General informations on air diffusion systems

Indoor Air Quality

Indoor air quality conditions change according to the type of application, the activities and the type of clothing used.
UNI 10339 standard recommends the following temperature and humidity values for residential and tertiary facilities:

Winter conditions

Dry bulb temperature (tdb): ≤ = **20 °C**
Relative humidity: **between 35 - 45%**

Summer conditions

Dry bulb temperature (tdb): ≥ = **26 °C**
Relative humidity: **between 50 ÷ 60%**

The standards foresee some exceptions for certain types of institutions such as: hospitals, nursery schools, historical buildings and museums, data processing centers, trade show areas, religious places, etc. Hence, room temperatures can differ from the ones mentioned above; even according to the preferences of each customer.

Table 1 shows the conditions applied to the various residential and tertiary buildings. These figures are proposed by ASHRAE (American Society of Heating, Refrigerating and Air Conditioning Engineers), therefore they are approved and authorized.
The table indicates 5 series of figures for each category:

- Comfortable winter and summer temperature
- Speed of air
- Number of air changes per hour
- Required filtering efficiency
- Hours of the day in which the thermal load reaches the maximum value.

The temperature values in the table should be compared to the external temperature to maintain the difference between indoor and outdoor values no higher than 5÷7 °C. There are two reasons for this: firstly, so that people coming from outside, feel a pleasant sensation when they enter a room and not an unexpected and unpleasant feeling of cold (potentially harmful); secondly to limit the energy consumption of the system during peak outdoor temperature values.
Tab. 1 does not indicate the necessary external ventilation air flow rates.

They must be determined always taking into account the UNI 10339 standard or other regional or international standards.
Certain external air flow rates, according to the UNI 10339 standard, are contained in *tab. 2* for a group of typical residential facilities.
The effects of the speed of the air in air conditioning applications are schematically summarized in *tab. 3*. As you can see, the comfort value goes from **0,13** and **0,25** m/s. Specific values per facility are in any case indicated in the UNI 10339 standard.

Tab. 1 *Typical project conditions for residential facilities*

Type of application	Winter		Summer		Speed of air m/s	Air changes	Filter performances (ASHRAE std. 52-76) opacimetric %	Peak time air flow rate
	°C	U.R. %	°C	U.R. %				
Hotels - Rooms	20 - 22	40 - 50	25 - 26	45 - 50	0,13 - 0,15	4 - 10	> 60	15.00 - 16.00
Apartments			24 - 26	45 - 50	0,13 -0,15	4 - 10	> 35	14.00 - 15.00
Shops, banks, etc.	22 - 23	25 - 30	24 - 26	45 - 50	0,15 - 0,25	4 - 10	> 35	15.00 - 16.00
Coffee shops, snack bars			23,3-25,6	55 - 60	0,13 - 0,15	8 - 12	> 35	13.00 - 14.00
Restaurants	21 - 23	20 - 30	26	40	0,25 at 1,8 mt. from floor	12 - 15	> 35	13.00 - 14.00
Offices			23,3-25,6	40 - 50	0,13 - 0,23	4 - 10	≥ 60	16.00
Night Clubs	21 - 23	20 - 30	23,3-25,6	50 - 60	< 0,13 at 1,5 mt. from floor	20 - 30	> 35 active carbon + filters	2.00 - 4.00

Source: ASHRAE

Tab. 2 *External air flow rate per person, according to the UNI 10339 standard*

Type of building or environment		External air flow rate per person l/s	m³/h
Buildings	- Residential buildings	11	40
Hotels	- Rooms	11	40
	- Dining rooms	10	36
	- Conference rooms	5,5	20
Offices	- Single and open space	11	40
	- Meeting rooms	10	36
	- Data processing offices	7	25
Recreational or religious buildings	- Cinemas, theaters	5,5	20
	- Museums, exhibition halls	6	22
	- Bars	11	40
	- Restaurants and self-services	10	36
	- Pastry shops	6	22
	- Dancing clubs, discos	16,5	60
Department stores	- Ground floor	9	32
	- Upper floors	6,5	23
Shops and sections of department stores	- Beauty salons, barber shops	14	50
	- Clothing, shoe, furniture, eye-glasses, flower and photo shops	11,5	41
	- Food, laundry and pharmacy shops	9	32
Public areas	- Banks, trade show areas	10	36

Tab. 3 *Effect of the speed of air on people in a room*

Speed m/s	Effects on people	Typical applications
0 - 0,08	Oppression, stuffy air	None
0,13	Ideal project conditions	Residential and tertiary indoor air quality systems
0,13 - 0,25	Ideal conditions for commercial areas. *A speed of 0,25 m/s is the maximum acceptable for theses environments*	Industrial system
0,35	Unpleasant feeling, small sheets of paper move	Department stores, supermarket systems, etc.
0,40	Limiti of acceptable conditions for people that move around a bit	Systems for department stores, manufacturing buildings, etc.

In air conditioning systems, the main problem in reaching good indoor air quality levels is the uniform distribution of the air in the environment. The supply air flow must extensively clean the room, covering the number of air changes established, but without exceeding the speed values indicated.

Most of the complaints are caused by air distribution systems that haven't been designed or installed properly, or both. Choosing the right type of diffuser is in fact very important to guarantee satisfying indoor air conditions.

Heat given off by people and convective air movements

The human body, as we all know, constantly produces heat, according to the mass and the activity being carried out. This heat generates convective air movements around the person, because the surrounding air is heated through contact, it decreases its density and then moves upwards. We must take into account these constant air motions, especially where there are crowds or a high concentration of people, like at trade shows, theaters, cinemas, etc.
Tab. 4 Indicates approximate figures of heat and convective air flows produced by an average person.

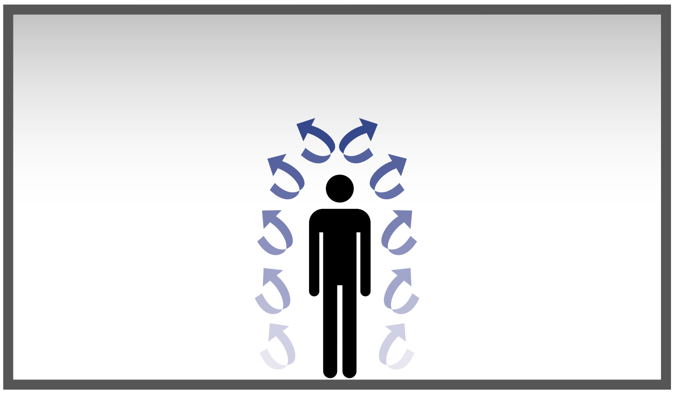


Fig. 1 *Convective movement*

Tab. 4 *Heat produced by an average person and convective air flow around the person*

Activity the person is doing	Heat produced W	Convective air flow rate l/s
Resting, sitting	100	8 - 10
In activity, sitting	130	10 - 12
Light activity, standing	170	25 - 30
Average activity, standing	200	30 - 35
Intense activity, standing	300	35 - 40

Application and functional suggestions

Before facing the specific issue of air distribution, we would like to give you a few general suggestions on the selection of the system and the application of the diffusers or exhaust elements.

