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Analysis of radiant characteristics of electric panels FENIX for heating.

final report

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OBSAH

(1) Subject

(1.1) Fundamental information

Testing laboratory:	Czech Technical University in Prague, University Centre for Energy Efficient Buildings, Quality of Indoor Environment Třinecká 1024 273 43 – Buštěhrad
Customer:	FENIX Trading s.r.o. Slezská 535/2, 790 01, Jeseník
Subject of analysis:	analysis of radiant characteristics of electric panels for heating
Period:	October till December 2016
Place of experiments:	Buštěhrad
Responsible person:	prof. Ing. Karel Kabele, CSc
Report and experiments processed by:	Ing. Ondřej Nehasil Ing. Daniel Adamovský, Ph.D.

(1.2) Introduction

This final report concludes results of analysis focused on radiant characteristics of radiant electric panels for heating.

Description of analysed heating systems

The analysis have included following 10 panels:

- ECOSUN S+ 09
- ECOSUN S+ 12
- ECOSUN S+ 18
- ECOSUN S+ 24
- ECOSUN S+ 30
- ECOSUN S+ 36
- ECOSUN 700 U
- ECOSUN 1000 U
- ECOSUN TH10
- ECOSUN TH15

(2) Methodology of measurement and analysis of results

(2.1) Description of measuring setup

Measurements of all panels were conducted in the hall of university centre UCEEB where was restricted area of dimensions 8 x 6 m dedicated only to experiments. In the centre of this area each panel was hung on a crane.

Each tested radiant panel was mounted on auxiliary suspending structure and elevated in high 4 m above the hall's floor. In this position every panel was fixed into the horizontal plane by ropes. The correct position was examined by spirit level fixed on the auxiliary structure.

A mesh of measuring points covered half of a vertical layer perpendicular to the longitudinal axe of the panel starting in the middle point of radiant panel. In the mesh were 15 measuring points distanced 1 x 1 m (Figure 2-1). The immediate point under panels was excluded due to measured values exceeding measuring range of used devices.

Concurrently was established comparative measuring point away of direct radiation from panel where ambient conditions were measured.

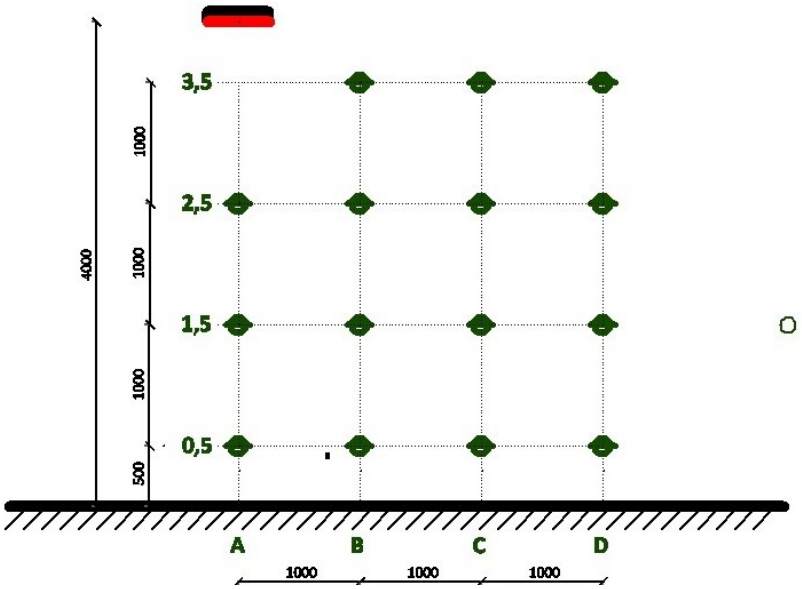


Figure 2-1 Scheme of measuring mesh under tested panel

(2.2) Procedure of measurement

When tested panel was fixed into the correct position (see previous point 2.1) electric supply was connected into the grid and period of stabilizing thermal output started. This period lasted at least 3 hours until the panel and directly exposed surface (floor) reached steady stated conditions. Steady state conditions were evaluated by stability of panel's surface temperature.

Before measurements in points of the mesh started, ambient state was measured in the comparative point. This measurement was performed also at the end.

Measurement of input data for analysis of each panel was done consecutively point by point of the mesh and repeated three times.

Concurrently was gathered data of surrounding air temperature, air temperature above the measured panel and supporting data of electric input.

Finally infrared images of front area and rear cover were collected.

(2.3) Measuring devices and sensors

Table 2-1 Summary of measuring devices

Description	Type	Range	Accuracy	SN.
Indoor Climate Analyser	Brüel & Kjær type 1213			1406645
Radiant temperature asymmetry sensor	Radiant Temperature Asymmetry Transducer MM 0036	±50 °C (air temperature)	±0,05 K when (t_r – t_a) < 15 K; ±0,05 - ±2,0 K when 15 < (t_r – t_a) < 50 K.	372-010
Datalogger	Datataker DT85-3	3 V	0,08 mV	106146

Temperature and relative humidity	HC-2-S + E2-XX	-50 až 100 °C, 0 až 100 %	0,3 °C, 2,7 %	20043030
Air velocity	SVO hotwire	0,5 až 3 m/s	0,13 m/s	4F150807719
Air temperature (4 pcs.)	TG8-40, Pt 1000	-20 až 60 °C	0,21 °C	30704/1015, 30705/1015, 30125/1015 30709/1015
Electric input – 1 phase	EKM 265	1,5 W - 2650 W	±1 %	-
Electric input – 3 phase	Voltcraft VC-5900LED	0,001 – 750 V, 0,01 – 600 A	0,8 %	-
Thermal Imaging Camera	InfraTec VarioCAM HD 1024 x 768 IR px	Temperature range -40 až 1200 °C	1,5 K (or 1,5 %)	1007616
Spirit label	Extol craft 600 mm			

(2.4) Summary of measured parameters

Table 2-2 Summary of measured parameters

Název	Značka	Jednotka
Specific radiant heat flux at a horizontal plane	q	W/m^2
Mean radiant temperature	t_r	°C
Difference of radiant temperature at a horizontal plane in radiant field of a panel against ambient radiant temperature	$\Delta t_{r,H}$	K
Air temperature	t_a	°C
Relative humidity of air	φ_a	%
Electric input – 1 phase	P_{el}	W
Electric current (3 phase)	I_{el}	A

(2.5) Description of analysis of measured data

The increase of mean radiant temperature in each measuring point is given as difference between radiant temperature in upper hemisphere in particular measured point and ambient radiant temperature measured away of the panel's direct influence. Depicted values of the increase of mean radiant temperatures in each point are average of three measurements.

The increase of specific radiant heat flux in each measuring point of mesh under the panel represents radiant flux at a horizontal layer due to direct radiation of measured panel. It has been calculated from total specific radiant heat flux minus specific radiant heat flux in ambient conditions away of panel's direct influence. Depicted values are again average of three measurements.

Isocurves of the increase of specific radiant heat flux are only graphical expression of heat transfer via radiation from panels. In estimation of isocurves was involved linear and second order attenuation of radiant heat flux in order of measuring point's distance from the panel and incident angle between the point and the panel (third order polynomic function). Conformity of calculated isocurves with measured data is acceptable, but priority has measured values before isocurves.

Thermal images of front area and rear cover depict tentative distribution of temperature field and maximum surface temperature.

(3) Results

(3.1) ECOSUN S+ 09

Table 3-1 Basic technical parameters of measured panel Ecosun S+ 09

Panel type, producer	ECOSUN S+ 09, FENIX Trading s.r.o.
Nominal electric input	900 W
Dimensions (length, width, height)	1550 mm, 150 mm, 60 mm

Table 3-2 Measurement conditions

Ambient mean radiant temperature	**19 °C**
Ambient air temperature	19 °C
Maximum surface temperature	317 °C
Air temperature above panel	22,2 °C
Air velocity	0 m/s
Air relative humidity	32,6 %

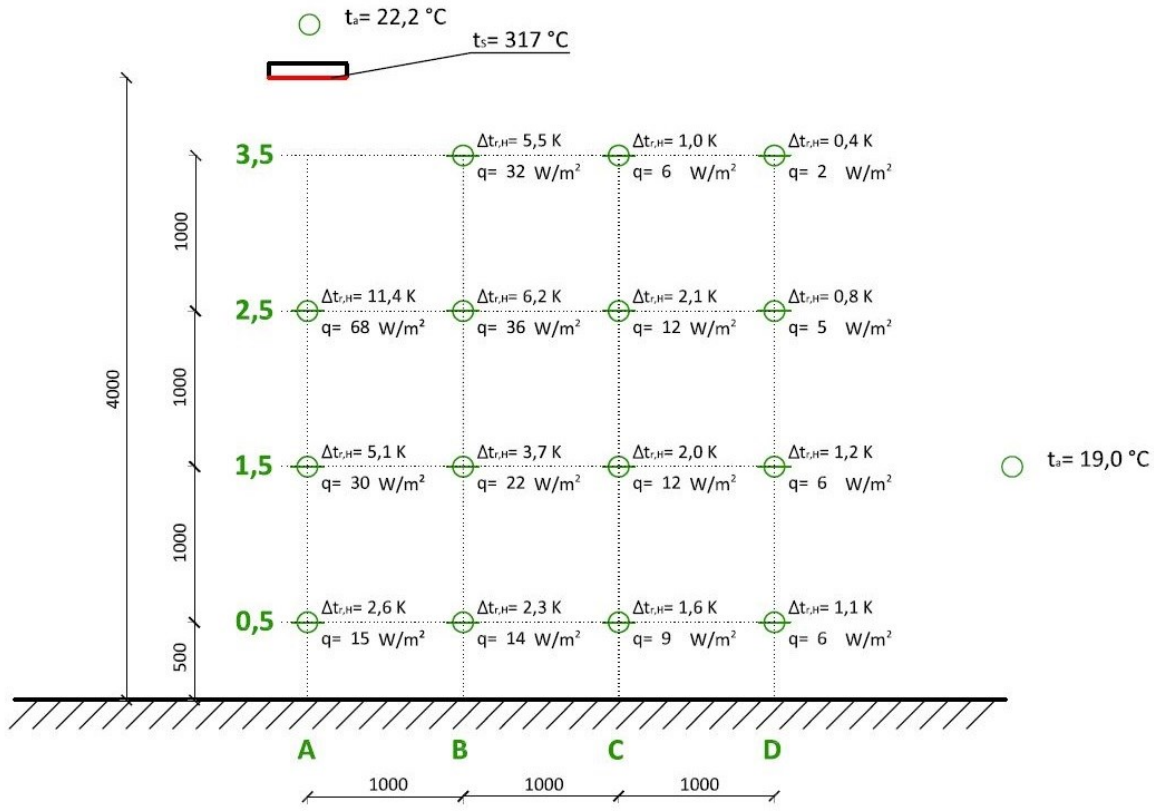


Figure 3-1 Resulting increase of mean radiant temperature and increase of specific radiant heat flux in the field of panel Ecosun S+ 09 against ambient conditions

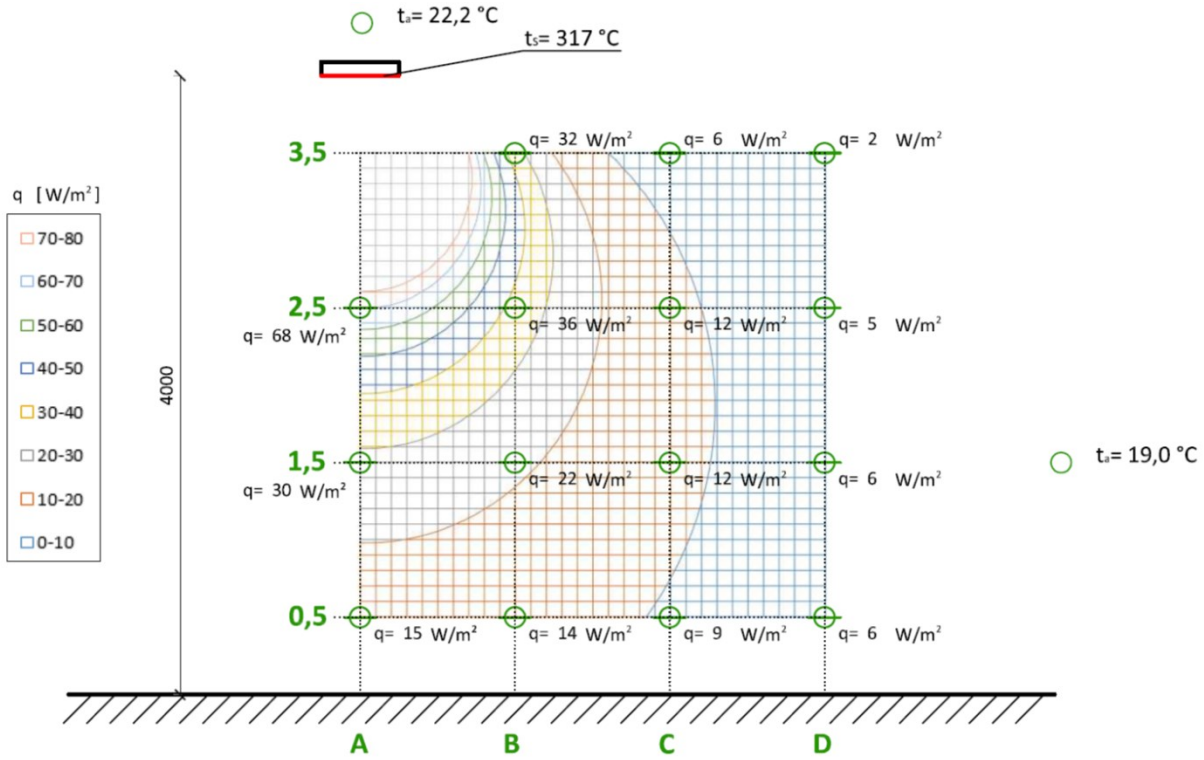
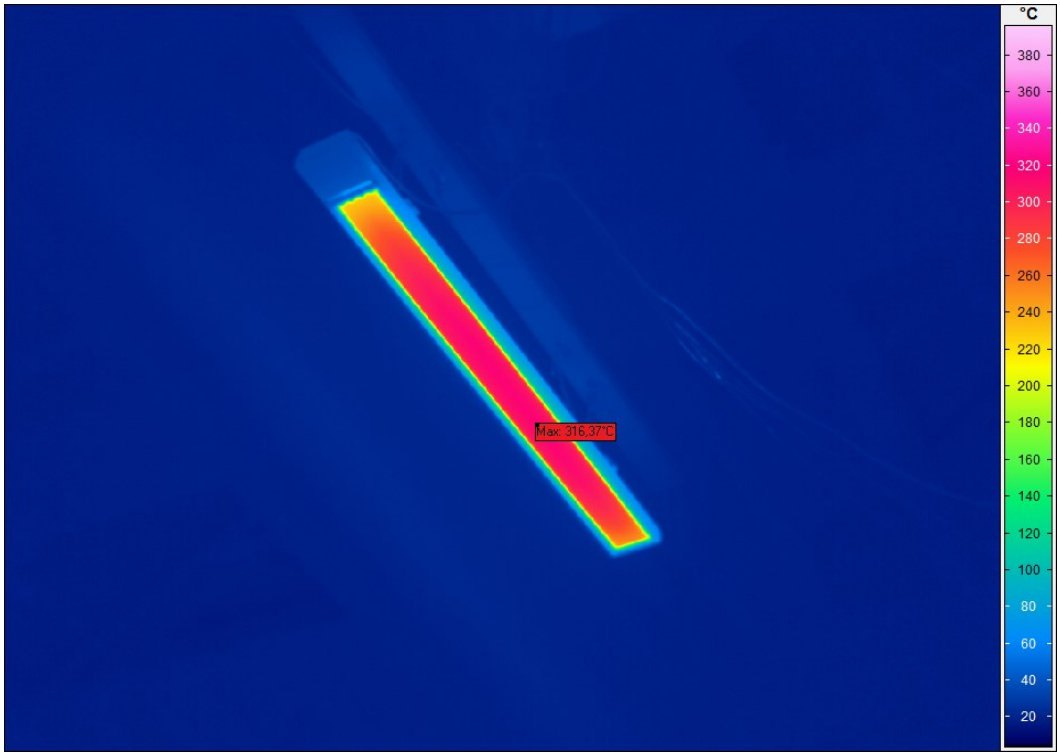


Figure 3-2 Isocurves of specific radiant heat flux in the field of panel Ecosun S+ 09



