Nafigate window screen
- Thermal comfort analysis
Research report

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14. 11. 2018

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UNIVERZITNÍ CENTRUM ENERGETICKY EFEKTIVNÍCH BUDOV

OBSAH

Colophon:

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- Thermal comfort analysis

Research report

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14. 11. 2018

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1 SUBJECT

Introduction information

Customer:	NAFIGATE a.s.
Address:	Sokolska 1365, 46001
	Liberec, Czech Republic
IČ:	24166855
Web:	http://www.nafigate.com
Represented by:	Baturalp Yalcinkaya
Contact:	email: baturalp.yalcinkaya@nafigate.com

Testing laboratory:	Czech Technical University in Prague,
	University centre for energy efficient buildings
Address:	Třinecká 1024, 273 43 Buštěhrad
IČ:	6840770
DIČ:	CZ68407700
Web:	www.uceeb.cz
Responsible person:	Ing. Daniel Adamovský, Ph.D.

Subject: This report summarizes the results from the thermal comfort assessment in the room with the Nafigate screen. Measurements were made in the contractor's climatic chamber, where it is possible to simulate real climatic conditions. The report consists of two parts. In the first part the air flow is analyzed using PIV anemometry. In the second part, thermal comfort in the room is assessed.

1.1 Introduction

This report summarizes the results of the thermal comfort assessment in a room equipped with a Nafigate window screen. The assessment is carried out in the climatic chamber of the contractor, where it is possible to simulate real climatic conditions.

The report consists of two parts. In part one, the air flow is analyzed using PIV anemometry near the window. In the second part, thermal comfort in the room is assessed using an thermal manikin.

2 METHODOLOGY

2.1 Methodology of experiments

2.1.1 Measure situation

The measurements were carried out in one boot of the climatic chamber of the University Center of Energy Efficient Buildings of CTU in Prague. Climatic chamber is a room in which the temperature can be adjusted to simulate the real conditions of the buildings during summer and winter. All measurements were made at a steady state when the interior temperature was 21 ° C and the interspace temperature reached 1 ° C. The Nafigate window screen was installed from the outside on the window frame. The window has been tilted all the time (ventilation position). The wind was taken into account by the fans. The fans were installed in front of the window. During the measurement, the climatic chamber was heated by underfloor heating or the electric radiant panel installed under the window. The air flow was measured immediately in front of the window. The thermal comfort assessment was done by thermal manikin sitting in the center of the room. The following 5 measurements were taken in total:

1) Underfloor heating - without the influence of wind,
2) Underfloor heating - with the influence of wind,
3) The radiator under the window - without the influence of wind,
4) The radiator under the window - with the influence of wind,
5) The radiator under the blind mesh window.

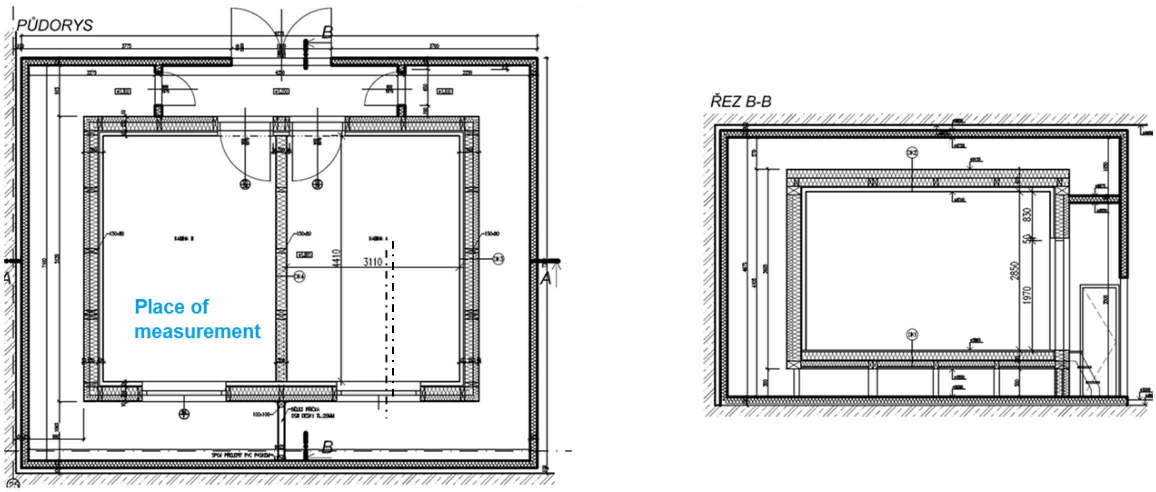

Figure 2-1 Place of measurement

2.1.2 Measured sample

The detail of the Nafigate window screen is shown in Fig. 2-2. The mesh consists of 3 layers in total:

1) Support base (plastic mesh)
2) a nanomaterial filter layer,
3) Fine protective fabric.

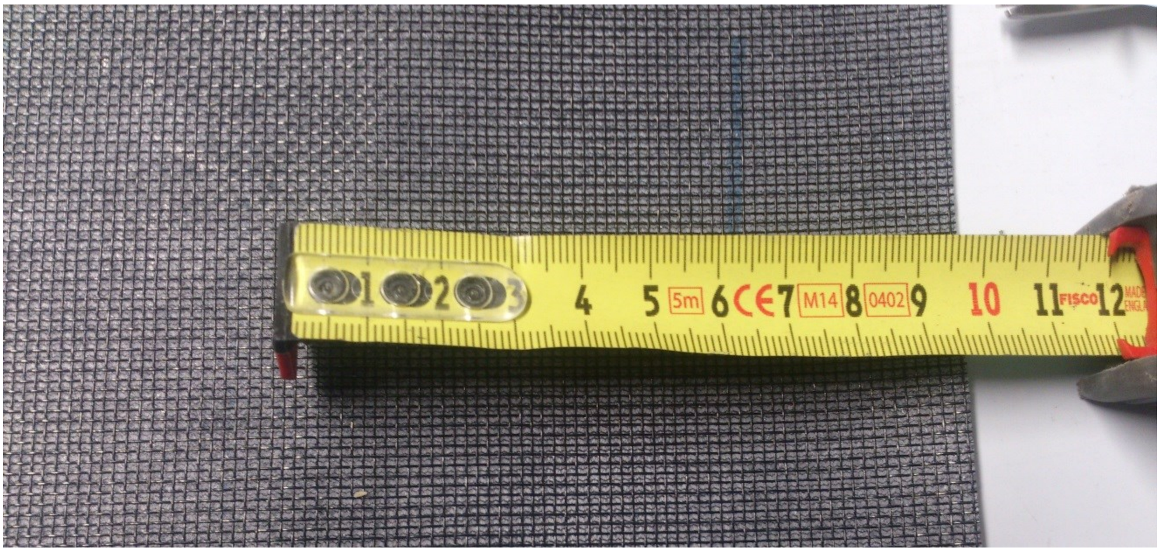

Figure 2-2 Nafigate window screen - view of the measured sample

2.1.3 Air flow measurement procedure

Method used

Particle image velocimetry (PIV) is an optical method of flow visualization. It is used to obtain instantaneous velocity measurements and related properties in fluids. The fluid is seeded with tracer particles which, for sufficiently small particles, are assumed to faithfully follow the flow dynamics. The fluid with entrained particles is illuminated so that particles are visible. The motion of the seeding particles is used to calculate speed and direction (the velocity field) of the flow being studied.

The LaVision system was used for measurement. This system consists of the following main components:

- Pulse laser Nd: YAG Litron NANO TLR PIV, 15 Hz, 325 mJ,
- ImagerPro X11M with 11 MP (4008 x 2672) resolution at 2.4 Hz with a NIKON 50 mm (f / 1.4) lens,
- PC equipped with synchronization unit and DaVis 8.2 software.

Oily particles (particle size of about 2 μm) were used as marker particles. The generator from La vision was used to disperse the particles.

The cross-correlation method was used to evaluate the images; the window size was 48x48 pixels with a 50% overlap. The full resolution of the cameras was used for scanning at a maximum scan rate of 2.4 Hz (number of double frame images).

Due to the type of flow that was turbulent and thus very variable in time, vector arrays are further represented by the average of more recorded double frame images. For the results presented here, 80 double frame images were used (corresponding to real time approx. 33 s).

Measuring position

The flow rates were evaluated in a plane perpendicular to the window. The measuring plane (laser beam) passed through a gap between the window and the wall. The width of the slot was 20 mm, the measuring plane passing through its center. The measurement area had dimensions of 400 x 575 mm. Besides the air flow rates, the following temperatures (° C) were also measured:

- t_{ex} - the temperature of the exterior (interspace),
- t_1 - the temperature between the window sill and Nafigate window screen - the top half,
- t_2 - the temperature between the window sill and the Nafigate window screen - the lower half,
- t_3 - the temperature at the edge of the windowsill at the location of the measured plane,
- t_{globe} - the temperature of the spherical thermometer

The positions of the temperature sensors are shown in Fig. 2-3.

