Heating and cooling ceiling systems
Radiant ceiling panels
Design example Zehnder Carboline

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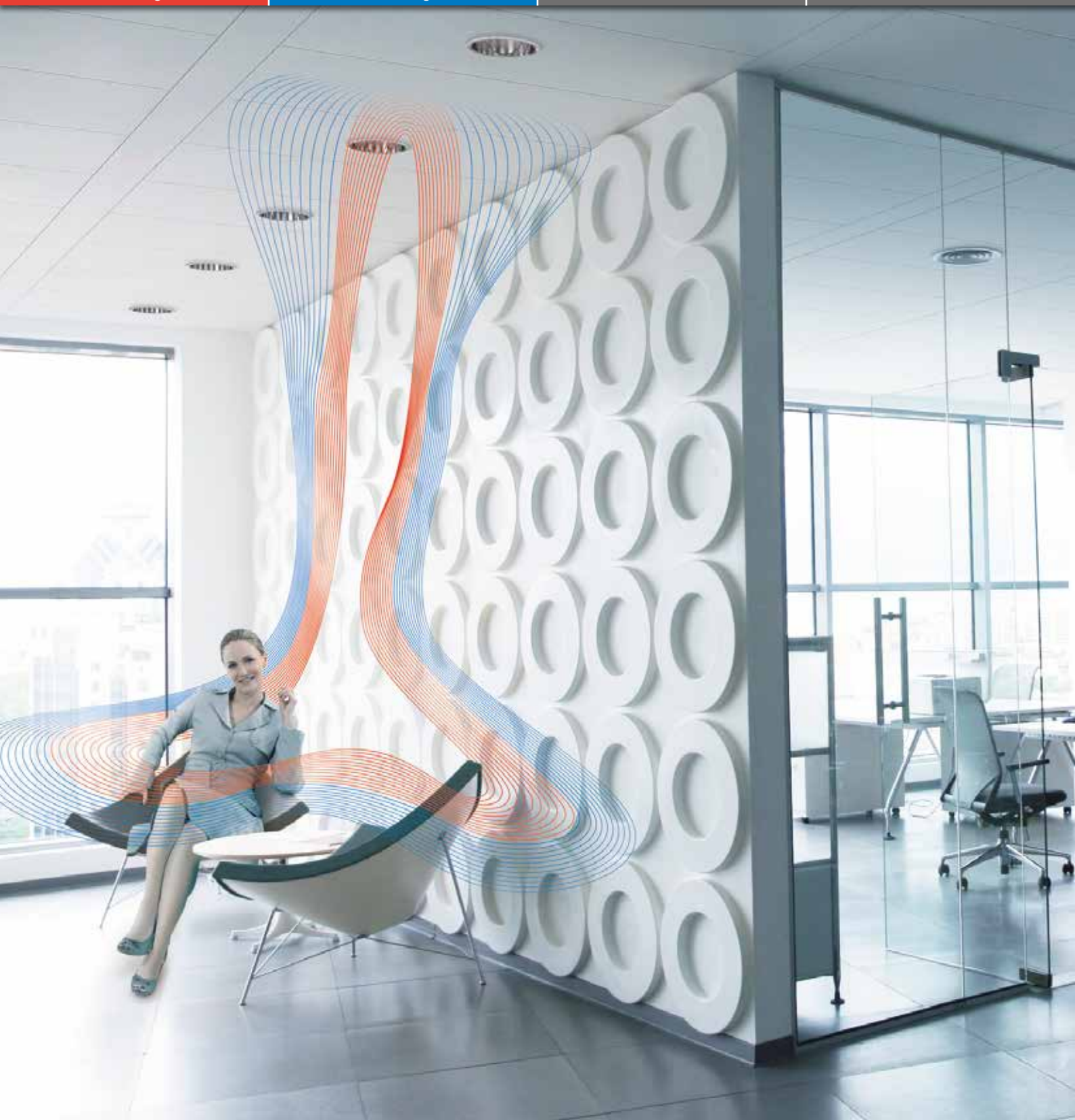


Design guidelines for Zehnder Carboline Radiant ceiling panels

Required design data

1. Drawings including section views of all rooms

2. Required outputs:
- Demand for heating and cooling to be covered by the radiant ceiling panels
- System temperatures

a) Heating operating temperatures
For heating only operation: according to design temperatures
For cooling and heating operation: according to cooling mass flow
b) Cooling (e.g. 16/19/26 °C)
Minimum supply temperature should be at least 1K higher than the dew point temperature of the air. This prevents condensation.

