CTU IN PRAGUE, FACULTY OF CIVIL ENGINEERING

Calculation

Bachelor project: Heating system with renewable energy sources

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Content

Transmission heat loss coefficient

Calculation according to ČSN 73 0540-(1-4)
Thermal conductivity coefficient…… λ [W/(m·K)]
It is given by the producers of the materials
Thermal resistance…………………..R [m2·K/W]
It is calculated from thickness of material and its thermal conductivity coefficient.

$$R = \frac{d}{\lambda}$$

Transmission heat loss coefficient………U [m^2·K/W]
It is calculated from thermal resistances in every layer

$$U = \frac{1}{R_{si} + R + R_{se}}$$

Construction	R_{si} ; R_{se} **[m2·K/W]**
The heat transfer to the ground	0,0
The resistant while transferring heat on the exterior side	0,04
The heat flow in the direction up– the resistant while transferring heat on the interior side	0,1
The horizontal heat flow – the resistant while transferring heat on the interior side	0,13
The heat flow in the direction down– the resistant while transferring heat on the interior side	0,17

Structures and their compositions

<u>SO1: External wall</u>

	d [mm]	λ [W/(m·K)]	R [m2·K/W]	U [m^2·K/W]
R_{si}	-	-	0, 040	
CDm	400	0,730	0,548	
R_{se}	-	-	0,130	
				1,393

<u>SN1: Internal wall (80 mm)</u>

	d [mm]	λ [W/(m·K)]	R [m2·K/W]	U [m^2·K/W]
R_{si}	-	-	0,130	
Partition bricks	80	0,440	0,182	
R_{se}	-	-	0,130	
				2,262

SN2: Internal wall (100 mm)

	d [mm]	λ [W/(m·K)]	R [m2·K/W]	U [m^2·K/W]
R_{si}	-	-	0,130	
Partition bricks	100	0,650	0,154	
R_{se}	-	-	0,130	
				2,415

SN3: Internal wall (150 mm)

	d [mm]	λ [W/(m·K)]	R [m2·K/W]	U [m^2·K/W]
R_{si}	-	-	0,130	
Full bricks	150	0,750	0,200	
R_{se}	-	-	0,130	
				2,174

SN4: Internal wall (300 mm)

	d [mm]	λ [W/(m·K)]	R [m2·K/W]	U [m^2·K/W]
R_{si}	-	-	0,130	
Full bricks	300	0,750	0,400	
R_{se}	-	-	0,130	
				1,515

SN5: Internal wall (200 mm)

	d [mm]	λ [W/(m·K)]	R [m2·K/W]	U [m^2·K/W]
R_{si}	-	-	0,130	
Full bricks	200	0,260	0,769	
R_{se}	-	-	0,130	
				0,972

SCH1: Roof

	d [mm]	λ [W/(m·K)]	R [m2·K/W]	U [m^2·K/W]
R_{si}	-	-	0,040	
PVC foil	1,5	0,200	0,008	
EPS	200	0,040	5	
2x SKLOBIT 40 mineral	8	0,200	0,040	
Perlitbeton (in slope)	100-300	0,130	0,769	
IPA 500 SH	8	0,200	0,040	
RC	150	1,580	0,095	
R_{se}	-	-	0,100	
				0,164

PDL1: Floor on ground (ground floor)

	d [mm]	λ [W/(m·K)]	R [m2·K/W]	U [m^2·K/W]
R_{si}	-	-	0,000	
Cermatic tiles	20	1,010	0,019	
Selfleveling concrete	70	1,200	0,058	
Underfloor heating	-	-	-	
EPS	60	0,040	1,5	
PVC foil	1,5	0,200	0,008	
Oversite concrete	150	0,520	0,288	
R_{se}	-	-	0,170	
				0,489

PDL2: Floor between basement and ground floor

	d [mm]	λ [W/(m·K)]	R [m2·K/W]	U [m^2·K/W]
R_{si}	-	-	0,170	
PVC	2,5	0,190	0,013	
Concrete screed	5	1,200	0,004	
Selfleveling concrete	70	1,200	0,058	
Underfloor heating	-	-	-	
EPS	40	0,040	1	
RC	150	1,580	0,095	
R_{se}	-	-	0,170	
				0,662

PDL3: Floor between ground floor and the first floor

	d [mm]	λ [W/(m·K)]	R [m2·K/W]	U [m^2·K/W]
R_{si}	-	-	0,100	
PVC	2,5	0,190	0,013	
Concrete screed	5	1,200	0,004	
Selfleveling concrete	70	1,200	0,058	
Underfloor heating	-	-	-	
EPS	40	0,040	1	
RC	150	1,580	0,095	
R_{se}	-	-	0,170	
				0,694

