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**MODULAR RADIANT PANELS**



## **Comparison between ceiling radiant panels and floor heating in industrial buildings**

Study carried out by HLK Laboratory  
University of Stuttgart (Germany)



## INTRODUCTION

The installation of floor radiant panels for the heating of industrial buildings started some years ago and recently this has spread out.

The European Association of Manufacturers of Ceiling Panels (EMCP) has appointed the HLK Institute of the University of Stuttgart to carry out a study, comparing floor radiant heating and ceiling radiant panels in the heating of an industrial building.

The study has produced the two reports here enclosed.

The report n. 393 considers an industrial hall with volume 5.000 m<sup>3</sup>, placed in two climate zones, which can be identified as Northern and Southern Europe. For this building the reference energy demand is calculated, namely a theoretical ideal value of the thermal energy required to heat the building, independently from the heating system used. Calculation is then carried out considering first the floor heating system and then heating by means of ceiling radiant panels, using two different operation options (with and without night setback) and with two different control systems.

The results of the calculation show that the energy demand required to heat the production hall with floor heating system is 20-25% higher than with ceiling radiant panels.

Furthermore, calculation shows that the heating system with ceiling radiant panels presents a faster reaction to the variations of internal and external loads.

The report is quite interesting and gives a complete answer to the analysed subject. In Italy, except some particularly cold mountain areas, temperature oscillations during winter are very heavy and values shown by this report result in terms of percentage higher.

When using methane gas heating, the system is usually switched completely off during the night and the weekends. The regulation system allows, by means of a simple room thermostat, to start the system again only when room temperature drops under 5°C (anti-freeze function). The use of programmable controllers with external probe allows also to start the system up at different times, granting the desired temperature in the room during working hours.

The second report n. 633 considers the heat flows into the ground and through the ground towards the environment. Different ground conditions and distances from the ground water are considered. The calculations show that, with the same ground conditions and distance from the ground water, the heat flows dispersed to the ground by the ceiling radiant panels heating system turn out to be from 44% to 59% lower than those dispersed by the floor heating system. Also in this case it is evident that the ceiling radiant panels heating allows to reduce the surplus of energy produced and dispersed to heat an industrial building.

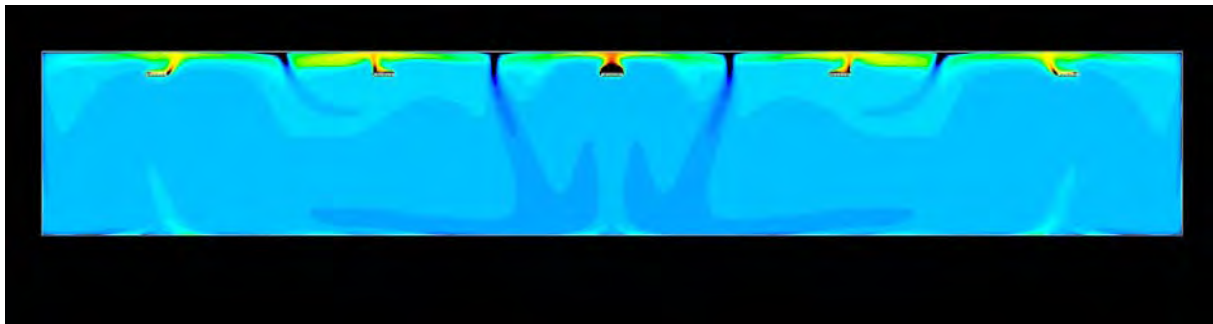
These real and scientifically validated data represent the ground for the statement that heating with ceiling radiant panels allows actual savings, in terms of energy and consequently of money, in comparison to the floor heating system.

# report no. H.0611.S.393.EMCP-production halls

Heating of industrial halls  
Computed comparison of heat emission  
from ceiling radiant panels and industrial floor heating  
- production halls -

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Stuttgart, 16 June 2009

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# 1 Definition of task

The heating from ceiling radiant panels is to be compared with the heating from industrial floor heating by using the example of a production hall.

## 2 General conditions

### 2.1 Production hall

Figure 1 illustrates the selected production hall. The required room temperatures will reach 18 °C on working days and 14°C at weekends (set back).

Additionally, the case of a nominal temperature which is to be reduced to 16 °C for the period from 17:00 PM to 6:00 AM is considered.