Zehnder Carboline model options

1. Available panel dimensions [mm]:
a) Width: 600
b) Length: 600, 1200, 1800, 2400, 3000

2. Mounting options:
a) Free hanging / sail
b) Installed into a grid ceiling

3. Thermal insulation:
a) YES (for panels heating only)
b) NO (for panels cooling only)
c) To be defined: panels used for heating and cooling

4. Perforation:
a) With (operating temperature max. 50 °C)
b) Without (smooth; max. operation temperature 85 °C)

Panel positioning

1. Principles:
a) The panels are usually spaced evenly in the entire room and parallel to the outside walls.
b) Panels should ideally be as long as possible and identical (for the ease of hydraulic balancing).
c) Turbulent flow should be maintained in the panels. This can be achieved by changing the number of panels that are connected in series.
d) Maximum velocity = 0.5 m/s
e) Minimum number of panel strips:

$$\frac{\text{Room width [m]}}{\text{Mounting height [m]}} + 1$$

f) Distance between the panels and the outside walls: 1/4 - 1/2 of panel mounting height.
g) Respect other built-in components (e.g. lighting, diffusers, smoke detectors).

Calculation of the required number of radiant ceiling panels

1. Calculation of the cooling output:
   The design temperature difference ΔT is the difference between the average radiant ceiling panel temperature and the temperature of the room.

$$\Delta t = \left| \frac{t_s + t_r}{2} - t_i \right|$$

Where:
t_s – supply temperature
t_r – return temperature
t_i – indoor temperature

2. Output of the panel [W] is given in the table below.
   (for more values see Zehnder Carboline Technical catalogue)

Cooling capacity											
Insulated panel						Panel without insulation					
Zehnder Carboline						Zehnder Carboline					
	600 x 600 625 x 625	600 x 1,200 625 x 1,250	600 x 1,800 625 x 1,875	600 x 2,400 625 x 2,500	600 x 3,000 625 x 3,125		600 x 600 625 x 625	600 x 1,200 625 x 1,250	600 x 1,800 625 x 1,875	600 x 2,400 625 x 2,500	600 x 3,000 625 x 3,125
K	4.195	8.390	12.585	16.780	20.975	**K**	4.770	9.540	14.310	19.080	23.850
n	1.047					**n**	1.060				
Δ t (K)	**W**	**W**	**W**	**W**	**W**	**Δ t (K)**	**W**	**W**	**W**	**W**	**W**
15	71	143	214	286	357	15	84	168	253	337	421
14	66	133	199	266	332	14	78	156	235	313	391
13	62	123	185	246	308	13	72	145	217	289	362
12	57	113	170	226	283	12	66	133	199	266	332
11	52	103	155	207	258	11	61	121	182	242	303
10	47	93	140	187	234	10	55	110	164	219	274
9	42	84	126	167	209	9	49	98	147	196	245
8	37	74	111	148	185	8	43	86	130	173	216
7	32	64	97	129	161	7	38	75	113	150	188
6	27	55	82	110	137	6	32	64	96	127	159
5	23	45	68	90	113	5	26	53	79	105	131
4	18	36	54	72	90	4	21	41	62	83	104
3	13	27	40	53	66	3	15	31	46	61	76
2	9	17	26	35	43	2	10	20	30	40	50
1	4	8	13	17	21	1	5	10	14	19	24

3. Required demand / panel output = number of panels.

Controls and balancing, limits

1. Controls:
   The ceiling panels can be controlled with constant regulators, on/off valves or mixing valves.

2. Balancing:
   For ease it is best to use reverse / return technology (Tichelmann system).
   To control zones a volume flow controller is advised.

Zehnder volume flow regulators:

Volume flow controller DN15	
Mass flow (kg/h)	Overall pressure loss (kPa)
30	20,0
35	20,9
40	21,8
45	22,7
50	23,6
55	24,4
60	25,2
65	26,0
70	26,8
75	27,5
80	28,2
85	28,9
90	29,6
95	30,3
100	30,9
105	31,5
110	32,1
115	32,7
120	33,2
125	33,7
130	34,2
135	34,7
140	35,2
145	35,7
150	36,1
155	36,5
160	36,9
165	37,3
170	37,7
175	38,0
180	38,3
185	38,7
190	39,0
195	39,2
200	39,5
205	39,8
210	40,0

Volume flow controller DN25	
Mass flow (kg/h)	Overall pressure loss (kPa)
150	20,0
175	20,9
200	21,8
225	22,7
250	23,6
275	24,4
300	25,2
325	26,0
350	26,8
375	27,5
400	28,2
425	28,9
450	29,6
475	30,3
500	30,9
525	31,5
550	32,1
575	32,7
600	33,2
625	33,7
650	34,2
675	34,7
700	35,2
725	35,7
750	36,1
775	36,5
800	36,9
825	37,3
850	37,7
875	38,0
900	38,3
925	38,7
950	39,0
975	39,2
1000	39,5
1025	39,8
1050	40,0

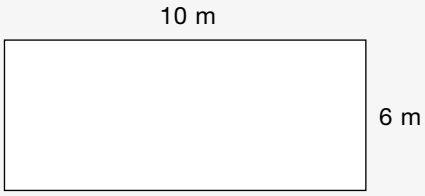
Volume flow controller DN32	
Mass flow (kg/h)	Overall pressure loss (kPa)
600	15,0
700	15,3
800	15,7
900	16,0
1000	16,3
1100	16,7
1200	17,0
1300	17,3
1400	17,7
1500	18,0
1600	18,3
1700	18,7
1800	19,0
1900	19,3
2000	19,7
2100	20,0
2200	20,3
2300	20,7
2400	21,0
2500	21,3
2600	21,7
2700	22,0
2800	22,3
2900	22,7
3000	23,0
3100	23,3
3200	23,7
3300	24,0
3400	24,3
3500	24,7
3600	25,0

