Infra-Heat

Appraisal over the thermal comfort in dwellings regarding electrical heating surfaces

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- This report covers 21 sides -

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Symbol and abbreviations

a	length	[m]
b	broad	[m]
h	height	[m]
H	height	[m]
$\dot{q}$	heat flow density	[W/m^2]
$\dot{Q}$	heat flow	[W]
t	temperature	[°C]
Tu	do to turbulence degree	[%]
V	volume	[m^3]
z	height	[m]
φ	Irradiating number	[-]

R	area
RL	room air
S	radiation
U	environment

1 Summary

The electrical heating surfaces of the company Infra-Heat (heating picture, ceramic heating, ceramic stand heating and heating mirror) represent an **alternative** heating system. They deliver the warmth up to 50% by infrared radiation and provide thereby for a comfortable room climate. (To the comparison: Today usual fan heating elements possess an infrared radiation portion on the average from approx. 32 %.)

The infrared radiation warms humans directly. Thus the room air temperature can be smaller with heating with the heating surfaces around 2 °C, than with the usual, predominantly convectively working systems. It sinks the heat requirement and in the long run the power requirement for heating.

Since the electrical heating surfaces possess only a very small storage mass, they heat themselves very fast. The heating picture e.g. already possesses after 5 minutes a temperature of 60°C.

Further the efficiency of the electrical heating surface amounts to 100%, since the necessary electricity is converted completely into usable warmth.

The installation costs are extraordinarily small. In addition no maintenance costs and the operation of the electrical heating surfaces develop are very easy.

Cleaning of the electrical heating surfaces is problem-free possible. Larger dust deposits are not to be expected.

The electrical panel heating are usable both in dwellings (especially heating picture, ceramic heating) and in wet areas (heating mirror). The heating mirror offers a further advantage: It does not fitted.

The ceramic stand heating takes a special role. It is mobile and permitted therefore purposeful, local heating.

2 Setting of tasks

The electrical heating surfaces of the company ***Infra-Heat, Magdeburger Str. 12, 35041 Marburg, Germany*** is to be examined regarding the thermal comfort in dwellings. In principle four different types of the electrical heating systems are to be differentiated, which are very similar however in the structure:

1. Heating picture (based on the new flexible infrared composition heating)

2. Ceramic heating

3. Ceramic stand heating

4. Heating mirror

In detail for the evaluation of the thermal comfort with the aforementioned electrical heating surfaces the following criteria are determined instrumentation and/or computationally:

- Power output of the panel heating
- Maximum surface temperature
- heating behaviour
- Estimation of the emissivity of the surface
- Estimation of the radiation portion
- Radiation temperature asymmetry

3 Structure of the electrical heating surfaces

3.1. Heating picture

The heating picture consists of a flexible heating element on the inside (glass fibre carbon fibre combination also in-woven metallized wire at two facing edges), which heats itself after admission with electric current. This element with electrically isolating fleeces from glass fibre is overlapping enclosed. Whereupon applied a temperature-steady electro sensitive paper is reciprocal. The different levels with a suitable polymer bonding agent are held together. The space lateral electro sensitive paper possesses the character of a poster. The heating picture is fastened with spacers to the wall.

Width: 900 mm

Height: 600 mm

Distance to the wall: 50 mm

The same heating element as the heating picture uses

3.2 Ceramic heating

The ceramic heating, however here the ceramic panel serves as insulator. Back the ceramic heating is thermal insulated (approx. 9 mm). The individual levels of a suitable framework are held together.

Width: 900 mm

Height: 600mm

3.3 Ceramic stand heating

The ceramic condition heating is based on the ceramic heating. The heating element is here reciprocally enclosed of a ceramic panel. Are held together the individual elements with a wooden framework, which possesses feet at the lower surface.

Width: 500 mm

Height: 400 mm

2.1 Heating mirror

The heating mirror differs only insignificantly from the ceramic heating. Form and dimensions agree. The back thermal insulation amounts to also here 9 mm. In place of the ceramic panel a so-called “Feeler gauge” mirror (chrome glass) is used here.

