Analysis of the heat flux from the floor and ceiling heating

Research report

Ing. Daniel Adamovský, Ph.D.
Ing. Martin Kny, Ph.D.

20. 8. 2018

ČVUT
ČESKÉ VYSOKÉ UČENÍ TECHNICKÉ V PRAZE

UCEEB
UNIVERZITNÍ CENTRUM ENERGETICKY EFEKTIVNÍCH BUDOV

OBSAH

Tiráž:

Analysis of the heat flux from the floor and ceiling heating
Research report

Ing. Daniel Adamovský, Ph.D. | daniel.adamovsky@fsv.cvut.cz | +420 778 403 299
Ing. Martin Kny, Ph.D. | martin.kny@cvut.cz |

20. 8. 2018

Czech Technical University in Prague
University centre for energy efficient buildingsTřinecká 1024 | 273 43 Buštěhrad | www.uceeb.cz

1.1 SUBJECT

1.2 Introduction information

Customer:	Fénix Trading s.r.o.
Address:	Slezská 535/2, Jeseník
IČ:	48399043
Web:	http://www.fenixgroup.cz/
Represented by:	Ing. Cyrilem Svozilem
Contact:	email: c.svozil@fenixgroup.cz
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:	Determination of radiant heat flux for electric floor and ceiling heating depending on the distance from the heating surface. The radiant flow is determined for the steady state temperature in the measuring chamber (interior temperature 21 °C, outdoor temperature -10 °C). Radiation efficiency is also determined. This is the proportion of heat flow by radiation to electrical input.

1.3 Specification of the order content

The subject of this research report is the determination of radiant heat flux for electrical floor and ceiling heating (customer's product) depending on the distance from the heating surface. The radiant flow is determined for the steady state temperature in the measuring cabin (interior temperature 21 °C, outdoor temperature -10 °C).

The subject of the report is also to determine the proportion of heat flux by radiation to electrical input.

2 METHODOLOGY

Measurements were made in the climatic chamber of the contractor.

2.1 Methodology of experiments

2.1.1 Measure situation

The measurements were carried out in the climatic chamber of the University Centre for Energy Efficient Buildings of Czech Technical University in Prague. It is a room in which the temperature can be adjusted in order to imitate the real conditions of the buildings during summer and winter.

Floor and ceiling heating was realized by means of electric heating film. The ECOFILM F (40 W/m^2) foil has been placed under the floor layer (laminate "floating floor") in floor heating and in the ceiling heating of the ECOFILM C film (100 W/m^2) above the plasterboard. The heating system together with its control (room thermostat mounted on the cabin wall) was installed by the customer (see Figure 2-1).

All measurements were made at a steady state when the interior temperature was controlled by a room thermostat at 21 °C and the temperature of the exterior was -10 °C.

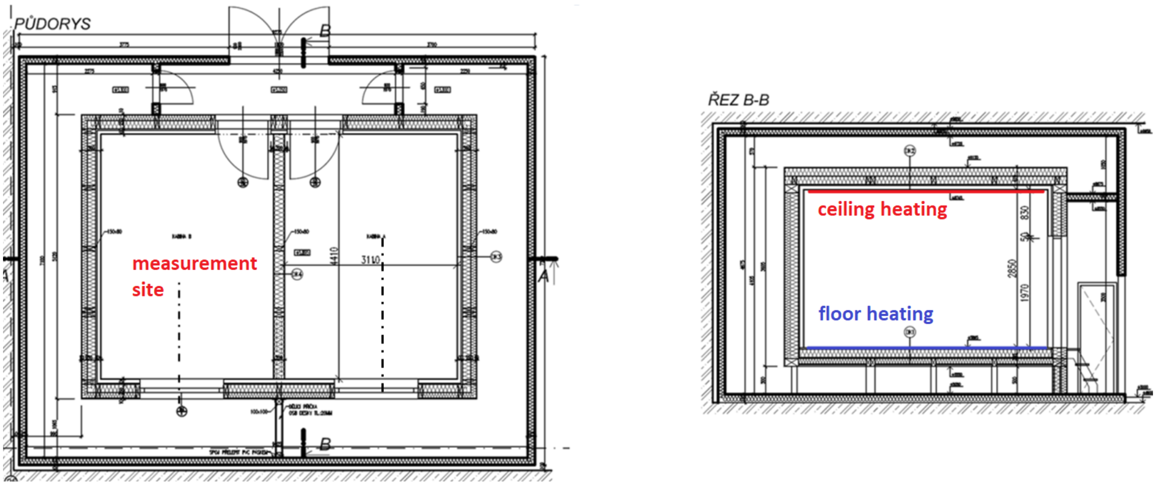

Figure 2-1 Measurement site - climatic chamber

2.1.2 Radiant heat flux measurement procedure

The measuring chamber was first equipped with the necessary measuring technique (see Table 2-1):