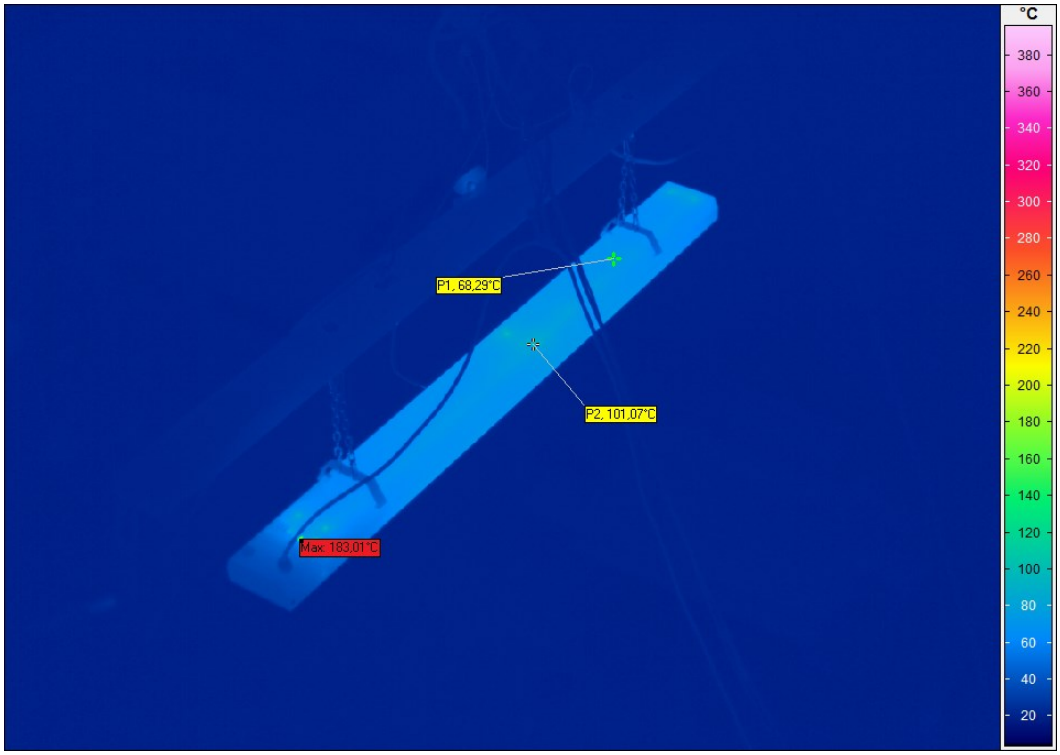


Figure 3-3 Thermal images of front area and rear cover of panel Ecosun S+ 09

(3.2) ECOSUN S+ 12

Table 3-3 Basic technical parameters of measured panel Ecosun S+ 12

Panel type, producer	ECOSUN S+ 12, FENIX Trading s.r.o.
Nominal electric input	1200 W
Dimensions (length, width, height)	1550 mm, 150 mm, 60 mm

Table 3-4 Measurement conditions

Ambient mean radiant temperature	**19,2 °C**
Ambient air temperature	18,9 °C
Maximum surface temperature	357 °C
Air temperature above panel	25,1 °C
Air velocity	0,01 m/s
Air relative humidity	31,8 %

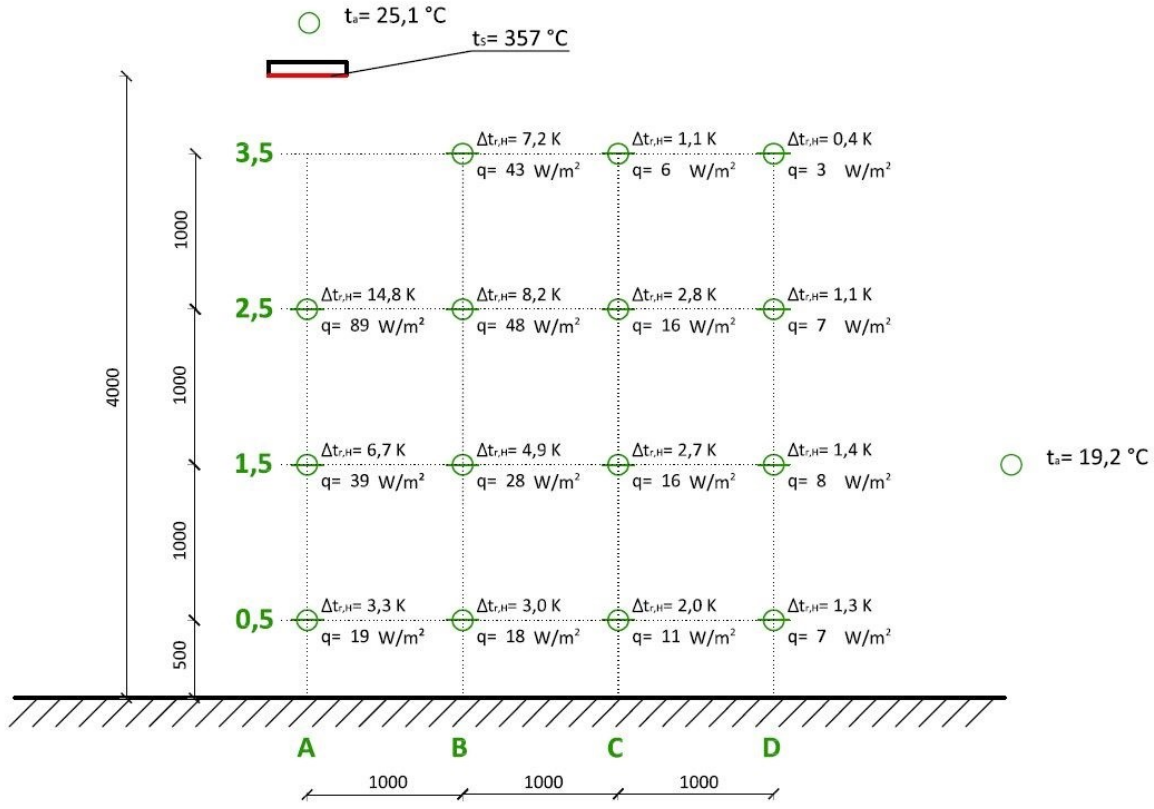


Figure 3-4 Resulting increase of mean radiant temperature and increase of specific radiant heat flux in the field of panel Ecosun S+ 12 against ambient conditions

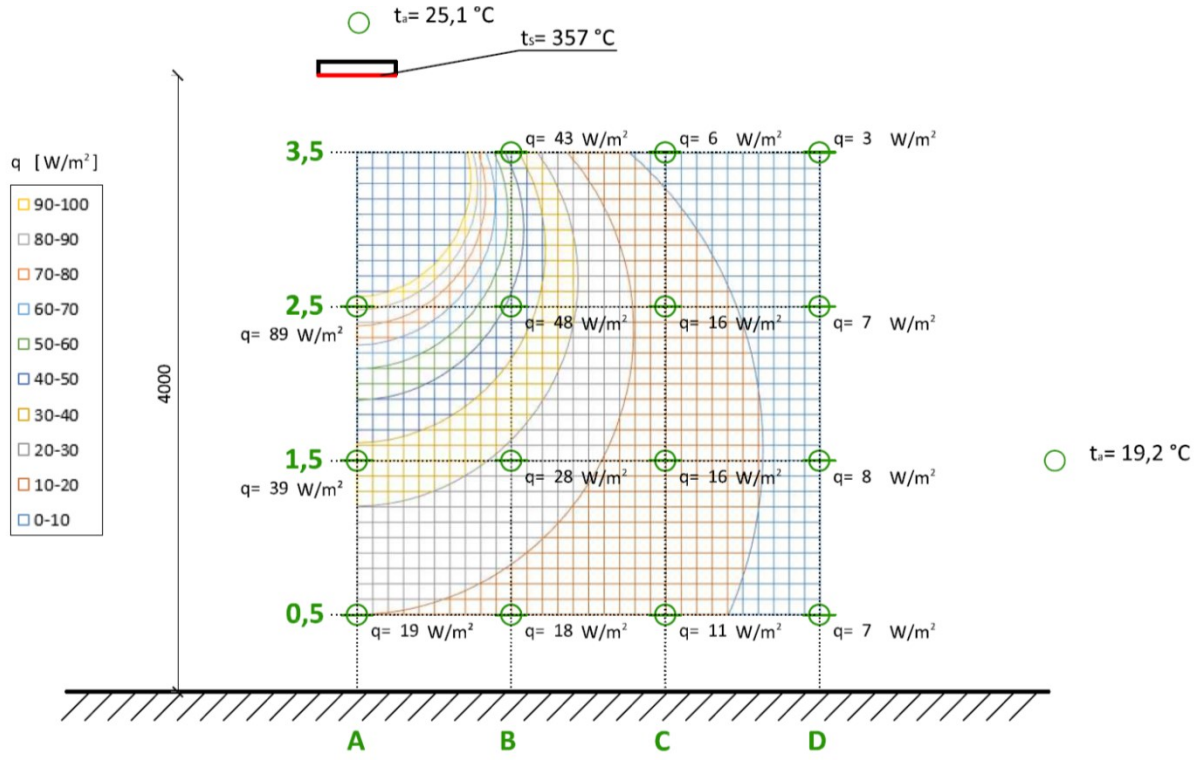
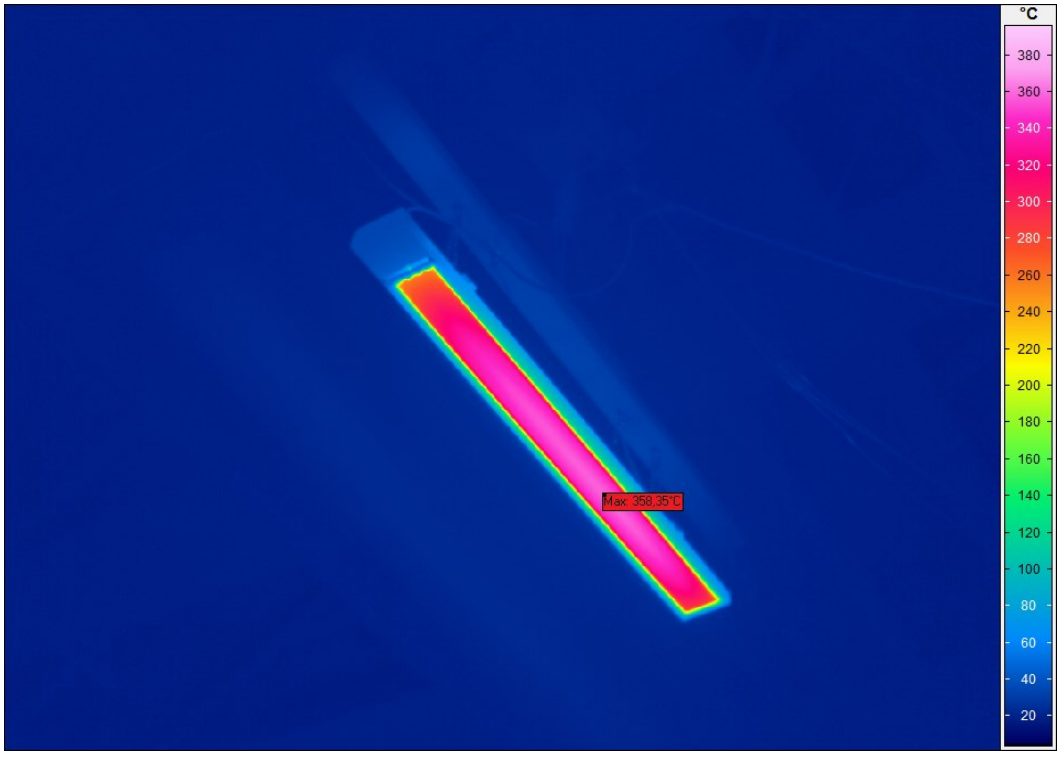


Figure 3-5 Isocurves of specific radiant heat flux in the field of panel Ecosun S+ 12



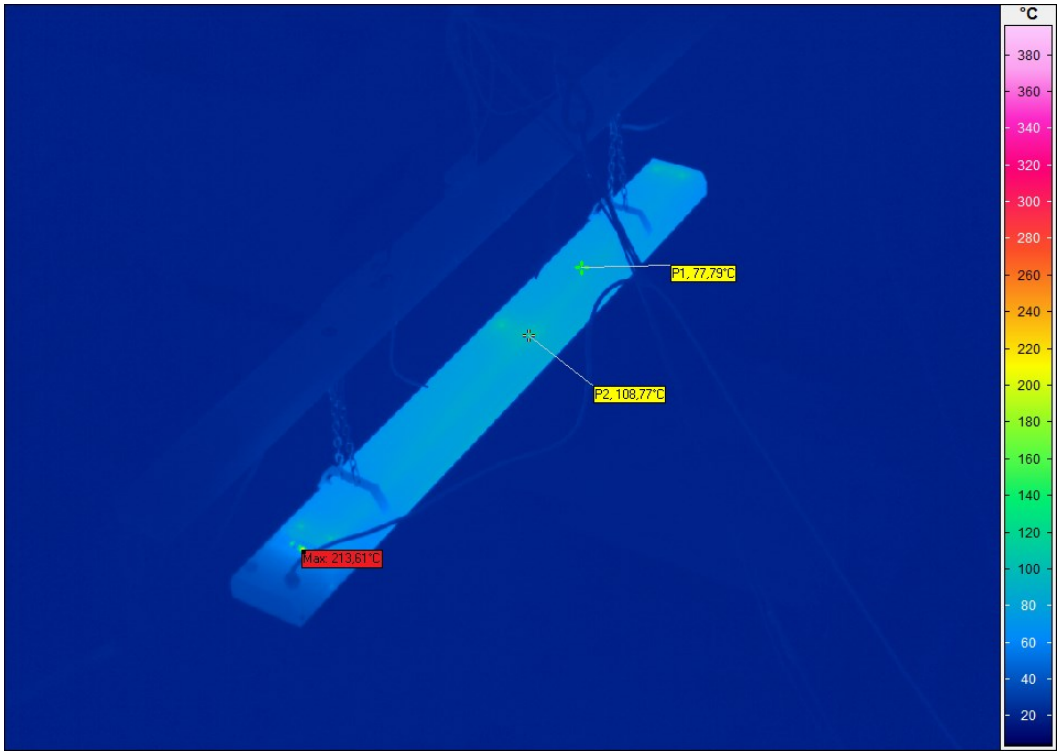


Figure 3-6 Thermal images of front area and rear cover of panel Ecosun S+ 12

(3.3) ECOSUN S+ 18

Table 3-5 Basic technical parameters of measured panel Ecosun S+ 18

Panel type, producer	ECOSUN S+ 18, FENIX Trading s.r.o.
Nominal electric input	1800 W
Dimensions (length, width, height)	1550 mm, 250 mm, 60 mm

Table 3-6 Measurement conditions

Ambient mean radiant temperature	**19 °C**
Ambient air temperature	19,7 °C
Maximum surface temperature	341 °C
Air temperature above panel	25,9 °C
Air velocity	0,02 m/s
Air relative humidity	29,3 %

