RADIATORS,

FINNED COILS/BASEBOARD HEAT

CONVECTOR HEATING SYSTEM

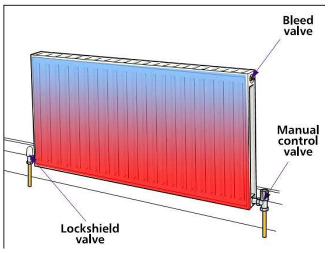
FAN-COILS

ACTIVE BEAMS / CHILLED BEAMS

UNIT HEATERS

Radiators 1/2

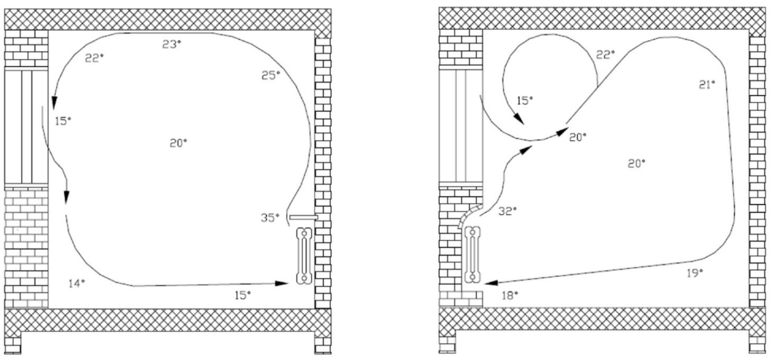
- They are used only for heating;
- Water based emission system;
- They may be equipped with additional electric resistances (especially in bathrooms).
- They present a shut-off valve to interrupt the water flow, a beed (vent) valve and a manual control valve or a thermostatic valve .



Radiators 2/2

- Radiators are made of vertical elements in cast iron, sheet steel, or aluminium, put together.
- Each element can have one or more columns or planar, smooth or with vertical profiles

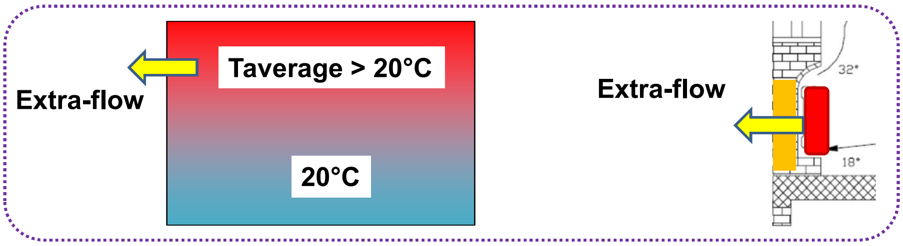
Radiators positioning



They are usually installed below the windows in order to counteract the down draft effect which may occur with the windows.

This makes the air temperature distribution more uniform in the room

Radiators efficiency

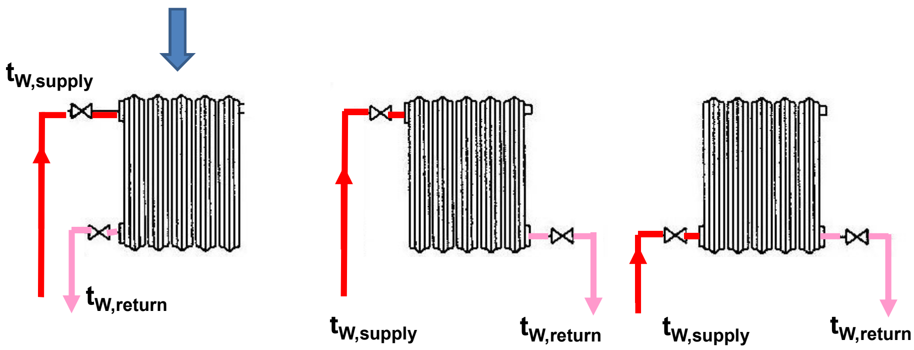


Emission efficiency

Although trying to make the air distribution in the room more uniform, with radiators stratification effects occur. Hence in order to get 20°C in the occupied zone, the average temperature is higher. This leads to higher losses.

Moreover the installation of the radiator in the nieche below the window leads to losses named embedded losses. The radiator when is on heats up the wall below the window and this heat flows outwards.