- For wide and crowded areas we suggest all-air systems.
- The distribution of air in big areas is more efficient with ceiling diffusers or displacement diffusers rather than with wall grilles.
- The position of the exhaust devices is very important to avoid creating short-circuits between supply and exhaust systems.
- When you need a high number of air changes, high induction diffusers are the best choice. They rapidly equalize the conditions of supply air compared to the conditions of the air of the room and prevent cold air drafts.
- Air flow rate being equal, it is better to use many small diffusers than just one big one.
  The distribution is more uniform and more silent.
- To neutralize the effects of big glass walls, we recommend the installation of linear diffusers. The linear air flow could neutralize the effects both in summer and winter. It's better than many other solutions.
- What is important is the zone division of the system. This will guarantee a distribution that will match, as much as possible, the groups of people subject to the same conditions. However, always keep in mind that the higher the number of areas, the higher the cost of the system.
- The position of the room thermostat is very important for creating good indoor air conditions.
  The position must be chosen very carefully. A thermostat hit by air flows will not react correctly, thus causing the system to work irregularly.
  Particularly, the thermostat must not be positioned near a grille or a supply diffuser, nor near an exhaust grille.
- The position of outdoor ventilation air intake grilles and stale air exhaust elements must be chosen very carefully to especially avoid:
  - the intake of air blown out from nearby cooling towers. This condition is very important to avoid the distribution of Legionnaire's bacteria in the air (Legionnaire's disease can be lethal)
  - short circuits between outtake and intake air
  - the effect of prevailing winds which, due to the pressure or the depression exerted on the building, can alter the regular distribution of the air.
  - the intake of air polluted from exhaust gases, urban traffic, etc.

Currently there are two very different air distribution systems.

The mixing system
This system was traditionally used by the first air conditioning systems up to today, and most of the grilles and diffusers on the market today still use it.
It consists in mixing the primary air, supplied by the grille or the diffuser, and the secondary air (the air in the room), with temperature and speed equalization.

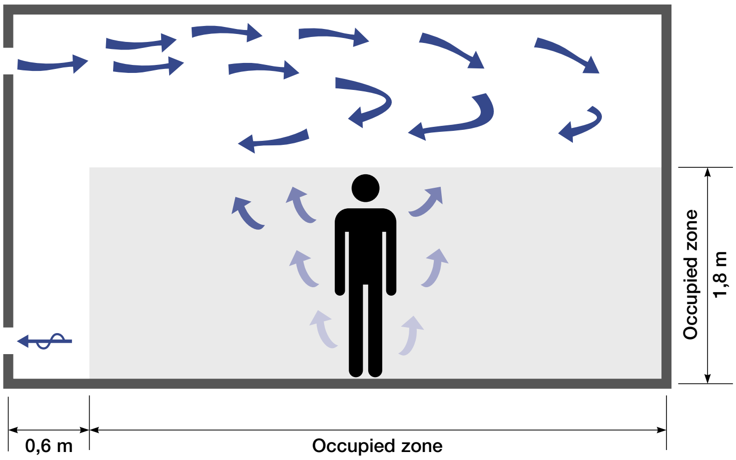


Fig. 2 *Mixing system*

The displecement system
This system is much more recent and it was developed originally in Northern Europe for industrial facilities.
It consists in the supply of a flow of fresh air, with specific features, that is not mixed with the air in the room. On the other hand, it lifts it constantly upward, where it is captured by the grilles or other terminals and totally or partially eliminated.

This is how the so-called "*displacement diffusers*" , described later, work.
Regardless of the system chosen, there are certain functions and requirements that must be met.
The air must be distributed uniformly in the entire area, in order to completely clean it and it must generate the following conditions:

- neutralization of thermal loads, positive or negative, in the room
- maintenance of temperature gradients within certain limits determined on both the vertical and horizontal level
- development of uniform motions within certain speed values in the room
- collection of the dust particles suspended in the air and transportation towards exhaust devices.

On the other hand, these conditions must **not** be generated because they could cause problems:

- excessive air speed
- creation of stagnating and stratification areas
- cold air drafts in the room
- localized flows *(usually caused by an uneven distribution of the air)*
- excessive room temperature variations on the vertical and/or horizontal level
- short circuits of supply air towards the exhaust device.

