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Thermal environment in public libraries

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Abstract

In this paper the thermal environment of public libraries was investigated.

First, both the book preservation criterion and human thermal comfort criterion were explored. Secondly, the thermal environmental quality of campus library of South-Eastern Finland University of Applied Sciences in terms of both book preservation and human thermal comfort was investigated. For this purpose, the building was divided into representative zones, in which specific measurements took place. Thirdly, annual simulation of thermal environment parameters alteration was conducted by IDA ICE software. Fourthly, survey among visitors and librarians was made to gather their indoor environment perception.

Then the results were analyzed together. An inference about each zone condition was done. In the end, the whole library thermal environmental quality condition was analyzed and thermal Category for each representative zone was identified.

The study showed that books in the campus library are preserved, and thermal comfort of visitors and librarians mainly meet requirements of Category A(I) of EN 15251. Also, complaints from librarians were gathered and the origin of those were explained.

Finally, possible improvements for a campus library building were suggested.

Keywords

Library, thermal environment, thermal comfort, preservation

CONTENTS

NOMENCLATURE

RH	Relative humidity (°C)
PI	Preservation index
EMC	Equilibrium moisture content
MRF	Mold risk factor
ε_g	Emissivity of black globe
T_a	Mean air temperature (K)
t_a	Mean air temperature (°C)
T_g	Black globe temperature (K)
T_r	Mean radiant temperature (K)
h_{cg}	Coefficient of heat transfer by convection (W/m^{2}K)
v_a	Mean air velocity (m/s)
D	Diameter of the black globe (m)
σ	Stefan-Boltzmann constant
SD	Standard deviation of the velocity (m/s)
n	Measurement step
v_{ai}	Instantaneous air velocity (m/s)
t_o	Operative temperature
A	Coefficient (v_a)
t_r	Mean radiant temperature(°C)
PMV	Predicted mean vote
PPD	Predicted percentage dissatisfied (%)
DR	Draft rate(%)
$t_{a,l}$	Local air temperature (°C)
T_u	Local turbulence intensity
$v_{a,l}$	Local mean air velocity (m/s)
PD	Percentage of dissatisfied(%)
$\Delta t_{a,v}$	Difference in the air temperature between head and ankles(°C)
t_f	Floor temperature(°C)
Δt_{pr}	Radiant temperature asymmetry(°C)

1 INTRODUCTION

The problem of conservation of knowledge have been existing through the whole human history and it is still a crucial issue nowadays. The knowledge of mankind is saved in different sources. The gigantic part of them consists of paper resources such as books, newspapers, magazines, booklets and i.e. Who haven't ever read a paper book or turned over a few pages of a newspaper? This rhetorical question leads us to the idea, that the preservation of printed and written information sources must be thoroughly concerned by everyone who takes care of the future of the humanity. From the other hand, books are written not only for being stacked at shelves, but to be read by people. Public library purpose consists of both collection preservation and providing space for visitors to read books indoors. It leads to the fact, that the public library indoor environmental quality (IEQ) must be thoroughly determined.

In libraries it is necessary to maintain both comfortable indoor climate for visitors, librarians and for library collection. The collection itself mostly consists of hydroscopic materials, vulnerable for thermal environment fluctuation. Paper condition of the library savings is exposed to moisture content in the air, and therefore relative humidity changes in a preservation area. Paper related matter is able to adsorb moisture then the relative humidity increases and release extra moisture if it decreases. In the same time there is still is vital issue regarding visitors and library stuff perception of the indoor condition. The summation of these two criteria (collection preservation and attendants' comfort) must be taken into account during the process of maintaining of public library microclimate conditions.

One of the aims of this paper is to determine the overlapping criterion for both book collection preservation and human thermal comfort. This is done by comparison of existing legislation related to thermal environment and recommendations related to book collection preservation conditions. Other two aims are related to real case investigation. The second aim is to explore if the thermal environment of the existing library building is acceptable for visitors and

staff. The third aim is to discover simultaneously if the book collection of this building is safe in long term perspective.

The distinction of this papers from other works on this topic consists of the following point. Firstly, the real case is investigated. Theoretical approach and calculation of indices, recommended by the legislation and standards are implemented in an existing library building. Secondly, survey investigation is gathered from real people to get the actual opinion of those about indoor thermal quality, not only calculated predictable percent of dissatisfied. Thirdly, annual simulation of thermal environment indices represents multifaceted analysis of those parameters.

At first, theoretical introduction in book behavior in different conditions will be introduced. Then it will be explained about human thermal comfort in general and in the library circumstances. Then measurements of the thermal environmental quality will be conducted in a real case. Having done that, annual thermal simulation of that building by IDA ICE software will be performed. At the same time, occupants and stuff surveying will be carried out in order to find their perception of the library thermal environment conditions. Finally, thermal environment will be classified in accordance with European legislation and book collection safety in long term perspective will be analysed.

2 LITERATURE REVIEW

As it was proved in the introduction, sustaining of a library indoor environmental conditions is a complicated issue requiring both maintaining desirable thermal climate for visitors, staff and conserving of a library collection. First, requirements for book preservation and the factors influencing paper materials will be analysed. Next, human satisfaction criterion with the thermal environmental quality will be considered.

2.1 Library collection preservation criterion

First, temperature and moisture criterion are considered. As it was mentioned above, average library collection consists primarily of paper materials: books, newspapers, magazines and i.e. The principal component of paper is cellulose. Cellulose fibres are hydroscopic in the environment. Being hydroscopic, paper is able to absorb moisture from damp atmosphere and release water in a dry atmosphere. Subjected in a particular environment for a long-term period, paper comes to equilibrium moisture content (EMC) with it. /1,1-12./

There are two basic physical values, expressing the moisture content of the air: absolute humidity and relative humidity. Absolute humidity is the concentration of water vapour in air whereas relative humidity represents moisture content of the air expressed as a percentage of the maximum amount of water the air can hold at this temperature. What value to use regarding moisture behaviour of paper? Heated air doesn't change its absolute humidity, but relative humidity decreases because the maximum amount of water the air can hold increases with temperature growth. Therefore, relative humidity together with temperature is the primary atmospheric factor that affects paper moisture content whereas absolute humidity value doesn't always show the difference. Figure 1 illustrates the effect of paper moisture content change as the relative humidity changes.

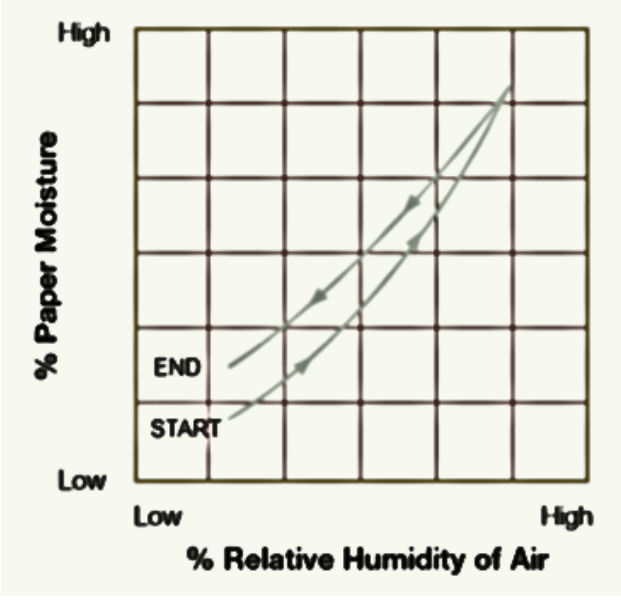

Figure 1. Effect of paper moisture change as the relative humidity changes /1/

This figure represents the process of absorption and release of moisture by paper. As it can be seen, this process isn't fully reversible. At first, the relative humidity of ambient air increases, paper moisture content increases as well. Subsequently, the relative humidity of air changes to initial value, while paper moisture content reaches value, which is higher than the initial one. It means that a part of absorbed moisture isn't released to the surroundings that can lead to spoilage of paper. Therefore, the RH of the surrounding air is in charge of paper quality. This factor should be thoroughly controlled in order to prevent book spoilage and damage.

The question of actual preferable values should be considered. Paper material should be in EMC with an atmosphere under conditions of 22°C and 40 – 50% relative humidity (this is an average value, that is given for a common type of paper) /2/.

As a result, T and RH values should be measured in the process of indoor climate evaluation of a library building. Desirable indoor values are T=70°F=21°C and RH=30 – 50% for combined stack and user areas of paper storage building, in other words, for public libraries /2/.

Preservation index (PI) represents the rate of chemical decay based on constant T and RH. As higher the PI is, as lower is the rate of chemical decay is. PI is evaluated basing on T and RH values. It is useful tool to evaluate the effect of these indoor climate parameters on collection aging and probable rick of natural decay. /3./

Next, *biological criterion* is considered. High RH fosters mold growth on surfaces, paper is not an exception. The probability of mold growth is expressed by Mold risk factor (MRF). MRF evaluation is based on T and RH values. If the MRF<0.5 then the environment is considered as low mold growth environment. Increasing of MRF imperils the indoor climate to mold origination and distribution. Figure 2 illustrates the influence of the RH on the mold growth.

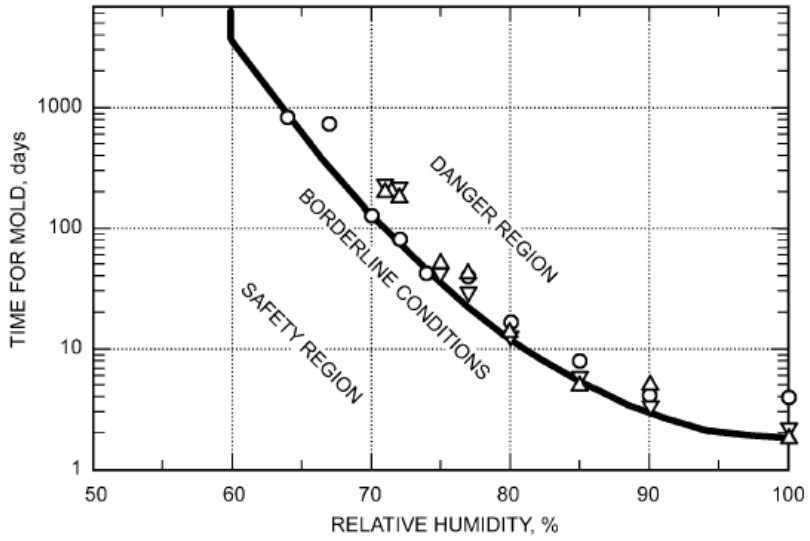

Figure 2. Relative humidity impact on mold origination /3/

Figure 2 represents the relation between relative humidity change and mold growth probability. The higher the relative humidity, the higher the probability of mold origination. The dew point maintained above -1°C at a maximum of 55% RH is recommended to avoid mold growth /3/.

2.2 Human thermal comfort criterion

In this chapter human thermal comfort criterion is explained. Environmental parameters to be measured in process of evaluation of thermal environment are clarified. The indices related to thermal comfort and thermal discomfort are described. Moreover, thermal environmental categories in accordance with legislation are presented.

2.2.1 Human comfort

A human's thermal sensation is related to the thermal balance of one's body. The following environmental parameters are vital for the heat balance of a human: air temperature, mean radiant temperature of surrounding surfaces, air velocity, relative humidity. Two personal factors, metabolic rate and clothing insulation are also of importance. /4./ In the following paragraphs the importance of these parameters and the way of measuring them and needed equipment according to existing legislation will be clarified.

Air temperature is the basic environmental parameter that should be taken into account while determining the thermal balance of human body. Air temperature in a human thermal comfort theory is the temperature of air in the surroundings, that should be taken into account when determining heat transfer by convection. Measuring devices used for air temperature determination should meet the requirements given in ISO 7726 /5/. According to this legislation, either expansion, electrical thermometer or thermomanometer could be used to measure air temperature. /5./

Mean radiant temperature is the second vital value. Mean radiant temperature is the uniform temperature of an imaginary enclosure in which the radiant heat transfer from the human body is equal to the radiant heat transfer in the actual non-uniform enclosure. This important parameter takes into account the influence of thermal radiation on a person's heat balance. Basically, mean radiant temperature should be calculated taking into account surface temperature of a room enclosure and the factors of human relatively location. But in another simpler way it can be done from the measurement of the temperature of the black globe, air velocity and air temperature. /5./

The black globe is placed in the place where the mean radiant temperature should be measured. After the response time (20 – 30 minutes) it comes to thermal balance with surroundings. Mean radiant temperature is being obtained from the thermal balance equation. The thermal balance of the black globe is expressed by the Equation 1.

$$\varepsilon_g \sigma \left(T_r^4 - T_g^4\right) + h_{cg}(T_a - T_g) \qquad (1)$$

where

ε_g	emissivity of the black globe	[-]
σ	Stefan-Boltzmann constant	[W/(m^{2}K^4]
T_a	mean air temperature	[K]
T_g	black globe temperature	[K]
T_r	mean radiant temperature	[K]

h_{cg}	coefficient of heat transfer by convection	[W/m^{2}K]

In the case of forced convection h_{cg} is found in accordance with the Equation 2.

$$h_{cg} = 6.3 * \frac{v_a^{0.6}}{D^{0.4}} \tag{2}$$

where

v_a	air velocity	[m/s]
D	Diameter of the globe	[m]

From the Equation 1 and Equation 2 mean radiant temperature can be expressed as shown in the Equation 3.

$$T_r = \sqrt[4]{\frac{\varepsilon_g \sigma T_g^4 - 6.3 \frac{v_a^{0.6}}{D^{0.4}} * (T_a - T_g)}{\varepsilon_g \sigma}} \tag{3}$$

where

ε_g	emissivity of the black globe	[-]
σ	Stefan-Boltzmann constant	[W/(m^{2}K^4]
T_a	mean air temperature	[K]
T_g	black globe temperature	[K]
T_r	mean radiant temperature	[K]
v_a	air velocity	[m/s]
D	Diameter of the globe	[m]

Third environmental parameter is air velocity. Air velocity takes into account air flow fluctuations indoors. According to (ISO 7726, 1998) the air flow should be described by both the mean velocity of the air (average in time) and by the standard deviation of the velocity.
The second mentioned value is given by the Equation 4.

$$SD(v_a) = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(v_{ai} - v_a)^2} \quad (4)$$

where

SD	standard deviation of the velocity	[m/s]
n	measurement step	[-]
v_{ai}	instantaneous air velocity	[m/s]
v_a	mean air velocity	[m/s]

Relative humidity is vital as for book preservation, as for human thermal comfort. Low relative humidity causes body discomfort and partial tissue irritation. Different equipment is applicable to measure relative humidity.

Several environmental indices, which are listed below are crucial to determine the human perception of thermal environment. *Operative temperature* is defined as the uniform temperature of an enclosure in which a human would exchange the same amount of heat by radiation and convection as in the existing non-uniform environment.

With the high precision the operative temperature can be calculated in accordance with the following Equation 5.

$$t_o = At_a + (1 - A)t_r \quad (5)$$

where

t_o	operative temperature	[°C]
A	coefficient (v_a)	[-]
t_a	mean air temperature	[°C]
v_a	air velocity	[m/s]
t_r	mean radiant temperature	[°C]

Coefficient A can be found from the following Table 1.

Table 1. Coefficient A in accordance with air velocity

v_a	$v_a < 0.2$	$0.2 < v_a < 0.6$	$0.6 < v_a < 1.0$
A	0.5	0.6	0.7

In other way, the operative temperature may also be calculated in accordance with the Equation 6.

$$t_o = \frac{t_a * \sqrt{10 * v_a} + t_r}{1 + \sqrt{10 * v_a}} \quad (6)$$

where			
	t_o	operative temperature	[^{o}C]
	t_a	mean air temperature	[^{o}C]
	v_a	air velocity	[m/s]
	t_r	mean radiant temperature	[^{o}C]

For a thorough description and prediction of thermal climate satisfaction *predicted mean vote (PMV)* and *predicted percentage dissatisfied (PPD)* indices are used. The PMV predicts the mean value of the thermal votes of a large group of people exposed to the same environment. It is found by procedure, presented in ISO 7730 /6/. The PPD is an index that establishes a quantitative prediction of the percentage of thermally dissatisfied people. PPD is related to PMV value and can be found from the equation 7.

$$PPD = 100 - 95 * \exp\left(-0.03353 * PMV^4 - 0.2179 * PMV^2\right) \quad (7)$$

where			
	PPD	predicted percentage dissatisfied	[%]
	PMV	predicted mean vote	[-]

2.2.2 Human discomfort

People in normal surroundings can experience local discomfort due to undesirable heating or cooling of human's body. Among the reasons of such discomfort there are radiant temperature asymmetry, draft, vertical air temperature difference, warm or cool floors.

The discomfort perceived by humans due to *draft* may be represented as the percentage of people predicted to be dissatisfied with draft. According to ISO 7730 /6/**,** this value which is also called draft rate should be calculated in accordance with the following equation.

The draft rate can be defined through Equation 8.

$$DR = (0.37 * v_{a,l} * T_u + 3.14)(34 - t_{a,l})(v_{a,l} - 0.05)^{0.62} \quad (8)$$

where	*DR*	draft rate	[%]
	$t_{a,l}$	local air temperature	[^{o}C]
	T_u	local turbulence intensity	[%]
	$v_{a,l}$	local mean air velocity	[m/s]

Local turbulence intensity is expressed as shown in Equation 9

$$T_u = \frac{SD(v_a)}{v_a} * 100 \quad (9)$$

where	SD	standard deviation of the velocity	[m/s]
	T_u	local turbulence intensity	[%]
	v_a	mean air velocity	[m/s]

Vertical air temperature difference is the second local discomfort parameter, that should be considered in the process of IEQ investigation. In common cases air temperature increases as the height of the room increases. According to ISO 7730 /6/**,** the percentage of people dissatisfied with vertical air temperature difference should be calculated in accordance with the following equation.