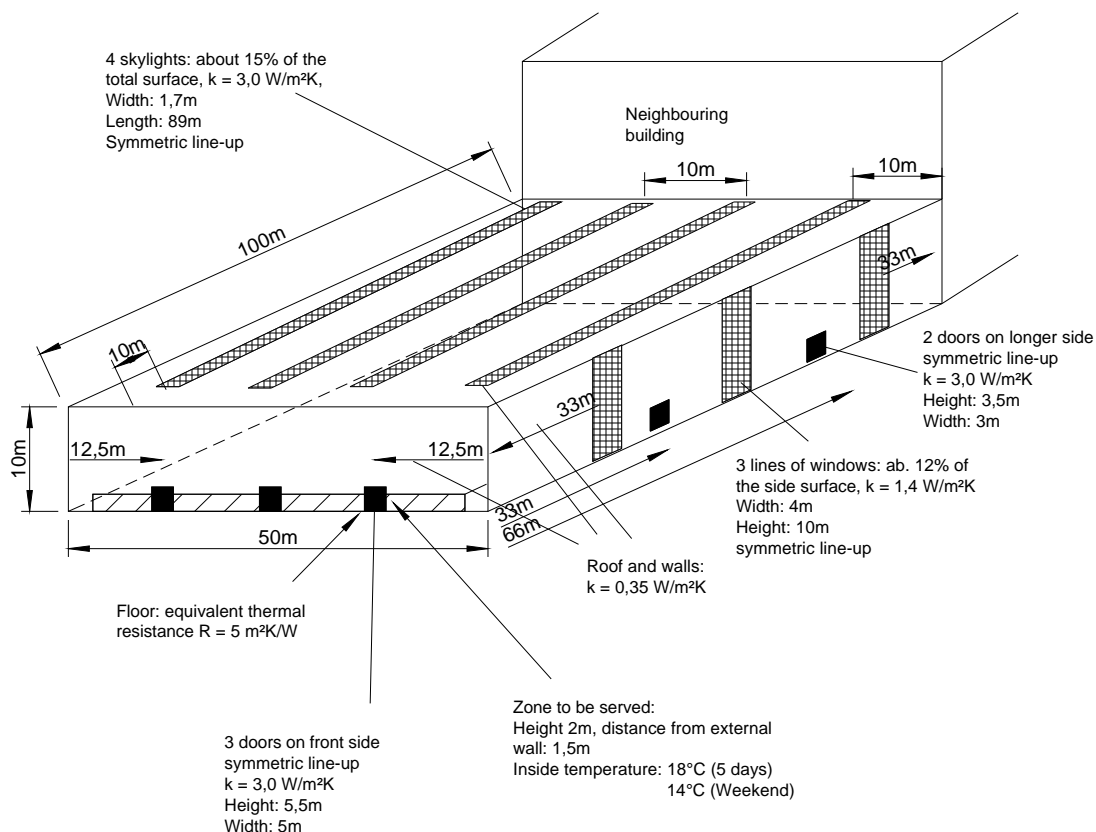


Figure 1: Production hall

The hall ventilation via air conditioning system guarantees an air change rate of for Germany:

- A) 0,2 l/h or alternatively
- B) 0,5 l/h.

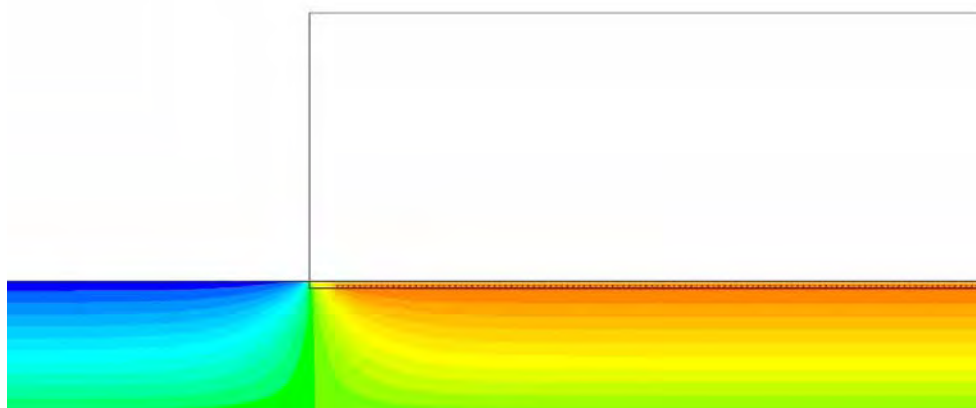
for Great Britain (or Italy):

- A) 0,3 l/h or alternatively
- B) 0,5 l/h.

The reduced air flow is considered additionally, because the large hall volume increases the air flows and heating load. A reduced air flow seems possible in modern production processes equipped with an appropriate emission extraction (exhaust system).

The hall floor is insulated from the ground. Figure 2 shows the temperature distribution at the bottom for the non-insulated case and heating via industrial floor heating. The calculations have shown, that the losses into the ground increase significantly for the non-insulated case and that the remaining capacity (max. 50% of the floor area) is not sufficient to heat the hall. In the case of industrial floor heating the temperature difference between the pipe plane and the ground or the surrounding outside air is very much more important than in the case of radiant ceiling heating.

For ceiling radiant panels, the temperature of the floor surface is higher than the air temperature by only approx 2K, but the temperature in the under floor heating pipes (which are nearer to the ground) is a minimum of 50°C (to ensure sufficient heat is transferred to the room). This increases the downward heat losses of the under floor heating.



**Figure 2:** Temperature distribution under the production hall for the case of industrial floor heating without insulation

## 2.2 Meteorological data

The outside conditions are given for two climate zones:

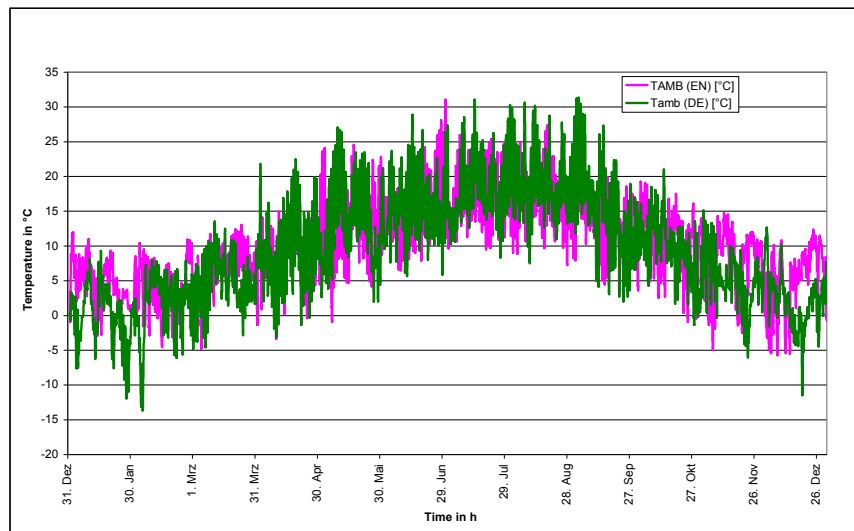
A) Germany:

The climate data are applied for a design temperature of  $-12^{\circ}\text{C}$ .

B) Great Britain (or Italy)

The climate data are applied for a design temperature of  $-5^{\circ}\text{C}$ .

Figure 3 shows the graphical presentation of data sets for both climate zones. The values of the heating period ( $T_{\text{amb}} < T_{\text{soll}}$ ) are relevant for the following calculations.



**Figure 3:** Meteorological data as a basis for calculations (test reference years) for both climate zones.

## 2.3 Heating load

The heating loads for different use cases are firstly determined according to the technical regulations (DIN EN 12831) for the steady-state technical case.

In a second step, the reference energy demand is identified. This means that the internal heating sources, the arrangement of windows (external heating sources) and the daily variations must be considered.

The external and internal heating gains are considered by the calculation of the requested reference energy and lead to a reduction of this value compared to the steady state approach on heat load calculating.

