

Technical insulation

HVAC Ducts Handbook

ISOver

HVAC design – combining comfort with efficiency

When defining an HVAC installation, comfort is the most obvious primary consideration, as it is invariably the main reason for installing an HVAC system in the first place.

As a first step the parameters that define comfort need to be identified – temperature, humidity, air replenishment and noise levels etc. These then need to be regulated to deliver the perception of comfort to the user. However, this needs to be achieved with the rational and efficient use of energy, in turn saving natural resources, and also money at the local level. Furthermore, it is also vital to factor ‘safety’ into the design, since, irrespective of what and where, a ‘safe solution’ is the only solution.

The air duct distribution network is an important component of HVAC installations, helping to significantly reduce energy costs and reduce noise nuisance generated by the system’s equipment.

ISOVER solutions for HVAC – The safe option for saving energy and providing comfort

ISOVER provides solutions for HVAC ducts and pipes in glass wool, stone wool and *ULTIMATE* mineral wool, which help not only to deliver desired levels of comfort but also both reduce energy consumption and contribute significantly to fire safety. ISOVER solutions provide possibly the best combination of thermal and acoustic comfort, energy efficiency and safety for the user.



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1. Introduction

An HVAC installation is designed to ensure the thermal and acoustic comfort of a building's occupants, use energy efficiently and comply fully with safety requirements.

Installation design takes into account the air exchange rates in the building, the number of its occupants and their activities, its interior characteristics and the materials from which it is constructed.





When selecting a building's a/c system, the design engineer needs to take the following factors into account:

- The characteristics of the air conditioned spaces and activities therein: for example, choosing the appropriate airflow device for buildings of variable occupation.
- Installation costs and effective energy consumption. European Directive 93/76/CEE on CO₂ emissions requires member states set up and implement programmes that enable and encourage owners and occupiers to seek alternative energy solutions to reduce energy consumption, including free choice of supplier.
- Reduction and treatment of noise levels, i.e. the noise emitted by the installation etc.
- Air quality control. In addition to temperature and humidity, parameters such as CO₂ need to be monitored as an indicator of 'air staleness'.
- Efficiency of air distribution. Studies of air velocity and distribution are required, both for cooling and heating systems.
- Installation Maintenance.

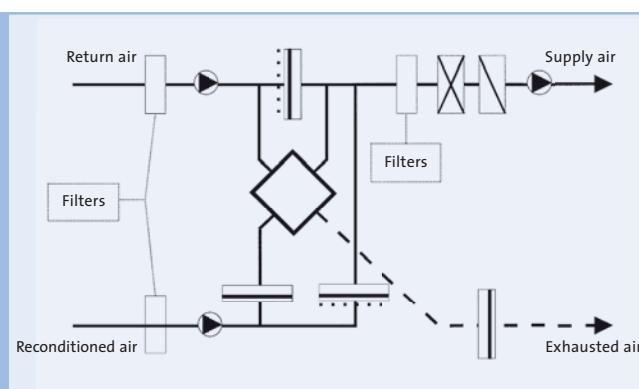
Air Ducts Systems

In air conditioning systems the 'duct' is considered a static component of the installation through which air flows within the building, connecting all parts of the system and via which used or exhaust air is discharged.

The Advantages of Air Duct Systems

- Centralized filtration
- Humidity control
- Quiet operation – all air handling equipment is centrally located allowing much simpler acoustic design
- Return air passes through the central treatment unit, is re-filtered and humidified, increasing air quality
- Fresh air replenishment from a external intake point, located to minimize the influence of wind turbulence and avoid contamination with discharging exhaust air
- Centralized maintenance and easy installation – filters, humidity systems, mobile heat exchangers and equipment all located in the same area
- Multi-area control options

The chapter on Air Quality emphasizes the importance of introducing air from outside into the building, as a means of diluting potential 'pollutants'.



Advantages of Installing HVAC Ductwork

Deciding on the type of HVAC system in the initial design stages invariably means it is better adapted to type of house intended by the architect.

Furthermore, installing an HVAC duct work system during a building's construction often means reduced costs in the long run, as it avoids any future necessary structural modifications.

Installations typically consist of designing space for the air distribution network and the location of the air handling equipment. Some systems also include the installation of regulators such as dampers and attenuators.

Compared to other systems, air duct installations offer better air exchange rates without the need for additional ventilation devices. They also allow 'free' cooling during most of the year in temperate climates, supplying the building with fresh air with no need to warm or cool it.

Note that cooling is usually more costly in terms of energy consumption than heating (per energy unit), and the ultimate target is maximum functional efficiency throughout the year. Zone Control systems form part of a new approach in energy consumption rationalization and allow the use of equipment requiring less power.

Another option is the installation of combined air conditioning systems, for both heating and cooling. Electrical and/or gas equipment is available on the market and its selection depends on climatic zone, cost and efficiency of operation etc.



Air ducts should ideally be equipped with their own insulation. Thermal insulation materials, such as ISOVER glass wool or ISOVER **ULTIMATE** new generation mineral wool, have the additional advantage of also significantly reducing noise. Operational and airflow noise are practically eliminated if glass wool is used, especially with systems based on ductboard, such as **CLIMAVER** or ISOVER duct liner products.

Summary – Chapter 1

The basic function of air conditioning is to guarantee the ambient comfort of a building's occupants. To achieve this, the designer selects the appropriate air conditioning system, guided by several criteria, such as the type of the building, acoustic requirements, cost, maintenance etc. Air duct systems enjoy several advantages over other air conditioning systems, including such factors as centralized maintenance, power savings, and high quality interior air.

*As a general rule, an HVAC duct work system such as **CLIMAVER** is renowned for the excellent quality of interior air, the system's efficiency and adaptability to user needs.*



2. Air ducts and insulation solutions

Air ducts are the elements of an installation through which the air is distributed, including the air supply, air processing units, diffusers, air return, extraction, etc. The properties of ducts determine to a large extent the quality of the installation, as they have a key influence on certain factors such as energy savings or the acoustic properties of the system.