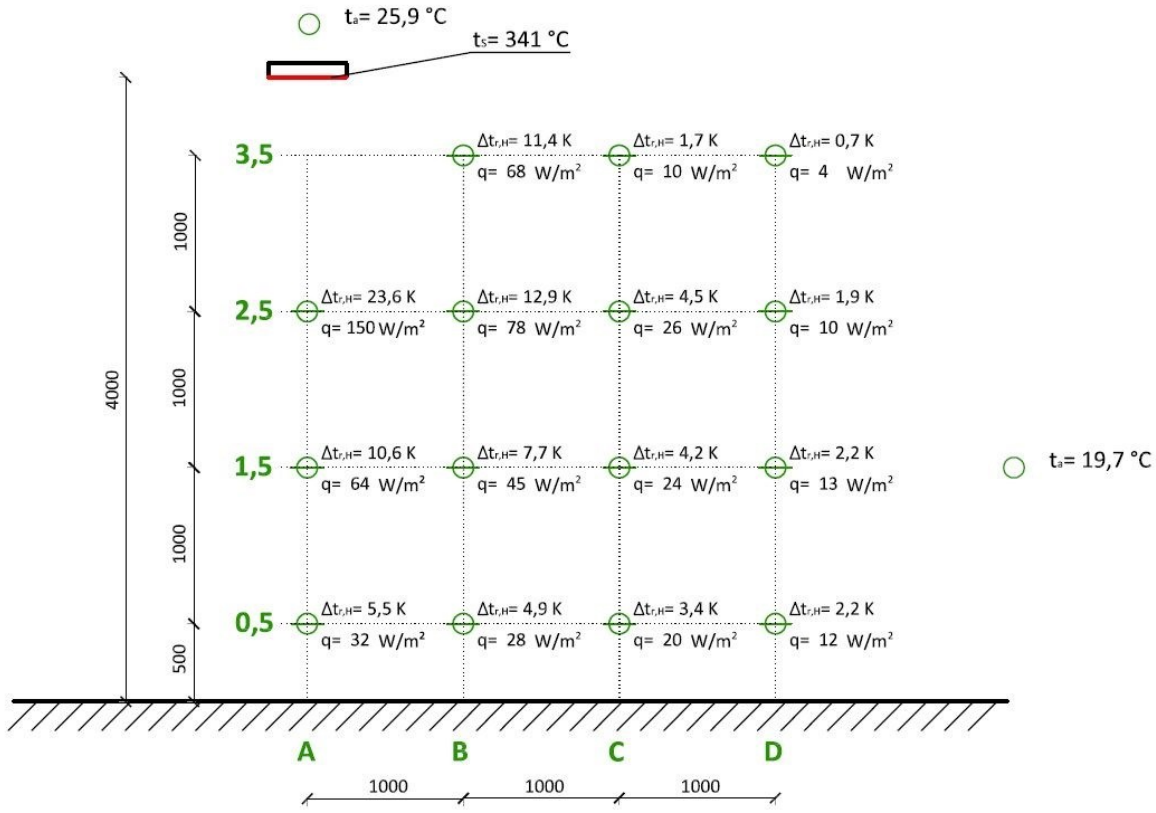


Figure 3-7 Resulting increase of mean radiant temperature and increase of specific radiant heat flux in the field of panel Ecosun S+ 18 against ambient conditions

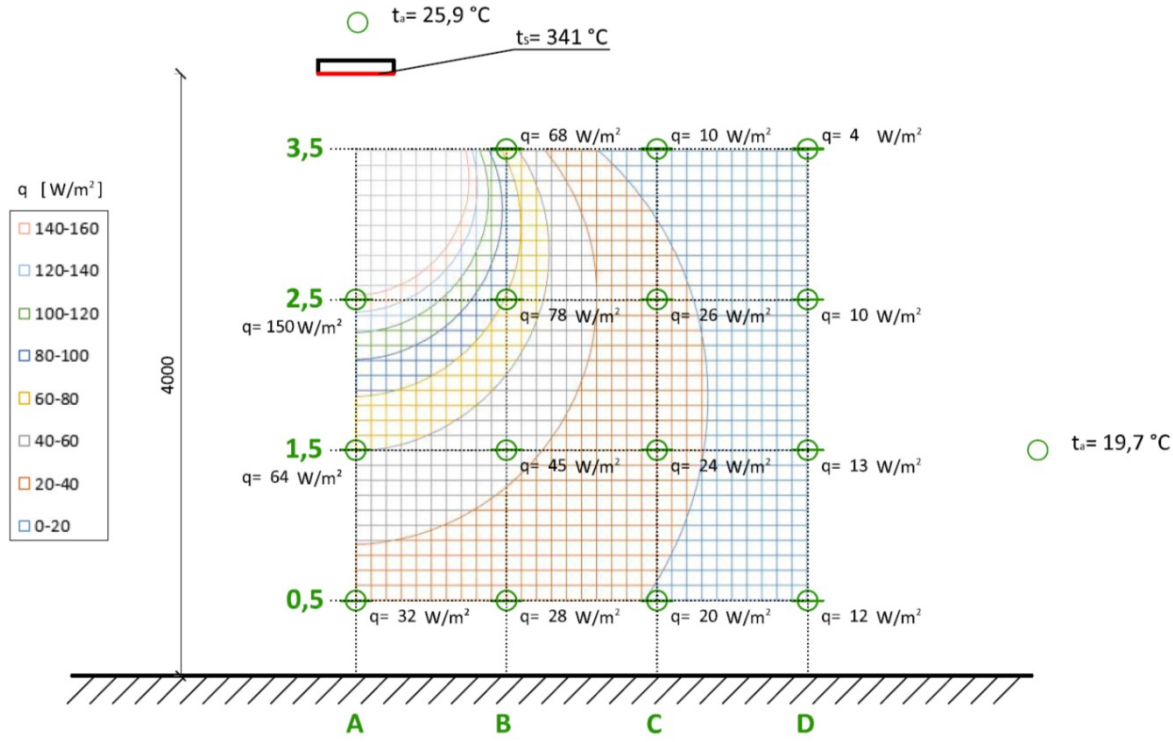
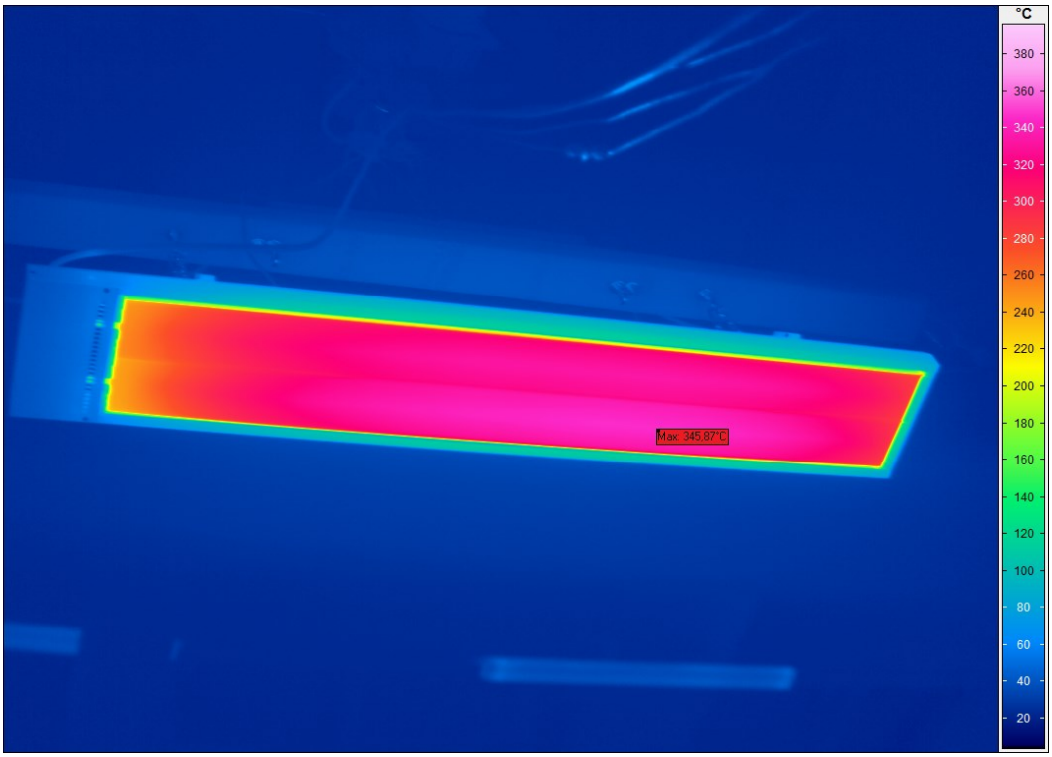


Figure 3-8 Isocurves of specific radiant heat flux in the field of panel Ecosun S+ 18



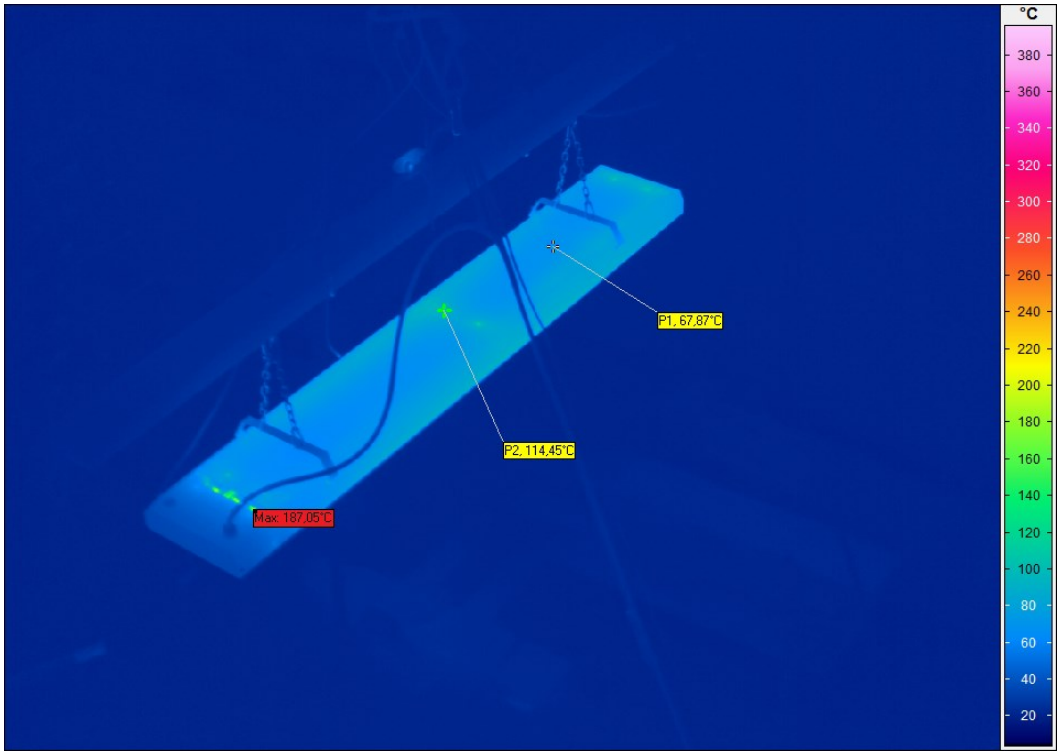


Figure 3-9 Thermal images of front area and rear cover of panel Ecosun S+ 18

(3.4) ECOSUN S+ 24

Table 3-7 Basic technical parameters of measured panel Ecosun S+ 24

Panel type, producer	ECOSUN S+ 24, FENIX Trading s.r.o.
Nominal electric input	2400 W
Dimensions (length, width, height)	1550 mm, 250 mm, 60 mm

Table 3-8 Measurement conditions

Ambient mean radiant temperature	**18,6 °C**
Ambient air temperature	19,4 °C
Maximum surface temperature	399 °C
Air temperature above panel	26,4 °C
Air velocity	0,06 m/s
Air relative humidity	29,8 %

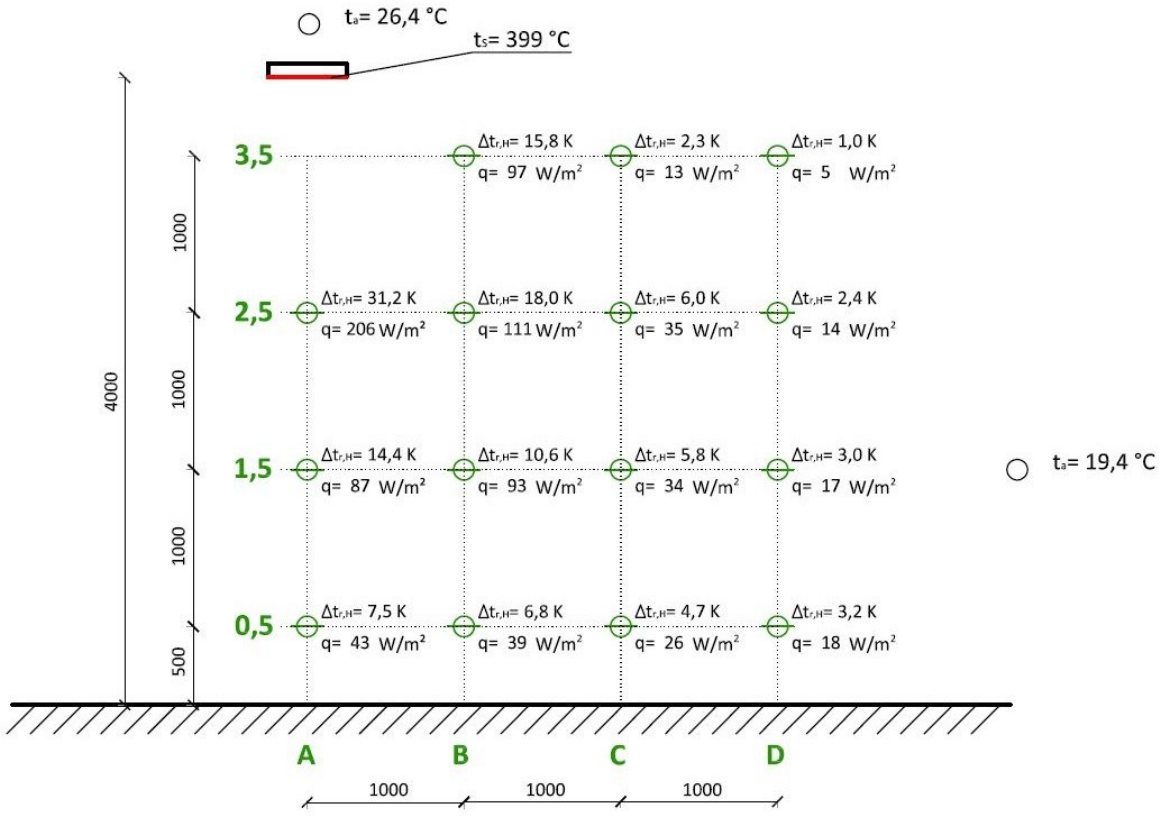


Figure 3-10 Resulting increase of mean radiant temperature and increase of specific radiant heat flux in the field of panel Ecosun S+ 24 against ambient conditions

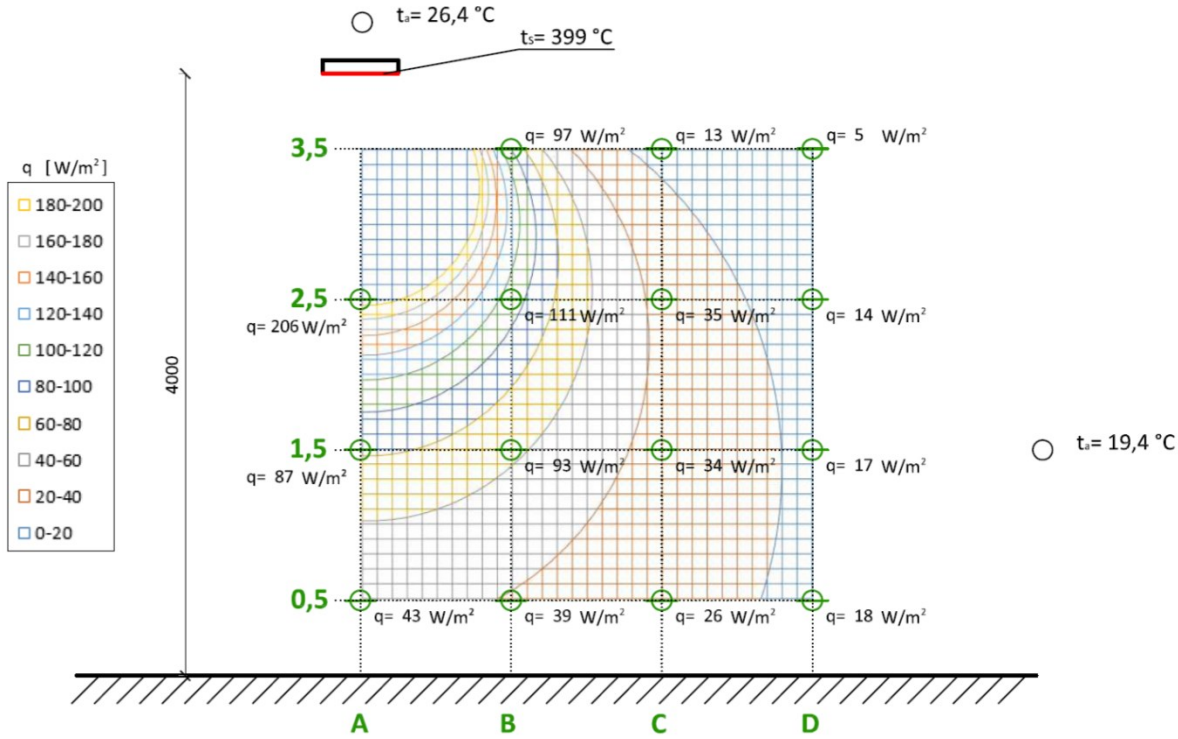
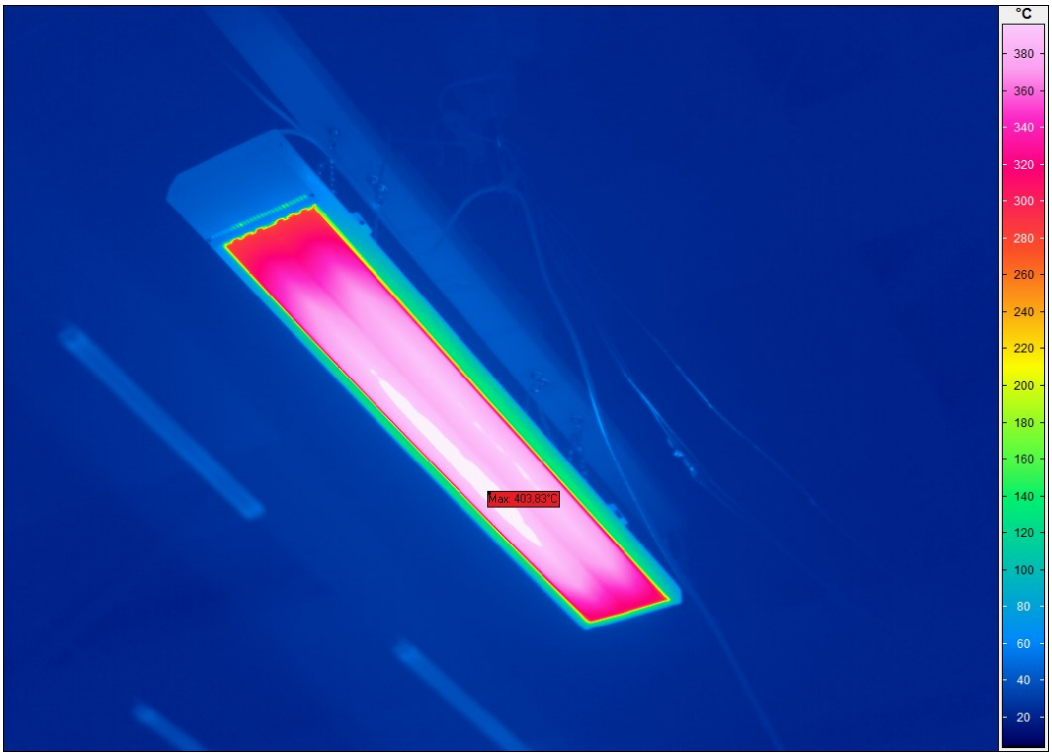