## 2.4 Internal heat sources

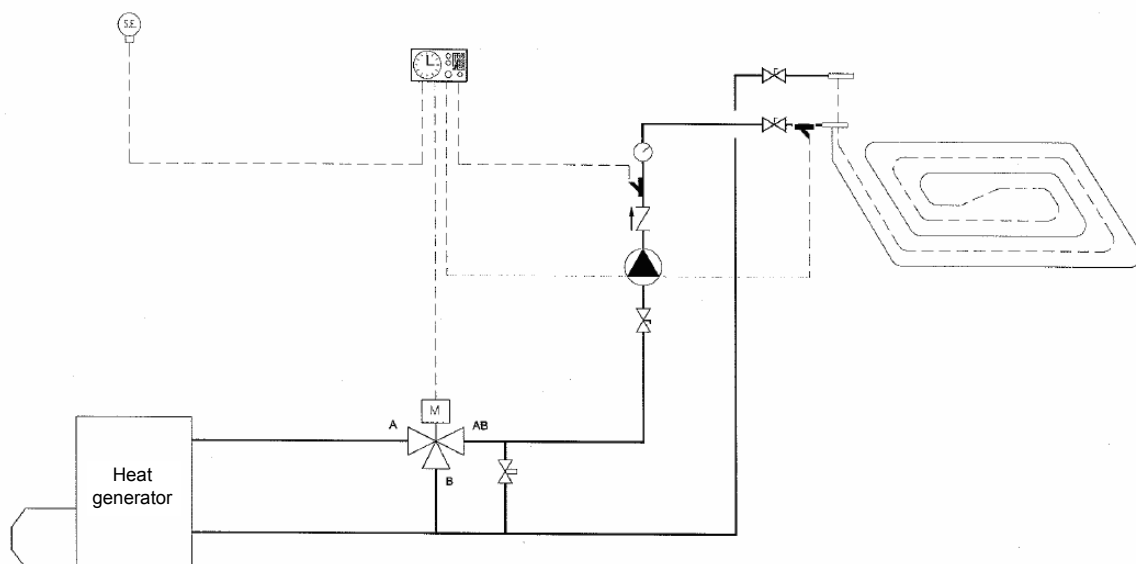
After a pre-defined use profile, the internal heat gains (incidental gains by people and machines give off while working) of the production hall use are determined as follows (valid for working days):

Between 6:00 AM and 12:00 PM:	100%
Between 12:00 PM and 13:00 PM:	20% of the maximum gain
Between 13:00 PM and 17:00 PM:	100%

## 3 Calculation results

### 3.1 Industrial floor heating

Figure 4 is a schematic drawing of the floor heating control presented by the client. The floor heating is supplied by a continuous heating medium flow. The flow temperature is determined by the outside temperature and the room temperature.



**Figure 4:** Schematic drawing of the floor heating control



Table 1 indicates the values for the reference heating demand with insulation under the floor.

In contrast, table 2 demonstrates the results for the case with night setback in the production hall. The reference energy demand is reduced in the hall, because during night hours the required room temperature is lower.

The tables 3 and 4 present the simulation results (real operation) given for floor heating in both cases.

Production	kWh	MWh	Infiltration
Deutschland	158.453	158	0,2
Deutschland	276.249	276	0,5
England	187.881	188	0,3

**Table 1:** Calculated energy demand with heat insulation for ideal heating

Production	kWh	MWh
Deutschland, n=0,2 1/h	109.050	109
Deutschland, n=0,5 1/h	201.471	201
England, n=0,3 1/h	127.660	128

**Table 2:** Calculated energy demand with heat insulation and night setback for ideal heating

Production	kWh	MWh	Consumption increase
Deutschland, n=0,2 1/h	211.425	211	1,33
Deutschland, n=0,5 1/h	375.899	376	1,36
England, n=0,3 1/h	272.873	273	1,45

**Table 3:** Calculated energy demand (additional effort) for floor heating with heat insulation and without night setback.

Production	kWh	MWh	Consumption increase
Deutschland, n=0,2 1/h	182.168	182	1,67
Deutschland, n=0,5 1/h	319.363	319	1,59
England, n=0,3 1/h	225.605	226	1,77

**Table 4:** Calculated energy demand (additional effort) for floor heating with heat insulation and with night setback.



It's obvious that the additional effort without night setback is in the range of 1,33 to 1,45; i.e. 30% to 40% more energy has been delivered as it should be necessary for heating the hall in an ideal case.

For the case of night setback the relative value increases from 1,59 to 1,77.

The reason is the decrease of the reference energy demand – measured at the initial state. As a result, the relative index “additional effort” increases in spite of decreasing absolute values.

Using the example of a production hall in Germany,  $n= 0,2$ , the following explanation is given:

Reference energy demand without night setback:	158 MWhr
Energy demand industrial floor heating without setback:	211 MWhr
Calculated additional effort:	1,33 or 33%
Reference energy demand with night setback:	109 MWhr
Energy demand industrial floor heating with setback:	182 MWhr
Therefore, calculated additional effort:	1,67 or 67%

This means that the potential saving through the night setback of 50 to 75 MWhr can be realised only partially by the heating system. The absolute reduction of the energy demand amounts in this case 29 to 57 MWhr.

### **3.2 Radiant ceiling heating – Ceiling radiant panels**

The cases of radiant ceiling heating are regarded for two different control systems:

#### Control system 1:

The mass flow is constantly controlled by a throttle control. The controlled variable is the value of the operating temperature. The manipulated variable is a control signal with the values “0” or “1”.



The controller set point is fixed in this way in order to avoid the drop of the temperature below the set-point. Thus, over different long periods, the temperature in the hall is maintained at a higher temperature level than should be necessary. That implies an additional effort compared to the reference demand of an ideal heating system equipped with an ideal controller.

Control system 2:

Analogous to the floor heating the mass flow is kept constant in the modified variant of the ceiling radiant panels. The flow temperature depends also on the air temperature and the outside temperature.

The values for the reference energy demand obtained from the tables 1 and 2 (paragraph 3.1) are used for the ceiling radiant panel heating independent from the heating system.

The simulation results (real operation) of the radiant ceiling heating without and with night setback for the control system 1 are shown in the tables 5 and 6.

Production	kWh	MWh	Consumption increase
Deutschland, n=0,2 1/h	182.922	183	1,15
Deutschland, n=0,5 1/h	315.252	315	1,14
England, n=0,3 1/h	220.844	221	1,18

**Table 5:** Calculated energy demand (additional effort) for radiant ceiling heating with heat insulation without night setback, control system 1

Production	kWh	MWh	Consumption increase
Deutschland, n=0,2 1/h	148.093	148	1,36
Deutschland, n=0,5 1/h	257.928	258	1,28
England, n=0,3 1/h	171.214	171	1,34

**Table 6:** Calculated energy demand (additional effort) for radiant ceiling heating with heat insulation with night setback, control system 1

The values for the additional effort are between 1,15 and 1,18. In case of the operation with night set back the values increase to 1,28 – 1,34. The reason is the smaller reference energy demand.



