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 bleed (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.
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 niche 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.
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:

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

- Thermal output (power [W])
- Overall heat exchange coefficient [W/(m² K)]
- Outer reference surface [m²]
- Average water temperature [°C]
- 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: $h_R = 5.5 \text{ W/(m}^2 \text{ K)}$

• The convective heat exchange coefficient is dependent on the temperature difference between the air and the surface of the radiator:

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

• 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:

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

Radiator model constant $n = 1.25 - 1.35$

• 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 – Choice

• Once known the peak power load of a room the amount of terminal units has to be decided (depending on 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) $q_{\text{actual}}$ is different from the declared value ($q_{\text{nominal}}$) at $t_{\text{W,average}} = 70^\circ\text{C}$ and the room at $t_i = 20^\circ\text{C}$:

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

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

$$N = \frac{q_{\text{design}}}{q_{\text{actual}}}$$

- 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 strategies 2/2

- By choosing a suitable function for reducing the average temperature in the radiator it is possible in principle to adapt the power 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 $\Delta t$ (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

![Graph showing thermal output vs. water supply temperature](image)

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;

![Diagram of convector heating systems](image)
Convector heating systems 2/2

• They can be used as additional auxiliary system for large glazing elements;
• The fin coil is usually fed by water supply at 60 °C and 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 of 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 of the fan
  - Outlet air temperature
  - Noise of the unit
- These data are provided by the manufacturer based on laboratory tests.
- Fan-coils are usually 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 residential 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.
Examples of fan-coils

<table>
<thead>
<tr>
<th>Example</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flush mounted</td>
<td>(a incasso)</td>
</tr>
</tbody>
</table>

Warm air

Fin coil

Fan

Filter

Room air
Ceiling mounted

Cassette installation
Built-in floor installation

Active beams

The system combines fresh air and a water terminal unit
Nozzles

Fin coil

Ceiling installation, with and without false ceiling

Open beams

Closed beams
High induction

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 $t_{\text{dew point}} = 14$ °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

<table>
<thead>
<tr>
<th>Fin coil power</th>
<th>Primary air (l/s,m)</th>
<th>Induced air (l/s,m)</th>
<th>Mixed air (l/s,m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>250 W/m</td>
<td>15 l/s,m</td>
<td>30 l/s,m</td>
<td>45 l/s,m</td>
</tr>
<tr>
<td>350 W/m</td>
<td>15 l/s,m</td>
<td>45 l/s,m</td>
<td>60 l/s,m</td>
</tr>
<tr>
<td>500 W/m</td>
<td>15 l/s,m</td>
<td>60 l/s,m</td>
<td>75 l/s,m</td>
</tr>
<tr>
<td>700 W/m</td>
<td>15 l/s,m</td>
<td>90 l/s,m</td>
<td>105 l/s,m</td>
</tr>
</tbody>
</table>
**Active chilled beams:**

**Recommended values**

*Chilled Beam Application Guidebook – REHVA*

<table>
<thead>
<tr>
<th>Heating and cooling</th>
<th>COOLING</th>
<th>HEATING</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optimal thermal load:</td>
<td>60÷80 W/m²</td>
<td>25÷35 W/m²</td>
</tr>
<tr>
<td>Maximum thermal load:</td>
<td>&lt; 120 W/m²</td>
<td>&lt; 50 W/m²</td>
</tr>
<tr>
<td>Optimal specific thermal load:</td>
<td>&lt; 250 W/m</td>
<td>&lt; 150 W/m</td>
</tr>
<tr>
<td>Maximum specific thermal load:</td>
<td>&lt;350 W/m</td>
<td>&lt; 150 W/m</td>
</tr>
</tbody>
</table>

**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.
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.