Distribution of the water within the radiators



Radiators – Thermal output

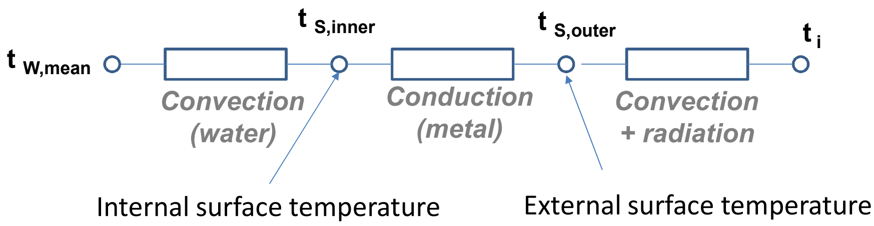
- Factors influencing the radiators performance:
  - Position;
  - Temperature of the water;
  - Characteristics of the finishing/painting.

- The radiator is a heat exchanger between the water and the room. It is a combination between natural convection and radiation:

$$q_R = K_R \, S_e \, (t_{W,mean} - t_i)$$

- q_R: Thermal output (power [W])
- K_R: Overall heat exchange coefficient [W/(m^2 K)]
- S_e: Outer reference surface [m^2]
- $t_{W,mean}$: Average water temperature [°C]
- t_i: Indoor temperature [°C]

- In principle the coefficient K_R could be calculated as a function of the geometry of the heat exchanger.



- The internal heat transfer coefficient depends on the velocity and on the average temperature of the fluid
- The conduction depends on the material and the geometry of the heat exchanger
- The external resistance is the most relevant for the heat exchange.

- The radiant heat transfer coefficient is constant: h_R = 5.5 W/(m^2 K)
- The convective heat exchange coefficient is dependent on the temperature difference between the air and the surface of the radiator:

$$h_c = f\,(t_{surface} - t_{air})$$

- Hence the overall heat transfer coefficient K_R depends on the surface temperature. The calculation would require an iterative process. Moreover the calculation would change from one radiator to another. Thus there is the need of a simpler solution.
- The radiators are modular elements made combining different vertical elements.

- The thermal output is defined based on standardized tests (EN 442) where the radiators are defined in an experimental way. The thermal output is defined by means of two coefficients:

$$q_R = K_m\,(t_{W,average} - t_i)^n$$

Radiator model constant (for K_m)

n= 1.25 - 1.35

- The test room dimension is 4 m x 4 m x 3 m
- Different sets of measurements are carried out. The nominal thermal output is defined at an average water temperature of 70°C

Radiators - Example

3 COLONNE
3 COLUMNS

Cod. Modello *Cod. Model*	Altezza *Height* H mm	Interasse *Dist. betw. centers* *N mm*	Cont. acqua *Water content* *lt*	Peso *Weight* kg	Resa/Outputs EN 442-1 Δt=50k watt/el.	 kcal/h-el.	K_m	Esponente n *Exponent n*
C3/300	300	230	0,60	0,85	**32,2**	27,6	0,225	1,26863
C3/350	350	280	0,66	0,96	**37,1**	31,9	0,260	1,26802
C3/400	400	330	0,72	1,08	**41,9**	36,0	0,294	1,26740
C3/450	450	380	0,77	1,18	**46,7**	40,2	0,329	1,26679
C3/500	500	430	0,83	1,29	**51,4**	44,2	0,363	1,26617
C3/550	550	480	0,89	1,40	**56,2**	48,3	0,398	1,26556
C3/600	600	530	0,95	1,51	**60,9**	52,4	0,432	1,26495
C3/685	685	615	1,06	1,69	**68,9**	59,2	0,491	1,26390
C3/750	750	680	1,13	1,83	**75,0**	64,5	0,536	1,26310
C3/885	885	815	1,29	2,13	**87,8**	75,5	0,631	1,26144
C3/900	900	830	1,31	2,16	**89,2**	76,7	0,642	1,26126
C3/1000	1000	930	1,43	2,38	**98,6**	84,8	0,689	1,26901
C3/1100	1100	1030	1,55	2,60	**108,1**	92,9	0,733	1,27675
C3/1200	1200	1130	1,67	2,82	**117,7**	101,2	0,773	1,28450
C3/1500	1500	1430	2,03	3,47	**146,7**	126,1	0,880	1,30774
C3/1800	1800	1730	2,39	4,13	**176,4**	151,7	0,966	1,33098
C3/2000	2000	1930	2,62	4,56	**196,6**	169,0	1,098	1,32603
C3/2200	2200	2130	2,86	5,00	**217,2**	186,8	1,237	1,32108
C3/2500	2500	2430	3,22	5,65	**249,0**	214,1	1,460	1,31365
C3/2800	2800	2730	3,58	6,30	**282,0**	242,5	1,598	1,32242
C3/3000	3000	2930	3,82	6,74	**304,5**	261,8	1,698	1,32648