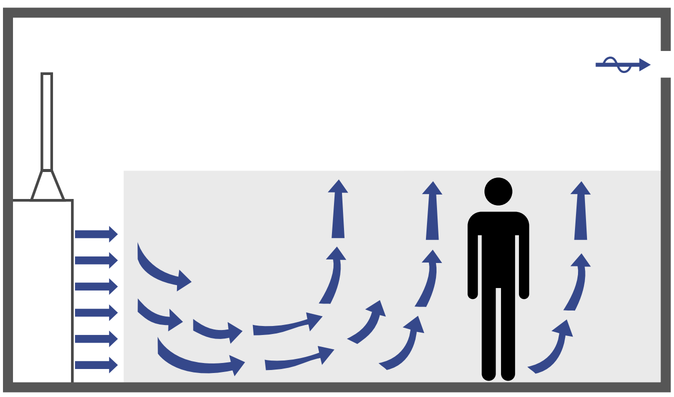


Fig. 3 *Displacement system*

Basic air distribution concepts

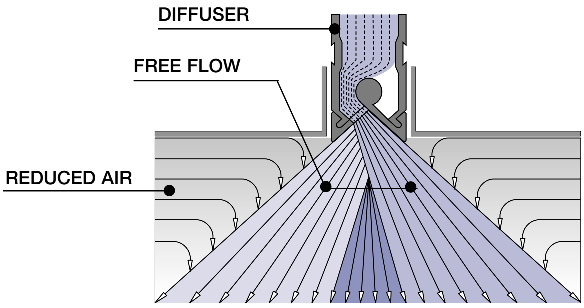


Fig. 4 *Induction system*

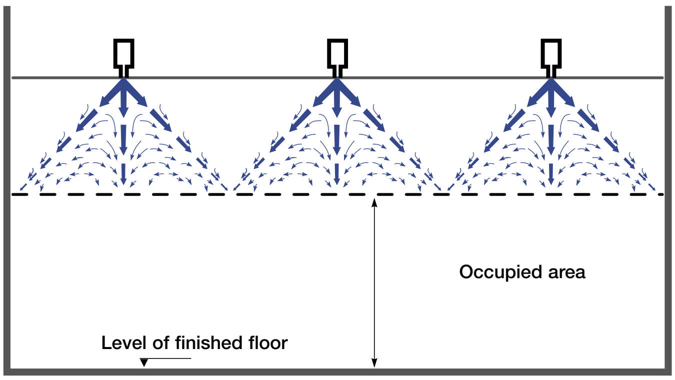


Fig. 5 *Example of the distribution of air through an induction system*

Induction

Induction is a phenomenon through which primary air, or supply air, produced by the diffuser drags a certain quantity of air in the room.
The two flows are mixed and the temperature is balanced. The “induction rate” of a diffuser is the number of air parts of the room that is dragged by a part of the air supply at a reference distance by the diffuser itself.
The higher the induction rate, the faster the two air flows mix and the temperature balances off.
High induction diffusers are particularly suitable for environments where a high number of air changes are required, because they produce a good distribution of the air with a great air flow rate and they prevent cold air drafts.
High induction diffusers distribute air with high induction rates. Hence they can operate with wide temperature differentials, which reach 14 K.
This allows for a reduction of the air flows needed compared to traditional diffusers.

They work according to the principle of supplying several individual flows, directly towards the occupied area, hence with a non-tangential trend, as shown in the drawings on the left.

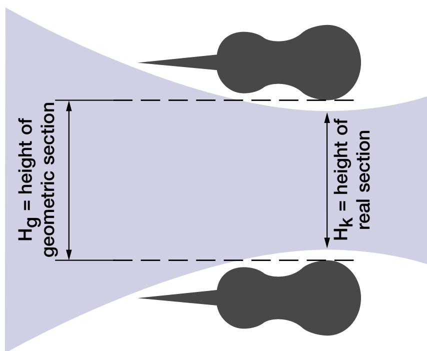


Fig. 6 *Contraction of the air flow grain*

Real passage section

The real passage section of the air (AK) through a grille or a diffuser is the section really used by the air flow to move outwards. It is influenced by the contraction of the fluid particles of the flow and it is lower than the net geometric sections, minus a K coefficient called “contraction factor” which depends on the shape and configuration of the blades.

The rule is:

A_k = ***Ageom*** x ***kr***

Where 0.7 </= k </= 0.9 for supply
and 0.5 </= k </= 0.8 for exhaust.

The real speed (V_k) of the air eliminated by the diffuser can be calculated as follows:

V_k = ***Air flow rate :*** A_k

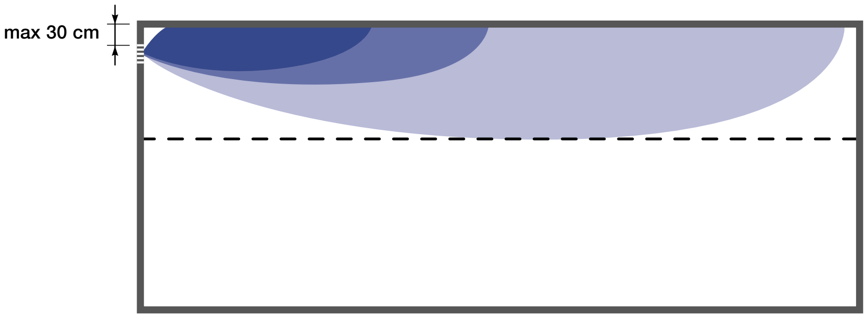


Fig. 7 Air throw pattern with Coanda effect in cooling conditions

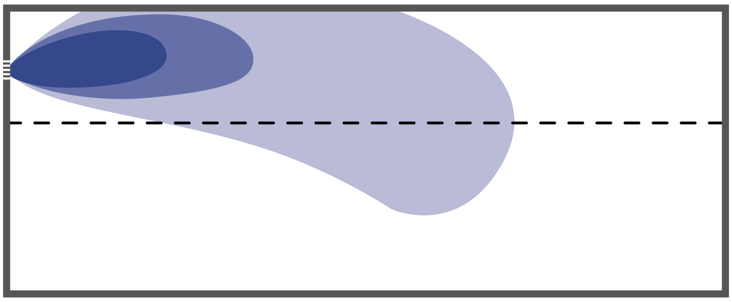


Fig. 8 Air throw pattern without Coanda effect in cooling conditions

Coanda effect

The **Coanda** effect (after the name of the physicist who discovered it), also called *"ceiling effect"*, consists in the adherence to the ceiling of the flow of air exhausted by a diffuser or a grille. The Coanda effect is created only if the air is supplied at a certain height from the ceiling itself (max 30 cm).
It contributes to increasing the flow of the diffuser (about 20% more than a diffuser that does not use the Coanda effect), also foreseeing cold air drafts in the room. The Coanda effect requires the real speed of the air eliminated by the diffuser to be higher than **2 m/s**.

Envelope

It represents the geometric surface of the supply air flow in relation to which the measured air speed keeps the same value.

Air throw

It is the maximum distance between the center of the diffuser and a surface tangent to a certain envelope, perpendicular to the direction of the flow, in which the speed of the air (Vt), in the selection tables of our products, is **0.33 m/s.**

Air fall

It is the vertical distance between the center of the diffuser or grille and the lowest point on the horizontal surface tangent to an envelope in which the speed of the air is 0.25 m/s.
Generally, the fall refers to the introduction of cold air in a room.

Air rise

It is the vertical distance between the center of the diffuser or the grille and the highest point on the horizontal surface tangent to an envelope in which the speed of the air is 0.25 m/s.
Air ascent generally refers to the introduction of hot air in the room.

Diffuser radius
(for conventional diffusers with 3 m. high rooms).

It is the distance between the center of the diffuser and a vertical surface tangent to an envelope in which the speed of the air has three specific values:
minimum radius: distance between the center of the diffuser with an air speed of V_t 0.6 m/s and the vertical surface tangent to the envelope with residual air speed V_r of 0.25 m/s
average radius: distance between the center of the diffuser with an air speed of V_t 0.33 m/s and the vertical surface tangent to the envelope with residual air speed V_r 0.17 m/s
maximum radius: distance between the center of the diffuser with an air speed of V_t 0.25 m/s and the vertical surface tangent to the envelope with residual air speed V_r 0.12 m/s

Features of the mixing diffuser system

In the mixing system, the movement of the air flow in a room can consist of several different combinations of drafts, sub-drafts and vortexes, according to the size of the room, the position of partition walls and furniture, the activity of the people in the room, the temperature gradients, the position of the supply diffusers and the exhaust elements, etc.

