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# The influence of the wall temperature on the flow from the floor convector (experimental results)

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**Abstract.** This article describes the measurement of the influence of the wall temperature on flow from the floor convector. The measurement is realized in an open space laboratory. The velocity field at the convector inlet and outlet is visualized using PIV technique. Two temperatures 19.8 °C and 12.5 °C are set at the wall to evaluate the influence of the wall cooling.

## 1 Introduction

Floor convectors are heating bodies intended for the installation into floor. The floor convectors can utilize the free convection or forced convection for the heating. The main objective of this study is a convector, which flow is driven by a fan placed in the front part of the convector. The floor convectors are usually placed by windows to shield the cold flow from the window. In an experiment the window can be replaced by a cooled wall. The hot flow from the convector can be at some position at the cooled wall reversed by a cold flow falling down along the wall. This effect is very strong especially in the convectors utilizing the free convection effect [1]; however it can also occur in convectors based on the forced convection. Basic scheme of a floor convector assembly is shown in Figure 1. It consists of a sheet metal housing, which allows placing of other convector components and also collects the water from

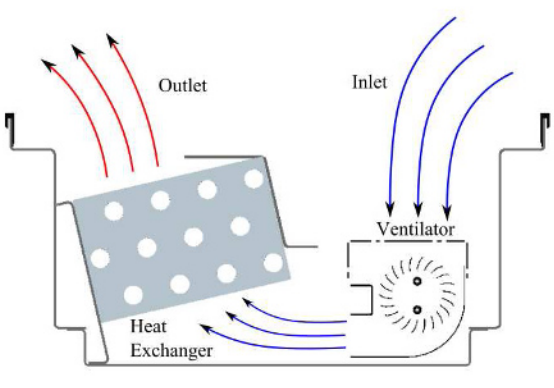


**Fig. 1.** Floor convector principle.

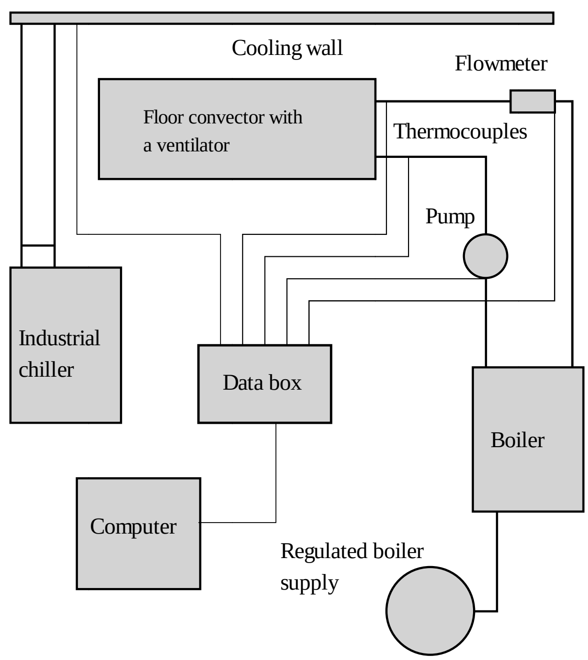


**Fig. 2.** Experimental setup.

condensation in the case of the cooling regime. The forced convection in the convector is usually driven by a centrifugal fan. The fan sucks the cold air trough the upper grid and directs trough thought the heat exchanger (hot or cold) out of the convector. Tube finned heat exchangers are commonly used in the floor convectors.

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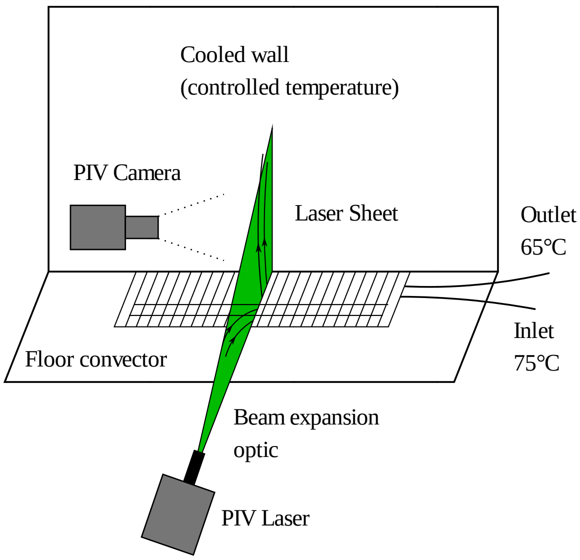


**Fig. 3.** PIV Measurement.

The distance between the fins is large for natural convection and small for the forced convection. As the convectors has been studied intensively for many years there is a wide theoretical background given e.g. in [2], [3]. Note that the most of the literature is focused on the design and optimization of the heat exchangers generally [4], however there is lack of literature focused on the floor convectors design. One of methods which can be used for the investigation of the flow above the convector is PIV (Particle Image Velocimetry) [5], [6]. This method provides the information about the flow patterns and the velocity. In this method the flow is visualized by introducing particles into the investigated flow. The introducing of the particles has to be adjusted carefully as it could disturb the investigated flow.