Lunghezza= numero elementi x 46 mm toll. +/- 1.5% - *Length= number of elements x 46 mm tol. +/- 1.5%*

Radiators – Choice

- Once known the peak power load of a room the amount of terminal units has to be decided (depending opn the size of the room);
- It has to be decided the mean water temperature in the radiator;
- Choice of the type of radiator. Based on the Tables declared by the producer the area of the radiator is fixed; the amount of elements is calculated as the ratio between the peak load and the nominal power per element;
- Once determined the amount of the elements the water temperature has to be refined
- Check the effective size of the radiators, if they fit in the room

Sizing

- The values “C” and “n” are provided by the producer
- The actual power output of the radiator (or by an element) q_{actual} is different from the declared value ($q_{nominal}$) at $t_{W,average}$ = 70°C and the room at t_i = 20°C) :

$$q_{actual} = q_{nominal} \left[\left(t_{W,average} - t_i \right) / 50 \right]^n$$

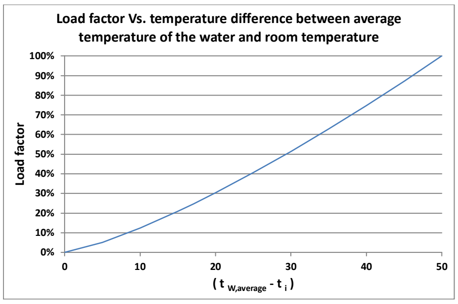
- If q_{actual} is referred to a single element, the amount N of elements is given by:

$$N = q_{design} / q_{actual}$$

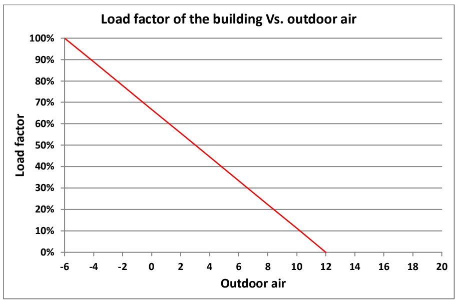
- The value N is usually rounded up.

Climatic control startegies 1/2

- The radiator has a self-regulation power output depending on the average temperature of the water

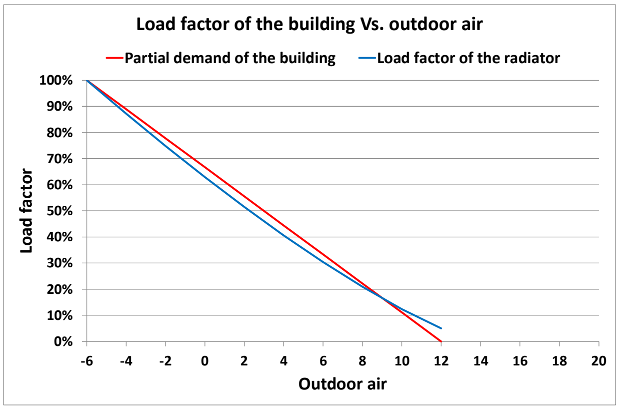


- The room in the most simple approach has a linear heat loss as a function of outdoor air



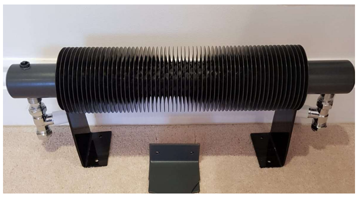
Climatic control startegies 2/2

- By choosing a suitable funciotn for reducing the average temperature in the radiator it is possible in principle to adapt the poeìwer output of the radiator by means of outdoor temperature

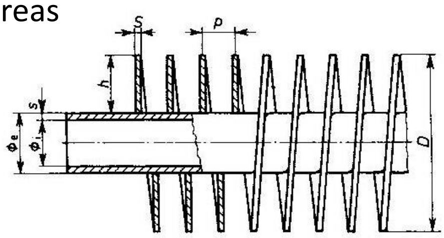


- It has to be underlined that the linear model for the energy need of the building does not take into account the internal gains and the solar radiation, hence the approach has some limits.