The percentage of dissatisfied can be defined through Equation 10.

$$PD = \frac{100}{1 + \exp\left(5.76 - 0.856 * \Delta t_{a,v}\right)} \quad (10)$$

where	*PD*	percentage of dissatisfied	[%]
	$\Delta t_{a,v}$	difference in the air temperature between head and ankles	[^{o}C]

Warm or cool floors remain a significant issue for spaces and areas where people spend significant amount of time. In rooms where the floor temperature deviates from the normal value so that the floor becomes cold or warm occupants may feel additional discomfort at their feet. According to ISO 7730 /6/, the percentage of people dissatisfied with warm or cool floor temperature should be calculated in accordance with the following equation.

The percentage of dissatisfied can be defined through Equation 11.

$$PD = 100 - 94 * \exp\left(-1.387 + 0.118 * t_f - 0.0025 * t_f^2\right) \quad (11)$$

where	*PD*	percentage of dissatisfied	[%]
	t_f	floor temperature	[^{o}C]

Radiant temperature asymmetry takes into account the influence of cold or hot surfaces on thermal comfort. Sitting by the cool window cause local discomfort, that is why the following parameter is crucial to be calculated.

The percentage of dissatisfied can be defined through Equation 12.

$$PD = \frac{100}{1 + \exp\left(6.61 - 0.345 * \Delta t_{p,r}\right)} \quad (12)$$

where	*PD*	percentage of dissatisfied	[%]

Δt_{pr} radiant temperature asymmetry [°C]

When all mentioned values are measured and all necessary indices are calculated, thermal environment quality should be evaluated in terms of legislation recommendations. There are four categories of indoor environmental quality /7/. They are: I (high level of expectation); II (normal level of expectation); III (moderate or acceptable) level of expectation; IV (acceptable for limited part of the year). These categories can be denoted with A,B,C,D letters, where A denotes the most acceptable category. Table 2 represents thermal categories classification in accordance with EN 15251 /7/.

Table 2. Thermal comfort classification according to EN 15251 /7/

Category	Thermal state of the body as a whole		Local discomfort			
	PPD %	PMV	DR %	PD % caused by		
				vertical air temperature difference	warm or cool floor	radiant asymmetry
A	< 6	– 0,2 < PMV < + 0,2	< 10	< 3	< 10	< 5
B	< 10	– 0,5 < PMV < + 0,5	< 20	< 5	< 10	< 5
C	< 15	– 0,7 < PMV < + 0,7	< 30	< 10	< 15	< 10

Table 2 shows, that for each index related category should be determined. Thermal comfort and local discomfort are classified simultaneously. In the end of this classification, final category is determined according to this range of indices.

3 METHODS

3.1 Case building description

Case library building is located in Mikkeli, Finland. It is a campus library of South-Eastern Finland University of Applied Sciences. This building consists of two storeys.

Floor area (1st floor): 625 m^2

Floor area (2nd floor): 263 m^2

Building volume: 3510 m^3

Building envelope structure:
External wall: old brick, 510 mm
Internal wall: plaster board, 13 mm; stone wool insulation, 70 mm; plaster board, 13 mm.
Slab against the ground: Water proofing; reinforced concrete, 200 mm; filter fabric; polystyrene, 50 mm.
Roof: old wood structures; wind lion, 12 mm; mineral wool, 250 mm; plastic, 0.2 mm; gypsum plasterboard, 13 mm; accumulation board, 10 mm.

Domestic hot water: 70-25/10-55.
Space heating (water radiators): 115-45/40-70.
Ventilation: Rotary heat exchanger; heating coil; supply air: +1910 l/s; return air: -1920 l/s

1st floor layout can be found in Appendix 2; 2nd floor layout can be found in Appendix 3; 1st floor ventilation layout can be found in Appendix 4; 2nd floor ventilation layout can be found in Appendix 5.

Library self-service hours: Monday-Sunday 7:00-21:00; Customer service hours (staff present): Monday-Wednesday 10:00-17:00, Thursday-Friday 10:00-15:00.

3.2 Indoor environmental quality evaluation

There are three methods applicable in order to investigate the indoor environment quality of an existing building. They are measurements of selected parameters for the indoor environment, whole year computer simulation and subjective responses from occupants. /7./ All three methods are used in this Bachelor's thesis. Each method results will be compared to each other in order to find out indoor environmental quality in studying library building from different points of view.

3.2.1 Measurements of indoor environment

In order to investigate the whole building indoor environment quality, the building should be divided into representative zones. In each zone typical room or area where measurements will be conducted should be selected. /7./

Figure 3 illustrates selected representative zones and typical areas for a investigating library building. Three representative zones were chosen. First zone is located on the first floor of the building. This zone can be called “library zone”. It includes book shelves area, staff table area and student tables area. The second zone which is placed on the first floor as well is occupied by staff offices. Third zone representing the studying area for students is on the second floor. Computer classroom was taken as typical area for this zone.

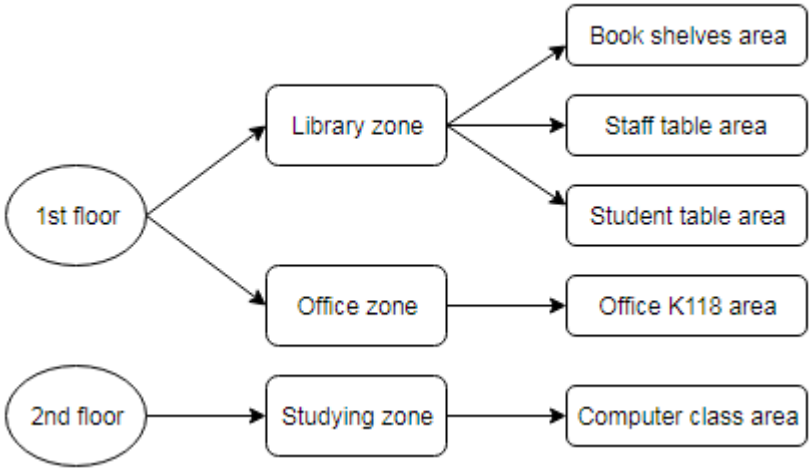

Figure 3. Representative zones and typical areas for measurements

Figure 4 shows the locations of representative zones and measuring points of the first floor. Library zone is marked in green color. Offices zone is marked in blue. Measuring points are marked by triangles. Green triangle – book shelves area, red – staff area, yellow – student area.

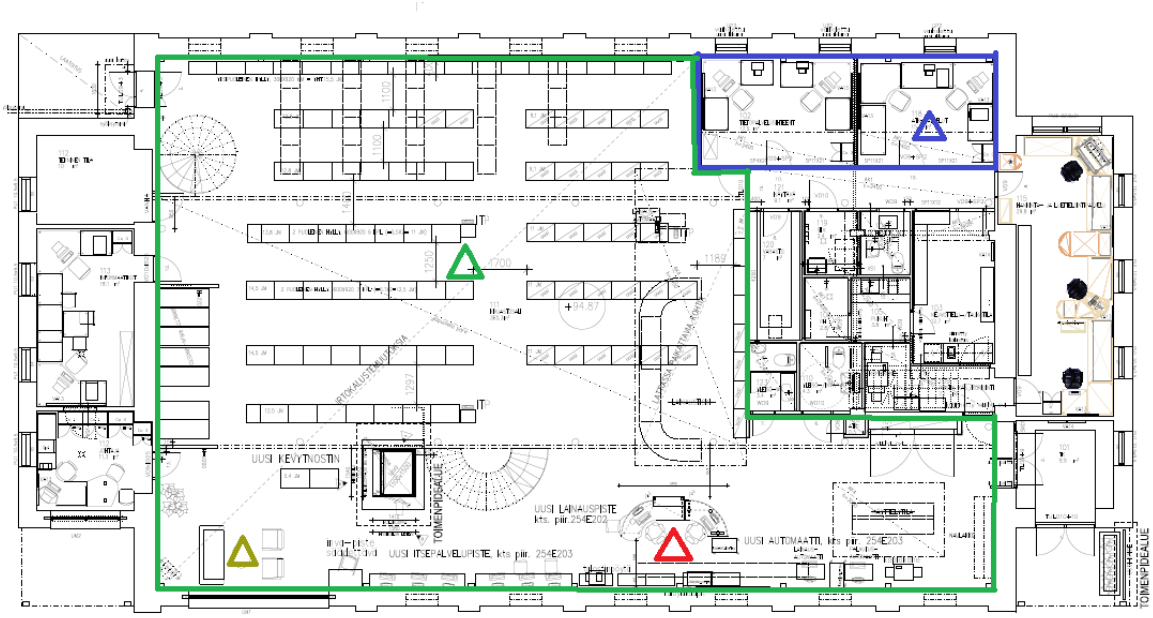

Figure 4. Library 1st floor representative zones and measuring locations

Figure 5 shows the locations of representative zones and measuring points of the second floor. Studying zone is marked in violet color. Brown triangle represents measuring point in computer classroom.

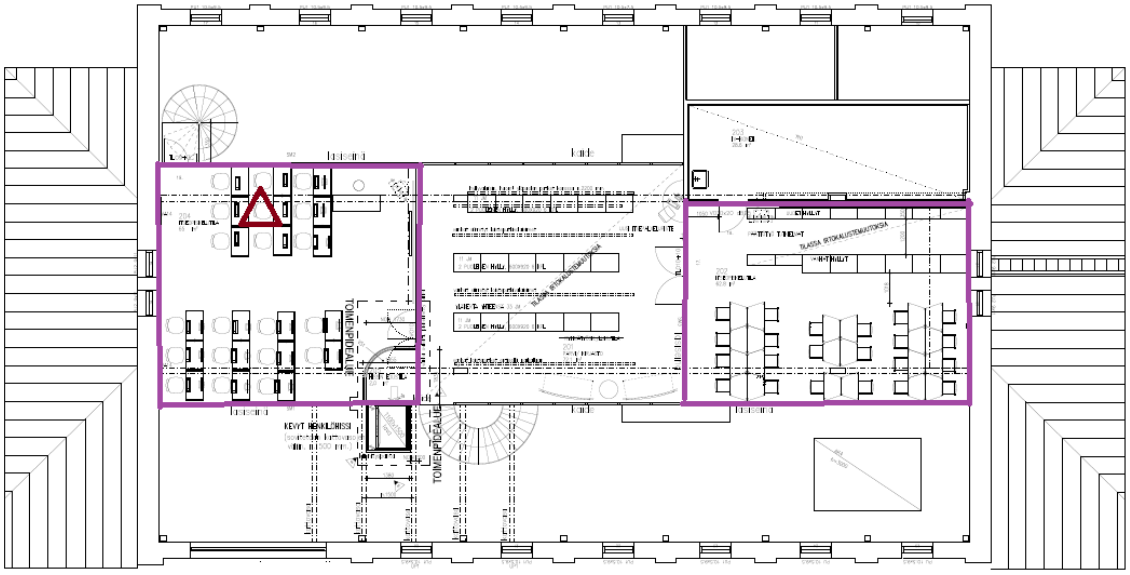

Figure 5. Library 2nd floor representative zones and measuring locations

Figure 6 represents measuring point 1 – in corridor among book shelves. This point was selected to illustrate environmental quality conditions near the library

paper collection. Measurements were carried out at this area at 21st of November, 2019 for one hour 14:00-15:00.

Figure 6. Book shelves measuring point

Figure 7 represents measuring point 2 – near the staff table. Measurements were carried out at this area at 21st of November, 2019 for one hour 10:00-11:00. Measurement results in this point will show thermal comfort of library staff during the working day.

Figure 7. Staff table area measuring point

Figure 8 represents measuring point 3 –near the student table. As can be seen from the floor layout, this point is located next to the large window. Possibility of local discomfort in this area justifies the selection of this point to be a measuring location. Measurements were carried out at this area at 21st of November, 2019 for one hour 12:00-13:00.

Figure 8. Student table area measuring point

Figure 9 represents measuring point 4 – office room K118. Several complains about the indoor thermal quality had been heard from the library staff (more information about complains can be seen in the chapter 5.2.3), therefore this point was included in the investigation. Measurements were carried out at this area at 21st of November, 2019 for one hour 11:00-12:00.

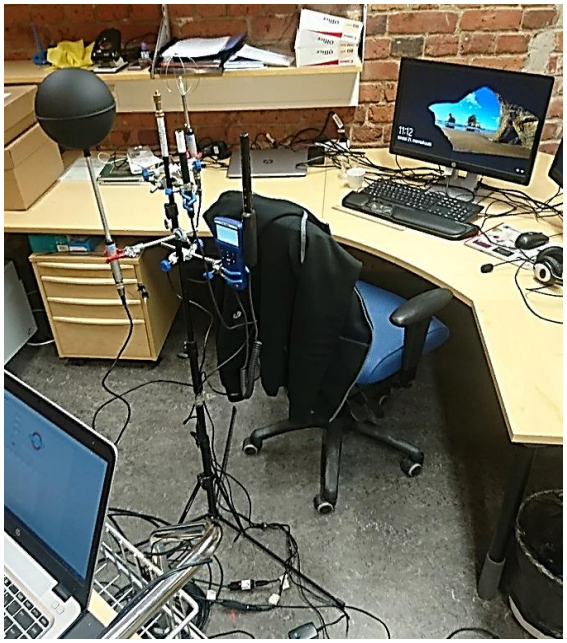

Figure 9. Office K118 area measuring point

Figure 10 represents measuring point 5 – beside the table in a computer classroom. Student comfort during the lecture or barely during the self-studying in this room should have been estimated. Measurements were carried out at this area at 22nd of November, 2019 for one hour 10:00-12:00.

Figure 10. Computer class area measuring point

Location of the measuring equipment meets the requirements given in ISO 7726 /5/.

Values to be measured in terms of current investigation were listed in the literature review chapter. They are: air temperature, black globe temperature, air velocity, relative humidity, surface temperature. They were chosen based on ISO 7730 /6/. Two measuring devices were used in current investigation. First device consists of three sensors. It is Swema multipoint. First sensor measures black globe temperature, second sensor meters air velocity and air temperature, third sensor measures relative humidity. Second device is used for surface temperature measurements. Fluke 52 thermometer was used for this purpose.

The sensitivity of devices was set to be 0.1 second, that means that measuring value was being recorded each 0.1 second. Then the device calculates average value for each 3 seconds and gives this value as an output. Measurement equipment, measuring range of gauges, their accuracy and response time meets the requirements given in ISO 7726 /5/.

The way of processing of the measurements results is explained further. According to equations, mentioned in the literature review part the following results have been gathered. First, mean radiant temperature was calculated based on air velocity, air temperature and globe temperature. Then, operating temperature was calculated. Having done that, PMV and PPD indices were obtained from equations. Moving forward, all local thermal discomfort indices were computed. Afterwards, calculated values were compared to thermal comfort categories, given in EN 15251 /7/. Then, a final category for each representative zone have been chosen.

3.2.2 Whole year computer simulation

As a second method whole year computer simulation by means of IDA ICE software was performed. At first, all construction materials of external walls, internal walls, external floors, internal floors, slabs, roof, from which the existing library had been erected, were uploaded to IDA ICE. Then, the building model

was constructed in accordance with the floor layouts of the library building. Existing windows, doors were added to the model. Having done that, air flow rates for both supply and return air were implemented in the model according to the ventilation systems layouts of the library building. Afterwards, water radiators with their dimensions and heat outputs were added. Next, occupancy schedule and average amount of people in each zone were supplemented to the model. Subsequently, both weather trend of Mikkeli site orientation of the building were uploaded to IDA ICE. Clothing insulation was assumed to be 1 clo (typical winter indoor clothing). Metabolic rate was assumed to be 1 met (writing, sedentary activities).

As a final step, whole year simulation was started. Time range was set from 01.01.2019 to 01.01.2020. Output of the described simulation consists of 2 graphs for each representative zone: annual operative temperature alteration; annual PMV and PPD fluctuation.

Results processing of this method is similar to the measurement method. Operative temperature, PMV, PPD alterations were compared to thermal comfort categories.

3.2.3 Subjective evaluation

Several complains from library staff and visitors had been heard, that is why this third method is vital to evaluate the indoor environmental quality. Therefore, subjective questionnaire was established in order to estimate the indoor environment perception by library occupants and staff. The questionnaire is represented in the Appendix 1. It was made in accordance with recommendations given in EN 15251 /7/.

Visitors and staff were asked about their thermal sensation indoors, perception of temperature in library. The seven-point Fanger’s scale for thermal comfort was used for this purpose. Subsequently, people were asked if they feel local cooling and vertical air temperature difference. They also voted about floor and surfaces temperature perception. Their votes were used to calculate the value of mean

vote and therefore get an idea how many percent of visitors and staff are dissatisfied with the indoor environment.

Results processing of this methods consists of creation of graphs representing abovementioned votes distribution among sampling group of people. Analysis of these results will give both the idea of current indoor environmental quality situation in the library and number of people given in percent, who are dissatisfied with the library environmental conditions.

4 RESULTS AND ANALYSIS

In the following chapter results for each method are represented firstly. At the same time analysis of those results is represented for each method. All the suggestions and recommendations are presented in Discussion chapter.

4.1 Measurements

In this chapter, human thermal comfort results are presented firstly, then book preservation results are presented secondly.

4.1.1 Area 1 – book shelves area

Figure 11 represents how the operative temperature at measuring point 1 changes with the measuring time. Colored areas on the graph show the four categories of indoor environmental quality.