Figure 3-11 Isocurves of specific radiant heat flux in the field of panel Ecosun S+ 24



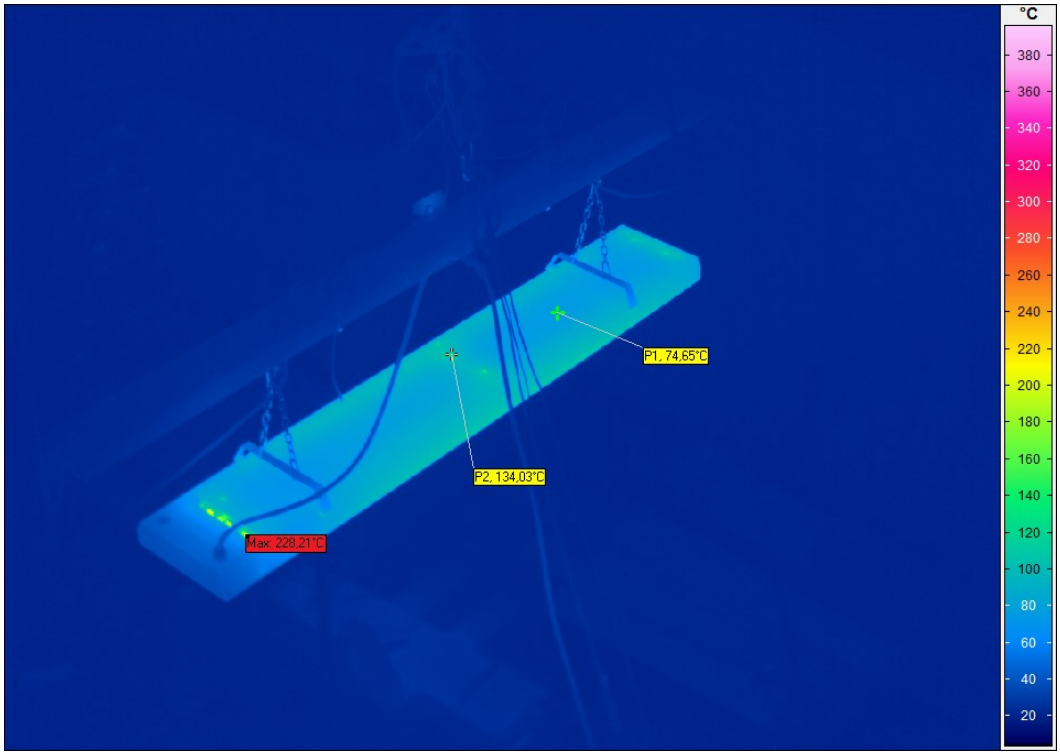


Figure 3-12 Thermal images of front area and rear cover of panel Ecosun S+ 24

(3.5) ECOSUN S+ 30

Table 3-9 Basic technical parameters of measured panel Ecosun S+ 30

Panel type, producer	ECOSUN S+ 30, FENIX Trading s.r.o.
Nominal electric input	3000 W
Dimensions (length, width, height)	1550 mm, 350 mm, 60 mm

Table 3-10 Measurement conditions

Ambient mean radiant temperature	**18,8 °C**
Ambient air temperature	19,6 °C
Maximum surface temperature	388 °C
Air temperature above panel	25,7 °C
Air velocity	0,04 m/s
Air relative humidity	30,7 %

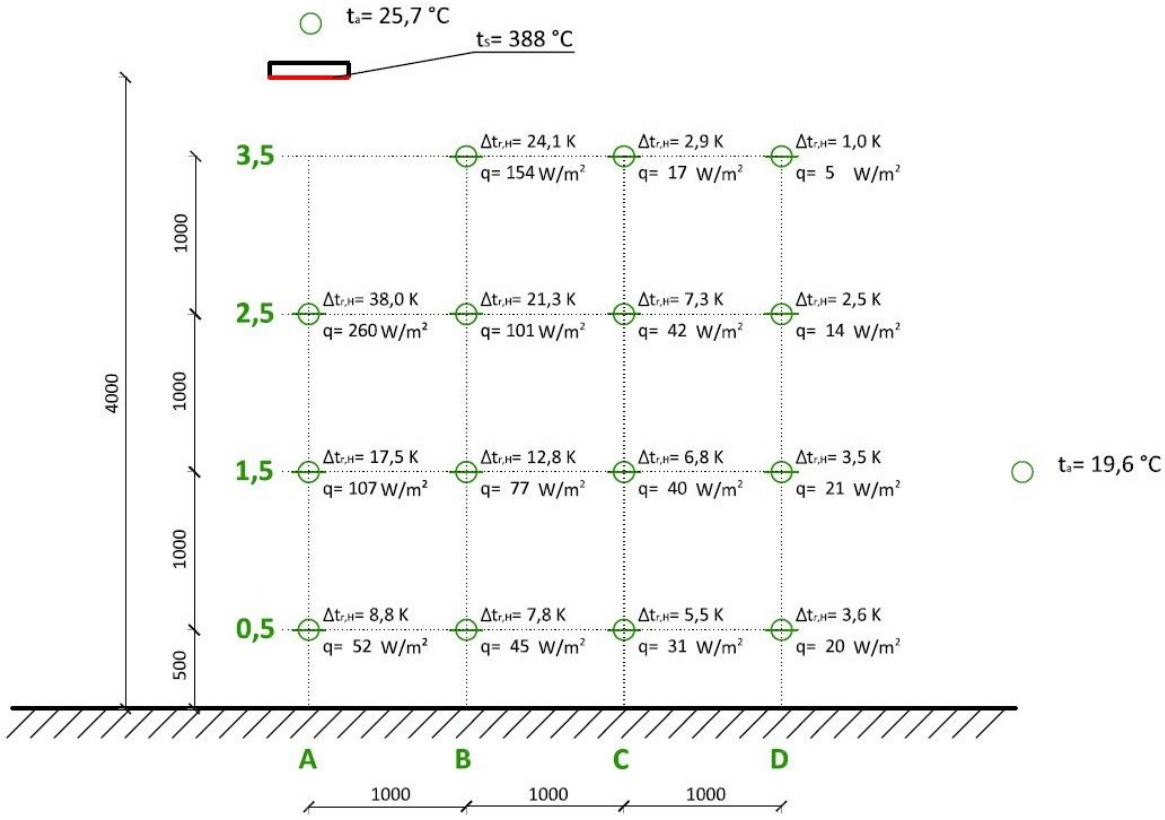


Figure 3-13 Resulting increase of mean radiant temperature and increase of specific radiant heat flux in the field of panel Ecosun S+ 30 against ambient conditions

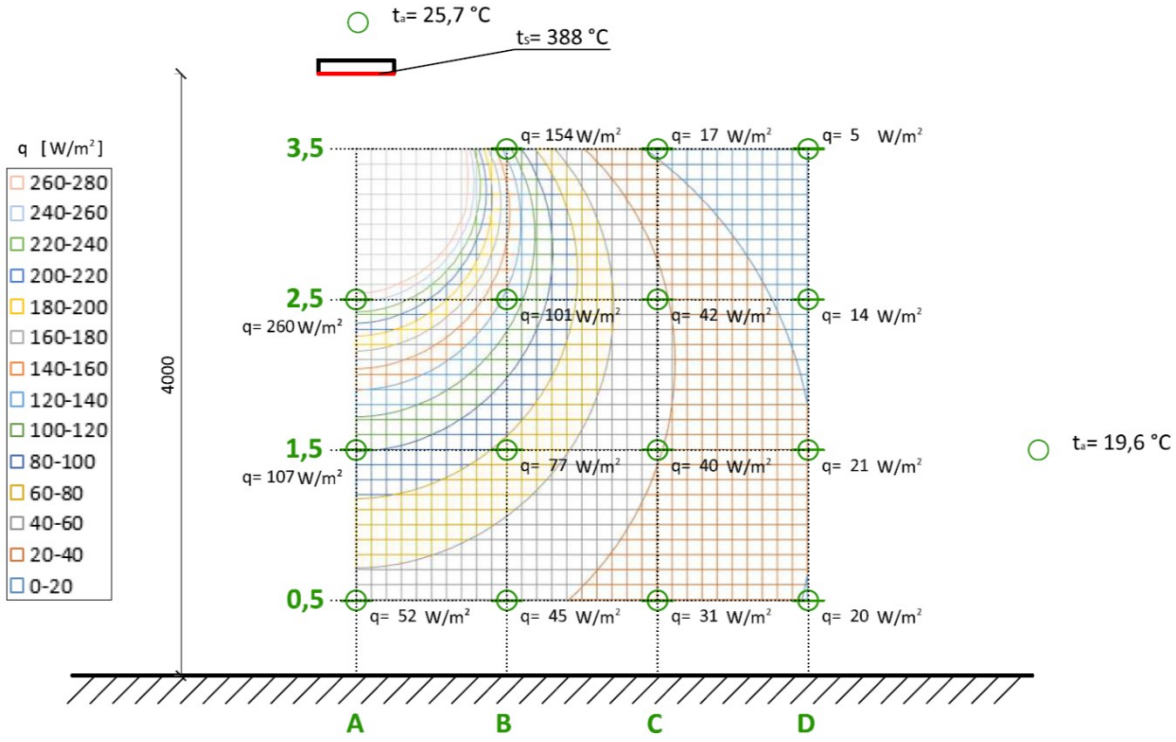
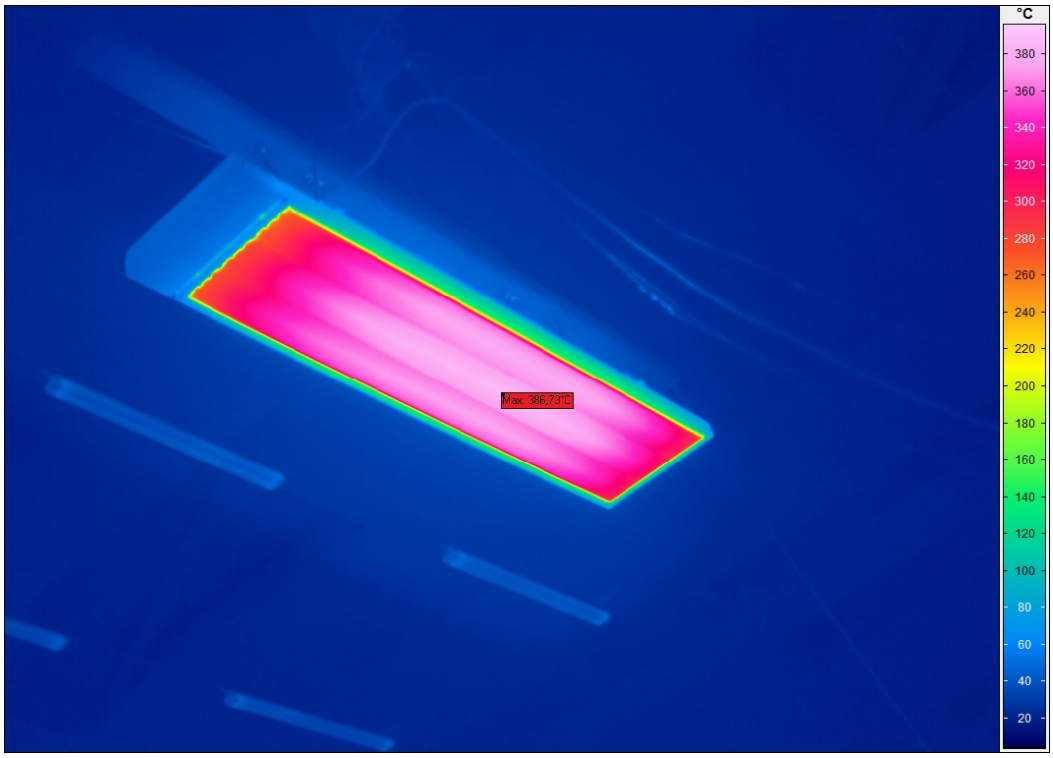


Figure 3-14 Isocurves of specific radiant heat flux in the field of panel Ecosun S+ 30



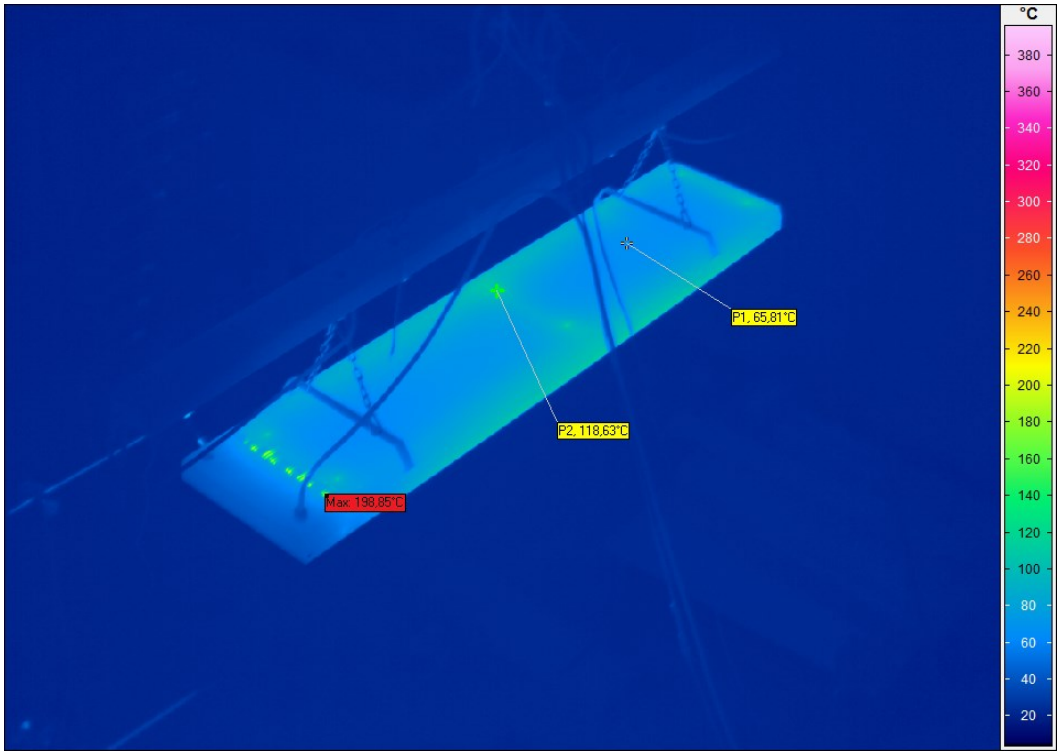


Figure 3-15 Thermal images of front area and rear cover of panel Ecosun S+ 30

(3.6) ECOSUN S+ 36

Table 3-11 Basic technical parameters of measured panel Ecosun S+ 36

Panel type, producer	ECOSUN S+ 36, FENIX Trading s.r.o.
Nominal electric input	3600 W
Dimensions (length, width, height)	1550 mm, 350 mm, 60 mm

