Розглянуто існуючі перегородки, які використовуються у офісних приміщеннях та на підприємствах, виконано аналіз використання перегородок задля забезпечення комфортних умов праці, систематизовано та внесені доповнення у систему класифікації. Звернуто увагу на те, що існуючі системи класифікації розглядають перегородки, виходячи із зручності їх використання, матеріалу та дизайну, упускаючи при цьому їх вплив на метеорологічні фактори.

Перегородки виготовляють, як правило, з одного або двох шарів матеріалів, які мають різні властивості та перекривають приміщення або робочий простір на різній відстані від підлоги. В роботі було показано, що невірно розташовані перегородки, виготовлені з дорогих будівельних матеріалів, можуть звести нанівець заплановані задачі щодо покращення умов праці. В приміщеннях з високими стелями з високою вірогідністю створюються умови нераціонального обігріву, як приміщення в цілому, так і конкретних робочих зон. Виконані дослідження довели, що це вирішується шляхом встановлення перегородок, які скеровують та зберігають тепло.

В ході досліджень було встановлено, що на температурні показники у приміщеннях, які перегороджуються, тип матеріалу перегородки суттєво не впливає, а першочергове значення має ступень перекриття приміщення перегородкою по висоті.

У результаті досліджень температур у приміщеннях типу open space, де були застосовані різні варіанти перегородок (скляні труби у металевому каркасі, керамічні плити, пінополістирол), було встановлено, що перегородки можуть суттєво впливати на температурні показники, але тільки за умов повного перекриття приміщення по висоті. Встановлено, що матеріал перегородок не впливає на температурні показники, якщо ступінь перекриття не повний (менш 100 %).

Дослідження довели перспективність наукового обґрунтування застосування перегородок та визначення зв'язку перекриття приміщення із факторами, які впливають на працівників, задля підвищення працездатності

Ключові слова: офіс типу open space, локалізація робочого простору, розподіл температур, будівельні перегородки

UDC 331.45:657.47
DOI: 10.15587/1729-4061.2018.141014

STUDYING THE EFFECT OF MULTIFUNCTIONAL PARTITIONS ON TEMPERATURE INDICATORS AT OFFICES OF THE OPEN SPACE TYPE

V. Berezutskyi
Doctor of Technical Science, Professor,
Head of Department*
E-mail: viaberezuc@gmail.com
N. Berezutska
PhD, Associate Professor
Department of Occupational Safety
Kharkiv National University of
Radio Electronics
Nauky ave., 14, Kharkiv, Ukraine, 61166
E-mail: ecoloji7@ukr.net
O. Ilinska
Assistant*
E-mail: souzbgd@gmail.com
V. Raiko
PhD, Professor*
E-mail: raiko.hpi@gmail.com
*Department of Labor &
Environment Protection
National Technical University
"Kharkiv Polytechnic Institute"
Kyrpychova str., 2, Kharkiv, Ukraine, 61002

1. Introduction

The issue of organizing optimal working conditions with a simultaneous achievement of required indicators of energy saving is one of the most pressing challenges that employers are facing. Man is the main component of any production process and, at the same time, man is a living being spending a part of its life in conditions determined by techno-sphere. Widespread use of office facilities of open space type advances the task of studying this problem and finding ways of its solution. Use of partitions is one of the options of this problem solution. Partitions separate working zones according to their purpose and levels of temperature to be maintained during working hours to meet existing requirements to occupational health management systems at enterprises [1].

Partitions separate working space in a building confined with main walls to smaller working spaces according to their intended purpose (rooms, room sections, etc.). Partitions are not load-bearing construction elements but functional parameters of the building, such as noise and thermal insulation, depend to a large extent on their design. Partitions must be strong and stable and comply with certain sanitary and hygienic requirements.

At present, many establishments use offices of open space type. This relates to the new construction technologies (for example, monolithic construction) when minimum main walls are used and with space planning in new office buildings.

Open offices are used in many areas of human activities ranging from dwelling to large enterprises like IT companies, call centers, shopping and entertainment centers.

© V. Berezutskyi, N. Berezutska, O. Ilinska, V. Raiko, 2018

That is, the open offices are used when it is necessary to separate a certain space in a large work space for efficient and comfortable work of people.

Offices of the open space type represent relatively large- or medium-sized premises in which jobs (workplaces) are separated by partitions [2]. Use of partitions in offices of the open space type is appropriate because in addition to the space separation function, optimal conditions for workers are created [3, 4]. The partitions properly selected according to their design and material help to improve working conditions and, consequently, raise productivity [5] and reduce costs of maintaining the premises.

By their purposes, partitions have a much greater variety than walls [6]. The diverse purpose of partitions extends their types from desktop screens and sliding curtains to building elements that replace inter-room walls. Managers pin their hopes namely on these partitions as building elements most of all. They believe that partitions will help them in solving production problems. Besides, partitions can also facilitate maintaining of thermal comfort.

