The use of in-floor convectors in rooms with a large glazing area

V Pukhal

1Saint Petersburg State University of Architecture and Civil Engineering 4 Vtoraya Krasnoarmeiskaya, 190005, Saint Petersburg, Russian Federation
E-mail: pva1111@rambler.ru

Abstract. To prevent the flow of downward cold air from translucent structures into the served area of the room, convectors with natural and forced convection are used, which are built into the floor structure. An analysis of the requirements of manufacturers of convectors with natural convection for the placement of heating elements in the body and the distance from the glazing to the convector showed their inconsistency. A test bench was made for the study of heating systems with in-floor convectors with natural convection. The heat flow of the convector KKKD 43.14.150 (Izotherm LLC, Russia) was studied with various options for the location of the heating element in the installation box: from the side of the room close to the box wall; from the side of the glazing close to the wall of the box; placement of the heating element in the center of the box. The studies were performed at various distances from the glazing to the convector. The test data of the convector “Gulfstream” KRK 20.11.150 (Izotherm LLC) with natural convection with different placement of the heating element, performed by the HLK Stuttgart Institute (Germany), are presented. The simulation of the test chamber and convector was performed using the Axis Engineering FloEFD software package. The conditions for the use of in-floor convectors with natural air circulation are determined.

1. Introduction

Floor convectors are designed for water heating systems of residential, public and administrative buildings, including child-care centers, cottages and offices [1 - 4].

Convectors successfully solve the problems of space heating, where the installation of traditional appliances is difficult due to the lack of space for their placement (for example, when the facade is completely glazed) or impractical according to the requirements of modern design. Convectors are mounted in the floor structure along the windows and walls of heated rooms and are connected to water heating systems. In residential buildings, they can be installed in vestibules, winter gardens and other similar facilities. Convectors with natural convection are used as screens on the path of cold air in translucent structures. The flow of cold air from the windows is prevented, and thereby a comfortable microclimate is created in the room.

Floor convectors are recommended for use only in pump heating systems. Convector designs are available with natural and forced convection. When installing an in-floor convector, the box with the heat exchanger is hidden in the floor structure, immersed in a cement screed or openings made in raised floors. Only the decorative grill remains visible, the color of which can be matched to the interior of the room. The grill can be longitudinal or roll. It is made of anodized or polymer coated aluminum, as well as stainless steel, brass and fine wood.
Most build-in convectors have a box made of galvanized or stainless steel. A copper-aluminum heat exchanger is most often used as a heating element, but fully copper heating elements are also used (in rooms with high humidity). For ease of installation, the heat exchangers are made both end-type (supply and return pipelines are supplied from one side) and through-type. Convectors with one-way connection have the advantage that when connected to the heating system using flexible hoses, they make it possible to remove the heat exchanger from the box without disconnecting from the system, which is convenient when cleaning rooms.

An analysis of the recommendations of manufacturers of convectors with natural convection allowed us to draw the following main conclusions:

- the choice of the location of the heating element (heat exchanger) in the casing (installation box) is determined by the ratio of heat loss through the glazing and the heat flux of the convector (Figure 1);
- the distance from the glazing to the convector is from 0 to 350 mm.

When placing the heat exchanger from the room side (Figure 1.a), the downward flow of cold air from the glazing enters the convector body. The upward flow of heated air promotes the natural circulation of air in the room and creates a curtain in front of the window surface. This arrangement is recommended in rooms where heat loss through glazing is 70–100% of the total heat loss of the room [5].

The installation of the heat exchanger on the glazing side is recommended in cases where the heat loss through the glazing is not more than 20%. The distance between the convector and the window should be as small as possible [5].

These data and recommendations require experimental verification. In publications on the results of studies of in-floor convectors, this issue was not considered [6-10]. Therefore, the aim of this study was to test a heating device (in-floor convector with natural induction of air movement) with a different location of the heat exchanger in the installation box and to establish the effect of the location of the heating element and the distance from the convector to the barrier on the heat flow of in-floor convectors.

2. Materials and Methods
For the study, three options for the location of the heating element in the installation box were adopted (Figure 2):

- option 1 - placement of the heating element from the side of the room close to the wall of the box;

![Figure 1](image-url)
• **option 2** - placement of the heating element from the side of the glazing close to the wall of the box;
• **option 3** - placement of the heating element in the center of the box.