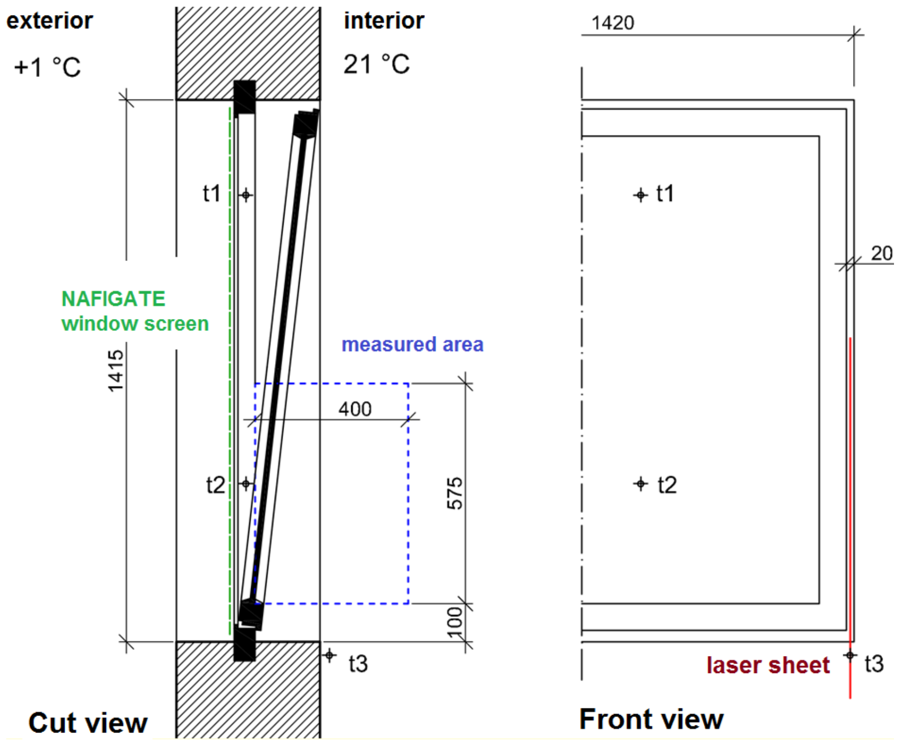

Figure 2-3 Position of the measuring plane and temperature sensors

To take into account the influence of the wind, a fan construction was installed in front of the window. In total, there were used 18 fans with a diameter of 120 mm. The air output of the fan was about 230 m^3/hour (total 4140 m^3/hour). Fans drained the bottom half of the window at a speed of about 3.5 m/s.

Figure 2-4 fans installed in front of the window

The measurement was extended by the variant where the Nafigate window screen was blinded from the outside by a plastic foil. This measurement was necessary to determine the flow of fresh (outside) air into the room.

Figure 2-5 Blinds the window with a plastic foil

2.1.4 Thermal comfort assessment procedure

The thermal comfort analysys was done using the thermal manikin. The manikin has 36 independently heated and measured zones (Newton by Thermetrics). It is a device for accurate analysis of thermal comfort in steady state conditions. The analysis is based on measure of heat exchange (convection, conduction and radiation body heat losses) in either direction of either the entire surface or in selected zones.

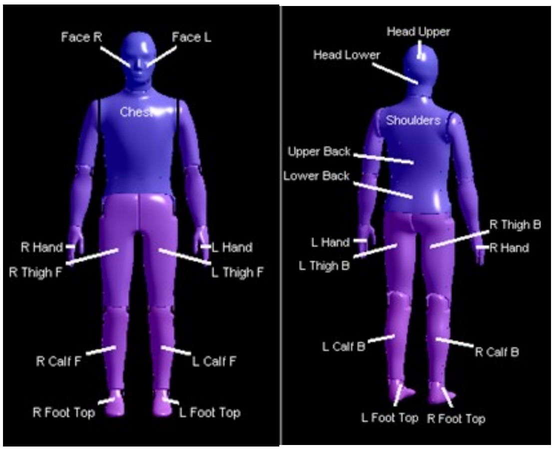

Figure 2-6 Manikin zones – Front side and back side

Experimental conditions represented seated person with a low activity, for example a person in a home environment sitting in a chair and reading his book. His clothing has thermal resistance 0.132 m^2.K/W (0.85 clo). Air temperature was maintained by heating system at 21 °C.

Auxiliary sensors of thermal comfort which are connected to the manikin and measure ambient environment were positioned for the mesurement. The thermal comfort sensors – four of temperature sensors were also positioned in stand next to the manikin.

Room preparation took place for every measurement to reach steady stated conditions. It took several hours for each state to balance the cabin. Then was gathered data and selected the appropriate part of the working measurement cycle to asses the thermal comfort. These parts were selected differently according to different boundary conditions:

- for steady state with closed window,
- for steady state with open window and the screen,
- for steady state with open window and without screen,
- for steady state with wind effect.

Principle

Calculation of the TMS index and its variants (TMS_o a TMS_z – thermal manikin sensation overall and zone) index was used to assess thermal comfort. This index represents detailed objective assessment for the body as whole and for its parts – zones.

Thermal manikin is suitable for measurement of thermal comfort in vehicles, airplanes and indoors. It has independently working (and measuring) zones and precise prediction of thermal sensation that´s why it can determine which body part senses discomfort and draught. These obtained values then help engineers to optimize and to model heating systems (and air conditioning systems) for the chosen type of operation.

The standard ČSN EN ISO 14505-2 is applicable to assess indoor environment. This standard was written purposely for indoor environment of vehicles but can be used for indoor conditions where there are only a few deflections from thermal neutrality. The assessment is based on equivalent temperature (ET) measurement. This ET incorporates independent influences of convection and radiation on thermal interchange of human body and its surroundings.

Equivalent temperature (ET)

ET describes level of thermal neutrality. To determine and calculate an equivalent temperature, it is suitable to use a thermal manikin whose surface is covered by separately controlled, heated zones. Consumption of energy during steady state is the rate of heat loss through radiation, convection and conduction. All measurements and regulation are carried out by a special software in a computer.

As the ET and the comfort zone diagram are not commonly used for indoor thermal comfort in the Czech Republic, it is more difficult to interpret the results. Therefore, the TMS index methodology was used.

Assessment of thermal comfort is based on TMS_o index (Thermal Manikin Overall Sensation) and TMS_z (Thermal Manikin Zone Sensation - Individual Zones) makes it possible to be compared with the predicted mean vote (PMV). In the Czech Republic we use commonly PMV to measure the overall thermal comfort of the indoor environment.

According to the definition of equivalent temperature (ET = t_{eq}), if the air temperature is equal to the mean radiant temperature $\overline{tr}$ and the air flow rate (air velocity) is zero, then $t_a = \overline{tr} = t_{eq}$. In this case, the equivalent temperature in the actual environment must give the same thermal sensation as the PMV index value according to standard ČSN EN ISO 7730.

$$TMS_{z,o} = \frac{(t_s - t_{eq} - R_{Ta} \cdot A_{MTV})}{R_{Ta} \cdot B_{MTV}}$$

where:

t_{eq} – ET calculated for individual comfort zones of the whole body [°C];

t_s – surface temperature of thermal manikin, (t_s = 35 °C) [°C];

R_{Ta} - the total thermal resistance of the thermal manikin, when the resistance was determined during thermal manikin calibration [(m^2·K)/W];

A_{MTV} – linear regression constant [W/m^2] according to Nilsson;

B_{MTV} - linear regression constant [W/m^2] according to Nilsson;

$TMS_{z,o}$ - index TMS_o for whole body and index TMS_z pro individual zones of thermal manikin [-].

In order to compare the PMV and $TMS_{z,o}$ index values, a scale of thermal sensations for the TMS_z index was created as shown in the following table (compared to the ASHRAE PMV index scale).

Table 2-1 Thermal sensation scale

PMV	ASHRAE	TMSz,o	Thermal sensation
3	hot	3	hot
2	warm	2	warm
1	slightly warm	1	slightly warm
0	neutral	0	comfortable
-1	slightly cool	-1	slightly cool
-2	cool	-2	cool
-3	cold	-3	cold

Explanation of graphical assessment

For a more comprehensible interpretation of the data is performed the evaluation on partial charts.

The first row represents a scale of values -3 to +3 where the index can range. The second row represents the value for the whole body TMS_o. The next 18 rows of the chart represent the TMS_z values for each zone. On the right side of the chart, there are names of each individual investigated zone listed.

The chart legend below the chart shows the thermal sensation of the manikin for operated heating system and the given boundary conditions. The boundary conditions were as follows: open window, closed window, wind effect and presence of the screen.

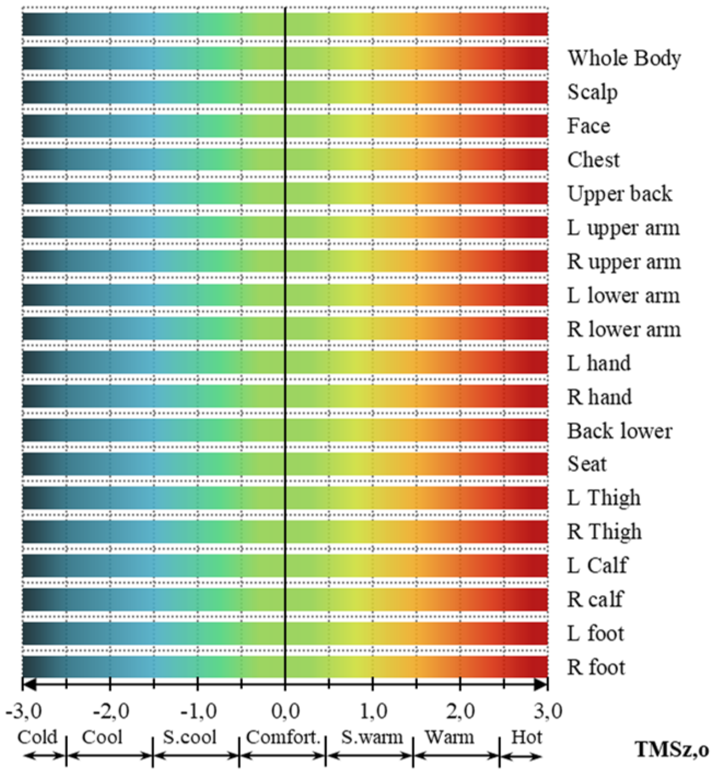

Figure 2-7 Explanation of the TMS assessment

The ideal result would be for each zone to reach a value in comfortable interval of -0.5 to +0.5. The best value in terms of thermal comfort would have been zero value in the middle of the chart in the area of light the green colour. The red color represents the hot sensation and blue one cold sensation. Both hot and cold sensations are undesirable.

Depending on the assignment, the evaluation focuses primarily on the sensation values for the calves and feet. It focuses on the last four rows in the assessment.