- surface temperature sensors have been installed on the walls,
- checkpoints were set on the floor and ceiling to evaluate the scale of the thermal camera,
- a tripod with a globe thermometer (height 1.1 m) was installed,
- a height-shifting tripod was installed with a radiant heat flow sensor,
- an auxiliary heat source (sheet metal cylinder with a 75 W lamp) was installed.

The climatic chamber was then brought to a steady state (thermostat set temperature 21 °C, interspace temperature set to -10 °C). Initial stabilization occurred after about 40 hours (underfloor heating). In addition to its own heating surface, an additional heat source was also in operation.

During the measurement, the heating surface was firstly photographed with a thermal camera, and the radiant heat flux at each distance from the heating surface (300 mm, 800 mm, 1300 mm, 1800 mm, and 2300 mm) was measured immediately. Radiant heat flow measurement was repeated 3 times in succession. Measurement took place for about 30 minutes. After the underfloor heating was measured, the ceiling heating was activated. Once the chamber has been re-established, the measurements have been made in the same way for ceiling heating.

Thermal imaging and radiant heat flow measurements required the presence of a person in the chamber. This person could influence the thermal balance of the cabin during the measurement period (increase of the temperature sensed by the thermostat and the decrease of the heating surface). To avoid this, a 75 W auxiliary heater was installed in the chamber. This heater was switched off during the presence of a person in the cabin. The thermal balance of the cabin was not significantly disturbed during the measurement.

During the measurement, the surface temperature of the walls, the temperature of the globe thermometer, the temperature of the air in the chamber and the refrigerated interspace as well as the power consumption of the heating surface (see Table 2-2) were continuously measured (in minute intervals).

2.1.3 Measuring devices and sensors

Table 2-1 Summary of measuring devices

Description	Type	Range	Accuracy	SN.
Indoor Climate Analyzer	Brüel & Kjær type 1213			1406645
Radiant temperature asymmetry sensor	Radiant Temperature Asymmetry Transducer MM 0036	±50 °C (air temperature)	±0,05 K at ($t_r - t_a$) < 15 K, ±0,05 till ±2,0 K at 15 < ($t_r - t_a$) < 50 K	372-010
Datalogger	Datataker DT85-3	3 V	0,08 mV	106146
Air temperature (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 %	-
Thermal Imaging Camera	InfraTec VarioCAM HD 1024 x 768 IR px	Temperature range -40 till 1200 °C	1,5 K (or 1,5 %)	1007616

2.1.4 Summary of measured parameters

Table 2-2 Summary of measured parameters

Parameter	Abbreviation	Unit
Heat flux	Q	W
Specific radiant heat flux at a vertical plane	q	W/m^2
Air temperature	t_a	°C
Surface temperature	t_s	°C
Electric input 1f	P_{el}	W

3 RESULTS

3.1 Radiant heat flux - floor heating

Table 3-1 Radiant heat flux for floor heating

Distance from the surface (mm)	300	800	1300	1800	2300
Specific radiant heat flux of the surface (W/m^2)	443	440	438	435	432
Ambient specific radiant heat flux (W/m^2)	426	426	426	427	428
Ambient specific radiant heat flux (W/m^2)	**17**	**14**	**11**	**8**	**4**

