



## THEORY SECTION

The intention of this Theory Section is to explain the basic principles of acoustics and ventilation.

The theory section concludes with a description of the parts which are integral to a ventilation unit or an air-handling unit, i.e. fans, heaters, heat exchangers and filters.

Explanatory texts and further information are provided in the margin.

Some diagrams and formula also feature in the margins, together with examples of their application.

### Contents

Fans .....page 238

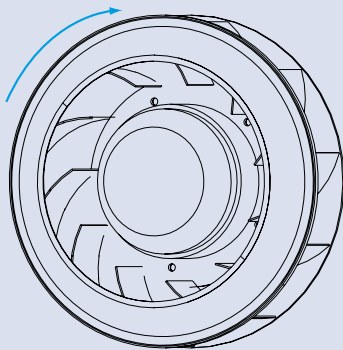
Heat recovery units, heaters and filters .....page 242

Acoustics.....page 244

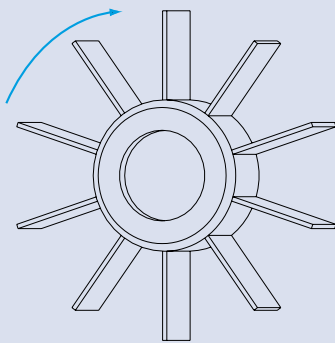
Air curtains.....page 249

Demand Ventilation .....page 250

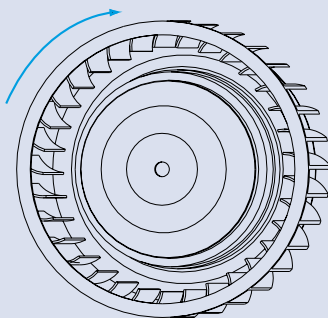
Blade profiles for radial fans  
The arrow indicates the impeller's direction of rotation.



Backward curved



Straight radial



Forward curved

## Fans

Fans are used in ventilating units to transport the air from various air intakes through the duct system to the room which is to be ventilated. Every fan must overcome the resistance created by having to force the air through ducts, bends and other ventilation equipment. This resistance causes a fall in pressure, and the size of this fall is a decisive factor when choosing the dimensions of each individual fan.

Fans can be divided into a number of main groups determined by the impeller's shape and its operating principle: radial fans, axial fans, semi-axial fans and cross-flow fans.

### Radial fan

Radial fans are used when a high total pressure is required. The particular characteristics of a radial fan are essentially determined by the shape of the impeller and blades.

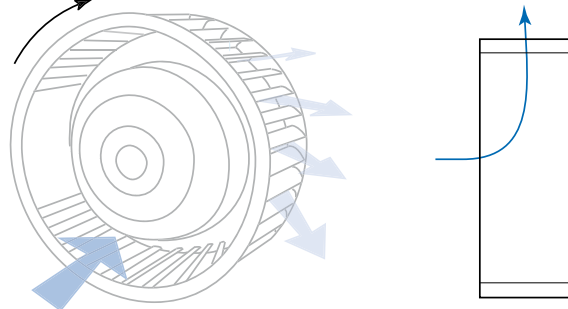


Figure 24: The air stream through a radial fan with forward-curved blades

**Backward-curved blades (B impeller):** The air volume which can be delivered by backward-curved blades varies considerably according to the pressure conditions. The blade form makes it less suitable for contaminated air. This type of fan is most efficient in a narrow range to the far left of the fan diagram.

Up to 80% efficiency is achievable while keeping the fan's sound levels low.

**Backward-angled straight blades (P impeller):** Fans with this blade shape are well suited for contaminated air. Up to 70% efficiency can be achieved.

**Straight radial blades (R impeller):**

The blade shape prevents contaminants from sticking to the impeller even more effectively than with the P impeller. No more than 55% efficiency can be achieved with this type of fan.

**Forward-curved blades (F impeller):** The air volume delivered by radial fans with forward-curved blades is affected very little by changes in air pressure.

The impeller is smaller than the B impeller, for example, and the fan unit consequently requires less space. Compared with the B impeller, this type of fan's optimal efficiency is further to the right on the diagram. This means that one can select a fan with smaller dimensions by choosing a radial fan with an F impeller rather than a B impeller.

An efficiency of approximately 60% can be achieved.

### Axial fan

The simplest type of axial fan is a propeller fan. A freely-rotating axial fan of this type has a very poor efficiency rating, so most axial fans are built into a cylindrical housing. Efficiency can also be increased by fitting directional vanes immediately behind the impeller to direct the air more accurately. The efficiency rating in a cylindrical housing can be 75% without directional vanes and up to 85% with them.

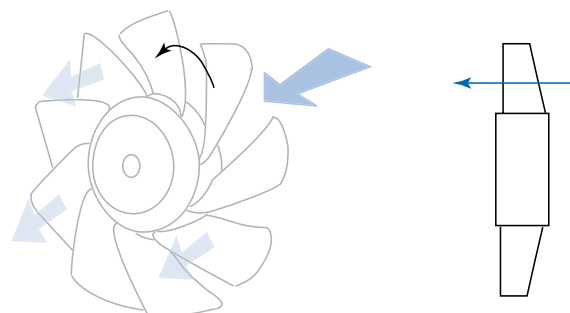


Figure 25: The air flow through an axial fan

### Mixed flow fan

Radial impellers produce a static pressure increase because of the centrifugal force acting in a radial direction. There is no equivalent pressure increase with axial impellers because the air flow is normally axial. The mixed flow fan is a mixture between radial and axial fans. The air flows in an axial direction but then is deflected 45° in the impeller. The radial velocity factor which is gained by this deflection causes a certain increase in pressure by means of the centrifugal force. Efficiency of up to 80% can be achieved.

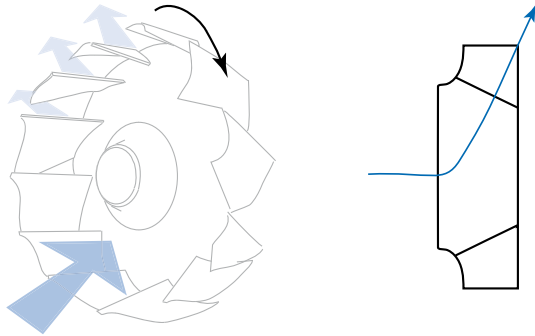


Figure 26. The air flow through a mixed flow fan

### Cross-flow fan

In a cross-flow fan the air flows straight across the impeller, and both the in and out flow are in the periphery of the impeller. In spite of its small diameter, the impeller can supply large volumes of air and is therefore suitable for building into small ventilation units, such as air curtains for example. Efficiency of up to 65% can be achieved.