2.2 Measuring devices and sensors

Table 2 1 Summary of measuring devices

Description	Type	Range	Accuracy	SN.
Particle image velocimetry	LaVision Stereo PIV	0.01 till 20 m/s	by setting	KA14138
Datalogger	Datataker DT85-3	3 V	0,08 mV	106146
Air temperature sensor (2 pcs)	TG8-40, Pt 1000	-20 till 60 °C	0,21 °C	-
Surface temperature sensor (6 pcs)	TG7, Pt 1000	-20 till 60 °C	0,21 °C	
Electric input – 1 ph.	EKM 265	1,5 W - 2650 W	±1 %	-
Newton Thermal Manikin System	36 – Zone Thermal Manikin System	-20 to 50 °C	Temperature Sensors: ±0.1 °C Humidity: to ±3% RH. Heat Flux: to ±1%	501-73

3 RESULTS

3.1 Airflow analysis

3.1.1 Radiator under the window

The airflow rates reached up to 0.40 m/s. The highest speeds were reached at a height of about 400 mm above the windowsill. The velocity of the flow outside the air flow from the windowsill was about 0.075 to 0.1 m/s, and the temperatures in the space between window and Nafigate screen reached 18.1 °C and 10.3 °C.

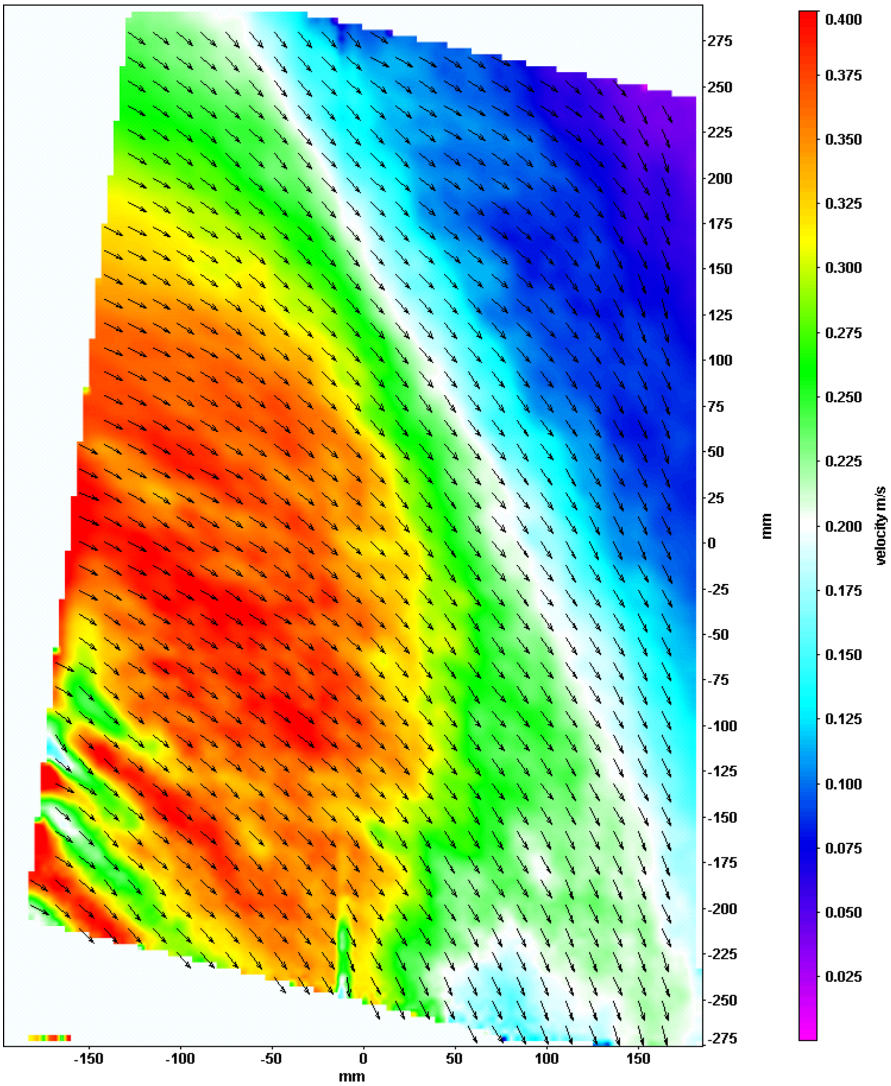

Figure 3-1 velocity field – Radiator under the window

Table 3 1 Temperatures during measurement

measurement	t_{globe} (°C)	t_1 front of the window screen - upper (°C)	t_2 front of the window screen - lower (°C))	t_3 at the windowsill (°C)	$t_{exterior}$ (°C)
Radiator under the window	21.4	18.1	10.3	18.4	1.0

3.1.2 Radiator under the window – with the influence of wind

Airflow rates reached up to 0.77 m/s. The highest speeds were reached at a height of about 500 mm above the windowsill. Unlike the wind-free version, the flow direction was more horizontal. Temperatures in the space between the window and the window screen reached 15.6 °C and 2.1 °C

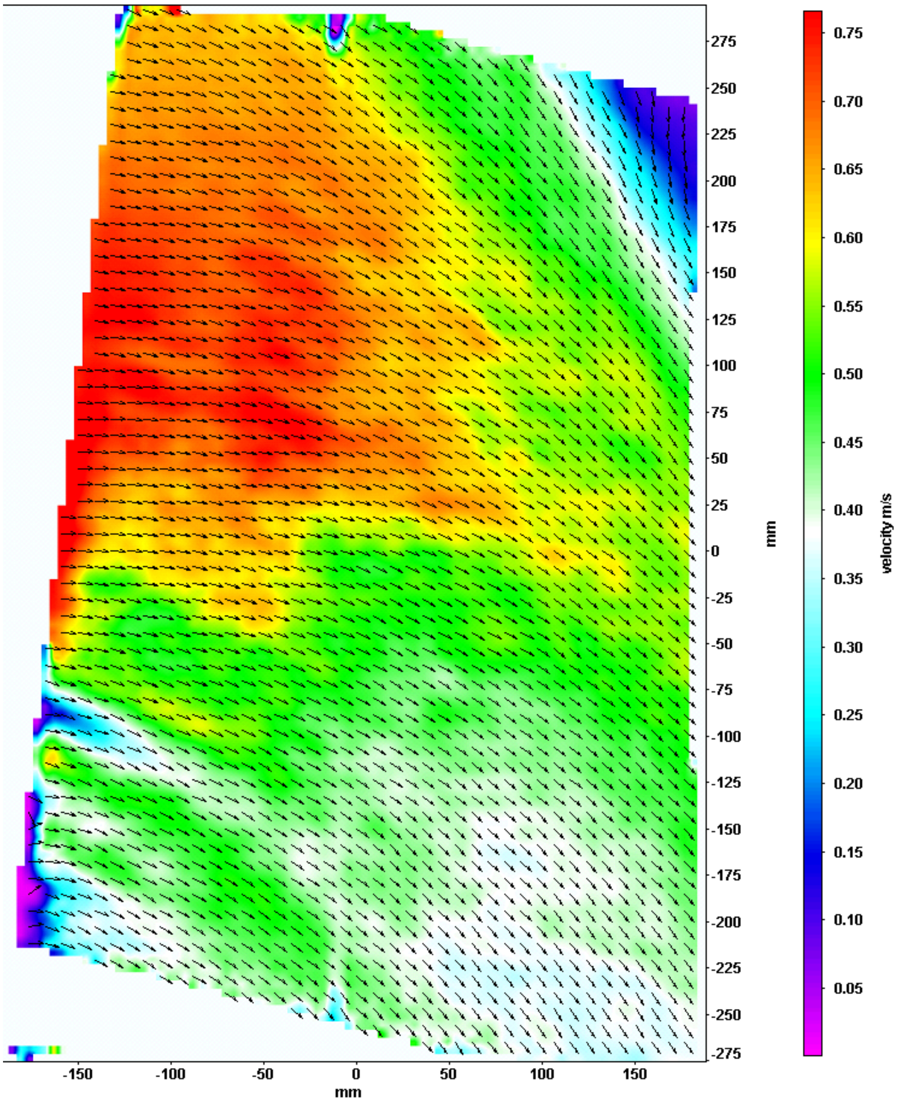

Figure 3-2 Radiator under the window + wind

Table 3-2 Temperatures during measurement– Radiator under the window + wind

measurement	t_{globe} (°C)	t_1 front of the window screen - upper (°C)	t_2 front of the window screen - lower (°C))	t_3 at the windowsill (°C)	$t_{exterior}$ (°C)
Radiator under the window + wind	20.7	15.6	2.1	18.6	1.4

3.1.3 Underfloor heating

Measured airflow velocities were up to 0.34 m / s. The highest speeds were reached at a height of about 400 mm above the windowsill. The air flow in this case is less turbulent. The reason for these differences is probably that the flow is not influenced by the radiator under the window. Temperatures in the space between the window and the window screen reached 18.6 °C and 10.2 °C.