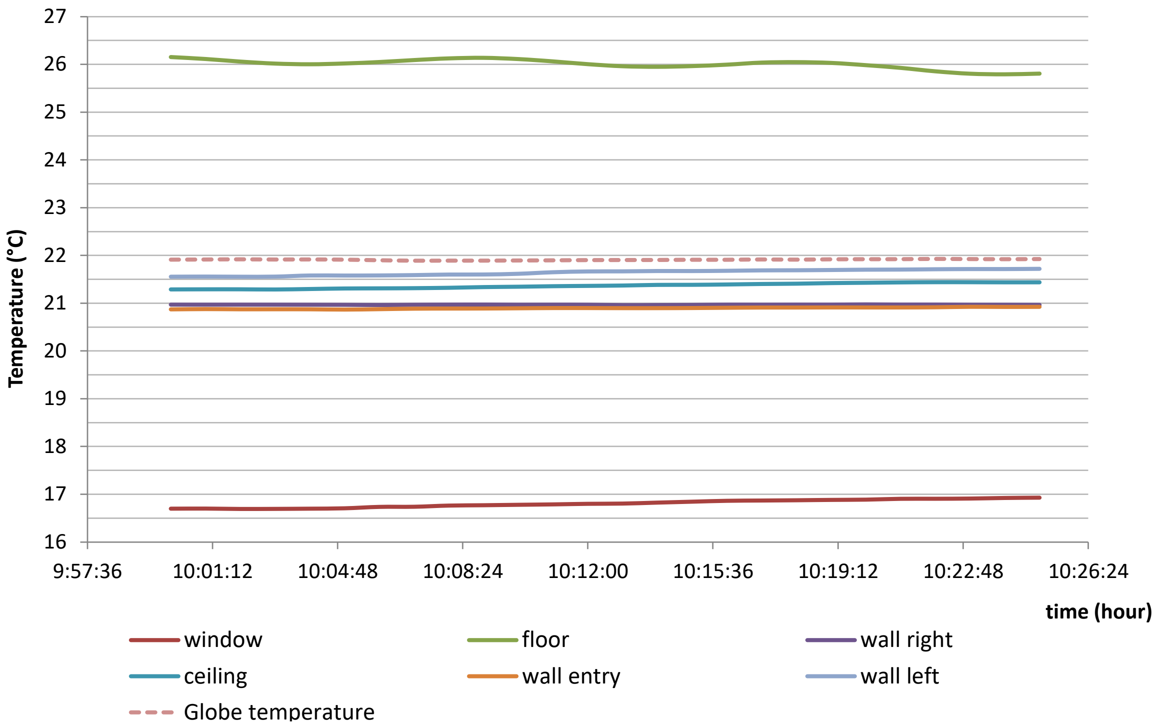

Figure 3-1 Cabin conditions during floor heating measurements

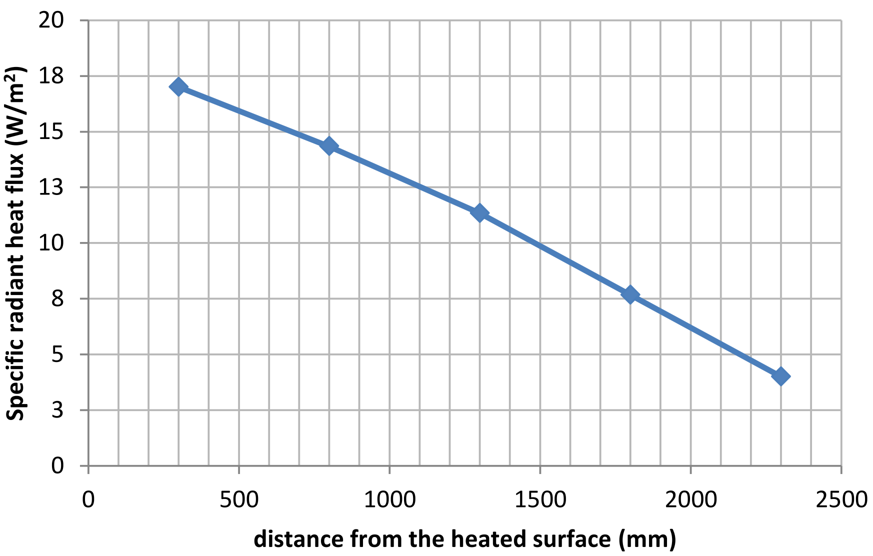

Figure 3-2 Heat flux dependence on the distance from the surface (floor heating)

3.2 Proportion of the radiant heat flux to electric input - floor heating

The proportion of the radiant heat flux to electric input was determined from the measured values of the surface temperature distribution in the chamber (the heating surface was rated by the thermal camera). The heat flux was then calculated by radiation from the heating surface, which was compared to the surface heating power input. The measured and calculated values are shown in Tab. 3-2

The estimated proportion of heat flux from floor to electric power is 77%.