This chapter looks at four alternative types of ducting in some detail.

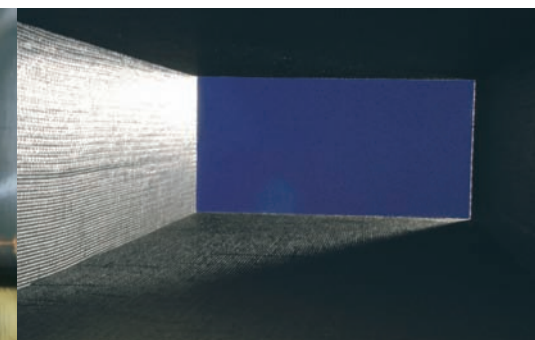
1. Metal ducts
2. Glass wool ductboards
3. Plastic ducts
4. Flexible ducts



Metal ducts must be thermally insulated



High physical resistance of the internal facings makes cleaning of the duct interior quick and easy.



Glass fabric facings allow optimum acoustic insulation

2.1. Metal ducts

Such ducts are made from sheet metal (galvanized or stainless steel, copper, aluminium), cut and shaped to the required geometry for the air distribution system.

Since metal is a good thermal conductor, such ducts require thermal insulation, the commonest material for which is glass wool, usually in roll form (known as ‘wraps’ or ‘wrapped insulation’), wrapped around the outer duct wall. Wraps incorporate an aluminium foil facing that acts as a vapour barrier. Insulation can also be installed on the inner wall of the duct (‘duct liners’), as glass wool duct wraps or duct slabs faced with a glass matting or mesh providing acoustic insulation and strengthening the inner face of the duct.

Metal ducts classification (Europe)

a) By maximum pressure

The metal sheet ducts are classified according to the maximum pressure they can withstand.

Maximum pressure (Pa)
500 Pa (1)
1000 Pa (2)
2000 Pa (2)
2000 Pa (2)

(1) Positive or negative pressure
(2) Positive pressure. EN-12237:2003

b) By degree of air tightness

Three classes are recognized. The assembly systems and types of reinforcements are defined in prEN 1507. See also EN-12237:2003.

Ducts class
Air tightness A
Air tightness B
Air tightness C
Special applications

Insulation for metal ducts

ISOVER has a wide range of products that covers virtually all applications.

Application	ISOVER products	Thermal resistance
Wrapped insulation for metal ducts	Glasswool blanket faced with an aluminium vapour barrier, generally reinforced with a glass fibre mesh	Depending mainly on thickness, can vary from 0.80 to 1.3 (m ² /KW)
	ULTIMATE blanket (can be also faced with reinforced aluminium). This product should be applied if fire resistance is required in addition to thermal and acoustic insulation.	Depending mainly on thickness, can vary from 0.7 to 1.3 (m ² /KW)
Duct liner	Glass wool blanket or board, faced on the airstream side with a glass mesh or fabric	

2.2. CLIMAVER glass wool ductboards

These are ducts made from high density glass wool board. Ducts are shaped from the boards, by cutting and folding in order, to obtain the required geometry required. In Europe, they are regulated by EN13403:2003.

The face of the original board in contact with the air stream when assembled as a duct is called the ‘internal face’, i.e. inside the duct. The other surface of the original board is called the ‘external face’.

Panels are supplied with double facing such that:

- The external face of the duct is faced with a robust reinforced aluminium foil which acts as a vapour barrier and confers air tightness on the duct.
- The internal face of the duct has either an aluminium coating, a glass mat or fabric layer, depending on the properties required of the duct.

Considering fire performance, a critical issue is the potential for flashover to occur – the spontaneous ignition of hot smoke and gases – that can lead to the uncontrollable spread of a fire. Glass mineral wool, and therefore **CLIMAVER**, is not susceptible to flashover. CLIMAVER self-supporting ducts can be assembled either on or off site, reducing in the first option the costs of transportation and allowing flexibility and adaptations to necessary changes on the building site.



CLIMAVER ducts provide thermal and acoustic insulation in a single operation



Flexible ducts usually limited in length due to high air drops

ISOVER ductboards

Air conditioning needs of an installation can vary depending on its type, users, etc. ISOVER has developed a wide range of products to meet this diversity.

ISOVER solutions for self-supporting air ducts

ISOVER product	Description		Working conditions			
			Thermal resistance	Maximum static pressure	Maximum air speed	Maximum air temperature
CLIMAVER Plus R	High density glass wool ductboard offering thermal and acoustic insulation	Outer lining of aluminium reinforced with a glass fibre mesh, kraft paper and a glass veil to ensure rigidity. Inner lining with aluminium foil, kraft paper and glass mesh	$R \geq 0.75 \text{ m}^2\cdot\text{K}/\text{W}$	< 80 mm c.a	18 m/s	90 °C
CLIMAVER Neto	Enhanced acoustic insulation	Outer lining of aluminium reinforced with a glass fibre mesh, kraft paper and a glass mesh to ensure rigidity. Inner lining: woven black glass cloth, 'neto'				
CLIMAVER A2	Enhanced fire reaction	Similar to CLIMAVER Plus R, avoiding the use of kraft paper				
CLIMAVER A2 Neto	Enhanced acoustic insulation and fire reaction	Similar to CLIMAVER Neto, avoiding the use of kraft paper				
CLIMAVER 284	Enhanced acoustic insulation	Outer lining of aluminium, inner lining with a glass mesh				

2.3. Plastic ducts

This category includes ducts made from plastic or foam boards, shaped by cutting and folded to produce the required cross-sectional geometry. Boards are faced usually with an aluminium coating both internally and external.

The main drawback of this type of ducting is their fire classification. Even if they comply with local standards, when exposed to fire they often exhibit poor performance in terms of the production of both smoke and flaming droplets.