Width: 900 mm

Height: 600 mm

3 Terms and definitions

3.1 Thermal comfort

The thermal comfort over the following six measured variables one judges:

- Air speed
- Air temperature
- Temperature of the space confinement surfaces (strahlungstemperatur)
- Humid one
- Clothing
- Degree of activity

The clothing and the degree of activity are dependent on the respective person and far not the subject of this investigation. Likewise the air humidity plays a role rather subordinated. The upper limit value is to kg of dry air and a relative dampness of 65% about 11,5 g water per. For the lower limit value nothing is fixed in DIN 1946 part of 2. The humidity should not fall below however 30% of relative dampness. An appropriate investigation is not necessary in the connection with the electrical panel heating.

3.2 Ambient temperature

The ambient temperature is the arithmetic means from the local room air temperature and the local radiation temperature.

$$\boxed{t_R = 0{,}5\,(t_{RL} + t_S)} \qquad (4.1)$$

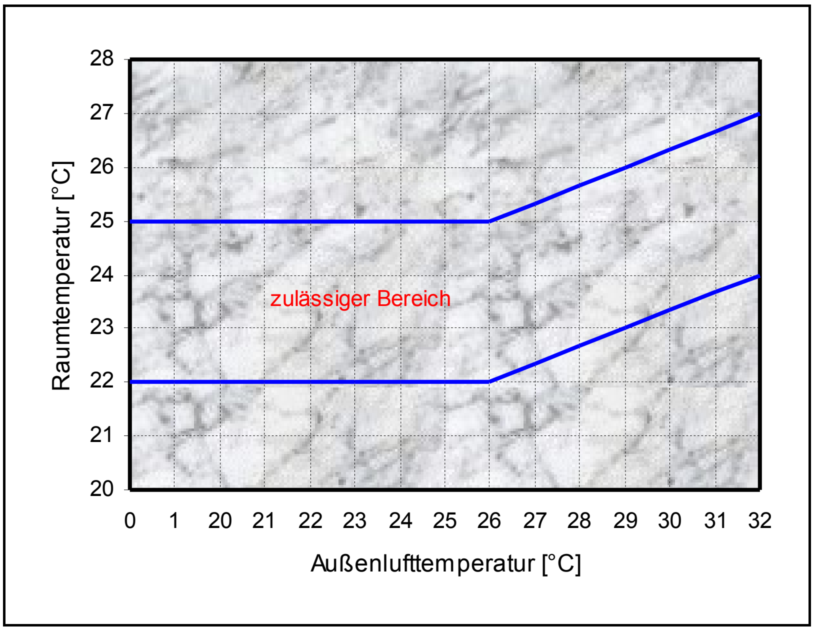


Fig. 01: Permissible ambient temperature according to DIN 1946 T2

3.3 Radiation temperature

The radiation temperature is the sum of the products of solid angle and associated surface temperature for each patch of the space confinement in the radiation exchange.

$$t_S = \sum_{i=1}^{n} \varphi_i \, t_i \qquad (4.2)$$

The solid angle for the radiation exchange between a rectangular surface I and a ball element, which must be perpendicularly underneath a corner of the surface I, is to be computed as follows:

$$\varphi_I = \frac{1}{4\pi} \arctan\left[\frac{a\,b}{h\,\sqrt{(a^2 + b^2 + h^2)}}\right] \qquad (4.3)$$

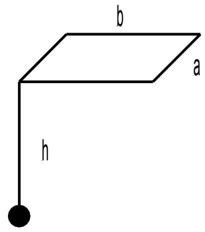


Fig. 02: Diagram for irradiating number computation the geometrical sizes contained

In the equation (4.3) for the computation of the irradiating numbers are in the accompanying design avowed. Since the indicated special case occurs only very rarely in practice, the knowledge of the addition law is necessary:

$$\sum_{i=1}^{n} \varphi_i = 1 \qquad (4.4)$$

3.4 Radiation temperature asymmetry

From the temperatures of the space confinement surfaces the respective difference of the semi-infinite space radiation temperatures is to be determined for the view place. The appropriate limit values are listed in table 01.