The simulation results (real operation) of the radiant ceiling heating without and with night setback for the control system 2 are shown in the tables 7 and 8.

Production	kWh	MWh	Consumption increase
Deutschland, n=0,2 1/h	197.187	197	1,24
Deutschland, n=0,5 1/h	334.112	334	1,21
England, n=0,3 1/h	223.913	224	1,19

**Table 7:** Calculated energy demand for radiant ceiling heating with heat insulation without night setback, control system 2

Production	kWh	MWh	Consumption increase
Deutschland, n=0,2 1/h	148.510	149	1,36
Deutschland, n=0,5 1/h	265.615	266	1,32
England, n=0,3 1/h	178.284	178	1,40

**Table 8:** Calculated energy demand for radiant ceiling heating with heat insulation with night setback, control system 2

The additional effort values without night set back are between 1,19 and 1,24. During the operation with the night set back the values increase to 1,32 – 1,40.

This demonstrates, that the control strategy (steady control) produces a lower value of the additional effort. Therefore, this solution is energetically profitable. The control system 2 with approx. 5% higher effort has advantages in relation to the thermal comfort, because only in this way is it possible to heat the hall evenly.



## 4 Summary

The project results show that the heating of industrial halls with industrial floor heating can be only reduced adequately by insulating under the floor to reduce the heat flow into the ground. In this example of an industrial hall (50 m x 100 m) the required heat flow could be only reduced by this insulation, so that the free area (assumption 50%) was sufficient for the heating through the industrial floor heating.

For different cases (without night set back, with night set back) the calculations indicate the required additional effort for both systems: industrial floor heating and heating by ceiling radiant panels.

The additional effort (effort number) is the relation from the real required demand (heat energy) to the theoretical ideal value (reference energy demand). The following tables 4 and 7 present the results for the case with night set-back in various climate zones (Great Britain, Germany).

Production	kWh	MWh	Consumption increase
Deutschland, n=0,2 1/h	182.168	182	1,67
Deutschland, n=0,5 1/h	319.363	319	1,59
England, n=0,3 1/h	225.605	226	1,77

**Table 4:** Calculated energy demand (additional effort) for floor industrial heating with heat insulation with night setback

Production	kWh	MWh	Consumption increase
Deutschland, n=0,2 1/h	148.510	149	1,36
Deutschland, n=0,5 1/h	265.615	266	1,32
England, n=0,3 1/h	178.284	178	1,40

**Table 7:** Calculated energy demand for radiant ceiling heating with heat insulation with night setback, control system 2

The results show that the energy demand for floor heating is 20% - 25% higher than is the case for radiant ceiling heating.

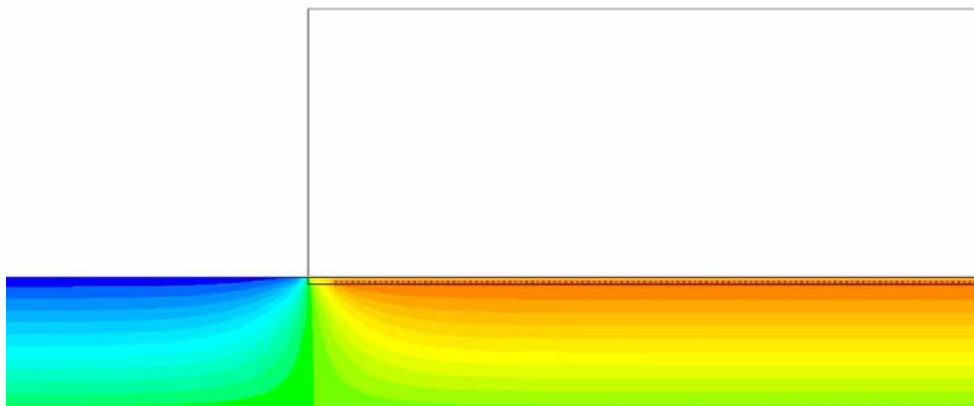
Furthermore, it offers the possibility to react faster to changes of the internal and external loads because of the smaller inertia of the heating system by radiant ceiling panels. This reduces the periods with inside temperatures above the desired temperature. A faster reaction to reduced internal heat gains (e.g. shutdown of the machines) is also possible.

# report no. H.0906.S.633.EMCP

## Heating of industrial halls - Computed comparison of heat emissions into the ground from ceiling radiant panels or industrial floor heating systems

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Stuttgart, 12 June 2009



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The report includes 12 pages. It's not allowed to copy it at full volume without the approval of the testing laboratory. The test results refer solely to the test objects and the present test set-up.



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## 1 Definition of task

The heat flows both into and through the ground to its surroundings shall be determined for an industrial hall. The hall is heated via ceiling radiant panels or by industrial floor heating. The measurements of those heat losses through the floor panel have been carried out for different hypotheses concerning the ground beneath the hall.

## 2 General conditions

### 2.1 Production hall

Figure 1 illustrates the selected production hall. The required room temperatures reach 18°C on working days.

