Vertical Distribution of Air Temperatures in Heated Dwelling Rooms

Ondrej Sikula

University of Technology Brno, Brno

Corresponding email: sikula.o@fce.vutbr.cz

SUMMARY

The paper presents an experimental and theoretic research on one of factors influencing the indoor climate in dwelling rooms heated by heating systems – the vertical distribution of temperatures. The paper summarizes results from simulation of the room heated by a gas space heater and a plate radiator. Among main factors causing unfavorable distribution of temperatures in a room belong insufficient elimination of cold dropping airflows and high temperature of heating air.

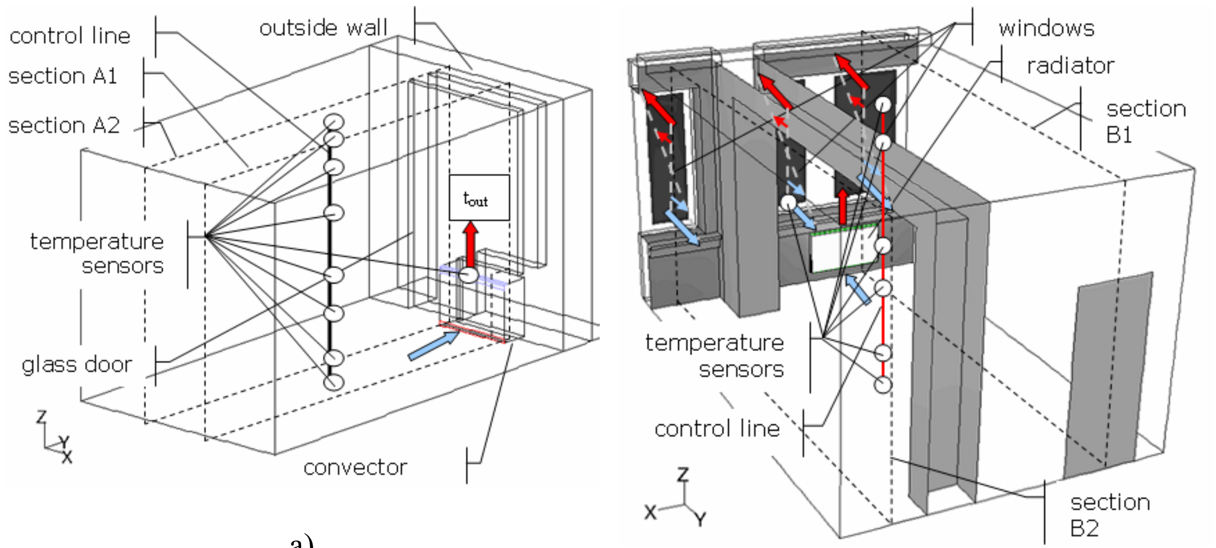
INTRODUCTION

The subject of the paper belongs to the field of formation of indoor climate in residential buildings. One of factors influencing the quality of indoor climate in a dwelling room is the vertical distribution of temperatures. It is described by a vertical temperature gradient or by temperature difference between the position of a head and an ankle of a person in the given space. Indoor climate is created by various HVAC systems which have different influences on the observed vertical distribution of temperatures. We try to identify factors leading to unfavorable vertical distribution of temperatures in a room heated by a gas space heater and a plate radiator.

METHODS

The vertical distribution of temperatures of chosen spaces was investigated by experimental measurements and CFD simulations. The measurement was performed during a regular operation of chosen rooms. The room A is a dwelling room in an old brick house with one outer wall. The room is situated in the third floor under a cold sloping roof with leaking tiling. Surrounding spaces have the same or similar temperature regime. The walls are made of solid bricks; the ceiling is made of wooden girders. The leaking wooden windows and balcony doors in the room have a double glassing. The room is heated by a local gas space heater, see fig. 1a).

The room B is an office for two people in a new building with one outer wall made of medium thick façade, see fig. 1b). The office is surrounded by rooms with the same or similar temperature regime.



a) b)

Figure 1. Geometry of rooms

In case A was measured and investigated the vertical distribution of temperatures while pre-heating.
In case B was measured and investigated the vertical distribution of temperatures while short-term ventilation by windows.