At present, jobs in offices of open space type and use of a variety of partitions are ever growing [7, 8] but there are no scientifically substantiated approaches to making appropriate decisions on the use *of these building elements*. Similar studies are currently taking place in Poland Central Institute of Labor Protection and State Institute of Construction. A report was made on the study results at the 7th Scientific Conference on Labor Safety – Environment – Contamination, which took place at the School of Occupational Health Management in 2017 [9]. These studies were also discussed at INTER-NOISE and NOISE-CON Congress and published in Conference Proceedings, Inter Noise 17, Hong Kong, China [10].

Analysis of the above-mentioned information sources has shown absence of appropriate classifications and recommendations in this area of labor organization. Therefore, we believe that the study topic is relevant and resonates with the studies conducted in European countries.

2. Literature review and problem statement

Partitions can be classified according to various parameters [7, 11]: functionality, dimensions, methods of construction, types of material, design, etc.

Taking into account the fact that the existing classifications are incomplete, we consider that it would be expedient to supplement the existing classifications with the degree of space separation from the adjacent room with the partition in height, namely:

– partitions ensuring a 100 % separation from the space of the adjacent room;

– partitions ensuring a 75 % to 99 % separation from the space of the adjacent room;

– partitions ensuring a 50 % to 74 % separation from the space of the adjacent room;

– partitions ensuring less than a 50 % separation from the spac e of the adjacent room.

Not only appearance of the room will depend on the choice of design, size and material of the partition but also microclimate, staff efficiency, durability and cost-effectiveness of the office.

Paper [12] presents results of studies in the field of development of low-impact degree (LID) technologies that satisfy human needs. It was shown that the LID technologies enable solution of many human problems including environmental and similar ones. The problems of providing thermal comfort are among such human problems but the existing solutions of this problem are insufficiently effective and difficult to implement. One of the options of this problem solution is the use of partitions. Mere installation of partitions without scientific analysis of their effectiveness and expediency will be a waste of time because they will not justify costs (economic, moral, etc.) in their future use.

A scientific approach to development of the concept of optimal thermal environment and study of human reaction to its change was proposed in [13]. Issues of open thermal environment was considered, a concept of optimal thermal environment for active recreation has been developed, behavioral reactions to thermal environment of people differing by their gender, age, types of activity, etc. have been studied. That is, the researchers proved that the state of thermal environment affects the human body at various stages of its activity but they did not offer ways and a mechanism for implementation of this concept in an open thermal environment and indoors.

A more profound analysis of the studies dedicated to thermal environment has been proposed in [14, 15] where these issues were ascertained using computer models. When modeling, it is very difficult to take into consideration the human factor and its manifestations in habitation rebuilding. It is customary for people to change their living environment at their own discretion and this is usually done by means of installing construction partitions. This was not taken into account in modeling, but the results shown prove the necessity of controlling thermal indicators and taking into account variation of their parameters.

Analysis of the results obtained in studying ergonomic factors in premises and working zones was presented in [16]. The authors included working space of the premises to these factors. According to self-assessment of workers, furniture is the most important ergonomic indicator affecting human health and comfort. However, conditions of human comfort are a complex of conditions to which thermal comfort should be included. The issue of maintaining thermal comfort was considered in [17] where use of personalized heating was studied. A personalized heating system consisting of heated chair, table and floor was tested on 13 volunteers in a climatic chamber at working temperature of 18 °C. Besides, the entire system has been tested with a fixed setting and automatic control of temperature indicators using skin temperature as a control signal. The study has established that the complete system significantly improved thermal comfort and the heated chair turned out to be the most efficient heater. Researchers have pointed out effectiveness of such an approach to a certain category of people but at our discretion, attention should be paid to the fact that people are quite different in terms of health and constitution, so this option of heating and maintaining heat balance should be approached very carefully, with certain restrictions.

A study of planning internal conditions relating to both the content of environment and the process of planning the interior space was presented in [18]. Unlike the previous work, this one has considered issues that include building of rooms and effective spatial sequences, planning of efficient air circulation systems, etc. The above study does not contain scientific justification of choice and application of partitions with taking into consideration influence of the latter on thermal comfort and air circulation. Other studies were carried out in [19, 20], where a general classification was made and influence of partitions on air circulation by means of controlled partitions and walls was elucidated. Importance of conducting studies to find required working space and create ideal workplaces for various tasks was highlighted in [20]. These objectives can only be realized by space limitation with partitions and creating thermal comfort in the workplace.

The above suggests that the study of partitions made of various materials and having various heights for creation of thermal comfort in a working zone in an office of open space type is reasonable and substantiated.

We are sure that this problem cannot be solved without the use of partitions.

Proceeding from the above, creation of thermal comfort indoors is one of the main indicators used by specialists in choosing partitions. Partitions should be environmentally friendly, comfortable and mobile in use. The most popular materials used for manufacture of partitions: polyurethane foam, polystyrene, wood, aerated concrete, glass, expanded clay plates. It is suggested to study partitions made of polystyrene, glass and expanded clay panels in an experiment of creation of thermal comfort in offices of the open space type.

3. The aim and objectives of the study

This study objective was to ascertain dependence of meteorological factors in offices of open space type on the material and height of partitions.