DO1: External door with dimensions 3000x2000

U= 1,2 m^2·K/W

DN1: Internal door with dimensions 800x1970

U= 1,2 m^2·K/W

DN2: Internal door with dimensions 1800x1970

U= 1,2 m^2·K/W

DN3: Internal door with dimensions 1600x1970

U= 1,2 $m^2 \cdot K/W$

DN4: Internal door with dimensions 900x1970

U= 1,2 $m^2 \cdot K/W$

DN5: Internal door with dimensions 700x1970

U= 1,2 $m^2 \cdot K/W$

DN6: Internal door with dimensions 600x1970

U= 1,2 $m^2 \cdot K/W$

OZ1: Window with dimensions 3000x1500

U= 1,0 $m^2 \cdot K/W$

OZ2: Window with dimensions 1200x600

U= 1,0 $m^2 \cdot K/W$

OZ3: Window with dimensions 1500x600

U= 1,0 $m^2 \cdot K/W$

OZ4: Window with dimensions 1500x1500

U= 1,0 $m^2 \cdot K/W$

OZ5: Window with dimensions 1200x1500

U= 1,0 $m^2 \cdot K/W$

OZ6: Window with dimensions 1180x600

U= 1,0 $m^2 \cdot K/W$

OZ7: Window with dimensions 1500x1500

U= 1,0 $m^2 \cdot K/W$

Calculation of consumption of energy

Calculation is according to ČSN 06 0320.

According to the new Regulation no. 120/2011 Sb. the consumption of water per person per year in administrative building with WC, sink and hot water and without the catering is 14m^3.

The consumption of hot water per person per day in administrative building is 10-15l.

n….. number of person in a building

n= 13

V_{2P} = 15*13=195 l/day =0,195 m^3/day

Annual consumption of energy for heating according to day-degree method

$$Q_{H,y} = \frac{24 * Q_c * \varepsilon * D}{t_{is} - t_e}$$

$Q_c = 20\ 332\ W \ldots losses\ of\ the\ building$

$\varepsilon = \frac{e_i * e_t * e_d}{\eta_0 * \eta_r} \ldots reduction\ coefficient$

$e_i = 0{,}8$

$e_t = 0{,}9$

$e_d = 0{,}8$

$\eta_0 = 0{,}97$

$\eta_r = 1{,}0$

$\varepsilon = \frac{0{,}8 * 0{,}9 * 0{,}8}{0{,}97 * 1{,}0} = 0{,}5938$

$D = (t_{is} - t_{es}) * d = (18 - 0{,}0) * 225 = 4050\ K.day \ldots.\ degree - day$

$$Q_{H,y} = \frac{24 * 20332 * 0{,}5938 * 4050}{18 - (-11)} = 40465840{,}12\ Wh = 40\ 465{,}8\ kWh$$

$$Q_{H,d} = \frac{40\ 465{,}8}{225} = 179{,}85\ kWh$$

$$Q_{H,h} = \frac{179{,}85}{24} = 7{,}494\ \ kWh$$

Daily consumption of energy for heating of water

$$Q_{HW,d} = \rho * c * V_{2P} * (t_2 - t_1) * (1 + z)/3600$$

ρ = 1000 kg/m^2
$c = 4186\ J/kgK$
$V_{2P} = 0{,}195 m^3$
t_2 = 55°C
t_1 = 10°C
z = 0,8

$$Q_{HW,d} = 1000 * 4186 * 0{,}195 * (55 - 10) * (1 + 0{,}8)/3600$$

$$Q_{HWd} = 18\ 366\ Wh/day$$

$$Q_{HW,d} = 18{,}37\ kWh/day$$

Annual consumption of energy for heating of water

$$Q_{HW,y} = Q_{HW,d} * d + 0{,}8 * Q_{HW,d} * \frac{55 - t_s}{55 - t_w} * (N - d)$$

d= 225
$t_s = 15°C$
N= 350
$t_w = 5°C$

$$Q_{HW,y} = 18\ 366 * 225 + 0{,}8 * 18\ 366 * \frac{55 - 15}{55 - 5} * (350 - 225) = 5\ 600\ 750\ Wh/year$$

$$Q_{HW,y} = 5\ 600{,}75\ kWh/year$$

Annual consumption of energy

Q_y .... Annual consumption of energy
$Q_{H,y}$ .... Annual consumption of energy for heating
$Q_{HW,y}$ .... Annual consumption of energy for heating of water
$Q_{AC,y}$ .... Annual consumption of energy for ventilation with recuperation
$Q_{TECH,y}$ .... Annual consumption of energy for technology