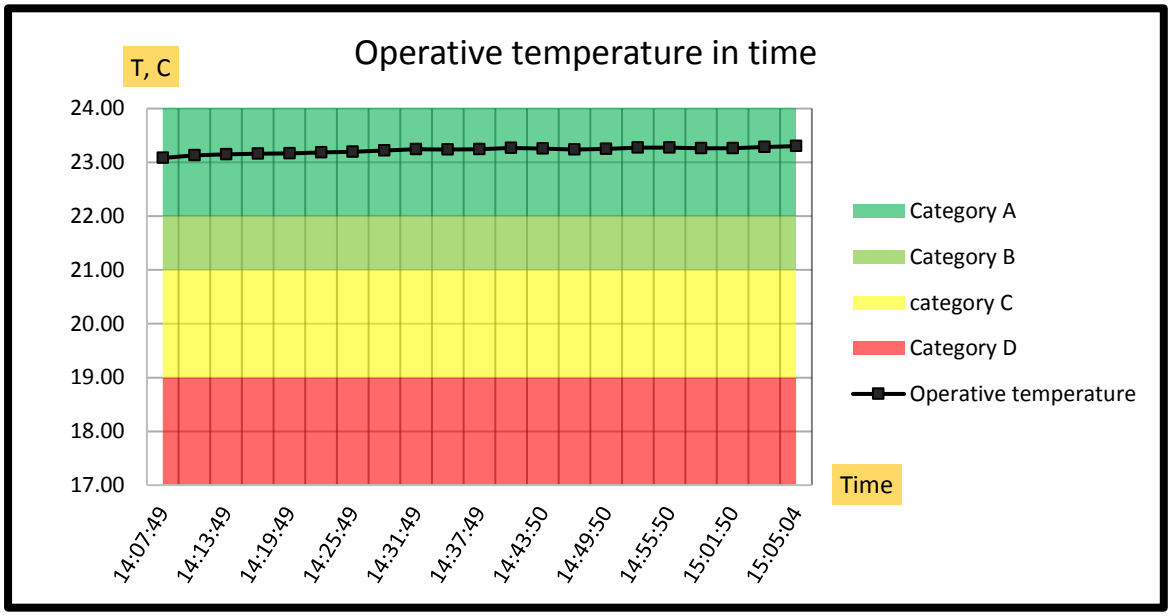

Figure 11. Operative temperature in time at measuring point 1

Operative temperature at this point corresponds to category A. Such category is considered as clearly acceptable for the majority of people, even for old people, children and sick humans.

From table 3 threshold values of operative temperature can be seen.

Table 3. Threshold values of operative temperature at measuring point 1

Minimum	Maximum	Average
23.08 °C	22.30 °C	22.22 °C

Figure 12 illustrates how the predictable percentage of people, who are dissatisfied with the indoor environmental quality, changes during sampling period. This index value is based on metabolic energy production of person, air temperature, mean radiant temperature, air velocity, relative humidity, clothing insulation. PPD is also categorized in accordance with EN 15251 /7/.

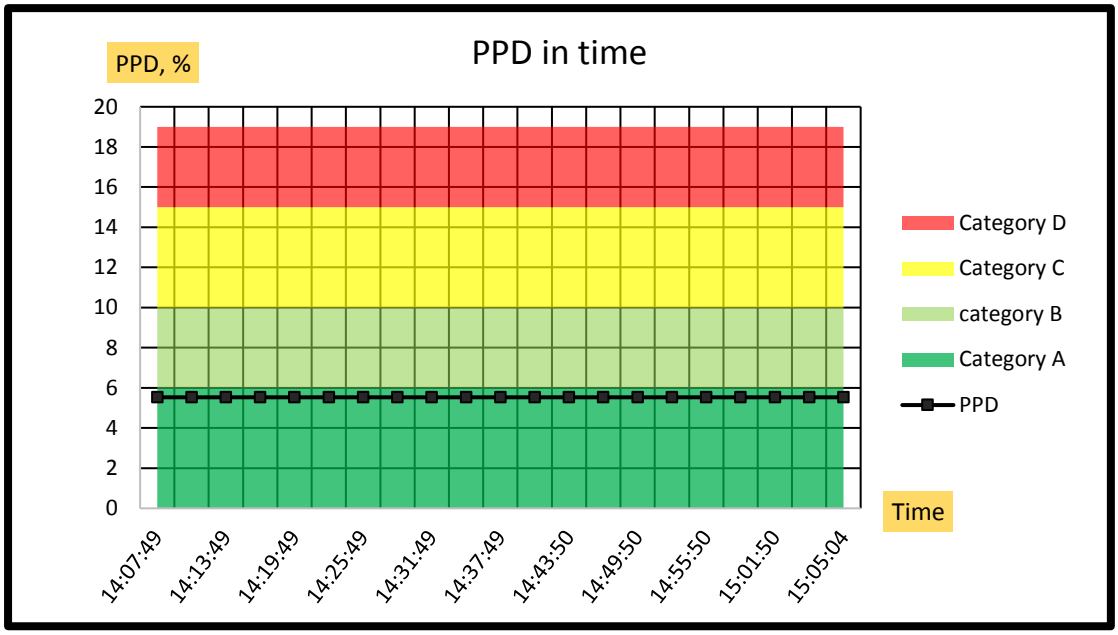

Figure 12. PPD index in time at measuring point 1

PPD value within the sampling period is constant, because changes of air temperature, globe temperature, relative humidity and air velocity are negligible. 6% of people dissatisfied with indoor environmental quality is the border between categories A and B. Therefore, IEQ is fully acceptable.

From table 4 threshold values of PPD can be seen.

Table 4. Threshold values of PPD at measuring point 1

Minimum	Maximum	Average
5.53%	5.53%	5.53%

Figure 13 shows the relation between PPD and PMV.

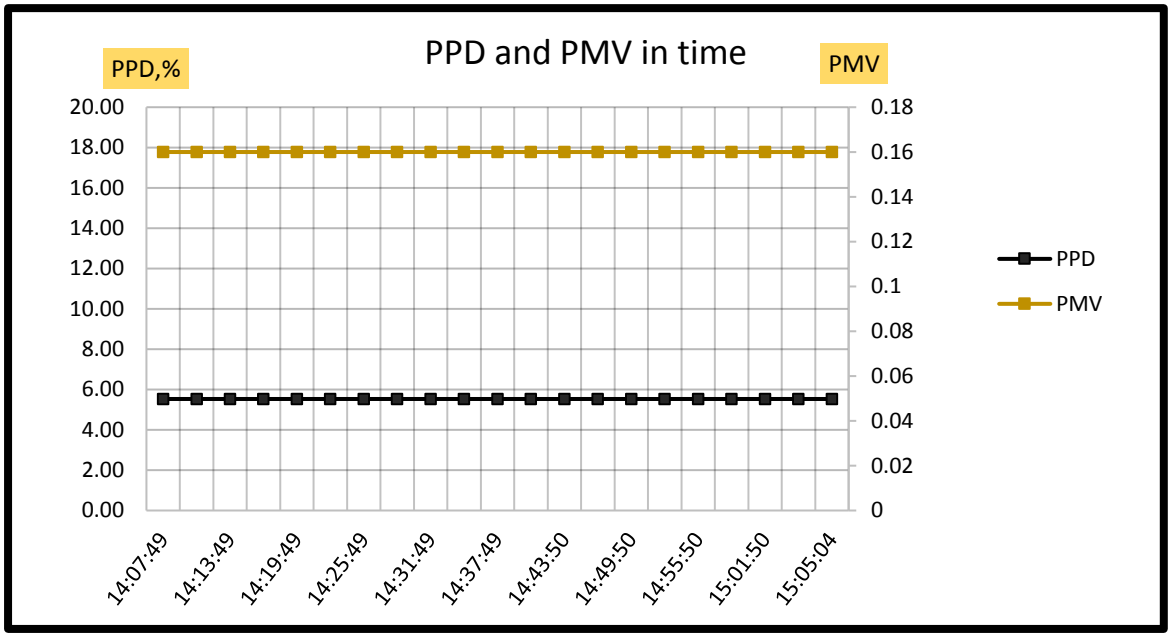

Figure 13. PMV and PPD in time at measuring point 1

From table 5 threshold values of PMV can be seen.

Table 5. Threshold values of PMV at measuring point 1

Minimum	Maximum	Average
0.16	0.16	0.16

At this measuring point local thermal discomfort indices were not calculated due to lack of relevance. Visitor spends only a few minutes near the book shelves and therefore local discomfort is negligible.

The book preservation evaluation results are presented further.
As it was explained in the Literature review chapter, main parameters to evaluate book safety conditions are relative humidity, air temperature and dew point temperature.

Relative humidity at this measuring point varies from 25.3% to 25.7%. At the same time air temperature ranges from 22.91°C to 22.79°C. Dew point temperature at this point is -9°C.

Equilibrium moisture content of books with the environment is reached at temperature of 22°C and RH=40 – 50% /1/. It means that comparing to this

source the relative humidity in the campus library is almost two times lower. It means, respectively, that the amount of moisture transferred between the book and the environment is lower, while the amount of moisture released by paper is higher. Too low moisture level leads to physical damage because of dry paper condition. ASHRAE Handbook /3/ recommends to maintain dew point temperature above -1°C at a maximum 55% RH. Campus library conditions meet this requirement. Therefore, there is no risk of mold growth and distribution.

Mold risk factor was also checked with IPI calculator /8/. Figure 14 represents the results of this evaluation. Mold risk doesn't take place with such indoor environment.

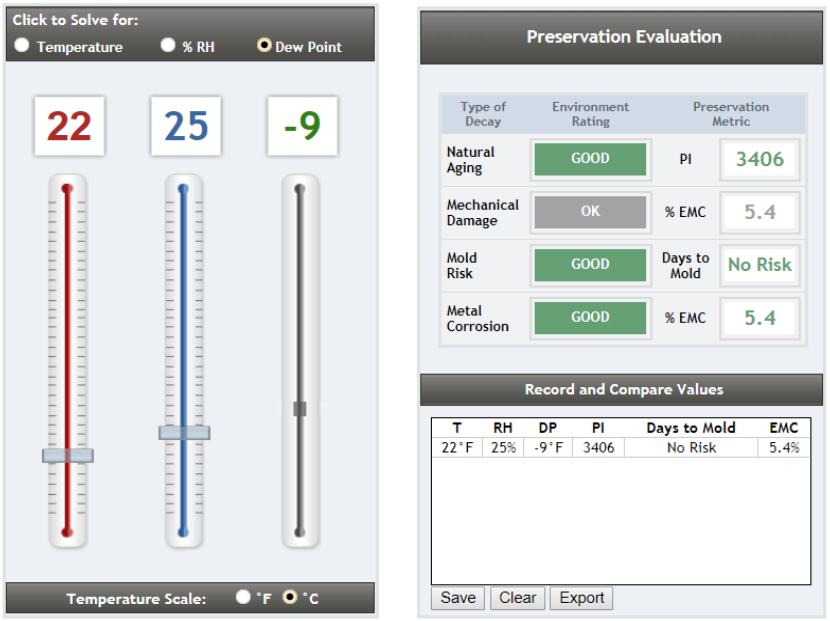

Figure 14. Mold risk evaluation by IPI calculator /8/

All abovementioned leads to the fact, that conditions for book preservation in campus library are completely acceptable.

4.1.2 Area 2 – staff table area

Figure 15 represents how the operative temperature at measuring point 2 changes with the measuring time.

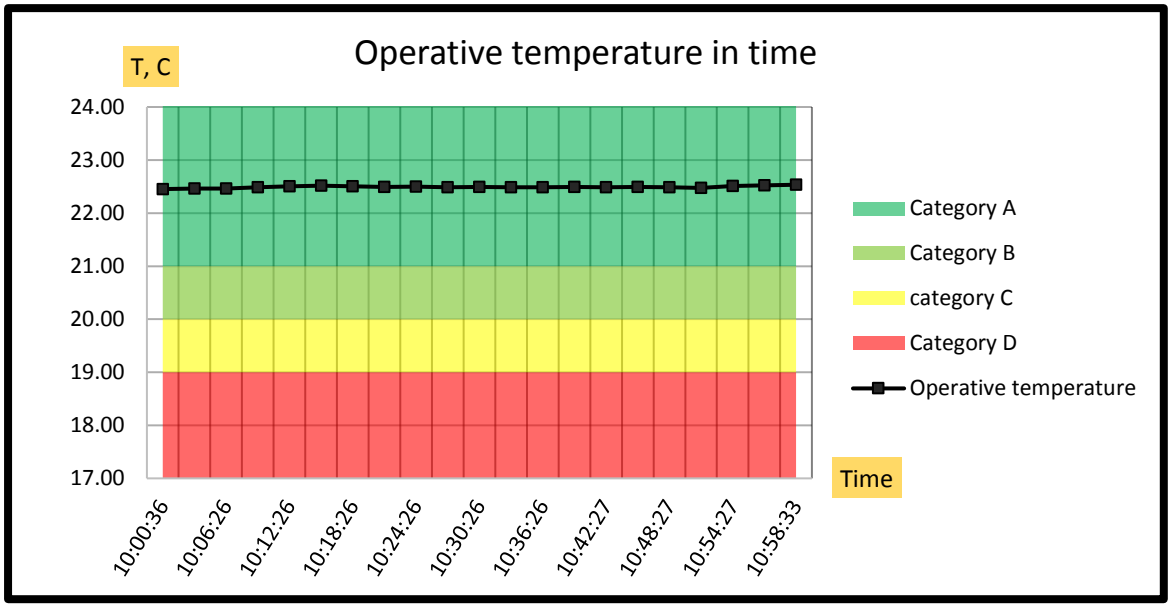

Figure 15. Operative temperature in time at measuring point 2

Operative temperature lies within the category A – fully acceptable. The librarian who spend one's working day at this area should be predictably pleased with the air temperature.

From table 6 threshold values of operative temperature can be seen.

Table 6. Threshold values of operative temperature at measuring point 2

Minimum	Maximum	Average
22.45 °C	22.53 °C	22.49 C

Figure 16 illustrates how the predictable percentage of people, who are dissatisfied with the indoor environmental quality, changes during sampling period.

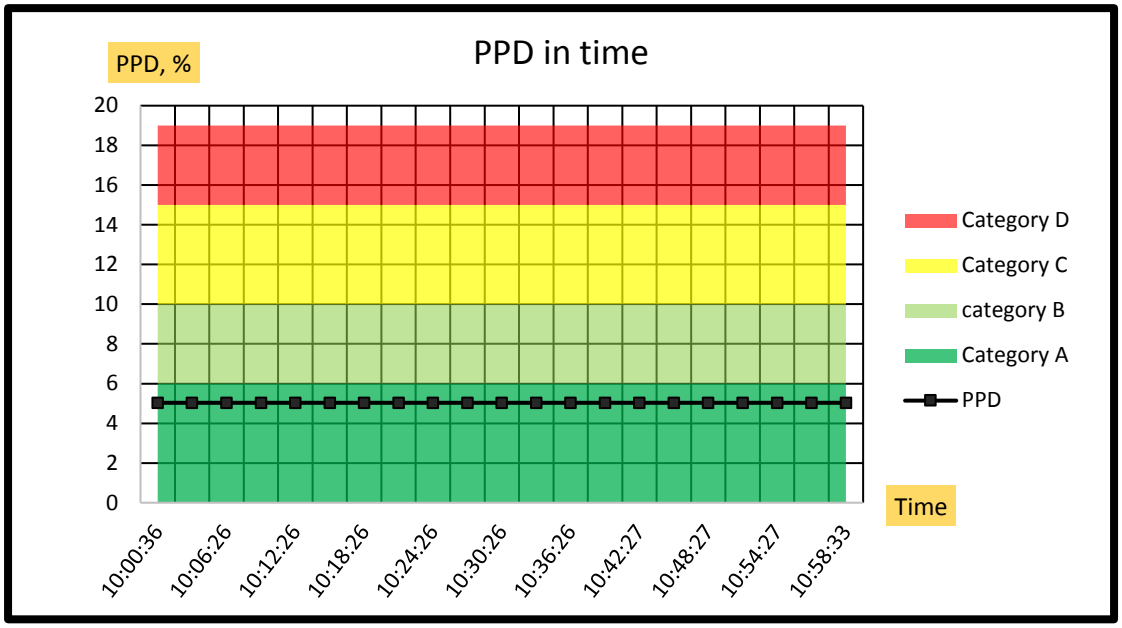

Figure 16. PPD index in time at measuring point 2

The forecast, that is based on measurements at this point predicts only 5.1% of librarians, dissatisfied with the IEQ.

From table 7 threshold values of PPD can be seen.

Table 7. Threshold values of PPD at measuring point 2

Minimum	Maximum	Average
5.1%	5.1%	5.1%

Figure 17 shows the relation between PPD and PMV.

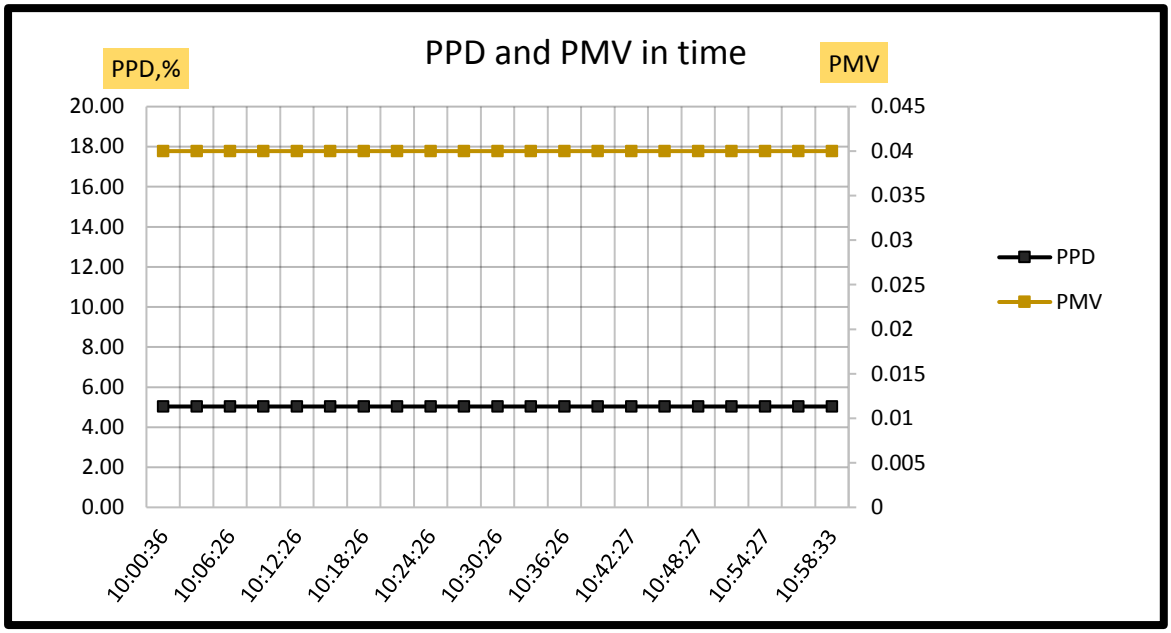

Figure 17. PMV and PPD in time at measuring point 2

From table 8 threshold values of PMV can be seen.