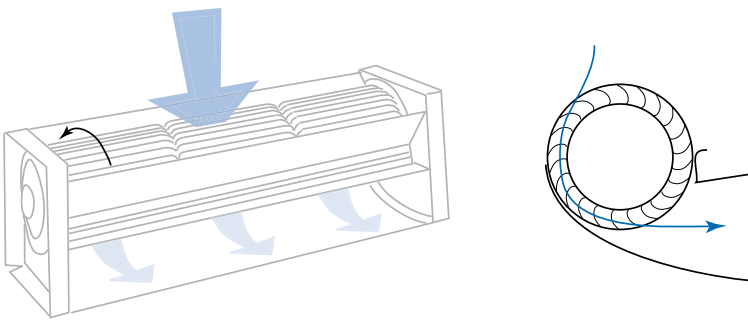


Figure 27. The air flow through a cross-flow fan

Theoretical calculation of the system line

$$\Delta P = k \cdot qv^2$$

where

$\Delta P$  = the fan's total pressure (Pa)

$qv$  = air flow (m<sup>3</sup>/h or l/s)

$k$  = constant

Example

A certain fan produces an air flow of 5000 m<sup>3</sup>/h at a pressure of 250 Pa.

A. How does one produce a system line in the diagram?

a) Mark the point on the fan curve (1) where the pressure is 250 Pa and the air flow is 5000 m<sup>3</sup>/h.

Enter the same value in the formula above to obtain a value for the constant  $k$ .

$$k = \Delta P/qv^3 = 250/5000^2 = 0.00001$$

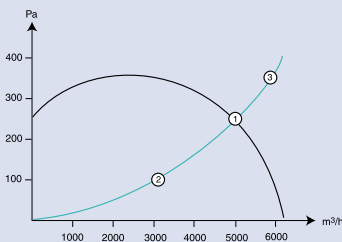
b) Select an arbitrary pressure reduction, for example 100 Pa, calculate the air flow and mark point (2) in the diagram.

$$q = \sqrt{100/(0.00001)} = 3162 \text{ m}^3/\text{h}$$

c) Do the same thing for 350 Pa and mark point (3) in the diagram.

$$q = \sqrt{350/(0.00001)} = 5916 \text{ m}^3/\text{h}$$

d) Now draw a curve that indicates the system line.



B. What will happen if the pressure in the system increases by 100 Pa, (for example because of a clogged filter)?

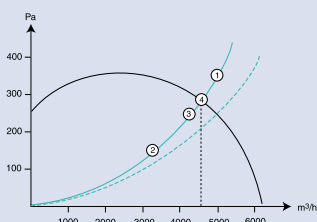
a) Calculate the constant for the new system line:  $k = 350/5000^2 = 0,000014$

b) Select two other pressure reductions, for example 150 and 250 Pa, and calculate the air flow for them.

$$q = \sqrt{150/0.000014} = 4225 \text{ m}^3/\text{h}$$

$$q = \sqrt{250/0.000014} = 3273 \text{ m}^3/\text{h}$$

c) Plot in the two new points (2 and 3) and draw in the new system line.



The new working point (4) is located at the intersection between the fan curve and the new system line.

This diagram also indicates that the pressure increase causes a reduction of the air flow to approximately 4500 m<sup>3</sup>/h.

Fan curves

The fan diagram indicates the fan's capacity at different pressures. Each pressure corresponds to a certain air flow, which is illustrated by a fan curve.

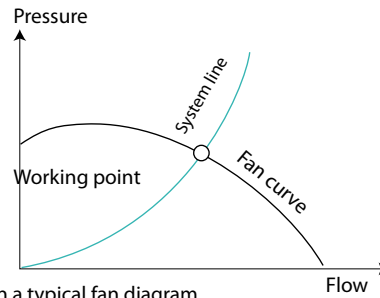


Figure 28. Curves in a typical fan diagram

System lines

The duct system's pressure requirement for various air flows is represented by the system line. The fan's working point is indicated by the intersection between the system line and the fan curve. This shows the air flow which the duct system will produce.

Each change of pressure in the ventilation system gives rise to a new system line. If the pressure increases, the system line will be the same as line B. If the pressure reduces, the system line will be the same as line C instead. (This only applies if the rotational speed of the impeller, i.e. the revolution count, remains constant).

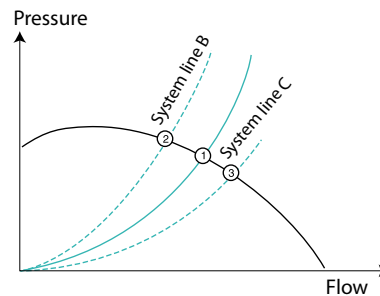


Figure 29. Changes in pressure give rise to new system lines

If the ventilation system's actual pressure requirement is the same as system line B, the working point will move from 1 to 2. This will also entail a weaker air flow. In the same way, the air flow will increase if the system's pressure requirement corresponds instead to line C.

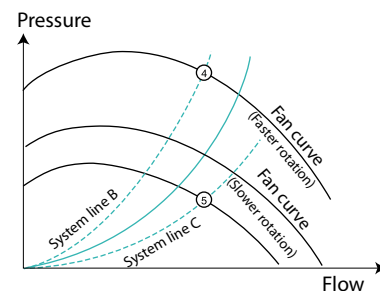


Figure 30. Increase or reduction of the fan speed

To obtain the same air flow as calculated, one can in the first case (where the system line corresponds to B) quite simply increase the fan speed. The working point (4) will then be at the intersection of system line B and the fan curve for a higher rotational speed. In the same way, the fan speed can be reduced if the actual system line corresponds to line C.

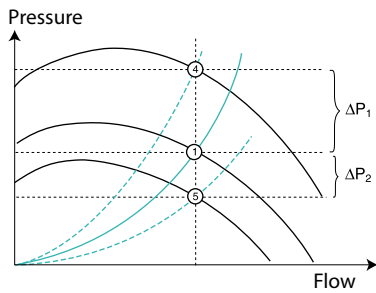


Figure 31. Pressure differences at different rotational speeds

In both cases, there will be a certain difference in pressure from that of the system for which the dimensioning has been calculated, and this is shown as DP1 and DP2 respectively in the figure. This means that if the working point for the calculated system has been chosen so as to give the maximum degree of efficiency, any such increase or decrease of the fan's rotational speed will reduce the fan's efficiency.

Efficiency and system lines

To facilitate the selection of a fan, one can plot in a number of considered system lines in a fan diagram and then see between which lines a particular type of fan should operate. If the lines are numbered 0 to 10, the fan will be completely free-blowing (maximum air flow) at line 10 and will be completely choked (no air flow at all) at line 0. This then means that the fan at system line 4 produces 40% of its free-blowing air flow.