Table 3-12 Measurement conditions

Ambient mean radiant temperature	**19,2 °C**
Ambient air temperature	20,7 °C
Maximum surface temperature	420 °C
Air temperature above panel	25,0 °C
Air velocity	0,05 m/s
Air relative humidity	30,2 %

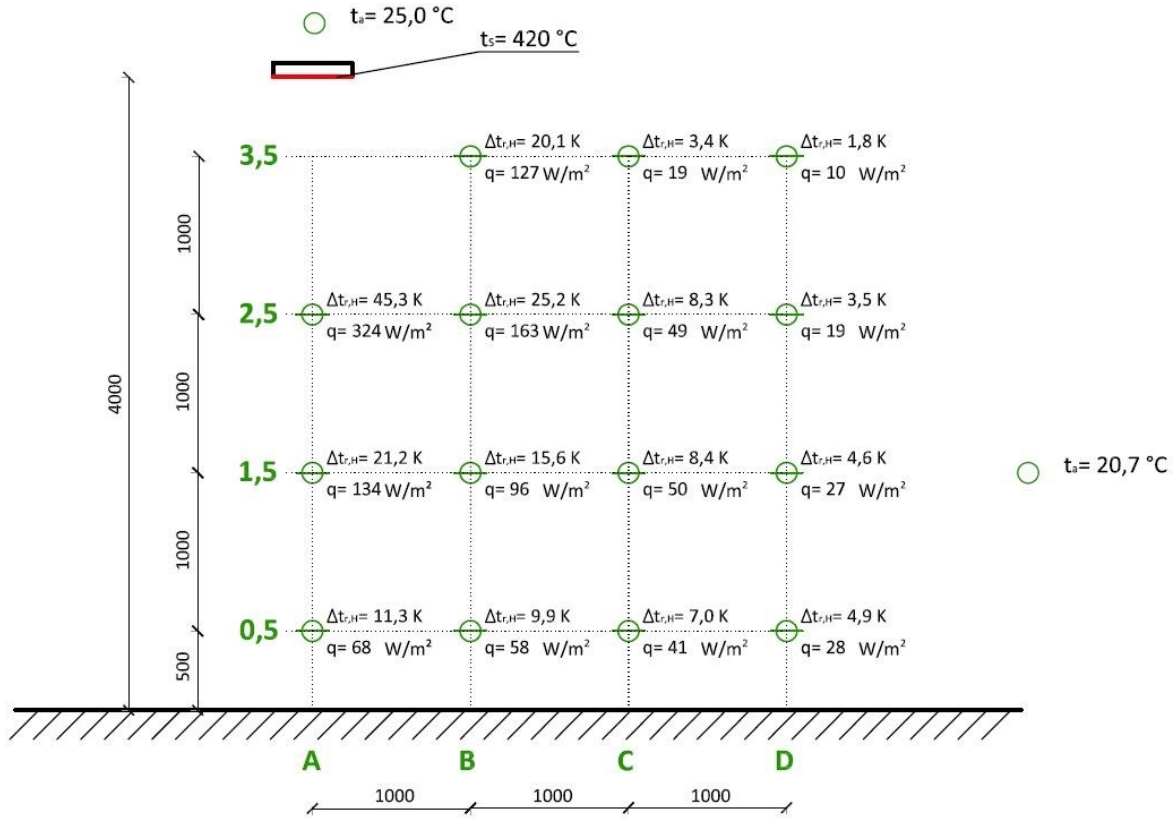


Figure 3-16 Resulting increase of mean radiant temperature and increase of specific radiant heat flux in the field of panel Ecosun S+ 36 against ambient conditions

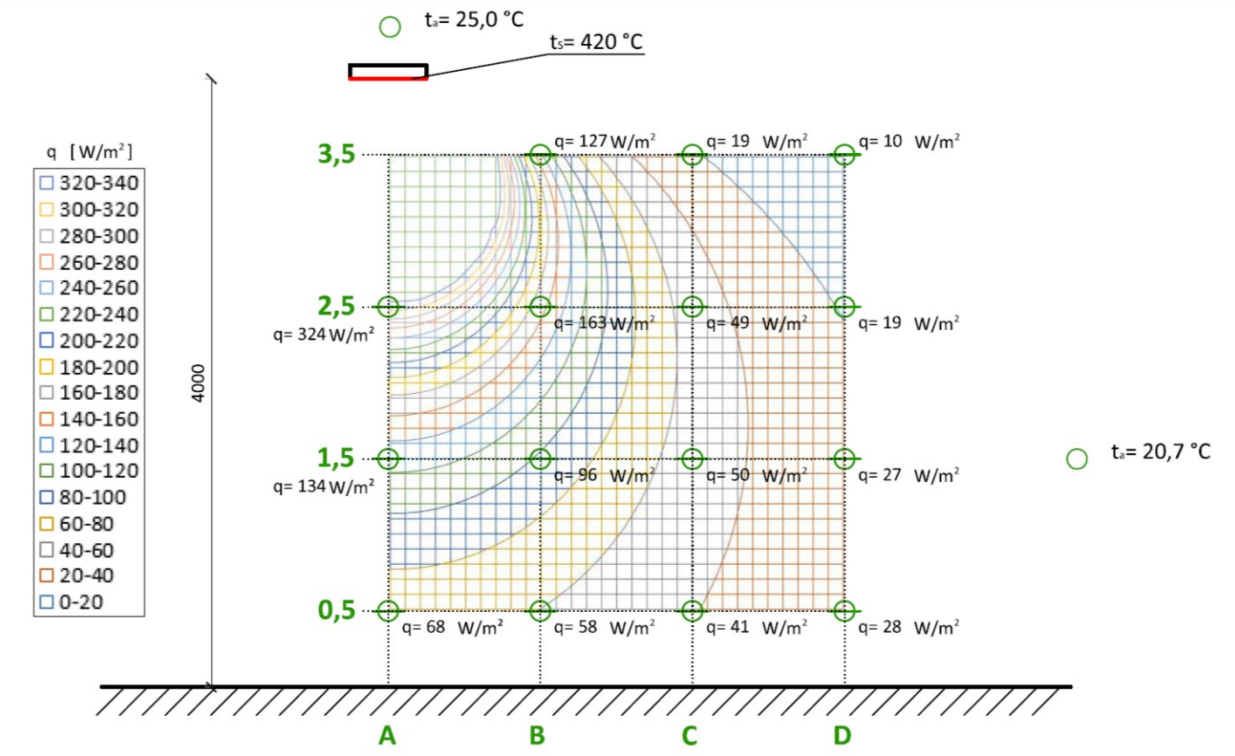
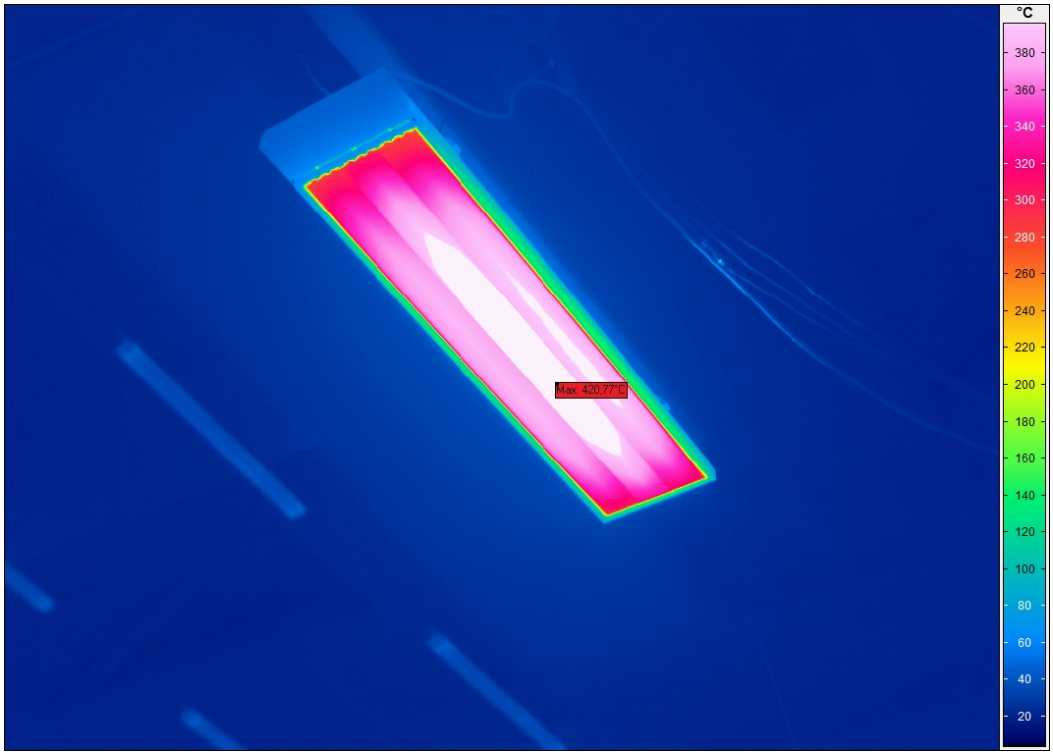


Figure 3-17 Isocurves of specific radiant heat flux in the field of panel Ecosun S+ 36



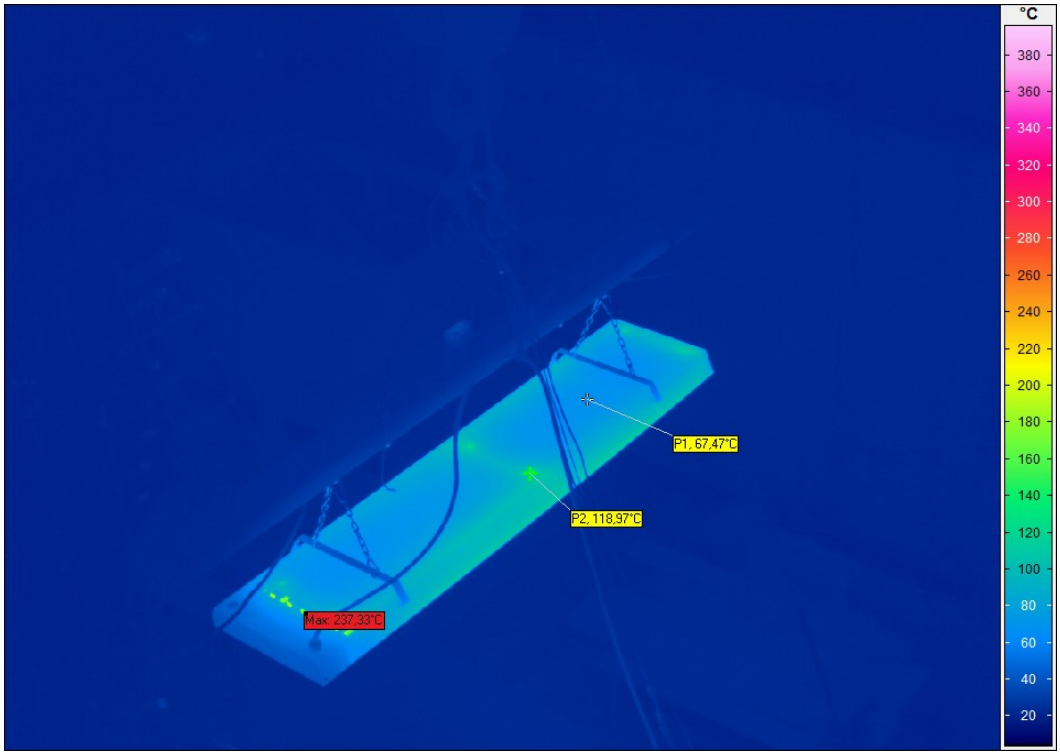


Figure 3-18 Thermal images of front area and rear cover of panel Ecosun S+ 36

(3.7) ECOSUN 700 U

Table 3-13 Basic technical parameters of measured panel Ecosun 700 U

Panel type, producer	ECOSUN 700 U, FENIX Trading s.r.o.
Nominal electric input	700 W
Dimensions (length, width, height)	1190 mm, 600 mm, 30 mm

Table 3-14 Measurement conditions

Ambient mean radiant temperature	**18,5 °C**
Ambient air temperature	18,3 °C
Maximum surface temperature	109 °C
Air temperature above panel	49,6 °C
Air velocity	0,01 m/s
Air relative humidity	42,0 %

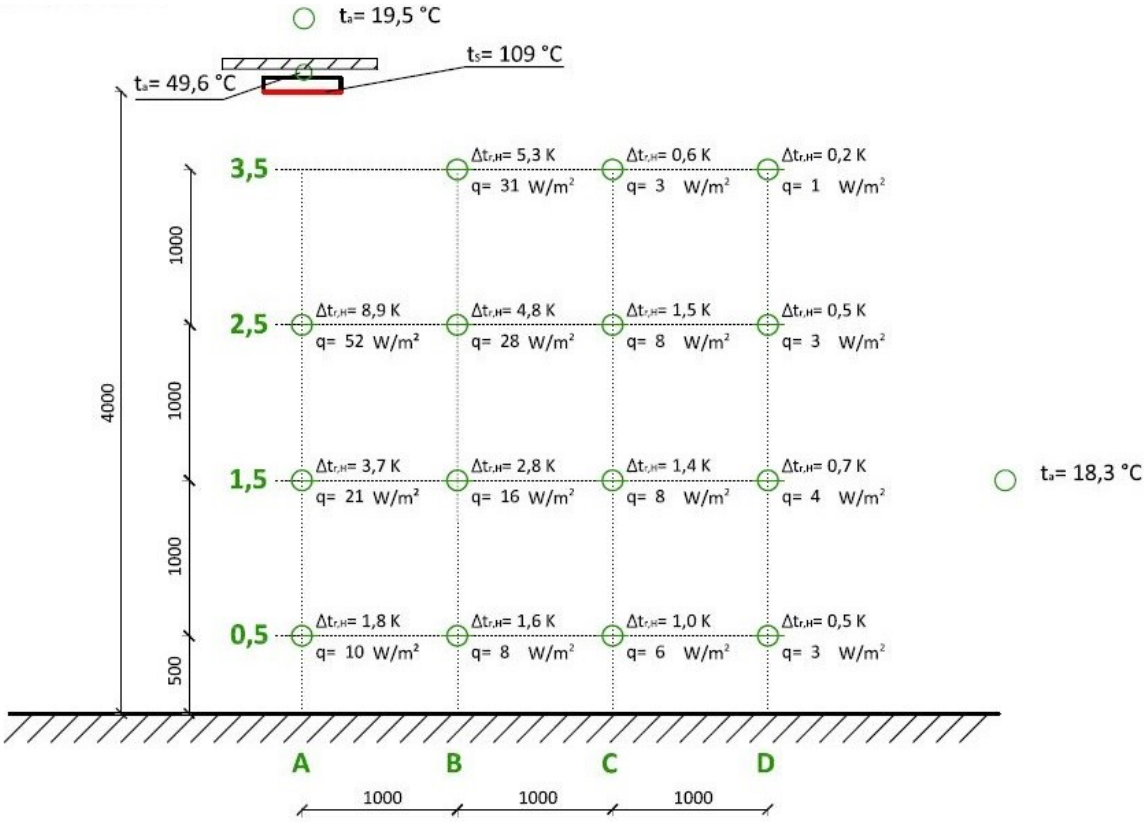


Figure 3-19 Resulting increase of mean radiant temperature and increase of specific radiant heat flux in the field of panel Ecosun 700 U against ambient conditions