$$Q_y = Q_{H,y} + Q_{HW,y} + Q_{AC,y} + Q_{TECH,y}$$

$$Q_y = 40\ 465{,}8 + 5\ 600{,}75 + 0 + 0$$

$$Q_y = 46\ 066{,}55\ Wh$$

Calculation of storage tank

Storage tank

n….. number of person in a building
n= 13
Calculation according to ČSN 06 0320

V_{2P} = 15 l/person per day*n = 15*13 = 195 l/year
V_{2P} = 0,195 m^3/day

$$E_{2P} = E_{2T} + E_{2Z}$$

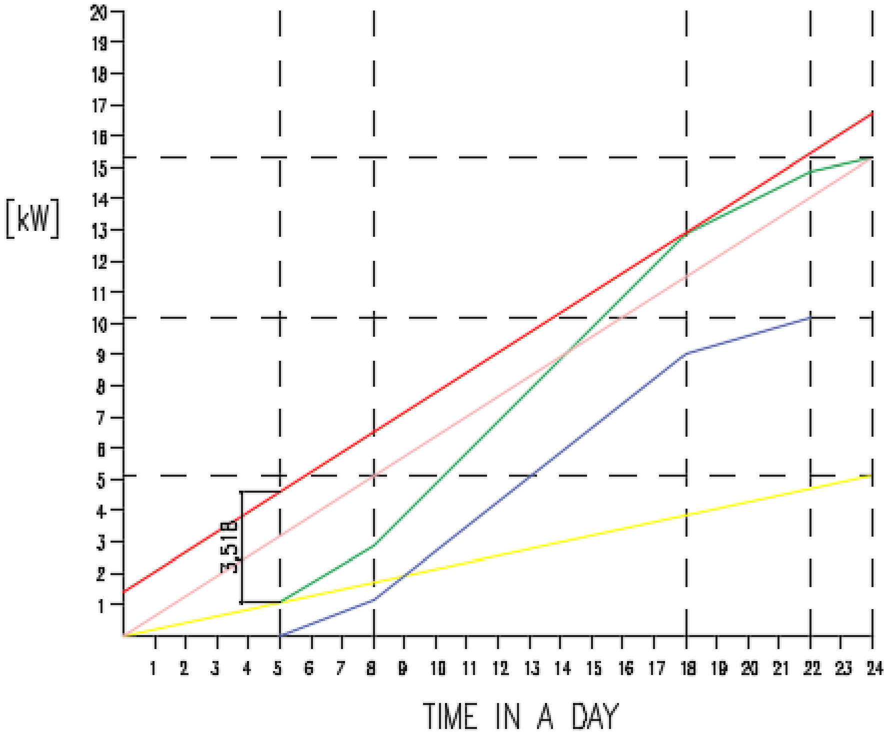
$$E_{2T} = V_{2P} * \rho * c * \Delta t = 0{,}195 * 1000 * 1{,}163 * 45 = 10\ 205{,}325\ W/day$$

$$E_{2Z} = E_{2T} * 0{,}5 = 5\ 102{,}663\ W/day$$

$$E_{2P} = 10\ 205{,}325 + 5\ 102{,}663 = 15\ 307{,}99\ W/day$$

$$E_{2P} = 15{,}308\ kW/day$$

Graph



$$V_{2T} = \frac{\Delta E_{max}}{\rho * c * \Delta t} = \frac{3518}{1000 * 1{,}163 * 45} = 0{,}07\ m^3$$

Design of expansion vessel

According to EN 12 828

V_{system} .. total volume of heating system

$$V_{system} = 11 + 198 + 100 \ + 300 = 609\ l$$

V_e ….. expansion volume

e ..... volumetric expansion in %

e=1,29 %

$$V_e = e * \frac{V_{system}}{100} = 1{,}29 * \frac{609}{100} = 7{,}856\ l$$

p_{sv}....pressure of safety valve

p_{sv}= 3,0 bar

p_e....maximum operating pressure

p_e= 2,7 bar

p_o....minimum pressure (static pressure plus vapour pressure)

$$p_o \geq h * \rho * g + 0{,}3$$

$$p_o \geq 4{,}8 * 1000 * 9{,}81 * 10^{-5} + 0{,}3$$

$$p_o \geq 0{,}47 + 0{,}3$$

p_o=0,8 bar

V_{WR} ….. volume of reserve

V_{WR} =0,2*V_e =1,57 l

$$V_{exp,min} = (V_e + V_{WR}) * \frac{p_e + 1}{p_e - p_0}$$

$$V_{exp,min} = (7{,}856 + 1{,}57) * \frac{2{,}7 + 1}{2{,}7 - 0{,}8}$$

$$V_{exp,min} = 18{,}36\ l$$

Calculation of radiant floor heating system in room 2.08

The information about the room:

$Q_c = 1219\ W$ ....heat loss in the room

A= 4,3 m

B= 3,65 m ..... the dimensions of the room

$t_i = 20°C$ .... the interior temperature

$t_{p,max} = 28°C$ ... the maximal surface temperature

Furniture covers 3,785 m^2.

Construction of the floor:

	d [mm]
PVC	2,5
Concrete screed	5
Selfleveling concrete	70
Underfloor heating (KARI net)	-
EPS	40
RC	150

The determination of Λ_a , Λ_b and m.