Table 3 2 measured and calculated values for radiant heat flux determination

Active heating surface (determined by thermal camera)	**S1**		**8.308**	**m^2**

Constants	**Abbrev.**		**Value**	**Unit**
Emissivity of radiation of a real body	ε		0.95	-
Stefan-Boltzman constant	σ_0		5.67E-08	$W/(m^2.K)$

Surface temperature	**Abbrev.**		**Value**	**Unit**
Average surface temperature of the heated area	$t_{s,p}$		26.20	°C
Average thermodynamic temperature of the heated surface	$T_{s,p}$		299.35	K

Surface temperatures of surrounding structures	**Abbrev.**	**Value**	**Value**	**Unit**
1 - window	t_{s1}	1.82	16.81	°C
2 - left wall (from the entrance)	t_{s2}	11.97	21.64	°C
3 - right wall (from the entrance)	t_{s3}	11.97	20.97	°C
4 - ceiling	t_{s4}	13.23	21.36	°C
5 - wall with window (without window)	t_{s5}	7.16	20.97	°C
Total area of the surrounding walls		46.15		m^2
Average surface temperature of surrounding walls	t_s		21.1	°C
Mean thermodynamic temp. of the surrounding surfaces	T_s		294.24	K

Parameter	**Abbrev.**		**Value**	**Unit**
Electric input (mean steady state) *	P_{el}		308.7	W
Radiant heat flux	Q_s		239.1	W
Proportion of the radiant heat flux to electric input	**η_s**		**77.43%**	**-**

** The maximum power input was 535 W*

3.3 Radiant heat flux - ceiling heating

Table 3-3 Radiant heat flux for ceiling heating

Distance from the surface (mm)	300	800	1300	1800	2300
Specific radiant heat flux of the surface (W/m²)	459	448	442	438	434
Ambient specific radiant heat flux (W/m²)	426	426	426	427	427
Ambient specific radiant heat flux (W/m²)	**33**	**22**	**16**	**11**	**7**