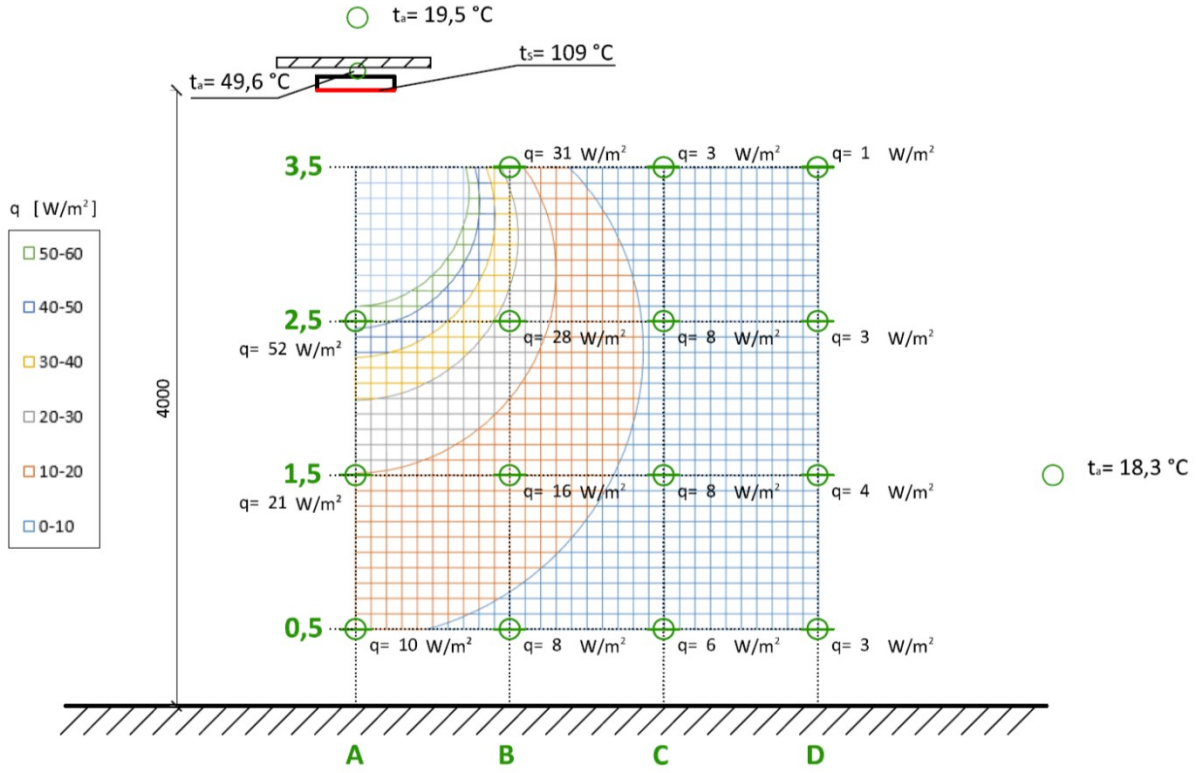
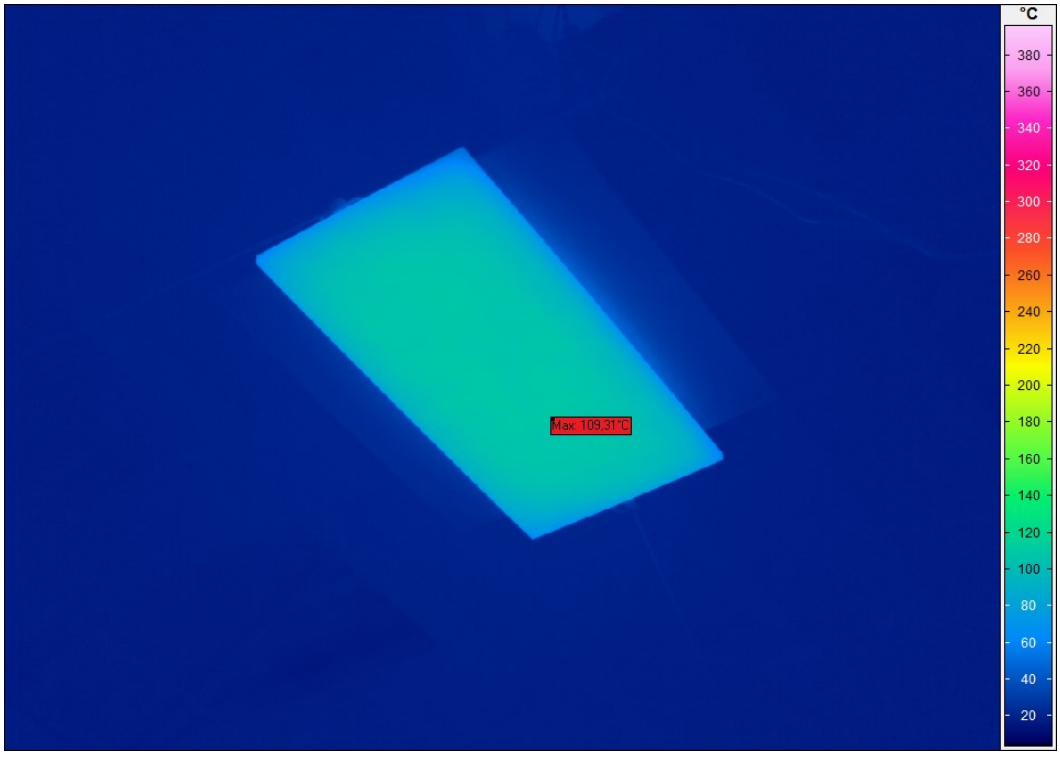


Figure 3-20 Isocurves of specific radiant heat flux in the field of panel Ecosun 700 U



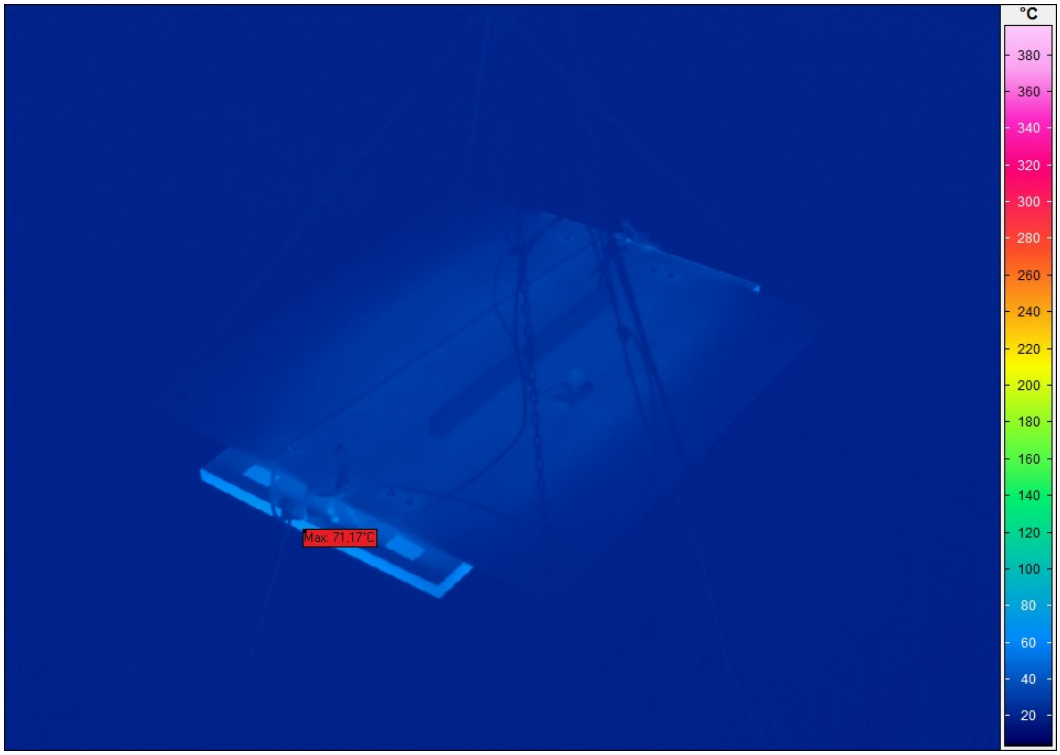


Figure 3-21 Thermal images of front area and rear cover of panel Ecosun 700 U

(3.8) ECOSUN 1000 U

Table 3-15 Basic technical parameters of measured panel Ecosun 1000 U

Panel type, producer	ECOSUN 1000 U, FENIX Trading s.r.o.
Nominal electric input	1000 W
Dimensions (length, width, height)	1190 mm, 850 mm, 30 mm

Table 3-16 Measurement conditions

Ambient mean radiant temperature	**18,7 °C**
Ambient air temperature	18,6 °C
Maximum surface temperature	133 °C
Air temperature above panel	54,8 °C
Air velocity	0 m/s
Air relative humidity	39,9 %

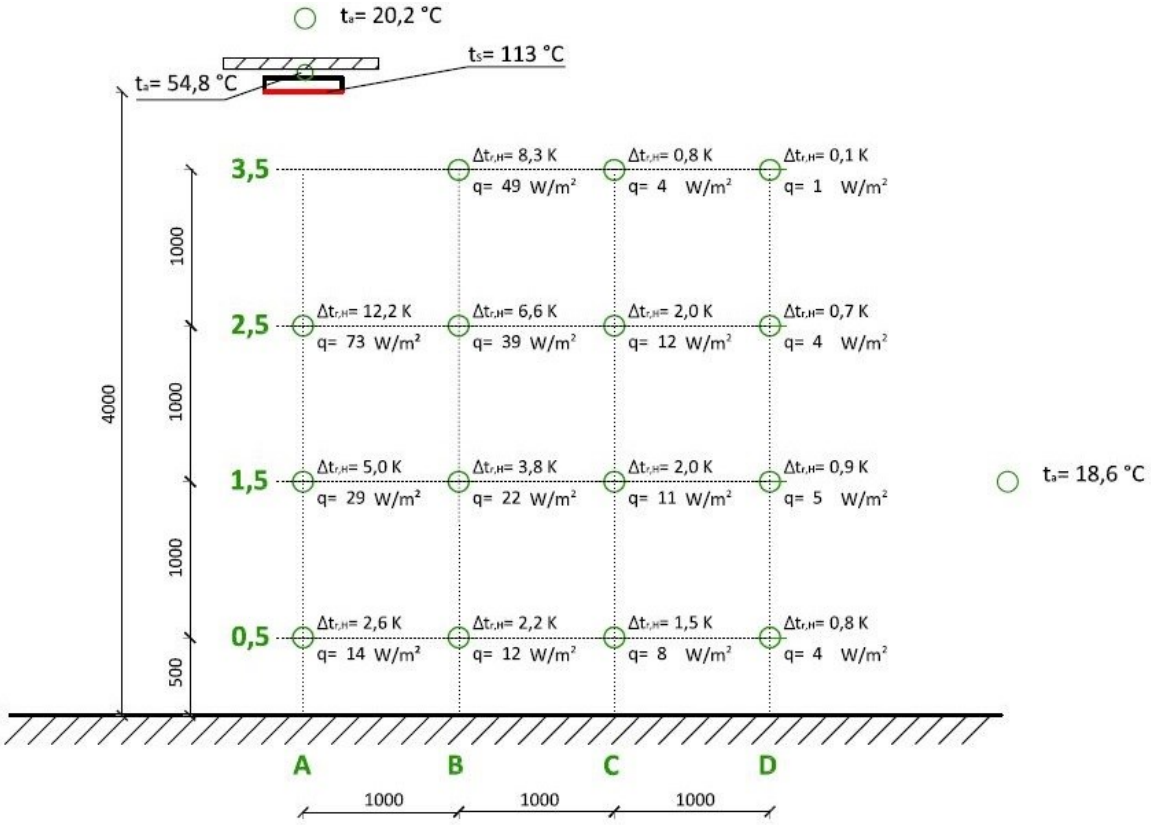


Figure 3-22 Resulting increase of mean radiant temperature and increase of specific radiant heat flux in the field of panel Ecosun 1000 U against ambient conditions

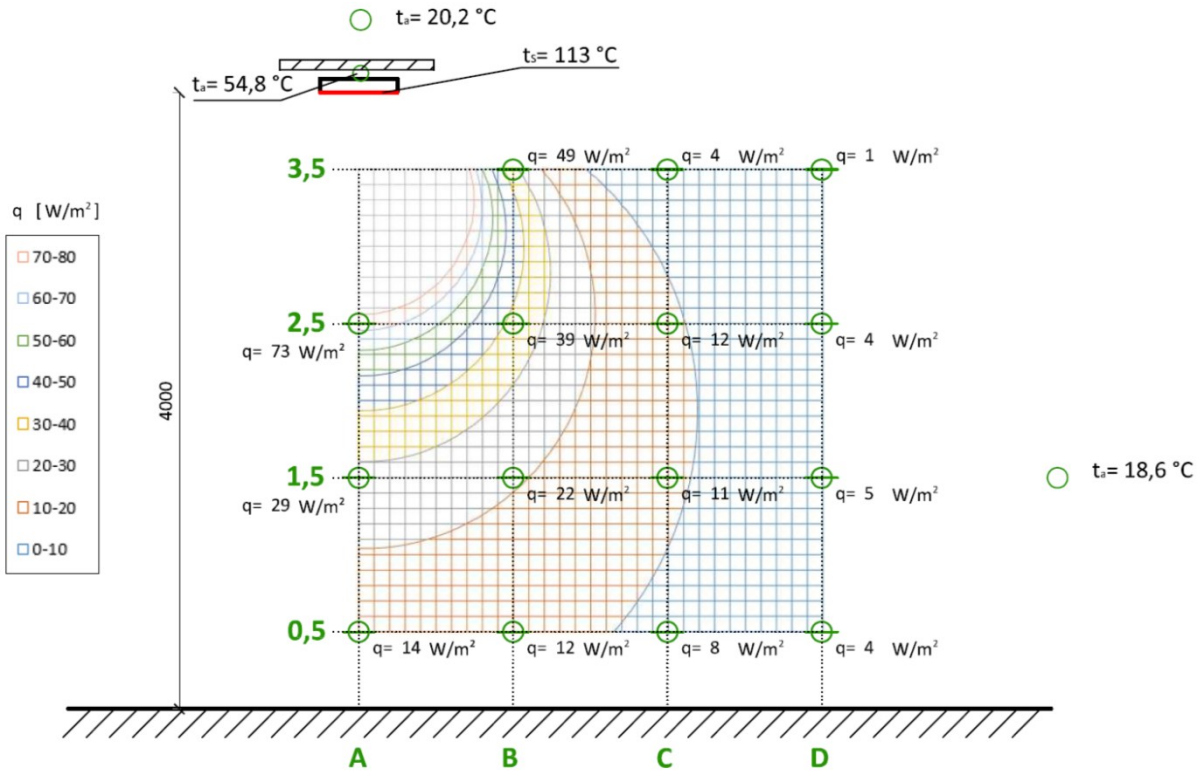
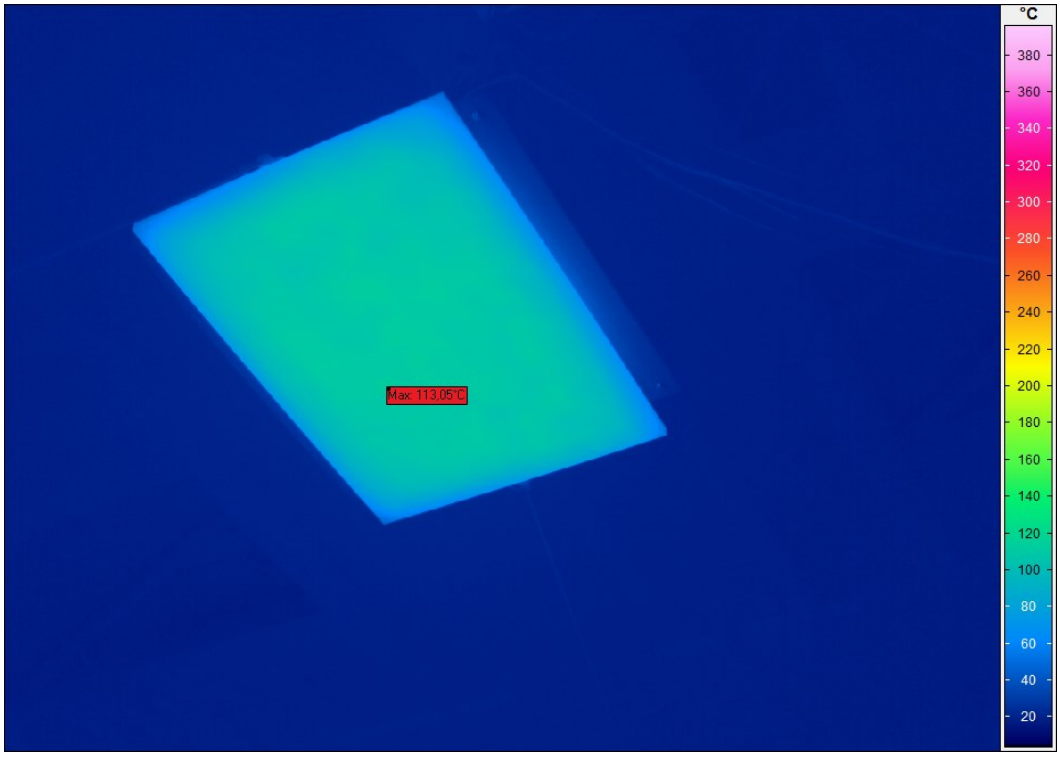