Finned tube

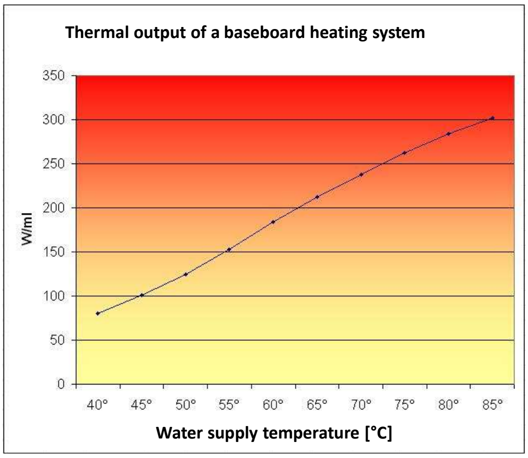


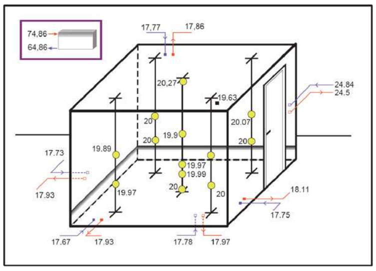
- They operate with high Δt (60°C)
- Power from 350 W/m to 625 W/m depending on the amount of fins
- Used mainly in industrial buildings, green houses, car garages, etc.
- It may be used in Central Europe as auxiliary system in case of large glazed areas to cover the peak load



Baseboard heating

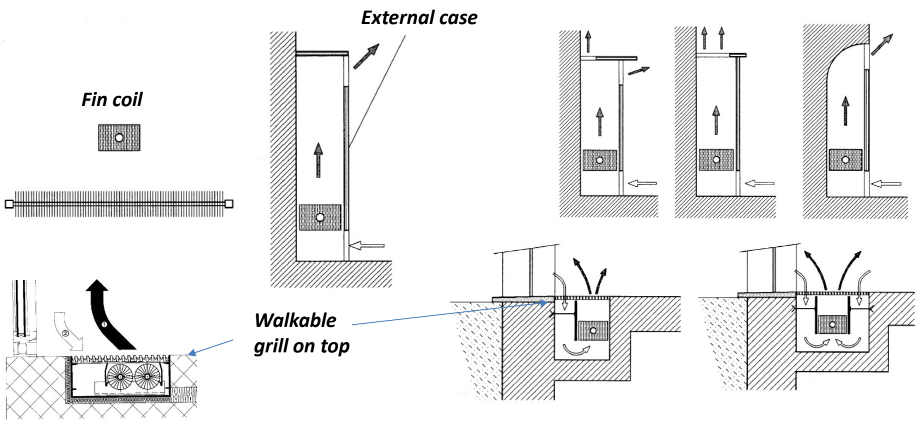
Finned coils installed in the bottom part of a wall with a plastic casing which allows the natural convection





Convector heating systems 1/2

- Convector heating systems are mainly based on convection.
- They are based on fin coils in casings with openings which allow the natural convection and the buoyancy effect;
- They can be verticals, horizontal, or they can put in the floor;



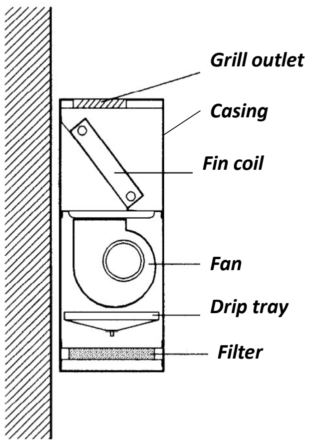
Convector heating systems 2/2

- They can be used as additional auxiliay system for large glazing elements;
- The fin coil is usually fed by water supply at 60 ÷ 80 °C, also used with high pressure hot water.
- Material used is usually iron or copper for the pipes and for the heads, steel or aluminium for the fins.
- Compared to radiators (pros): less thermal inertia, more compact, cheaper
- Compared to radiators (cons): more difficult to be cleaned (they are not suitable for dusty applications), they are not modular solutions, it is not possible to modulate the thermal output by reducing the supply temperature

Fan-coils 1/3

(heating and cooling)

- Terminal units which release (heating) and extract (cooling) heat in the room by means of forced convection.
- They are made of:
  - One or two fin coils
  - One or two fans
  - An air filter
  - A drip tray
  - A casing
- They can be iof different types
  - Vertical
  - Horizontal
  - Cassette