CFD simulations were performed on simplified geometric models of real rooms. Simulations included stationary and non-stationary solution of thermal transfer by convection, conduction and radiation. For airflow turbulence calculations the RNG k-ε model with standard wall functions was used. The heat transfer was solved by DO (Discrete ordinates) model [3]. Boundary conditions for CFD simulations were taken from the experimental measurement. The experimental measurement consists of measurement of air temperature and airflow velocity. We performed the measurement of the air temperature, the floor temperature, the ceiling temperature and the outer air temperature. We also compared thermal fields by using thermo-graphical images showing surface temperatures of internal constructions in the room. Airflow velocities were measured by anemometers. This paper presents only results from temperature measurements.
From the point of view of thermal comfort is recommended the maximal temperature difference between the position of a head and an ankle to be 2,0 K for standing person and 1,5 K for sitting person, see [2]. The legal regulation for working environment requires the maximal vertical temperature difference to be 3 K, see [1].

RESULTS

At fig. 2, 4 we can see the course of measured temperatures in chosen time intervals. Air temperatures are marked by a blue color and floor and ceiling temperatures by a red color. Vertical dashed lines indicate time moments in which were observed vertical distributions of temperatures in the room. In case A we can also see temperature of the air coming out of the gas space heater marked by black color at fig. 2.