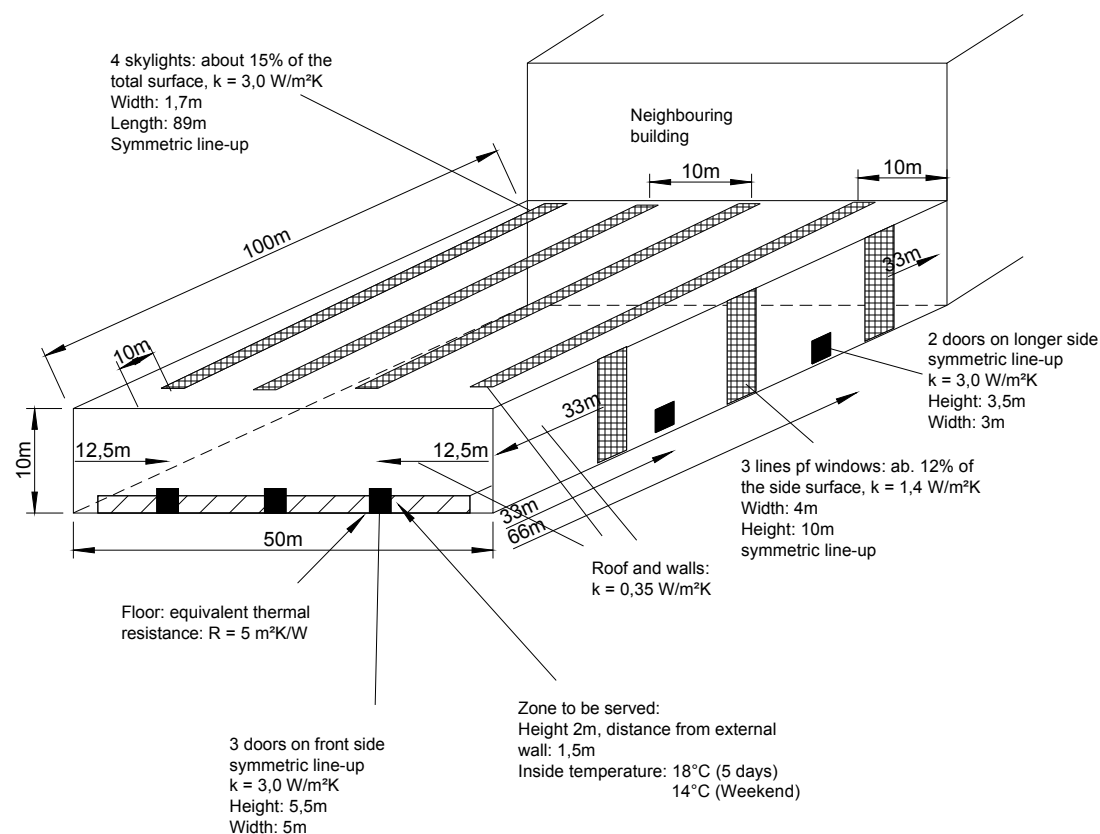


figure 1: Production hall

## 2.2 Meteorological data

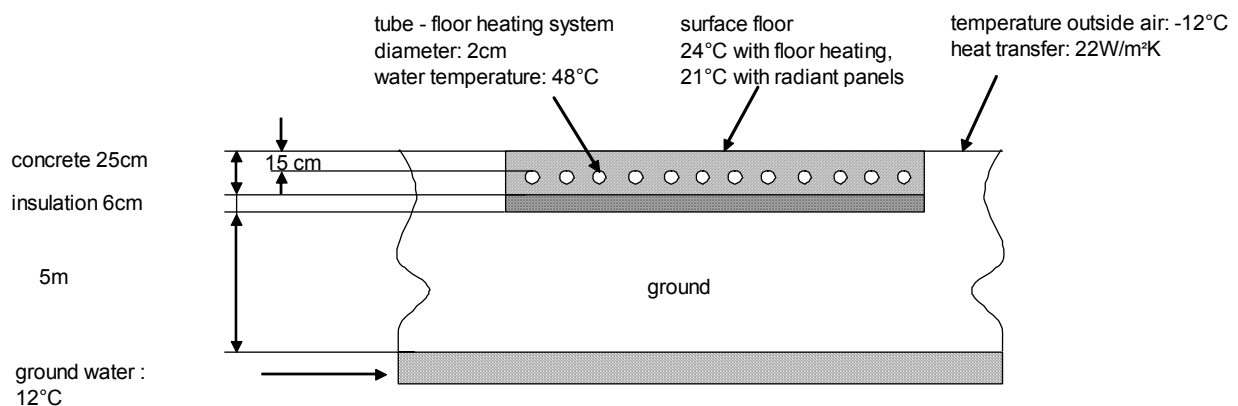
A design temperature of  $-12^{\circ}\text{C}$  is given for the surroundings.

## 2.3 Floor foundation / ground

Figure 2 shows the floor foundation of the production hall. The measurements have been carried out under the floor panel

- A) without insulation (6 cm)
- B) with insulation (6 cm).

At first, different variants has been taken into account for the ground and the distance to the ground water (see table 1), in order that the influence of these sizes can be estimated. For the industrial hall heating, the surface temperature of the area to the hall results from the required heat transfer. For the radiant panel heating, the value is increased to  $20^{\circ}\text{C}$  (hall temperature:  $18^{\circ}\text{C}$ ). This evaluated value consider the additional radiation of the ceiling panels at the hall bottom.



**figure 2:** Foundation of the production hall

	Density [ $\text{kg/m}^3$ ]	heat capacity [ $\text{J/kgK}$ ]	thermal conductivity [ $\text{W/mK}$ ]
concrete	2400	1000	2,1
ground	2000	830	2,1
insulation	40	2090	0,031

**Table 1:** Hypotheses of values for the main materials



### 3 Calculation results

#### 3.1 Industrial floor heating

Table 2 shows the calculation results for the heat flow into the ground under the above information about water temperature (48°C) and ground ( $\lambda = 2,1 \text{ W/mK}$ ). The area under the floor is 5000 m<sup>2</sup>.

	Floor heating without insulation (Water temperature: 48°C)	Floor heating with insulation (Water temperature: 48°C)
Heat flow through the lower surface of the floor [W]	76900	39300
Heat flows through the side surface of the floor (concrete) [W]	9800	10900
Heat flows through the side surface of the floor (insulation) [W]	0	32
Heat flows through the front surface of the floor (concrete) [W]	4900	5450
Heat flows through the front surface of the floor (insulation) [W]	0	16
<b>Total [W]</b>	<b>91600</b>	<b>55698</b>

**Table 2:** Calculated heat flow without and with heat insulation for water temperature of 48 °C

The heat flow reduction caused by insulation provides approx. 40%.

Table 3 demonstrates analogous values, if the ground water distance to the hall floor is 10 m (before 5 m) and the ground has a lower thermal conductivity ( $\lambda = 1,5 \text{ W/mK}$  instead of 2,1 W/mK).

This case shall demonstrate how the foundation beneath the production hall (ground water, kind of ground) influences the calculated results.

As expected, the heat flow into the ground will decrease to 50% of the original value.