To achieve the goal, the following tasks were set:

– to investigate dependence of temperature in workrooms of open space type on the type of partition material and the degree of room isolation (the working zone);

– to analyze a possibility of reducing room heating without personnel by means of local heating just those rooms or working zones where people are present by means of separation of such zones with partitions;

– to assess influence of partitions on blocking light flows from windows;

– to assess influence of a 100 % separation of rooms in height on room ventilation.

4. Materials and methods used in studying the effect of installed partitions on temperature in the working zones of the room

4. 1. The instruments and equipment used in the study

To measure temperature:

– TTZh-M alcohol thermometer. Measuring range: 0...+140 °C. Division value: 1 °C;

– TN-3 glass mercury thermometer, GOST 400-64. Measuring range: 0...+60 °C. Division value: 0.5 °C;

– TL-16 glass mercury thermometer, GOST 5.2157-74. Measuring range: 0...+40 °C. Division value: 0.5 °C.

Air velocity (outdoors) was measured by means of MS-13 cup anemometer, GOST 6376-74. Measuring range: 1 to 20 m/s.

Atmospheric pressure was measured by means of M67 aneroid barometer (Gidrometpribor Plant JSC, Safonov, Russia). Measurement error: ±0.8 mm mercury.

Humidity measurements. Indoors: by means of VIT-1 hygrometer of psychrometric type, TU 314307481.001-92 (Ukraine). Relative humidity measurement range: 20 to 90 %. Temperature range of humidity measurement: 5 to 25 °C. Temperature measurement range: 0 to 25 °C. Devices of domestic production were used in the studies.

4. 2. Procedure of measurement of microclimate parameters

Air temperature was measured by means of mercury and alcohol thermometers at several points of the room and then average temperature was calculated.

Outdoor air velocity was measured with a cup anemometer. Initial readings of the instrument were taken in all scales and then the anemometer was placed in an air flow at a distance of 1.5 m from the ground and switched on simultaneously with the stopwatch. After 60 seconds, it was switched off and readings were taken from the anemometer scales. Measurement was repeated 3 times and a mean value was determined.

Atmospheric pressure was measured by an aneroid barometer throughout the room.

Relative humidity was measured by August's psychrometer. Wet and dry thermometer readings were taken and relative air humidity was determined by means of the nomogram for readings of static August's psychrometer.

Classic procedure of measuring microclimate parameters was used in the studies. Fig. 1 shows a layout of rooms and measurement points (1–10) in the premises and wind direction (W).

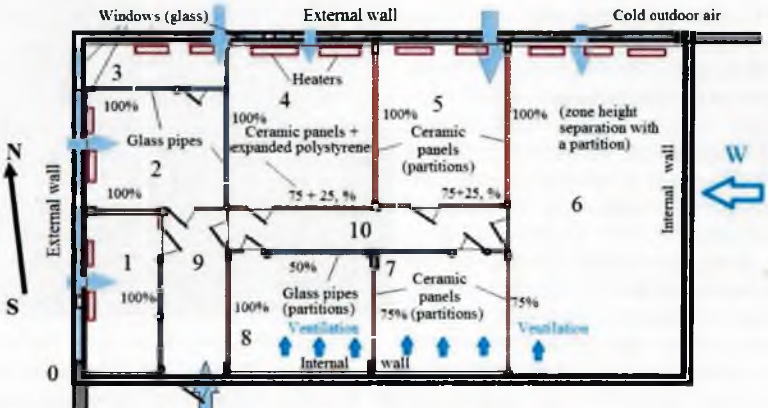

Fig. 1. Layout of measurement points (0–10) in the building (0 is for outdoors)

Description of measurement points:

Point 1. The room (zone) had a building wall on one side (90 % window glass), partitions of glass pipes (100 % separation in height) on both sides and a main building wall on one side.

Point 2. The room (zone) had a building wall on one side (90 % window glass), partitions of glass pipes on three sides (100 % separation in height).

Point 3. The room (zone) had building walls (90 % window glass) on two sides and partitions of glass pipes (100 % separation in height) on two sides.

Point 4. The room (zone) had a building wall on one side (90 % window glass), a partition of glass pipes (100 % separation in height) on the second side, a partition of ceramic panels (75+25 % separation in height) on the third side and a partition of ceramic panels (100 % separation in height) on the fourth side.

Point 5. The room (zone) had a building wall (90 % window glass) on one side, a partition of ceramic panels (75+25 % separation in height) on the second side and partitions of ceramic panels (100 % separation in height) on two sides.

Point 6. The room (zone) had a building wall (90 % window glass) on one side, a partition of ceramic panels (100 % separation in height) on the second side and extension of this partition of ceramic panels (5 % separation in height) at a certain distance and capital building walls at the third and fourth sides.

Point 7. The room (zone) had a main wall of the building on one side, a partition of ceramic panels (75 % separation in height) on the second side and partitions of glass pipes (75 % separation in height) on the third and the fourth sides.

Point 8. The room (zone) had a main wall of the building on one side, a partition of ceramic panels (100 % separation in height) on the second side and partitions of glass pipes (50 % and 75 % separation in height) on the third and the fourth sides.