Drip tray: Raccolta condensa

Fan-coils 2/3

- The choice can be done according to the following issues:
  - Power delivered by the fan-coil
  - Volume flow rate fo the fan
  - Outlet air temperature
  - Noise of the unit
- These data are provided by the manufacturer based on laboratory tests.
- Fan-coils are uaually fed by water:
  - cooling: water at 7°C (supply) / 12°C (return)
  - heating: water at 45°C (supply) / 40°C (return)

  In the past greater temperatures for heating were used, today lower temperature can be provided (in this case the fan-coil will be larger)

Fan-coils 3/3

The following aspects should be appropriate:

- Subdivide the power in different fan-coils in order to get more uniform conditions of the air
- Check that the volume flow rate of the fan-coils is not lower than 3÷4 times the volume of the room (3÷4 ACR)
- The outlet temperature of the air from the fan-coils in heating would be between 35 and 45°C
- Connect each fan-coil with the circuit draining the condensed water, if cooling is required

Fan-coils: Selection

- Based on the peak power in heating and cooling, in usual rooms one fan-coil is sufficient. Sometimes (if the peak load is limited in adjacent rooms a fan-coil can be installed in a common area and by means of ducts the fan-coil can provide heating and cooling in the rooms (ducted fan-coil). In this case the rooms need to have the similar loads (same exposition).

- Else, if the peak load of a room fits with the power output of a fan-coil, one fan-coil can be installed

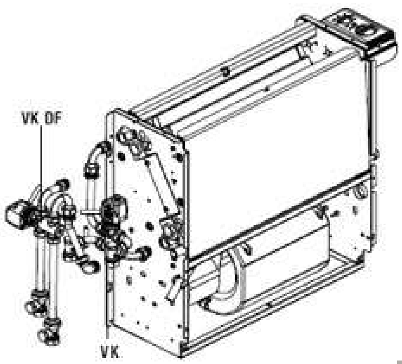
Fan-coils: Selection

- If the room has relevant dimensions more fan-coil units may be installed. In this case the sum of the flow rate of the fan-coils should be equal to 3 ACR.
- The heating and cooling power of a fan-coil is function of the velocity of the fan, the water temperature and the room temperature.
- Usually the velocities of the fan-coils have 3 to 5 possible velocities. The greater the velocity the higher the noise. Hence the velocity if the fan should be selected depending on the type of installation. In resideIntial buildings or in hotels the 1st velocity should be selected for the peak load. In office rooms an intermediate velocity could be selected. Today there are also variable speed fans.

Tbs_1	°C	19											
Tw_1 / Tw_2	°C	50 / 45						60 / 50					
	Vr	PT W	PT kcal/h	Qw l/s	Qw l/h	Δpw kPa	Δpw m H_2O	PT W	PT kcal/h	Qw l/s	Qw l/h	Δpw kPa	Δpw m H_2O
FC/NT 11	3	1418	1219	0,069	248	20,85	2,13	1798	1546	0,044	158	9,17	0,94
	2	1177	1012	0,057	205	15,05	1,54	1499	1289	0,036	130	6,67	0,68
	1	880	757	0,043	155	9,05	0,92	1125	968	0,027	97	4,04	0,41
FC/NT 22	3	2048	1761	0,099	356	27,96	2,85	2580	2219	0,063	227	12,15	1,24
	2	1729	1487	0,084	302	20,81	2,12	2186	1880	0,053	191	9,09	0,93
	1	1294	1113	0,063	227	12,52	1,28	1640	1410	0,040	144	5,49	0,56
FC/NT 33	3	3197	2749	0,155	558	18,49	1,89	4031	3467	0,098	353	8,05	0,82
	2	2687	2311	0,130	468	13,63	1,39	3403	2927	0,083	299	5,97	0,61
	1	2006	1725	0,097	349	8,18	0,83	2552	2195	0,062	223	3,61	0,37
FC/NT 44	3	3782	3253	0,183	659	24,99	2,55	4779	4110	0,116	418	10,91	1,11
	2	3233	2780	0,156	562	18,99	1,94	4099	3525	0,100	360	8,35	0,85
	1	2443	2101	0,118	425	11,64	1,19	3119	2682	0,076	274	5,17	0,53