2.4. Flexible ducts

These usually consist of two aluminium and polyester concentric tubes. A glass wool layer is inserted between the two tubes as thermal insulation. Flexible ducts in Europe are regulated by standard EN 13180:2002.

Their use is generally limited to short lengths, due to high pressure drop-off and the acoustic problems they create: they are mainly used to connect main air duct and terminal units (diffusers, grids). In most countries the regulations do not permit their use in lengths greater than 1.5 m.

Summary – Chapter 2

The following options for air conditioning ducts are available:

- *Metal ducts. Shaped in a workshop, they need additional thermal and acoustic insulation. Regulated in Europe by EN 12237:2003.*
- *Glass wool ductboards. Can be shaped on or offsite, provide thermal and acoustic insulation. Regulated in Europe by EN 13403:2003*
- *Plastic ducts. Provide thermal but little acoustic insulation. Regulated in Europe by EN 13403:2003.*
- *Flexible ducts. Suffer high pressure drop-off and therefore limited in length in various countries. Mainly used for the connections between main duct and terminal units. Regulated in Europe by EN 13180:2002.*



3. Thermal Insulation in HVAC duct work

The first significant factor to consider when attempting to reduce energy consumption in duct work is the building's thermal insulation. Knowledge of a building's thermal load and its compliance with regulations is essential, and ultimately this will pay dividends in achieving minimum thermal insulation providing maximum thermal performance.

The design of an efficient duct work system can significantly modify thermal loads in buildings. ISOVER solutions provide the highest quality insulation and help reduce energy consumption.

Some thermal loss is due to the fact that the temperature of the air in the duct may not be same as that of the surrounding ambient air. Heat transfer between the two air masses can represent a loss of efficiency and increase energy costs.

Finally, duct work and pipe work also can represent a condensation risk, caused by localized cooling of air and a rise in relative humidity. Regulations define a minimum thickness for the thermal insulation in pipes and ducts to minimize the danger of condensation.

This chapter details an example of how to calculate minimum insulation thickness for a duct. All calculations are done according to the appropriate European Standard, EN ISO 12241:1998 'Thermal insulation for building equipment and industrial installations. Calculation rules'.

3.1. Calculating insulation thicknesses

Heat conduction

If two areas are of different temperature, then heat tends to flow from the area of higher temperature to that with the lower temperature. If a physical body separates these two areas, heat transfer depends on:

- the geometry of the physical element
- the thermal conductivity of the material

The heat flow through such an element is given by Fourier's law:

$$q = -\lambda \cdot \text{grad}(T)$$

With:

q : heat passing perpendicularly through the separating element (W/m²)

λ : the thermal conductivity of the material (W/m.K)

grad T: is variation of temperature with material thickness (K/m)

Different expressions of Fourier's law are used for different geometries of separating (insulating) element.

a) Flat walls

Fourier's law is written as:

$$q = \frac{\theta_{si} - \theta_{se}}{R} \text{ (W/m}^2\text{)}$$

Where:

θ_{si} : surface temperature of the warmer side (K)

θ_{se} : surface temperature of the cooler side (K)

R : total thermal resistance (m².K/W), with

$$R = \sum \frac{d_j}{\lambda_j}$$

Where:

d_j : thickness of the layer j (m)

λ_j : thermal conductivity of the layer j (W/m.K)

b) Cylindrical elements

Fourier's law is written as:

$$q = \frac{\theta_{si} - \theta_{se}}{R} \text{ (W/m)}$$

With R: total thermal resistance (m.K/W)

And

$$R = \frac{1}{2\pi} \sum \frac{1}{\lambda_j} \ln \frac{D_{oj}}{D_{ij}}$$

Where:

D_{oj} : internal diameter

D_{ij} : external diameter

c) Rectangular elements

The following expression describes linear heat flow through an element of rectangular cross-section (applicable for a duct of rectangular section):

$$q = \frac{\theta_{si} - \theta_{se}}{R_d} \text{ (W/m)}$$

R_d is the linear thermal resistance of this element and can be evaluated using the following approximation:

$$R_d = \frac{2d}{\lambda(P_e + P_i)}$$

Where:

P_i : internal perimeter of the duct (m)

P_e : external perimeter of the duct (m)

D : insulating layer thickness (m)

Surface heat transfer

In addition to heat transfer by conduction through the separating element between two areas at different temperatures, heat transfer also occurs at the surface delimiting this separating element.

Heat flow passing through the element must be equal to heat flow emitted by the warmer side and equal to the heat flow received by the colder side.

This means the surface heat transfer rate is defined as:

$$\theta_i > \theta_{si} > \theta_{se} > \theta_e$$

$$q = h_e (\theta_i - \theta_{si}) = h_i (\theta_{se} - \theta_e)$$

Where:

h_i : surface heat transfer rate of the environment i (W/m².K)

h_e : surface heat transfer rate of the environment e (W/m².K)

A surface heat transfer rate is the sum of two terms, one resulting from radiation and the other from heat convection:

$$h = h_{cv} + h_r$$

Where:

h_{cv} is the surface heat transfer rate resulting from convection

h_r is the surface heat transfer rate resulting from radiation

Different algorithms can be used to estimate these rates, with variations based on flow characteristics (position and geometry of the surface, laminar or turbulent flow, material, temperature, etc), listed in European Standard EN ISO 12241:1998 'Thermal insulation for building equipment and industrial installations. Calculation rules'.



3.2. Thermal insulation of ducts

Heat transferred through the duct network represents a loss of energy, and in turn increased operating costs. Moreover, thermal losses can lead to fluctuations in the desired air-conditioned temperature of the building. Therefore, it is necessary to know the relationship between calorific transfer and air temperature variation for the geometric characteristics of the duct network and internal air flow.

Heat transfers in ducts

Thermal transmittance between two environments is defined as the amount of heat that passes from one to the other per unit of area, divided by the temperature difference. The transmittance, **U**, is the inverse of the total thermal resistance of the system, including surface resistances **h**.