Space confinement surface	permissible semi-infinite space radiation temperature difference [K]
warm cover surfaces	≤ 3,5
cold wall surfaces	≤ 8,0
cooled cover surfaces	≤ 17,0
warm wall surfaces	≤ 19,0

Table 01 : Limit values of radiation asymmetry according to DIN 1946 T2

5. Results of the investigation

5.1. Power output and surface temperature

Heating	power output	surface temperature
	[W]	[°C]
Heating picture	470	77,2
Ceramic heating	300	59,1
Ceramic stand heating	180	71,3
Heating mirror	320	68,9

Table 02: Power output and surface temperature of the electrical panel heating at an ambient temperature of 22 °C

The surface temperatures indicated in table 02 are average values over the entire surface. The achievement data are total values, thus radiant heat and convection.

5.2. Heating behaviour

Heating	after 2 min	after 5 min	after 10 min	after 30 min
	[°C]	[°C]	[°C]	[°C]
Heating picture	46,0	61,9	69,2	74,9
Ceramic heating	23,9	33,7	43,4	53,9
Ceramic stand heating	24,0	36,2	49,1	63,9
Heating mirror	22,3	28,8	40,4	57,8

Table 03: Heating behaviour of the electrical panel heating

In table 03 the averaged surface temperatures are indicated, which adjust themselves after appropriate time and with an ambient temperature of 22°C.

5.3. Estimation of the emissivity of the surface

Heating	Emissivity
	[-]
Heating picture	0,95
Ceramic heating	0,95
Ceramic stand heating	0,95
Heating mirror	0,85

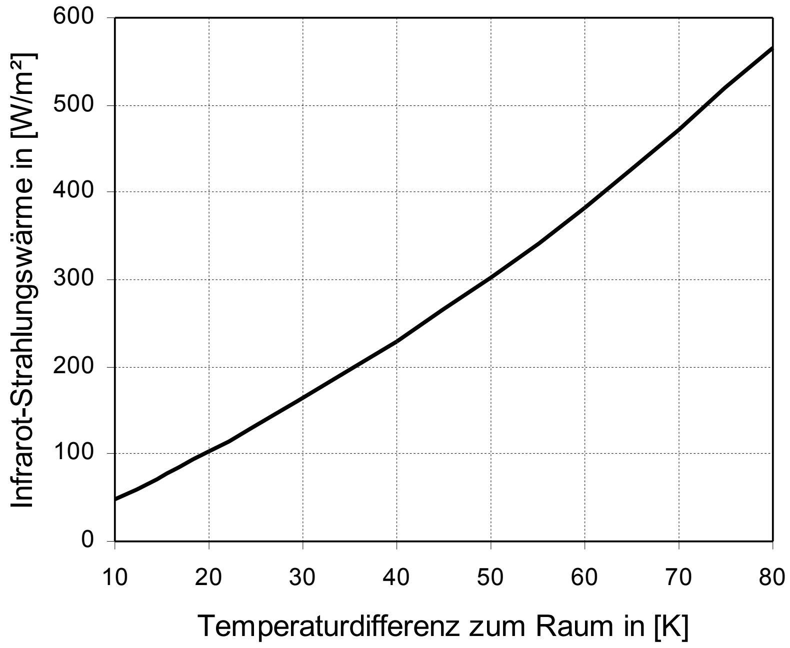
Table 04: Emissivity of the individual electrical heating surfaces

The emissivities were won by comparison by thermal graphically determined and temperatures measured over contact thermometer.

The values for the emissivities, registered in table 04, indicate, how well the radiant heat is emitted by the surface. The value 1.0 is a theoretical limit value, which is reached not completely by technical surfaces. 0,95 is a very favourable value. The emissivity of 0,85 of the heating film lie for a reflector surface amazingly highly.

5.4. Estimation of the infrared radiation portion

In following the diagram the heat emission of a black surface is indicated related to a surface of 1 m² into a black area in dependence of the temperature difference to the



area.

Fig. 03: Infrared radiation heat emission and temperature difference to the area

Heating	Heat emission by infrared radiation [W]	Infrared radiation portion [%]
Heating picture	218,5	46
Ceramic heating	134	45
Ceramic stand heating	98,5	53
Heating mirror	159	43

Table 05: Total heat emission and infrared radiation portion

(To the comparison: Today usual heating elements possess on the average an infrared radiation portion of 32 %.)