Figure 3-23 Isocurves of specific radiant heat flux in the field of panel Ecosun 1000 U



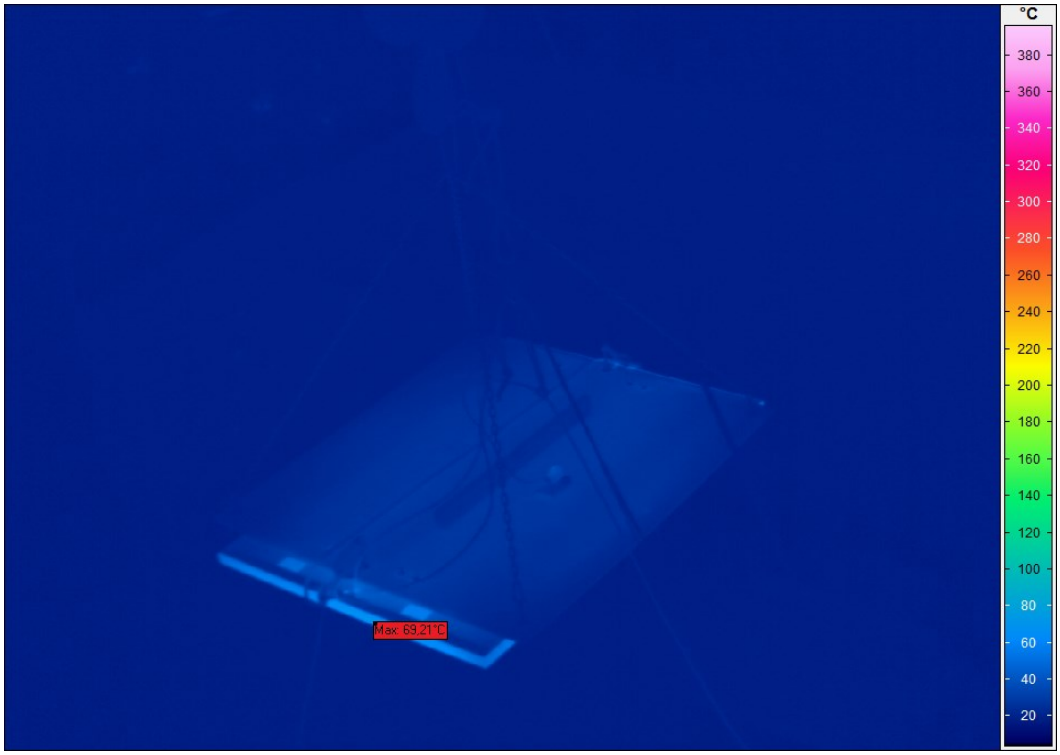


Figure 3-24 Thermal images of front area and rear cover of panel Ecosun 1000 U

(3.9) ECOSUN TH 10

Table 3-17 Basic technical parameters of measured panel Ecosun TH 10

Panel type, producer	ECOSUN TH 10, FENIX Trading s.r.o.
Nominal electric input	1000 W
Dimensions (length, width, height)	1080 mm, 140 mm, 45 mm

Table 3-18 Measurement conditions

Ambient mean radiant temperature	**18,5 °C**
Ambient air temperature	17,9 °C
Maximum surface temperature	360 °C
Air temperature above panel	23,0 °C
Air velocity	0,05 m/s
Air relative humidity	40,1 %

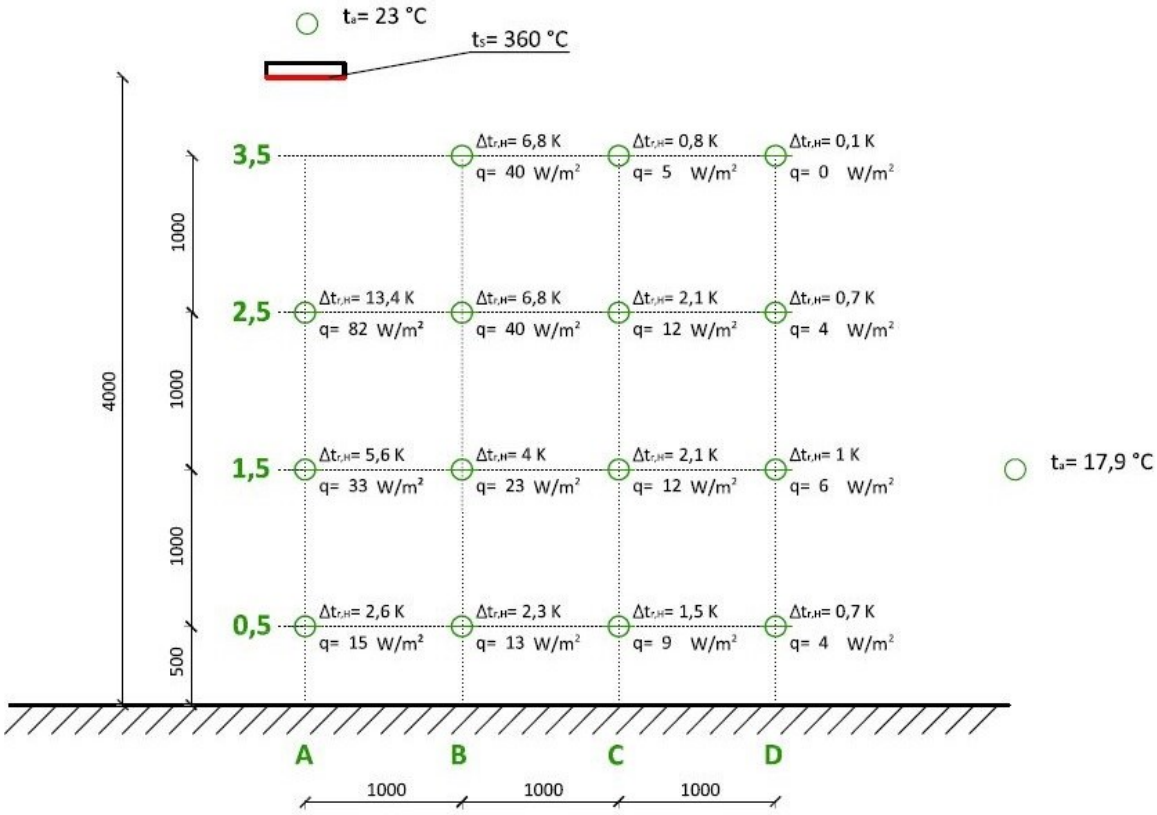


Figure 3-25 Resulting increase of mean radiant temperature and increase of specific radiant heat flux in the field of panel Ecosun TH 10 against ambient conditions

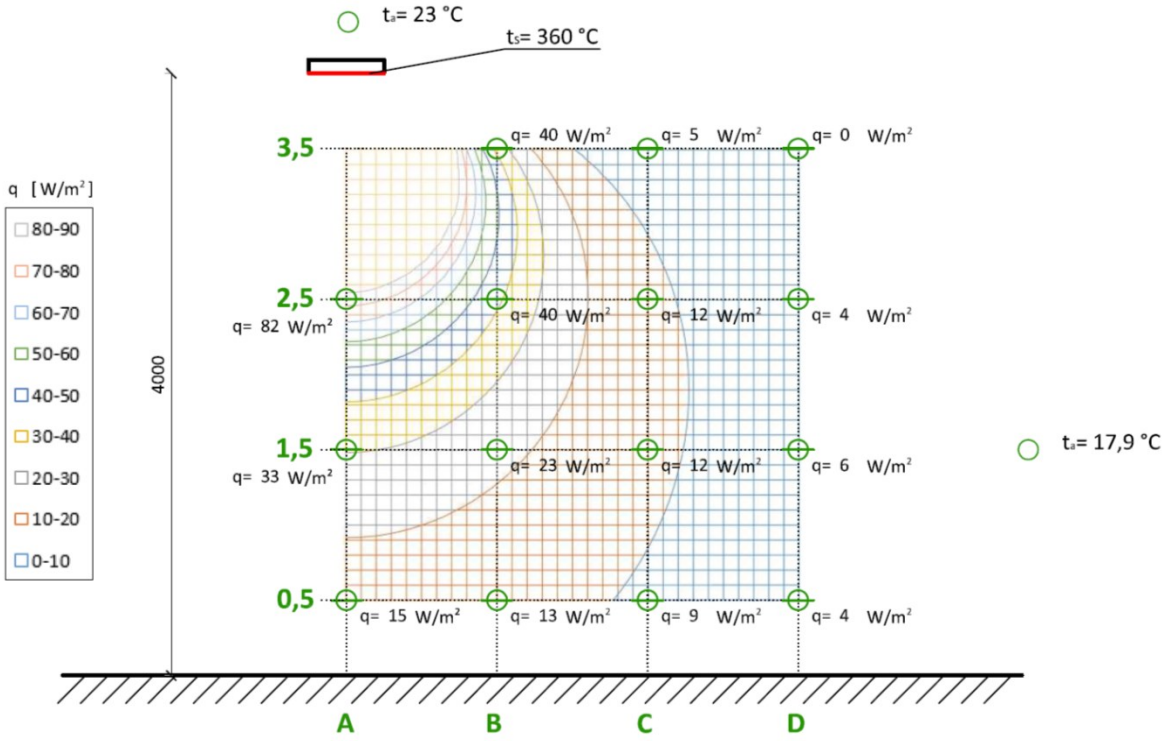
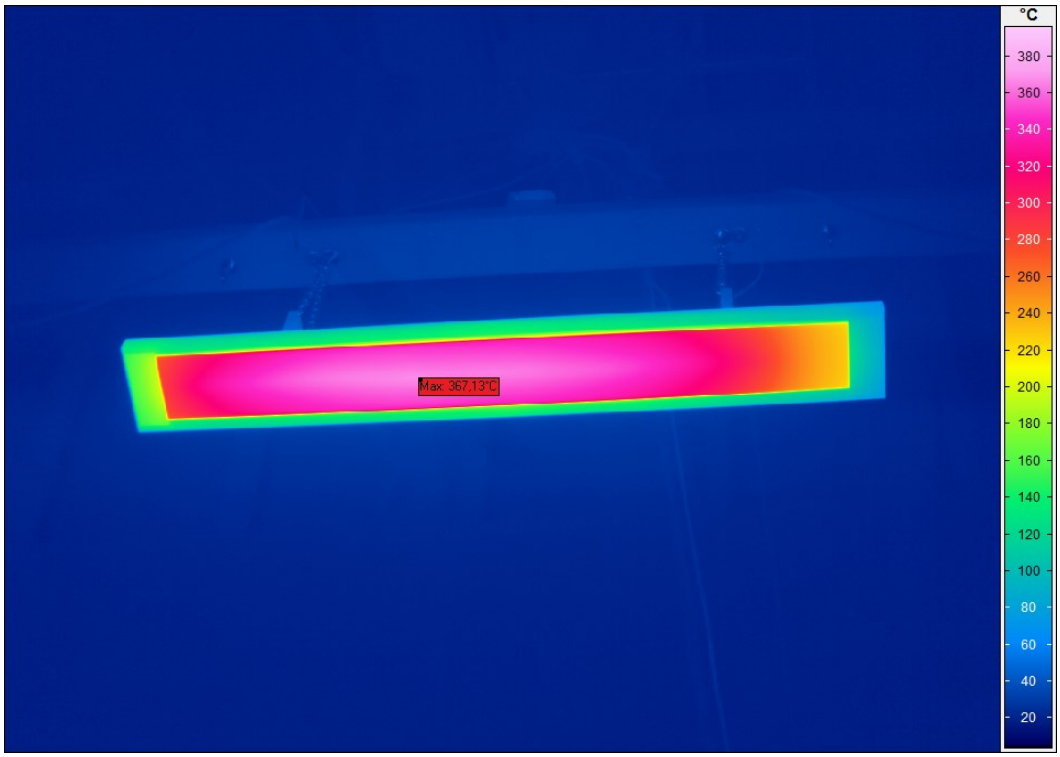


Figure 3-26 Isocurves of specific radiant heat flux in the field of panel Ecosun TH 10



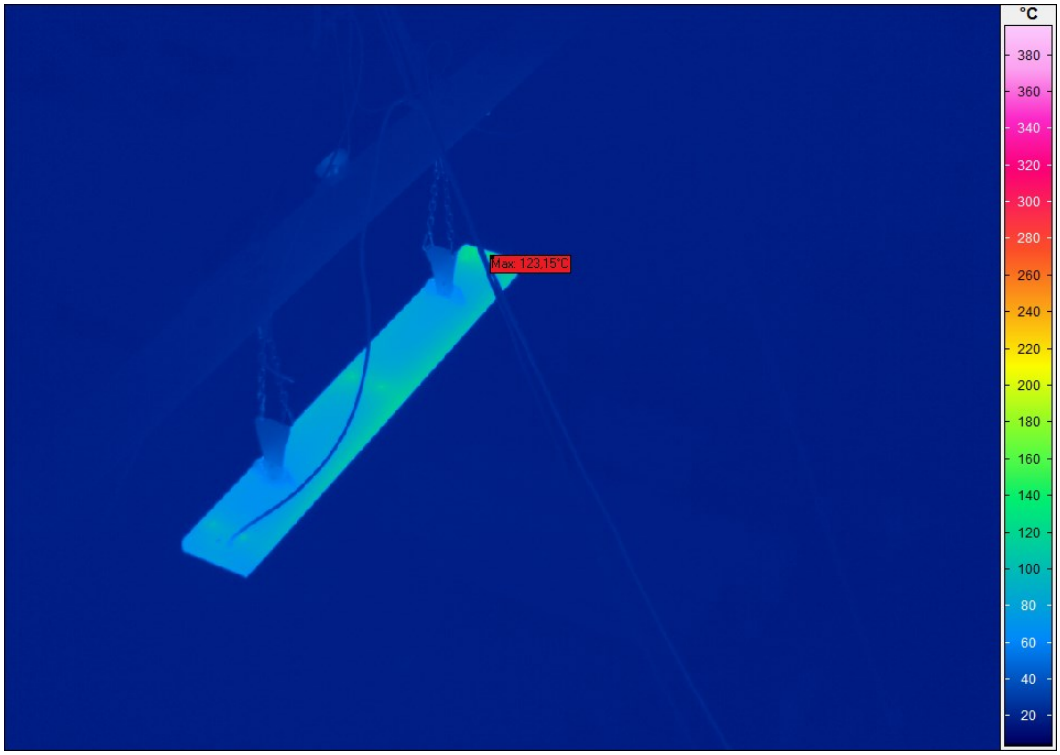


Figure 3-27 Thermal images of front area and rear cover of panel Ecosun TH 10

(3.10) ECOSUN TH 15

Table 3-19 Basic technical parameters of measured panel Ecosun TH 15

Panel type, producer	ECOSUN TH 15, FENIX Trading s.r.o.
Nominal electric input	1500 W
Dimensions (length, width, height)	1580 mm, 140 mm, 45 mm

Table 3-20 Measurement conditions

Ambient mean radiant temperature	**18,4 °C**
Ambient air temperature	18,4 °C
Maximum surface temperature	348 °C
Air temperature above panel	25,6 °C
Air velocity	0,02 m/s
Air relative humidity	36,3 %