Experimental studies of the KRKD 43.14.150 in-floor convector (Izoterm LLC, Russia, Figure 2) with an eight-pipe heating element were performed. The heating element is equipped on both sides with side cut-off bars 32 mm high. The main dimensions of the tested convector model: length - 1500 mm; convector depth - 430 mm; convector height - 140 mm. Pipes along the coolant are connected in pairs in each tier according to the scheme from top to bottom for two tiers.

Characteristics of the convector heating element:
- dimensions of fins plates (depth/height) - 200/100 mm;
- length of the finned part of the heating element - 1173 mm;
- number of finning plates - 168 pcs;
- spacing of finning plates - 7.0 mm;
- thickness of the fins - 0.22 mm;
- height of the side shut-off bars - 32 mm;
- number of pipes - 8 pcs.;
- outer diameter of the pipes after their burnishing - 15.5 mm;
- pipe wall thickness - 0.4 mm.

The convector was located at a distance of 0, 100, 190, 300, and 400 mm from the wall (glazing). During experimental studies, the wall did not cool.

The HLK Stuttgart Institute (Germany) tested the Gulfstream KRK 20.11.150 in-floor convector with natural convection (Izotherm LLC) with various designs. The test procedure was in accordance with [11-13].

The following options for the location of the heating element in the installation box were studied (Figure 3):

• **option 2a** - placement of the heating element from the side of the glazing close to the wall of the box with a side strip;
• **option 2b** - placement of the heating element from the glazing side close to the wall of the box without a bar;
- **option 3** - placement of the heating element with side bars in the center of the box.

![Figure 3](image)

**Figure 3.** Options for the location of the heating element in the installation box of the convector KRK 20.11.150. 1 - heating element; 2 - bars; 3 - grill.

The convector was modelled in a test chamber based on the Axis Engineering FloEFD software package. The convector is placed at a distance of 50 mm from the cooled wall of the chamber. In tests, the convector heating element with a side bar was located near the casing wall from the side of the cooled wall. The test chamber has one cooled wall at full height. The temperature of the cooled wall was set equal to 16 °C.

3. Results

The results of the study of convectors are presented in the form of the dependence of the heat flux of the heating device, $\Phi_{me}, \text{W}$, on the average temperature difference (Figure 4, 5)

$$\Phi_{me} = f(\Delta T), \text{W},$$

where $\Delta T = t_m - t_R$ – average temperature difference, °C;
$t_m = (t_1 + t_2)/2$ - average water temperature in the heater, °C;
$t_1$ - water temperature at the inlet of the heater, °C;
$t_2$ - water temperature at the outlet of the heater, °C;
$t_R$ – determinative air temperature in the room, °C.

![Figure 4](image)

**Figure 4.** The dependence of the heat flow of the convector KRKD 43.14.150 on the average temperature difference when the convector is located at a distance of 100 mm from the wall. 1 - option 1; 2 - option 2; 3 - option 3.
The maximum heat flow of the convector is ensured when the heating element is located near the glazing side of the box wall (option 2) when the convector is located at a distance from 0 to 100 mm from the wall.

For example, with an average temperature difference $\Delta T = 70 \, ^\circ C$, and the convector is located at a distance of 100 mm from the wall, the heat flow $\Phi_{me} = 1441 \, W$.

When the heating element is placed in the center of the box (option 3), the heat flow is reduced by 5% ($\Phi_{me} = 1365 \, W$), and when placed on the side of the room (option 1) - by 22% (Figure 3). When placing the convector heating element on the side of the room close to the box wall, a reverse flow of heated air enters through the grill into the heating element.

A change in the distance from the wall to the convector in the range from 100 to 200 mm slightly affects the heat flux of the convector. With an increase in the distance from 100 to 190 mm in option 3 (the location of the convector heating element in the center of the box), the heat flow at an average temperature drop of 70 $^\circ C$ decreased by 3% (from 1365 W to 1323 W). Further increase in the distance from the wall to the convector to 300 mm leads to a decrease in heat flow by 7% (from 1365 W to 1266 W).

Reducing the distance from 100 to 0 mm in option 1 (placing the heating element on the side of the room close to the box wall) allows increasing the heat flow by 3%.

When testing the Gulfstream KRK 20.11.150 in-floor convector with natural convection, the dependence of the heat flow of the heater on the average temperature difference is obtained and shown in Figure 5.