Point 9. The entrance to the building (zone) had a main wall of the building (with an entrance door) on one side, a partition of ceramic panels (100 % separation in height) on the other side and partitions of glass pipes (100 % separation in height) on the third and the fourth sides.

Point 10. The passage (zone) had a partition of ceramic panels (100 % separation in height) on one side, a partition of ceramic panels (100 % separation in height) on the second side and partitions of glass pipes (50 % and 75 % separation in height) on the third and the fourth sides.

In the course of the experiment, it was necessary to ascertain influence of partitions of various heights on temperature indicators of various zones of the premises.

Temperature gradient was determined to establish effect of thermal conductivity of partitions on temperature indicators in the premises. It was determined as the difference between average temperature on one side of partition and average temperature on the other side measured at five points (along perimeter of the premises (zone) at a distance of 1 m from walls and partitions (4 points) and in th (one point of measurement) at a height of 1 m from surface.

The study area had total area of 200.18 m^2 be stallation of partitions. The height of walls was 3. accordance with the tasks put forward by manage necessary to maintain working process and workp the highly skilled staff and service personnel in th In addition, it was necessary to place scientific a nical literature, laboratory and office equipment age. Managers of the subdivision to which this b was allocated had a limited choice of partition m and terms of partition installation. By that time, ing to sanitary norms, working area for one wo was 4.5 m^2 and no computers were available. The side illumination and north-western and northern orientation. The area of windows was almost equa area of side walls. Distance between windows wa Air conditioner was installed in only one very sma (Fig. 1, point 3). In the course of experiments, the tioner was not switched on. At present, the artifi conditioning system is not working in the buil ventilation is organized by manual opening of trans the top of windows. There was a parquet floor, walls ed with a water-based light-green paint. Internal the building separated one office of open space ty another. They did not affect the study in any w area of windows occupied 90 percent of the north- and northern walls. The southern and east-southe had no windows.

Fig. 2 shows photographs of rooms with the pa under study.

Fig. 2. Photographs of the rooms in the office of open spa partitions: 100 % separation (ceramic panels and expanded p 75 % separation (ceramic panels) (*b*); 50 % separation (gl rubber gaskets) (*c*); 100 % separation (glass pipes with rubb

Fig. 3 shows materials of the partitions under study and their thickness.

a b c

Fig. 3. Materials from which the studied partitions were made: a 15 mm thick ceramic panel (*a*); a 5 mm WT glass pipe (*b*); 97 mm thick block of expanded polystyrene (*c*)

The materials were chosen based on recommendations of specialists and according to the table of thermal conductivity of building materials which is given in [21]. Partitions of ceramic panels were two-layered and mounted in a metal frame. Partitions of expanded polystyrene were single-layered and modeled depending on the tasks, separation in height (75 %+25 %). Partitions of glass pipes were mounted in a metal frame with rubber gaskets between them.

5. Results obtained in studying the temperature in offices of open space type

5. 1. Definition of partition

There is a formula for calculating energy costs on heating the premises, Qt (kW/h) [22]:

$$Qt=(100\times S\times K1\times K2\times K3\times K4\times K5\times K6\times K7)/1000, \quad (1)$$

where S is the floor area of the premises, m^2; K1 is the coefficient of heat loss through windows with values of 0.85, 1, 1.27 varied depending on quality of the windows used and their insulation; K2 is the amount of heat loss through walls. Depending on the wall insulation (1.27 for poor insulation, 1 for average insulation (with the use of special warmth-keeping materials), 0.854 for a high level of thermal insulation); K3 is the indicator determining the window to floor area ratio: K3=1.2 at the ratio of 50 %; K3=1.1 at the ratio of 40 %; K3=1.0 at the ratio of 30 %, K3=0.9 at the ratio of 20 %, K3=0.8 at the ratio of 10 %; K4 is the coefficient depending on the outdoor temperature: when t_{out}=35 °C, K4 is taken 1.5; when t_{out}=25 °C, K4 is taken 1.3; when t_{out}=20 °C, K4 is taken 1.1; when t_{out}=15 °C, K4 is taken 0.9; when t_{out}=10 °C, K4 is taken 0.7; K5 is the coefficient which reflects the number of exterior walls (1.4 for 4 walls; 1.3 for 3 walls; 1.2 for 2 walls; 1.1 for 1 wall); K6 is the coefficient depending on the type of thermal insulation of the premises under study. If the room is heated, K6=0.8, if there is warm garret, then K6=0.9, if the room is not heated, K6=1; K7 is the coefficient depending on the room height (H). If H=4.5 m, K7=1.2; if H=4 m, K7=1.15; if H=3.5 m, K7=1.1; if H=3 m, K7=1.05; if H=2.5 m, K7=1.

It can be concluded from an analysis of formula (1) that this formula should be written for partitions with only two indicators having a significant effect on the heating costs of the premises, namely S and K7 because there are no windows (as a rule) in partitions, there is no significant temperature gradients including minus temperatures. The cost of heating an office of open space type with floor area of 200 m^2 and height of 4.0 m will be cut almost in 30 times at all other indicators being similar at a localized working area of 6 m^2 per person. This also applies to the use of air conditioners whose power is calculated according to the room floor area and volume. It is clear that there will be different values in each case but undoubtedly the heating costs will be reduced.