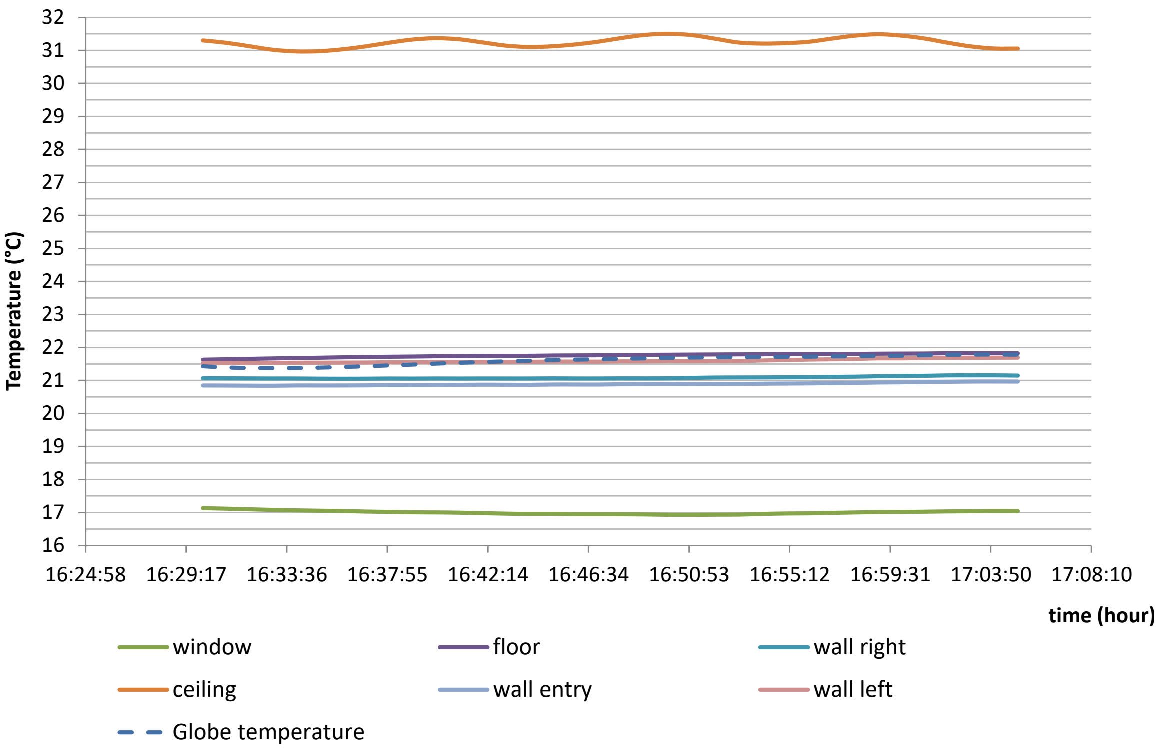

Figure 3-3 Chamber conditions during ceiling heating measurements

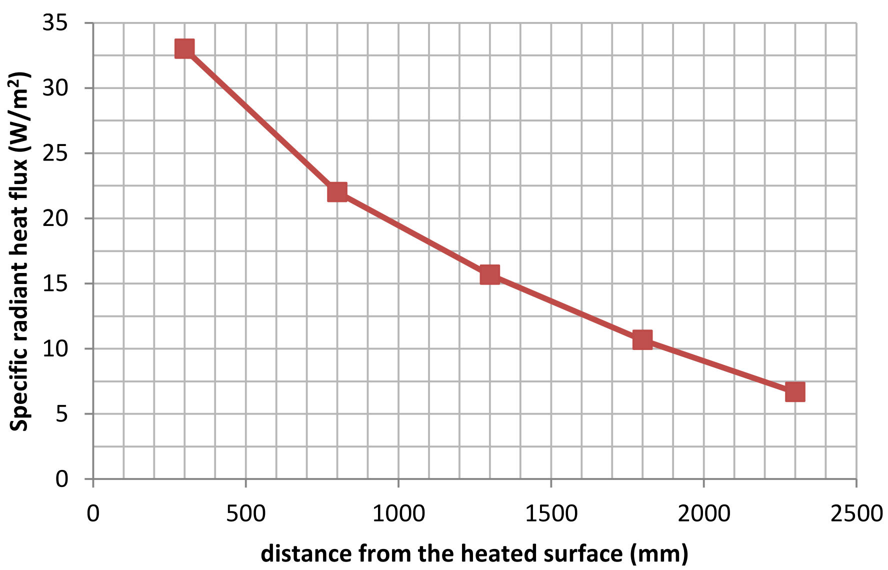

Figure 3-4 Heat flux dependence on the distance from the surface (ceiling heat.)

3.4 Proportion of the radiant heat flux to electric input - ceiling heating

The proportion of the radiant heat flux to electric input was determined from the measured values of the surface temperature distribution in the chamber (the heating surface was rated by the thermal camera). The heat flux was then calculated by radiation from the heating surface, which was compared to the surface heating power input. The measured and calculated values are shown in Tab. 3-4.

The estimated proportion of heat flux from ceiling to electric power is 84 %.

Table 3-4 measured and calculated values for radiant heat flux determination

Active heating surface (determined by thermal camera)	**S1**		**5.440**	**m^2**

Constants	**Abbrev.**		**Value**	**Unit**
Emissivity of radiation of a real body	ε		0.95	-
Stefan-Boltzman constant	σ_0		5.67E-08	$W/(m^2.K)$

Surface temperature	**Abbrev.**		**Value**	**Unit**
Average surface temperature of the heated area	$t_{s,p}$		29.60	°C
Average thermodynamic temperature of the heated surface	$T_{s,p}$		302.75	K

Surface temperatures of surrounding structures				
1 - window	t_{s1}	1.82	17.00	°C
2 - left wall (from the entrance)	t_{s2}	11.97	21.59	°C
3 - right wall (from the entrance)	t_{s3}	11.97	21.08	°C
4 - floor	t_{s4}	13.23	21.36	°C
5 - wall with window (without window)	t_{s5}	7.16	21.08	°C
Total area of the surrounding walls		46.15		
Average surface temperature of surrounding walls	t_s		21.1	°C
Mean thermodynamic temp. of the surrounding surfaces	T_s		294.29	K

Parameter	**Abbrev.**		**Value**	**Unit**
Electric input (mean steady state) *	P_{el}		313.6	W
Radiant heat flux	Q_s		264.0	W
Proportion of the radiant heat flux to electric input	**η_s**		**84.17%**	**-**

** The maximum power input was 538 W*

4 CONCLUSION

The report summarizes the conclusions from the radiant heat flux measurement for electrical floor and ceiling heating.