In flat walls (ducts with rectangular cross-section), transmittance **U** is expressed per unit surface area:

$$U = \frac{1}{\frac{1}{h_i} + \sum R_j + \frac{1}{h_e}} \text{ W/m}^2 \cdot \text{K}$$

In pipes (or ducts of circular cross-section) it is usually expressed per unit length:

$$U = \frac{1}{\frac{1}{h_i \cdot \pi \cdot D_i} + \sum R_j + \frac{1}{h_e \cdot \pi \cdot D_e}} \text{ W/m} \cdot \text{K}$$

Therefore, the first formula can be used for rectangular ducts:

- Values of h_e are presumed constant, considering the relatively quiet environment around the outside of the ducts.
- $\sum e_j / \lambda_j$ depends on duct material and is strongly linked to heat insulation – if there is no insulation, λ_j is usually elevated and $\sum e_j / \lambda_j$ has a very low value. In contrast, heat insulation supposes a very low λ_j for this layer and thus a relatively high value for $\sum e_j / \lambda_j$
- Rate h_j can show greater variations, since its value increases strongly with air velocity inside the duct.

The influence of these terms over the global value of **U** is restricted to:

- Ducts without thermal insulating material – elevated values of **U** which increase with air velocity inside the duct.
- Duct with thermal insulating material – low values of **U** with very moderate increases in air velocity inside the ducts. This is because the values of the term $\sum e_j / \lambda_j$ are always greater than $1/h_i$ for 'normal' velocities ($v < 18 \text{ m/s}$).

The ASHRAE graph shows experimental values of **U** based on air speed and different materials used for ducts, and indicates that **U** values are relatively independent of air velocity when glass wool ductboards are used, or when insulation is installed for metallic ducting (wrapped insulation).

This is due to the airflow inducing movement of the air contained within the glass wool which creates an increase of λ value for the material. This side-effect diminishes with increased material density, so that in rigid glass wool ductboards this factor is virtually negligible.

Heat transfer in ducts

Thermal transmittance, '**U**', can be calculated if global heat transfer per unit area/length duct surface per unit temperature difference ($^{\circ}\text{C}$) between the air within the duct and ambient air is known.

Documents from ASHRAE (Standard 90 A) provide the solution to this heat transfer estimate and allow a calculation for each segment of equivalent section.

$$Q_e = \frac{U \cdot P \cdot L}{1000} \left(\frac{t_e + t_i}{2} - t_a \right)$$

$$t_e = \frac{t_i(y+1) - 2t_a}{y-1} \quad y \cdot t_i = \frac{t_e(y+1) - 2t_a}{y+1}$$

Where:

$y = (2 \cdot AV\rho/UPL)$ for rectangular ducts

$y = (0,5 \cdot DL\rho/UL)$ for circular ducts

A = Surface of the duct transverse section (mm^2)

V = Average velocity (m/s)

D = Duct diameter (mm)

L = Duct length (m)

Q_e = Heat variations (+/-) through the ducts walls (W)

U = Total heat transfer rate for ducts walls ($\text{W/m}^2 \cdot ^{\circ}\text{C}$)

P = Duct perimeter (mm)

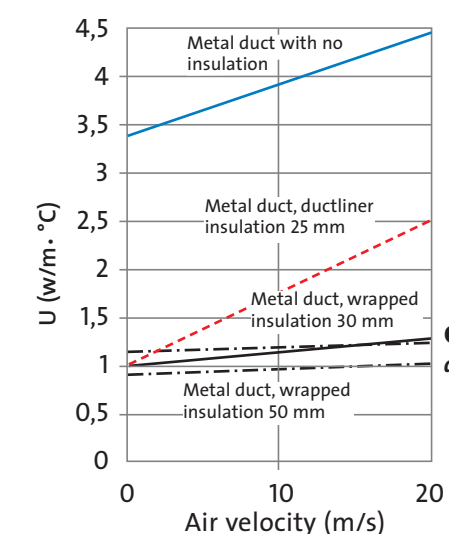
ρ = Air density, kg/m^3

t_e = Air temperature in the duct inflow ($^{\circ}\text{C}$)

t_i = Air temperature in the duct outflow ($^{\circ}\text{C}$)

t_a = Air temperature of the surrounding air ($^{\circ}\text{C}$)

ASHRAE Chart



CLIMAVER
ductboard



Self-supporting ductboards can reduce thermal losses by up to 70 % compared to metal ducts



Reduction of power consumption

As explained above, energy losses for a given set of air conditions (environmental and entry) and duct geometry depend to a large extent on individual material U value. As an approximation, the U value for each material type can be considered as a source of loss.

EXAMPLE

A duct network placed between the framework and a suspended ceiling, has the following characteristics:

- Cross section 400 x 400 mm, length 20 m
- Air flow speed: 8 m/s
- Air temperature in the inflow air: 14 °C
- Air temperature of the surrounding air: 26 °C

Using this basic construct, the aim is to compare heat transfer when different materials are used – in this example, uninsulated metallic ducts versus glass wool ductboarding.

The heat transfer rates used in this example are (according to Ashrae graph):

- Galvanized sheet metal duct: $U = 3.8 \text{ W}/(\text{m}^2 \cdot ^\circ\text{C})$
- Glass wool ductboards: $U = 1.1 \text{ W}/(\text{m}^2 \cdot ^\circ\text{C})$

And therefore, total heat losses of:

- Q (Galvanized steel duct) = 1,403.2 W
- Q (Glass wool ductboards) = 415 W

Conclusion: Heat loss from a glass wool ductboard network can be 70.4 % lower than from uninsulated galvanized sheet metal ducting. Furthermore, this example did not consider heat losses due to air leakage. If metal ducting is insulated, then, depending on the insulation thickness and the air leakages in the joints, ductboards can save up to 30 % thermal losses when compared to insulated metal ducting.

Using the formulae described in section 1, it is possible to make comparative analyses of heat loss for different types of insulation.