The flow of air in the room especially depends on the outflow speed and the physical features of the diffuser.
There is a relation between the turbulence of the air flow in the area occupied and the features of the air flow of the diffuser itself. The diffusers must also be chosen to offer a uniform distribution of the air without producing cold air drafts in the occupied space. They must be built for the maximum air speed that does not exceed the specific noise level for that room.

These are the most common terminals and diffusers currently on the market:

• *Wall grilles*
They are not very expensive and they are very easy to install compared to other terminals, but they do have limits as regards the treatment of high density thermal loads and as regards the uniformity of the distribution of air in bigger rooms. Today, their design is rejected by architects in certain elegant rooms.

• ***Ceiling, circular, square or rectangular diffusers, with concentric cones or elements or perforated***
The treatment capacity of thermal loads and air distribution are favorable but they generally require a false ceiling.

• **linear ceiling diffusers**
They provide a good distribution of the air in long rooms and they effectively neutralize the effect of long glass surfaces. Their design is accepted by modern architecture, also because they tend to disappear in the false ceiling.
Over the past years, new diffusers have been created that have high induction operating features.
The most popular are:

- *twist flow diffusers, ceiling and wall versions, with fixed and variable throws*
- *linear, square, rectangular or circular ddiffusers with multiple throws*
- *floor diffusers*
- *spot diffusers*
- *under-seat diffusers.*

As we have said, all these diffusers, including the ones listed before, use the mixing procedure: the air distributed in the room is mixed with the room air via the induction effect of the diffuser. They are described in this manual together with the standard models listed above.

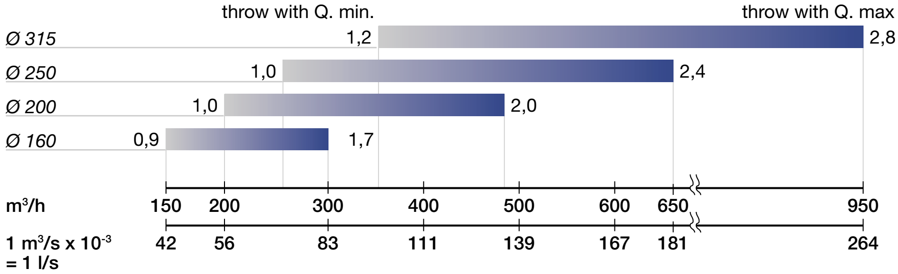
Choosing the terminal unit

After choosing the type of mixing diffuser and grille, you need to determine the air flow rate, the outflow speed, the pressure drop and the noise level. *Tab. 5* indicates the approximate performance levels for standard diffusers and grilles. According to these figures it is quite easy to check the compliance of a certain terminal with the air flow rate requirements, number of air changes needed and temperature differences.

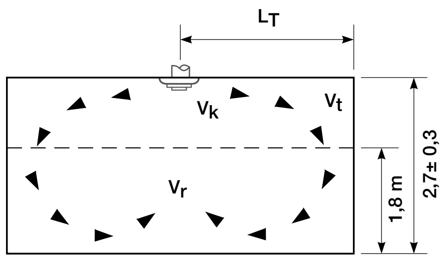
The throw

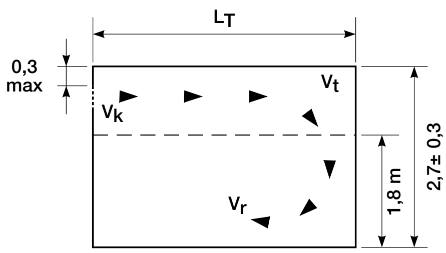
The flow of the diffuser or the grille must be equal to the length of the room.
The values in the quick selection tables of our products refer to a terminal speed (Vt) of 0.33 m/s, and a residual speed (Vr) in the occupied area of 0.17 m/s with a room height of 3m.

Quick selection example
Every single quick selection it is based on NR and pressure drop (Pa) values indicated near the tables.



	Q min.	Q max
NR	< 25	< 35
Pressure drop Pa	10	< 30





Product quality certifications

*The air flow rates and the pressure drop values contained in the technical tables of the main products of this manual are certified in accordance with the **UNI 8728 and prEN 12238** standards, by an independent certified body in full compliance with the legislation in force regarding energy saving standards.*

Pressure drop

Depending on the expected work conditions it is possible to select the pressure drop.
We suggest keeping it as low as possible for two reasons:

- to limit the noise level, this would assure a more silent operation
- to limit the energy consumption level of the fan.

Tab. 5 *Performances of various types of traditional air diffusers*

Type of diffuser	Air flow rate for sq.m. of floor surface **l/s x m²**	Max. number of air **Change/hour***	Typical difference temperature (Δt) room air/inlet cooling/heating **°C**
Grilles	3 - 6	7	-8 / 15
Linear diffusers	4 - 10	12	-11 / 15
Perforated diffusers	5 - 15	18	-11 / 11
Concentric diffusers	5 - 18	20	-11 / 20

*** Number of air changes/hour referred to a 3 m high ceiling***

Tab. 6 *Performances of twist flow diffusers for residential facilities*

Installation height min. - max. for fixed diffusers max. for adjustable diffusers	2,4 - 4,5 m 20 m	
Temperature difference between room air and supply air cooling heating	- 14 °C + 20 °C	
Capacity of removing the room thermal load according to the height of the diffuser	h = 2,2 m h = 2,7 m h = 3,0 m	100 W/m² 125 W/m² 140 W/m²
Max. number of air changes/hour	> 30	

Tab. 6 indicates the reference data for high induction diffusers with twist flows. We would like to point out some of the features you should keep in mind when choosing a diffuser, both standard or high induction.

1. if specific noise levels are specified in the chapter, the diffuser you choose will have to meet these requirements. Hence, air flow rates, pressure drop, speed of the air supplied will have to be set so that the diffuser produces a noise level no higher than the value indicated in the technical specifications. However, this may not be enough, due to noises generated by the system: ex. the fan, partially closed dampers, quick duct section variation, etc. In these cases, an expert needs to draw up a specific acoustic project for your system.
Attention: an incorrect installation of the diffuser can seriously increase the noise level, (see Chapter on Acoustics).

2. Any diffuser, "at its maximum limit" or undersized is always noisier than under nominal conditions.

3. If there are environments with high density thermal loads, we certainly recommend choosing high induction diffusers. Choose the diffuser according to the specific flow rates and check the noise level. If it exceeds the typical values allowed for this type of application, you need to use a bigger version, or even see whether you could use two diffusers for better air treatment procedures.

4. Carefully follow the instructions contained in the technical documentation to choose a high induction diffuser. For more specific information contact our technical office.
Compared to standard grilles and diffusers, you need to be a bit more careful with the high induction version in order to fully exploit its features.