The conclusions for each section of the report:

Specific radiant heat flux:

- For the floor heating, the radiant heat flux (measured over a range of 300 mm to 2300 mm) achieves values ranging from 17 W/m^2 to 4 W/m^2,
- For the ceiling heating, the radiant heat flux achieves values ranging from 33 W/m^2 to 7 W/m^2,
- The decrease in heat flux with increasing distance is initially more pronounced in the ceiling heating compared to floor heating. This state is given by a smaller active area (heated area) used for ceiling heating.

Proportion of the radiant heat flux to electric input η_s:

- parameter η_s reaches about 77 % for underfloor heating,
- for ceiling heating reaches about 84 %.

General Summary:

The results of this report correspond to the generally published conclusions in the literature. The radiant heat flux increases with the 4th power of the difference in surface temperatures. For this reason, the thermal flow for the ceiling heating is higher than the floor heating. This condition is further supported by the lower convective heat transfer in the ceiling heating.

5 PHOTOS

Figure 5-1 View into the measuring chamber ready to measure the heat flux of floor heating. On the left is a datalogger and a sensor for measuring radiant heat flux. On the floor is a length scale for the thermal camera. On the right is a globe thermometer.

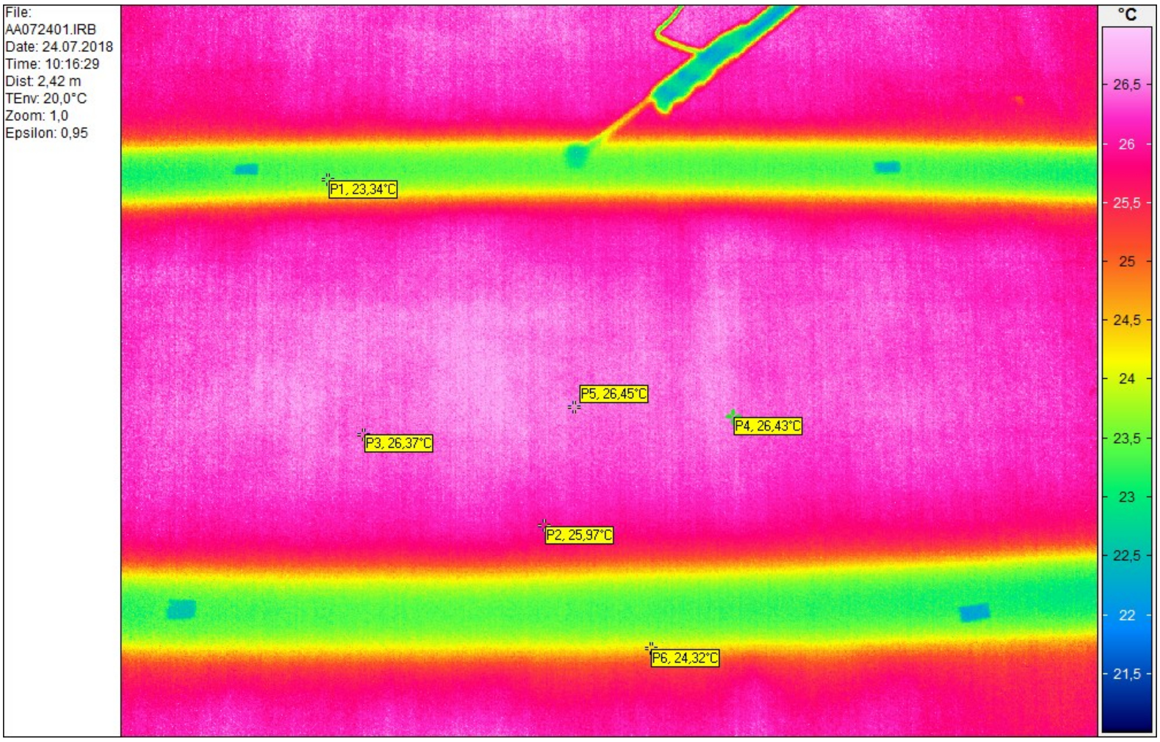

Figure 5-2 Surface temperatures for underfloor heating (steady state)