In this case, the reduction of the heat flow by insulating amounts to approx. 20%

	Floor heating without insulation (Water temperature in pipe: 48°C)	Floor heating with insulation (Water temperature in pipe: 48°C)
Heat flow through the lower surface of the floor [W]	34800	23600
Heat flows through the side surface of the floor (concrete) [W]	8500	9400
Heat flows through the side surface of the floor (insulation) [W]	0	34
Heat flows through the front surface of the floor (concrete) [W]	4250	4700
Heat flows through the front surface of the floor (insulation) [W]	0	17
<b>Total [W]</b>	<b>47550</b>	<b>37751</b>

**Table 3:** Calculated heat flow for water temperature of 48°C and a changed ground data

### 3.2 Ceiling radiant panel heating

Table 4 shows the values for the original floor foundation (distance to the groundwater: 5 m, ground  $\lambda = 2,1 \text{ W/mK}$ )

	Radiant panels without insulation (Surface floor temperature: 20°C)	Radiant panels with insulation (Surface floor temperature: 20°C)
Heat flow through the lower surface of the floor [W]	24300	11500
Heat flows through the side surface of the floor (concrete) [W]	8700	9800
Heat flows through the side surface of the floor (insulation) [W]	0	28
Heat flows through the front surface of the floor (concrete) [W]	4350	4900
Heat flows through the front surface of the floor (insulation) [W]	0	14
<b>Total [W]</b>	<b>37350</b>	<b>26242</b>

**Table 4:** Calculated heat flow without and with heat insulation for a floor temperature of 20 °C



The calculated values lie significantly under the comparable values for the industrial floor heating. The reduction of the heat flow by insulating amounts to approx. 30%.

Table 5 finally shows the values if the distance from the ground water layer to the hall floor amounts to 10 m (before 5 m) and if the ground has a lower thermal conductivity ( $\lambda = 1,5$  W/mK instead of 2,1 W/mK).

These values decrease, but not to an extent comparable to those of the industrial floor heating.

The reduction of the heat flow by insulation amounts to approx. 16% in this case.

	Radiant panels without insulation (Surface floor temperature: 20°C)	Radiant panels with insulation (Surface floor temperature: 20°C)
Heat flow through the lower surface of the floor [W]	13800	8300
Heat flows through the side surface of the floor (concrete) [W]	7600	8500
Heat flows through the side surface of the floor (insulation) [W]	0	29
Heat flows through the front surface of the floor (concrete) [W]	3800	4250
Heat flows through the front surface of the floor (insulation) [W]	0	14,5
<b>Total [W]</b>	<b>25200</b>	<b>21094</b>

**Table 5:** Calculated heat flow for floor temperature of 20°C and a changed ground data



## 4 Summary

The calculated heat flows vary between 20 kW and approx. 90 kW according to the heating system and the properties of the ground (thermal conductivity and deepness of the ground water ).

The results show that the heat flow into the ground is significantly lower when heating by radiant ceiling panels than by floor heating.

When using the radiant ceiling panel heating, the heat flow values are even smaller without heat insulating under the floor than those for the industrial floor heating with heat insulation.

The example with typical ground ( $\lambda = 2,1 \text{ W/mK}$ ) and ground water deepness of 5 m reveals the following:

Radiant ceiling heating, without heat insulation: 37350 W

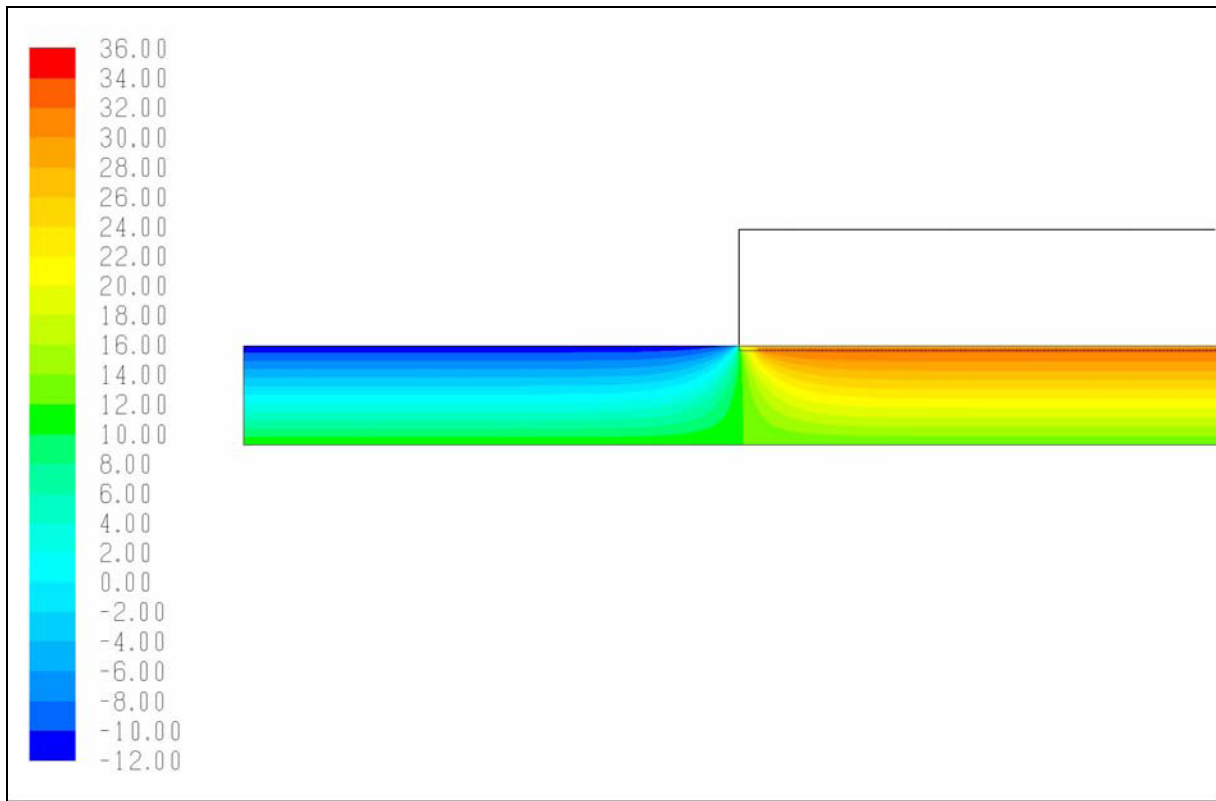
Industrial floor heating, with heat insulation: 55698 W

In spite of additional heat insulation, the additional effort amounts to approx. 50% for the industrial floor heating.