Features of chilled beams

Chilled beams are elements for ceiling installation to control room conditions. Despite the name, chilled beams are units able not only to cool but also heat a room, control the humidity and the change of air. The beams are equipped with a thermal exchange element (one or more batteries with blades or aluminium plates) fed during the summer period with water cooled at a temperature no lower than 15 °C and during the winter period with hot water at 35/45 °C. Air flows through the exchange element. The flow of air is formed through natural air movements or induction.
Chilled beams are available on the market in three different models:

- induction beams
- high induction radiant beams
- natural convection beams

Induction beams

Temperature control and air diffusion functions are integrated in just one device in these induction beams.
They are equipped with a joint for connection to the primary air ducts and an air distribution plenum with supply holes that create a depression area that causes the forced induction of room air through the thermal exchange battery.
The induction relation is 4, which means that the supplied flow (sum of the primary air flow and recycled air) is 4 times the primary air flow. The air is taken in from the bottom of the device through linear diffusers with Coanda effect.
Unlike fan convectors, there is no air recycling fan or filter or condensate collection tray.
Induction beams are available in two different models according to the type of ceiling: exposed installation or ceiling mounted, in which case they lie flush with the false ceiling. In both cases the beams can be integrated with lighting devices and fire detection devices.
The beams are available in the 2-tube or 4-tube version. Access to the battery for periodical cleaning operations is possible by sliding the inner grid panel.

High induction radiant beams

Temperature control and air diffusion functions are integrated in just one device in these induction beams.
These high induction beams have a cold radiating plate which lies flush with the false ceiling. The plate is made of extruded aluminium blades and copper tubes with cold water flowing inside. A plenum is mounted right above the plate equipped with a continuous punched diffuser which allows the primary air to flow into the room. The flow of air through the cooling coil contributes to the increased cooling effect, when compared to convection beams, due to the use of induction of air jets from the supply air duct. The high induction effect also enables to supply air with a lower temperature up to 12 °C in relation to the environment, hence cool the room using primary air.
This type of beam assures a very high cooling effect and the room air never passes through the exchange element.
Therefore, the exchange surface never gets clogged. These beams can be used even to heat the environment but this type of beam is available only in the 2-tube version.

Natural convection beams

A convection beam, also called passive beam, has no air supply but is based on the circulation of air through the exchange element, made of a battery with copper tubes and aluminium blades contained in a metal box. As the air is heated it moves upward and moves back down after passing through the cooling coil.
The beams are mounted for exposed installation or ceiling mounted, in which case they lie flush with the false ceiling. The false ceiling must also allow for the circulation of room air.
This kind of chilled beams are used only for cooling purposes: the primary ventilation air is supplied to the room through a separate system with traditional ceiling or floor diffusers.

Features of chilled beams

The benefits

Many are the benefits of induction type chilled beams.
First of all the comfort conditions are higher: in fact the heat exchange with the occupants is mainly of the radiant type (with a higher operating temperature) and the supply air in the occupied zone has a very low velocity with a temperature close to the ambient one.
The noise level is very low, with values lower than 30 dB(A).
Installation is very easy and quick: the chilled beams integrate in one terminal both the functions of temperature control and air distribution: therefore it is sufficient to connect the beams to the water pipes and to the air duct.
Given the absence of fan, filter and drain condensate pan, maintenance is very simple: only periodic inspections are necessary to verify the coil conditions.
The terminal are installed on the ceiling so any risk of damage or misuse by the occupants are avoided.
Energy consumption during summer may be reduced thanks to the use of cold water with a temperature not lower than 15 °C, which means a higher energy efficiency of the water chillers.
Cold water at this temperature may be taken from free sources such as ground, river, sea or lake or may be produced using directly the external air (free-cooling) when its temperature drops below 15 °C.
The most important issue for the owner and the architect is the possibility to install all the terminals at the ceiling leaving the floor completely free, with relevant economical benefits.
The design of a chilled beam system has to take into consideration some peculiar aspects. First of all any condensate formation on the cooling coil must be avoided. In order to achieve this, it is necessary to provide a precise control of the ambient relative humidity and to feed the beams with a water temperature not lower than 15 °C, 2 °C higher than the air dew point of 13 °C corresponding to the summer design conditions (26 °C with 45%).
In order to avoid any risk, in case of loss of humidity control (i.e. in case of window opening), it is sufficient to provide dew point sensor on the cold water pipes which controls the valve shut-off and stops the water circulation inside the beams.
The design must be based on a close cooperation between the architect and the HVAC consulting engineer, especially during the lay-out and the ceiling design phase, in order to study the position of chilled beams and lighting fixtures based on the internal partitions.

Design Software

Vari sono i vantaggi che derivano dall'imIn order to evaluate chilled beams models, quantity and positions for every specific project, it is possible to use specific design software. The selection programs offer effective support for fast selection and provide in a simple way the graphical simulation of the chilled beams performances given the position and the operating data. The flow pattern with the air velocity values in the occupied zone in the room can be simulated. Each relevant operation can be displayed on screen, for both a vertical section and horizontally. Cooling requirement calculations can also be made in the program.

Balancing

In order to guarantee the design air flow to all the chilled beams it is wise to install balancing dampers on the main risers and one iris damper for each beam to be placed on the flexible duct.
The induction type chilled beams may be provided with the comfort control system with patended rails which permit to adjust the size of the hole length in the supply air plenum. This systems allows to vary the total air supply and to have different supply air directions: two ways, one way or intermediate positions. In this way it is possible to adapt the chilled beams to lay-out modifications or to obtain the optimal conditions when two beams are installed close to each other. Another option is the flow pattern control system where the airflow can be directed up to 45 degrees through integrated vanes. The flow pattern is easily and safely adjusted by a simple operation. Different directions can be set at sections of 300 mm in the beam and a combination of different angles on one side is possible. When increased air flow is required, the flow pattern can be adapted to maintain optimal comfort in the room. Highest possible efficiency can be maintained by adjusting the comfort control and air vanes.
For an optimal control of the air flow values during the balancing procedures, the chilled beams are provided with a system based on a pressure gauge placed on the air inlet.

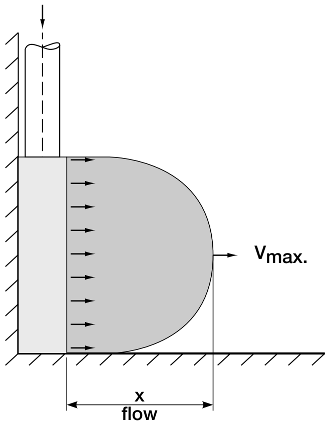
Control system

The ambient temperature control is achieved through the modulation of the water flow with 2 or 3 ways control valves under a signal coming from an ambient temperature sensor. The use of 2 ways valves means that variable flow circulation pumps must be installed. DDC controllers allows the interface with Building Management Systems.