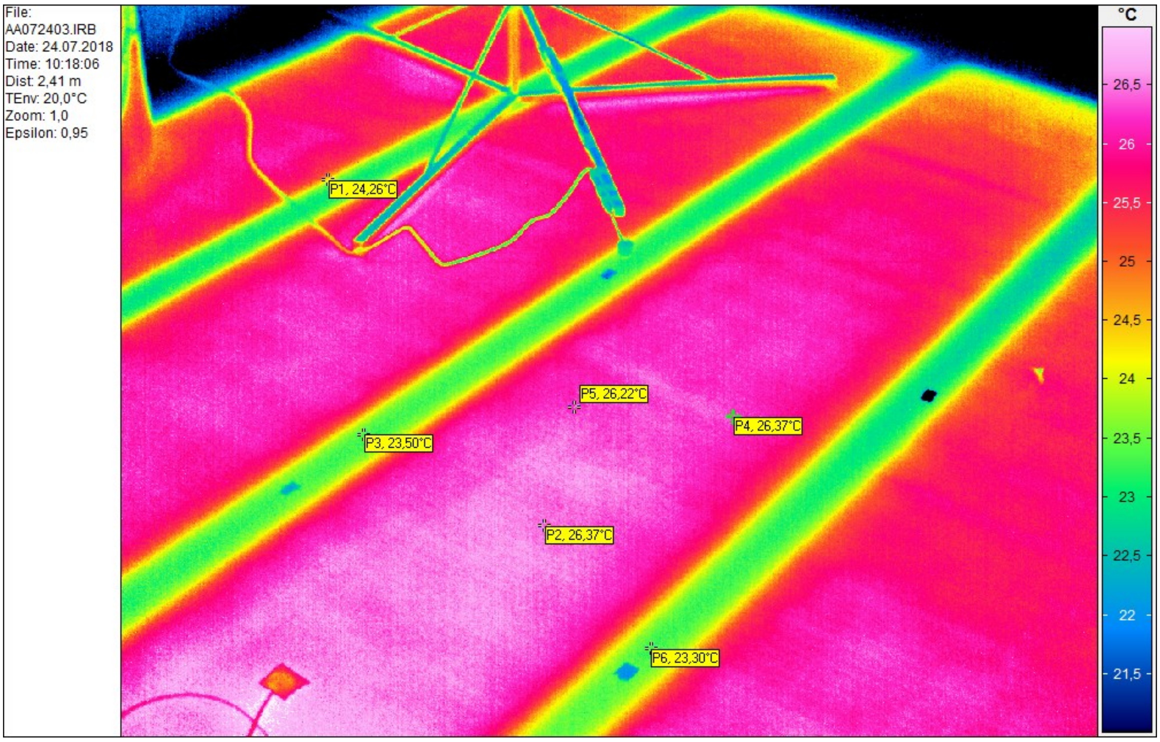

Figure 5-3 Surface temperatures for underfloor heating - wider shot (steady state)