Λ_a = 8,0 W/m^2K

Λ_b =0,8 W/m^2K

$$m = \sqrt{\frac{2*(\Lambda_a+\Lambda_b)}{\pi^2*\lambda_d*d}} = \sqrt{\frac{2*(8+0,8)}{\pi^2*1,2*0,02}} = 8,62\ m^{-1}$$

m .... characteristic number of floor

Λ_a ...... heat permeability coefficient of layers above piping

Λ_b ...... heat permeability coefficient of layers below piping

d .... external diameter of pipes

λ_d ...... heat conductivity coefficient of the material in which the pipes are situated

The width of the edge (the distance between the walls and the nearest pipe)

$$r = \frac{2,3}{m} = \frac{2,3}{8,62} = 0,267\ m$$

$$S_p = A_p * B_P = (A - 2*r)*(B - 2*r) = (4,3 - 2*0,267)*(3,65-2*0,267) = 11,735\ m^2$$

$$O = 2*((A - 2*r) + (B - 2*r)) = 2*((4,3 - 2*0,267) + (3,65 - 2*0,267)) = 13,764\ m$$

$$\frac{O}{S_P} = \frac{13,764}{11,735} = 1,173$$

$$Q_O = Q_P * \frac{O_P}{S_P} * \frac{0{,}448 * l}{tgh * (m * \frac{l}{2})} = Q_P * 1{,}173 * \frac{0{,}448 * 0{,}2}{tgh * (8{,}62 + \frac{0{,}2}{2})} = 11\%\ z\ Q_P$$

The room is in the last floor so the heating area is calculated by following equation.

$$q_P = \frac{Q_c}{S_P} = \frac{1219}{11{,}735} = 104\ W/m^2$$

$$q_p = q + q' + q_0 - \frac{S_n}{S_P}(q - q_n)$$

$$q' = 0{,}1 * q$$

$$q_0 = 0{,}12 * (q + q') = 0{,}12 * 1{,}1q$$

$$\frac{S_n}{S_P} = \frac{3{,}785}{11{,}735} = 0{,}323$$

$$q_n = (0{,}3\ to\ 0{,}5)\ q$$

$$q_P = q + 0{,}1q + 0{,}12 * 1{,}1q - 0{,}323 * (1 - 0{,}4)q$$

$$q = \frac{q_P}{1 + 0{,}1 + 0{,}12 * 1{,}1 - 0{,}323 * 0{,}6} = \frac{104}{1{,}0382} = 100\ W/m^2$$

From the graph:

$$(t_m - t_i) = 21\ K$$

$$t_m = 41°C$$

$$l = 0{,}2\ m$$

The temperature difference is $\Delta t = 8°C$ so $t_1 = 45°C$and $t_2 = 37°C$

The power input is given by relationship

$$Q_c = \left(1 + \frac{Q_0}{Q}\right) * (q + q') * S_P$$

m= 8,62 m^{-1}, l= 0,2 m, and Op/Sp= 1,173 from the graph it can be found that Q_0/Q=0,19

$$Q_c = (1 + 0{,}19) * (100 + 10) * 11{,}735 = 1536{,}11\ W$$

The reduction of heating area due to the furniture

$$q_n = \alpha_{SP}(t_P + t_n) + \alpha_{KP}(t_P + t_i)$$

$$t_n = 0{,}45t_P + 0{,}55t_i = 0{,}45 * 27{,}7 + 0{,}55 * 20 = 23{,}5°C$$

$$q_n = 5(27,7 + 23,5) + 2(27,7 + 20) = 36,4\, W/m^2$$

The real power input

$$Q_{real} = Q_c - S_n * (q - q_n) = 1536,11 - 3,785 * (100 - 36,4) = 1295,384\, W$$

Hydraulic calculation

$$\Delta p_z = \Delta p_\lambda + \Delta p_\xi$$

Δp_z ..... total pressure losses
Δp_λ.....pressure losses due to friction
Δp_ξ.....pressure losses due to local resistance

$$M = \frac{Q_{PC} * 3600}{c * \Delta t} = \frac{1290 * 3600}{4180 * 8} = 138,875\, kg/h$$

$$Q_{PC} = (q + q^{'}) * S_P = (100 + 10) * 11,735 = 1290,85\, W$$

Pressure losses due to friction

$$\Delta p_\lambda = R * l_p$$

For meander layout

$$l_p = n * \left(A + l - l_0 - \sum b - (4 - \pi) * R\right)$$

$$l_p = 16 * (4,3 + 0,2 - 0,534 - 0,543 - (4 - \pi) * 0,1)$$

$$l_p = 53,25\, m$$

$$R = \frac{\lambda}{d_i} * \frac{w^2}{2} * \rho$$

$$w = \frac{M}{A * \rho} = \frac{M}{{d_i}^2 * \frac{\pi}{4} * \rho} = \frac{138,875}{720} = 0,193\, m/s$$