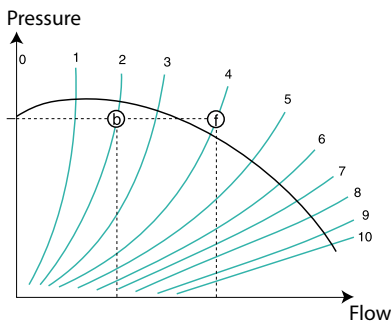


Figure 32. System lines (0-10) in a fan diagram

Each fan's efficiency remains constant along one and the same system line. Fans with backward-curved blades frequently have a greater efficiency than fans with forward-curved blades. But these higher levels of efficiency are only achievable within a limited area where the system line represents a weaker air flow at a given pressure than is the case with fans with forward-curved blades. To achieve the same air flow as for a fan with forward-curved blades, while at the same time maintaining a high level of efficiency, a fan with backward curving blades in a larger size would have to be selected.

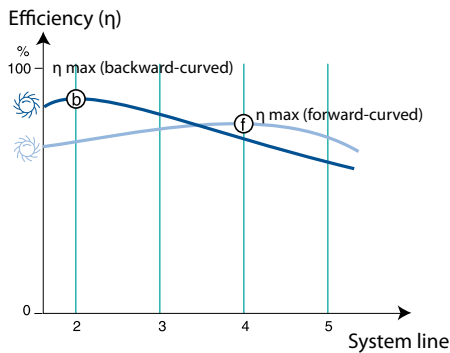


Figure 33. Efficiency values for the same size of radial fan with backward curved and forward-curved blades respectively

Definition of the system line

$$L = 10 \cdot \sqrt{\frac{\Delta p_d}{\Delta p_t}}$$

where

- L = the fan's system line
- Δpd = dynamic pressure (Pa)
- Δpt = total pressure (Pa)

Efficiency of a fan

$$\eta = \frac{\Delta P_t \cdot q}{p}$$

where

$\Delta P_t$  = total pressure change (Pa)

$q$  = air flow ( $m^3/s$ )

$P$  = power (W)

Specific Fan Power

The Specific fan power for an entire building

$$SFPE = \frac{P_{tf} + P_{ff}}{qf} \text{ (kW/m}^3\text{/s)}$$

where

$P_{tf}$  = total power for air supply fans (kW)

$P_{ff}$  = total power for air exhaust fans (kW)

$qf$  = dimensioned air flow ( $m^3/s$ )

Theoretical calculation of a fan's power consumption

$$P = \frac{P_t \cdot q}{\eta_{fan} \cdot \eta_{belt} \cdot \eta_{motor}}$$

where

$P$  = the fan's consumption of electric power from the network (kW)

$p_t$  = the fan's total pressure (Pa)

$q$  = air flow ( $m^3/s$ )

$\eta_{fan}$  = the fan's efficiency

$\eta_{belt}$  = efficiency of the transmission

$\eta_{motor}$  = efficiency of the fan motor

Fan application

It is assumed in the fan diagram that the fan's connections to the inlet and outlet are designed in a specific way. There must be at least 1 x the duct diameter on the suction side (inlet) and 3 x the duct diameter on the pressure side (outlet).

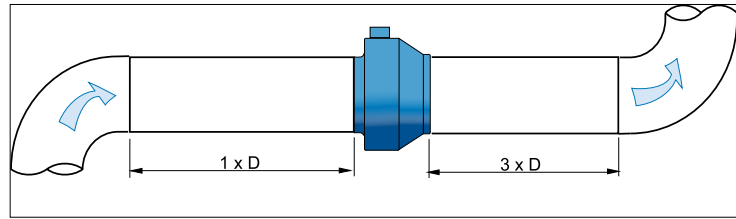


Figure 34. Correctly installed duct fan

If the connections are different from this, there could be a greater pressure reduction. This extra pressure drop is called the system effect or system dissipation and can cause the fan to produce a smaller volume of air than indicated in the fan diagram. The following factors must be considered in order to avoid system dissipation:

At the inlet

- The distance to the nearest wall must be more than 0.75 x the inlet's diameter
- The inlet duct's cross-section must not be greater than 112% or less than 92% of the fan inlet
- The inlet duct's length must be at least 1 x the duct diameter
- The inlet duct must not have any obstacles to the air flow (dampers, branching or similar)

At the outlet

- The angle at the reduction of the duct cross-section must be less than 15°
- The angle at the enlargement of the duct cross-section must be less than 7°
- A straight length of at least 3 x the duct diameter is required after a duct fan
- Avoid 90° bends (use 45°)
- Bends must be shaped so that they follow the air stream after the fan

Specific Fan Power

There are now stringent requirements to ensure that power consumption in a building is as efficient as possible so as to minimise energy costs. The Svenska Inneklimateinstitutet [Swedish Inner Climate Institute] has introduced a special concept known as the Specific Fan Power (SFPE) as a measurement of a ventilation system's energy efficiency.

The Specific Fan Power for an entire building can be defined as the total energy efficiency of all the fans in the ventilation system divided by the total air flow through the building. The lower the value, the more efficient the system is at transferring the air.

The recommendations for public sector purchasing and similar are that the maximum SFPE should be 2.0 when maintaining and repairing ventilating units, and 1.5 for new installations.

## Heat Recovery Units

### Heat recovery units

In a ventilating unit, it is often economical to attempt to recover the heat which is contained in the exhaust air and use it to warm the supply air. There are several methods for achieving this type of heat recovery.

#### Plate heat recovery units

The exhaust air and supply air pass on each side of a number of plates or lamellae. The exhaust- and supply air are not in contact with each other which results in low leakage. There may be some condensation in a plate heat recovery unit, so they need to be fitted with condensation drains. The drains should have a water seal to prevent the fans from sending the water back into the unit. Because of this condensation there is also a serious risk of ice formation, so some type of defrosting system is also needed. Heat recovery can be regulated by means of a bypass valve which controls the intake of exhaust air. Plate heat recovery units have no moving parts. High efficiency (50-90%).

#### Rotary heat recovery units (Thermal Wheels)

Heat is transferred by a rotating wheel between exhaust and supply air. This system is open and there is a risk that impurities and odours will be transferred from the exhaust to the supply air. This can be avoided to some extent by correct designed ventilation system with the right pressure conditions or by positioning the fans in a preventing way. The degree of heat recovery can be regulated by increasing or decreasing the rotational speed. There is little risk of freezing in the heat recovery unit. Rotary heat exchange units contain moving parts. High efficiency (75-95%).