Table 8. Threshold values of PMV at measuring point 2

Minimum	Maximum	Average
0.04	0.04	0.04

Figure 18 represents draft rate alteration in time at staff table. Results are categorized according to DR categories of EN 15251 /7/.

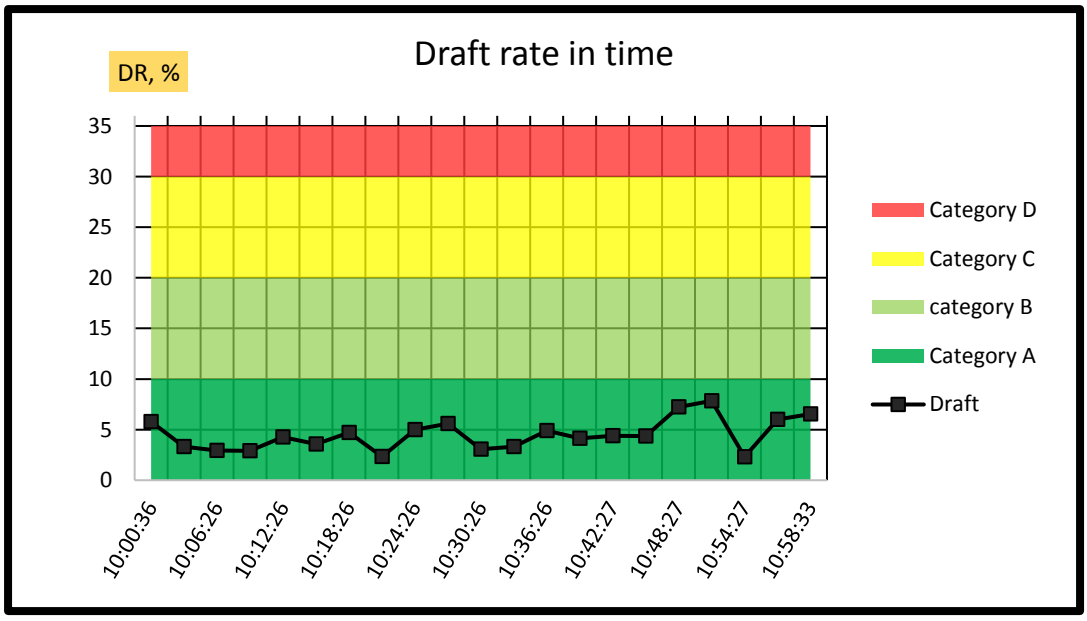

Figure 18. Draft rate alteration in time at measuring point 2

Even though the DR fluctuates within the sampling period, it still meets the Category A of thermal environment. Although, there is a potential of draft at winter time, when the operative temperature is lower. Staff perception of draft were gathered at Subjective questionnaire chapter.

From table 9 threshold values of draft rate can be seen.

Table 9. Threshold values of draft rate at measuring point 2

Minimum	Maximum	Average
2.32	7.8	4.5

Temperature difference between head level and ankles level has been negligible, therefore predicted percentage of people dissatisfied with the vertical air temperature difference:

PD ≈ 1%

In this case graph doesn't make sense.

Radiant temperature difference between measuring point and closest building envelope surface has been negligible, therefore predicted percentage of people dissatisfied with the radiant temperature asymmetry:

PD ≈ 0%

Floor temperature at this measuring point equals 21.7°C

$$PD = 100 - 94 * \exp(-1.387 + 0.118 * 21.7 - 0.0025 * 21.7) \approx 6\%$$

PD values, which are lower than 10% correlates with Category A. Floor temperature doesn't make a lot of sense at this kind of buildings. Even though some sensitive people may complain about freezing feet.

4.1.3 Area 3 – student table area

Figure 19 represents how the operative temperature at measuring point 3 changes with the measuring time.

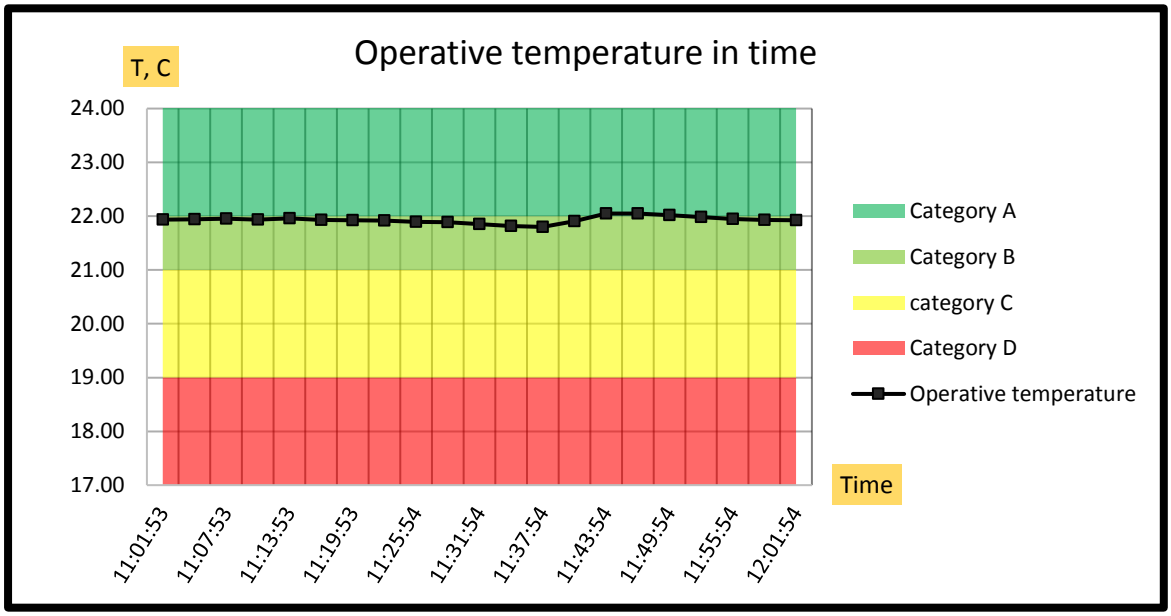

Figure 19. Operative temperature in time at measuring point 3

In comparison with the previous measuring point, calculated operative temperature at student table area is lower for approximately 0.5°C. Although staff table area and student table area are located not far away from each other, the temperature difference takes place. The explanation of this deviation is probably related to the fact, that student table is placed near the big window. As the measured globe temperature takes into account radiation release, cool surface window leads to decrease of operative temperature at this point. Anyway, the operative temperature meets the range of Categories A-B, and therefore it is clearly acceptable.

From table 10 threshold values of operative temperature can be seen.

Table 10. Threshold values of operative temperature at measuring point 3

Minimum	Maximum	Average
22.20 °C	22.42 °C	22.32 C

Figure 20 illustrates how the PPD changes.

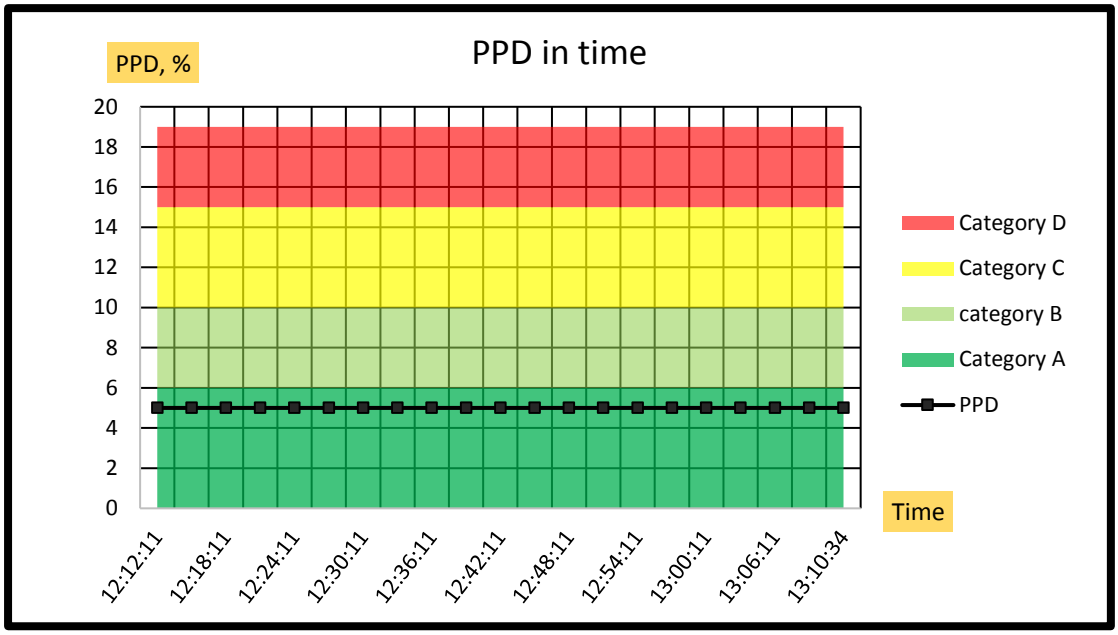

Figure 20. PPD index in time at measuring point 3

PPD at this point is within the acceptable range.

From table 11 threshold values of PPD can be seen.

Table 11. Threshold values of PPD at measuring point 3

Minimum	Maximum	Average
5%	5%	5%

Figure 21 shows the relation between PPD and PMV.

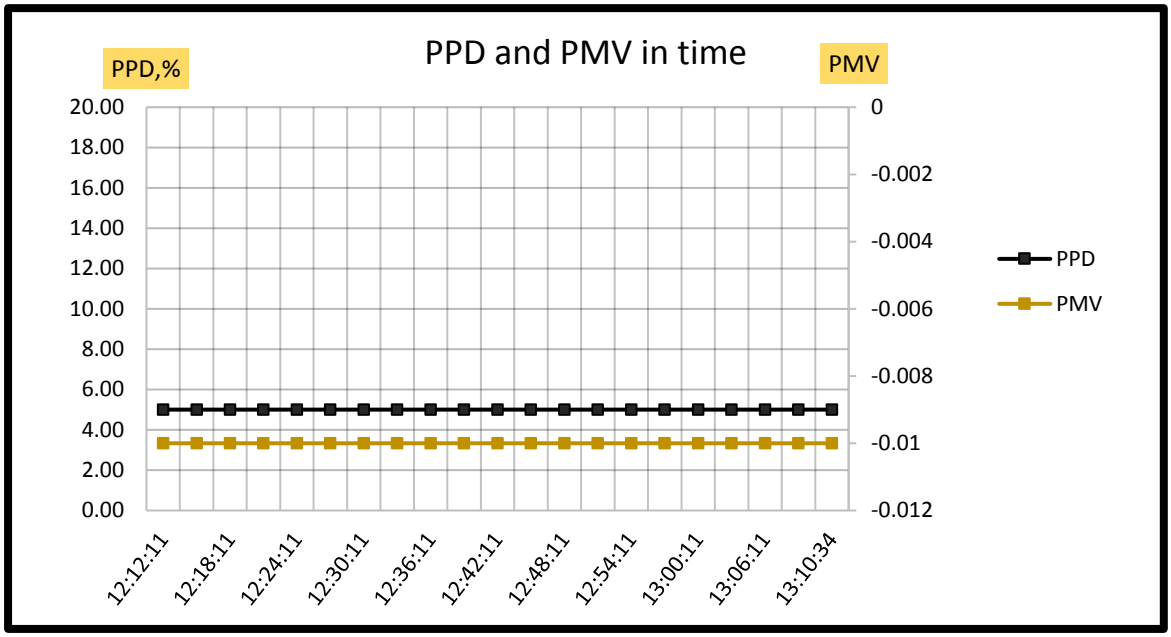

Figure 21. PMV and PPD in time at measuring point 3

From table 12 threshold values of PMV can be seen.

Table 12. Threshold values of PMV at measuring point 3

Minimum	Maximum	Average
-0.01	-0.01	-0.01

As the air velocity at this measuring point is less than 0.05m/s, according to ISO 7730 /6/, air velocity is assumed to be 0.05m/s. Therefore, draft rate:

$$DR = (0.37 * 0.05 * T_u + 3.14)\left(34 - t_{a,l}\right)(0.05 - 0.05)^{0.62} = 0\%$$

Temperature difference between head level and ankles level has been negligible, therefore predicted percentage of people dissatisfied with the vertical air temperature difference:

PD ≈ 1%

Radiant temperature difference between measuring point and closest building envelope surface has been negligible, therefore predicted percentage of people dissatisfied with the radiant temperature asymmetry:

PD ≈ 0%

Floor temperature at this measuring point equals 21.5°C

$$PD = 100 - 94 * \exp(-1.387 + 0.118 * 21.5 - 0.0025 * 21.5) \approx 6\%$$

As at the previous measuring points, floor temperature meets Category A.

4.1.4 Area 4 – office K118 area

Figure 22 represents how the operative temperature at measuring point 4 changes with the measuring time.

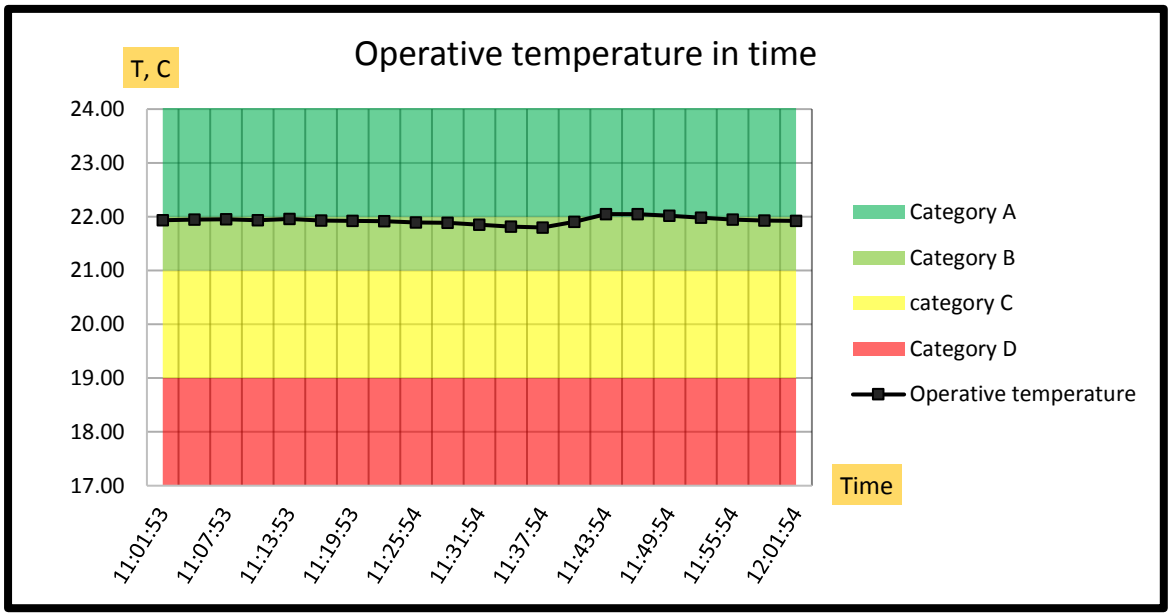

Figure 22. Operative temperature in time at measuring point 4

The operative temperature at staff office K118 is similar to operative temperature at student table. Presence of cool windows and walls justifies this relation. Uninsulated brick, from which the wall was made is not the best material to safe the heat indoors.

From table 13 threshold values of operative temperature can be seen.

Table 13. Threshold values of operative temperature at measuring point 4

Minimum	Maximum	Average
21.80 °C	22.05 °C	21.93 C

Figure 23 illustrates how the PPD changes.

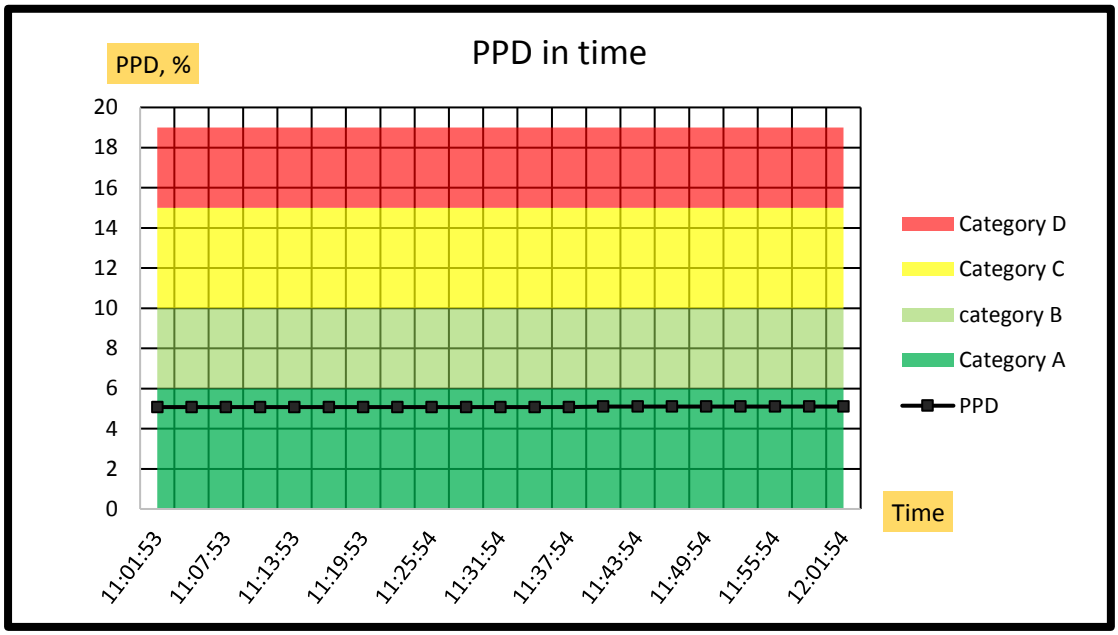

Figure 23. PPD index in time at measuring point 4

Only 5.1% of librarians should be dissatisfied based on these measurements. From table 14 threshold values of PPD can be seen.

Table 14. Threshold values of PPD at measuring point 4

Minimum	Maximum	Average
5.07%	5.10%	5.085%

Figure 24 shows the relation between PPD and PMV.