The friction coefficient λ depends on Reynold's number

Piping: PE- Xa REHAU Rautherm S - piping for radiant floor heating

$$Re = \frac{w * d_i}{v} = \frac{0,193 * 16 * 10^{-3}}{0,66 * 10^{-6}} = 4678,78$$

$$\lambda = \frac{0{,}316}{Re^{0{,}25}} = 0{,}038$$

$$R = \frac{\lambda}{d_i} * \frac{w^2}{2} * \rho = \frac{0{,}038}{16 * 10^{-3}} * \frac{0{,}193^2}{2} * 1000 = 44{,}233\ Pa/m$$

$$\Delta p_\lambda = R * l_p = 44{,}233 * 53{,}25 = 2355{,}407\ Pa$$

Pressure losses due to local resistance

$$\Delta p_\xi = \sum \xi * \frac{\rho * w^2}{2}$$

6 x 90° curve (d=20mm; r=100mm; r/d=5)

$$\xi_{90^\circ} = 0{,}034\ 083 + 0{,}744\ 580\ 769 * ln\frac{r}{d} = 1{,}232$$

15 x 180° curve (d=20mm; r=100mm; r/d=5)

$$\xi_{180^\circ} = \xi_{90^\circ}\sqrt{(\frac{180}{90})^3} = 3{,}454$$

$$\Delta p_\xi = \sum \xi * \frac{\rho * w^2}{2} = (6 * 1{,}232 + 15 * 3{,}45) * \frac{1000 * 0{,}193^2}{2} = 1101{,}49\ Pa$$

Hydraulic pressure losses

$$\Delta p_z = \Delta p_\lambda + \Delta p_\xi = 2355{,}407 + 1101{,}49 = 3457\ Pa$$

Calculation of radiant floor heating system in room 1.03

The information about the room:

$Q_c = 1452\ W$ ….heat loss in the room

A= 4,1 m

B= 4,85m ..... the dimensions of the room

$t_i = 20°C$ .... the interior temperature

$t_{p,max} = 28°C$ ... the maximal surface temperature

Furniture covers 3,88 m^2.

Construction of the floor:

	d [mm]
Ceramic tiles	20
Selfleveling concrete	70
Underfloor heating (KARI net)	-
EPS	60
PVC foil	1,5
Oversite concrete	150

The determination of Λ_a , Λ_b and m.

Λ_a = 8,0 W/m^2K

Λ_b =0,35 W/m^2K

$$m = \sqrt{\frac{2*(\Lambda_a+\Lambda_b)}{\pi^2*\lambda_d*d}} = \sqrt{\frac{2*(8+0,35)}{\pi^2*1,2*0,02}} = 8,4\ m^{-1}$$

m .... characteristic number of floor

Λ_a ...... heat permeability coefficient of layers above piping

Λ_b ...... heat permeability coefficient of layers below piping

d .... external diameter of pipes

λ_d ...... heat conductivity coefficient of the material in which the pipes are situated

The width of the edge (the distance between the walls and the nearest pipe)

$$r = \frac{2,3}{m} = \frac{2,3}{8,4} = 0,27\ m$$

$$S_p = A_p * B_P = (A - 2*r) * (B - 2*r) = (4,1 - 2*0,27)*(4,85-2*0,27) = 15,344\ m^2$$

$$O = 2*\big((A - 2*r) + (B - 2*r)\big) = 2*\big((4,1 - 2*0,267) + (4,85 - 2*0,267)\big) = 15,764\ m$$

$$\frac{O}{S_P} = \frac{15,764}{15,344} = 1,027$$

$$Q_O = Q_P * \frac{O_P}{S_P} * \frac{0,448 * l}{tgh * (m * \frac{l}{2})} = Q_P * 1,027 * \frac{0,448 * 0,2}{tgh * (8,4 + \frac{0,2}{2})} = 10\% \; z \; Q_P$$

The room is in the first floor so the heating area is calculated by following equation.

$$q_P = \frac{Q_c}{S_P} = \frac{1452}{15,344} = 94,63 \; W/m^2$$

$$q_p = q + q^{'} + q_0 - \frac{S_n}{S_P}(q - q_n)$$

$$q^{'} = 0,1 * q$$

$$q_0 = 0,12 * (q + q^{'}) = 0,12 * 1,1q$$

$$\frac{S_n}{S_P} = \frac{3,8}{15,344} = 0,248$$

$$q_n = (0,3 \; to \; 0,5) \; q$$

$$q_P = q + 0,1q + 0,12 * 1,1q - 0,248 * (1 - 0,4)q$$

$$q = \frac{q_P}{1 + 0,1 + 0,12 * 1,1 - 0,248 * 0,6} = \frac{94,63}{1,0832} = 87,36 \; W/m^2$$

