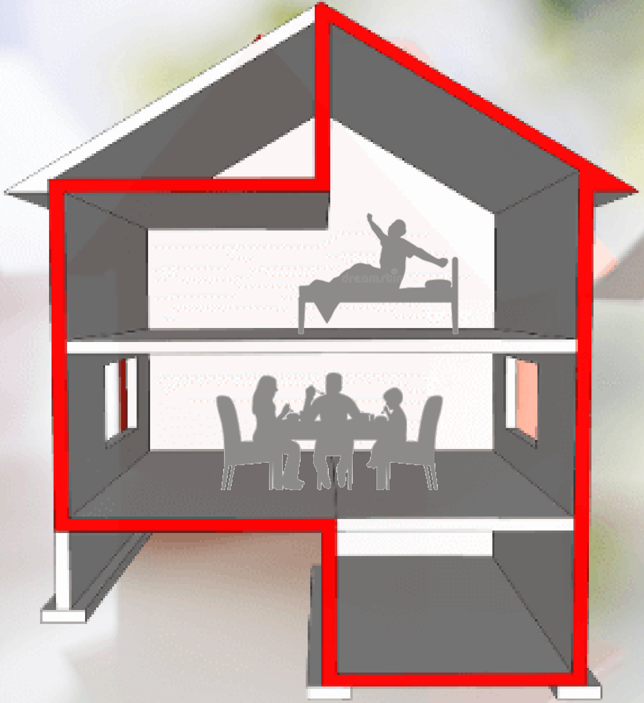
PRACTICE EXERCISES

ENG-445 Building Energetics

Heating in Buildings – Emission Systems and Thermal Comfort



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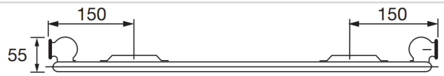
Exercise 1: Radiators

- The heating demand of a **4x4 m²** room to maintain operative temperature of **20°C** is **80 W/m²**.
- What should be **the inlet water temperature** (T_{wi}) of the single-wall radiator Type 10 when it is **undersized** vs. **oversized**?
- Use a table provided from a manufacturer's catalogue.

type 10



		hauteur						
longueur	watt	**300**	**400**	**450**	**500**	**600**	**750**	**900**
450	ΔT 50	145	186	206	225	263	318	370
600	ΔT 50	193	248	275	301	351	424	493
750	ΔT 50	242	310	344	376	439	530	617
900	ΔT 50	290	372	412	451	527	635	740
1050	ΔT 50	338	434	481	526	614	741	863
1200	ΔT 50	386	496	550	601	702	847	986
1350	ΔT 50	435	558	618	676	790	953	1110
1500	ΔT 50	483	620	687	752	878	1059	1233
1650	ΔT 50	531	681	756	827	965	1165	1356
1800	ΔT 50	580	743	824	902	1053	1271	1480
EN 442 - 75/65/20°C		322	413	458	501	585	706	822
EN 442 - 90/70/20°C		411	526	584	638	745	899	1046
valeur n		1,3325	1,3307	1,3297	1,3288	1,3270	1,3242	1,3215

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Exercise 1: Radiators

- Total heat required is

$$Q_{demand} = 4 \times 4 \times 80 = \mathbf{1280}\ W$$

- Depending on the space available for the radiator and a designers choice, there could be the following options available from the table:
  - Option **A (undersized)**: **1271 W,** 750 x 1800 mm
  - Option **B (oversized)**: **1356 W,** 900 x 1650 mm

type 10

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longueur	**watt**	**300**	**400**	**450**	**500**	**600**	**750**	**900**
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valeur n		1,3325	1,3307	1,3297	1,3288	1,3270	1,3242	1,3215

A

B

- The following correlation should be applied (slide 33):

$$Q_{demand} = Q_{fabricant} * \left(\frac{\Delta T_{actual}}{\Delta T_{standard}}\right)^n$$

$$\Delta T_{actual} = \left(Q_{demand}/Q_{fabricant}\right)^{1/n} \cdot \Delta T_{standard}$$

equal

$$\Delta T_{actual} = \frac{(T_{wi}+T_{wo})}{2} - T_{room} = \frac{(T_{wi}+T_{wi}-\Delta T)}{2} - T_{room}$$