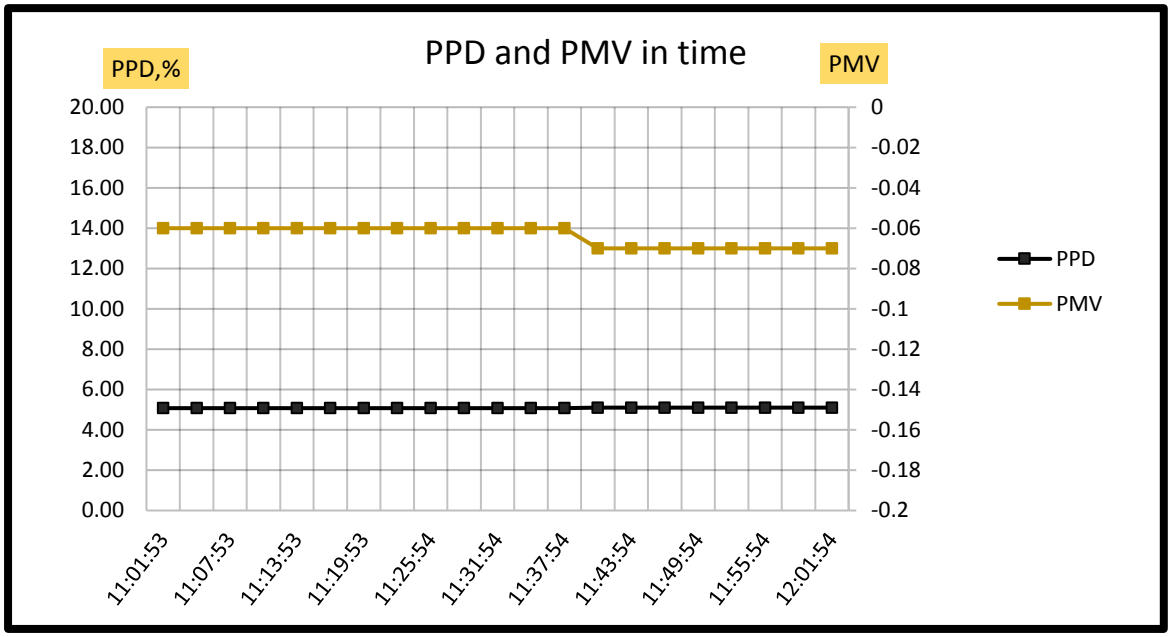

Figure 24. PMV and PPD in time at measuring point 4

From table 15 threshold values of PMV can be seen.

Table 15. Threshold values of PMV at measuring point 4

Minimum	Maximum	Average
-0.07	-0.06	-0.065

As the air velocity at this measuring point is less than 0.05m/s, according to ISO 7730 /7/, air velocity is assumed to be 0.05m/s. Therefore, draft rate:

$$DR = (0.37 * 0.05 * T_u + 3.14)\left(34 - t_{a,l}\right)(0.05 - 0.05)^{0.62} = 0\%$$

Temperature difference between head level and ankles level has been negligible, therefore predicted percentage of people dissatisfied with the vertical air temperature difference:

PD ≈ 1%

In this case graph doesn't make sense.

Radiant temperature difference between measuring point and closest building envelope surface has been negligible, therefore predicted percentage of people dissatisfied with the radiant temperature asymmetry:

PD ≈ 0%

Floor temperature at this measuring point equals 21.9°C

$$PD = 100 - 94 * \exp(-1.387 + 0.118 * 21.9 - 0.0025 * 21.9) \approx 6\%$$

PD remains the same. Same floor temperature cause same percentage of people dissatisfied.

4.1.5 Area 5 – computer class area

Figure 25 represents how the operative temperature at measuring point 2 changes with the measuring time.

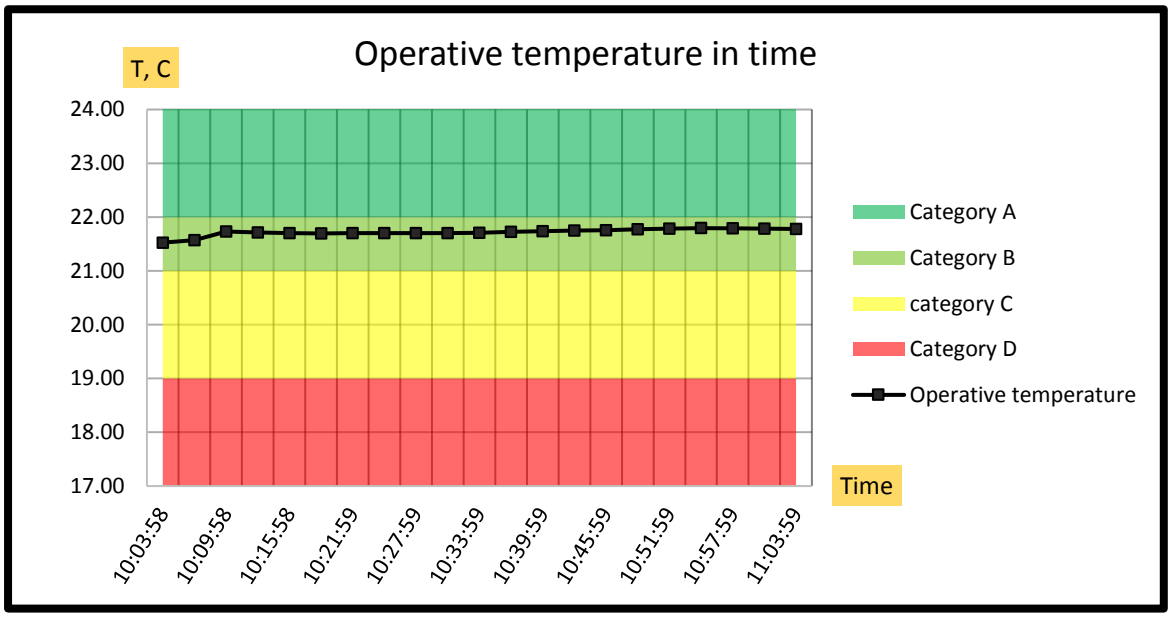

Figure 25. Operative temperature in time at measuring point 5

The lowest operative temperature within all measuring points was gathered at computer classroom. From table 16 threshold values of operative temperature can be seen.

Table 16. Threshold values of operative temperature at measuring point 5

Minimum	Maximum	Average
21.53 °C	21.79 °C	21.72 C

Figure 26 illustrates how the predictable percentage of people, who are dissatisfied with the indoor environmental quality, changes during sampling period.

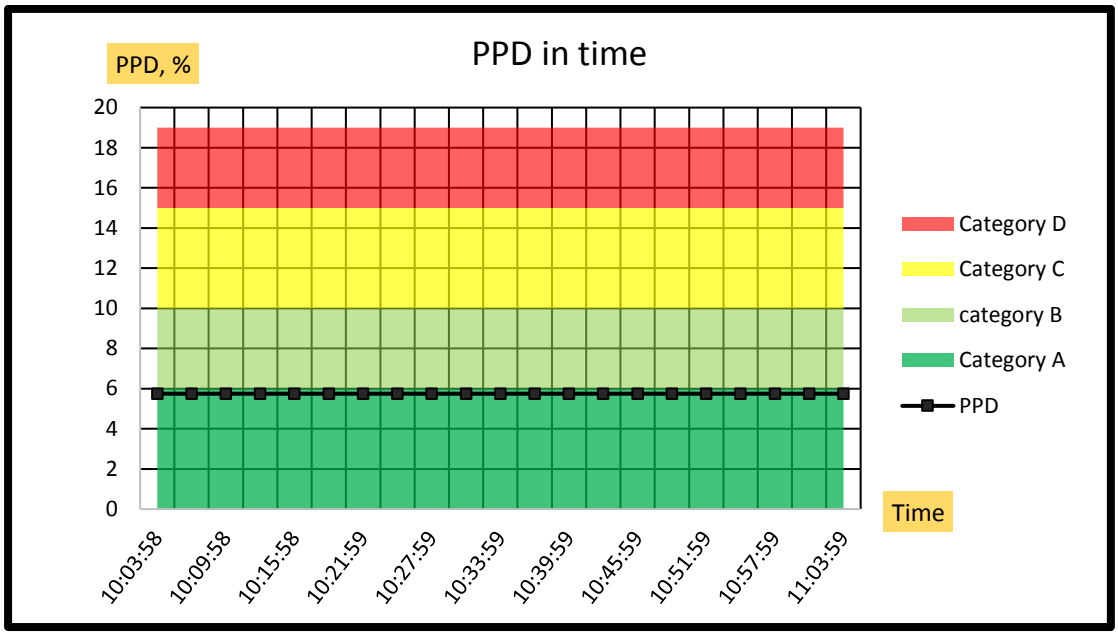

Figure 26. PPD index in time at measuring point 5

The lower the operative temperature, the higher is the PPD. Even though PPD value meets category A requirements.

From table 17 threshold values of PPD can be seen.

Table 17. Threshold values of PPD at measuring point 5

Minimum	Maximum	Average
5.75%	5.75%	5.75%

Figure 27 shows the relation between PPD and PMV.

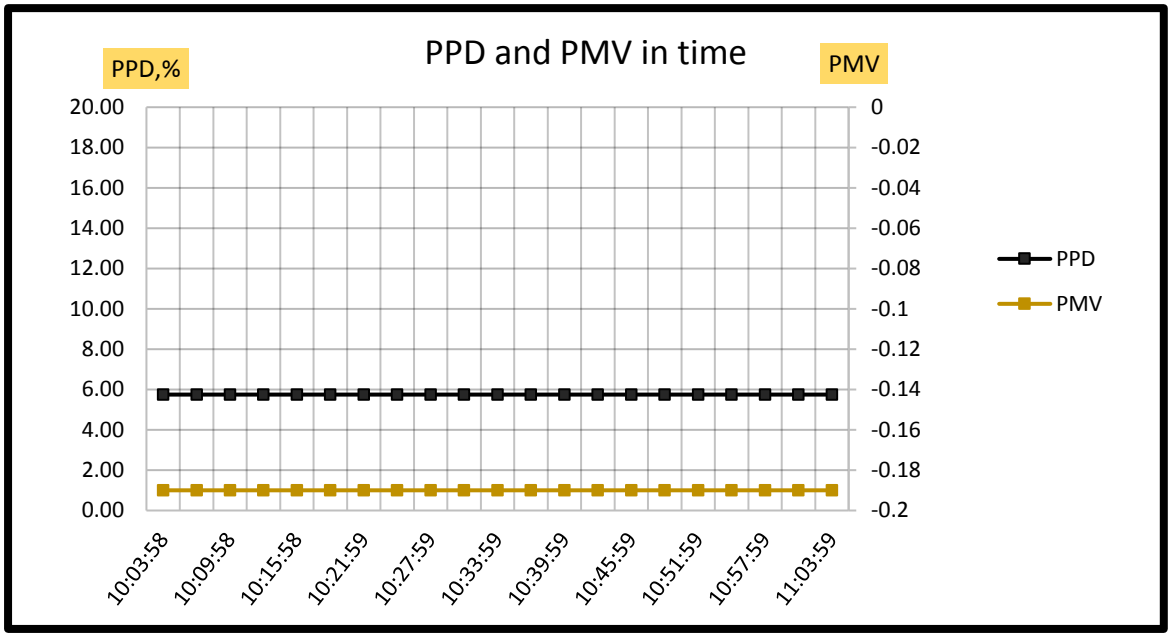

Figure 27. PMV and PPD in time at measuring point 5

From table 18 threshold values of PMV can be seen.

Table 18. Threshold values of PMV at measuring point 5

Minimum	Maximum	Average
-0.19	-0.19	-0.19

Figure 28 represents draft rate alteration in time. Results are categorized according to DR categories of EN 15251 /7/.

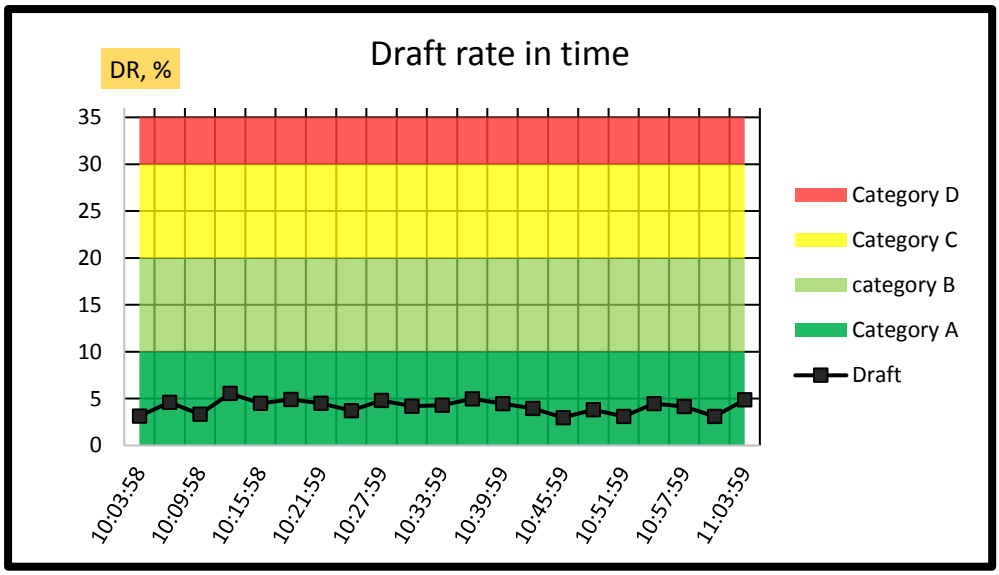

Figure 28. Draft rate alteration in time at measuring point 5

Draft rate fluctuation lies within A-Category. The majority of people should be satisfied with the IEQ. From table 19 threshold values of draft rate can be seen.

Table 19. Threshold values of draft rate at measuring point 5

Minimum	Maximum	Average
2.98%	5.54%	4.16%

Temperature difference between head level and ankles level has been negligible, therefore predicted percentage of people dissatisfied with the vertical air temperature difference:

PD ≈ 1%

In this case graph doesn't make sense.

Radiant temperature difference between measuring point and closest building envelope surface has been negligible, therefore predicted percentage of people dissatisfied with the radiant temperature asymmetry:

PD ≈ 0%

Floor temperature at this measuring point equals 21.7°C

$$PD = 100 - 94 * \exp(-1.387 + 0.118 * 21.7 - 0.0025 * 21.7) \approx 6\%$$

Percentage of people dissatisfied with the floor temperature is acceptable.

4.2 Whole year computer simulation

As the steps mentioned in methods had been finished, the BIM (building information modelling) model was finished. Figure 29 represents how the library BIM model is look like in IDA ICE.

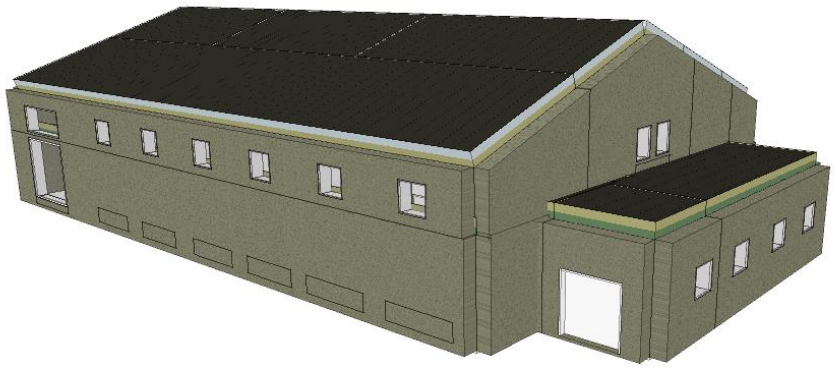

Figure 29. 3D-view of the library BIM model

In order to make the indoor thermal environment as close to real library building as possible, BIM model was established in details.

4.2.1 Library zone

Figure 30 illustrates the annual operative temperature alteration in library zone. Colored areas represent thermal comfort categories. Green-A, light green-B, yellow-C, red-D.

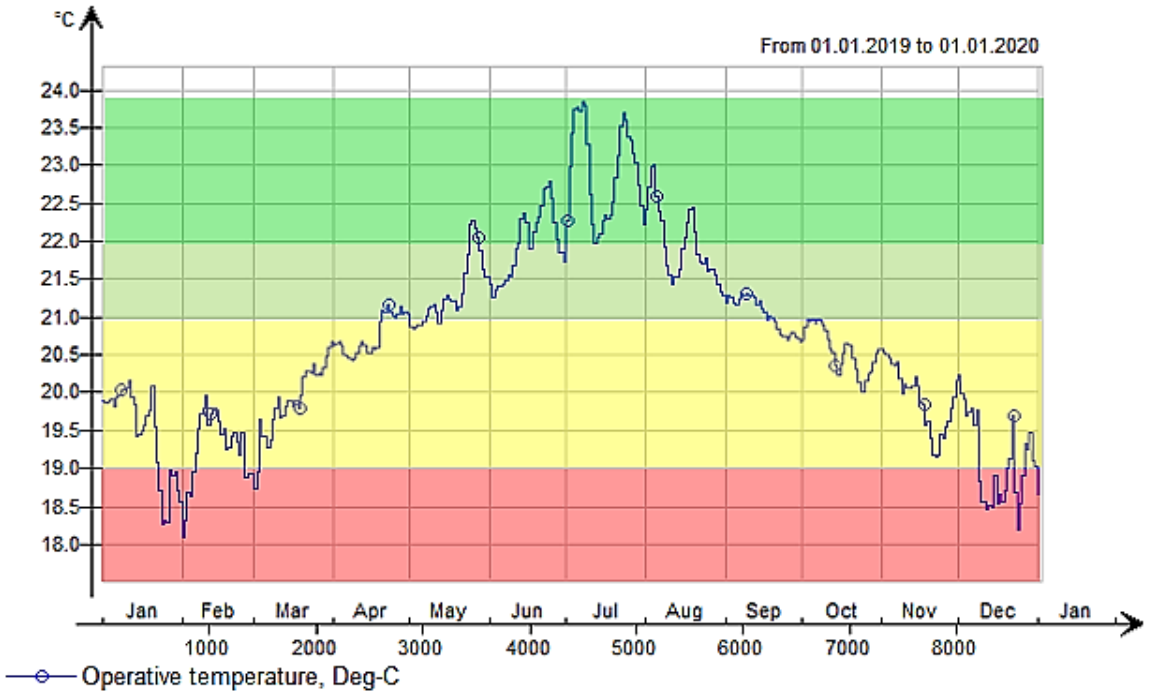

Figure 30. Annual operative temperature alteration in library zone

According to Figure 30, for the majority of time of a year operative temperature meet the conditions of categories A,B,C. During the end of January, the beginning of February and during December operative temperature in library zone is related to category D. As it can be seen from the graph operative temperature fluctuates near 19°C, related to category C. Therefore whole year operative temperature alteration is acceptable, because deviations from A,B,C categories are limited. Even though, operative temperature improvement suggestions should be considered.