This general case can be simplified, especially for h_e and h_i . For example, systems with internal liquids have very low $1/h_i$ values which is negligible compared to U values.

The following formulae apply for internal installations in a building:

- Horizontal pipes: $h_e = C_A + 0,05 \Delta\theta \text{ W}/(\text{m}^2 \cdot \text{K})$
- Vertical pipes and flat walls: $h_e = C_B + 0,05 \Delta\theta \text{ W}/(\text{m}^2 \cdot \text{K})$

Depending on the facing material used, the appropriate values can be selected from this table:

Material	C_A	C_B
Polished aluminium	2.5	2.7
Oxidized aluminium	3.1	3.3
Galvanized steel duct (clean)	4.0	4.2
Galvanized steel duct (dirty)	5.3	5.4
Austenitic Steel	3.2	3.4
Zinc-aluminium board	3.4	3.6
Non metallic materials	8.5	8.7

The previous equations are applicable for horizontal pipes of diameters from 0.25 m to 1 m, and for vertical pipes of any diameter.

C_A and C_B are approximate values and applicable only if $\Delta\theta < 100 \text{ }^\circ\text{C}$ and if radiation is negligible, as the temperature difference between the external surface of the equipment and the surrounding air is negligible.



3.3. Condensation risks

If an air mass with a given temperature and relative humidity (H_r) cools, condensation occurs if the "dew point" is reached (t_d), corresponding to $H_r = 100\%$. This is important when the temperature inside the equipment or the duct is lower than that of the surroundings:

The temperature of the outer air falls and H_r increases, resulting in a risk of condensation.

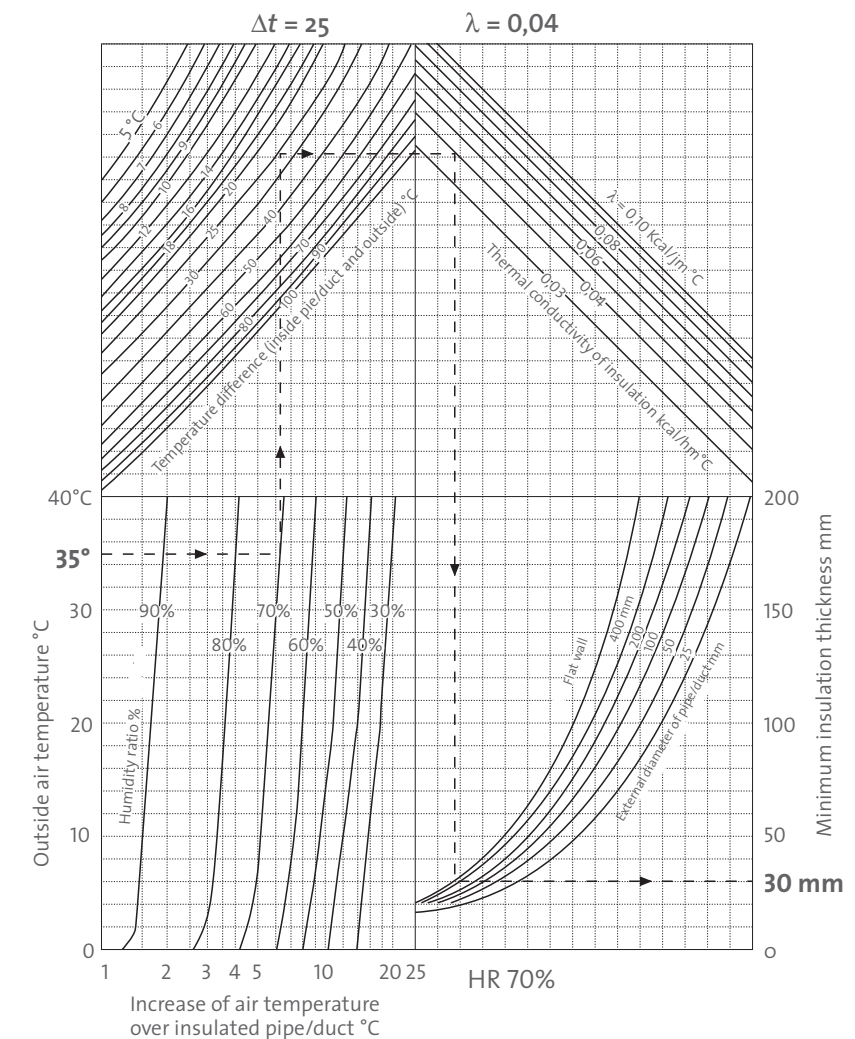
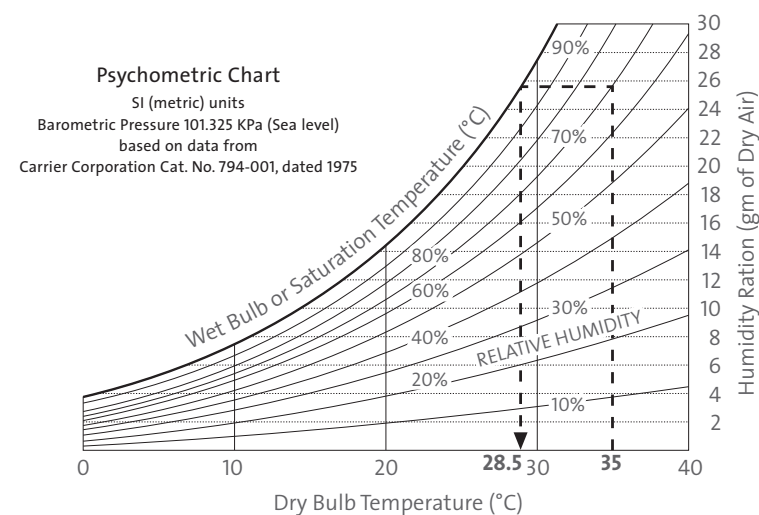
If the separating element is metallic or a good thermal conductor, usually the risk of condensation is high, even with low temperature differences between inner and outer air, and particularly in environments with high humidity (H_r).

