Handbook

Planning Underfloor Heat

Planning criteria

Essential requirements for all calculations:

- Detailed plan of building, construction of outer walls, and size and type of windows.
  These data are essential for calculating the heating load in accordance with DIN EN 12831.
- Information on the type of flooring and its thermal resistance $R_{\lambda,B}$, since the heat output is dependent on the floor construction, particularly that over screed (in accordance with DIN EN 1264 a thermal resistance of $R_{\lambda,B}$ = 0.1 m² K/W $R_{\lambda,B}$ for living rooms is specified, in bathrooms $R_{\lambda,B}$ = 0.0 m² K/W. Other values up to a maximum of 0.15 m² K/W are to be separately agreed.) $R_{\lambda,B}$ = 0.0 m² K/W.
- Building plans, building drawings and all room data have to be shown. After the calculations, the pipe layout and data are included in the building plan.
- Danfoss forms for calculations.

Changes in building methods over the last few decades have brought about lower requirements for heating homes, so that Danfoss underfloor heating can meet respective heating requirements for even physiologically acceptable surface temperatures. In some rooms, such as bathrooms, additional heating may be necessary, as areas under bath and shower cannot be heated and a higher temperature is required (24 °C instead of 20 °C). In such rooms the underfloor heating maintains the temperature in the floor while other heat comes from sources such as wall heating, heated towel rails, etc.

DIN-standards for underfloor heating

The following DIN -standards have to be observed when planning and installing floor heating.

DIN 1055	Effect on supporting structures
DIN EN 1264	Underfloor Heating, Systems and Components
DIN 4108	Thermal Insulation in the Building Industry
DIN 4109	Sound Insulation in the Building Industry
DIN 18195	Insulation of Building
DIN 18202	Tolerances in the Building Industry
DIN 18353	VOB, Part C: General Technical Regulations for construction work, screed
DIN 18560	Screed in Building Industry

Professional information on interface co-ordination when planning heated underfloor constructions (ref: BVF)

Standards and guidelines

ENEV and DIN EN 1264 are crucial for the construction of underfloor heating.
With the inclusion of DIN 18560 'Screed in the Building Industry' three Basic Danfoss constructions are possible. They comply with minimum values of insulation in relation to use and position within the building.

Estimated pre-calculations

The output tables of Danfoss SpeedUp and Basic heating systems show output values for various room temperatures as well as the temperatures of the central heating water in relation to different floor finishes. These tables give calculations of the mean central heating water temperature with which to run the underfloor heating in order to achieve the desired output.

The required excess heat source temperature determines the supply temperature which is described in more detail in the chapter 'Calculating the supply Temperature'. The heat flow densities are distributed evenly over the edge and comfort zones. The mean central heating water temperature is determined by the type of installation (see output tables).

Standard heating load of an underfloor heated room

When making calculations for Danfoss underfloor heating the standard heat load $Q_{N,f}$ of the room is essential. For underfloor heating in multi-storey buildings the heat gain of the shared floor can be included into the calculations if there are no restrictions on the work.
The heat output Q_H is generally calculated from the standard heat load of an underfloor heated room $Q_{H,f}$ plus an extra calculation allowance in accordance with DIN 4701 Part 3.

$$Q_H = (1 + x)^* Q_{N,f}$$

$Q_{N,f}$: Standard heating load of an underfloor heated room [W]
QH: Heat output calculation

If the heating system, such as an underfloor system, can raise the heat output by raising the heat source temperature the extra allowance is is zero. Thus the calculated temperature output equals the standard heat load of an underfloor heated room.

Thermal insulation to avoid downward heat loss

It is important to consider the thermal resistance of the insulation below the underfloor heating so that the heat of the underfloor heating radiates mainly upwards.
In accordance with DIN EN 1264, Part 4 there are three different kinds of floor/storey constructions and various minimum heat resistances.