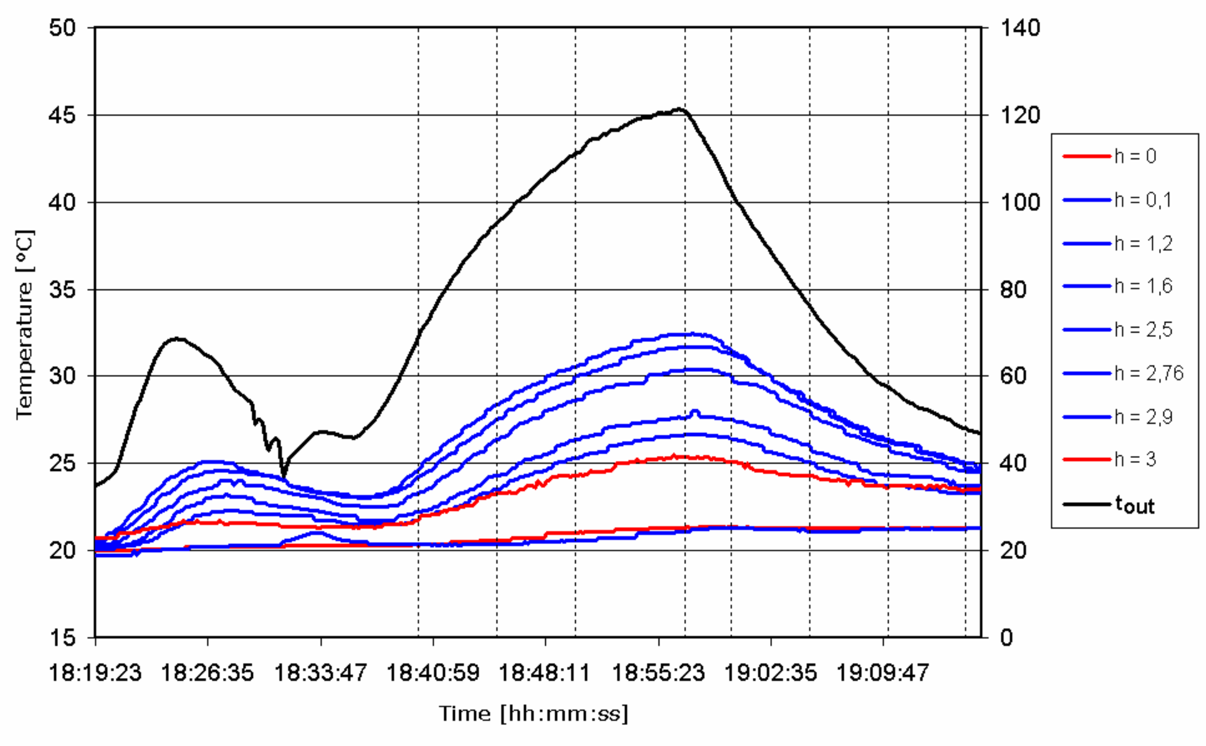


Figure 2. Temperature course in time, case A