In any case, it is essential to work from the worst possible set of conditions when considering the insulation for equipment, including conditions under which condensation is likely.

Surface temperatures likely to give rise condensations can be calculated from 'U' and 'h_e' values by determining outer surface temperature and the increase in 'H_r' in ambient air at that temperature. However, such calculations are laborious and a simplified graphical method is much easier and permits the calculation of the insulation without recourse to complex algorithms.

The use of mineral wools as insulation requires the installation of a vapour barrier to prevent the condensation occurring inside the insulating material itself. This is why ISOVER insulation products for metal ducts and glass wool ductboards have an outer facing that acts as a vapour barrier.

ISOVER's solutions eliminate condensation risks even with high temperature differences.



Summary Chapter 3

The energy consumption of a duct work system can be reduced by using adequate thermal insulation, not only in the building itself but also in the duct work and pipe work used to distribute fluids (air and water) throughout the building.

Thermal insulation in a duct network is dependent on the insulation material, its thickness,

and air leakage. These three effects are consolidated as high thermal resistance, and the correct air tightness.

ISOVER products, both for wrapped or duct-liner insulation of metal ducting, or self-supporting ducts, deliver excellent thermal insulation efficiency.



4. Acoustic Insulation in HVAC duct work

Noise (considered unwanted sound) was declared an environmental pollutant at the 1972 International Conference for the Environment, in Stockholm.

Noise has a wide range of consequences for humans, from general disturbance, reducing personal comfort (such as lack of privacy or difficulty in talking) and even leading to serious health problems such as heart failure, hearing difficulties, stress etc.

HVAC installations generate different levels and spectra of sound, depending on the design, installation and equipment power source; in particular the noise produced by fans and air conditioning units transmitted via the ducts. How this transmitted noise level can be reduced is described later in this chapter.



Maximum Admissible Sound Level in Buildings.

With the aim of trying to reduce the effects of noise disturbance as much as possible, European countries have established limits for admissible maximum sound levels in buildings and dwellings, according to the building's use.

Besides regulation and specific standards applicable to the HVAC installation, the designer should never forget that the primary function of air conditioning installations is to improve user comfort. It would indeed be remiss if noise discomfort generated by the installation were ignored. Probably one of the most effective strategies for tackling noise issues is careful design and selection of the ducting.

4.1 Origins and paths of sound transmission in installations

When seeking a solution for noise in HVACs it is necessary to:

- analyse the noise
- identify its origin and transmission path(s)
- implement the appropriate solutions

Such an undertaking requires an initial study of the entire building's acoustic requirements, taking steps to avoid inadequate sound reduction, and to secure a minimum level of acoustic comfort for the building's occupants.

Noise Types

a) Airborne sound

It is generated and transmitted through air, such the human voice, TV, radio etc.

The source of the noise is easy to identify and transmission is propagated directly via air to receiver, or more accurately by the vibration of air molecules.

In HVAC installations aerial noise transmitted by the ducts may have various different origins, such as:

- Emissions from ventilation equipment, i.e. fans.
- Aerodynamic emissions, produced by pressure variations in the flowing air, and air friction in the ducts (typically from direction changes or high speed airflow).
- Sound transmission along the duct network resulting in a sound produced in one room being transmitted and thereby heard in another.

b) Impact sound

This is sound produced by impact or a shock to the building's structure that subsequently produces vibrations transmitted through the building elements.

It is possible that the source of sound is some distance from the points it is perceived. One explanation for this is the high speed of sound transmission through and along solid objects, often making detection of true origin of the sound difficult.

Typical examples of this type of noise are vibrations produced by operating machinery, transmitted through their structural supports (for instance, washing machines, dishwashers, and of interest here, air conditioners, exhaust ducts, etc.).

4.2 Solutions for installation noise

As a rule there is no simple, universal solution for noise reduction in HVAC installations. However, solutions do exist and they will be more effective and easier if considered at the initial design stage of the installation.

It is also a simple fact that some equipment transmits airborne and impact noise simultaneously, motors being a good example.

Furthermore, the noise emitted by equipment is related to its operational characteristics, such as its power consumption.

For example, the acoustic energy emitted by electromechanical equipment can range from 10^{-3} to 10^{-7} times the energy consumed. Nevertheless, the human ear is able to detect sounds with acoustic intensities as low as 10^{-12} W/m², and can register disruptive sounds around 10^{-4} W/m², representing approximately 80 dB (dB, or decibel, is the logarithmic transformation of sound intensity, and a familiar unit of sound).

Ergonomics also needs to be considered, as perception of human comfort determines maximum desirable sound levels in buildings. In all cases, selecting a corrective method depends on the sound level emitted by the source, the distance it travels and manner of its transmission.

The next few paragraphs describe the methods used, based on noise source, with special attention paid to that transmitted by ducts.

4.2.1 Air Handling Units

This type of equipment, with moving parts, is invariably a source of noise, both transmitted as impact sound and as airborne noise, due to the vibrations of its constituent components.

The location of processing units in a building is an important factor to consider if measures to combat noise are planned: those employed when equipment is located on the terrace will be different to those needed for equipment located deep inside the building.

a) Impact noise

If equipment foundations, hangers, or supports are rigid, some of the acoustic energy is invariably transmitted through the building structure, vibrations giving rise to impact noise.

The solution here is the use of flexible, vibration-damping instead of rigid fixtures, thus reducing the vibration produced by the equipment.