	Thermal Insulation	$R_{Ins,\,min}$
A	above rooms with similar use	0.75 m² K / W
B	above rooms with different use*, unheated rooms (e.g. cellar) and on ground floor	1.25 m² K / W
C	above external air (-15°C) (e.g. garages, passage ways)	2.00 m² K / W

** e.g. rooms above commercially used premises*

The heat resistance $R_{\lambda,ins}$ with a single insulation layer is calculated as follows:

$$R_{\lambda,ins} = \frac{S_{ins}}{\lambda_{ins}}$$

with:
S_{ins}: effective insulation thickness [m]
λ_{ins}: thermal conductivity [W/m K]

Maximum surface temperature Θ_{Fmax}

In accordance with DIN EN 1264 maximum surface temperatures for physiological reasons are set as follows:
Comfort zone: 29 °C
Edge zone: 35 °C
Bathrooms: ti + 9 °C = 33 °C

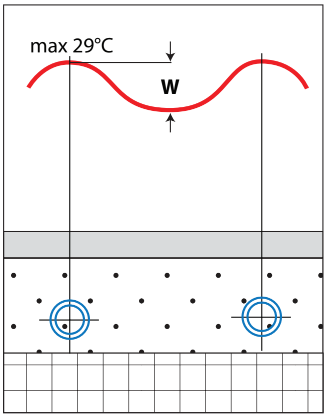
Standard room temperatures of 20 or 24 °C in bathrooms result in a difference in surface temperature and room temperature of 9K (in comfort zones and bathrooms) or 15K (in edge zones). Limiting the surface temperature has the effect of limiting the heat output of the underfloor heating. It is an important factor when deciding whether to choose additional heating.
However, with modern insulation the heat output in underfloor heating is sufficient in 99 of 100 cases.

Fluctuation in temperature (W)

The position of the heating pipe can further influence the output. Depending on the position, varying surface temperatures can occur. Output is higher above the pipes than in between. The difference between the maximum and minimum surface temperatures is called fluctuation (W).

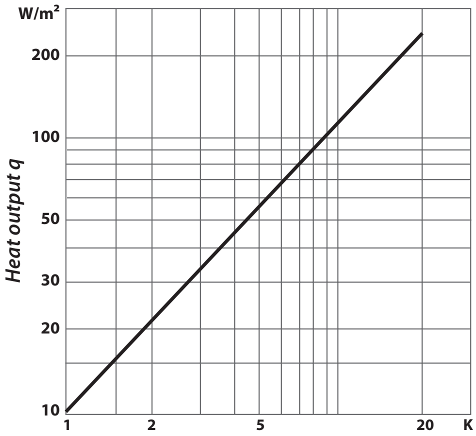
$$W = \theta_{F\,max} - \theta_{F\,min}$$

Larger distances between pipes cause larger fluctuation. Lower lying pipes slow down the heating system but the 'long way' to the surface distributes the temperature evenly, the fluctuation remains small. Since the maximum floor temperature must not be exceeded, larger fluctuation causes greater loss in output than a smaller fluctuation. In the first case, average floor temperature is significantly lower than the maximum permitted temperature.



Characteristic base line

The Characteristic Base Line shows the relationship between the heat flow density and the surface temperature (surface temperature minus room temperature) when the heated area is evenly heated (fluctuation = 0).



Mean surface temperature difference

With a surface temperature of 9K above room temperature an output of approx. 100W/m² is achieved, with an excess temperature of 15K a heat output of approx. 175 W/m².

Since the characteristic base line has idealised physical parameters and is valid independent of the system, no system, kept at the maximum permitted surface temperature, can reach an output of more than 100 W/m² or 175 W/m² in edge zones.
Consequently the specific heat output q of the floor surface depends on the difference between room and surface temperatures as well as the transferability. The latter is dependent on the room data, including the needs to air the room and is described as heat transfer coefficient α_{ges} here 11.1 W/m²K.

$$q = \alpha_{ges} (\theta_F - \theta_i)$$

θ_F = Floor temperature °C
θ_i = Room temperature °C

Example:
At a room temperature of 20 °C and a floor temperature of 27 °C a heat output of

q = 11.1 W/m² K * 7°K (27 °C - 20 °C)
= 77.7 W/m² would be achieved.