Table 20 represents threshold values of operative temperature.

Table 20. Threshold monthly average values of operative temperature in library zone

Minimum	Maximum	Average
18,71°C	22,93°C	20,70°C

Minimum monthly average operative temperature relates to January, maximum refers to July.

Figure 31 illustrates the annual PMV and PPD alteration. Colored areas represent thermal comfort categories only for PPD. It is enough, because as it could be seen from the Literature chapter, PPD is calculated using PMV.

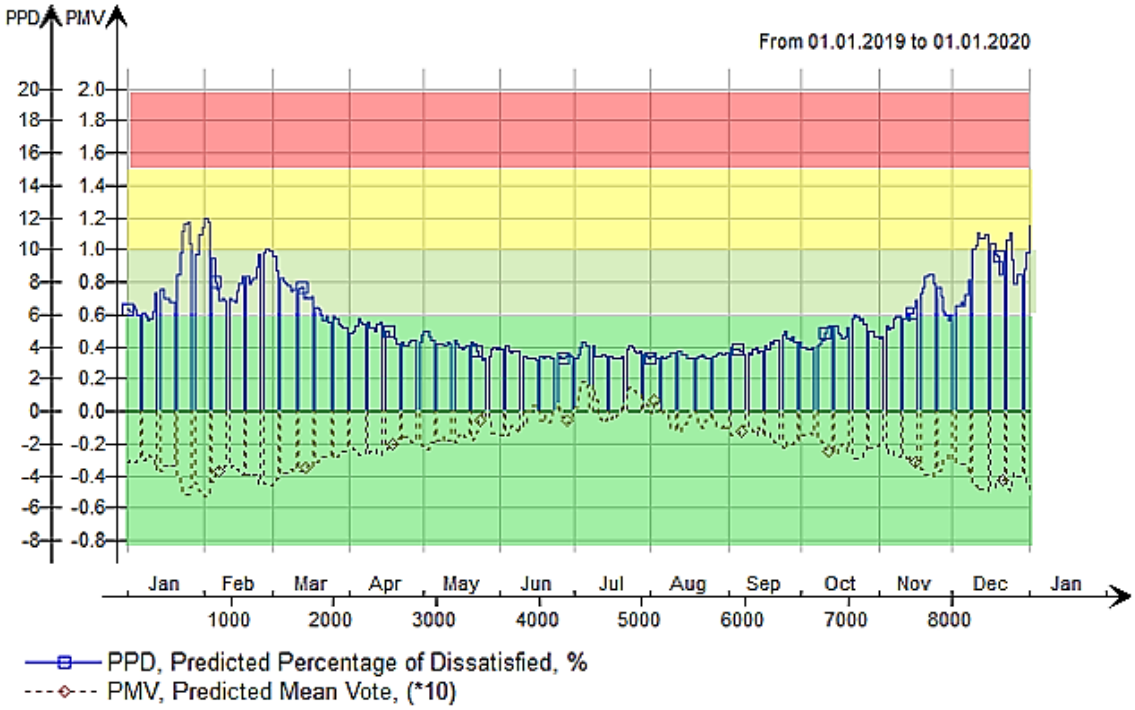

Figure 31. Annual PPD and PMV alteration in library zone

PPD index meets A and B categories for almost the year. Small fluctuations in category C are negligible, therefore people are predictably satisfied with the indoor environment.

Table 21 represents threshold values of PMV and PPD.

Table 21. Threshold monthly average values of PMV and PPD in library zone

	Minimum	Maximum	Average
PPD	2,89%	11,46%	4,81%
PMV	-0,51	0,05	-0,19

In the end of January PPD reaches its' maximum value of 11.46%. Even though it is relatively low number. PMV values nearby zero illustrates human perception of indoor environment as neutral.

4.2.2 Office zone

Figure 32 illustrates the annual operative temperature alteration in office K118 area.

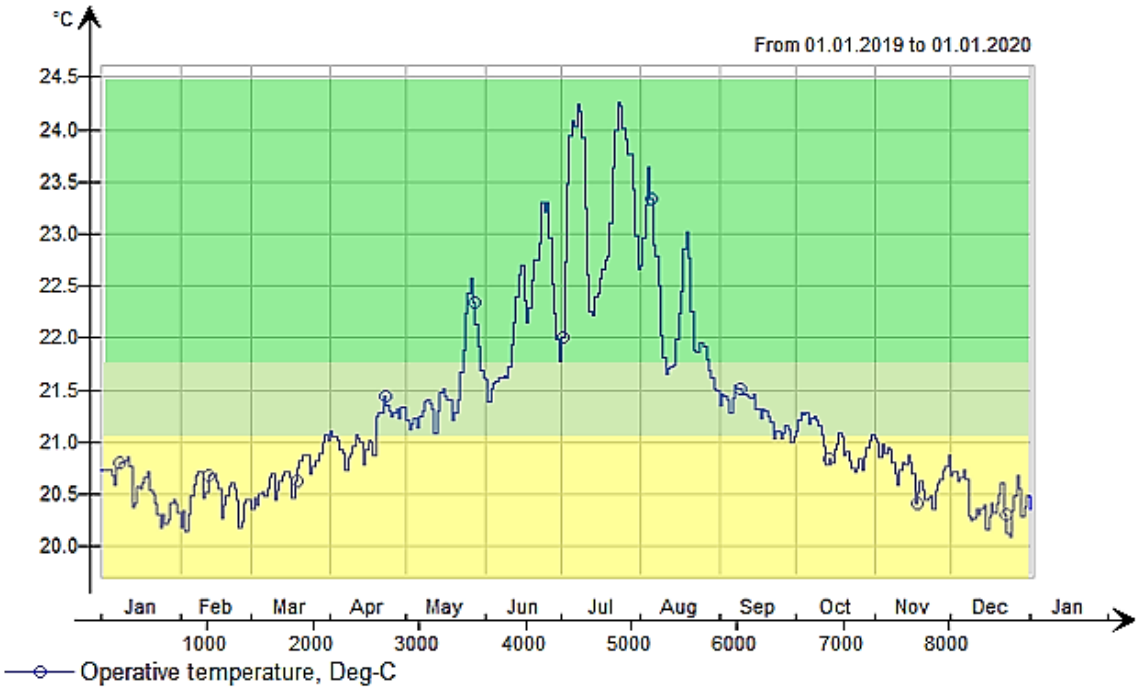

Figure 32. Annual operative temperature alteration in office zone (office K118)

Winter and autumn months are primarily related to B,C categories, when the summers months refers to category A. Therefore, operative temperature within the office representative zone meets the indoor environmental requirements.

Table 22 represents threshold values of operative temperature.

Table 22. Threshold monthly average values of operative temperature in office zone (office K118)

Minimum	Maximum	Average
20.37°C	23.3°C	21.3°C

Figure 33 illustrates the annual PMV and PPD alteration in office K118 area.

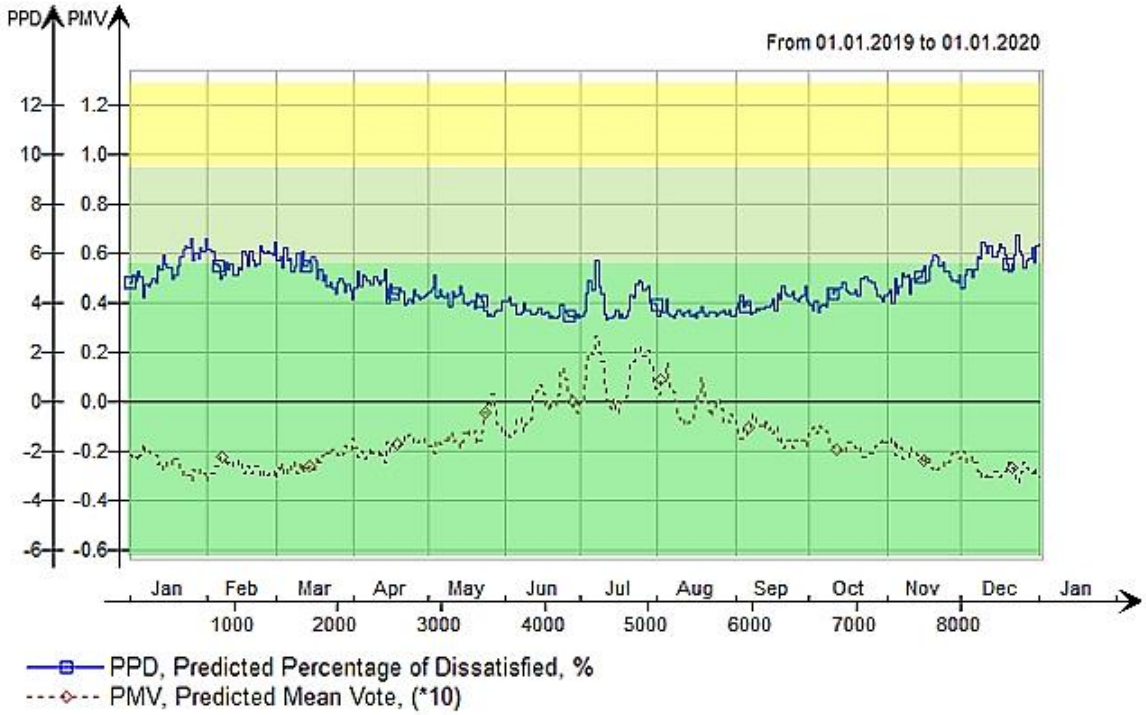

Figure 33. Annual PPD and PMV alteration in office zone (office K118)

Predicted percentage of people dissatisfied with the indoor environmental conditions is the lowest among all representative zones. For the whole year it meets requirements of category A.

Table 23 represents threshold values of PMV and PPD.

Table 23. Threshold monthly average values of PMV and PPD in office zone (office K118)

	Minimum	Maximum	Average
PPD	3,57%	6,31%	4,61%
PMV	-0,31	0,11	-0,15

The maximum PPD is 6,31%. Even this value is quite low it is referred to category B – normal level category.

4.2.3 Studying zone

Figure 34 illustrates the annual operative temperature alteration in studying zone.

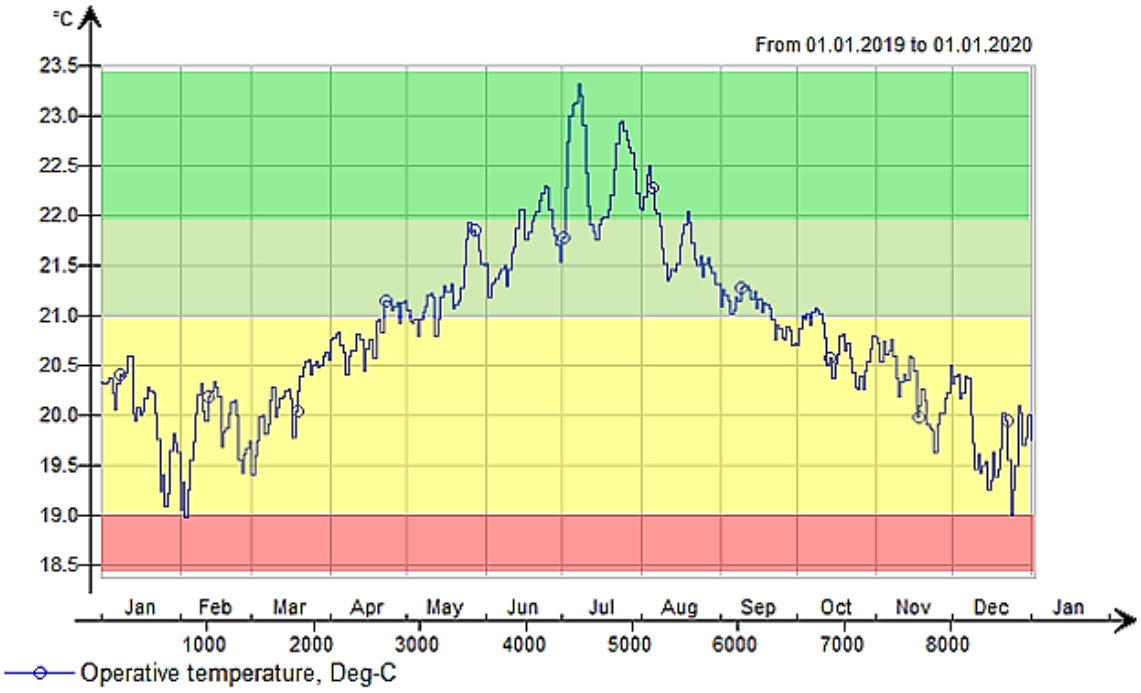

Figure 34. Annual operative temperature alteration in studying zone

Time period from January to April and from September to December lies within category C. Sensitive and sick people may predictably feel uncomfortable due to low temperature.

Table 24 represents threshold values of operative temperature.

Table 24. Threshold monthly average values of operative temperature in studying zone

Minimum	Maximum	Average
19,75°C	22,46°C	20,83°C

Figure 35 illustrates the annual PMV and PPD alteration in studying zone.

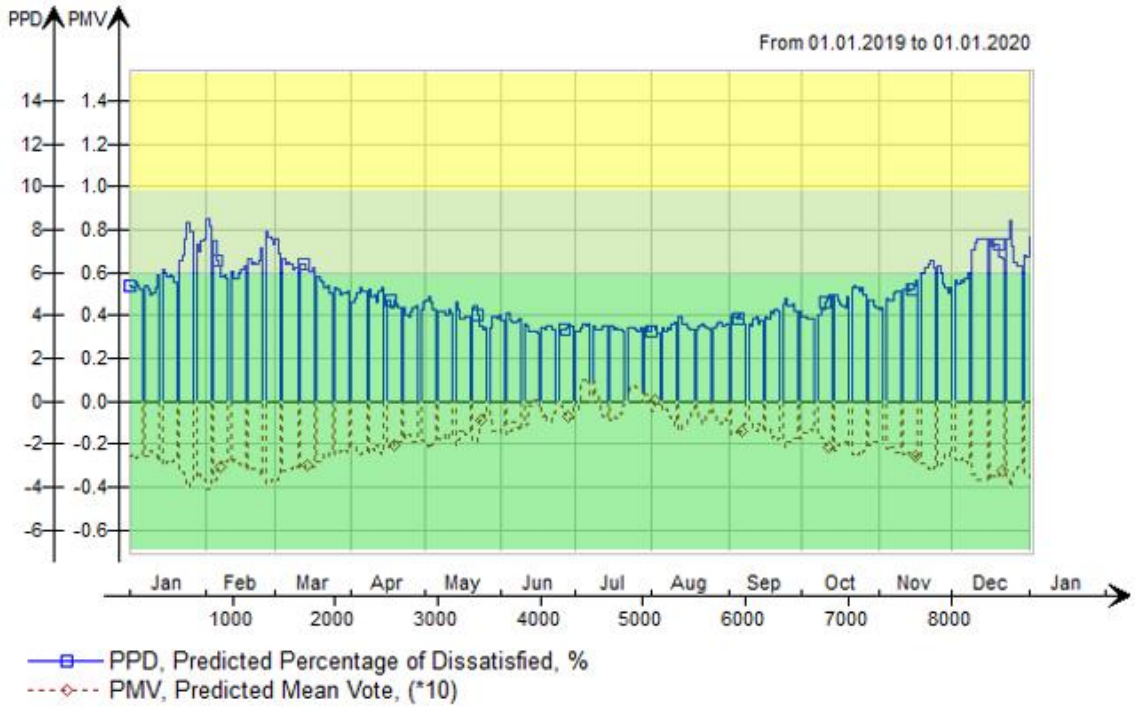

Figure 35. Annual PPD and PMV alteration in studying zone

As in the office zone PPD index in studying zone changes within A-B categories. Therefore, thermal conditions indoors are clearly acceptable.

Table 25 represents threshold values of PMV and PPD.

Table 25. Threshold monthly average values of PMV and PPD in studying zone

	Minimum	Maximum	Average
PPD	2,92%	7,71%	4,21%
PMV	-0,37	0,01	-0,17

Maximum monthly average value is reached at winter time. Though, it is acceptable as well.

4.3 Subjective questionnaire

Library environmental quality questionnaire can be found in Appendix 1. Twenty people of different age were asked about their perception of indoor environmental quality in library. Three of them were librarians, when the others were common visitors, primarily students. The results of the questionnaire are represented further.

Figure 36 illustrates how occupants' thermal perception is distributed. It is given in percent.