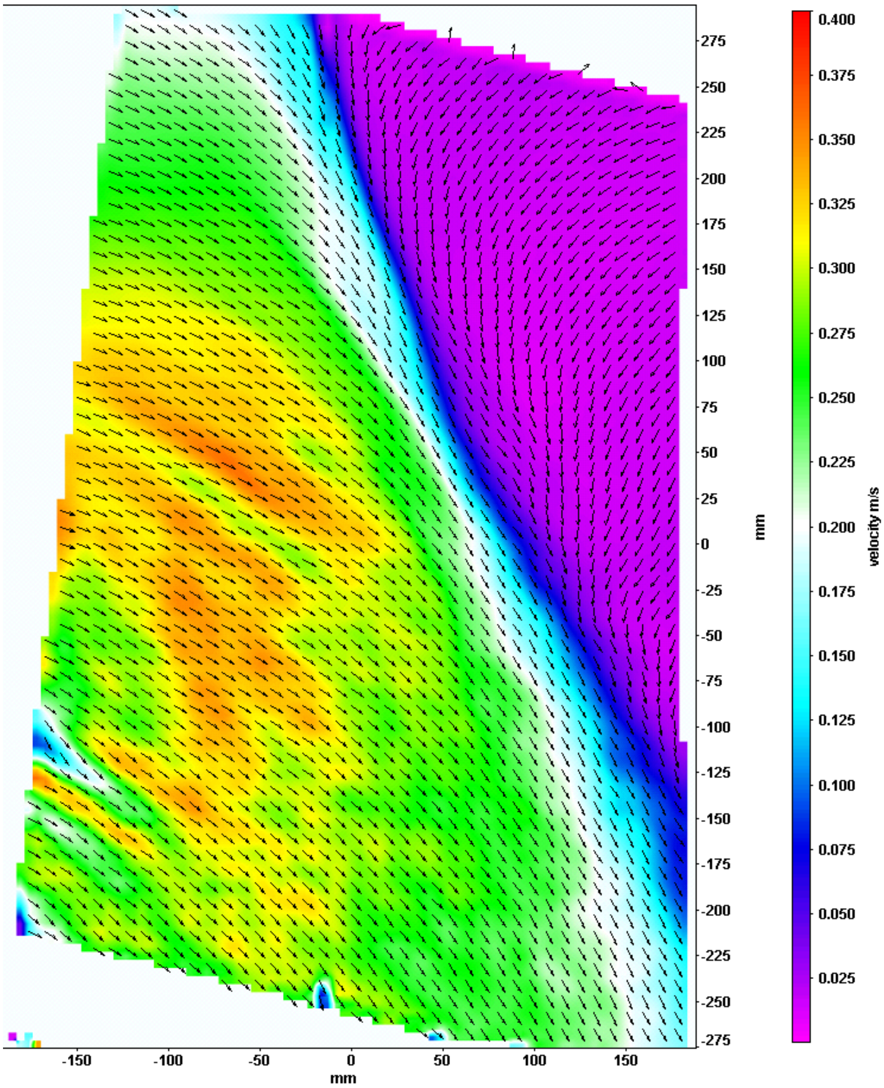

Figure 3-3 velocity field – Floor heating

Table 3-3 Temperatures during measurement– Underfloor heating

measurement	t_{globe} (°C)	t_1 front of the window screen - upper (°C)	t_2 front of the window screen - lower (°C)	t_3 at the windowsill (°C)	$t_{exterior}$ (°C)
Underfloor heating	21.5	18.6	10.2	18.5	1.0

3.1.4 Underfloor heating – with the influence of wind

The measured airflow velocities were up to 0.77 m/s. The highest speeds were reached at a height of about 400 mm above the windowsill. The temperatures in the space between window and mesh reached 16.6 °C and 2.2 °C and were similar to the radiator version.

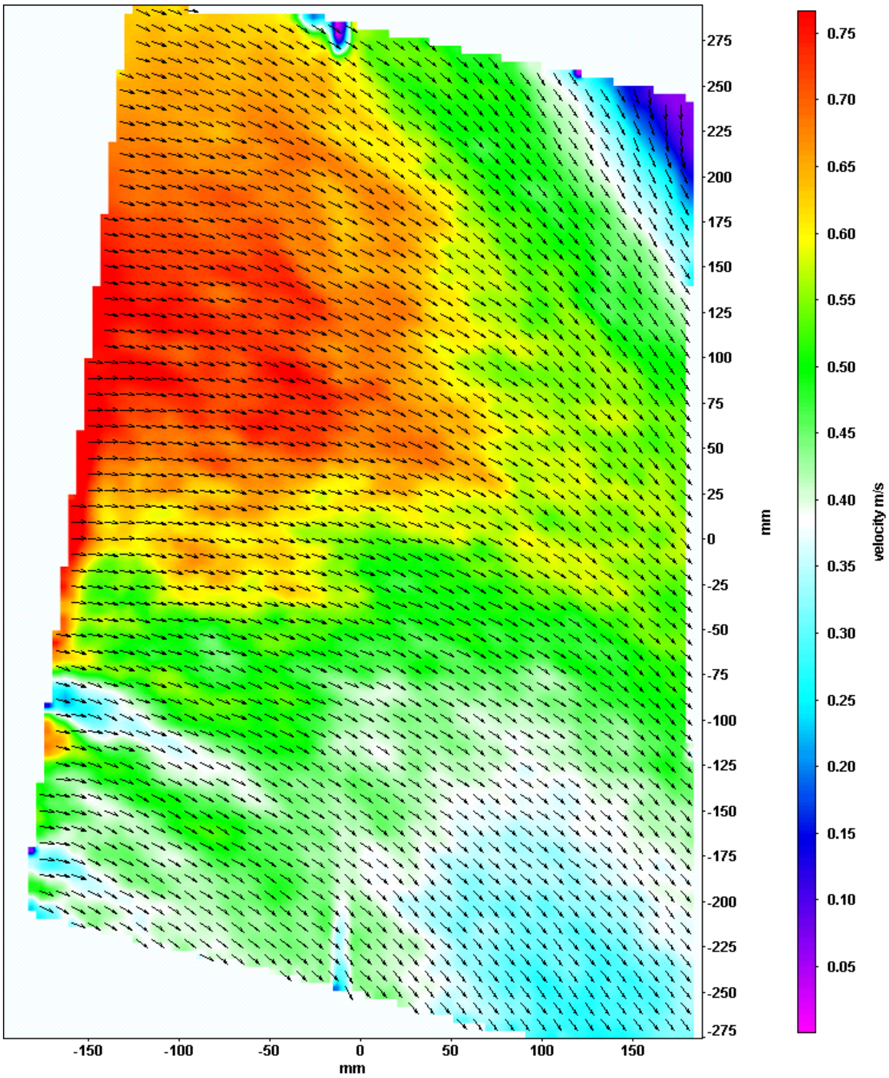

Figure 3-4 velocity field – Underfloor heating + wind

Table 3-4 Temperatures during measurement – Floor heating + wind

measurement	tglobe (°C)	t1 front of the window screen - upper (°C)	t2 front of the window screen - lower (°C)	t3 at the windowsill (°C)	texterior (°C)
Underfloor heating + wind	20.4	16.6	2.2	18.0	1.2

3.1.5 Radiator with blind window screen

In this variant, the net was blinded from the outside by a plastic foil. The air flow in this variant is caused by its cooling in the space between the window screen and the window sash.

The measured airflow velocities were up to 0.36 m / s. The highest speeds were reached at a height of about 400 mm on the windowsill. The shape of the air stream was similar to the open windowsill variant, only the speeds were about 10 % lower. The temperatures in the space between window and mesh reached 18.3 °C and 11.8 °C and were only about 1 K higher than in the open screen version with the radiator under the window.

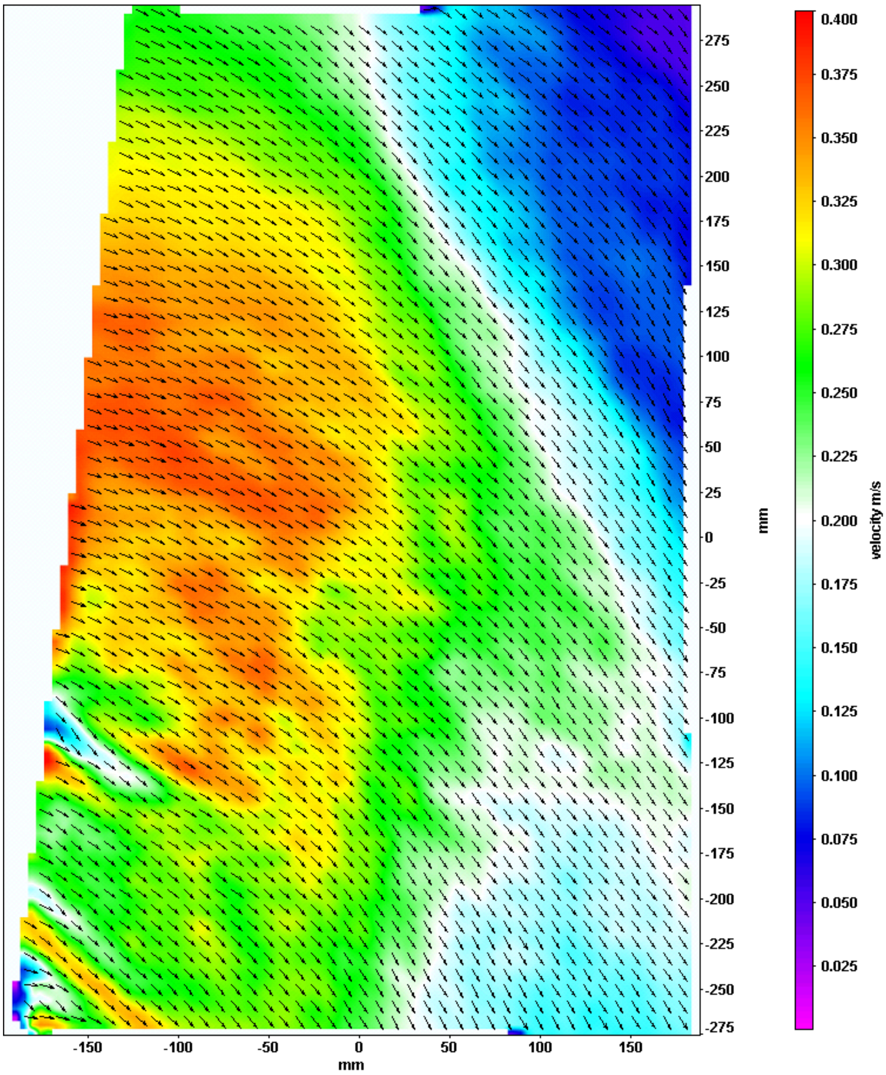

Figure 3-5 velocity field – Radiator with blind window screen

Table 3-5 Temperatures during measurement – Radiator with blind window screen

measurement	t_{globe} (°C)	t_1 front of the window screen - upper (°C)	t_2 front of the window screen - lower (°C)	t_3 at the windowsill (°C)	$t_{exterior}$ (°C)
Radiator with blind window screen	21.4	18.3	11.8	19.4	1.2

3.1.6 Summary of measurement boundary conditions

Table 3-6 Temperatures during measurement

measurement	t_{globe} (°C)	t_1 front of the window screen - upper (°C)	t_2 front of the window screen - lower (°C)	t_3 at the windowsill (°C)	$t_{exterior}$ (°C)
Radiator under the window	21.4	18.1	10.3	18.4	1.0
Radiator under the window + wind	20.7	15.6	2.1	18.6	1.4
Floor heating	21.5	18.6	10.2	18.5	1.0
Floor heating + wind	20.4	16.6	2.2	18.0	1.2
Radiator with blind window screen	21.4	18.3	11.8	19.4	1.2

3.1.7 Airflows

The air flow rates were determined from measured velocity profiles at a known joint width of 20 mm. The neutral axis position was estimated from the measured profiles. Airflows are summarized in tab. 3-7.

