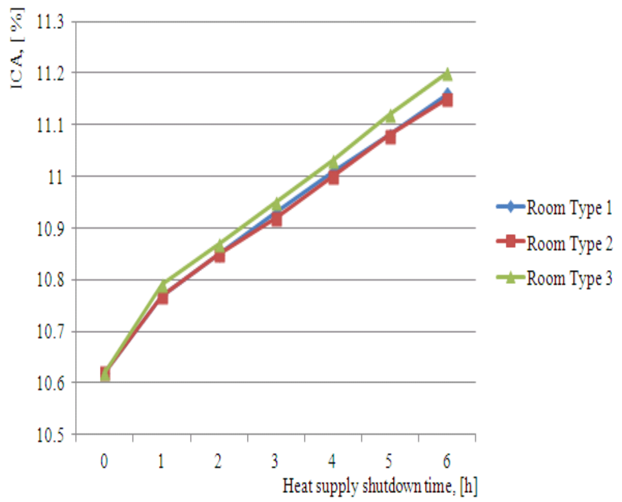

Fig. 5. Hourly variation of the air current discomfort, ICA, during the heat supply interruption interval, depending on the type of room: type 1 - room located on the ground floor; type 2 - room located on the intermediate floor; type 3 - room located on the top floor.

IV. CONCLUSION

The intermittent (discontinuous) operation of heat supply systems has the main advantage of the reduction of thermal energy consumption for heating. It should be noted that, at low outdoor temperatures and for long intervals of interruption of the thermal agent supply, the thermal comfort indicators that define the climate inside an enclosure, can undergo important changes. Thus, situations may arise in which the level of thermal comfort inside the heated rooms no longer satisfies the requirements of the occupants or of a certain number of people.

An important aspect that should be emphasized is that the intermittent operating regime of heating installations is not imposed by the manufacturer / distributor of the heating agent, but by the final consumers, regardless of their nature, in order to reduce maintenance costs as much as possible.

In the case study it is observed that:

1. The thermal comfort index, B, after 6 hours of interruption of the thermal agent supply for heating varies much more emphatic, shifting from a positive value (0.81)

to a negative value (-0.61), which means a transition from an occupant- like sensation of neutral to slightly warm to a sensation of neutral to cool (fig. 3).

2. In the case of type 1 and type 3 rooms, after the first hour of interruption of the thermal agent supply the thermal comfort index, B, worsens sharply, decreasing from 0.60 to 0 in the case of type 1 and type 0 rooms, from 0,27 to -0.34 in the case of type 3 rooms (fig.3).

3. The effective temperature, meaning the temperature felt by the human body and which produces the sensation of cold or heat, varies very little depending on the type of room, and during the interval of 6 hours of interruption of the thermal agent supply, this variation is between 16,31°C and 15,94°C.

4. The actual temperature varies mainly depending on the number of exterior construction elements. It is observed that in the case of the type 3 room, regardless of the value of the outside temperature, the actual temperature has a different variation from the other room types (fig.4), which is explained by the fact that in the case of this type of room the number of exterior construction elements is three, not two, as in the case of type 1 and 2 rooms.

5. Regarding the discomfort of the air current, it has values higher than 5% (fig. 5) which means that, from the point of view of this indicator, the climatic conditions inside the studied room do not satisfy the thermal comfort of the occupants. By analyzing the diagram it is observed that in the case of rooms type 1 and type 2, characterized by the same number of construction elements outside (two elements) discomfort of the air flow is identical for every interruption time of the heat supply (blue curve overlaps the red one) with slight deviations after the 2 hour interval of power supply interruption. In the case of the type 3 room, the variation of the air current discomfort is different in comparison with the first two types of rooms, due to the higher number of external construction elements.

6. In the case of other categories of rooms (bathrooms, kitchens, etc.) the value of the absolute humidity of the air is higher, so that the thermal comfort indices will have different variations compared to the case of the living rooms studied in this paper. Also, major differences in the variation of thermal comfort indexes occur if the construction structure of the exterior and interior construction elements is greatly modified.

Source of research funding in this article: Research program of the Electrical Engineering Department financed by the University of Craiova.

Contribution of authors:
First author – 50%;
First co-author – 20%;
Second co-author – 15%;
Third co-author – 15%

Received on July 07, 2020
Editorial Approval on November 20, 2020

REFERENCES

[1] Cocora, O., *Auditul şi expertiza termică a clădirilor şi instalaţiilor aferente,* Editura MatrixRom, Bucureşti, 2004.

[2] Sârbu, I., Kalmar, F., *Optimizarea energetică a clădirilor*, Editura Matrix Rom, Bucureşti, 2002.

[3] Ilina, M., ş.a., *Enciclopedia tehnică de instalaţii. Manualul de Instalaţii – Încălzire.* Ediţia a II - a, Asociaţia Inginerilor de Instalaţii, Editura ARTECNO, Bucureşti, 2010.

[4] Dinu, R., C., *Instalaţii în construcţii – Note de curs*, www.retele.elth.ucv.ro/Dinu Radu Cristian/Instalaţii în construcţii.

[5] Mircea I., Dinu R.C., *Producerea energiei electrice şi termice, partea a-II-a,* Editura Universitaria, 2006.

[6] Sârbu, I., Kalmár, F., Cincă, M., *Instalaţii termice interioare. Optimizare şi modernizare energetică,* Editura Politehnica, Timişoara, 2007.

[7] Ilina, M., Lungu, C., *100 de probleme practice de instalaţii de încălzire,* Editura MatrixRom, Bucureşti, 2005.

[8] Dinu R. C., Mircea I., Ruieneanu L., Popescu N., "*The Evaluation of Thermal Confort Indices in Households*", Journal of Sustainable Energy, Volume 3, no. 3, 2011

[9] Mircea, P.M., Dinu, R.C., Popescu, N., Buzatu, G., „*Monitoring and analysis of thermal confort parameters in a living room of a building”,* Journal of Sustainable Energy, Volume 5, no. 1, 2014, cotat BDI, ISSN 2067 – 5534.

[10] N.-M., Rădulescu - Brănişteanu, Influenţa funcţionării intermitente a sistemelor de încălzire asupra temperaturii interioare, Craiova: Sesiunea Naţională a Cercurilor Ştiinţifice Studenţeşti, ELSES – 2020, 10.07.2002.

[11] Bánhidi, L., Zöld, A., Kalmár, F., Csoknyai, T., *Influenţa variaţiei dinamice a temperaturii interioare asupra confortului termic,* Conferinţa “Instalaţiile pentru Construcţii şi Confortul Ambiental”, Timişoara, 2000.