The diagram illustrates a simple case; showing equipment of mass 'm', force 'F', and an input vibration frequency of 'f_p'. If dampening elements of rigidity 'K' are inserted into the supports, the system will tend to vibrate with a frequency:

$$f_n = \frac{1}{2\pi} \sqrt{\frac{K}{M}}$$

Where 'f_n' is the so-called "natural frequency of the system". This system would vibrate indefinitely at this frequency if there were no sources of dampening (for example friction)

Of interest is what proportion of 'F' is really transmitted, where 'T' is transmission. It can be calculated as:

$$T = \frac{F}{\left(\frac{f_p}{f_n}\right)^2 - 1}$$

The result of this formula indicates:

- < 1, increase of 'T', increasing as 'f_p' approaches 'f_n'.
- > 2, diminution of 'T' with respect to 'F' – an increase in the frequencies relationship.

The solution to this problem is simplified for the designer by the following:

- It is assumed that equipment geometry and load are known for each of the supports, based on manufacturer's specifications.
- The input frequency of the system is usually taken as the rotor's working frequency.
- Selection of two dampening elements is made considering effective dampening for k = 3 or 4 and also the load supported by each shock absorber.

The last point is very important in terms of selection: commercial shock absorbers (soft, natural rubbers etc.), are constructed for pre-determined load conditions, for which they have a calculated rigidity, as defined by load deflection or static deflection (d_{est}). Static deflection is defined as:

$$d_{est} = \frac{M}{K}$$

The natural system frequency is:

$$f_n = \frac{15.76}{\sqrt{d_{est}}}$$

d_{est} is in millimetres.

EXAMPLE

The target is to determine the type of shock absorbers for a compressor with a motor turning at 1,450 r.p.m., a total weight of 2,000 kg, mounted on a large stone plinth with 6 support benches each with the same loading.

Solution:

- Reaction by support: 2,000/6 = 333.33 kg.
- Input Frequency: f_p = 1,450/60 = 24.16 Hertz.
- Natural frequency of the system: f_n = f_p/3 = 8.05 Hertz (max).
- Static deflection:

$$d_{est} = \left(\frac{15.76}{8.05}\right)^2 = 3.85 \approx 4 \text{ mm}$$

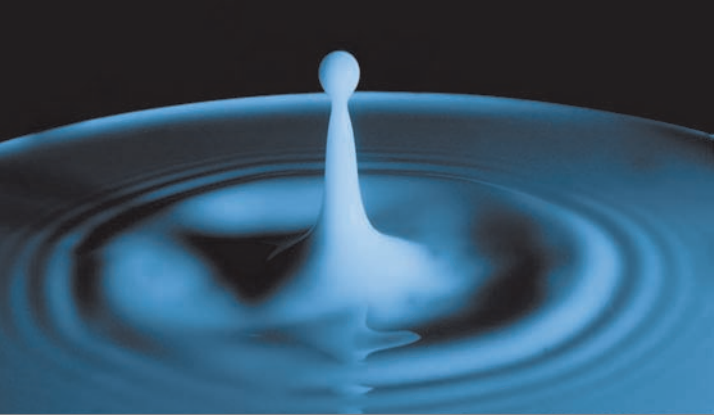
Flexible elements should have a d_{est} = 4 mm.

b) Noise breakout

There are two possibilities: equipment located in open spaces (for example, building terraces) and equipment enclosed inside the building.

Equipment in open spaces

Airborne noise generated by protective housing or blower pipes can be transmitted to the surroundings, affecting the building and the surrounding buildings.



In open spaces sound levels dissipate similar the ripples created by a drop of water falling into pool of infinite dimensions.



The perceived sound level in each case depends on the total emitted energy, sound direction and distance from the source. Sound intensity decreases with distance, according to the following expression:

$$L_p = L_w + 10 \log \left(\frac{\phi}{4 \pi r^2} \right)$$

Where:

L_p is the sound pressure at a distance “r” from the source (dB)

L_w is the source acoustic power (dB)

r is the distance (m)

ϕ is the directivity ($\phi = 1$ if the emission is spherical, 4 if the emission is semi spherical)

Knowing the emitted acoustic power ‘ L_w ’ (or calculating), the next step is to determine ‘ L_p ’ for the nearest receptor.

If ‘ L_p ’ global value is greater than the permitted value determined by regulation or self-imposed conditions, the necessary corrective measures need to be invoked.

To achieve this, external containment should be considered for equipment located in open spaces. Furthermore, exhaust ducts situated in open areas are emission points with the greatest sound levels and they should be the first target for corrective measures. This is usually done with acoustic attenuators. In order to control such open areas, silencers are generally used, with glass wool being used as a sound absorber.

Absorption silencers contribute to significant sound attenuation without producing, in most of the cases, significant pressure fall-off. The absorbent material is placed on the lateral sides and at the centre of the air flow and installed on frames. The number of elements, separation between the elements, and silencer height define the effective length of duct section.

Protection of the absorbent material against damage depends on the airflow velocity and is generally considered unnecessary for speeds less 10 m/s. For speeds up to 25 m/s, in addition to a glass tissue lining, the absorbent material should be protected with perforated metallic sheet or reinforcement facing of high mechanical resistance.

The silencer needs be appropriate to the characteristics of the noise emitted by the equipment and the position of the receiver, bearing in mind the relevant existing regulations.

Some manufacturers provide empirically-derived frequency spectra for their equipment – if not, it needs to be calculated. It is generally assumed that fans are the major emission point and the following empirical formulae can help evaluate the noise generated by fans (global level L_w):

$$L_w = 25 + 10 \log Q + 20 \log P \text{ (dB) (Madison-Graham)}$$
$$L_w = 77 + 10 \log W + 10 \log P \text{ (dB) (Allen)}$$

Where:

Q: Air flow rate (m³/h)

P: Static pressure (mm.c.a)

W: Fan power (kW)

In order to determine the sound power in each frequency band, global level ‘ L_w ’ can be adapted by introducing corrective coefficients for each frequency. These coefficients vary according to the type of fan. Ventilators emit noise in a wide range of frequency spectrums, presenting a peak at the so-called ‘blade frequency’, which can be determined from the following expression:

$$f_{blade} = \frac{W_g \cdot N}{60} \text{ Hz}$$

Where:

W_g : blades spinning speed (r.p.m)

N: number of blades

When the spinning speed is increased, the noise emitted increases, stabilizing itself at a level characteristic for particular type of ventilator. The following approximation is useful – doubling the rotation speed increases sound level by approximately 17 dB.