## 2 Experimental setup

Experimental setup used for the convector supply and the measurement of the heat power is shown in Figure 2. The floor convector is heated from a boiler which is supplied by the regulated electrical supply. The heat power $\dot{Q}$ of the convector is calculated using calorimetric equation as

$$\dot{Q} = \rho \times \dot{V} \times c_p \times (t_{in} - t_{out})\,, \tag{1}$$

where $\rho$ is water density which depends on temperature, $\dot{V}$ is the water volume flux measured at the convector outlet, $c_p$ is the heat capacity at constant pressure and $t_{in}$ and $t_{out}$ are the inlet and outlet temperatures of the flow at the convector. Note that the density and heat capacity are functions of temperature. The volume flux trough the convector is measured using an inductive flow meter. The temperatures on the convector inlet and outlet are measured using three thermocouples each. Two thermocouples from each pair are used for measurement and the third is used to set the right value. The temperature difference at the convector is set up using the following procedure. First, the inlet temperature is set at required value. Then by the controlled boiler supply and by the flow rate adjustment the outlet temperature is set to required value. The temperature at the wall is controlled by the cold water delivery from an industrial chiller with the regulation range 1K. All the data from the measurement are collected in a databox and monitored by a LabView signal express application. The convector is placed in the floor of an open space laboratory. The laser sheet for the PIV measurement is generated perpendicularly to the cooled wall as it is visible in Figure 3. The camera is placed perpendicularly to the sheet. For the comparison of the influence of the wall temperature on the flow from the convector the wall temperature was to 19.7 °C and to 12.5 °C. The temperature difference between the convector inlet and outlet was set at 10°C. The flow was saturated by oil based particles, which were introduced at the fan inlet into the convector by a perforated hosepipe. This setup provided an uniform saturation along the convector length.

## 3 Results

Figure 4. shows basic flow patterns at the convector inlet and outlet. At the inlet the air saturated with the particles is sucked trough the covering grid into the fan. As the fan sucks the cold air trough its upper part the inlet region is wide. The flow in the inlet region is slightly tubulised, which results in small inlet velocities.