Features of the displacement diffuser system

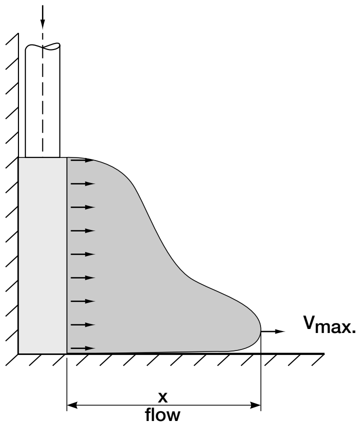
Isotherm

Δt = 0 °C



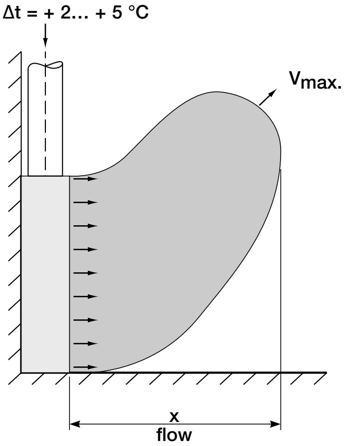
Cooling

Δt ~ 2... - 5 °C



Heating

Δt = + 2... + 5 °C



The displacement air diffusion system operates according to principles that differ from traditional diffusers.
It does not mix intake air and room air. In fact, the air generally flows from the bottom and moves upward, removing the heat from hot surfaces (lamps, furniture, computers, people) and dragging away the polluting substances in the room. The hot and polluted air is taken from the exhaust ceiling devices and eliminated or partially recycled. Hence, a separation “limit layer” is produced at a certain height in the room: under this level there are controlled air cleaning and temperature conditions, whereas below this there is a build up of polluting substances and a temperature increase.
In normal office environments, where people carry out sedentary activities, the limit layer is around 1.5 m. from the floor. Whereas in commercial environments, workshops or industrial facilities where people are generally standing, the height of the limit layer can be fixed at around 1.8 m. Hence, displacement diffusion systems operate very well in rooms with high ceilings, because the controlled area is below a fixed height (1.5 or 1.8 meters), with the obvious advantages it entails.

Operation of displacement diffusers

The temperature of the air supplied by displacement diffusers is very close to comfort temperature levels. In residential rooms, the temperature of the supplied air is around 20/23 °C, with temperature differences around 2 – 5 K. On the other hand, in rooms with more intense activities, such as department stores, recreational structures, halls, etc. the inlet temperature can reach 18 °C.
During intermediate seasons, when the conditions allow it, displacement systems can operate in free cooling stage, using only external air. The air is supplied by the diffuser with a face speed lower than 0.20 – 0.25 m/s, to avoid turbulence. At the beginning, outlet air flow has a cascade movement towards the floor. The flow radius of displacement diffusers (that must not be mistaken for the flow of standard diffusers) can reach 15 meters, according to the models and the capacity.
The displacement effect is produced only when the inlet air has a temperature lower than the room temperature. Instead, if the diffuser is fed with hot air, you loose the displacement effect and you obtain a normal mixing procedure.
The heating system must be provided through a separate traditional system (ex. radiators, floor vents, etc).
Keep in mind that the displacement can be programmed for the entire year, hence even in winter, to control the quality of the air. The heating system is created with a separate system, with radiating panels or radiators under the windows. Generally, the noise power level of displacement diffusers is lower or equal to 35 dB(A) of nominal conditions for residential applications. In most cases, however, the level of noise pressure in the room is acceptable without creating any damages.

Construction of displacement diffusers

The typical displacement diffuser has a vertical cylindrical, semi-cylindrical, corner or rectangular development. According to the model, there are different types of installation: floor, in the center of the room, wall or corner. The diffuser is fed by a vertical circular duct from top to bottom. The front surface of the diffuser has a perforated sheet, where the air blows out at low speed and equally for its entire surface and is distributed in the room. The rectangular models are made by a narrow frame and they can be integrated in the wall, or more commonly, they are applied against the wall, projecting in the room.
Displacement diffusers can be installed both in rooms with limited sizes, for ex. offices, restaurants, shops, or in large areas, like department stores.

Choosing displacement diffusers

There is a specific method used to choose displacement diffusers which differs from the one used for mixing diffusers.
Refer to the product technical documentation and if necessary contact our technical office.

Choosing the air diffusion system

Tab. 8 *Advantages and limitations of mixing diffusion*

Specifications	Yes	No
For cooling and heating	•	
Operation possible with high Δt	•	
Risks of cold air drafts	•	
Too much space occupied		•
Risks of air flows	•	
Risk of supply and exhaust short circuits	•	
Removal of polluting substances		•
Suitable for rooms with high ceilings	•	
High vertical temperature gradient		•
Suitable for high cooling conditions	•	

Tab. 9 *VAdvantages and limits of displacement diffusion*

Specifications	Yes	No
For cooling and heating	•*	
Operation possible with high Δt		•
Risks of cold air drafts		•
Too much space occupied	•	
Risks of air flows		•
Risk of supply and exhaust short circuits		•
Removal of polluting substances	•	
Suitable for rooms with high ceilings	•	
High vertical temperature gradient	•	
Suitable for high cooling conditions	• *(with limited Δt)*	• *(with high Δt)*

**** Under hot air heating conditions you loose the displacement effect, especially in industrial applications.***

The air diffusion system can be initially divided into two categories:

- ***mixing diffusion***
- ***displacement diffusion***

Tables 8 and *9* compare the specifications of both systems, which could be useful for a preliminary selection. The choice could be made according to the type of facility, as shown in *tab. 10* where the most common cases are highlighted. However, the Designer or the Installation Team could prefer other solutions. Furthermore, to calculate the average air flow rate required in different applications, you could refer to *tab. 11*. This table indicates the air flow rates (in l/s per square meter of floor surface), with reference to the position of the rooms and the internal spaces (without windows), if available.