The airflow through the window without wind effects reaches 20 to 25 m^3/hour. This value includes both circulating air and fresh air. From measurements made with blind mesh, the flow of circulating air reaches 21 m^3/hour. From these values it can be deduced that the fresh air flow is only about 4 m^3/hour.

The total air flow with the influence of wind reached 63.4 m^3/hour. From the measured values it can be estimated that the fresh air flow is about 42.4 m^3/hour.

Table 3-7 measured airflows

measurement	maximum flow velocity (m/s)	average flow velocity (m/s)	window gap length (m)*	air flow through the window to the interior (m3/hod)	air flow through the mesh into the interior (m3/hod)
Radiator under the window	0.4	0.31	1.12	25.0	approx. 4.0
Radiator under the window + wind	0.77	0.55	1.6	63.4	approx. 42.4
Floor heating	0.34	0.25	1.12	20.2	not stated
Floor heating + wind	0.77	0.55	1.6	63.4	not stated
Radiator with blind window screen	0.36	0.26	1.12	21.0	-

** the sum for both sides of the window (left and right)*

3.2 Thermal comfort

3.2.1 Heating systems with wind effect, open window

This is a comparison for floor heating system and panel heating system when they work with wind effect.

5 zones are in the comfortable interval. For the whole body, the panel is less comfortable than the floor heating, with values of -0.93 and -0.83.

The situation for the hands (both right and left) is similar for both systems with the sensation slightly cool. For floor heating the hands values were -0.61 and -0.65. Panel hands values were -0.63 and -0.64.

Situation for the calves - the panel is getting worse again. The panel have values in the area of calves -1.31 and -1.2 - slightly cool. For the floor heating the calves was -1.15 and -1.27 - again slightly cool.

Situation for the feet - differently for each foot and system. The worse situation was for left foot during panel use - 1.65, the value for the right foot during floor heating use was - 1.36. The situation for the right foot went better for the panel use. The value was -1.08. Then the value for the right foot during the floor heating use -1.48 on the border of slightly cool and cool sensation interval.

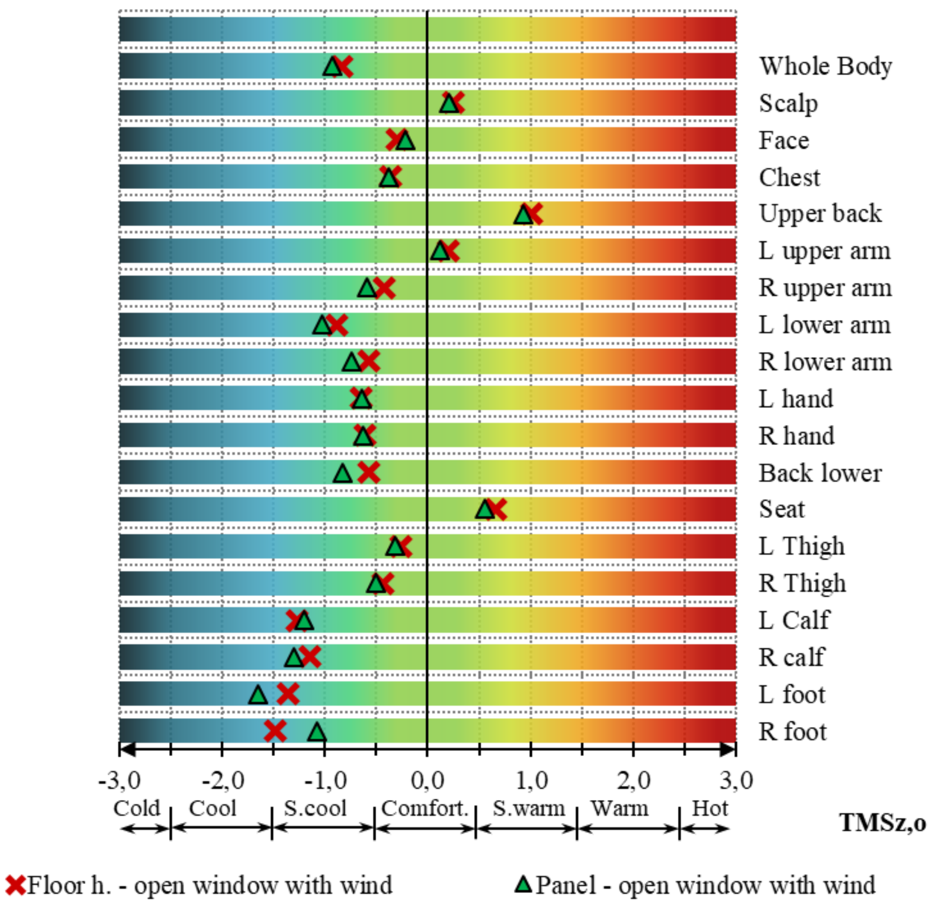

Figure 3-10 Results for wind effect (both heating systems)

3.2.2 Heating systems without wind effect, open window

This is a comparison for floor heating system and panel heating system when they work without wind effect.

6 zones are in interval of a comfortable sensation. For the whole body, both systems come out the same way – in the slightly cool sensation interval with values of -0.75 and -0.75.

The situation for the hands is almost similar for both systems – comfortable to slightly cool sensation. Floor heating values for hands were: -0.21 (comfortable) and -0.61 (slightly cool). Panel values for hands were -0.61 and -0.62.

In the situation for the calves - the panel is worse again. The panel has values for calves -0.93 and -1.11 - slightly cool. For the floor heating the valued for calves were -0.91 and -1.07 - slightly cool.

The situation for the feet was similar with the slightly cool sensation: for the floor heating -1.34 and -1.21 and for the panel -1.38 and -1.23.

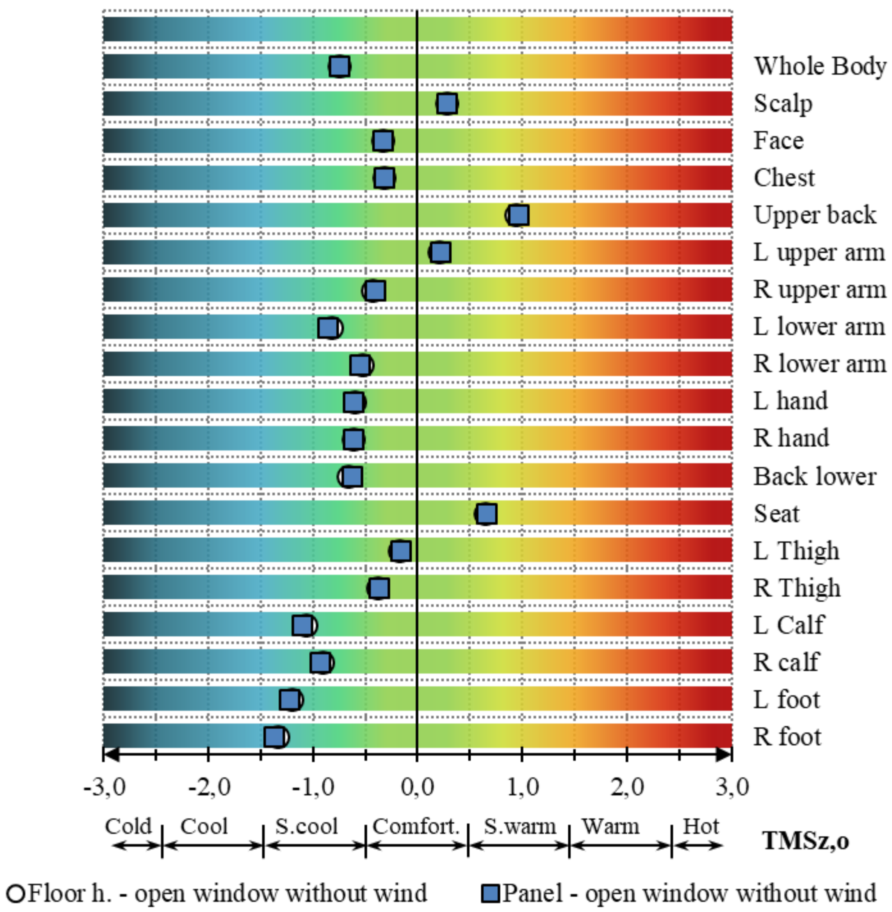

Figure 3 - 11 Results for both heating systems without wind

3.2.3 Floor heating - closed window and state without screen

This is a comparison for two states of floor heating system when they work with closed window and with open window plus without screen.

4 zones are in the interval of comfortable sensation. For the whole body, both states are different, when the situation with the closed window is warmer -0.68 and the situation without the screen -0.96. Both values are in the slightly cool interval. Even during the closed window state it is obvious that the whole body state is not in the comfortable sensation interval.

The situation for hands is the same for both states - slightly cool. Values for both states: -0.62 and -0.65.