Heat source temperature

The mean heat source temperature is a firm component of many calculations. It is calculated from the mean value of the supply and return temperatures:

$$\theta_m = \theta_i + \Delta\theta_H$$

with:
$\Delta\theta_H$: Excess Heat Source Temperature
θ_i: Standard - Inside Temperature
θ_m: Heat Source Temperature

Installation types

The heating system Danfoss Basic comprises two different installation types in edge zones and three in comfort zone areas.

The SpeedUp and SpeedUp Eco heating systems has installation types for the edge and comfort zones. They differ in pipe distance.

System	Possible pipe distance in cm
BasicRail	8.8 (mean)
BasicRail	12 (mean)
BasicRail	20
BasicRail	25
BasicRail	30
BasicGrip and BasicClip	10
BasicGrip and BasicClip	15
BasicGrip and BasicClip	20
BasicGrip and BasicClip	25
BasicGrip and BasicClip	30
SpeedUp and SpeedUp Eco	12.5
SpeedUp and SpeedUp Eco	25

Heat output curve Limiting curve

The heat output and the fluctuation of the surface temperature are dependent on several factors:

- Floor surface temperature
- Room temperature
- Pipe distances
- Thickness and thermal conductivity of the load bearing panels
- Lateral heat output
- Thermal resistance of floor finish
- Composition of the layers

In accordance with DIN EN 1264 all factors combine into the following equation heat flow density q:

$$q = K_H + \Delta\theta_H$$

with:
q: Heat output [W/m²]
K_H: Equivalent heat transfer coefficient [W/m² K] (official DIN check)
$\Delta\theta_H$: Excess heat source temperature

with:

$$\Delta\theta_H = \frac{\theta_V - \theta_R}{\ln \dfrac{\theta_V - \theta_i}{\theta_R - \theta_i}}$$

with:
θ_V: Supply temperature
θ_R: Return temperature
θ_i: Standard-inside temperature

When keeping to maximum permitted temperatures, the above factors will give, apart from fluctuation, limiting curves (calculated according to DIN EN 1264, Part 2). The intersections indicate the heat flow limits and the limits to excess heat source temperatures.

Calculated heat flow density

When doing the calculations for underfloor heating, the calculated heat flow density is to be worked out as follows in accordance with DIN EN 1264, Part 3 :

$$q_{des} = \frac{Q_{N,f}}{A_F}$$

with:
q_{des} Calculated heat flow density [W/m²]
$Q_{N,f}$ Standard-heat load of an underfloor heated room [W]
A_F Floor area to be heated [m²]

The heat output achieved from underfloor heating is

$$Q_F = q * A_F$$

with:
q_{des} Calculated heat flow density
$Q_{N,f}$ Standard-heat load of an underfloor heated room
A_F Floor area to be heated

where q is evenly distributed over the edge zone (maximum 1 m wide) and the comfort zone:

$$q = \frac{A_R}{A_F} * q_R + \frac{A_A}{A_F} * q_A$$

The data for the heat flow densities of the edge zones or comfort zones q_R and q_A can be calculated from the output diagrams where the excess temperature of the heat source applies.
The approved threshold of the heat flow density (intersection of curves with limiting curve) must not be exceeded. The approved density depends on the thermal resistance of the floor covering and the construction type.
If one value of the calculated and distributed heat flow density (q_R/q_A) is above the threshold heat flow density, the threshold density rather than the heat flow density applies. The resulting decrease in excess heat source temperature also reduces the heat flow density of the other combination type of installation.
If the standard heat load of a room heated with underfloor heating is greater than the heat output of the underfloor heating, additional heating for the shortfall should be considered. $Q_{N,f} - Q_F$.