#### Battery heat recovery units

Water, or water mixed with glycol, circulates between a water battery in the exhaust air duct and a water battery in the supply air duct. The liquid in the exhaust air duct is heated so that it can transfer the heat to the air in the supply air duct. The liquid circulates in a closed system and there is no risk of transferring impurities from exhaust air to supply air. Heat recovery can be regulated by increasing or decreasing the water flow. Battery heat recovery units have no moving parts. Low efficiency (45-60%).

#### Chamber heat exchangers

A chamber is divided into two parts by a damper valve. The exhaust air first heats one part of the chamber, then the damper valve changes the air stream so that the supply air is heated by the warmed-up part of the chamber. Impurities and odours can be transferred from exhaust air to supply air. The only moving part in a chamber heat exchanger is the damper valve. High efficiency (80-90%).

#### Heat pipe

This heat recovery unit consists of a closed system of pipes filled with a liquid that vaporises when heated by the exhaust air. When the supply air passes the pipes, the vapour condenses back into liquid again. There can be no transfer of impurities, and the heat recovery unit has no moving parts. Low efficiency (50-70%).

#### Pressure drop

The pressure drop caused by a completely clean filter is called the start pressure drop, and this is somewhere between 80 and 120 Pa for fine filters. After impurities have been trapped by the filter, the pressure drop will increase and the air flow will be reduced. Eventually there will be a pressure drop which makes the filter no longer usable. For fine filters this will be between 200 and 250 Pa. It is usual for filters in a unit to be fitted with some kind of filter monitor which constantly measures the pressure drop caused by the filter. This can give a signal when a pre-set pressure drop has been reached and it is time to replace the filter. In any event it is advisable to replace the filter twice a year, irrespective of whether or not the final pressure drop has been reached, so as to prevent the dirt in the filter becoming a breeding ground for bacteria. Suppliers of filters have been debating for a long time as to whether glass fibre or synthetic fibre provides the best filter material. Some research has been carried out, but without any clear results. It appears, however, that glass fibre filters maintain a better Dust Holding Capacity throughout their working life. Just as important as the selection of the filter material is the need to ensure that there is a good seal around the filter to prevent dirt and dust passing around the edge. The filter housing should be designed so that repeated filter replacements can be made without any space developing between the filter and the housing. It is also important to protect the filter from moisture as this can alter the characteristics of the filter fibres and impair its Dust Holding Capacity. Glass fibre filters are more susceptible to the effects of moisture than synthetic filters.

### Thermal efficiency

$$\eta = \frac{t_i - t_u}{t_f - t_u}$$

where

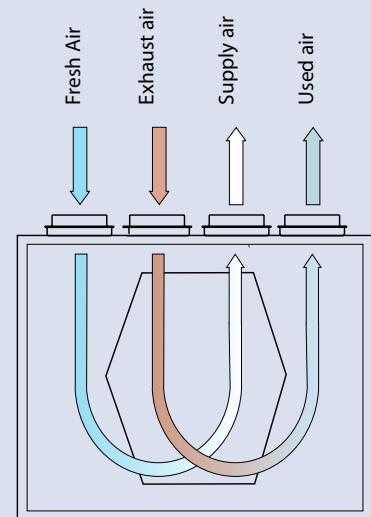
$t_u$  = outside air temperature

$t_f$  = exhaust air temp. (no heat recovery)

$t_i$  = supply air temp. (after heat recovery)

#### Counterflow plate heat recovery units

The air streams (exhaust and supply air) pass in opposite directions through the entire heat recovery unit, which results in an efficient recovery of heat.



**Water-heating battery**

The power input (kW) to a water-heating battery in a ventilating unit is:

$$Q = \frac{L \cdot 1.2 \cdot (t_i - t_u) \cdot (1 - \eta)}{3600}$$

where

L = the air flow (m<sup>3</sup>/h)

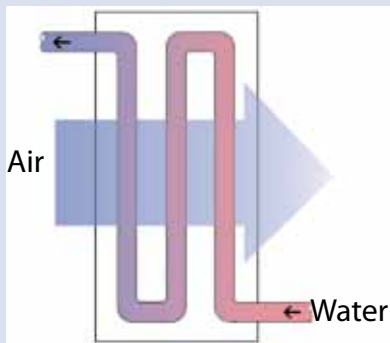
t<sub>i</sub> = required supply air temperature (°C)

t<sub>u</sub> = dimensioned outside temperature (°C)

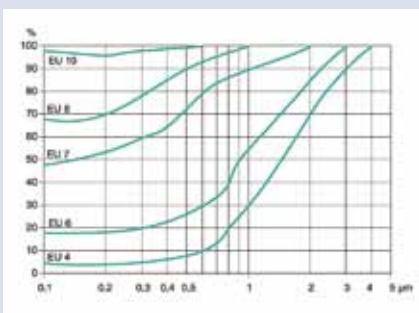
η = the efficiency of the heat recovery unit

**Water battery**

The hot water should be conducted in the opposite direction to the air, otherwise it will cool too quickly and the water battery's warming of the air will not be as efficient.



**Dust Holding Capacity for different filter classes**



**Heating batteries**

In most cases the outside air is colder than the required temperature for the supply air, so it is often necessary to warm the air before it enters the building. The air can be warmed in a heating battery, by using either a hot water, or an electric heating battery.

**Electric-heating battery**

An electric-heating battery consists of a number of enclosed metal filaments or wire spirals. They create an electrical resistance which converts the energy to heat. The advantages of the electric battery are: it has a small pressure drop, it is easy to calculate the power and it is inexpensive to install. The disadvantage is that the metal filaments have a considerable heat inertia so the electric battery has to be fitted with overheating protection.

**Water-heating battery**

Crossflow water-heating batteries are the most common type of water-heating batteries in ventilation units. The water flows at right angles and in the opposite direction to the air stream. The water is conducted from below and flows upwards through the battery, and this allows any air bubbles to collect at the highest point where they can be easily drawn off via a ventilating pipe.

Water-heating batteries have to be protected against ice formation to ensure they do not crack as the result of freezing. The greatest risk of this happening is actually when the air temperature is immediately below 0°C. Most water batteries therefore have a frost guard which stops the intake of fresh air when there is a risk of freezing. Because still water freezes faster than flowing water, it is also usual to fit an internal pump which keeps the water flowing through the battery.

The air velocity through the battery, calculated for the entire front area, should be dimensioned to 2-5 m/s. The water velocity should not be below 0.2 m/s, as this could cause difficulties with venting. Nor should the water velocity be higher than 1.5 m/s in copper pipes or 3 m/s in steel pipes, as this could lead to erosion of the metal pipes.