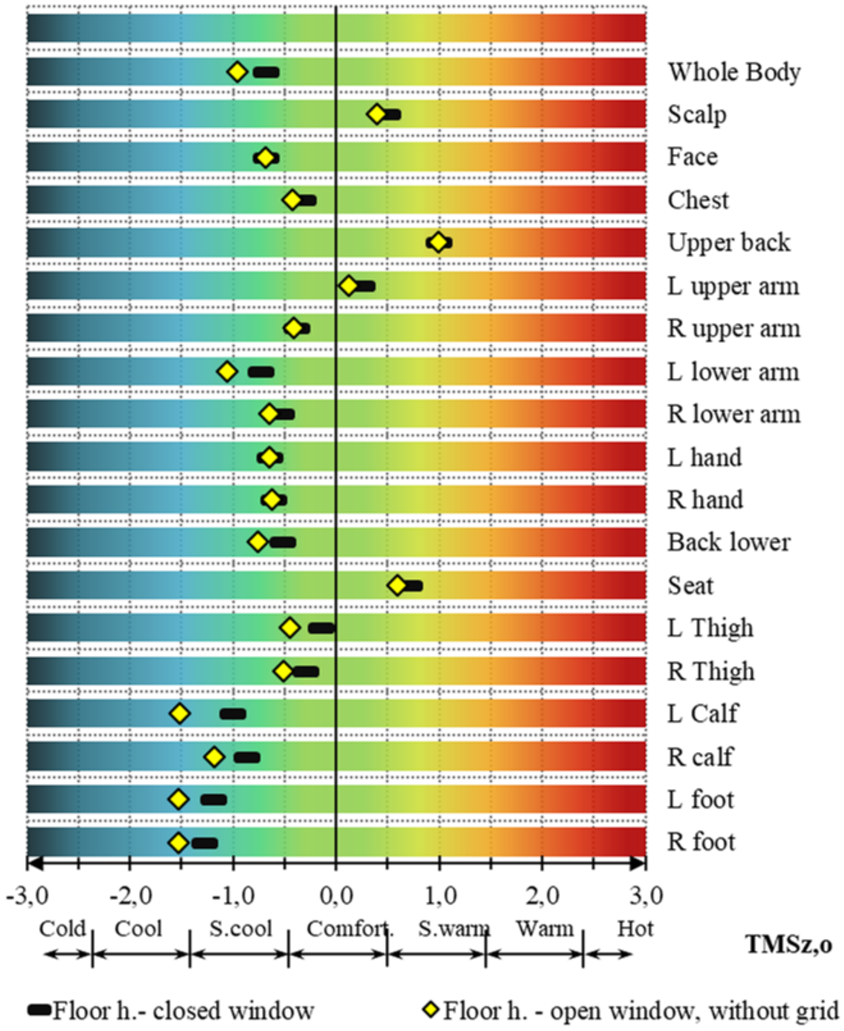

Figure 3-12 Results for floor heating with closed window and with open window + without screen

Situation for the calves - the condition without the screen is worse. Without screen, the values for the calves were -1.18 and -1.51, which means they are in the slightly cool to cool intervals. The value of -1.51 is in the border of slightly cool to cool interval. For the closed window the values for calves were -0.87 and -0.91- slightly cool.

The situation for the feet was worse for an open window state – in the cool sensation interval: -1.53 and -1.53, while for the closed window -1.29 and -1.2 - it was in the slightly cool interval.

3.2.4 Floor heating – without wind effect and with wind effect

This is a comparison for two states of floor heating system when they work with open window with and without screen.

7 zones are in the interval of comfortable sensation. For the whole body, both states came out differently, with the situation without wind coming out warmer -0.75 and the situation with wind -0.83. Both are in the sensation interval of slightly cold. Even when the window is closed, it is obvious that the manikin is not in the comfortable sensation interval.

The situation for hands is the same for both systems - slightly cold. Values for hands with wind effect: -0.61 and -0.65, without wind - 0.62 and -0.61.

The situation for the calves - the condition with wind is worse. With wind, the values for the calves -1, 15 and -1, 27 are slightly cold. For situations without wind it was -0.91 and -1.07 - slightly cold.

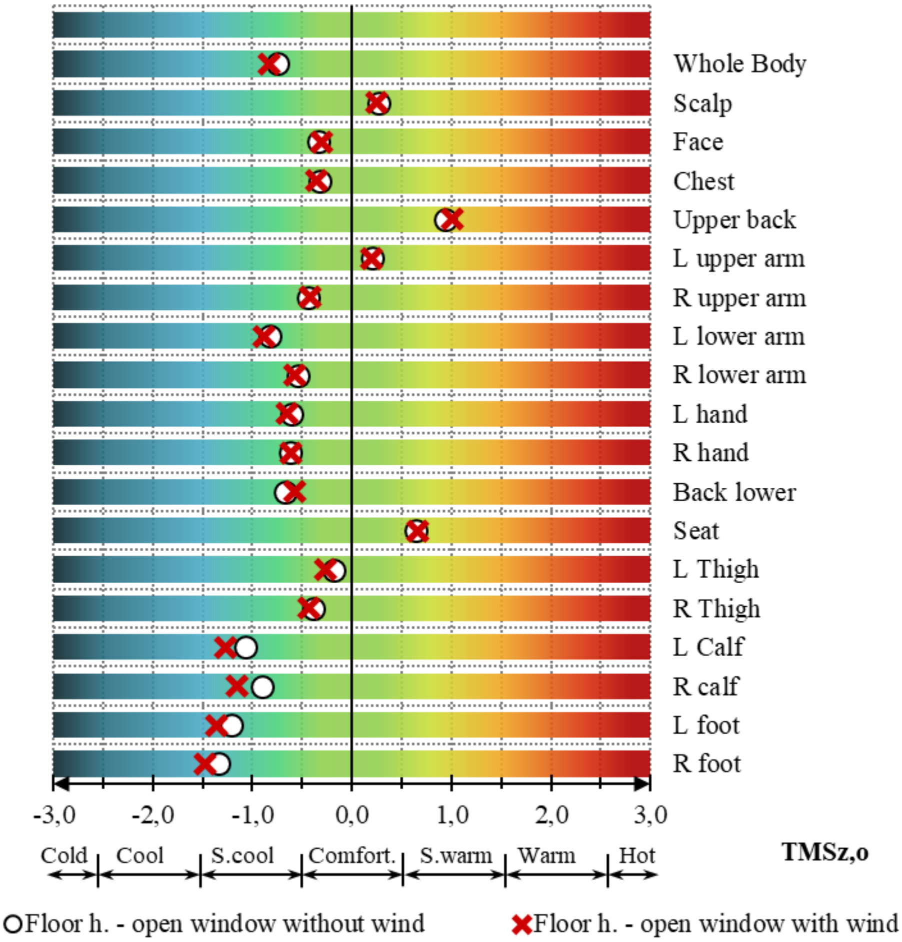

Figure 3-13 Results for floor heating with open window (with and without wind)

The situation for the feet based on calculation was worse with the wind. For the right foot it was on the border of cool and slightly cool -1.48 and for the left foot -1.36 and for the windless situation of -1.34 and -1.21 - slightly cool sensation.

3.2.5 Radiant panel - no wind effect and with wind effect

This is a comparison for two states of panel heating system when they work with open window with and without screen

5 zones are in the comfortable sensation interval. For the whole body, both states came out differently, with the situation without wind coming out warmer -0.75 and the situation with wind -0.93. Both are in the interval slightly cool.

For the face and foot zones of the right side, better situations with wind have come out.

The situation for hands is the same for both systems - slightly cool. Values for state with wind effect: -0.63 and -0.64, without wind effect - 0.61 and -0.62. The situation for the calves - the condition with the wind effect is worse. The wind effect caused values for calves -1.31 and -1.2 - slightly cool, closer to cool. For situations without wind effect it was -0.93 and -1.11 - slightly cool.

The situation for the feet was different for each one foot. It came out worse in a situation without wind - for the right foot on the border of slightly cool and cool -1.38 and for the left -1.23 (slightly cool); for the situation with the wind, the left foot based on calculation was worse -1.65 (cool) and the right then -1.08 - slightly cool.

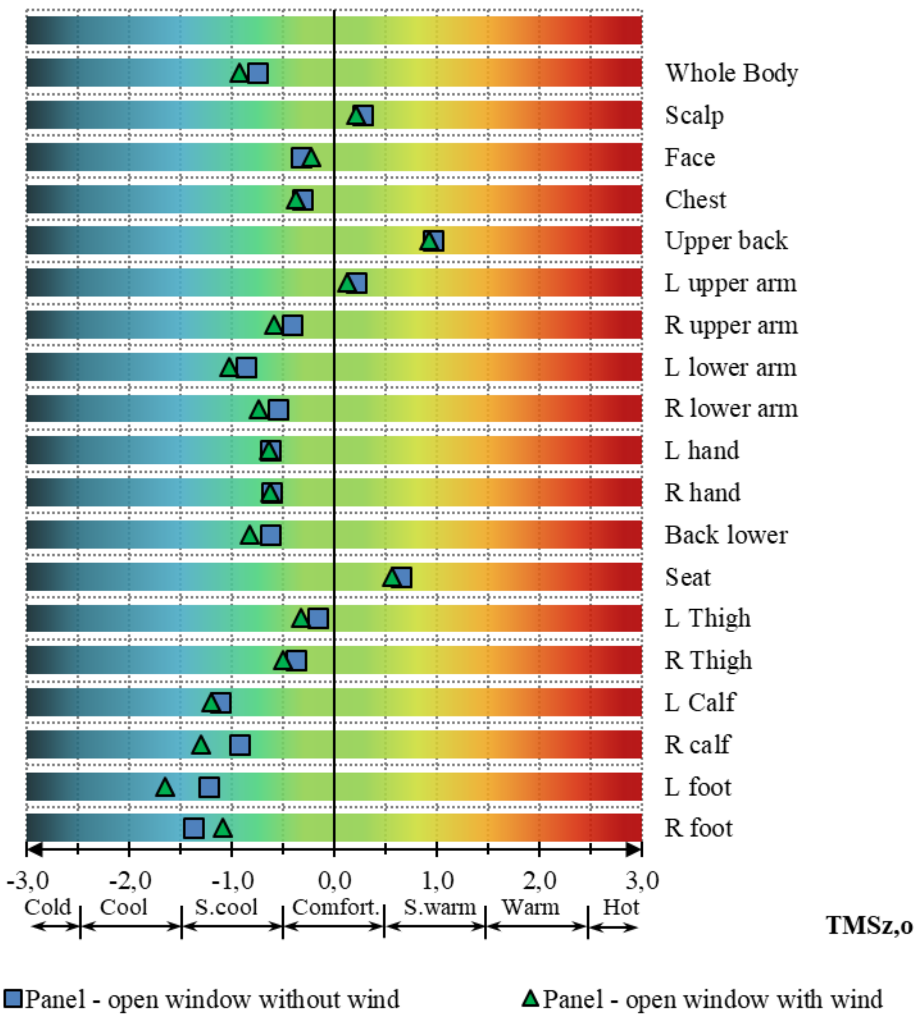

Figure 3 - 14 Chart V. – results for panel heating with open window (with and without wind)

3.2.6 Floor heating - all states

Here is a comparison of all states for the floor heating.