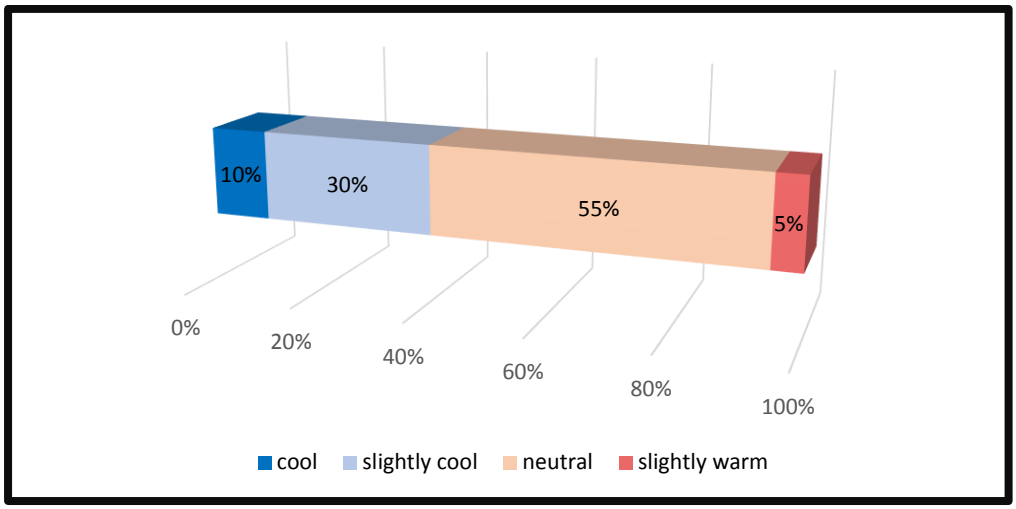

Figure 36. Distribution of thermal sensation vote, %

The distribution shows that 55% of people treat indoor thermal quality as neutral. 40% of interviewed finds the environment cool and slightly cool. In this case operative temperature is an issue to be reviewed.

Figure 37 shows how acceptable is the thermal environment for visitors and staff.

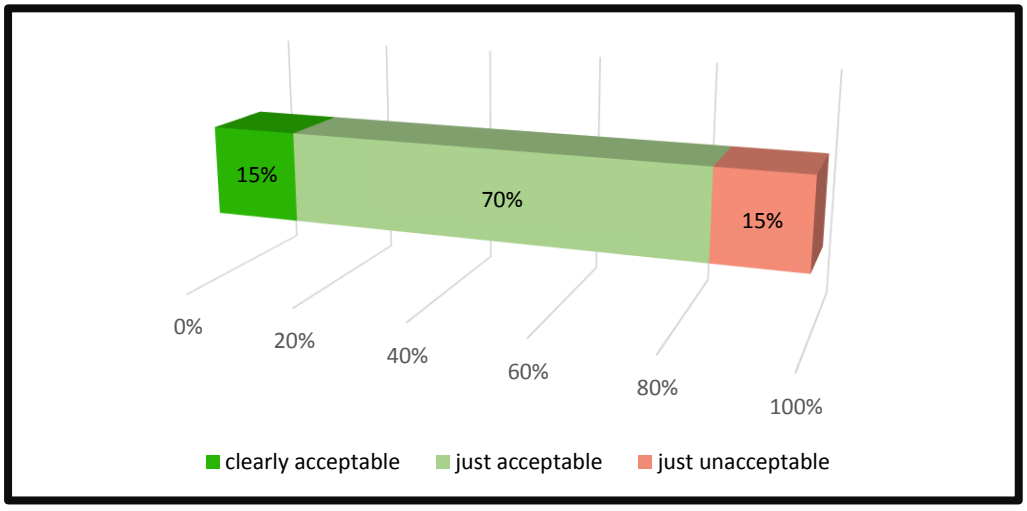

Figure 37. Acceptability of thermal environment, %

According to Figure 37 only 15% of people treat the library thermal environment clearly or fully acceptable. Other 15% are not satisfied. If we categorize this library thermal environment basing on the percent of people dissatisfied, in accordance with EN 15251 categories, it is category C (acceptable).

Figure 38 illustrates what is the air temperature preference of visitors and staff.

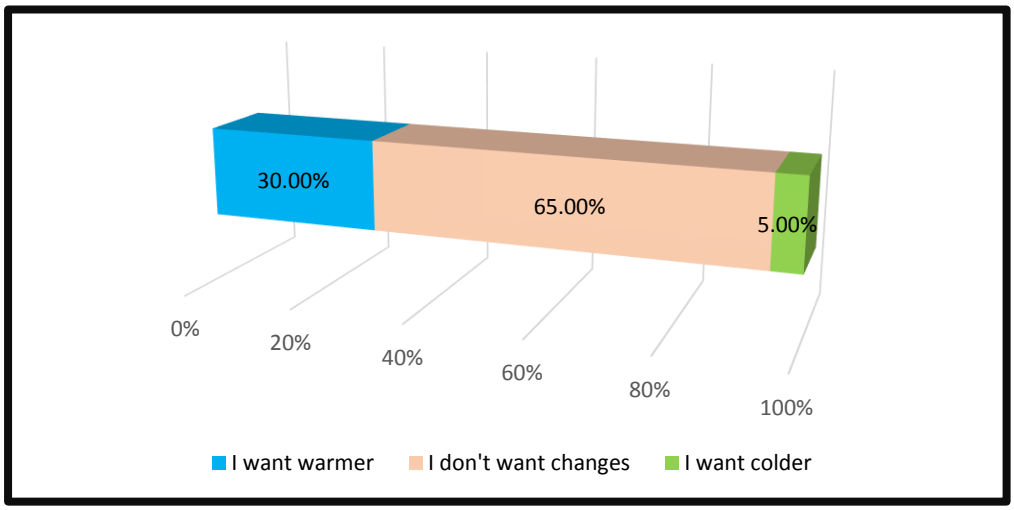

Figure 38. Distribution of air temperature preference, %

As the figure 38 shows, 35% of people want some regulations to be made with air temperature indoors. This value is considerably higher than the designed expectation level of dissatisfied persons.

Figure 39 represents local cooling (or draft) presence from occupants' point of view.

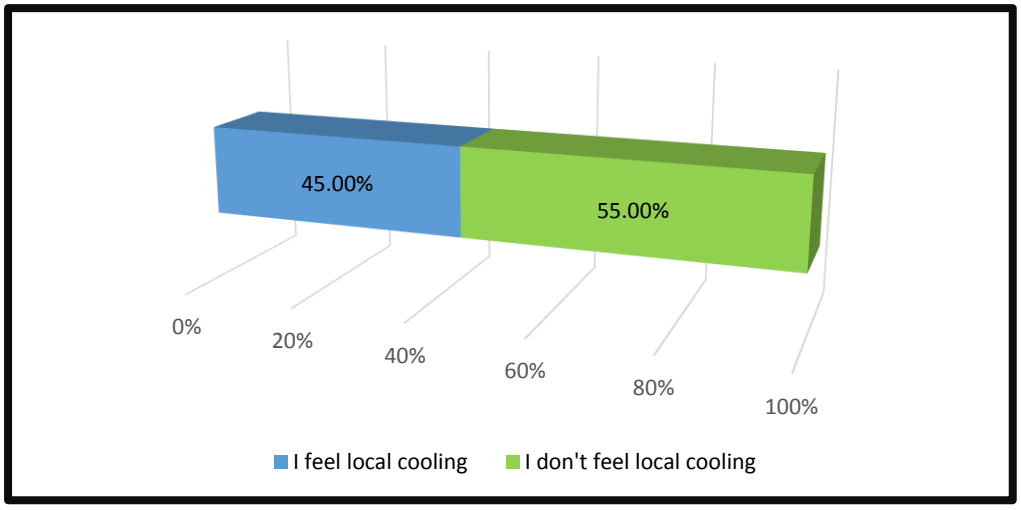

Figure 39. Local cooling (draft) perception, %

According to Figure 39, 45% of people feel draft. This significant value refers to category D. It means that such indoor environmental conditions are acceptable for only limited period of time. It is necessary to mention, that all interviewed librarians had complained about undesirable presence of draft, especially in office K118. All these leads to the inference that the indoor environment should be corrected to decrease draft and therefore increase visitors' and staff' acceptability with indoor conditions.

Figure 40 shows the presence of vertical air temperature difference from occupants' perspective.

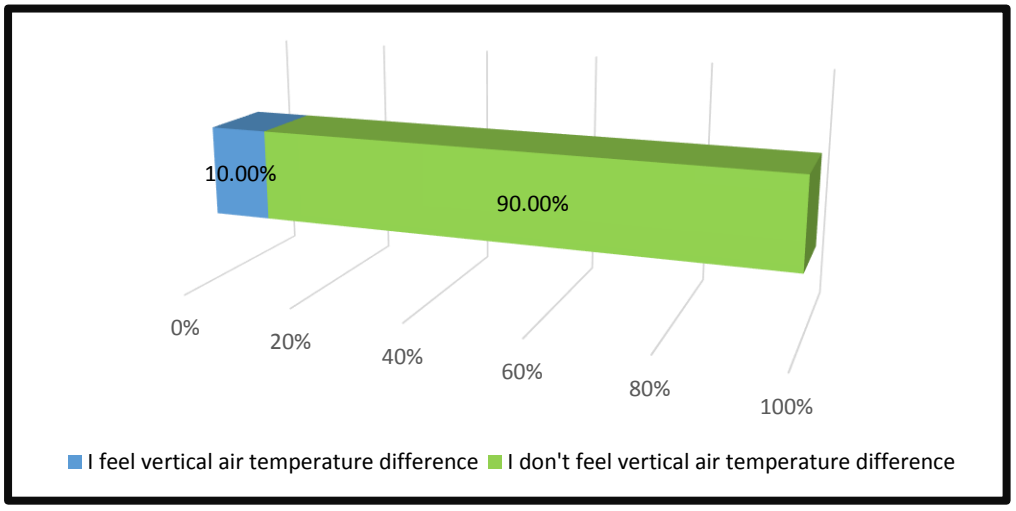

Figure 40. Vertical air temperature difference perception, %

Only a few people voted for presence of vertical air temperature difference. 10% of people dissatisfied is related to category C. This value meets the requirements of thermal quality.

Figure 41 illustrates how acceptable is the floor temperature for visitors and staff.

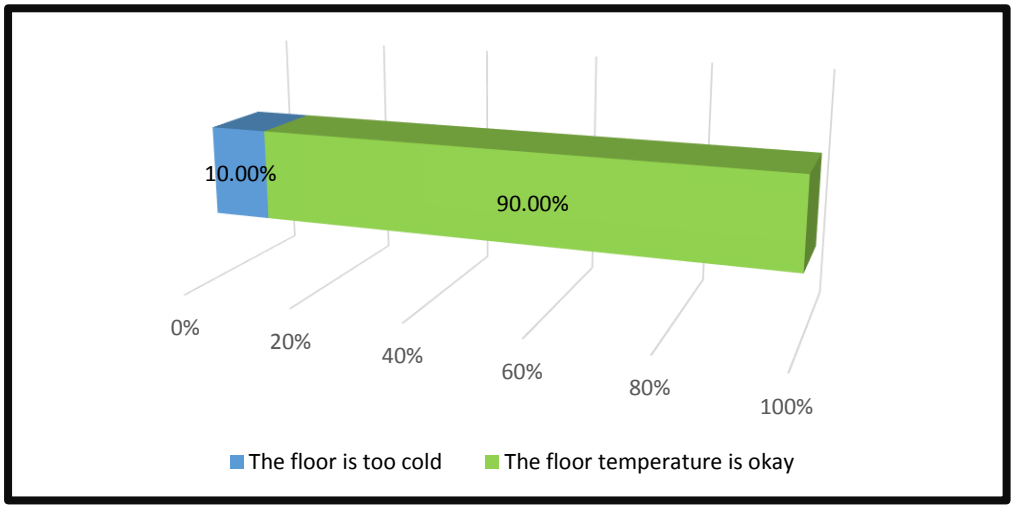

Figure 41. Floor temperature perception, %

Floor temperature is perceived as unacceptable among 10% of people. Related to this percent category A means that local discomfort due to cool floor is not felt by the majority of people, even by old sensitive humans and sick visitors. Any changes related to floor temperature are not necessary.

Figure 42 illustrates the surface temperature sensation by visitors and staff.

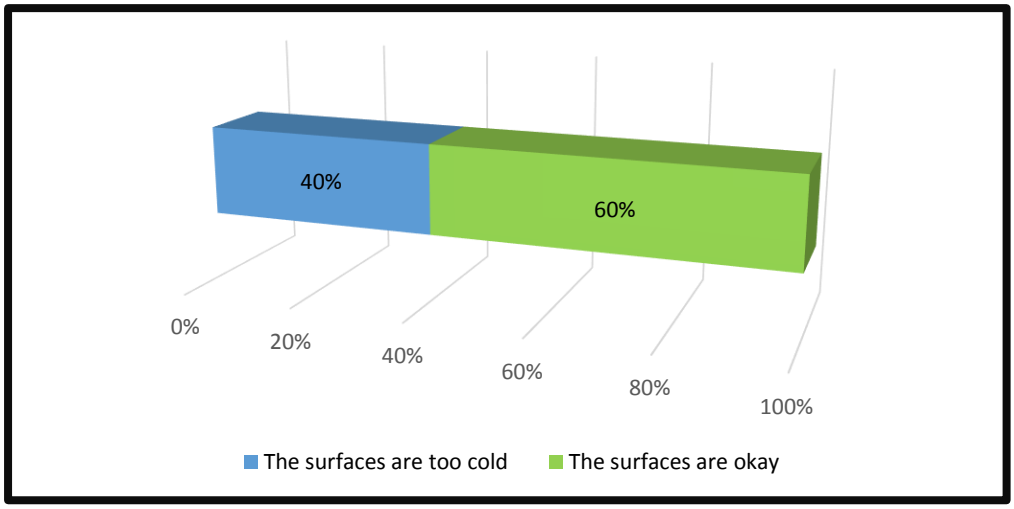

Figure 42. Surface temperature perception, %

Radiant asymmetry mainly represented by cold surfaces (external walls and windows) is perceived by 40% of interviewed people. Cold surfaces are mainly located near the student table measuring point and in the office representative zone. 40% of people dissatisfied relates to category D of thermal environment.

5 DISCUSSION

As the result of the research answers on main questions were obtained. In terms of library collection preservation, the campus library collection is mainly safe. Average temperature was found as 22°C and RH 25%. Mold growth potential doesn't present. It is shown by the measurements' results in library zone.

In terms of human thermal comfort, analysis of results of measurements, simulation and subjective questionnaire are presented further. *Library representative zone* thermal comfort is generally acceptable and meet the requirements of thermal categories A,B,C of EN 15251 /7/. Drawback of this zone is student table, located near the cool surface. Radiant temperature asymmetry local discomfort may take place at this location. Moreover, low operative temperature in winter time (gathered from simulation) corresponds to Category D of thermal comfort.

Office representative zone measurements illustrated perfect thermal environment conditions. Even though all librarians had complained about the presence of draft

and cool indoor temperature at winter time. It justifies the choice of methods applicable for current investigation: measurements and survey. The opinion of real people is much more important than calculated indices, that just predict the percentage of people dissatisfied with thermal environment.

Computer class representative zone generally meets requirements of thermal categories A, B, C and therefore doesn't require any indoor environmental changes.

The findings suggest to correct thermal environment. As it was mentioned in previous chapters librarians had complained about the presence of the draft in their offices and low air temperature during the winter time. Simulation also showed the fall of operative temperature during winter months, that may lead to draft growth. If we decrease the air flow rates and rise the supply air temperature in this office the warmer indoor air may be considered drier. One of the way to prevent draft distribution in this case is to change the type of the air terminal device or just readjust its' position. The distribution of the supply air in this room can be modelled with Autodesk CFD software in order to find out the best-suited solution, that will be both comfortable for librarians and energy efficient.

Further studies might be related to applicable ways of draft removing. Possible ways to decrease the draft rate should be thoroughly studied. Moreover, the studies might be related with issues with regards to designing a new library building. What ventilation system to choose? CAV or VAV is applicable for library building? How to maintain the desired conditions indoors? As it is already known how to evaluate the thermal environment, the way of designing the new one is a question of importance.

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LIST OF FIGURES

LIST OF TABLES

Appendix 1/2

Library environmental quality questionnaire

Please, circle your age: 0-18 18-24 25-39 40-54 55-100

1. How do you rate your thermal sensation in this library? Choose one answer.

a) hot
b) warm
c) slightly warm
d) neutral
e) slightly cool
f) cool
g) cold

2. How do you perceive (feel) the temperature in this library? Choose one answer

a) clearly acceptable
b) just acceptable
c) just unacceptable
d) clearly unacceptable