**Filters**

There are two reasons for using filters in an air-handling unit: to prevent impurities in the outside air from entering the building and to protect the unit's components from contamination. An analysis of the impurities in the air indicates that among other things the air contains soot particles, smoke, metallic dust, pollen, viruses and bacteria. The particles vary in size from less than 1 μm to whole fibres, leaves and insects. It is thought that these pollutants are a significant contributing factor in the cause of many asthmatic and allergic conditions, and it is therefore important for people to protect themselves against them. Since as much as 99.99% of all particles in the air are smaller than 1 μm, it is necessary to use filters in a ventilation system that are adequately fine-meshed. The filter's capacity to trap particles is called its Dust Holding Capacity and filters are often divided into three classes depending on this capacity: coarse filters, fine filters and absolute filters.

**Filter classes**

Coarse filter EU1 to EU4

Fine filter EU5 to EU9

Absolute filter EU10 to EU14

The coarse filter essentially only traps particles larger than 5 μm, and has virtually no effect at all on particles smaller than 2 μm. This means, therefore, that it does not trap soot particles, which are the most prevalent impurities in the outside air. Fine filters should be fitted in a ventilation unit instead. The best fine filters work effectively with particles larger than 0.1 μm, and therefore trap the most important impurities in the outside air.

ACOUSTICS

Basic principles of sound

Before we discuss the connection between the sound power level and the sound pressure level, we must define certain basic concepts such as sound pressure, sound power and frequency.

Sound pressure

Sound pressure is the pressure waves with which the sound moves in a medium, for instance air. The ear interprets these pressure waves as sound. They are measured in Pascal (Pa).

The weakest sound pressure that the ear can interpret is 0.00002 Pa, which is the threshold of hearing. The strongest sound pressure which the ear can tolerate without damage is 20 Pa, referred to as the upper threshold of hearing.

The large difference in pressure, as measured in Pa, between the threshold of hearing and the upper threshold of hearing, makes the figures difficult to handle. So a logarithmic scale is used instead, which is based on the difference between the actual sound pressure level and the sound pressure at the threshold of hearing. This scale uses the decibel (dB) unit of measurement, where the threshold of hearing is equal to 0 dB and the upper threshold of hearing is 120 dB.

The sound pressure reduces as the distance from the sound source increases, and is affected by the room's characteristics and the location of the sound source.

Sound power

Sound power is the energy per time unit (Watt) which the sound source emits. The sound power is not measured, but it is calculated from the sound pressure. There is a logarithmic scale for sound power similar to the scale for sound pressure.

The sound power is not dependent on the position of the sound source or the room's sound properties, and it is therefore easier to compare between different objects.

Frequency

Frequency is a measurement of the sound source's periodic oscillations. Frequency is measured as the number of oscillations per second, where one oscillation per second equals 1 Hertz (Hz). More oscillations per second, i.e. a higher frequency, produces a higher tone.

Frequencies are often divided into 8 groups, known as octave bands: 63 Hz, 125 Hz, 250 Hz, 500 Hz, 1000 Hz, 2000 Hz, 4000 Hz and 8000 Hz.

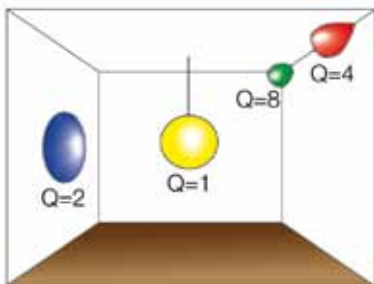
Sound power level and sound pressure level

There is a link between a sound source's sound power level and the sound pressure level. If a sound source emits a certain sound power level, the following factors will affect the sound pressure level:

The position of the sound source in the room, including the direction factor (1), the distance from the sound source (2) and the room's sound-absorbing properties, referred to as the room's equivalent absorption area (3).

1) Direction factor, Q

The direction factor indicates the sound's distribution around the sound source. A distribution in all directions, spherical, is measured as Q = 1. Distribution from a diffuser positioned in the middle of a wall is hemispherical, measured as Q = 2.



- Q = 1 In centre of room
- Q = 2 On wall or ceiling
- Q = 4 Between wall or ceiling
- Q = 8 In a corner

Figure 1. The distribution of sound around the sound source

Calculation of equivalent absorption area  $A_{eqv}$

$$A_{eqv} = \alpha_1 \cdot S_1 + \alpha_2 \cdot S_2 + \dots \alpha_n \cdot S_n$$

where

S = Size of surface (m<sup>2</sup>)

a = Absorption factor, depending on the material

n = Number of surfaces

Calculation of sound pressure level

Estimate based on figures 1, 2 and 3 together with table 1.

A normally damped room in a nursing home, measuring 30 m<sup>3</sup>, is to be ventilated. According to the information in the catalogue, the directional supply-air terminal device fitted in the ceiling has a sound pressure level (LpA) of 33 dB(A).

This applies to a room with a space damping equivalent to 10 m<sup>2</sup> Sabine, or 4 dB(A).

A) What will the sound pressure level be in this room, 1 m from the diffuser?

The sound pressure level depends on the room's acoustic properties, so first of all it is necessary to convert the value in the catalogue to a sound power level (LWA).

Fig.3 shows that  $\Delta L$  (space damping) = LpA - LWA

$$LWA = LpA + \Delta L$$

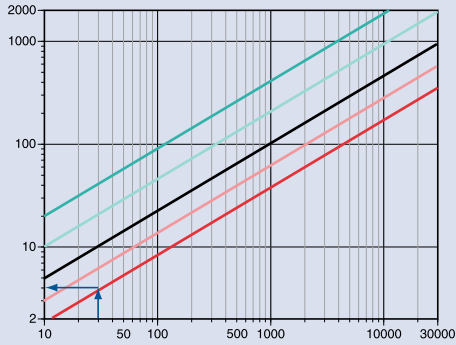
$$LWA = 33 + 4 = 37 \text{ dB(A)}$$

With the following values

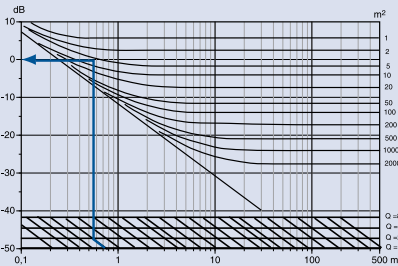
$$r = 1$$

$$Q = 2 \text{ (fig.1)}$$

and information about the room's dimensions, you can calculate the equivalent absorption area with the help of figure 2.