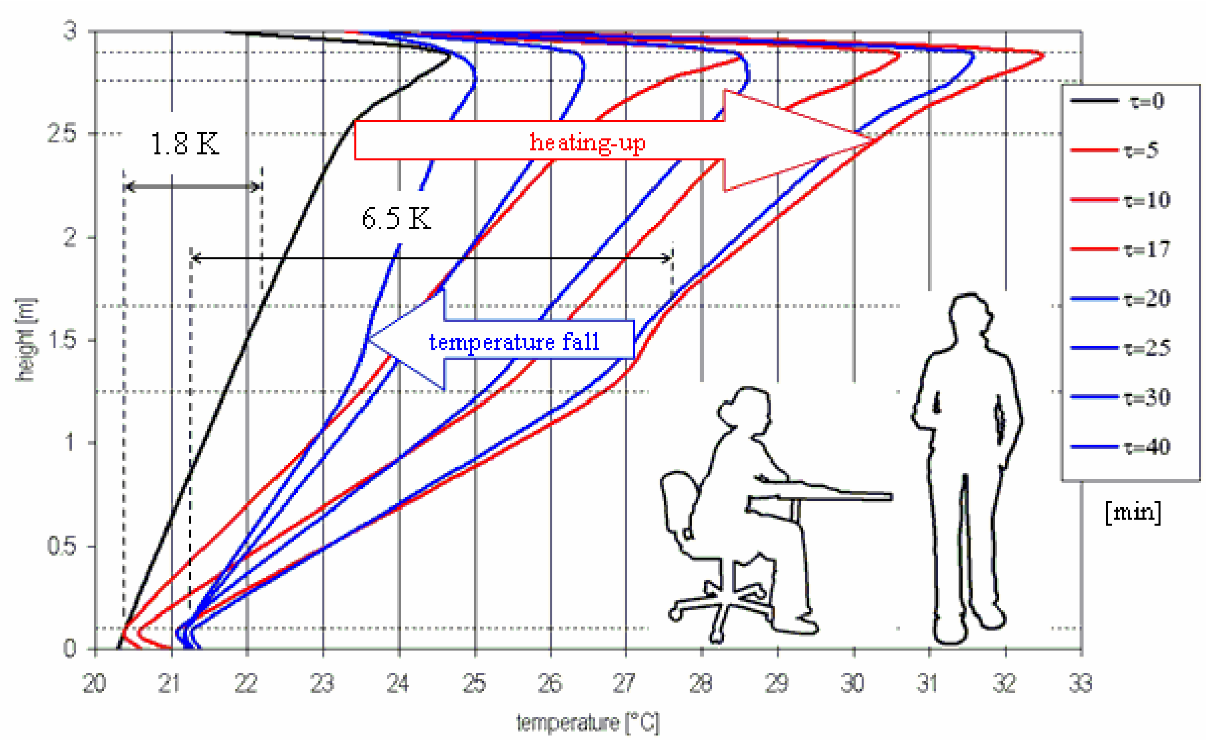
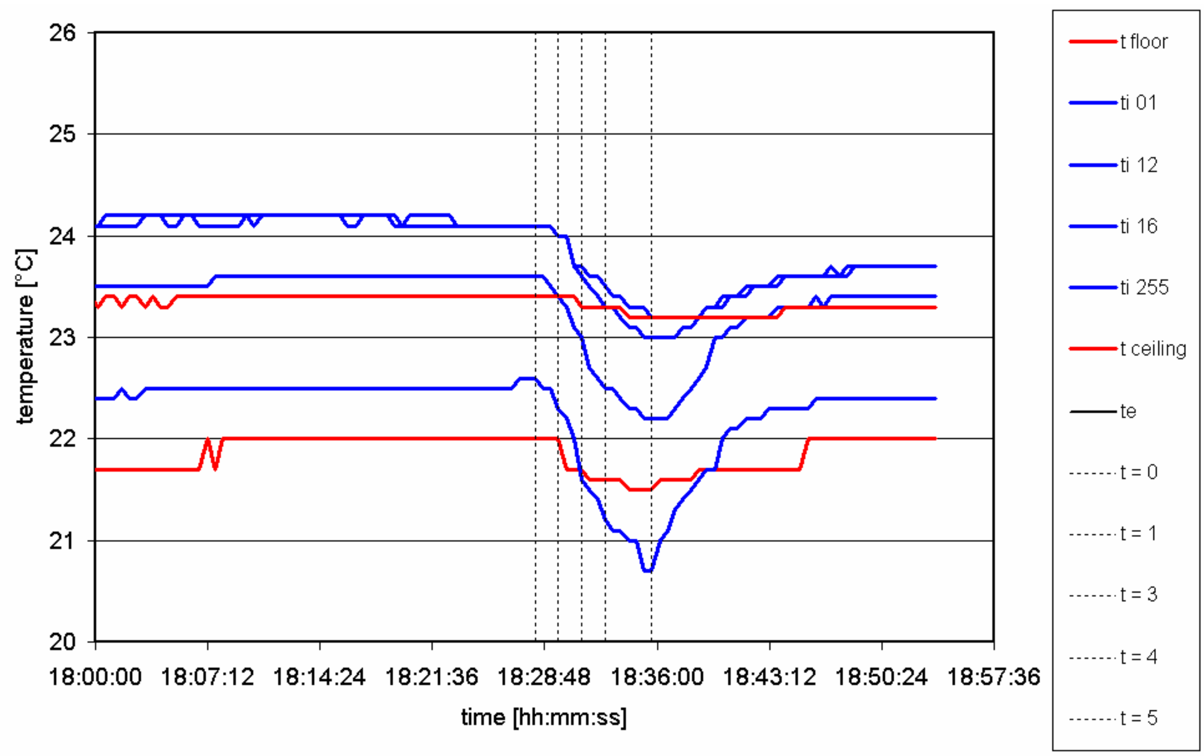