3. Do you want air temperature to be? Choose one answer.

a) higher
b) no change
c) lower

4. Do you feel local cooling of your body (near the neck for example)?

a) yes
b) no

5. Do you feel vertical air temperature difference in this building?

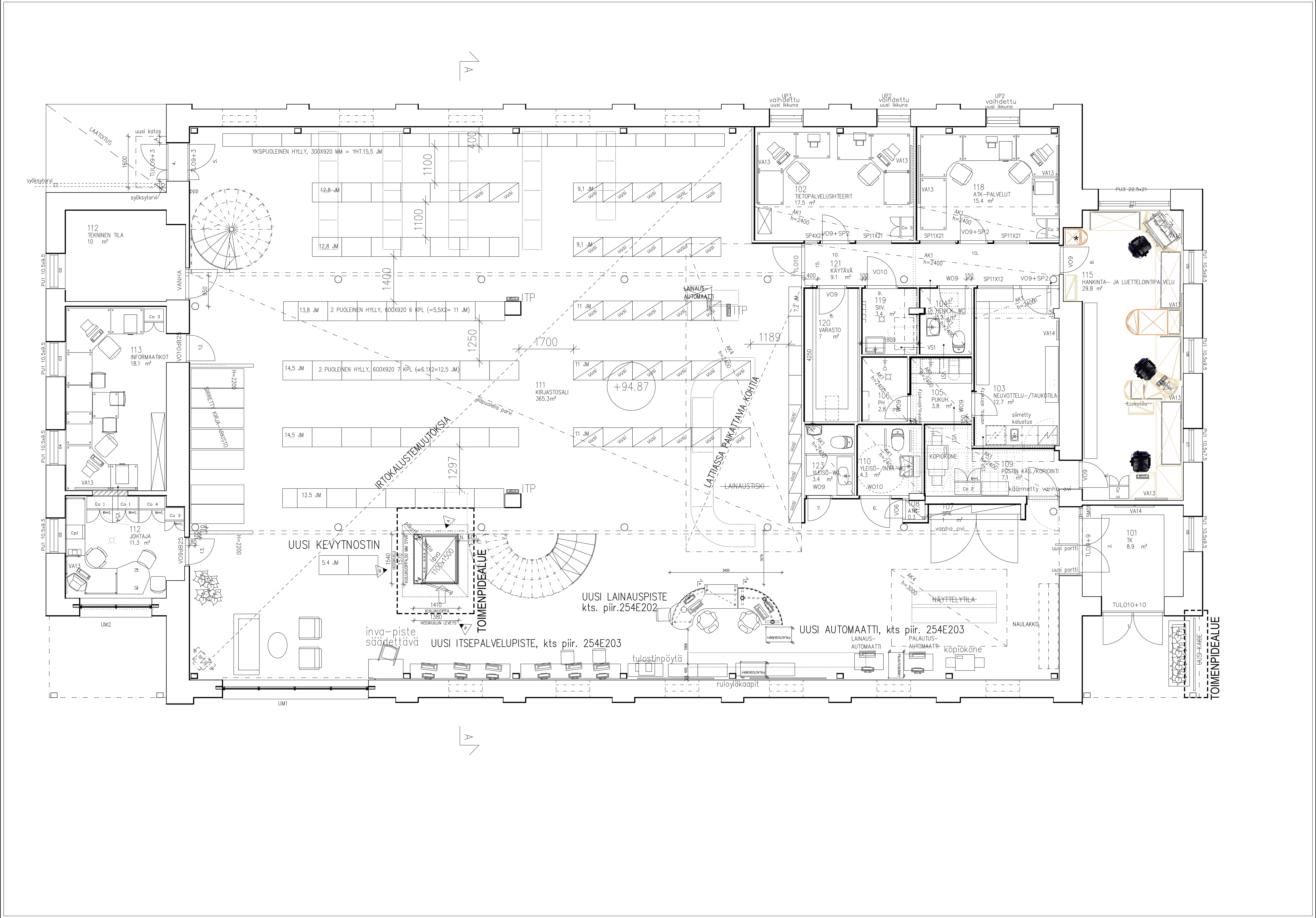
a) yes
b) no

6. Do you think that the floor is too cool in this building?

a) yes
b) no

7. Do you think that the surface next to you are cold and make you feel uncomfortable (walls, windows)?

a) yes
b) no



LAAJUUSTIEDOT 1. KERROS

KERROSALA	625 kem2
BRUTTOALA	625 brm2
HUONEISTOALA	546 hum2
TILAVUUS, KOKO RAKENNUS	3510 m3

VUODEN 2009 MUUTOSTYÖ:
IRTOKALUSTEMUUTOKSIA 260 M2 ALUEELLA
RAKENTEELLISIA MUUTOKSIA NOIN 5 M2 ALUEELLA

RAKENTAMIS AIK.MUUTOKSET

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A	11.01.2010	SIIRRETTY HISSIÄ, POISTETTU HISSIN UPOTUS VÄLIPOHJAAN	MLu

Kaupunginosa/kylä: 5
Kortteli/tila: 27
Tontti/Rn:o: 2
Viranomaisten arkistointimerkintöjä varten

Rakennustoimenpide: MUUTOS
Piirustuslaji: TEKNINEN PIIRROS

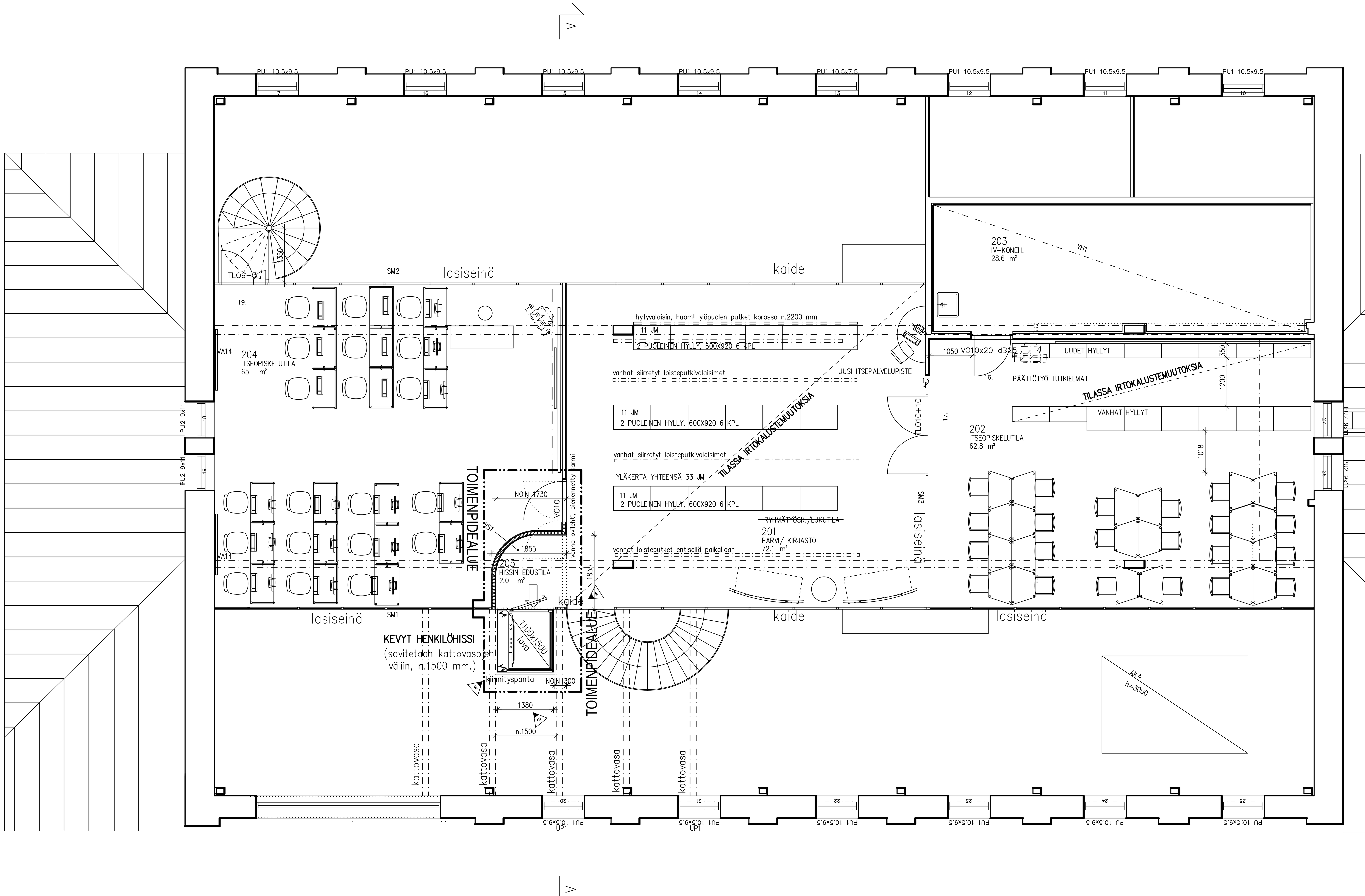
Rakennuskohteen nimi ja osoite:
MIKKELIN AMMATTIKORKEAKOULU
KASARMIN KAMPUKSEN MUUTOSTY¥ T 2009
KAMPUSKIRJASTO
PATTERISTONKATU 3
50100 MIKKELI

Piirustuksen sisältö: POHJAPIIRROS 1 KRS
Mittakaavat: 1:50

ARKKITEHTITOIMISTO HEIKKI KIRJALAINEN OY
Porrassalmenkatu 21 A 50100 MIKKELI
www.ark-kirjalainen.fi
p. 015-161869 fax. 015-161856
toimisto@ark-kirjalainen.fi

Piirtäjä: KP-R/MLu
Suunnittelija: MLu/HK
Tiedosto: G:\Kuvaark9\330 MKS hankkeet 2009\Ty piirustukset\MKS_ARK_POHJA_K_KRS.dwg
Päiväys: 10.12.2009
Vastuullinen suunnittelija: HK
Suunnitteluala, työnumero ja piirustusnumero:

ARK 254 T 102



LAAJUUSTIEDOT 2. KERROS

KERROSALA	263 kem2
BRUTTOALA	263 brm2
HUONEISTOALA	249 hum2

VUODEN 2009 MUUTOSTYÖ:
IRTOKALUSTEMUUTOKSIA 83 M2 ALUEELLA
RAKENTEELLISIA MUUTOKSIA NOIN 4 M2 ALUEELLA

RAKENNUS AIK.MUUTOKSET

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A	11.01.2010	SIIRRETTY HISSIÄ, POISTETTU HISSIN VÄLIPOHJAUPOTUS	MLu

Kaupunginosa/kylä: 5
Kortteli/tila: 27
Tontti/Rn:o: 2
Viranomaisten arkistointimerkintöjä varten

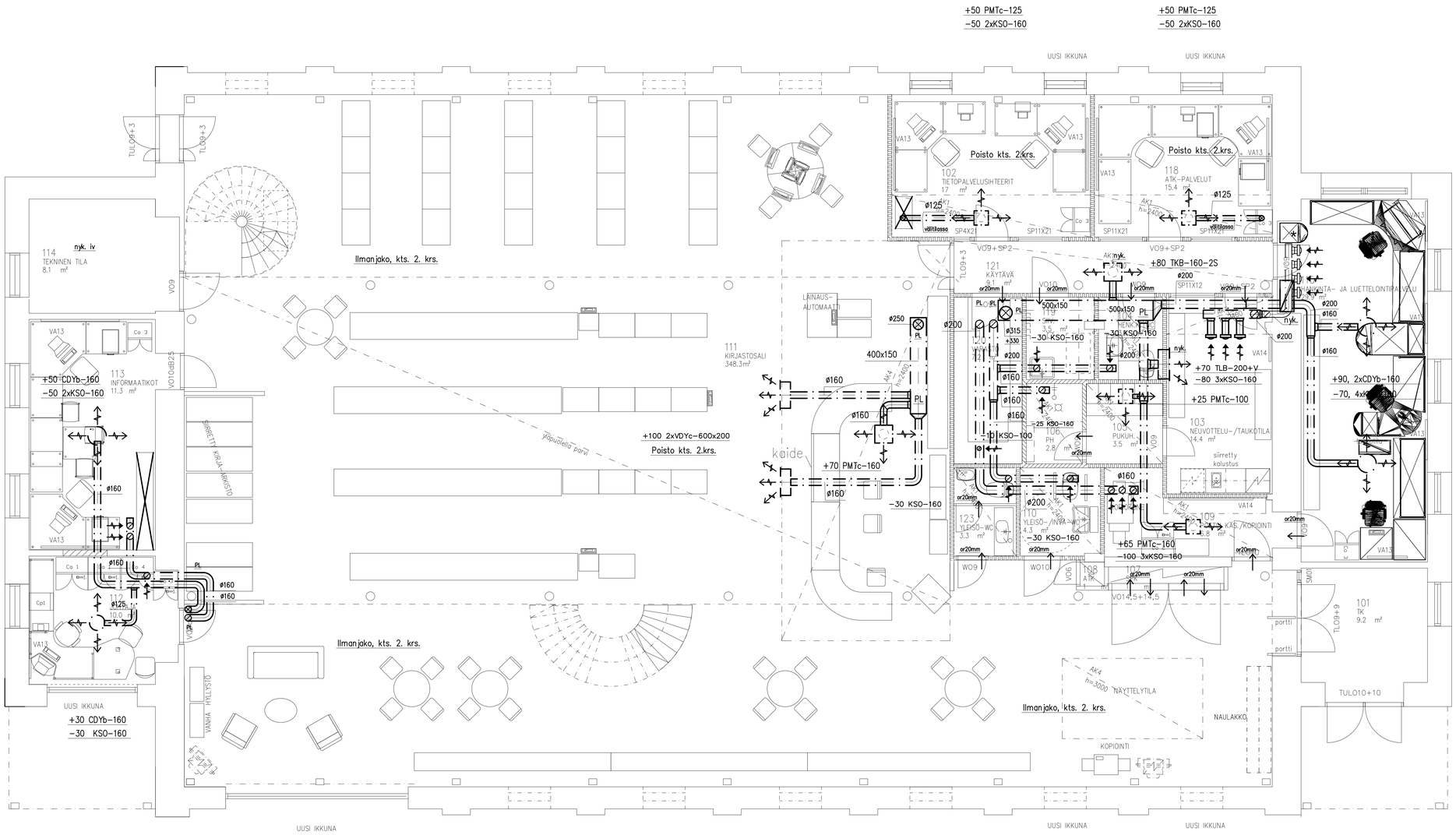
Rakennustoimenpide: MUUTOS
Piirustuslaji: TEKNINEN PIIRROS

Rakennuskohteen nimi ja osoite:
MIKKELIN AMMATTIKORKEAKOULU
KASARMIN KAMPUKSEN MUUTOSTY¥T 2009
KAMPUSKIRJASTO
PATTERISTONKATU 3
50100 MIKKELI

Piirustuksen sisältö: POHJAPIIRROS 2 KRS
Mittakaavat: 1:50

ARKKITEHTITOIMISTO HEIKKI KIRJALAINEN OY
Porrassalmenkatu 21 A 50100 MIKKELI
www.ark-kirjalainen.fi
p. 015-161869 fax. 015-161856
toimisto@ark-kirjalainen.fi

Piirtäjä: KP-R/MLu
Suunnittelija: HK
Tiedosto: G:\Kuvaark9\330 MKS hankkeet 2009\Ty piirustukset\MKS_ARK_POHJA_K_KRS.dwg
Päiväys: 10.12.2009
Vastuullinen suunnittelija: HK
Suunnitteluala, työnumero ja piirustusnumero: **ARK 254 T 103**



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Rakennustoimenpide: Muutos		Piirustuslaji: LVI
Rakennuskohteen nim. ja osoite: MIKKELIN AMMATTIKORKEAKOULU KAMPUSKIRJASTO Patteristonkatu 3, 50100 MIKKELI		Piirustuksen sisältö: 1. kerros Ilmanvaihto
Suunnittelijan nim. pätevyys ja yhteystiedot: LVI-INSINÖÖRITOIMISTO U. MOISALA OY Muurarinkatu 5A3 50100 MIKKELI Puh. 015-212363, Fax 212393 20.4.2005 Urho Moisala		Suunnitteluala, työn no ja piirustuksen no: LVI - 05 813 - 6
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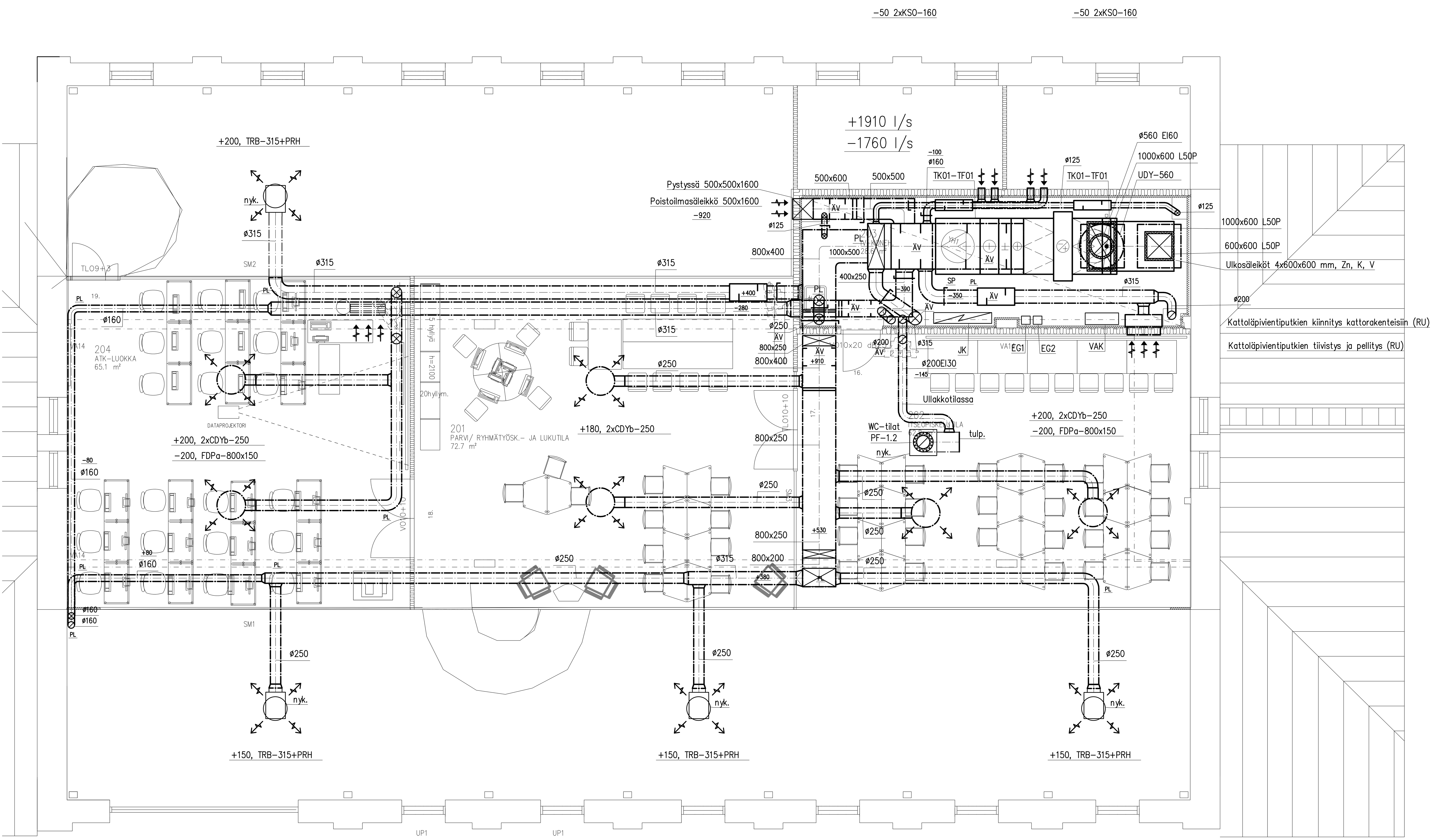

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Rakennuskohteen nimi ja osoite MIKKELIN AMMATTIKORKEAKOULU KAMPUSKIRJASTO Patteristonkatu 3, 50100 MIKKELI	Piirustuksen sisältö 2. kerros Ilmanvaihto — Mittakaavat 1:50
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