The equivalent absorption area is therefore 4 m<sup>2</sup>. It is now possible to use figure 3 to establish the difference between the sound pressure and the sound power.



$$L_{pA} - L_{WA} = 0$$

$$L_{pA} = 0 + L_{WA}$$

Enter the LWA value which has already been calculated.

$$L_{pA} = 0 + 37 = 37 \text{ dB(A)}$$

A) The sound pressure level (LpA) one metre from the diffuser in this particular nursing home room is therefore 37 dB(A).

This calculation has to be made for all rooms not corresponding to the information in the catalogue which assumes a standard 10 m<sup>2</sup> Sabine. The less damped (harder) the room is, the higher the actual sound pressure level will be in comparison with the value indicated in the catalogue.

2) Distance from sound source, r

Where r indicates the distance from the sound source in metres.

3) The room's equivalent absorption area, Aeqv

A material's ability to absorb sound is indicated as absorption factor a. The absorption factor can have a value between '0' and '1', where the value '1' corresponds to a fully absorbent surface and the value '0' to a fully reflective surface. The absorption factor depends on the qualities of the material, and tables are available which indicate the value for different materials.

A room's equivalent absorption area is measured in m<sup>2</sup> and is obtained by adding together all the different surfaces of the room multiplied by their respective absorption factors.

In many instances it can be simpler to use the mean value for sound absorption in different types of rooms, together with an estimate of the equivalent absorption area (see figure 2).

3) Equivalent absorption area based on estimates

If values are not available for the absorption factors of all the surfaces, and a more approximate value of the room's total absorption factor is quite adequate, an estimate can be calculated in accordance with the diagram below. The diagram is valid for rooms with normal proportions, for example 1:1 or 5:2.

Use the diagram as follows to estimate the equivalent absorption area: calculate the room's volume and read off the equivalent absorption area with the correct mean absorption factor, determined by the type of room, see also table 1.

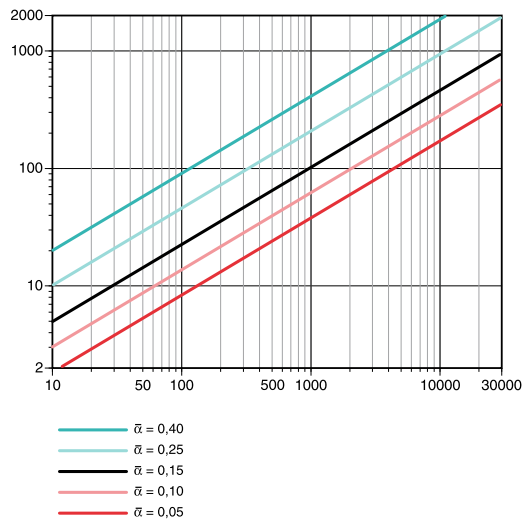


Figure 2. Estimate of equivalent absorption area.

Type of room	Mean absorption factor
Radio studios, music rooms	0.30 - 0.45
TV studios, department stores, reading rooms	0.15 - 0.25
Domestic housing, offices, hotel rooms, conference rooms, theatres	0.10 - 0.15
School halls, nursing homes, small churches	0.05 - 0.10
Industrial premises, swimming pools, large churches	0.03 - 0.05

Table 1. Mean absorption factors for different types of rooms

Calculation of sound pressure level

With the help of the factors previously described, it is now possible to calculate the sound pressure level if the sound power level is known. The sound pressure level can be calculated by means of a formula incorporating these factors, but this equation can also be reproduced in the form of a diagram.

When the diagram is used for calculating the sound pressure level, you must start with the distance in metres from the sound source (r), apply the appropriate directional factor (Q), and then read off the difference between the sound power level and the sound pressure level next to the relevant equivalent absorption area (A<sub>eqv</sub>). This result is then added to the previously calculated sound power.

The room's equivalent absorption area

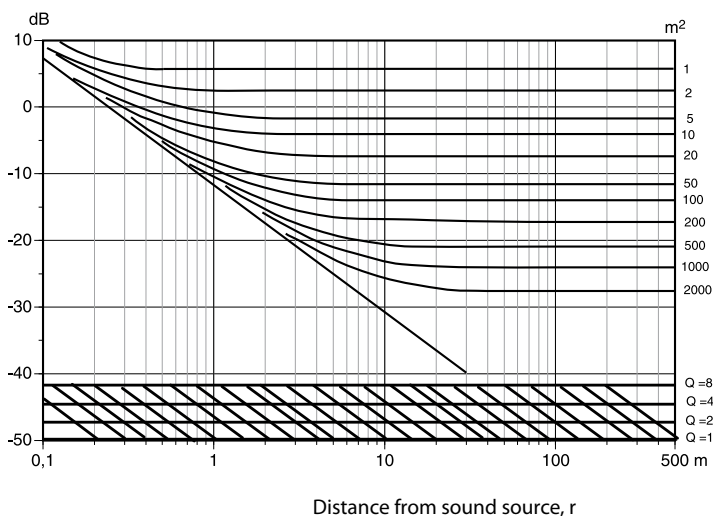


Figure 3. Diagram for estimating the sound pressure level

Near field and reverberation field

Near field is the term used for the area where the sound from the sound source dominates the sound level. The reverberation field is the area where the reflected sound is dominant, and it is no longer possible to determine where the original sound comes from.

The direct sound diminishes as the distance from the sound source increases, while the reflected sound has approximately the same value in all parts of the room.

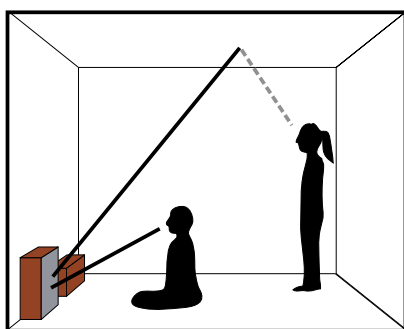


Figure 4. Direct and reflected sound

The reverberation time indicates the time it takes for the sound level to reduce by 60 dB from the initial value. This is the echo effect one hears in a quiet room when a powerful sound source is switched off. If the reverberation time is measured precisely enough, the equivalent absorption area can be calculated.