6. Radiation temperature asymmetry

Are enough: 5.0 m broad: 4.0 m height: 2.7 m in one of the side panels with the length from 5 m is a large panorama window. Three different cases were counted:

Humans are in an area, in which a wall is warm coldly and the opposite wall, it unevenly by these walls are kept at a moderate temperature. If the temperature difference of the warm and the cold wall crosses a certain limit value, humans feel uncomfortable. One calls this imbalance of the wall temperature radiation temperature asymmetry.

With the determination of radiation temperature asymmetry the area which can be examined is divided mental into two halves. During the view of the heating picture thereby the area is to be cut perpendicularly and parallel to the heating surface of the picture. For the two semi-infinite spaces the radiation temperature is to be computed according to the equations from section 4,3. It is to be noted that all surfaces of the semi-infinite space are to be computed doubly, so that in the long run again a full area develops and so that the sum of the irradiating numbers of 1 amounts to.

The computations in the context of this investigation are accomplished with a particularly developed radiation computation program on the basis a model room.

6.1 Model room for the radiation asymmetry computation

The model room for the determination of the radiation temperature asymmetry, which results from the use of panel heating, exhibits following geometry:

Are enough:	5,0 m
broad:	4,0 m
Height:	2,7 m

In one of the side panels with the length from 5 m is a large panorama window. Three different cases were counted:

Case 1: Three electrical heating surfaces opposite the window

Case 2: distributes three electrical heating surfaces on the side panels

Case 3: increased electrical heating surface opposite the window

The surface temperature of the window was accepted with 12°C. All other surfaces entered with a surface temperature of 20°C computation. In the case 1 and 2 possesses the heating surfaces a length of 1000 mm and a height of 500 mm. In the case 3 the length 1200 mm and the height of 700 mm amount to.

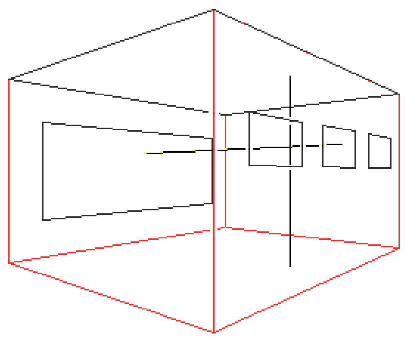


Fig. 04: Model room with three electrical heating surfaces opposite the window

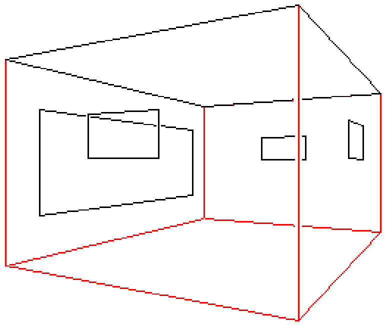


Fig. 05: Model room with three electrical heating surfaces on the side panels distributes

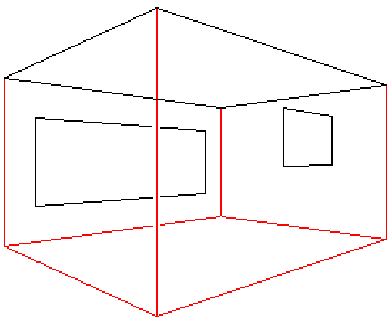


Fig. 06: Model room with a larger electrical heating surface opposite the window

6.2. Results of the radiation asymmetry computation

Temp of the heating	Surface distance from the middle heating surface opposite the window in [cm]						
	50	75	100	150	200	300	350
60 °C	9,2	5,9	4,4	1,3	1,6	2,1	2,1
80 °C	13,7	8,7	6,4	4,3	3,6	4,2	5,8
90 °C	16,0	10,1	7,4	4,9	4,0	4,4	6,0

Table 06: Radiation temperature asymmetry with three electrical heating surfaces opposite the window

Temp of the heating	Surface distance from the middle heating surface opposite the window in [cm]						
	50	75	100	150	200	300	350
80 °C	11,3	5,9	3,4	1,4	2,4	4,6	6,2

Table 07: Radiation temperature asymmetry with three electrical heating surfaces on the side panels distributes

Temp of the heating	Surface distance from the middle heating surface opposite the window in [cm]						
	50	75	100	150	200	300	350
80 °C	17,5	10,5	7,0	4,1	3,1	3,8	5,5
90 °C	**20,3**	12,2	8,1	4,6	3,4	3,9	5,6

Table 08: Radiation temperature asymmetry with a larger electrical heating surface (1200 mm x 700 mm) opposite the window

6.3. Evaluation of the radiation asymmetry computation

The managing tables' 05 to 07 show adjusting radiation temperature asymmetries, ever after as far radiation of absorbing bodies is distant from the heating surface and is adjusted to which surface temperature the heating surface.