Due to partitions, it is possible to change space in rooms and create comfortable working conditions that determine work quality and people's health. But this raises a question: what is a partition? A movable shield, stand or guide frame in subway are essentially partitions as well. Therefore, it is suggested that only building structures (screens, panels, etc.) that begin from the floor surface and cover not less than 50 % of the room height can be named partitions that localize working zones in premises. Partitions should not have permanent openings, except doors.

5. 2. The study of temperature indicators in the absence of heating during the cold period of the year (experiment 1)

Indicators of meteorological conditions indoors *in absence of heating* largely depend on natural meteorological parameters in the area where the study was being conducted, namely at the time of this study (8 November, 2017, city of Kharkiv). In parallel with the microclimate study inside the building, meteorological parameters were measured outside the building (point 0, Fig. 1). The measurement results were as follows:

– temperature: 11 °C;
– speed of air near the building: 2 m/s;
– wind direction: eastern.

Windows in the rooms under study were oriented to northwest. Atmospheric pressure: 993, air humidity: 65 %.

The building was constructed in the 1980s. According to the project, temperature parameters should have been regulated by general air conditioning for entire building. However, a year later, the air conditioner was disconnected and then dismantled. Holes have been made for ventilation in all rooms. The area of windows reaches almost 80–90 % the total wall surface area of the building. All distances between windows were actually concrete columns covered with plastic. Multiple slots and a large area of window glass led to a significant dependence of inside temperature changes on the state of temperature and direction of air outside the building. Therefore, there is heat and stuffiness in the summer and cold in the winter in correspondence with temperature outside the building.

Measurements were made in real time. Regarding the weather service information, they vary significantly over the city and in time. The meteorological service divides temperature data for night and day. The measurements in this study were made at noon.

As a result of the studies, temperature indicators were obtained which were further processed using the Microsoft Excel software (Fig. 4). Fig. 1 shows directions of cold air entering the rooms.

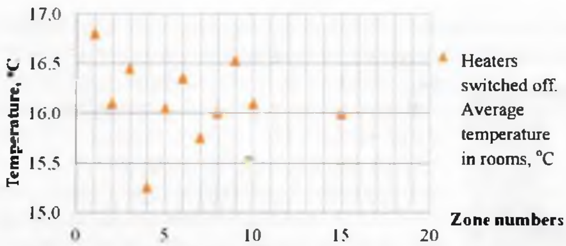

Fig. 4. Results of the temperatures study in the working zones of non-heated rooms

Average temperature throughout the premises was 15.99 °C. The level of temperature deviation from the average value in the rooms under study formed by the partitions is shown in the diagram of Fig. 5.

It should be noted that the temperature gradients relative to the average value varied significantly in the working zones of these premises.

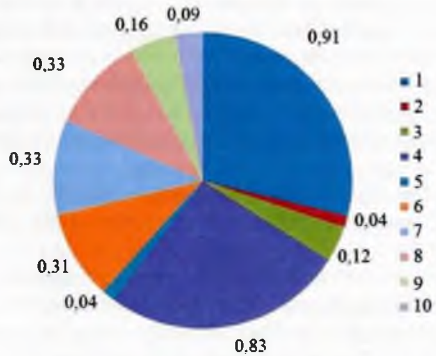

Fig. 5. Deviation of temperatures (°C) from average temperature in premises (zones) under study in the absence of heating

Based on the results obtained, we can draw a preliminary conclusion that the highest temperature was in the working zone 1 and the lowest temperature was in the working zone 4. Temperature gradients between maximum and minimum values were about 2.5 °C.

When analyzing the installed partitions and sizes of the zones formed by them, it follows that:

– zone 1 had the smallest area of all zones (8 m^2), partitions were made of ceramic panels (2 layers) and, in accordance with the above *size* classification, partitions separate the zone by 100 % from another room space;

– zone 4 area was similar to the area of rooms 5 and 6, partitions of zone 4 were installed on two sides and separated the space by 100 % in height and side by 75 % of height on the third side. Material of partitions was the same as in zone 1 (ceramic panels) and the open part of the partition (25 % of height) reached zones 9 and 10. These zones had partitions that separated 50 % from the other room space and there was a constant movement of personnel in these zones.

Zones 7 and 8 were separated from each other and from zones 10 and 6 by a partition of 50 % the room height (partition material: 2 layers of ceramic panels) and from zone 10 by a partition made from glass pipes by 50 % the room height.

Partitions separating 50 % the room height were used to improve ventilation because there are no windows in zones 8 and 7.

5. 3. Study of temperature parameters of the room heated in a cold season (experiment 2)

Indicators of meteorological conditions inside the building, *when premises are heated* depend on temperature of heat carriers and natural meteorological parameters in the area where the study was conducted, precisely at the time of the experiment (6 December, 2017, city of Kharkiv). Meteorological parameters were measured outside the building (point 0, Fig. 1). Experiment results are as follows: temperature: 0 °C; speed of air near the building: 4.6 m/s; wind direction: eastward.