5 zones are in the comfortable interval. For the whole body, the variants come out differently, when the hottest comes out: the closed window, then the situation without the fans, the situation with the fans and eventually the situation without the screen. All conditions are in the slightly cool interval, none is in the comfortable interval.

For the following zones, the states were very similar: chest, arms, hands and seat (buttocks). The situation in the zones of the calves and the hands came out similarly to the whole body.

For screenless measurements, we move to the border of a cool feeling.

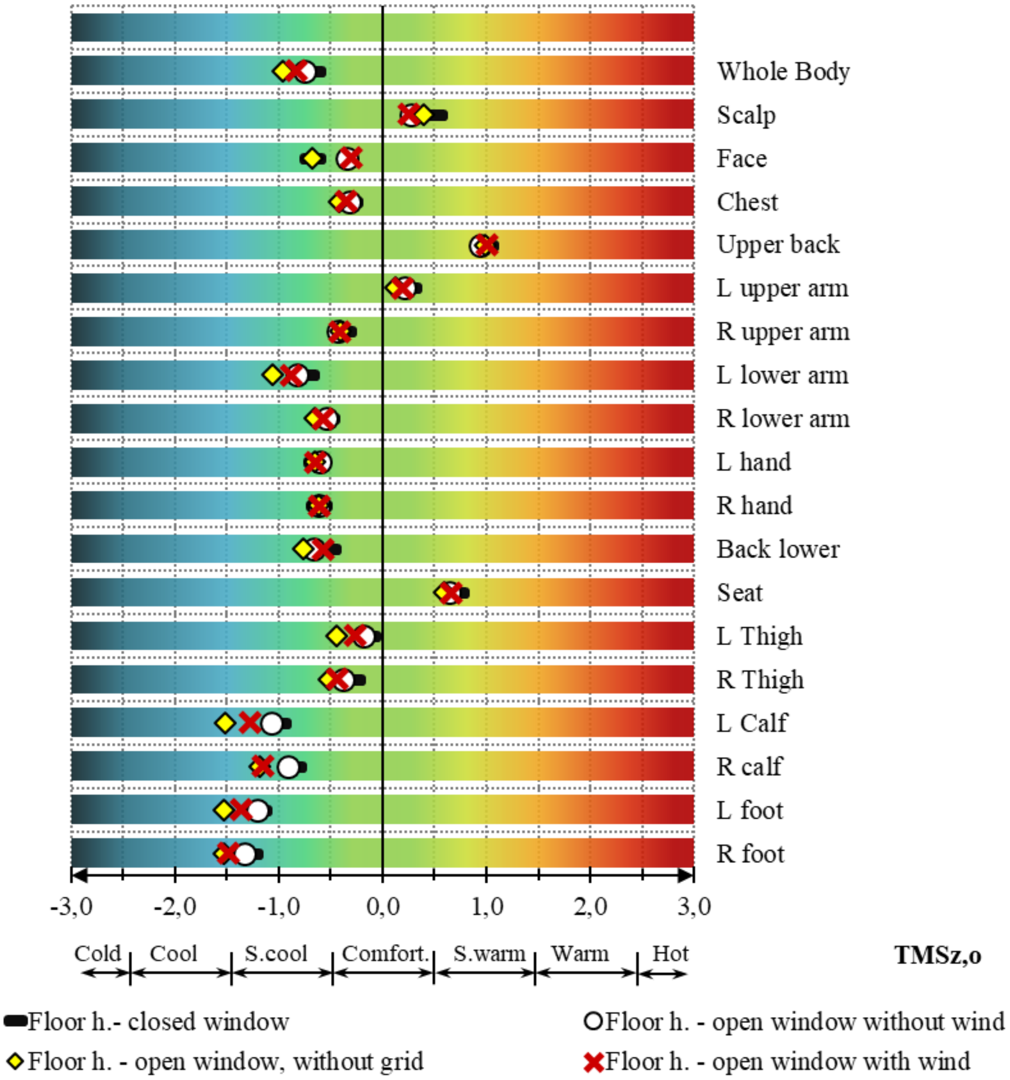

Figure 3 - 15 Chart VI. – results for floor heating – all states comparison

3.2.7 All states - overview

Here is a comparison of all states for both heating system - the floor heating and the panel heating.

4 zones are in the comfortable sensation interval. For the whole body the variants come out differently when the best (hottest) comes out: the floor heating and the closed window -0.68 (in the border of comfortable and slightly cool), then with the value of -0.75 (slightly cool) floor heating and panel without fans, then the floor heating with fans -0.83 (slightly cool), then the panel with fans -0, 93 (slightly cool) and finally a floor heating without a screen of -0.96 (slightly cool).

All the sensations are in the slightly cool interval, none are in comfortable one. For the following zones the states were very similar: hands and seat (buttocks). The situation in the zones of the calves and the hands came out differently, we move in sensations from slightly cool to cool. The worst situation for the left calf and right foot was the state without the screen, for the right calf and left foot the worst one was panel with the fans. (see Detail of the chart VII.).

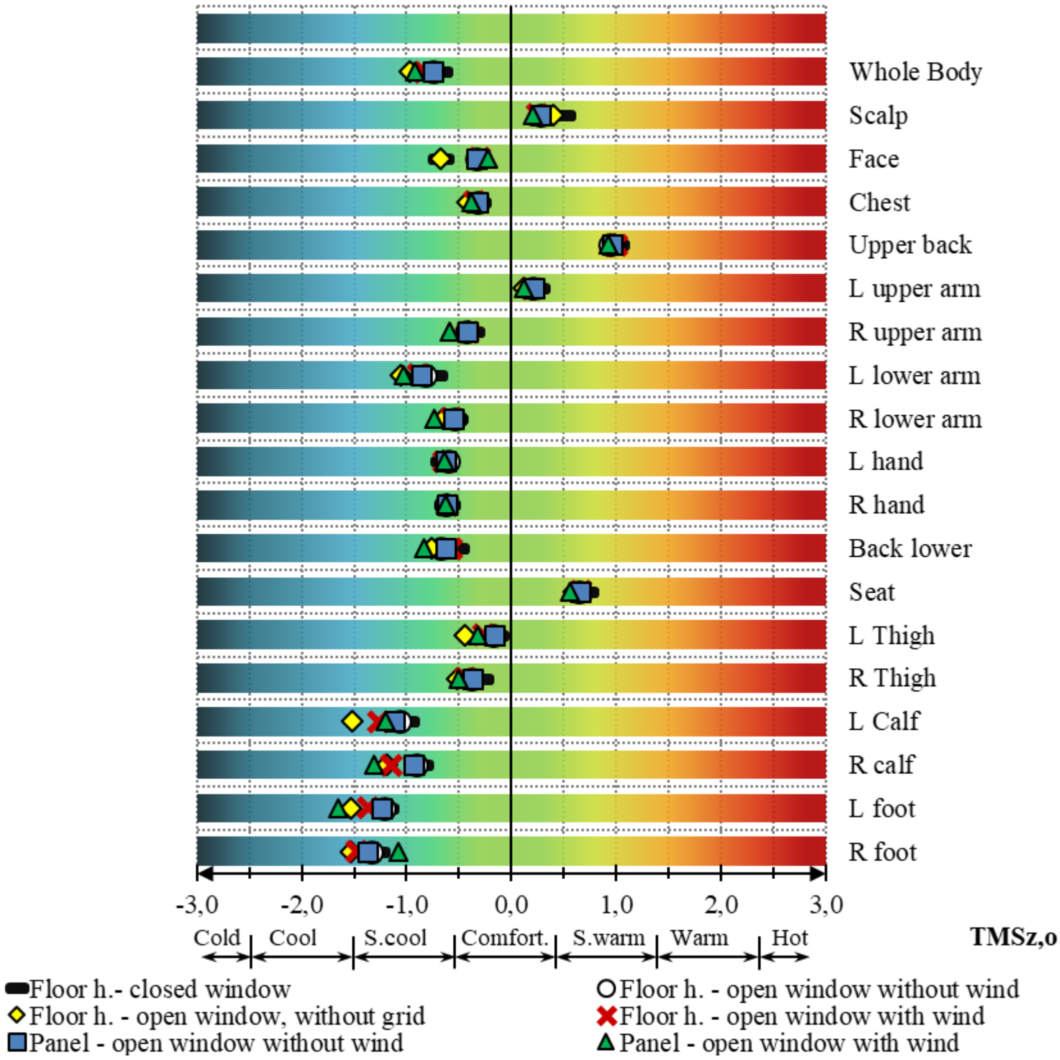

Figure 3 - 16 Chart VII. – results for both heating systems – all states comparison