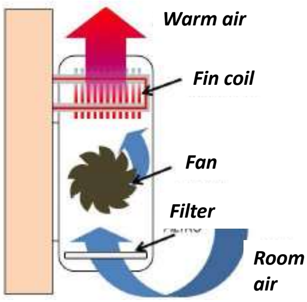
Tbs_1 / Tbu_1 (UR_1)	°C	25 / 18 (51%)															
Tw_1 / Tw_2	°C	6 / 11								7 / 12							
	Vr	PFT W	PFT Frig/h	PFS W	PFS Frig/h	Qw l/s	Qw l/h	Δpw kPa	Δpw m H_2O	PFT W	PFT Frig/h	PFS W	PFS Frig/h	Qw l/s	Qw l/h	Δpw kPa	Δpw m H_2O
FC/NT 11	3	931	801	706	607	0,044	158	11,05	1,13	814	700	659	567	0,039	140	8,69	0,89
	2	785	675	579	498	0,037	133	8,21	0,84	687	591	539	464	0,033	119	6,46	0,66
	1	600	516	428	368	0,029	104	5,12	0,52	526	452	397	341	0,025	90	4,05	0,41
FC/NT 22	3	1298	1116	1053	906	0,062	223	14,67	1,50	1116	960	982	845	0,053	191	11,19	1,14
	2	1102	948	866	745	0,053	191	11,01	1,12	945	813	804	691	0,045	162	8,37	0,85
	1	825	710	622	535	0,039	140	6,63	0,68	702	604	572	492	0,033	119	4,97	0,51
FC/NT 33	3	1951	1678	1583	1361	0,093	335	9,17	0,94	1668	1434	1472	1266	0,080	288	6,93	0,71
	2	1649	1418	1298	1116	0,079	284	6,83	0,70	1402	1206	1200	1032	0,067	241	5,11	0,52
	1	1228	1056	934	803	0,059	212	4,08	0,42	1026	882	852	733	0,049	176	2,96	0,30
FC/NT 44	3	2423	2084	1933	1662	0,115	414	13,25	1,35	2112	1816	1811	1557	0,101	364	10,36	1,06
	2	2091	1798	1620	1393	0,100	360	10,25	1,05	1820	1565	1512	1300	0,087	313	7,99	0,81
	1	1599	1375	1189	1023	0,076	274	6,40	0,65	1384	1190	1102	948	0,066	238	4,95	0,50

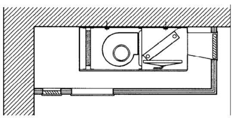
Examples of fan-coils



Flush mounted

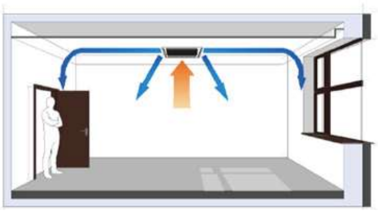
(a incasso)