From the graph:

$$(t_m - t_i) = 17 \; K$$

$$t_m = 37°C$$

$$l = 0,2 \; m$$

The temperature difference is $\Delta t = 8°C$ so $t_1 = 41°C$and $t_2 = 33°C$

The real power input is given by relationship

$$Q_c = \left(1 + \frac{Q_0}{Q}\right) * (q + q^{'}) * S_P$$

m= 8,4 m^{-1}, l= 0,2 m, and Op/Sp= 1,027 from the graph it can be found that Q_0/Q=0,12

$$Q_c = (1 + 0,12) * (87,36 + 8,736) * 15,344 = 1651,44 \; W$$

The reduction of heating area due to the furniture

$$q_n = \alpha_{SP}(t_P + t_n) + \alpha_{KP}(t_P + t_i)$$

$$t_n = 0,45t_P + 0,55t_i = 0,45 * 27,7 + 0,55 * 20 = 23,5°C$$

$$q_n = 5(27,7 + 23,5) + 2(27,7 + 20) = 36,4\ W/m^2$$

The real power input

$$Q_{real} = Q_c - S_n * (q - q_n) = 1651,44 - 3,88 * (87,36 - 36,4) = 1453,72\ W$$

Hydraulic calculation

$$\Delta p_z = \Delta p_\lambda + \Delta p_\xi$$

Δp_z ..... total pressure losses
Δp_λ.....pressure losses due to friction
Δp_ξ.....pressure losses due to local resistance

$$M = \frac{Q_{PC} * 3600}{c * \Delta t} = \frac{1474,5 * 3600}{4180 * 8} = 158,738\ kg/h$$

$$Q_{PC} = (q + q') * S_P = (87,36 + 8,736) * 15,344 = 1474,5W$$

Pressure losses due to friction

$$\Delta p_\lambda = R * l_p$$

For meander layout

$$l_p = 82\ m\ (From\ the\ drawing)$$

$$R = \frac{\lambda}{d_i} * \frac{w^2}{2} * \rho$$

$$w = \frac{M}{A * \rho} = \frac{M}{{d_i}^2 * \frac{\pi}{4} * \rho} = \frac{158,738}{720} = 0,22\ m/s$$

The friction coefficient λ depends on Reynold's number

Piping: PE- Xa REHAU Rautherm S - piping for radiant floor heating

$$Re = \frac{w * d_i}{v} = \frac{0,22 * 16 * 10^{-3}}{0,66 * 10^{-6}} = 5333,33$$

$$\lambda = \frac{0,316}{Re^{0,25}} = 0,037$$

$$R = \frac{\lambda}{d_i} * \frac{w^2}{2} * \rho = \frac{0,037}{16 * 10^{-3}} * \frac{0,22^2}{2} * 1000 = 55,96\ Pa/m$$

$$\Delta p_\lambda = R * l_p = 55{,}96 * 82 = 4588{,}72\ Pa$$

Pressure losses due to local resistance

$$\Delta p_\xi = \sum \xi * \frac{\rho * w^2}{2}$$

4x 90° curve (d=20mm; r=100mm; r/d=5)

$$\xi_{90^\circ} = 0{,}034\ 083 + 0{,}744\ 580\ 769 * ln\frac{r}{d} = 1{,}232$$

21 x 180° curve (d=20mm; r=100mm; r/d=5)

$$\xi_{180^\circ} = \xi_{90^\circ}\sqrt{(\frac{180}{90})^3} = 3{,}454$$

$$\Delta p_\xi = \sum \xi * \frac{\rho * w^2}{2} = (4 * 1{,}232 + 21 * 3{,}45) * \frac{1000 * 0{,}22^2}{2} = 1872{,}55\ Pa$$

Hydraulic pressure losses

$$\Delta p_z = \Delta p_\lambda + \Delta p_\xi = 4588{,}72 + 1872{,}55 = 6461{,}27\ Pa$$

Design of heat emitter

Calculated in programme RauCAD/TechCON 7.2

Radiators

Temperature difference: 45°C/35°C

Room no.	t_i [°C]	Heat loss [W]	Heat emitter	Capacity [W]	Coverage [%]
1.01	15	581	RADIK 22 VK (900/700)	632	109%
1.02	15	4581	RADIK 22 VK (600/3000)	1996	44%
1.02	15	4581	RADIK 22 VK (600/2000)	1331	29%
1.02	15	4581	RADIK 22 VK (600/2000)	1331	29%
1.04	18	375	RADIK 22 VK (900/500)	379	101%
1.05	18	809	RADIK 33 VK (600/1100)	878	109%
1.06	15	103	RADIK 11 VK (400/400)	114	108%
2.02	20	491	RADIK 22 VK (600/1200)	593	104%
2.09	15	114	RADIK 11 VK (400/400)	114	100%
2.10	18	856	RADIK 22 VK (900/1200)	911	106%
2.11	18	314	RADIK PLAN VERTIKAL –M10 (1800/600)	326	104%