Figure 3. Vertical distribution of temperatures, case A



case B

Figure 4. Temperature course in time, case B

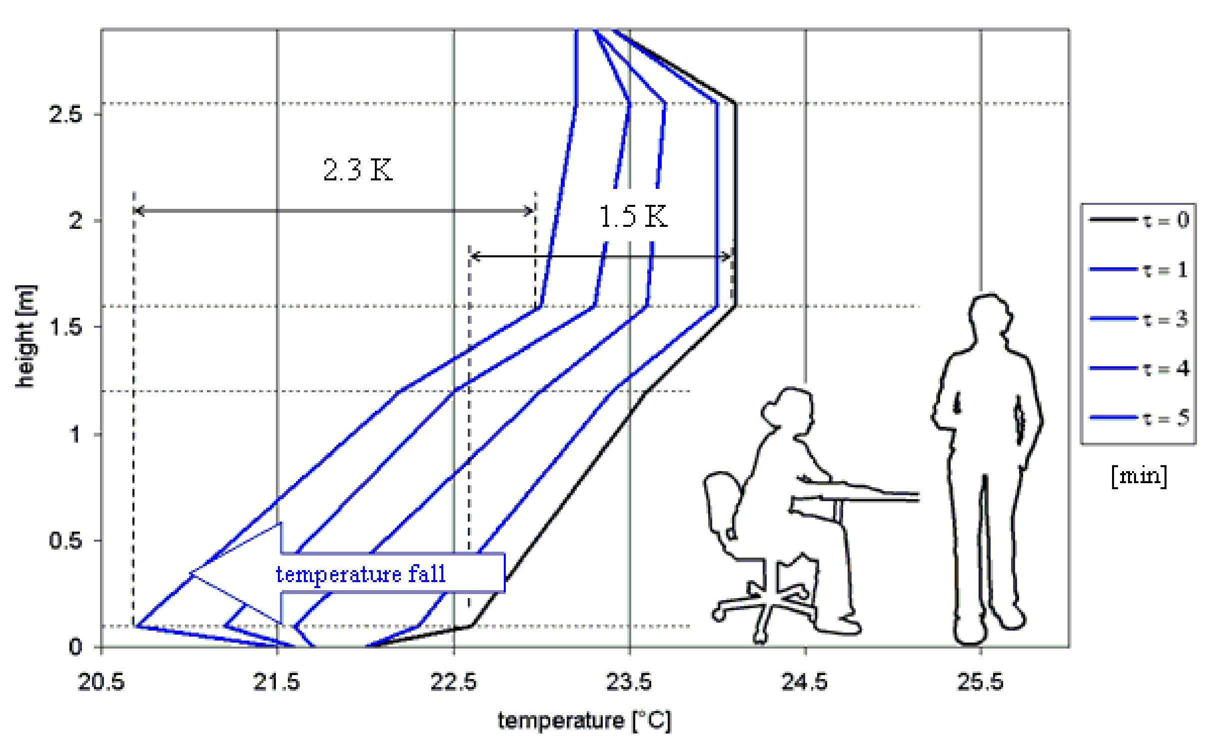
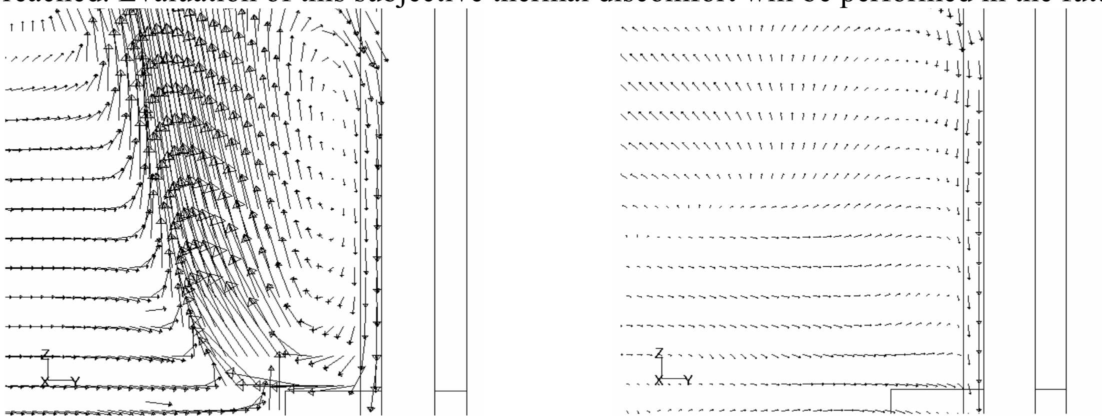


Figure 5. Vertical distribution of temperatures, case B

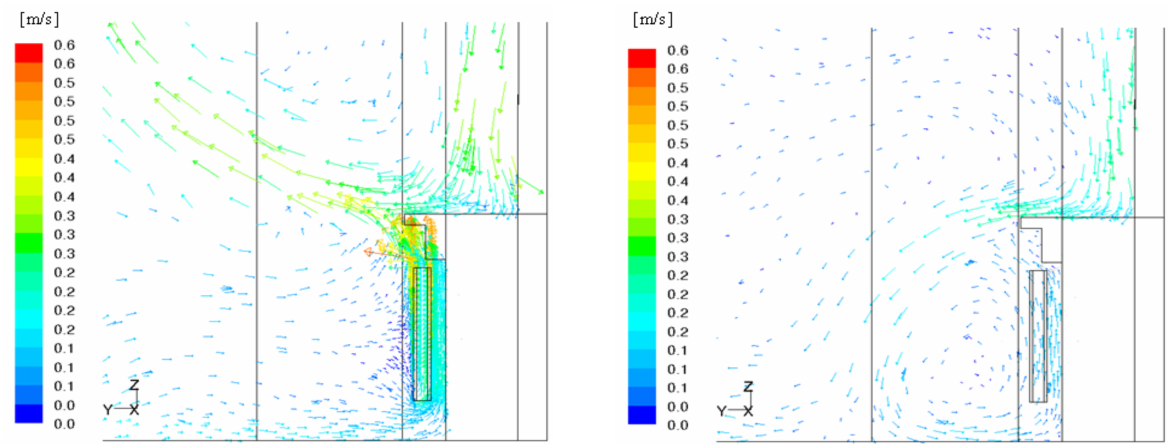
Obtained results show unfavorable vertical distribution of temperatures in the room for case A especially by pre-heating, see fig. 2. Inhabitants of this room are exposed to thermal discomfort because of the seriously overreached maximal temperature difference between the position of a head and an ankle required by [1] for time interval of approximately 30 minutes,