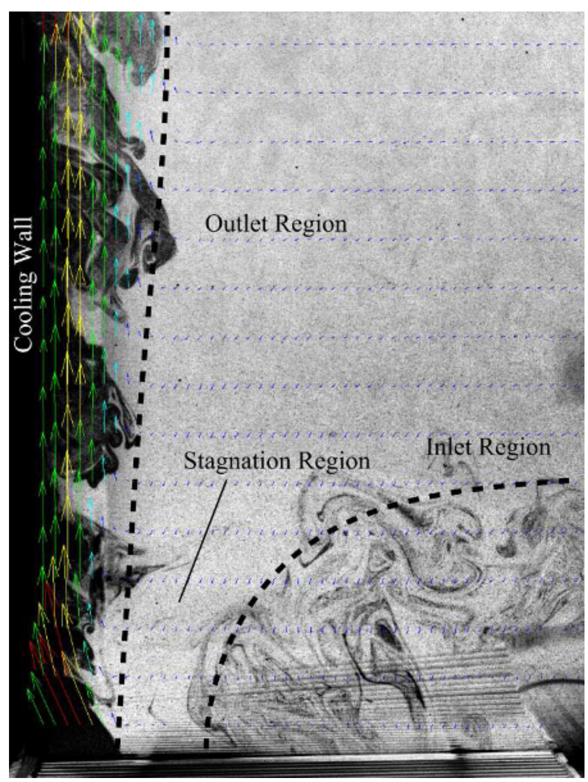


**Fig. 4.** The flow patterns above the convector.

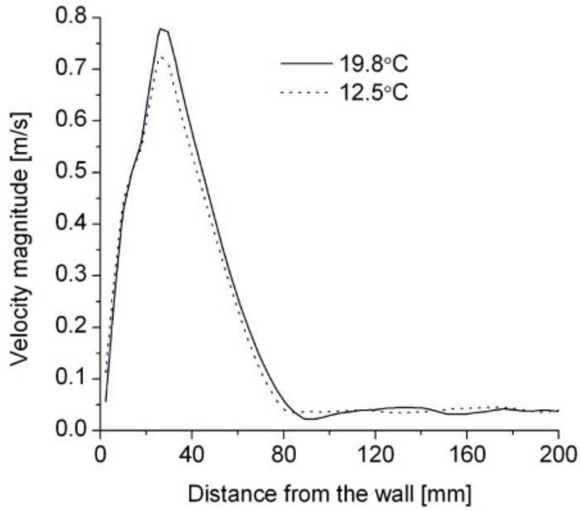


**Fig. 5.** The velocity profile at the position 340 mm above the convector outlet.

The inlet region ends with the stagnation region. Its position corresponds with the placement of the covering sheet metal, which is visible at the top of the Figure.1. The change in the length of this sheet can significantly influence the size of the inlet and the outlet region and also the inlet and outlet velocities. The outlet region has highest velocity close to the convector grid and the flow profile thickness is increasing with the vertical position. The Figure 5. shows the velocity profiles at the distance 340 mm above the convector for the wall temperatures 19.8 °C and 12.5 °C. The velocity profile for the lower temperature shows a lower maximum velocity. This is probably caused by the falling cold flow along the wall; however the difference between the velocity values is low. The measured heat power for the wall temperature 12.5 °C is 662 W and the heat power for the temperature 19.8 °C is 650 W. The increase in the heat power can be caused by a cold flow falling into the convector inlet from the cooled wall. The measured ribs temperature was about 55°C. Figure 6. shows the comparison of vertical velocity components for the wall temperatures 12.5 °C and 19.8 °C. The figures indicate no significant difference in the velocity magnitude. Slight flow deceleration can be deduced from the velocity close to the wall. The high velocity at the left corner of the picture is caused by a protrusion at the wall. Figure 7. shows the results of the PIV measurement of the velocity above the convector for the wall temperature 19.8 °C. The highest velocity is indicated in the layer close to the wall.

**Table 1.** Results summary.

| Wall temperature °C | Maximum velocity m/s | Heat power Watt |
|---|---|---|
| 19.8 | 0.95 | 650 |
| 12.5 | 0.85 | 662 |

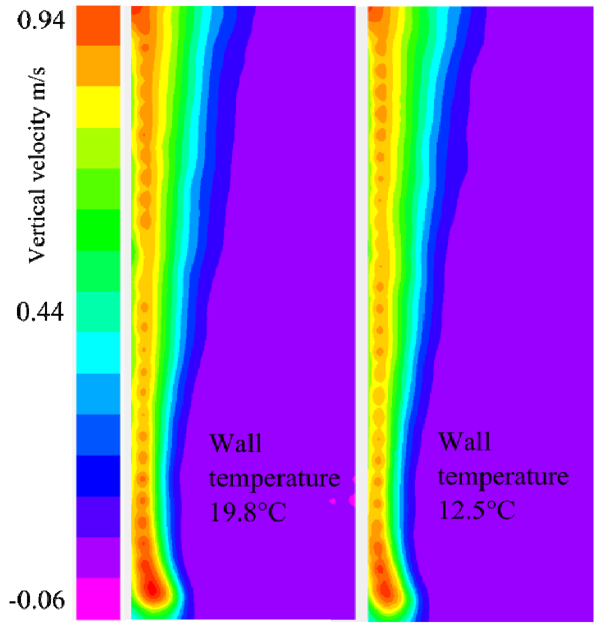


**Fig. 6.** The comparison of the vertical velocity for temperatures 19.8 °C and 12.5 °C.

The velocity does not change significantly along the vertical position. The Figure 8. shows the results of the PIV measurement of the velocity above the convector for the wall temperature 12.5°C. The velocity distribution is similar to the one for the wall temperature 19.8 °C, however the maximum velocity is lower. The summary of results is presented in Table 1.

## 4 Conclusions

The measurements of the influence of the wall temperature on the flow from a convector were realized using PIV method. The results show that the effect

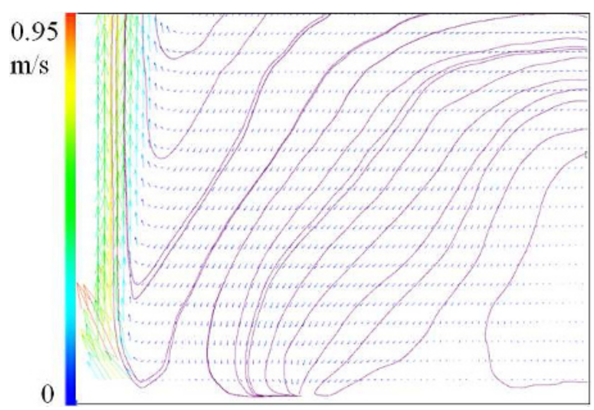


**Fig. 7.** The flow from the convector for the wall temperature 19.8 °C. The size of the displayed area was 630x480 mm.

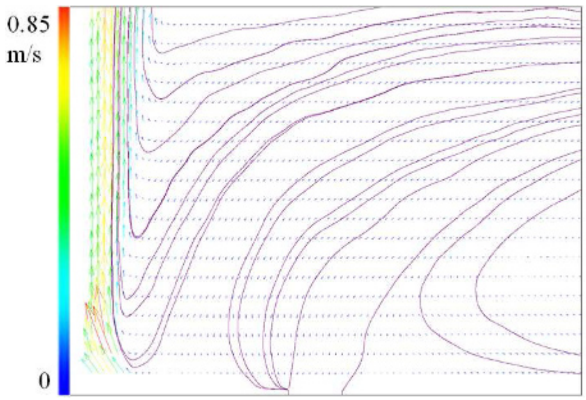


**Fig. 8.** The flow from the convector for the wall temperature 12.5 °C. The size of the displayed area was 630x480 mm.

of the wall cooling is insignificant in the measured area. However it does not mean that this effect cannot occur at a higher vertical position. The future investigation will be focused on the measurement of the velocity profiles at higher positions at the cooled wall where a flow deflection from the wall is expected. The results show that the real inlet velocity can be influenced by the velocity of the delivered visualization fluid, which is in this region of the same order.

## 5 Acknowledgements

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