Tab. 10 Selection of diffusers according to type of application

Application	Grilles	Circular or square diffusers	Perforated diffusers	Linear diffusers	High induction swirl diffusers	Spot diffusers	Floor diffusers	Diffusers with variable throws
Apartments	yes	no	no	no	yes	no	no	no
Cinema - Theaters	no	yes	no	sì	yes	yes	no	yes
University classrooms	no	no	no	sì	yes	no	no	no
Hospitals Hospitals rooms	yes	yes	no	no	no	no	no	no
Public space	yes	yes	yes	yes	yes	no	no	no
Hotels - Motels	yes	yes	yes	yes	yes	no	no	no
Libraries and museums	no	no	yes	yes	yes	yes	no	yes
Office buildings	yes	yes	yes	yes	yes	no	yes	no
Private offices	yes	yes	yes	yes	no	no	yes	no
Residential facilities Big	no	yes	yes	yes	no	no	no	no
Medium	yes	yes	yes	no	no	no	no	no
Restaurants Big	no	yes	yes	yes	yes	no	no	no
Medium	yes	yes	yes	no	no	no	no	no
Shopping centers	no	yes	yes	yes	yes	yes	no	yes
Department stores	no	yes	yes	yes	yes	yes	no	yes
Stores (generic)	yes	yes	yes	yes	yes	no	no	no

Tab. 11 Typical air flows, in l/s for sq. m. of surface, for different applications according to the position of the rooms

Facility	*SOUTH - EAST - WEST*			*NORTH*			*Internal rooms*		
	Min.	Average	Max.	Min.	Average	Max.	Min.	Average	Max.
Apartments	4,1	6,1	8,6	2,5	4,1	8,6	-	-	-
Cinema - Theaters	-	-	-	-	-	-	5,1	10,2	15,2
University classrooms	10,2	8,1	11,2	4,6	6,6	10,2	4,1	6,1	9,7
Hospitals Hospitals rooms	5,1	7,6	10,2	4,1	6,1	7,1	3,6	5,1	5,6
Public space	5,1	6,4	7,4	5,1	5,6	6,1	4,8	5,1	5,6
Hotels - Motels	5,1	7,1	7,6	4,6	6,1	7,1	-	-	-
Libraries and museums	5,1	8,1	10,7	4,6	5,6	6,6	4,6	5,1	5,6
Office buildings	5,1	8,1	11,2	4,6	6,6	10,2	4,1	5,1	6,1
Private offices	6,1	9,1	12,2	5,6	7,6	9,1	4,1	6,1	7,1
Residential facilities Big	4,1	6,1	8,1	2,5	4,1	6,6	-	-	-
Medium	3,6	5,6	7,1	2,5	3,6	6,1	-	-	-
Restaurants Big	9,1	12,2	18,8	6,1	8,1	10,7	4,6	5,6	7,1
Medium	7,6	10,2	15,2	5,6	7,14	9,1	4,6	5,1	6,6
Shopping centers	7,6	13,2	21,3	5,6	8,6	13,2	4,6	6,6	10,2
Department stores Ground floor	-	-	-	-	-	-	3,6	5,1	6,1
Main floor	-	-	-	-	-	-	4,6	7,1	10,2
Upper floor		-	-	-	-	-	4,1	5,1	6,1
Clothes shops	4,6	6,1	8,1	3,6	5,1	7,1	3,0	4,1	5,6
Shoe shops	6,1	8,1	10,7	5,1	7,1	9,1	4,1	5,1	6,1

ASHRAE source

About Noise

Noise level control in a room is very important to assure acceptable working conditions.
Its entity depends on the type of environment and on the activities carried out in that room; the acoustic conditions of the project are different according to whether, for example, we refer to a hospital room, rather than a restaurant.
The typical sound level varies according to the type of room, and, in the same way, noise control criteria differ.

Air conditioning systems include various noise sources that could produce noise at levels that sometimes are not even acceptable in the room, hence, it is necessary to foresee the consequences of their installation. Furthermore, the system can contribute to the distribution of the noise generated in noisy rooms to other more silent rooms; you need to take this into account, too.
The most important thing is that the noise level of the room does not exceed the acceptable values for each situation.

Tab. 1 *Background noise in Noise Criteria or Room Criteria for the sound control of air conditioning systems*

index	NC	RC
Section 1 - STUDIOS AND ROOMS		
Radio studio	15	20
Broadcasting room, television studio, recording room	20	25
Television studio (for the audience)	25	30
Concert hall, theater	20	25
Conference room, cinema	25	30
Section 2 - HOSPITAL		
Audiometric rooms	20	25
Operating rooms, single rooms	30	35
Wards, waiting rooms	35	
Hallway, laboratory	35	40
Laundry rooms, restrooms, kitchens	35	45
Personnel rooms, recreational rooms	30	40
Section 3 - HOTELS		
Single rooms, suites	20	30
Dancing rooms, reception rooms	30	35
Hallways, lobbies	35	40
Kitchens, laundry rooms	40	45
Section 4 - RESTAURANTS, SHOPS, DEPARTMENT STORES		
Restaurants, department stores (upper floors)	35	40
Night clubs, cafeterias, taverns, supermarkets (ground floor)	40	45
Section 5 - OFFICES		
Meeting rooms, big conference rooms	25	30
Small conference rooms, offices, porter's office	30	35
Open space offices	35	
Drawing offices, EDP rooms	35	45
Section 6 - PUBLIC OFFICES		
Court houses	25	30
Meeting rooms	25	35
Libraries, banks, museums	30	35
Restrooms, toilettes	35	45
Swimming-pools, sport centers	40	50
Garages, parking lots	55	
Section 7 - CHURCHES AND UNIVERSAL BUILDINGS		
Churches	25	30
Classrooms, conference rooms	25	35
Laboratories, workshops	35	40
Hallways, gyms	35	45
Section 8 - INDUSTRIES		
Warehouses, garages	45	50
Workshops (light mechanical work)	45	55
Workshops (heavy mechanical work)	50	65
Section 9 - PRIVATE HOUSES		
Bedrooms	25	30
Living-rooms	30	35

Noise elements

Sound or noise is produced by compression and rarefaction waves distributed through the air or through structures of the building, or the walls of the ducts and the ducts of the systems and even through the liquids travelling inside them.

Frequency

Frequency is the essential feature of noise.
It is measured in Hz (Hertz).
In normal situations, the reference frequency range is more limited: from 63 to 8000 Hz.
This range is divided in eight standardized frequency "sections", called "octave band" with precise center-band values: 63 Hz; 125 Hz; 250 Hz; 500 Hz; 1000 Hz; 2000 Hz; 4000 Hz and 8000Hz. While it is fairly easy to control or "eliminate" noise with medium or high frequencies, it is a lot more difficult to intervene on low frequency noise.

Decibel dB

Sound has a very wide intensity scale: from the sound of leaves moving to the drone of a big plane at take-off. If we use a linear unit of measure like Watts to quantify sound, it would go from 0.00000000001 W to 10,000 W. The watt, like any other linear unit of measure, is not adequate to measure sound. Hence, a logarithmic unit was chosen for sound: the dB, or decibel. It has the advantage of "compressing" in numbers with just 2 or 3 figures the entire variation field of sound. DB values represent the "sound level" of noise. *Tab. 2* describes the typical noise levels measured in dB of certain natural and artificial sound sources.