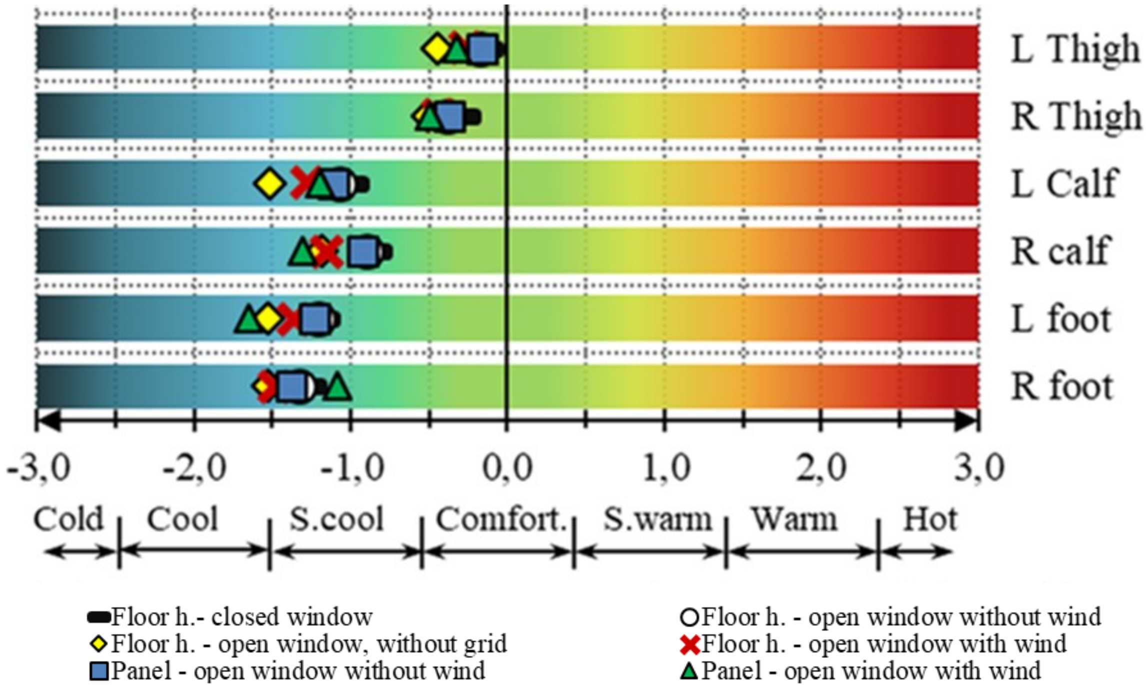

Figure 3 – 17 Detail of results in the area of legs in all states

4 CONCLUSION

4.1 Air flow

The measurements made in the climate cabin show the following:

- The flow velocities reach a maximum of about 0.4 m/s. With the wind increases to approximately 0.77 m/s
- The air flow through the window is approx. 25 m^3/hour without the influence of wind. However, it is predominantly circulating air. The amount of fresh air is only about 4 m^3/hour. This is due to the pressure loss of the Nafigate window screen.
- The airflow with wind effect reaches about 63 m^3/hour. The fresh air from this value reaches about 42 m^3/hour.
- The required amount of fresh air per person is min. 25 m^3/hr. Determined airflows without the influence of wind do not meet this requirement.

4.2 Thermal comfort

The assignment was to assess the thermal comfort in the laboratory at different states using the window screen. It was to evaluate the overall thermal comfort delivered by different heating systems with combination of screen influence and to create detailed view of the floor and foot situation These conditions included two heating systems, different air velocities (with or without wind effect), and a closed window state.

No condition for the whole body was comfortable, which means it was not in the range of -0.5 to +0.5 for the given boundary conditions, when the thermostat was set on the indoor temperature 22 °C and the outside temperature was set to 1 °C. Thus, even in the closed window state, the TMS_o value equals the thermal sensation of the slightly cool not comfortable.

For a detailed view on the legs - on the part of the calves and feet, the values for all states are in the interval -1 to -1.7 which means they are slightly cool.

Manikin´s hands sensations were also influenced by the air velocity value, which for all conditions were very similar in the interval -0.5 to -1, therefore, also slightly cool thermal sensation no comfortable sensation. The situation for the left side and right side of the body came out in the height of the armrest and underneath it differently, as the temperatures on the left armrest and on right armrest of the chair were not the same during the measurement of each state.

Thermal conditions in states of higher air velocities (with wind effect) were worse, it means that the following states of opened window without screen and all states with wind effect were less comfortable.

Tabulka 4-1 Resulting overal thermal sensation

Measured system	TMS_o	TMS_o description
Floor heating without grid with open window	- 0,96	Slightly cool
Panel heating with open window and wind effect	- 0,93	Slightly cool

Floor heating with open window and wind effect	- 0,83	Slightly cool
Floor heating with open window a without wind effect	- 0,75	Slightly cool
Panel heating with open window without wind effect	- 0,75	Slightly cool
Floor heating with closed window	- 0,68	Slightly cool

5 PHOTOS FROM THE MEASUREMENT

Figure 5-1 Fans before the outside of the window

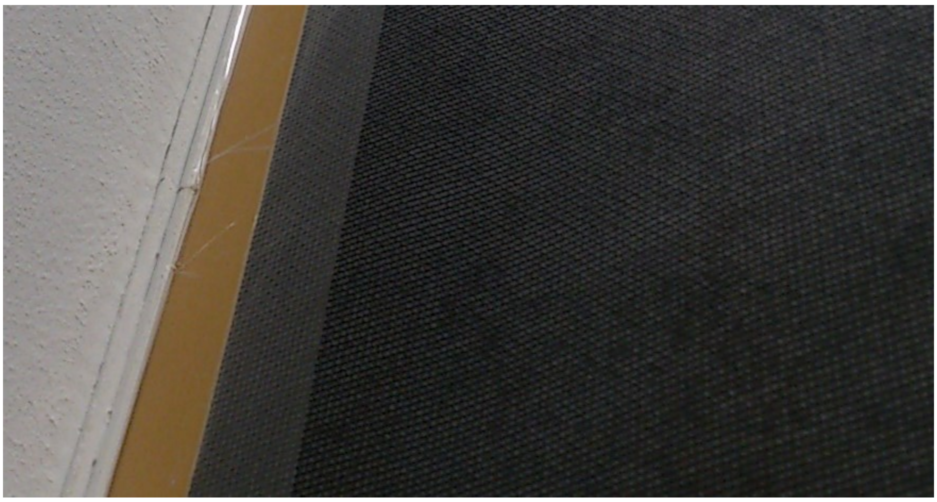

Figure 5-2 Detail of the Nafigate window screen at the window frame

Figure 5-3 View of a window with a window screen from the interior

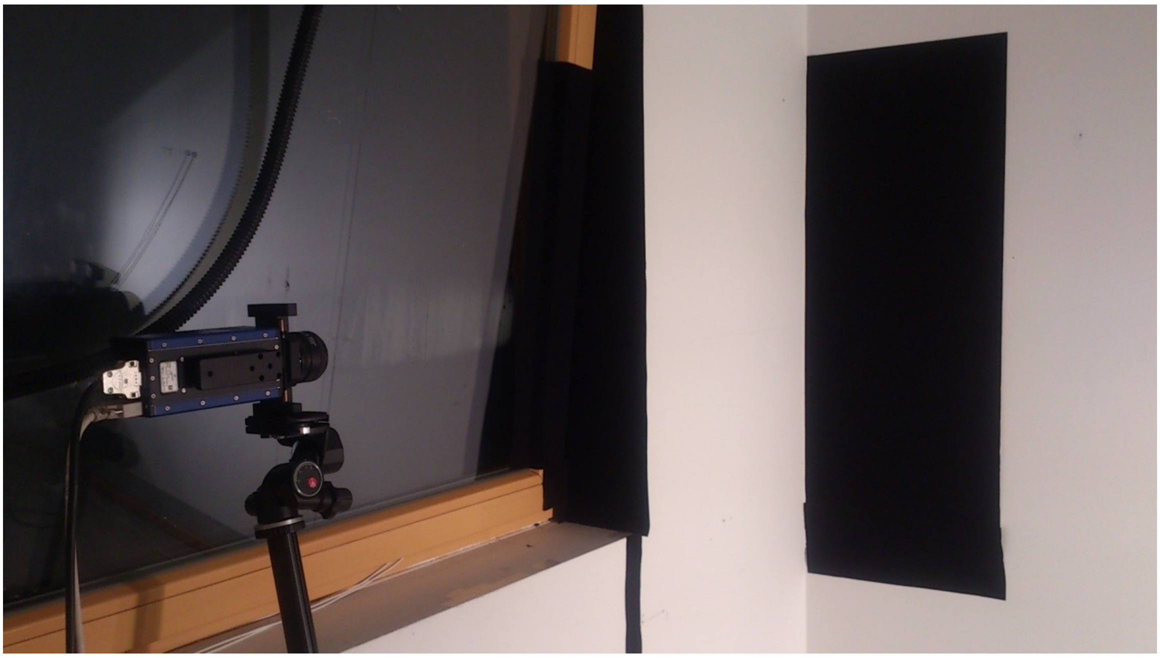

Figure 5-4 Camera position during measurement

Figure 5-5 Window blinded from the outside by a plastic foil

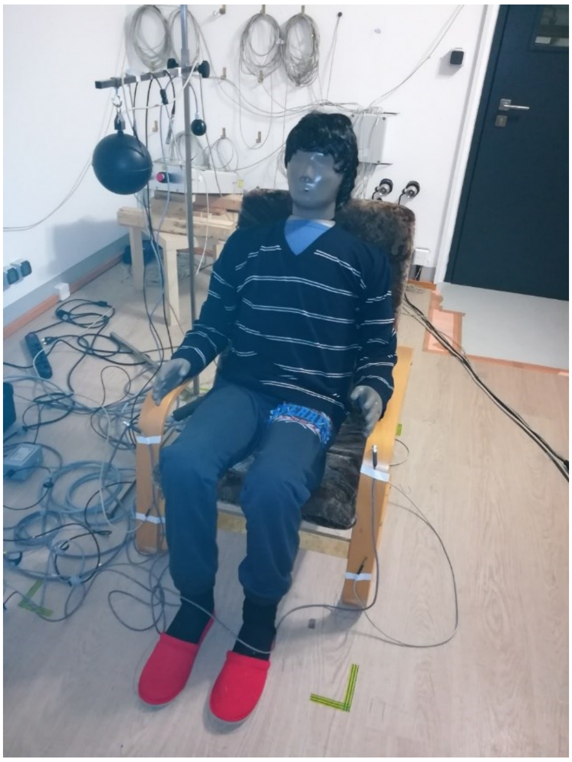

Figure 5-6 Thermal manikin with thermal comfort sensors – front side

Figure 5-7 Thermal manikin with thermal comfort sensors – rear side

Figure 5-8 Thermal manikin with thermal comfort sensors – right side