Windows in the studied premises were oriented to northwest. Atmospheric pressure: 869 hPa, air humidity: 72 %. Temperature of the heater surface: 30 °C.

Fig. 1 shows locations of rooms and measurement points (Nos. 1–10) in the building and wind direction (*W*).

As a result of experiment 2, data were obtained on temperature distribution in heated rooms. These data were processed using Microsoft Excel software (Fig. 6).

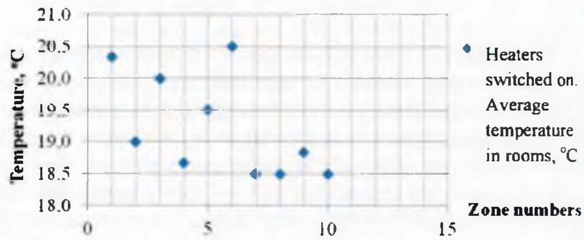

Fig. 6. Results of temperature study in the working areas of heated rooms

Average temperature throughout the heated premises: 19.23 °C.

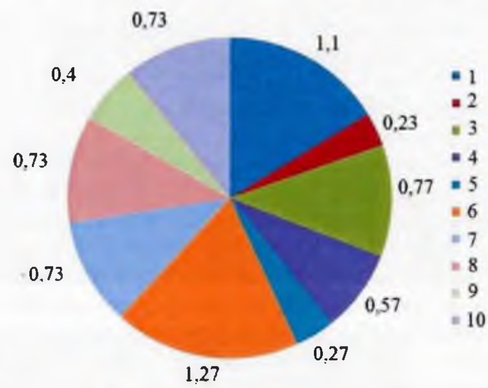

Fig. 7. Deviation of temperatures (°C) in the premises under study with general heating

Based on the results obtained and shown in Fig. 6, 7, it is possible to draw a preliminary conclusion: the highest temperature was in the working zones 1 and 6 and the lowest temperature was in the working zones 7, 8 and 10.

From an analysis of the installed partitions and sizes of these zones, it turns out that:

– Zone 6 had the largest area of all zones, 62.35 m^2. Partitions were made of ceramic panels (two layers) and, according to the above classification *by sizes*, partitions separated the zone by 100 % from another space of the room from three sides. Heaters were installed along windows (parameters of the working zone 1 are given above).

– Zones 7 and 8 were mentioned above for the case of absence of heating as zones with lower temperature. Zone 10 was added to them. These zones had partitions that separated them up to 50 % in height from another room spaces and there was a constant movement of personnel around these zones.

Concerning zones 3 and 5, it can be noted that in absence of heating, temperature distribution was more pronounced than in the case of heating, a certain role was played by the installed partitions. Difference between maximum and minimum temperatures was 2.0 °C when there was total heating.

It is necessary to pay attention to zones 2 and 4 which had indicators below average in presence of heating.

Experiment 3 was carried out additionally with a local heater added. Temperature on one side of partitions of different heights was raised (simulating local heating of the workplace). Data were obtained on temperature difference at opposite sides of partitions when local heating was used.

Fig. 8 shows dependence of the temperature gradient at workplaces separated by partitions of different heights in experiments 1, 2 and 3.

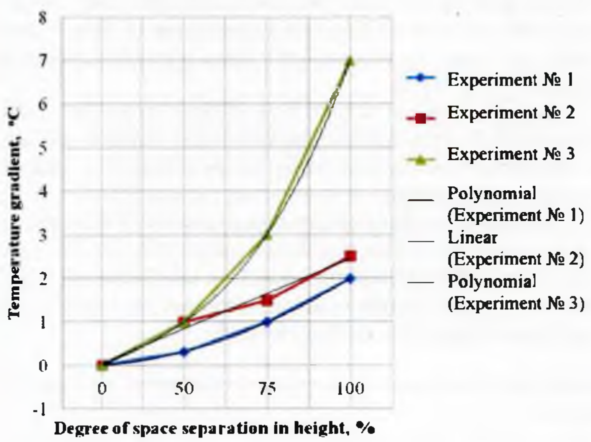

Fig. 8. Dependence of temperature gradient in rooms with partitions in three experiments

The results of these experiments were processed in Word Excel software by statistical methods. The resulting mathematical dependences correspond to trend lines (Fig. 8).

Experiment 1 is described by polynomial mathematical dependence with probability R^2=0.9998:

$$y=0.175x^2-0.205x+0.025. \quad (2)$$

Experiment 2 is described by a linear mathematical dependence with probability R^2=0.9486:

$$y=0.8x-0.75. \quad (3)$$

Experiment 3 is described by a polynomial mathematical dependence with probability R^2=1.

$$y=0.1667x^3-0.5x^2+1.333x-1. \quad (4)$$

As can be seen from Fig. 8, the greater the degree of separation by partitions, the greater difference between temperatures as a result of more effective use of local creation of optimal microclimate conditions. Experiments 1 and 2 are described by formulas (2), (3) which correspond to mathematical equations of the second and first order with a sufficiently high probability. Such results characterize uniform temperature distribution in a room with slight temperature fluctuations in individual zones. Formula (4) obtained as a result of experiment 3 with local artificial heating of a separate zone has a completely different character which differs by an order from the previous two experiments and has a mathematical equation of the third order. Such mathematical dependence characterizes rapid temperature rise and can be used in future for automatic control of thermal comfort by means of a processor or computer in accordance with requirements of working conditions specified by labor hygiene standards. Thus, with the help of programmable heat devices, one can create a system that will maintain necessary levels of thermal comfort in the workplace. Disadvantages of such heating include a very rapid temperature drop with switched off the heating sources. The rate of temperature drop depends on temperature difference between the two sides of partition. At a difference of up to 10 °C, temperature drop is 0.7–1.0 °C (depending on the partition material) in 300 seconds (in the cold period of the year).