Radiant floor heating

Room no.	t_i [°C]	Purpose of the room	Heat loss [W]	Spacing [mm]	Length [mm]	S [m^2]
1.03	20	Meeting room	1452	200	106,1	19,8
2.02	20	Office	1676	200	74,5	13,6
2.03	20	Office	1025	200	65,6	11,7
2.04	20	Office	1025	250	66	12,4
2.05-1	20	Office	1821	200	67,8	9,2
2.05-2	20	Office	1821	200	67,5	9,5
2.06-1	20	Office	1851	250	61,9	10,8
2.06-2	20	Office	1851	250	62	10,8
2.07	20	Office	1105	300	62	14,7
2.08	20	Office	1219	200	79,1	15,2

Room no.	t_{inco} [°C]	Δt [K]	t_{floor} [°C]	R*l+z [Pa]	Setting of valve	Coverage [%]
1.03	45	15	26,9	2331	2,5	102%
2.02	45	5	28,9	11966	6,0	117%
2.03	45	5,5	28,8	6807	2,85	112%
2.04	45	5,2	27,9	6828	2,85	105%
2.05-1	45	5,2	29	6727	2,83	103%
2.05-2	45	4,5	29	6718	2,83	103%
2.06-1	45	4,6	28	6486	2,83	103%
2.06-2	45	4,6	28	6490	2,83	103%
2.07	45	4,6	27	6658	2,85	101%
2.08	45	6,9	28,5	7481	2,88	118%

Dimension of pipes

Calculation of dimension of pipes of contra flow heating system and pressure losses

Branch number	First floor	
Temp.difference	**10**	°C
Elevation	**3**	m
Material	**REHAU Rautherm S**	

DATA GATHERED FROM PROJECT				DESIGN OF PIPING			
Segment	**Transferred thermal output [W]**	**Mass flow rate [kg/h]**	**Length l [m]**	**DN**	**w [m/s]**	**R [Pa/m]**	**Σξ [-]**
1	1944	167,03	0,28	17x2,0	0,38	189,5	2
1´	1944	167,03	0,28	17x2,0	0,38	189,5	3,5
2	593	50,95	10,9	17x2,0	0,127	17,6	7,5
2´	593	50,95	10,9	17x2,0	0,127	17,6	10
		Σl	22,36				

Segment	TYPE OF LOCAL RESISTANCE							**ξ**
	boiler	emitter	elbows	T piece, rectangular X piece				
	steel/cast-iron	acc. to DN	acc. to DN	1,5	2	1	0,2	**[-]**
1	0	0	0	0	**2**	**0**	**0**	2
1´	2	0	0	1,5	0	0	0	3,5
2	0	0	7,5	0	0	0	0	7,5
2´	0	2,5	7,5	0	0	0	0	10
							Σξ	23

CALCUATION OF PRESSURE LOSS		
R . l [Pa]	**Z [Pa]**	**R . l + Z [Pa]**
53,06	144,4	197,46
53,06	252,7	305,76
191,84	60,48375	252,32375
191,84	80,645	272,485
	Σ(R . l + Z)	1028,02875
	Design value	1028,02875

Branch number	Ground floor (North branch)	
Temp.difference	**10**	°C
Elevation	**0**	m
Material	**REHAU Rautherm S**	

DATA GATHERED FROM PROJECT				DESIGN OF PIPING			
Segment	**Transferred thermal output [W]**	**Mass flow rate [kg/h]**	**Length l [m]**	**DN**	**w [m/s]**	**R [Pa/m]**	**Σξ [-]**
1	2 628,00	225,79	6,757	20x2,0	0,334	116,3	1,7
1´	2 628,00	225,79	6,757	20x2,0	0,334	116,3	4,5
2	1 996,00	171,49	5,838	20x2,0	0,251	70,5	1,5
2´	1 996,00	171,49	5,838	20x2,0	0,251	70,5	4
		Σl	25,19				

Segment	TYPE OF LOCAL RESISTANCE							ξ
	boiler	emitter	elbows	T piece, rectangular X piece				
	steel/cast-iron	acc. to DN	acc. to DN	1,5	2	1	0,2	**[-]**
1	0	0	1,5	0	0	0	0,2	1,7
1´	2	0	1,5	0	0	1	0	4,5
2	0	0	1,5	0	0	0	0	1,5
2´	0	2,5	1,5	0	0	0	0	4
							Σξ	11,7

CALCUATION OF PRESSURE LOSS		
R . l [Pa]	**Z [Pa]**	**R . l + Z [Pa]**
785,84	94,82	880,66
785,84	251,00	1 036,84
411,58	47,25	458,83
411,58	126,00	537,58
	Σ(R . l + Z)	2 913,91
Design value		2 913,91

Branch number	Ground floor (South branch)	
Temp.difference	**10**	°C
Elevation	**0**	m
Material	**REHAU Rautherm S**	