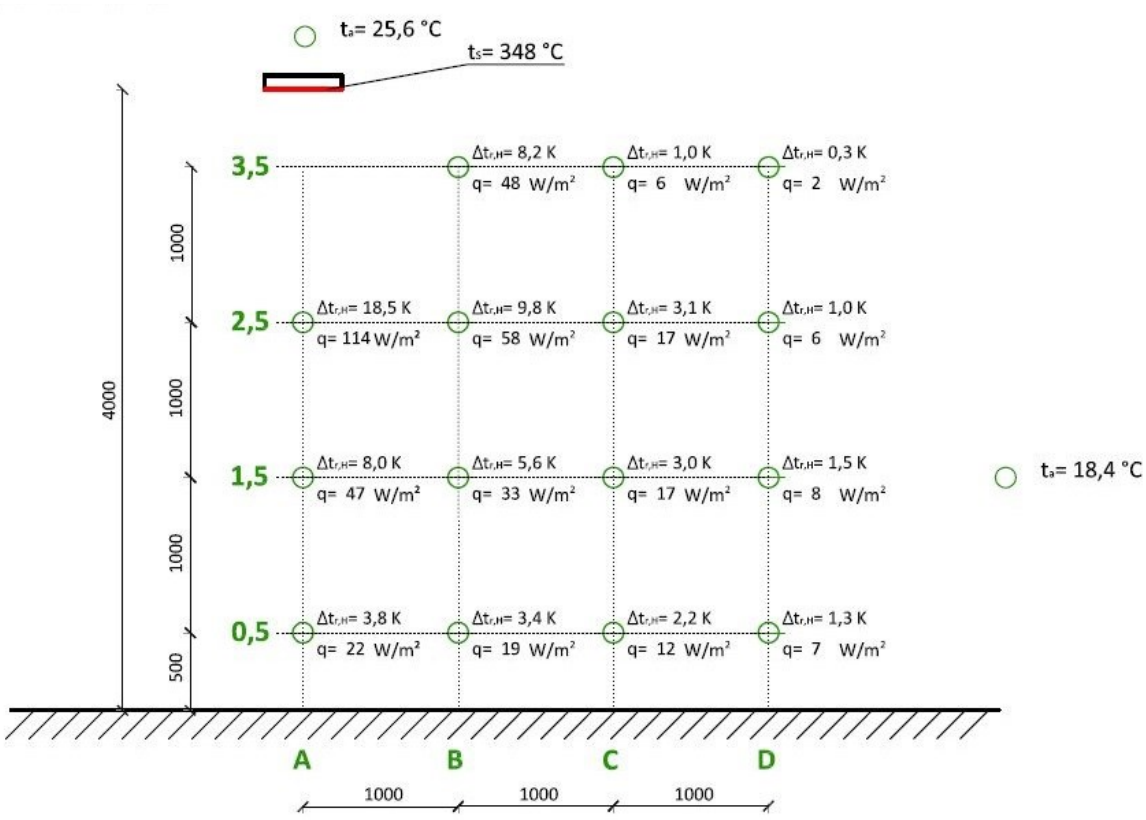


Figure 3-28 Resulting increase of mean radiant temperature and increase of specific radiant heat flux in the field of panel Ecosun TH 15 against ambient conditions

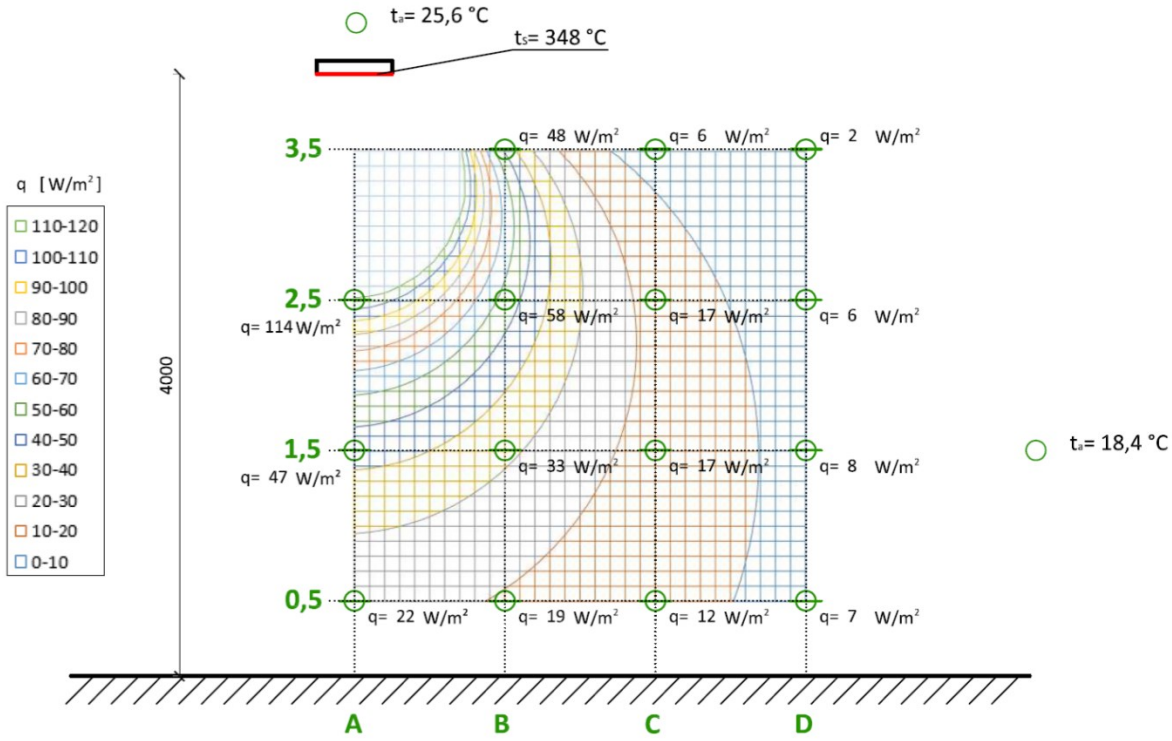
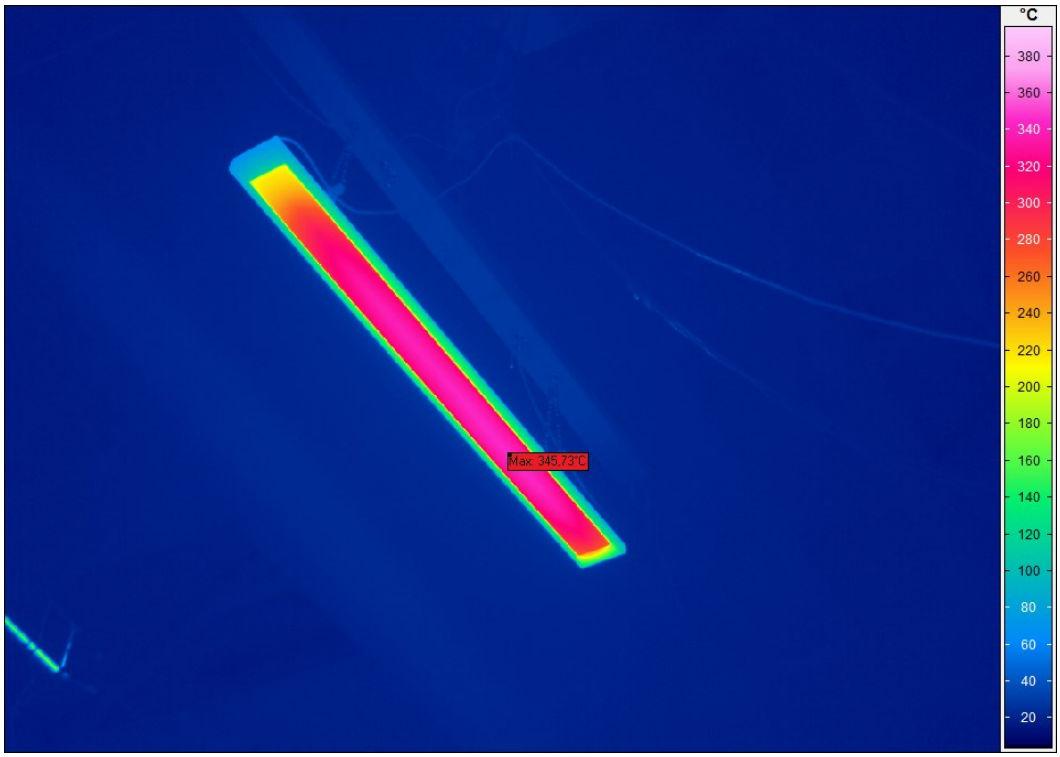


Figure 3-29 Isocurves of specific radiant heat flux in the field of panel Ecosun TH 15



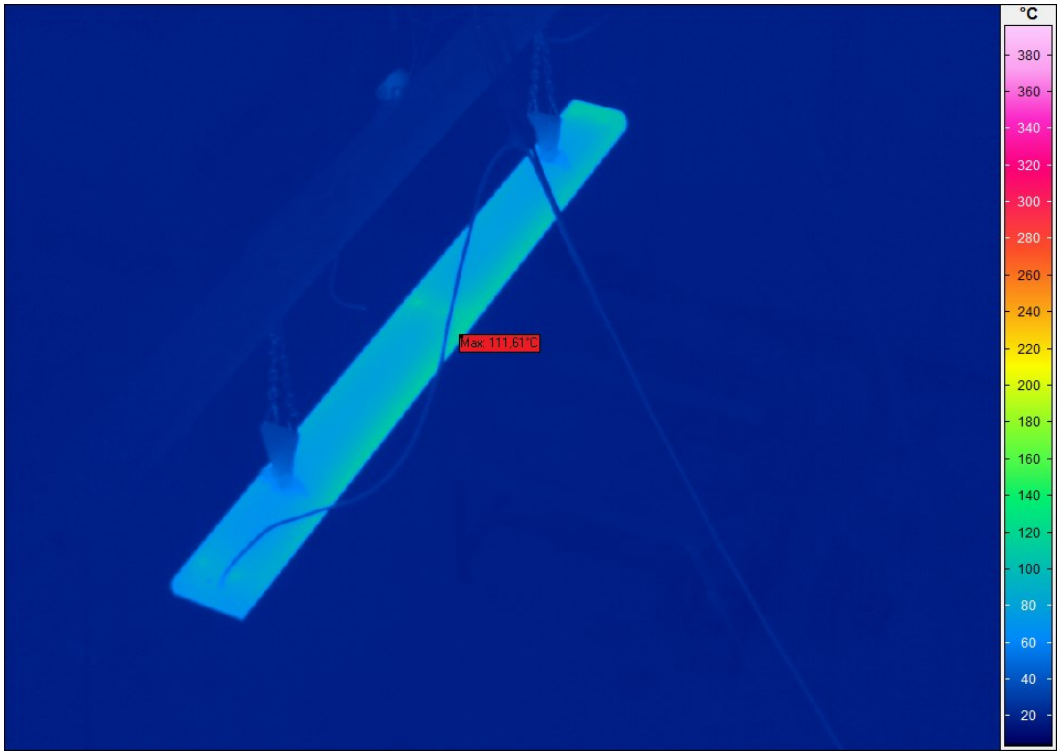


Figure 3-30 Thermal images of front area and rear cover of panel Ecosun TH 15

(4) Photo documentation

Figure 4-1 Radiant panel Ecosun hung on the crane in the measuring area

Figure 4-2 Radiant panel Ecosun S+ 30 suspended on auxiliary structure during stabilizing period (front view)

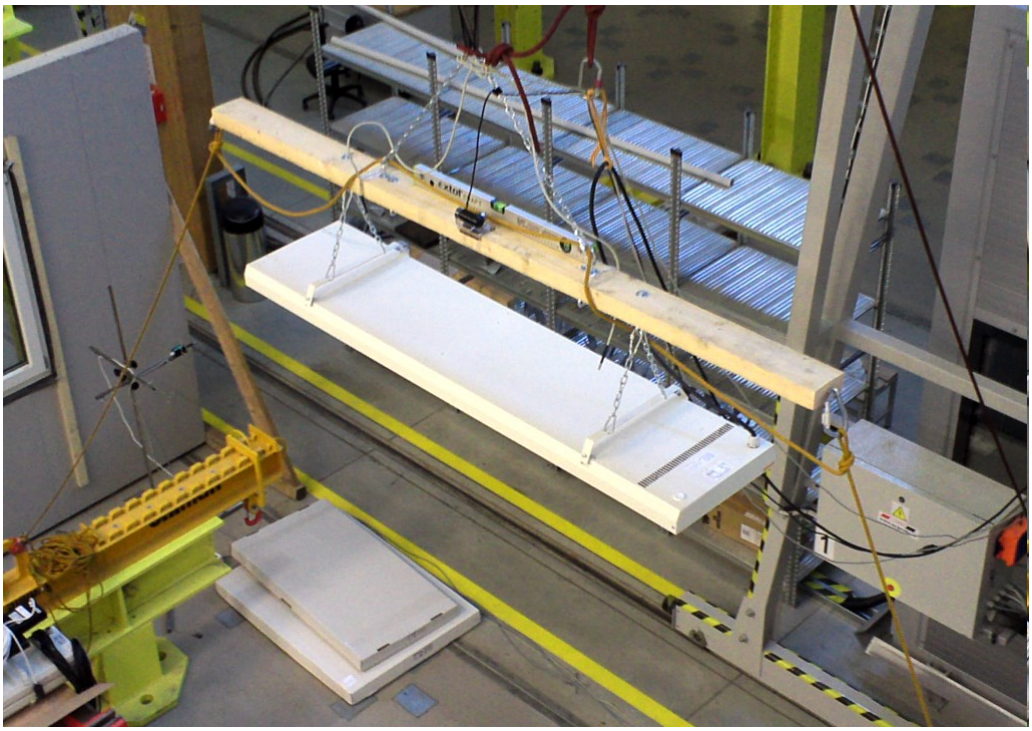


Figure 4-3 Radiant panel Ecosun S+ 30 suspended on auxiliary structure during stabilizing period (rear view)

Figure 4-4 Tripod with radiant asymmetry sensor and Indoor Climate Analyser located in one point of measuring mesh (white marks on the floor)

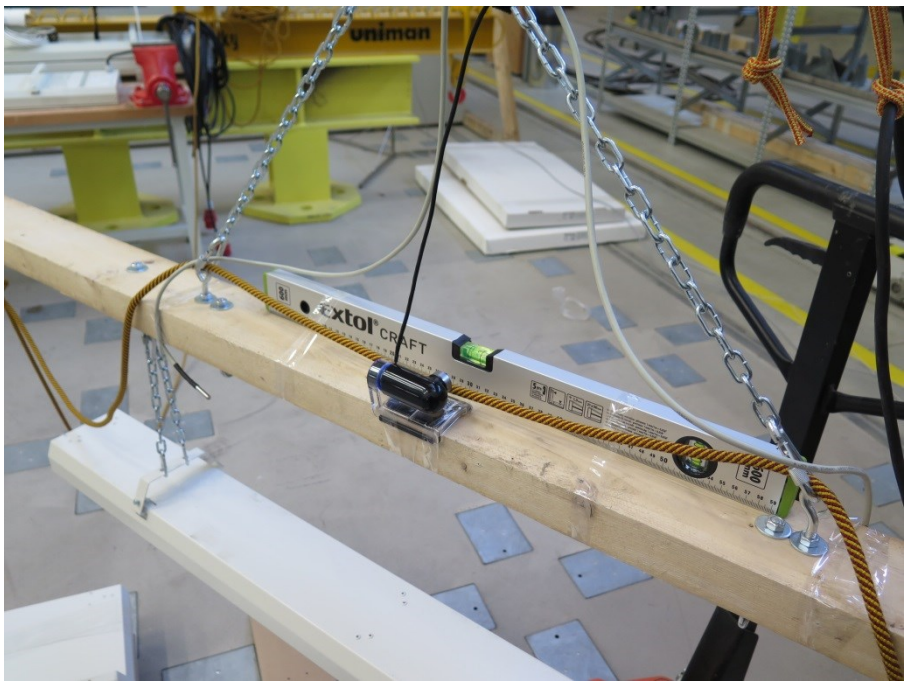


Figure 4-5 Preparation of a panel before elevated into 4 m high, mounting of spirit level on auxiliary suspended structure controlled by web camera

Figure 4-6 Thermal imaging camera used for control of panel's surface temperature

(5) Conclusion

This summary report concludes procedures and results of analysis of ten radiant panels.

The target was to describe radiant heat transfer from panels into the space adjacent to front area. Input data for analysis have provided values measured in 15 points of measuring mesh under tested panel.

Results in chapter (3) include description of specific radiant heat flux and mean radiant temperature. The results are express in figures of calculated values and figures of isocurves depicting the increase of radiant heat flux in the measuring mesh. Also approximate surface temperatures of panels and rear cover were defined by thermal imaging camera.

Parameters of tested radiant panels could be used for design of suitable type of radiant panel as a heating body.

This summary report is indivisible and must be used as a whole.