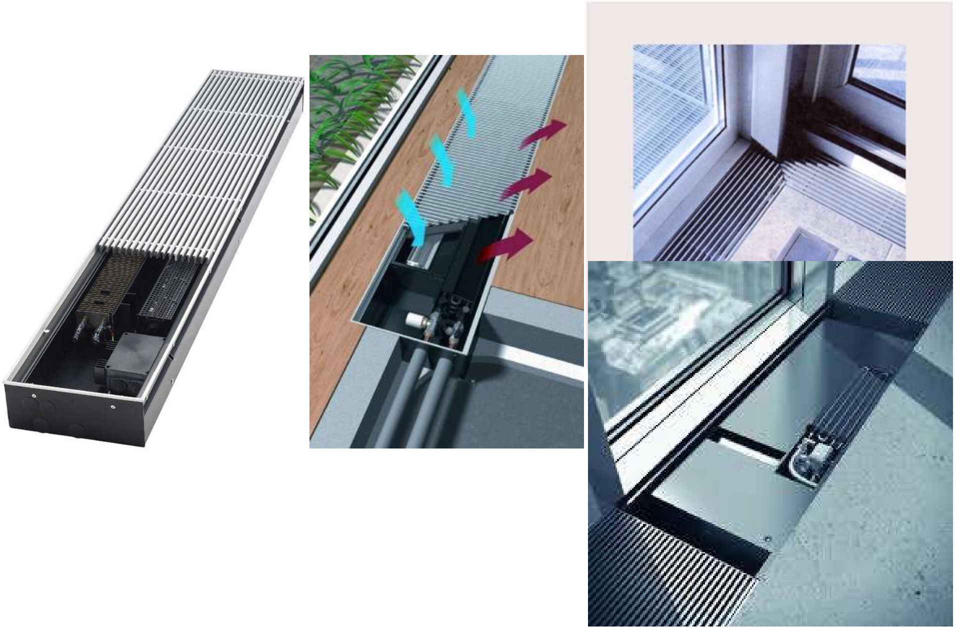


Ceiling mounted

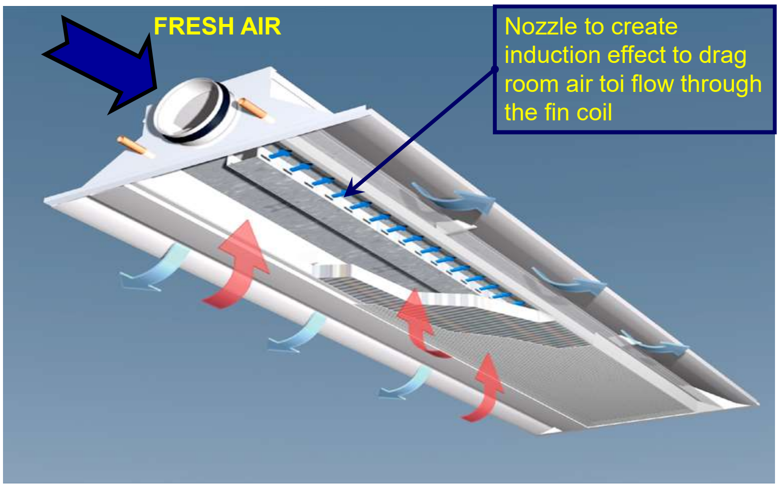
Cassette installation



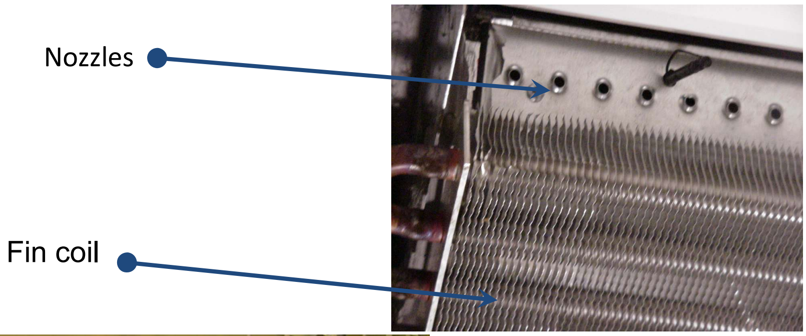
Built-in floor installation



Active beams

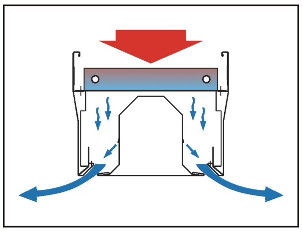


The system combines fresh air and a water terminal unit

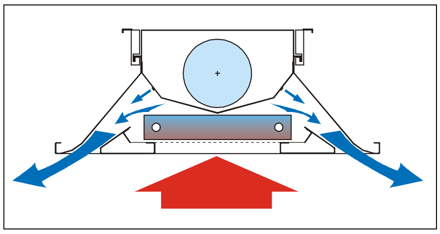


Ceiling installation, with and without false ceiling

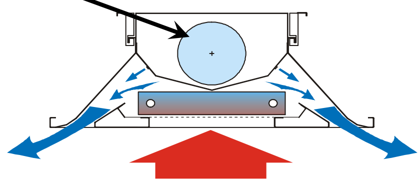
Open beams



Closed beams



High induction



Fin coil power	Primary air	Induced air	Mixed air
250 W/m	15 l/s,m	30 l/s,m	45 l/s,m
350 W/m	15 l/s,m	45 l/s,m	60 l/s,m
500 W/m	15 l/s,m	60 l/s,m	75 l/s,m
700 W/m	15 l/s,m	90 l/s,m	105 l/s,m