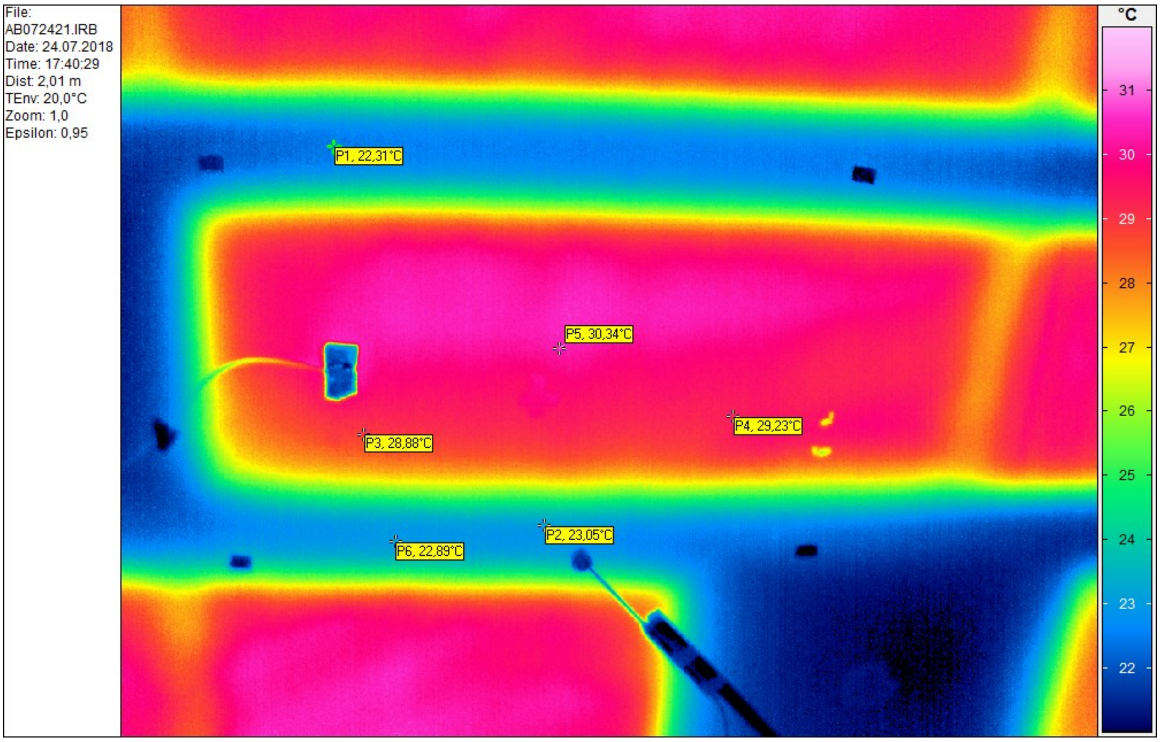

Figure 5-4 Surface temperatures for ceiling heating (steady state)

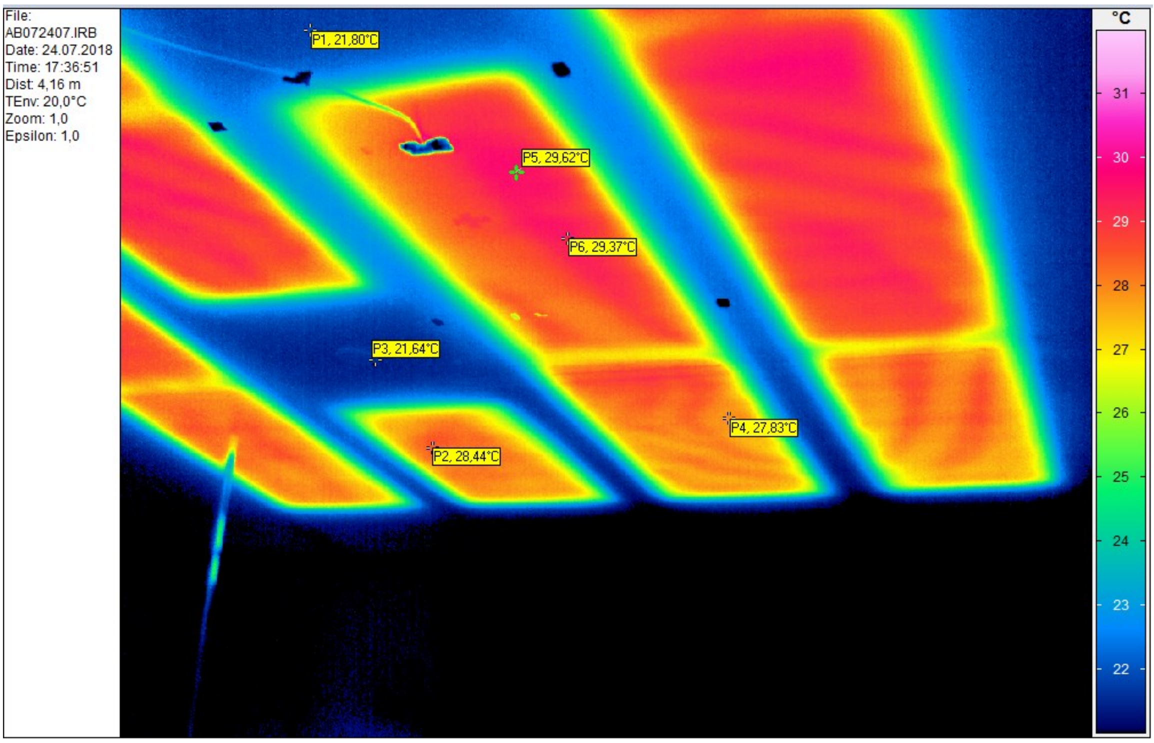

Figure 5-5 Surface temperatures for ceiling heating - wider shot (steady state)