6. Discussion of results obtained in the study of temperature distribution in premises of the open space type

Partitions

It can be seen from the study results that when the degree of room space separation is not high (≤50 %) temperature difference is also present, so local heating would also be effective, albeit not as much as with a greater degree of room space separation with partitions.

It is advisable to separate zones in large rooms in which people work and, consequently, create microclimate parameters in these zones in accordance with sanitary and hygienic requirements. When there are no workplaces, requirements imposed by technical regulations for equipment operation should be met.

It is also advisable to organize local cooling, heating and ventilation of workplaces taking into account optimal consumption of energy carriers. For this purpose, special partitions can be used which have built-in equipment of certain types but the cost of such partitions increases.

It is recommended to use partitions in a general working space proceeding from creation of an optimal psychological microclimate and increase in labour productivity.

Ventilation

Ventilation should be provided in any room where people work. Types of ventilation are selected depending on requirements for the work process. When partitions are used that limit air flow and, accordingly, limit operation of the ventilation system, it is imperative to take into account this impact on the overall microclimate and air exchange rates in the separated zones. Therefore, the ventilation system in separated zones must necessarily have sanitary and hygienic parameters according to normative documents.

If this cannot be achieved, then such separated zones should be provided with a ventilation system or an air-conditioning system (for example, a split system). In the rooms separated to a certain degree, it is necessary to take into account formation of stagnant zones which is very dangerous if there is a probability of occurrence of gases heavier than oxygen and nitrogen (combustion products, methane, etc.).

The performed studies have shown importance of choosing partitions based on the degree of room space separation and location with an account of windows and ventilation systems. It has been studied and shown how it is possible to change temperature conditions in office rooms by locating certain zones where people work with maintaining regulatory requirements to working conditions. The use of partitions has enabled maintaining of stable temperature indicators in a certain zone while temperature was significantly lower in other part of the room compared to normative temperature. This became achievable due to combination of total heating of the premises (which was inadequate) and an additional use of heating panels. Use of heating panels in the entire open space of the office is impossible because their total capacity is such that the electric network cannot stand and they shut down. At the same time, heating of local zones separated by partitions is possible and effective.

The study shortcomings include the fact that it was necessary to switch off all heaters and monitor observance of indoor conditions necessary for the study. It was necessary that the rooms were exposed to surrounding conditions (for 3–4 hours) to establish a temperature equilibrium throughout the office. At the same time, workers continued to work in unacceptable temperature conditions.

The study results can be used in premises of open space type. A possibility was considered as for creation of new types of partitions that will not only store and maintain temperature parameters but also perform other functions, for example, clean air from impurities, saturate with negative ions, and so on.

The study may be continued to explore other properties of partitions, such as absorbing and reducing noise in offices of open space type. The potential line of this study will be related to noise-absorbing properties of various materials from which the partitions are made, their shape, frequency characteristics, sound levels and others.

7. Conclusions

1. It was established that temperature indicators in workrooms of open space type depend on the type of partitions and the extent of their separation of rooms (working zones). Therefore, it is necessary to make a reasonable selection of partitions depending on labor categories and functional purpose. If there are temperature deviations in a room exceeding 2–3 °C from the permissible temperature established by hygienic standards, it is necessary to install partitions in order to bring temperature to a standardized value. The best thermal effect is obtained at a 100 % separation of one working zone from another by means of partition installation.

2. In order to efficiently and rationally use energy carriers, heating of premises without staff can be reduced while locally heating just those rooms where people work or heating individual workplaces with separation of these zones with partitions. In this case, the room separation in height should be 75–100 %.

3. It is advisable to take into account separation of the window light openings with partitions and therefore window separation should be realized by means of partitions made of transparent material.

4. When partitions separate rooms by 100 % in height, it is necessary to provide ventilation openings or install an air conditioner (the split system) based on calculations of premises ventilation in order to obtain meteorological parameters corresponding to the work performed.