According to table 01 the permissible value for radiation asymmetry amounts to 19 K.

Is according to the conditions according to table 06 a standing person 75 cm before the middle heating surface (this position is exemplarily characterized by the black cross in fig. 04) and amounts to the temperature of the heating surface 60°C, then this person feels warmth the affecting it as extremely pleasant, since radiation asymmetry with 5,9 K is clearly under the permissible value of 19 K.

If this person would stand itself according to the conditions according to table 08. 50 cm before the heating surface with a surface temperature of 90°C, it would unprobably feel, because radiation asymmetry amounts to in this case 20.3 K and is larger thereby than 19 K. (note: The space zone, in humans in the rule stopping, ends itself according to DIN 1946 T2 a half meter before an inner wall and a meter of an external wall.)

From it results that the temperature of the heating surfaces examined here should not be under any circumstances higher than 80°C, since otherwise thermal comfort cannot be guaranteed any longer.

Apart from the temperature also the arrangement of the heating surfaces is crucial. This becomes clear, if table 06 and table 07 are compared with one another. The arithmetic procedures from table 06 cause the arrangement of the heating surfaces opposite the window. If the heating surfaces are distributed evenly in the area, a more favourable radiation asymmetry, table 07 develops.

From the radiation asymmetry computations now the following statements can be derived:

1. It is of advantage to distribute the heating surfaces evenly in the area. This leads to a more favourable distribution of radiation asymmetry.

2. Up to a surface temperature of the heating surfaces of 80°C no thermal uncomfortable ness is present by a too large radiation asymmetry with the conditions examined here.

3. With a surface temperature of the heating surfaces of 90°C it can come to thermal uncomfortable ness by to large radiation asymmetry.

4. If it is possible, the heating surfaces should not be hung up opposite the window.

5. The optimal place of the electrical heating surfaces is direct beside a window. In this case the radiant heat transferred to the window is compensated directly again by the infrared radiation of the heating surface.

7. Final consideration

In the context of this investigation is the electrical heating surfaces of the company ***Infra-Heat, Magdeburger Str. 12, 35041 Marburg, Germany*** with use in dwellings regarding the thermal comfort to be examined. In addition appropriate computations and measurements were accomplished.

How could be shown, the electrical heating surfaces give the warmth to a large part (on the average approx. 50%) by infrared radiation to their environment off. Warmth by infrared radiation is felt as very pleasant. (To the comparison: Today usual heating elements possess an infrared radiation portion on the average from 32 %.)

The infrared radiation is converted directly with the impact a person or an article in warmth; the room air temperature can remain lower therefore (2°C). In this way energy can be saved when same comfort feeling.

The necessary electricity is completely converted in the area in warmth and used to 100% for space heating. Transportation losses at thermal energy from the boiler to the area cannot occur.

Since the electrical heating surfaces possess only a very small storage mass, they heat themselves very fast. The heating picture possesses already after 5 minutes a temperature of 60°C. The infrared radiation therefore already warms after very short time persons, furniture and walls. The room air is warmed up as convectively with every other space heating system with appropriate delay.

The ceramic stand heating takes a special role. It is mobile and permitted therefore direct, local heating. If this possibility is used accordingly, and heated, where the warmth is also needed, this contributes only further to the lowering of the heat requirement.

The installation costs of the electrical heating are extraordinarily small. In addition no maintenance costs and the operation of the electrical heating surfaces develop are very easy.

Cleaning of the electrical heating surfaces is problem-free possible. Dust deposits, e.g. between the radiators of a heating element are not to expect.

The electrical panel heating are usable both in dwellings (esp. heating picture, ceramic heating) and in wet areas (heating mirror). The heating mirror offers a further advantage: It does not fitted.

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