DATA GATHERED FROM PROJECT				DESIGN OF PIPING			
Segment	**Transferred thermal output [W]**	**Mass flow rate [kg/h]**	**Length l [m]**	**DN**	**w [m/s]**	**R [Pa/m]**	**Σξ [-]**
1	4 033,00	346,51	4,04	20x2,0	0,501	237,0	0,2
1´	4 033,00	346,51	4,04	20x2,0	0,501	237,0	3,5
2	3 919,00	336,72	1,68	20x2,0	0,474	214,3	0,2
2´	3 919,00	336,72	1,68	20x2,0	0,474	214,3	1
3	3 540,00	304,15	0,15	20x2,0	0,418	171,9	0,2
3´	3 540,00	304,15	0,15	20x2,0	0,418	171,9	1
4	2 662,00	228,72	8,47	17x2,0	0,506	313,9	4,7
4´	2 662,00	228,72	8,47	17x2,0	0,506	313,9	5,5
5	1 331,00	114,36	5,25	17x2,0	0,253	93,7	1,5
5´	1 331,00	114,36	5,25	17x2,0	0,253	93,7	4
		Σl	39,18				

Segment	TYPE OF LOCAL RESISTANCE							ξ
	boiler	emitter	elbows	T piece, rectangular X piece				
	steel/cast-iron	acc. to DN	acc. to DN	1,5	2	1	0,2	**[-]**
1	0	0	0	0	0	0	0,2	0,2
1´	2,5	0	0	0	0	1	0	3,5
2	0	0	0	0	0	0	0,2	0,2
2´	0	0	0	0	0	1	0	1
3	0	0	0	0	0	0	0,2	0,2
3´	0	0	0	0	0	1	0	1
4	0	0	4,5	0	0	0	0,2	4,7
4´	0	0	4,5	0	0	1	0	5,5
5	0	0	1,5	0	0	0	0	1,5
5´	0	2,5	1,5	0	0	0	0	4
							Σξ	21,8

CALCUATION OF PRESSURE LOSS		
R . l [Pa]	Z [Pa]	R . l + Z [Pa]
956,53	25,10	981,63
957,48	439,25	1 396,73
360,02	22,47	382,49
360,02	112,34	472,36
25,79	17,47	43,26
25,79	87,36	113,15
2 659,99	601,68	3 261,67
2 658,73	704,10	3 362,83
491,93	48,01	539,93
491,93	128,02	619,94
	Σ(R . l + Z)	11 174,00
	Design value	11 174,00

Setting of radiators KORADO VK

Setting was determined by calculation of mass flow rate and the pressure difference and after that the value was found in the graph provided by the producer.

Room	Radiator	Mass flow rate [kg/h]	Δp [kPa]	Setting
101	RADIK 22 VK (900/700)	54,3	10,05	1
102	RADIK 22 VK (600/3000)	171,49	9,051	6
102	RADIK 22 VK (900/2000)	114,36	0,79	8
102	RADIK 22 VK (600/2000)	114,36	1,95	8
104	RADIK 22 VK (900/500)	32,56	8,73	1
105	RADIK 33 VK (600/1100)	75,44	8,58	3
106	RADIK 11 VK (400/400)	9,79	9,59	1

Calculation of heat source

The energy needed for heating of water for heating system and domestic hot water as it was calculated by day-degree method: $Q_{HW,y} = 5\ 600{,}75\ kWh/year$.

The heat pump designed according to ČSN EN 14511. The heat pump is designed with respect to the maximal heat losses in the building which is $Q_c = 20\ 332\ W$.

From the economical reason the heat pump is designed for 70% of the heat losses.

Chosen heat pump: **IVT PremiumLine EQ E17**

Basic information:

Energetic class	-	A++
Output (0°C/35°C)	kW	17,0
Input	kW	3,64
Output (0°C/45°C)	kW	16,1
Input	kW	4,47
Max. pressure of cold water circle	bar	4
Volume of cold water circle inside the heat pump	l	5
Max. pressure of hot water circle	bar	3
Volume of hot water circle inside the heat pump	l	7
Weight	kg	192
Refrigerant	-	no freon refrigerant R 410A
Max. pressure on circle	bar	42
Dimensions	mm	600 x 645 x 1520
Max. temperature of hot water	°C	62

Dimensions of the horizontal collectors

The horizontal collectors are designed according to ČSN EN 15450 which is valid for the heat pumps with maximal output 30 kW.

$$\Phi_{ch} = \Phi_{TC} * (1 - \frac{1}{COP})$$

$$\Phi_{ch} = 17{,}7 * \left(1 - \frac{1}{5{,}1}\right) = 14{,}23\ kW$$

The regulation ČSN EN 15450 table A.2 show heat flows for different type of soils. According to the geological map the area Malacky has wet gravel – sand soil and the heat pump is used for heating system and also heating hot domestic water so the heat flow in the soil $q_A = 32\ W/m^2$.

$$A = \frac{1000 * \Phi_{ch}}{q_A}$$

$$A = \frac{1000 * 14{,}23}{32} = 444{,}69\ m^2$$

The horizontal collectors are divided into separate circuits with maximal length 100-300m in order to decrease friction losses. Each circuit should have the same length and the distance between pipes should be 1m.

There will be two circuits each of them with the length 230m. The layout of the horizontal collector is classical.