Calculation of excess supply temperature

The calculated supply temperature for a room with the highest calculated heat flow density is assigned q_{max} (except bathrooms) and given a thermal resistance for floor cover of $R_{\lambda,B} = 0.10\ m^2\ K/W$. Higher values for $R_{\lambda,B}$ have to be taken into account. Bathrooms will have $R_{\lambda,B} = 0.0\ m^2\ K/W$. The differential temperature σ for the room to be calculated is defined as σ = 5 K. The installation type is chosen so that q max fully achieves the threshold heat flow density indicated in the limiting curve. The maximum permitted excess flow temperature is

$$\text{when } \frac{\sigma}{\Delta\theta_H} \leq 0.5:$$

$$\Delta\theta_{V,\,des} \leq \Delta\theta_{H,\,des} + \frac{\sigma}{2} \text{ with } \Delta\theta_{H,\,des} \leq \Delta\theta_{H,\,G}$$

otherwise:

$$\Delta\theta_{V,\,des} = \Delta\theta_{H,\,des} + \frac{\sigma}{2} + \frac{\sigma^2}{(12\ \Delta\theta_{H,\,des})}$$

In all other rooms which are operating on calculated flow temperatures the differential temperature is calculated as follows, as long as the relation:

$$\frac{\sigma_j}{\Delta\theta_{H,\,j}} < 0.5$$

is:

$\Delta\theta_{H,j}$: Excess heat source temperature of each room j

with:

$$\sigma_j = 2 * [(\Delta\theta_{V,\,des}) - \Delta\theta_{H,j}]$$

otherwise:

$$\sigma_j = 3 * \Delta\theta_{H,\,j} * \left[\sqrt{1 + \frac{4(\Delta\theta_{V,\,des} - \Delta\theta_{H,\,j})}{3 * \Delta\theta_{H,\,j}}} - 1\right]$$

Calculation heat source temperature

For calculating the size of the circulating pump the mass flow rate is determined as m_H (flow rate of heating water in kg/s). It is independent of the total output (floor heating output, and heat losses to other rooms) as well as differential temperature.

$$m_H = \frac{A_F * q}{\sigma * C_W}\left(1 + \frac{R_o}{R_u} + \frac{\theta_i - \theta_u}{q * R_u}\right)$$

$$\text{with } C_W = 4190\ \text{J/kgK}$$

The partial heat transfer resistance of the floor construction R_o (upwards) encompasses both the thermal conductivity and thermal resistance upwards:

$$R_o = \frac{1}{\alpha} + R_{\lambda,B} + \frac{S_u}{\lambda_u}$$

$$\text{with } \frac{1}{\alpha} = 0.093\ m^2\ K/W$$

The sum of the downwards thermal conductivity and downwards thermal resistances is:

$$R_u = R_{\lambda,\,ins} + R_{\lambda,\,floor} + R_{\lambda,\,render} + R_{\alpha,\,floor}$$

$$\text{with } R_{\alpha,\,floor} = 0.17\ m^2\ K/W$$

The mass flow rate m_H can also be expressed when converted as the flow rate V_H:

$$V_H = \frac{m_H}{\rho}$$

$$\text{with } \rho = 0.998\ \text{kg/dm}^3$$

To determine the flow rate of a heating circuit the flow rate of the room V_H must be divided by the number of heating circuits:

$$V_{HK} = \frac{V_H}{\text{Number of heating circuits}}$$

Pressure loss

For the calculations and size of the circulating pump it is important to calculate pressure loss. In order to calculate pressure loss the total length of the pipes l_{HK} and supply and returns have to be determined. Here it is important that the length of the supply and return pipes FEED is double the distance of room to manifold (supply and return). Depending on the laying type the following values are relevant:

Pipe distance C-C	System	Pipe length per m²
C-C 8.8	BasicRail	11.25 m
C-C 12	BasicRail	8.33 m
C-C 20	BasicRail	5.00 m
C-C 25	BasicRail	4.00 m
C-C 30	BasicRail	3.33 m
C-C 10	BasicGrip and BasicClip	10.00 m
C-C 15	BasicGrip and BasicClip	6.67 m
C-C 20	BasicGrip and BasicClip	5.00 m
C-C 25	BasicGrip and BasicClip	4.00 m
C-C 30	BasicGrip and BasicClip	3.33 m
C-C 12.5	SpeedUp and SpeedUp Eco	8.00 m
C-C 25	SpeedUp and SpeedUp Eco	4.00 m

$$l_H = \text{Pipe length of edge zone layout plan} * A_R + \text{Pipe length of comfort zone layout plan} * A_A$$

The mean length of the heating circuit l_{HK} is calculated thus:

$$l_{HK} = \text{FEED} + \left(\frac{l_H}{\text{Number of heating circuits}} \right)$$

Here it must be mentioned that the area layout and the number of heating circuits are determined by the type of screed, i.e. the heating circuits must be compatible with the screed sections.
The pressure loss diagram (cf. pressure loss diagram for Danfoss composite pipe) shows, via flow rate per heating circuit V_{HK}, the pipe friction resistance as pressure loss Δp per m. To calculate the total loss of a heating circuit, this value has to be multiplied by the length of the heating circuit.

$$\Delta p_{HK} = \Delta p * l_{HK}$$

Individual heating circuits have different lengths and differential temperatures and show different loss of pressure. Pressure compensation ensures that all heating circuits are supplied with sufficient water. The flow adjustment is made on the return valve by determining the flow per minute (i.e. the volume flow [l/h] of the individual heating circuits is divided by 60 [min.]).

The total water volume within an underfloor heating system is calculated by the length of all heating circuits l_{HK} multiplied by a factor of 0.113 (l/m).

Correlation between flow rate, pressure loss and differential temperature:

The smaller the differential temperature:
- the higher the volume flow
- the higher the flow speed of the medium and
- the higher the pressure loss

Raising the differential temperature causes a reduction in flow rate.

Threshold values

- The maximum supply temperature must not exceed 55 °C.
- Heating circuits should not be longer than 100 m, 110 m maximum.
- The optimum length is 60 m.
- Pressure loss of 300 mbar must not be exceeded since the circulating pump, apart from maintaining the pressure head, has to cope with pressure losses in the heating circuits and in the whole system (in manifold, its valves, supply and return pipes, mixing valves, etc.).

Installation times of Danfoss heating systems*

System	Article/unit	Minutes per Unit	Unit
Basic Heating Systems - underfloor heating with heated screed	Manifold without cabinet	55:00	unit
	Manifold with cabinet	75:00	unit
	Additional insulation EPS 035 DEO 40 on e.g. soil	2:50	m^2
	Insulation EPS 035 DEO 20 without perimeter insulation	2:50	m^2
	Insulation overlap panels 11 mm / 35 mm - incl. perimeter insulation	2:50	m^2
	GC = 88 mm system (pipe layout, connect to manifold)	11:30	m^2
	GC = 100 mm system (pipe layout, connect to manifold)	10:00	m^2
	GC = 120 mm system (pipe layout, connect to manifold)	8:40	m^2
	GC = 150 mm system (pipe layout, connect to manifold)	6:70	m^2
	GC = 200 mm system (pipe layout, connect to manifold)	5:00	m^2
	GC = 250 mm system (pipe layout, connect to manifold)	4:00	m^2
	GC = 300 mm system (pipe layout, connect to manifold)	3:50	m^2
SpeedUp and SpeedUp Eco Heating Systems - dry installation underfloor heating	Manifold without cabinet	55:00	unit
	Manifold with cabinet	75:00	unit
	Additional insulation without perimeter insulation - per site	2:50	m^2
	GC = 125 mm system - SpeedUp	12:00	m^2
	GC = 250 mm system - SpeedUp	8:00	m^2
	GC = 125 mm system - SpeedUp Eco	16:00	m^2
	GC = 225 mm system - SpeedUp Eco	12:00	m^2
	System strongboard for tiles	10:00	m^2
	System strongboard for carpet	15:00	m^2

** Date 06/2004 - Values are based on many years of practical experience.*