Sound power level, Lw

In any kind of machine, refrigerator, boiler, or similar a certain quantity of energy is released as noise; this is the sound power level; it is expressed in dB and it is commonly indicated as Lw. It represents a fixed figure of the machine in relation with the operating regime and it cannot be changed by external causes, for example, due to the type of installation. The sound power cannot be perceived directly; it is produced through a corresponding level of sound pressure, that can be captured by the ear and measured with a sound-level meter.

Tab. 2 *Typical noise sources*

Noise source	Sound level (dB)
Jet at take-off	160
Big church organ	130
Screaming voice	90
Voice, conversation level	60 - 70
Light whisper	30
Leaves moving *Outlet air of diffuser from 0.1 sq. m. at 1 m/s*	20

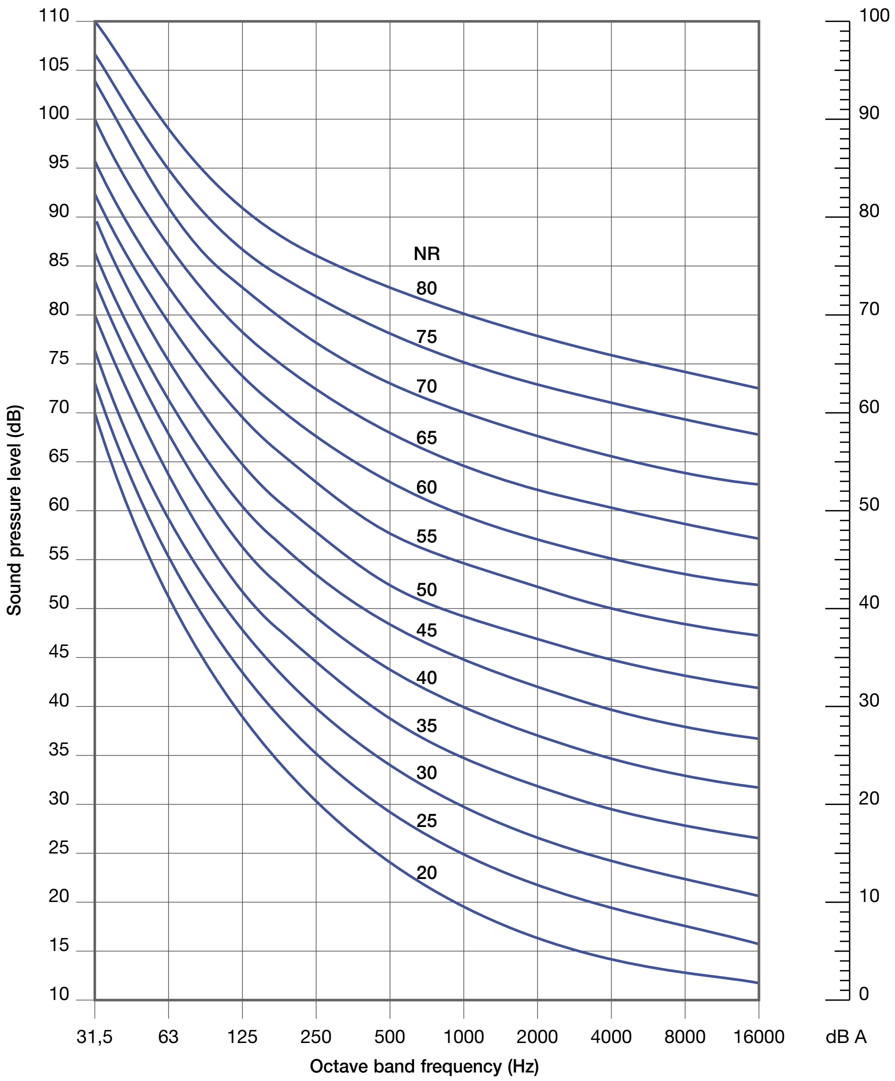
Sound pressure level, Lp

Unlike the sound power level, the sound pressure level (Lp) can be affected by several external factors: the distance between the source and the instrument, the presence of reflecting surfaces near the source, the presence of barriers or obstacles along the path, etc. hence, it is subject to variation according to the conditions in which it was measured.
Outside, the sound pressure level drops by 6 dB every time the distance doubles. In standard residential rooms this reduction ranges between 3 and 4 dB.
A difference of 1-2 dB can be barely felt, but a difference of 3 dB is a value the human ear hears clearly.

Tab. 3 *Difference between the two sound levels and the values to add to the highest to obtain the resulting noise*

	dB										
Difference between the two sound levels	0	1	2	3	4	5	6	7	8	9	10
Value to add to highest sound level	3	2,6	2,1	1,8	1,5	1,2	1	0,8	0,6	0,5	0,4

NR Curve



Decibel dB(A)

The sound pressure level expressed in dB is not very important because, as we said before, the human ear is particularly sensitive to the various frequencies, up to about 200 Hz, whereas the sensitivity level is flat between 200 and 2000 Hz. Around 4000 Hz it is really sensitive, but then it looses its sensitivity at higher frequencies. To take into account its features, the sound pressure level read by the sound-level meter is pondered according to a certain curve that follows the sensitivity of the ear, called curve “A”. The resulting sound pressure level is called *“A scale”* and it is indicated as LpA; its value is expressed in dB(A).
The dB(A) is a very popular method. It is used in acoustic calculations and in room sound level standard ratings.

Noise Ratings curve

The curves drawn out by ISO *(International Standard Organization)* called Noise Ratings (NR), determine the conditions of equal sound feeling for the human ear. These curves are then reproduced on a diagram that has the central band frequencies on the horizontal axis and the sound pressure levels expressed in dB on the vertical axis. The reference is to continuous wide band noise, not impulsive and without dominating tones.
Each curve has a two figure number corresponding to the sound pressure level, in dB, at a frequency of 1000 Hz.

Noise Criteria curves

The Noise Criteria curves (NC) ASHRAE, are built on the same principle of the NR ISO curves. The center band frequencies are on the horizontal axis, whereas the sound pressure levels in Db are on the vertical one. An NC value corresponding to a sound pressure level in the field between 1000 and 2000 Hz identifies each new curve. These curves have been used for years. ASHRAE hasn’t been using these curves for the past ten years. In fact it now uses the Room Criteria values. This system is quite complex and goes beyond the scope of this manual.

The sum of noises

Frequently more than one sound is produced in one room: for ex. two or more supply grilles, two or more exhaust grilles, etc. Noises cannot be summed up in a mathematical way. On the other hand, we produce results that can be quantified with simple operations taking into account the difference between the stronger and the weaker one. This procedure is described below and refers to *tab. 3.*