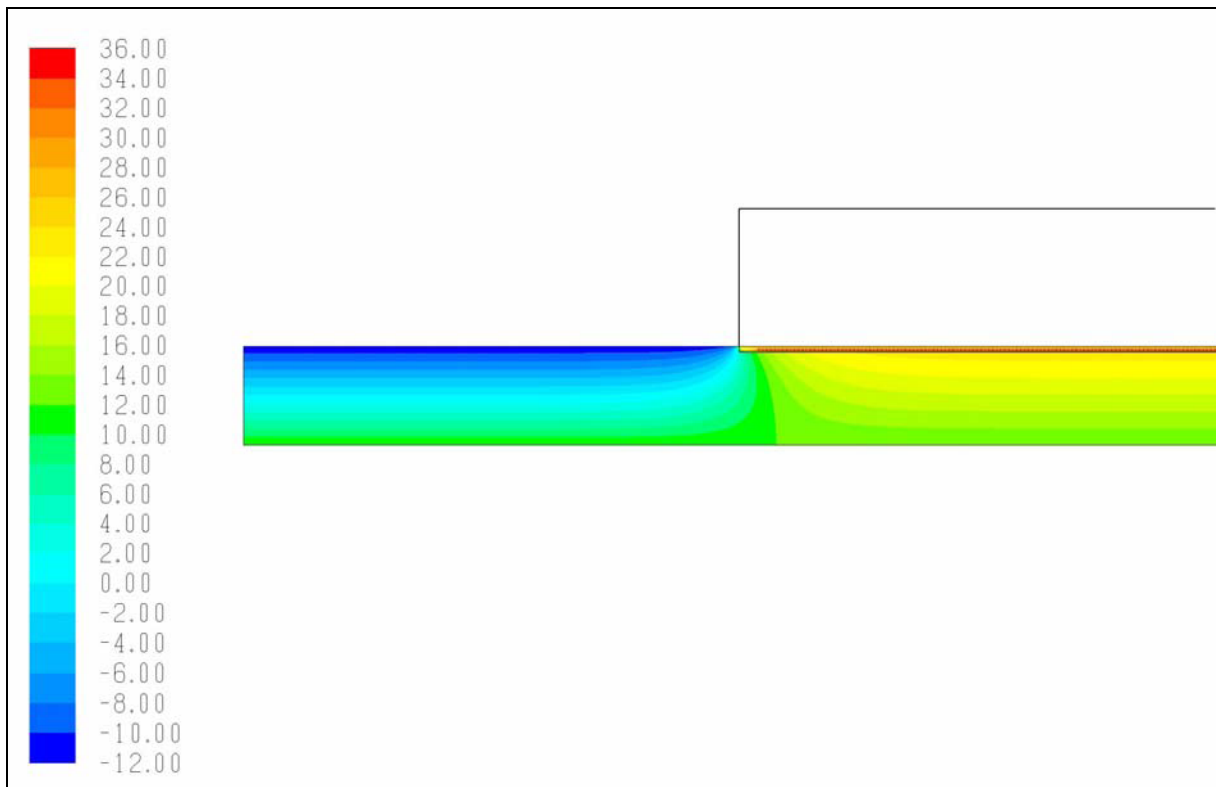


## 5 Appendix

- Ground temperatures
- Definition of partial heat flows on the floor of the hall