- For given room temperature and assuming the maximum temperature drop of water (**10 K**):

$$\Delta T_{actual} = T_{wi} - \frac{\Delta T}{2} - T_{room} = T_{wi} - \mathbf{5} - \mathbf{20} = T_{wi} - 25$$

- Inlet water temperature can be found as:

Option A: $T_{wi} - 25 = (1280/1271)^{1/1.3242} \cdot 50 \Longrightarrow T_{wi} = 50.3 + 25 = \mathbf{75.3\ ^oC}$

Option B: $T_{wi} - 25 = (1280/1356)^{1/1.3215} \cdot 50 \Longrightarrow T_{wi} = 47.7 + 25 = \mathbf{72.7^oC}$

"*Oversized*" **radiator B** has *a larger heat exchange area* leading to **a lower supply water temperature**

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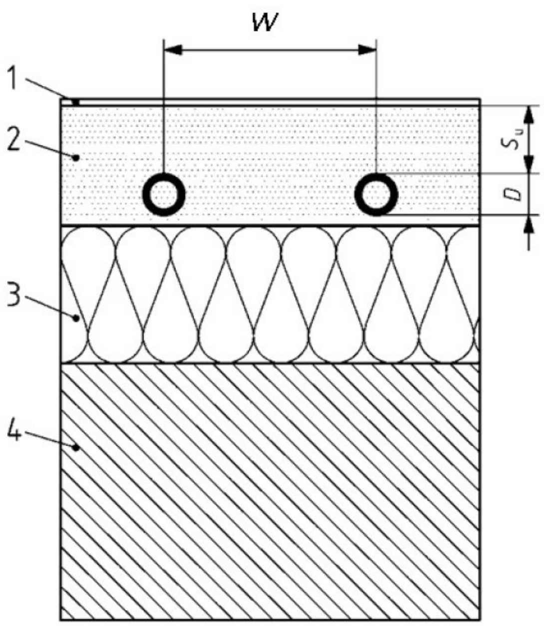
Exercise 2: Radiant Embedded System (Type A)

- Indoor temperature: T_{op} = **20°C**
- System Type: **type A**
- Pipe spacing: **W = 15 cm**
- Pipe diameter: **D = 25 mm**
- Thermal resistance of the floor covering: $R_{\lambda,B}$ = **0.15** m²K/W
- Thickness s_u = **10 mm**
- Design heat load: q = **80 W/m²**
- Parameters of the system are provided (see next slide)

Determine:

- Difference between average temperature and room (ΔT_h)
- Supply water temperature (T_{wi}) *
- Compare the supply temperature of the embedded system with the temperature of the radiator

** Water temperature difference between supply and outlet of embedded systems is typically limited to* $T_{wi} - T_{wo}$ ***= 5K***



1 – floor covering
2 – weight bearing and thermal diffusion layer (cement screed)
3 – thermal insulation
4 - structural base

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Exercise 2: Radiant Embedded System (Type A)

Source: ISO 11855-2

Table A.1 — Pipe spacing factor α_W for types A and C systems

$R_{\lambda,B}$ (m²K/W)	0	0,05	0,10	0,15
α_W	1,23	1,188	1,156	1,134

a_B - surface covering factor in accordance with the following equation

$$a_B = \frac{\frac{1}{\alpha} + \frac{s_{u,0}}{\lambda_{u,0}}}{\frac{1}{\alpha} + \frac{s_{u,0}}{\lambda_E} + R_{\lambda,B}}$$

where

α = 10,8 W/(m²·K);

$\lambda_{u,0}$ = 1 W/(m·K);

$s_{u,0}$ = 0,045 m;

$R_{\lambda,B}$ is the heat conduction resistance of the floor covering, in m²·K/W;