see fig. 3. The gas space heater used in the room is equipped with jump regulation switch on-off. There is no possibility for step-by-step regulation or gradual control of heating, therefore the discomfort occurs several times per day, see fig. 9.
Case B offers favorable vertical distribution of temperatures in the room during a regular operation. While short-term ventilation by windows is formed a cold air layer close to the floor which cause a slight thermal discomfort felt by inhabitants. Nevertheless the maximal temperature difference between the position of a head and an ankle required by [1] is not overreached. Evaluation of this subjective thermal discomfort will be performed in the future.



Section A1 Section A2

Figure 6. Velocities, case A



Section B1 Section B2

Figure 7. Velocities, case B

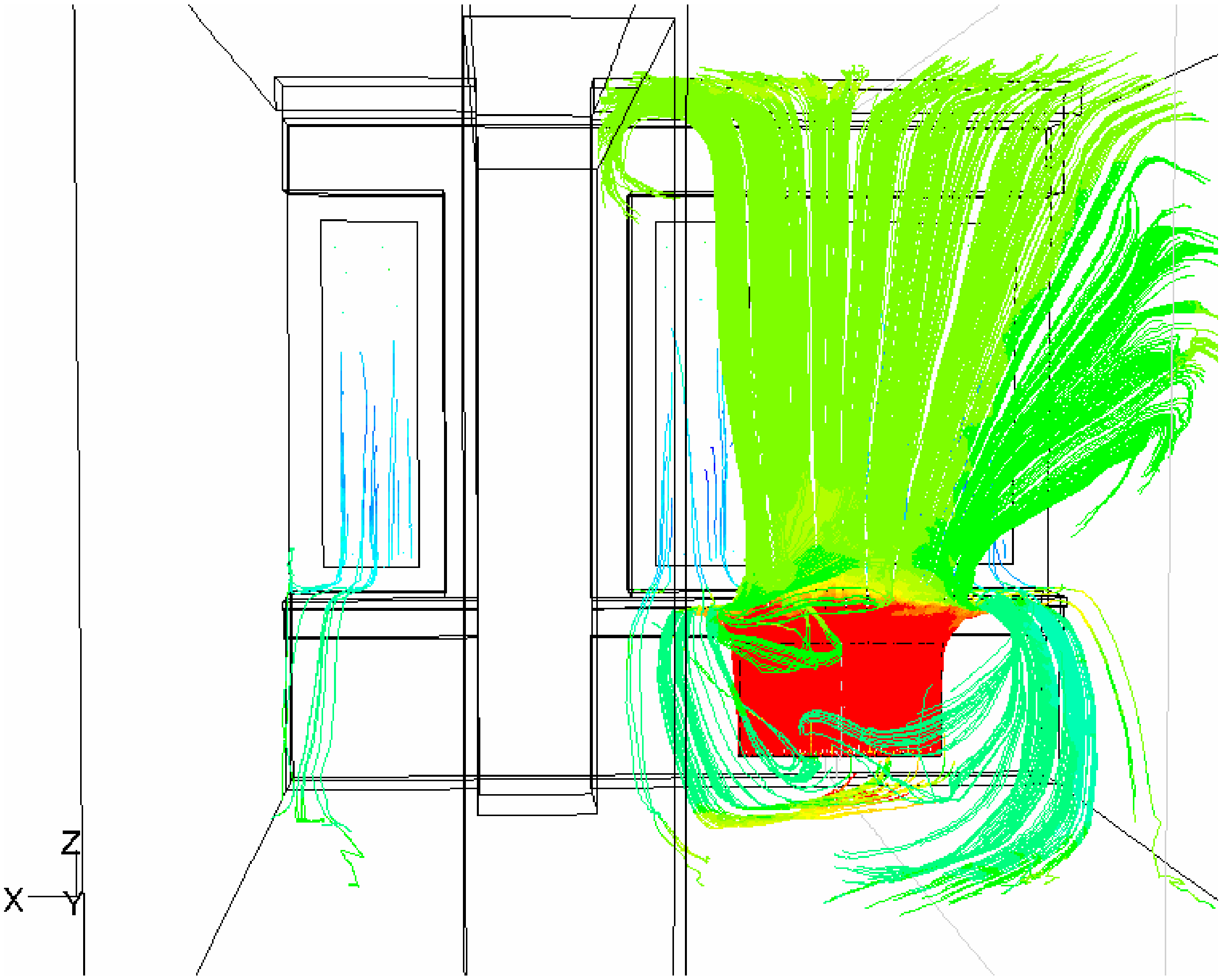


Figure 8. Path lines, case B

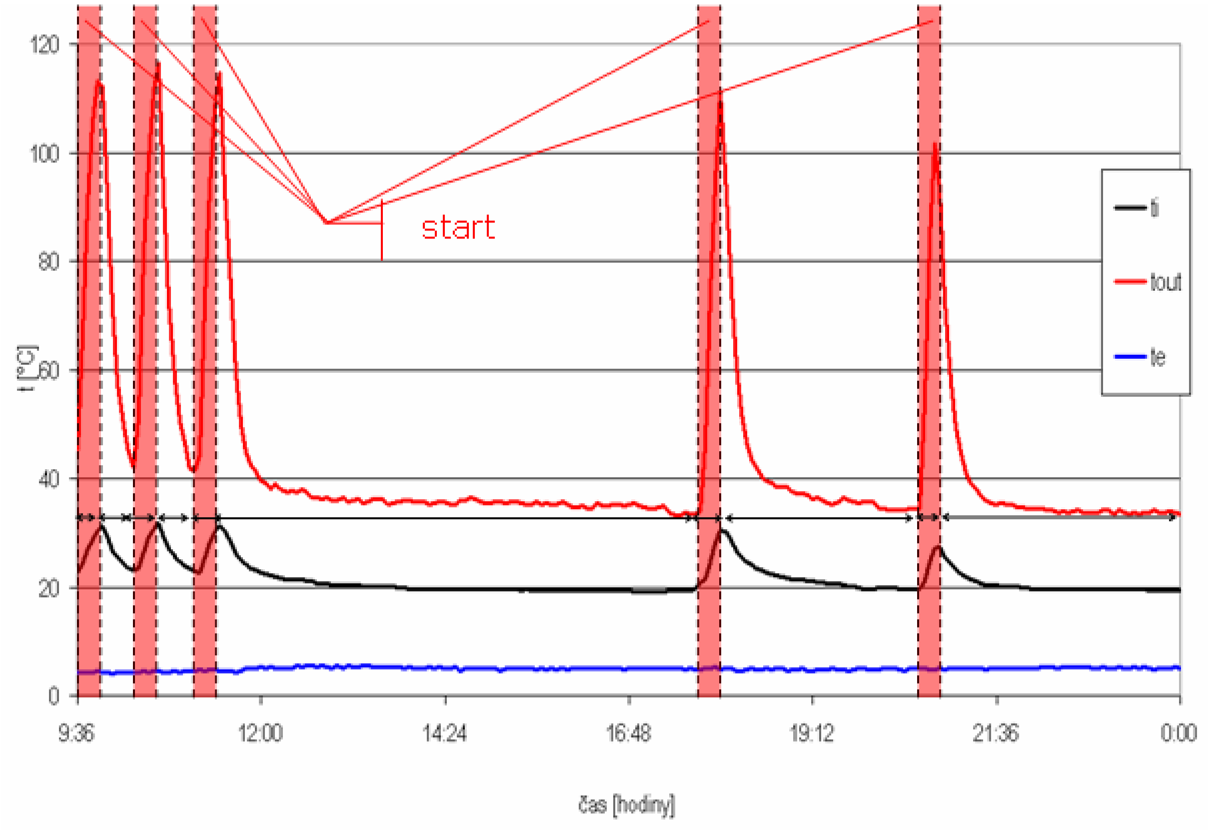


Figure 9. Temperature in the course of day, case A

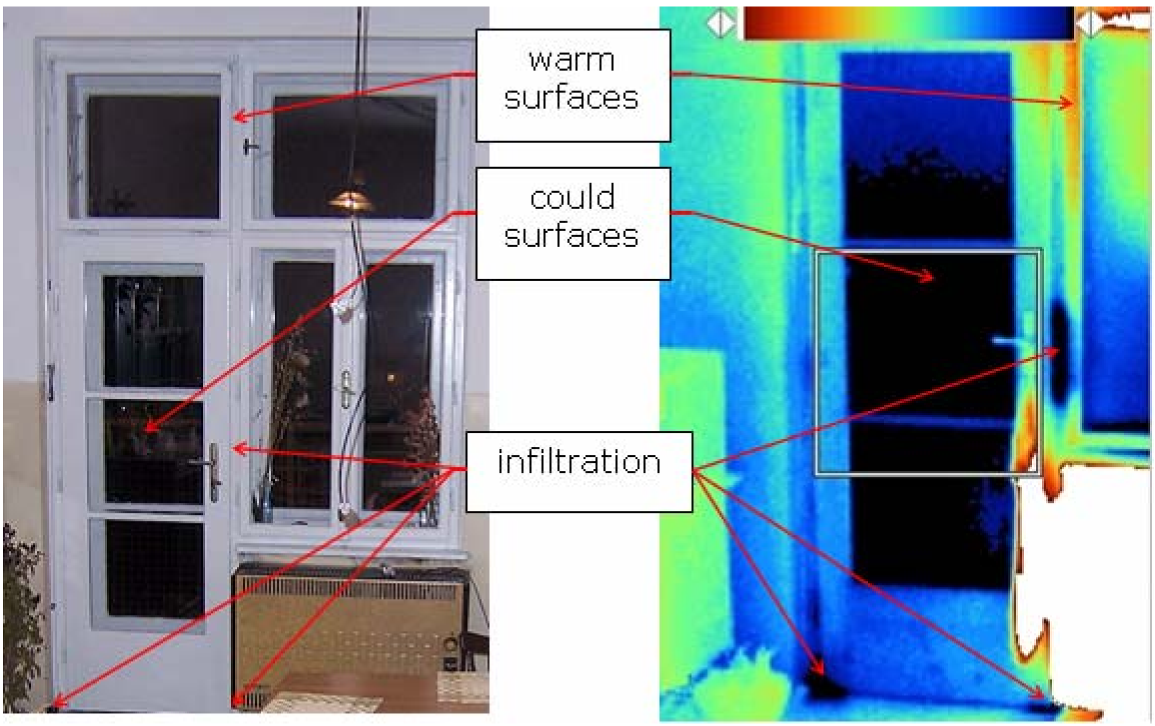


Figure 10. Surface temperatures, case A

DISCUSSION

Above mentioned and described results prove dependence of vertical distribution of temperatures in the heated room on time. In some dynamic states it can be considered as unfavorable, for example while pre-heating in case A, or while short-time ventilation by windows in case B. Following factors having unfavorable influence on vertical distribution of temperatures were found:

- ventilation by windows or high infiltration of the outer air
- the formation of dropping airflows at the vicinity of cool surfaces of outer walls and windows
- relatively high temperature of the heating air

Other factor causing unfavorable vertical distribution of temperatures is an insufficient shading out of dropping cool airflows by a heating air, see fig. 6, 7, 8. The reason for a relatively high temperature of a heating air in case A is above all the an unsuitable control system of a gas convector, see fig. 9.

ACKNOWLEDGEMENT

The paper was written with the support of the program TRVALÁ PROSPERITA national research program II., MPOČR code 2A – 1TP1/119. Numerical calculation in the Fluent software was performed in conjunction with the company Sobriety Ltd.

REFERENCES

1. Regulation No. 523/2002 Col.
2. FLUENT User's Guide, February 2003.
3. Cihelka, J. Vytápění a větrání, Praha: SNTL, 1969. 610 p.