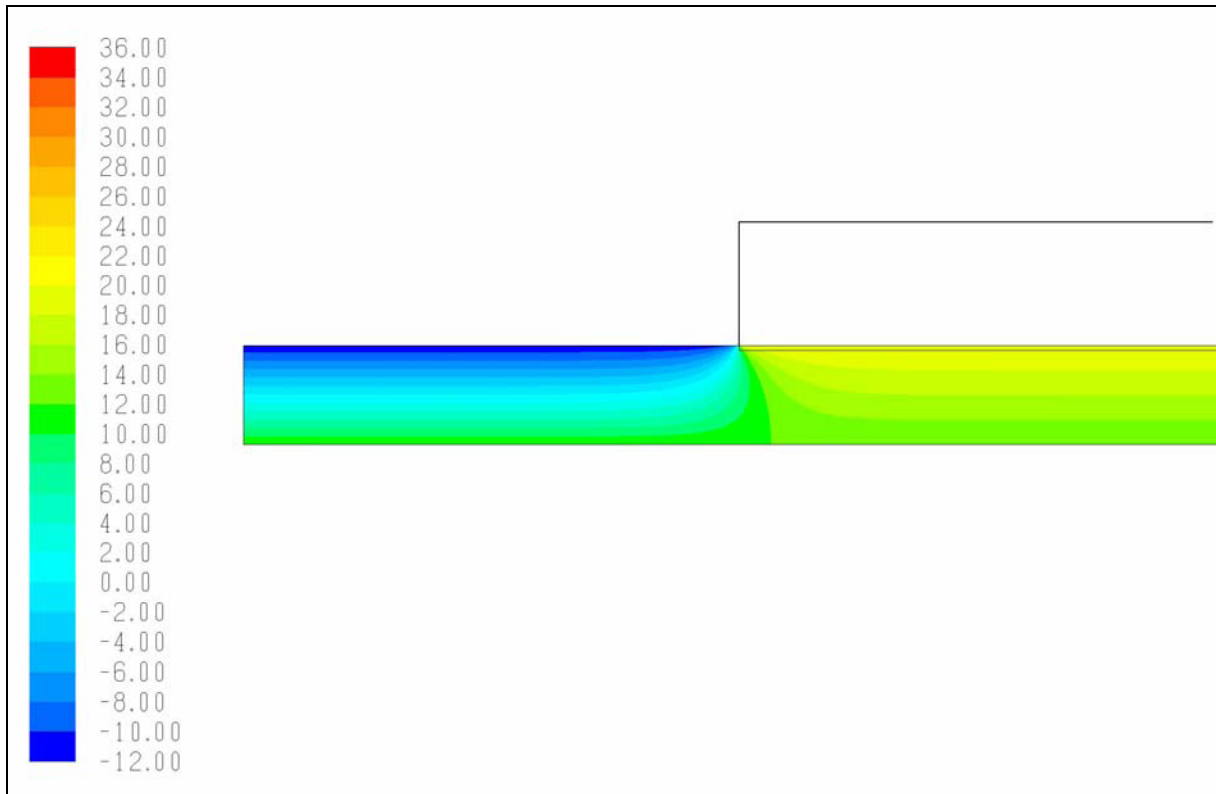


**Figure A1:** Industrial floor heating, hall floor without insulation

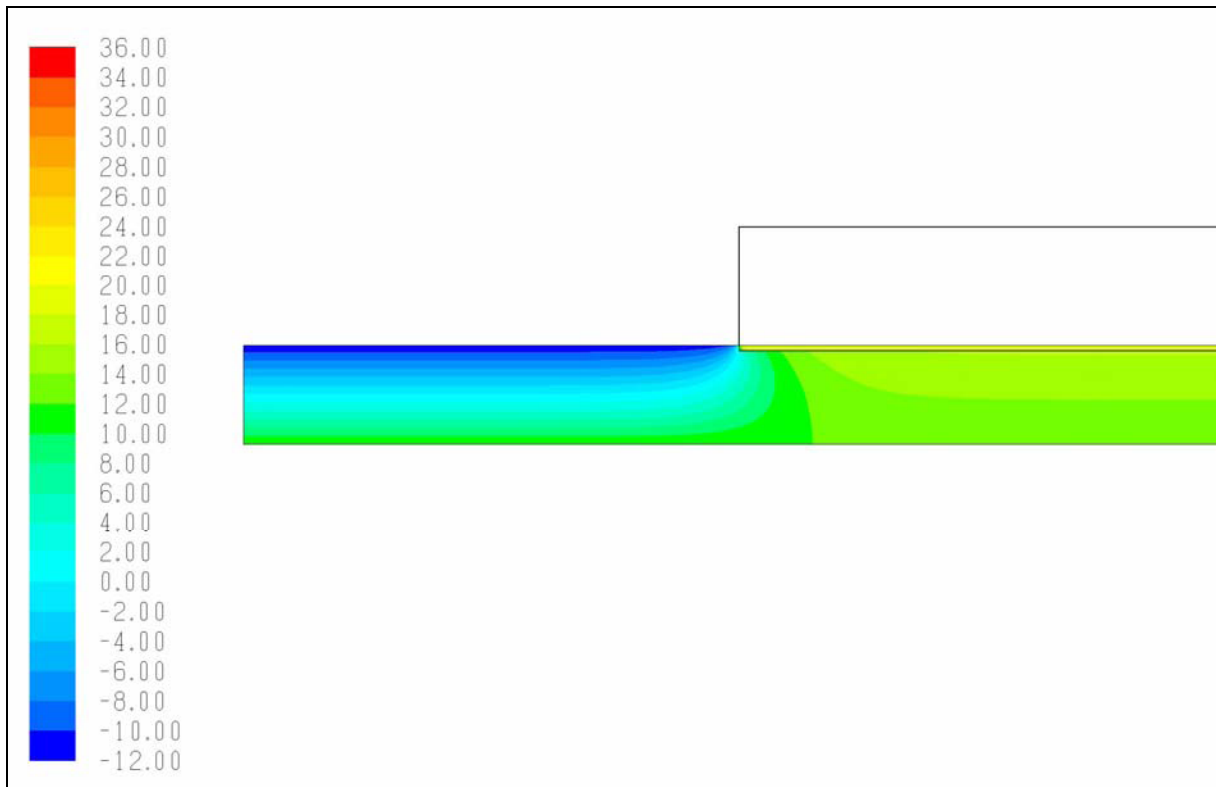


**Figure A2:** Industrial floor heating, hall floor with insulation

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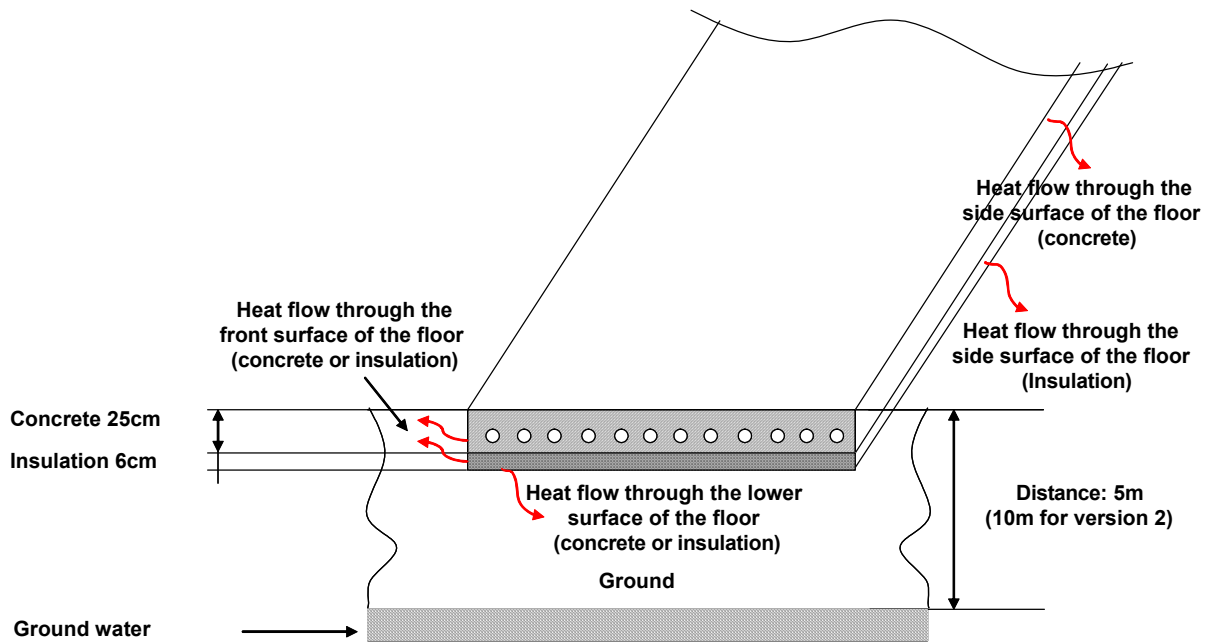


**Figure A3:** Ceiling radiant panel heating, hall floor without insulation



**Figure A4:** Ceiling radiant panel heating, hall floor with insulation

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**Figure A5:** Definition of partial heat flows on the floor of the hall

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