λ_E is the heat conductivity of the screed, in W/(m·K);

For a heating cement screed with reduced humidity, λ_E = 1,2 W/(m·K)

Table A.2 — Covering factor α_U depending on pipe spacing T and thermal resistance $R_{\lambda,B}$ of the surface covering for types A and C systems

$R_{\lambda,B}$ (m²K/W)	0	0,05	0,10	0,15
W (m)	Covering factor α_U			
0,05	1,069	1,065	1,043	1,037
0,075	1,066	1,053	1,041	1,035
0,1	1,063	1,05	1,039	1,0 335
0,15	1,057	1,046	1,035	1,0 305
0,2	1,051	1,041	1,0 315	1,0 275
0,225	1,048	1,038	1,0 295	1,026
0,3	1,0 395	1,031	1,024	1,021
0,375	1,03	1,0 221	1,018	1,015

Table A.3 — Pipe external diameter factor α_D depending on thermal resistance $R_{\lambda,B}$ of the floor covering and the pipe spacing W for types A and C systems

$R_{\lambda,B}$ (m²K/W)	0	0,05	0,10	0,15
W (m)	Pipe external diameter factor α_D			
0,05	1,013	1,013	1,012	1,011
0,075	1,021	1,019	1,016	1,014
0,1	1,029	1,025	1,022	1,018
0,15	1,04	1,034	1,029	1,024
0,2	1,046	1,04	1,035	1,03
0,225	1,049	1,043	1,038	1,033
0,3	1,053	1,049	1,044	1,039
0,375	1,056	1,051	1,046	1,042

Exercise 2: Radiant Embedded System (Type A)

1. Find heat-exchanger specific factors using the tables from the standard ISO 11855-2:

- B=6.7 $W/(m^2K)$
- a_B = 0.491 - surface covering factor
- a_W = 1.134 - the pipe spacing factor
- a_U = 1.0305- the screed covering factor
- a_D = 1.024 - the pipe external diameter factor
- $m_w = 1 - W/0.075 = 1 - 0.15/0.075 = 1 - 2 = -1$
- $m_u = 100 \cdot (0.045 - s_u) = 100 \cdot (0.045 - 0.01) = 3.5$
- $m_D = 250 \cdot (D - 0.020) = 250 \cdot (0.025 - 0.020) = 1.24$

$$a_B = \frac{\frac{1}{\alpha} + \frac{s_{u,0}}{\lambda_{u,0}}}{\frac{1}{\alpha} + \frac{s_{u,0}}{\lambda_E} + R_{\lambda,B}}$$

$$a_B = \frac{\frac{1}{10.8} + \frac{0.045}{1}}{\frac{1}{10.8} + \frac{0.045}{1.2} + 0.15} = \mathbf{0.491}$$

2. Find ΔT_h from the relationship $q = B \cdot a_B \cdot a_W^{m_w} \cdot a_U^{m_u} \cdot a_D^{m_D} \cdot \Delta T_h$

$$\Delta T_h = q/(B \cdot a_B \cdot a_W^{m_w} \cdot a_U^{m_u} \cdot a_D^{m_D}) = q/(6.7 \cdot 0.491 \cdot 1.134^{-1} \cdot 1.0305^{3.5} \cdot 1.024^{1.24}) = 80/3.3188 = \mathbf{24.1\ K}$$

3. Find water supply temperature T_{wi} using the definition of ΔT_h for a given $(T_{wi} - T_{wo})$ = 5 K

$$\Delta T_h = \frac{(T_{wi} - T_{wo})}{\ln[(T_{wi} - T_{op})/(T_{wo} - T_{op})]} = \frac{5}{\ln[(T_{wi} - 20)/((T_{wi} - 5) - 20)]} \Rightarrow T_{wi} = 46.7^{\circ}C$$

4. Supply water temperature for the embedded radiation system is *lower* compared to radiators. The temperature reduction is mainly attributed to *the larger surface area* occupied by the radiant system (16 m^2 vs 1.485 m^2, case B).