References

1. Berezutskyi V. V., Khalil V. V. Yevrointehratsiya ta keruvannia bezpekoiu pratsi na pidpryiemstvi u suchasnykh umovakh // Bezpeka zhyttia i diialnosti liudyny – osvita, nauka, praktyka: zb. nauk. prats XIV Mizhnar. nauk.-prakt. konf. Kyiv: NAU, 2016. P. 28–32.
2. Marans R. W., Spreckelmeyer K. F. Evaluating Open and Conventional Office Design // Environment and Behavior. 1982. Vol. 14, Issue 3. P. 333–351. doi: https://doi.org/10.1177/0013916582143005
3. Effects of acoustic environment on work in private office rooms and open-plan offices – longitudinal study during relocation / Kaarlela-Tuomaala A., Helenius R., Keskinen E., Hongisto V. // Ergonomics. 2009. Vol. 52, Issue 11. P. 1423–1444. doi: https://doi.org/10.1080/00140130903154579
4. Privacy and Communication in an Open-Plan Office / Sundstrom E., Herbert R. K., Brown D. W. // Environment and Behavior. 1982. Vol. 14, Issue 3. P. 379–392. doi: https://doi.org/10.1177/0013916582143007
5. Danielsson C. B., Bodin L. Office Type in Relation to Health, Well-Being, and Job Satisfaction Among Employees // Environment and Behavior. 2008. Vol. 40, Issue 5. P. 636–668. doi: https://doi.org/10.1177/0013916507307459
6. Karvatska Zh. K., Karvatskyi D. V. Budivelni konstruktsiyi. vyd. 2-e, pererobl. i dopov. Chernivtsi, 2008. 516 p.
7. Cherniavskyi V. H. Osnovni pryntsypy hnuchkoi planuvalnoi orhanizatsiyi hromadskykh budivel sotsialnoi sfery // Suchasni problemy arkhitektury ta mistobuduvannia. 2011. Issue 28. P. 387–394.
8. Vartapetova A. E. Principy organizacii sovremennogo ofisnogo prostranstva // ACADEMIA. Arhitektura i stroitel'stvo. 2010. Issue 2. P. 38–42.
9. Otchet 7-y nauchnoy konferencii «Bezopasnost' truda-okruzhayushchaya sreda-menedzhment». URL: https://www.wszop.edu.pl/aktualnosci/wydarzenia/vii-konferencja-naukowa-bezpieczenstwo-pracy-srodowisko-zarzadzanie-juz-za-nami,1,1,6085
10. Mikulski W. Open space rooms – using a computational program to determine necessary elements of the acoustic treatment // INTER-NOISE and NOISE-CON Congress and Conference Proceedings. Institute of Noise Control Engineering. 2017. Vol. 255, Is-

sue 5. P. 2788–2795. URL: https://www.ingentaconnect.com/contentone/ince/incecp/2017/00000255/00000005/art00096#expand/collapse

11. Zakharchenko P. V., Havrysh O. M., Kaluhina O. M. Doslidzhennia rynku konstruktsiynykh materialiv dlia ulashtuvannia mizhkimnatnykh perehorodok // Stroitel'nye materialy i izdeliya. 2011. Issue 1. P. 21–26.
12. Mazzotta M., Besedin E., Speers A. A Meta-Analysis of Hedonic Studies to Assess the Property Value Effects of Low Impact Development // Resources. 2014. Vol. 3, Issue 1. P. 31–61. doi: https://doi.org/10.3390/resources3010031
13. Outdoor thermal environments and activities in open space: An experiment study in humid subtropical climates / Huang J., Zhou C., Zhuo Y., Xu L., Jiang Y. // Building and Environment. 2016. Vol. 103. P. 238–249. doi: https://doi.org/10.1016/j.buildenv.2016.03.029
14. Adekunle T. O., Nikolopoulou M. Thermal comfort, summertime temperatures and overheating in prefabricated timber housing // Building and Environment. 2016.Vol. 103. P. 21–35. doi: https://doi.org/10.1016/j.buildenv.2016.04.001
15. Gorni D., Castilla M. del M., Visioli A. An efficient modelling for temperature control of residential buildings // Building and Environment. 2016. Vol. 103. P. 86–98. doi: https://doi.org/10.1016/j.buildenv.2016.03.016
16. Desk ownership in the workplace: The effect of non-territorial working on employee workplace satisfaction, perceived productivity and health / Kim J., Candido C., Thomas L., de Dear R. // Building and Environment. 2016. Vol. 103. P. 203–214. doi: https://doi.org/10.1016/j.buildenv.2016.04.015
17. Personalized heating – Comparison of heaters and control modes / Vesely M., Molenaar P., Vos M., Li R., Zeiler W. // Building and Environment. 2017. Vol. 112. P. 223–232. doi: https://doi.org/10.1016/j.buildenv.2016.11.036
18. Rengel R. J. The Interior Plan: Concepts and Exercises. New York: Fairchild Books, 2012.
19. Guthrie J. Architect's Portable Handbook. New York: McGraw-Hill Professional Publishing, 2010.
20. How to Create a Multifunctional Space with AEG Partition Systems // AEG TEACHWALL. URL: http://www.aegpartitions.com/create-multifunctional-space-aeg-partition-systems/
21. Tablytsia teploprovidnosti budivelnykh materialiv: koefitsienty. URL: http://horodom.pp.ua/474-tablicja-teploprovidnosti-budivelnih-aterialiv.html
22. Rozrakhunok teplovoi enerhiyi na opalennia prymishchen. URL: http://dovidkam.com/remont/opalennja/rozraxunok-teplovo%D1%97-energi%D1%97-na-opalennya-primishhen.html