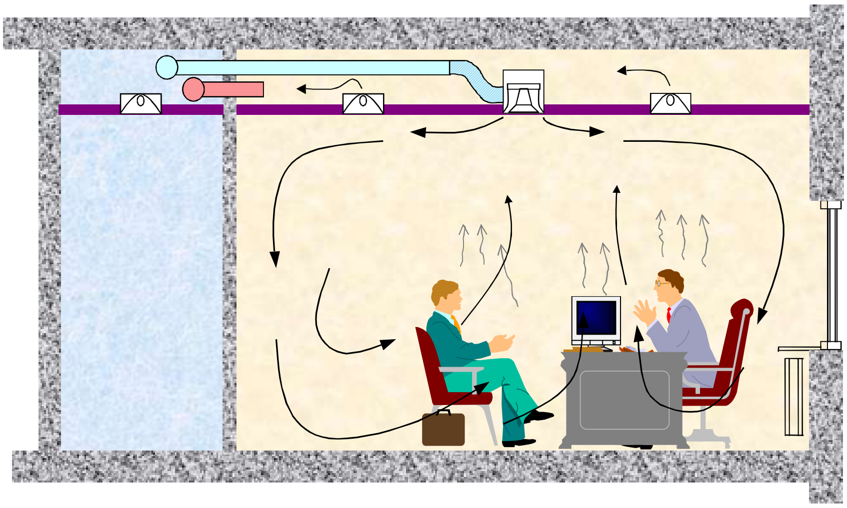
Precautions

- **Fresh air has to be completely dehumidified by the AHU**
- **The temperature of the water has to be constant (usually 15÷16 °C) and has to be always above the dew point temperature (e.g. if the air is at 25°C with RH = 50%, the dew point temperature $t_{dew\ point}$ = 14 °C)**
- **Condensing sensor on the pipes**
- **Sensor for the opening of windows**
- **The water temperature has to be greater the if the air is not dehumidified, and always above the dew point temperature**

Active chilled beams :
Recommended values
"Chilled Beam Application Guidebook – REHVA "

	COOLING	HEATING
Heating and cooling		
Optimal thermal load:	60÷80 W/m^2	25÷35 W/m^2
Maximum thermal load:	< 120 W/m^2	< 50 W/m^2
Optimal specific thermal load:	< 250 W/m	< 150 W/m
Maximum specific thermal load:	<350 W/m	< 150 W/m
Fresh air		
Specific flow rate:	5÷15 l/s m	5÷15 l/s m
Optimal temperature of supply air:	18÷ 20 °C	19÷21 °C
Pressure drop:	30÷120 Pa	30÷120 Pa

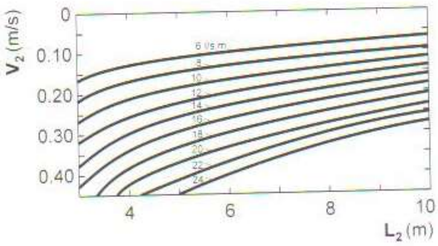
Active system:
usually it is preferable to install above the occupants (minimum velocity) and possibly in the centre of the room.
If the active beam is put in a peripheral position, it is recommended to use the unilateral flow.



	12 l/s,m · 25 W/m², 14 deg.C window · maximum velocity values (m/s)			
1.8 m	0.21	[illegible]	0.10	0.12
1.5 m	0.10	0.08	0.12	0.08
1.1 m	0.15	0.09	0.09	0.10
0.6 m	0.17	0.16	0.15	0.07
0.1 m	[illegible]	[illegible]	0.27	0.34
	3.6 m	2.4 m	1.5 m	0.6 m

	12 l/s m · 25 W/m², 14 deg C window · maximum velocity values (m/s)			
1.8 m	0.14	0.11	0.09	0.11
1.5 m	0.07	0.08	0.11	0.09
1.1 m	0.15	[illegible]	0.13	0.12
0.6 m	0.09	0.15	0.18	0.10
0.1 m	0.17	0.23	0.25	0.15
	3.6 m	2.4 m	1.5 m	0.6 m

Figure 4.9 Room air velocities in the intermediate season with the same beam installed either crosswise or lengthwise in the room. [11]



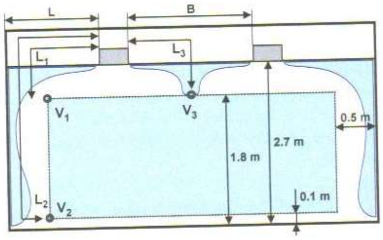


Figure 6.1 Example of velocity data of active chilled beam. Three critical points should be studied. Normally, velocity V_2 is the most critical.

Unit heaters

They are usually installed on the top of the room. They can be used in industrial applications, workshops, and in other environments where the aesthetic does not play a relevant role.
They are cheap and can be installed quite easily. Unit heaters can provide heating and cooling.
Noise can be critical and it has to be considered carefully.