Calculation of sound pressure level

$$L_{pA} = L_{wA} + 10 \cdot \log \left( \frac{Q}{4\pi r^2} + \frac{4}{A_{eqv}} \right)$$

where

L<sub>pA</sub> = sound pressure level (dB)

L<sub>wA</sub> = sound power level (dB)

Q = direction factor

r = distance from sound source (m)

A<sub>eqv</sub> = equivalent absorption area (m<sup>2</sup> Sabine)

Calculation of reverberation time

If a room is not too effectively damped (i.e. with a mean absorption factor of less than 0.25), the room's reverberation time can be calculated with the help of Sabine's formula:

$$T = 0.163 \cdot \frac{V}{A_{eqv}}$$

where

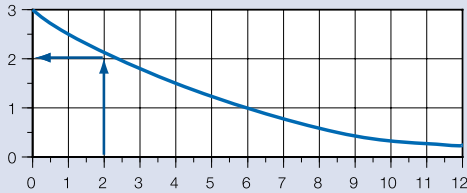
T = Reverberation time (s). Time for a 60 dB reduction of the sound pressure value

V = Room volume (m<sup>3</sup>)

A<sub>eqv</sub> = The room's equivalent absorption area, m<sup>2</sup>

**Example of addition**  
There are two sound sources, 40 dB and 38 dB respectively.

1) What is the value of the total sound level?

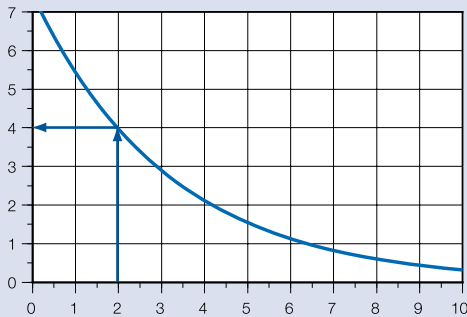


The difference between the sound levels is 2 dB and, according to the diagram, 2 dB must be added to the highest level.

1) The total sound level is therefore 42 dB.

**Example of subtraction**  
The total sound level is 34 dB in a room fitted with both supply and exhaust ventilation systems.  
It is known that the supply system produces 32 dB, but the value for the exhaust system is not known.

2) What is the sound level produced by the exhaust system?



The difference between the total sound level and the sound level of the supply system is 2 dB. The diagram indicates that 4 dB must be deducted from the total level.

2) Therefore the exhaust system produces 30 dB.

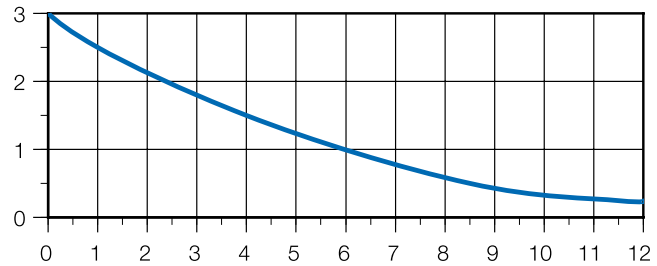
**Several sound sources**

To establish the total sound level in a room, all the sound sources must be added together logarithmically. It is, however, often more practicable to use a diagram to calculate the addition or subtraction of two dB values.

**Addition**

The input value for the diagram is the difference in dB between the two sound levels which are to be added. The dB value to be added to the highest sound level can then be read off the scale.

To add to the higher level, (dB)



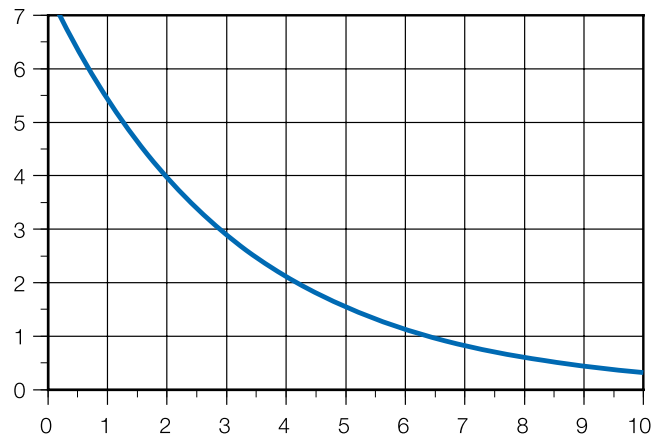
Difference between the levels to be added, (dB)

Figure 5. Logarithmic addition

**Subtraction**

The input value for the diagram is the difference in dB between the total sound level and the known sound source. The y scale then shows the number of dB that have to be deducted from the total sound level to obtain the value for the unknown sound source.

To deduct from the total level (dB)



Difference between the total level and sound source

Figure 6. Logarithmic subtraction

Adjustment to the ear

Because of the ear's varying sensitivity at different frequencies, the same sound level in both low and high frequencies can be perceived as two different sound levels. As a rule, we perceive sounds at higher frequencies more easily than at lower frequencies.

A filter

The sensitivity of the ear also varies in response to the sound's strength. A number of so called weighting filters have been introduced to compensate for the ear's variable sensitivity across the octave band. A weighting filter A is used for sound pressure levels below 55 dB. Filter B is used for levels between 55 and 85 dB, and filter C is used for levels above 85 dB.

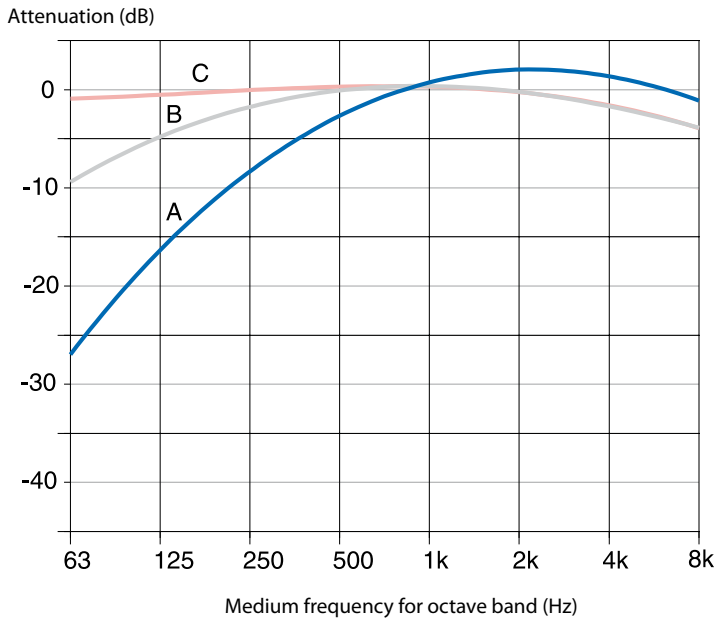


Figure 7. Damping with different filters

The A filter, which is commonly used in connection with ventilation systems, has a damping effect on each octave band as shown in table 2. The resultant value is measured in dB(A) units.