![Figure 5](image.png)

**Figure 5.** The dependence of the heat flow of the convector KRK 20.11.150 on the average temperature difference when the convector is located at a distance of 50 mm from the wall. 1 - option 3; 2 - option 2a; 3 - option 2b.

In this case, the heat flow at an average temperature difference $\Delta T = 70 \, ^\circ C$ is also maximum when the heating element is located on the side of the glazing close to the box wall. The presence of a side bar slightly affects the heat flow. If the temperature difference is reduced to 20 $^\circ C$ in the option of placing the heating element with side bars in the center of the box, the heat flow will exceed 30% of the heat flow for the option of placing the heating element without the bar on the glazing side close to the box wall.

The performed modeling of the convector in the test chamber based on the Axis Engineering FloEFD software package made it possible to establish the air flow pattern in the chamber and determine the temperature and velocity fields in the chamber (Figure 6, 7).
Performed visualization of airflows by smoke, thermal imaging and modeling show that for the test conditions when the temperature difference between the glazing surface (wall) and the determinative room temperature is up to 4.5 °C, there is an attaching of a heated air jet from the convector to the barrier. When attached, the jet is pressed against the barrier and accelerates. The attached jet increases the temperature of the glazing. The room does not form a single circulation circuit (Figure 6, 7).

4. Conclusions
1. If the temperature difference between the glazing surface (wall) and the determinative room temperature is up to 4.5 °C (test conditions), and the installation of in-floor convectors at a distance of up to 400 mm from the barriers (glazing, outer wall), an upward convective jet is created, which is attached to the barrier.
2. When attaching a convective jet, the temperature of the barrier increases and, accordingly, the heat loss through the barrier increases.
3. The maximum heat flow of the convector is ensured when the heating element is located near the box wall from the glazing side, and when the convector is located at a distance from 0 to 100 mm from the wall.
4. It is recommended that the heating element of the in-floor convector with natural air circulation from the glazing side be placed close to the box wall. The distance from the glazing to the convector should be in the range from 100 to 200 mm.
5. When choosing a placement option for a convector heating element, it should be taken into account that the nominal heat flow of heating devices (Φₘₑ, W) is determined under standardized conditions. The placement of the heating element during the tests is set by the manufacturer of the heating devices.
References

[1] Boriskina I V 2012 Buildings and structures with translucent facades and roofs. Theoretical foundations of the design of translucent structures. Under the general (St. Petersburg, Engineering and Information Center of Window Systems) 400 p

[2] Krupnov B A, Krupnov D B 2010 Heating appliances manufactured in Russia and neighboring countries (Publishing house of the Association of construction universities) p152

[3] Makhov L M 2014 Heating (Publishing house of the Association of construction universities) 400 p

[4] Heating devices and surfaces (Publishing Center “Aqua-Therm”) 84 p

[5] Convectors. Licon. http://www.liconrus.ru/upload/konvекторy_licon_2018.pdf, last accessed 2020/06/27

[6] Bašta J 6 Legner T 2017 Analýza podlahového otopného tělesa (ČVUT v Praze)

[7] Muller M, Frana K, Kotek M, Dancova P 2013 The influence of the wall temperature on the flow from the floor convector (experimental results). *EPJ Web of Conferences* 45 DOI: 10.1051/epjconf/20134501130

[8] Lemfeld F, Muller M, Frana K 2013 Fin Distance Effect at Tube-Fin Heat Exchanger *EPJ Web of Conferences* 45, 01130 DOI: 10.1051/epjconf/20134501130

[9] Peukert P, Muller M 2012 Measurement of floor convectors at special laboratory and first results. *EPJ Web of Conferences* 25, 01071 DOI: 10.1051/epjconf/20122501071

[10] Greššák T, Kapjor A, Hužvár J 2013 Measurement of influence geometry of floor convector on his performance. *EPJ Web of Conferences* 45, 01036 DOI: 10.1051/epjconf/20134501036

[11] DIN EN 16430-1: 2015. Fan assisted radiators, convectors and trench convectors - Part 1 Technical specifications and requirements; German version EN 16430-1:2014 - 14 p

[12] DIN EN 16430-2: Fan assisted radiators, convectors and trench convectors – Part 2: Test method and rating for thermal output; German version EN 16430-2:2014 – 26 p

[13] DIN EN 442-2-2015 Radiators and convectors - Part 2: Test methods and rating; German version EN 442-2:2014 - 80 p