3. The total pressure loss of the system should not exceed 50 kPa.

Design example of Zehnder Carboline radiant ceiling panels Heating and Cooling

Boundary conditions and design steps

Room dimensions: **6 x 10 m**
Room height: **3.2 m**
Ceiling grid 600 x 600 mm; 0.5 m suspended below the structural ceiling
Heating demand: **4600 W**
Cooling demand: **4400 W**
Cooling parameters: **16 / 19 °C**; room temperature: **26 °C**
Heating parameters: **according to mass flow cooling;** room temperature: **20 °C**



Installation height of Zehnder Carboline ceiling panels: 3.2 m – 0.5 m = 2.7 m

Calculation of the distance of the radiant panels from the outside walls: 2.7 m / 3 = ~1 m

Length of the radiant ceiling panels in a series: 4 panels x 2.4 m = 9.6 m

The minimum number of radiant ceiling panel strips:

$$\frac{6\ \text{m}}{2.7\ \text{m}} + 1 = 3.2 \rightarrow 4\ \text{strips}$$

Calculation of Δt for cooling:

$$\Delta t = \left| \frac{16\ °\text{C} + 19\ °\text{C}}{2} - 26\ °\text{C} \right| = 8.5\ \text{K}$$

Zehnder Carboline ceiling panels, free-hanging, without insulation are selected.

Zehnder Carboline panel output cooling: see Zehnder Carboline Technical catalogue =185 W/panel 600 x 2400

Number of 600 x 2400 radiant panels required:

$$\frac{4400\ \text{W}}{185\ \frac{\text{W}}{\text{panel}}} = 23.7\ \text{panels} \rightarrow 24\ \text{panels}$$

Number of radiant ceiling panel connection series:
24 panels / 4 panel strips = 6 series

Total output:
24 panels x 185 W/panel = 4440 W

The total mass flow of all radiant ceiling panels:

$$\text{Mass flow:}\quad \frac{4440\ \text{W}}{1.163\ \text{Wh/kg/K} \times (19\ °\text{C} - 16\ °\text{C})} = 1272\ \text{kg/h}$$

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Mass flow through one panel 600 x 2400:
1272 kg/h / 24 panels = 53 kg/h

The velocity for this panel, according to Zehnder Carboline Technical catalogue:
v = 0.22 m/s

In order to create turbulent flow 2 panels have to be connected in series.

Values for two panels connected in series, according to Zehnder Carboline Technical catalogue:
$\dot{m}$ = 106 kg/h
Δp = 2 x 8 kPa/panel = 16 kPa
v = 0.44 m/s

Calculation of heating parameters according to the cooling design:
$t_s - t_r$ = 4600 W / 1.163 Wh/K / 1272 kg/h = 3.1 K

The required heating output per panel:
4600 W / 24 panels = 192 W

According to the Zehnder Carboline Technical catalogue the heating output
of the 600 x 2400 panel at ΔT = 11 K is: 209 W

Calculation of operation temperatures heating:
$t_s - t_r$ = 3.1 K

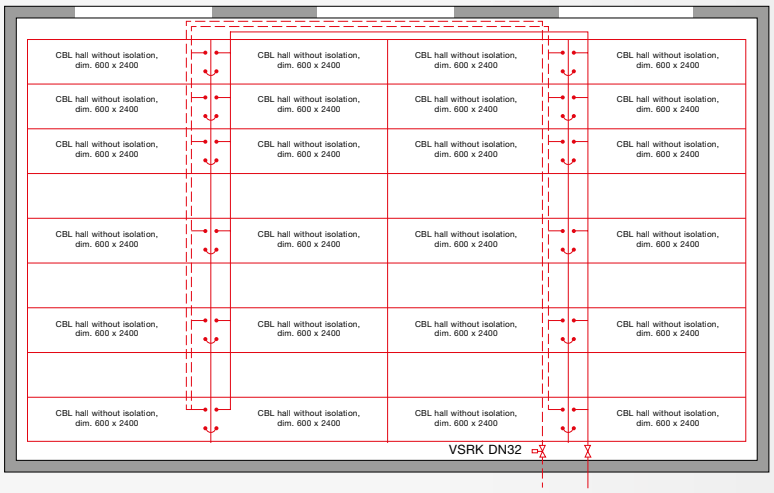
$$\frac{t_s + t_r}{2} - 20\ °C = 11\ K$$

Result:
t_s = 32.5 °C
t_r = 29.5 °C

Dimensioning of the volume flow regulator:
Total mass flow of the system: 1272 kg/h

See chapter “Controls and balancing, limits”: DN32
Pressure loss: 17.2 kPa

Zehnder Carboline radiant ceiling panels layout:



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