Hz	63	125	250	500	1k	2k	4k	8k
dB	-26,2	-16.1	-8.6	-3.2	0	+1.2	+1.2	-1.1

Table 2. Damping with the A filter

There are also other ways of compensating for the ear's sensitivity to different sound levels, apart from these filters. A diagram with NR curves (Noise Rating) shows sound pressure and frequency (per octave band). Points on the same NR curve are perceived as having the same sound levels, meaning that 43 dB at 4000 Hz is perceived as being as loud as 65 dB at 125 Hz.

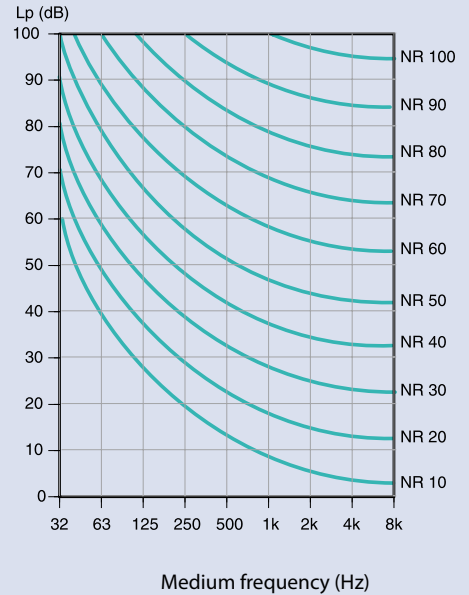
Sound attenuation

Sound attenuation is principally achieved in two ways: either by absorption or by reflection of the sound.

Attenuation by absorption is achieved by internal insulation in ducts, by special silencers or by means of the room's own sound absorption. Attenuation by reflection is achieved by forking or bending, or when the sound bounces back from a supply-air device into the duct, which is referred to as end reflection.

The degree of sound attenuation can be calculated by using tables and diagrams presented in the relevant suppliers technical documentation.

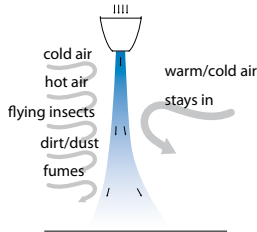
NR Curves



**Air Curtains**

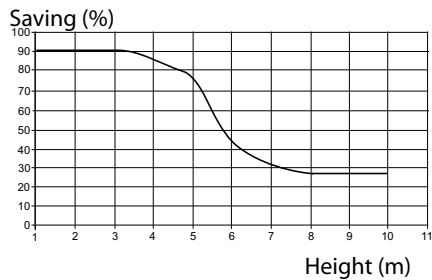
An open door is an invitation, something every shop owner knows! With the help of an air curtain you can achieve this and still avoid cold draughts or warm air coming in. However this is not the only reason why air curtains are so frequently used.

**Shut-out Function**

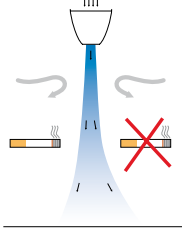


Separate climate zones, no cold draughts or hot air coming in. No insects, dirt, dust, fumes or pollution. Energy saving: with our air curtains the energy loss can be reduced by 70-90 %. This will lower heating and air conditioning costs.

Ideal for airports, hotels, offices, restaurants, shops, shopping malls, warehouses, grocery stores.

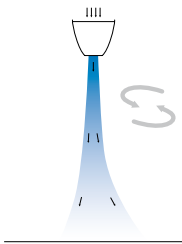


**Zoning Function**



The zoning function is perfect for separating air conditioning zone and non-air-conditioning zone; smoking area and non-smoking area. Ideal for lounges, lobbies, restaurants, bowling alleys.

**Circulation Function**



Facilitate air circulation in spacious areas. Ideal for halls and lobbies.

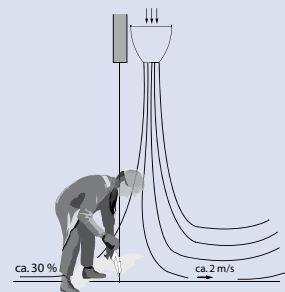
**Drying and heating Function**



Air curtains with heating elements contribute to the drying of the floor as well as to the heating of e.g. a shop. Ideal for restaurants, shops, shopping malls.

**Installation**

Put the air curtain as close as possible to the entrance, it should cover the whole door width. When installed to separate cooling or freezing rooms the air curtains should be put on the warmer side and tilted approx. 15° towards the warmer side. This is done to prevent the air curtain from blowing cold air, which can be felt like a draught, into the warm room and to keep the operating temperature for the electrical motor in the recommended temperature area. On Portier Basic and Portier Grand, this is easily done by adjusting the outlet grill.

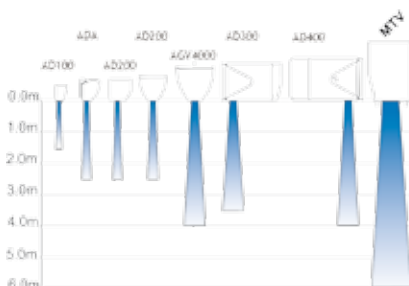


Approx. 30 % of the airflow should be directed outwards in order to prevent cold draught by the floor. To find the airflow's split location hold a handkerchief by the corner approximately 30 cm above the floor and move it gently back and forth in the doorway. The split location should be in the middle of the doorway or a little outside.

**Selection**

In our air curtain range you will find air curtains for most applications. You can be sure of always receiving the best combination between, air velocity, air flow and, if desired, heating power for optimum comfort.

Selecting the best suited air curtain is easy. Choose the air curtain after the height of the door; we have air curtains for every door height. The length of the air curtain should be equal or wider than the entrance. The sound level should also be as low as possible.



One has to decide if an air curtain with or without heating is desired. Air curtains with heating are preferred for drying and heating purposes but also add extra comfort, blowing tempered air

For air curtains with electrical heating it is easy to calculate the temperature increase knowing the heating power (P) and the air flow (q).

$$P \text{ (kW)}, q \text{ (m}^3\text{/s)}$$

$$\Delta T = \frac{P}{q \cdot 1.2}$$

The factor 1.2 is the approximate value of Density (p) \* Heating Capacity (Cp) of tempered air.

Ex:  $P = 12 \text{ kW}$   $q = 2700 \text{ m}^3\text{/h} = 2700/3600 = 0.75 \text{ m}^3\text{/s}$   
 $DT = 12 / (0.75 * 1.2) = 13.3^\circ\text{C}$

The temperature increase, DT, is the temperature difference between the inlet and the outlet temperature. DT is also an important factor when you compare air curtains.

The output power and temperature increase can be much higher using air curtains with hot water coil but depends of course of the system's water temperature. Last but not least, do not forget the appearance of your air curtain. Why degrade a beautiful entrance with an ugly air curtain. Choose one of our air curtains – you will not regret it!