EXAMPLE

Determination of the type of absorption silencer necessary to attenuate noise emitted by an exhaust duct with a helicoidally air circulating ventilator, with airflow of 5.5 m³/s (= 20.000 m³/h) and overcoming a pressure drop of 147 Pa (indicated by a manometer reading, 15 mm hydrostatic head), if the nearest sound receiver is at 20 m from the exit point of the exhaust duct.

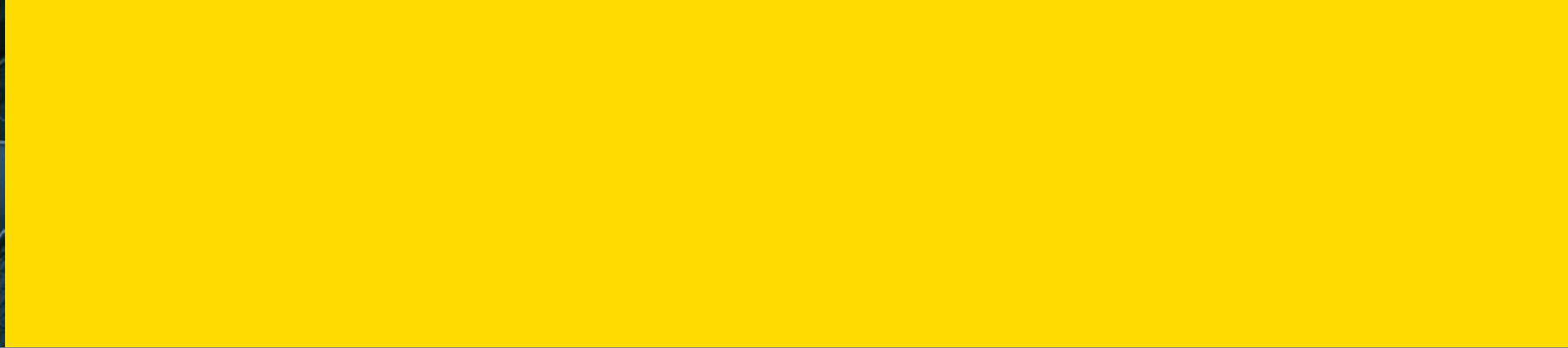
Solution:

Using Madison-Graham’s formula:

$$L_w = 91.5 \text{ dB}$$

Introducing corrective coefficients for an axial fan, the following noise spectrum is obtained:

F (Hz)	63	125	250	500	1,000	2,000	4,000	8,000
L_w (dB)	86.5	83.5	84.5	82.5	80.5	80.5	78.5	66.5



To calculate the intensity for the recipient (for each frequency band), with the formula for sound spread in open spaces:

$$L_p = L_w + 10 \log \frac{1}{4\pi(20)^2} = L_w - 37 \text{ dB}$$

F (Hz)	63	125	250	500	1,000	2,000	4,000	8,000
L _p (dB)	49.5	46.5	47.5	45.5	43.5	43.5	41.5	29.5
L _p (dBA)	23.5	30.5	38.5	42.5	43.5	44.5	42.5	28.5

The global level is obtained by the formula:

$$L_{p_g} = 10 \log \sum \text{anti log } L_p / 10$$

Then L_{p_g} = 49.8 dB(A)

or L_{p_g} = 59.6 dB

If it is assumed that regulations permit sound levels no greater than 40 dB(A), then a silencer that reduces the sound pressure by at least 9.8 dB(A) needs to be installed. Choosing within a range of available products, with the required characteristics and desired geometry, a silencer can be found from the following attenuation spectrum:

F (Hz)	63	125	250	500	1,000	2,000	4,000	8,000
Silencer attenuation (dB)	4	6	11	22	25	25	19	15

The sound level in the receptor's area would be:

L _p	45.5	40.5	36.5	23.5	18.5	18.5	22.5	14.5
L _p (A)	19.5	24.5	27.5	20.5	18.5	19.5	23.5	13.5

The global level is: L_{p_g} = 31.6 dBA or L_{p_g} = 47.2 dB

The system would now meet the requirements of the regulation in the above example.

(Note: manufacturer's data should be used to establish noise generation criteria. The designer then determines the required dampening and working conditions)

Equipment in enclosed spaces

Airborne noise affects the building where the equipment is located and can be transmitted to the rest of the building from the sound source. If vibrations are produced they can also be transmitted, even affecting non-adjacent buildings.

As already mentioned, equipment located in enclosed spaces can create vibration issues and therefore should be equipped with suitable shock absorbers. Extract or outlet ducts also need to be fitted with silencers.

As in the previous example, the perceived sound level depends on sound direction and distance, affecting the area of absorption according to the following expression:

$$L_p = L_w + 10 \log \left(\frac{\Phi}{4\pi r^2} + \frac{4}{A} \right)$$

L_p is the sound pressure at a distance "r" from the source (dB)

L_w is the acoustic power of the source (dB)

r is the distance (m)

Φ is the directivity (Φ = 1 if the emission is spherical, 4 if the emission is semi-spherical)

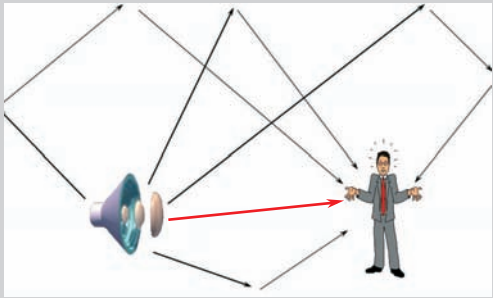
A is the area of absorption (A = ∑ α_i S_i) (m²)

α_i is the Sabine absorption coefficient for the materials in the interior surfaces of the room.

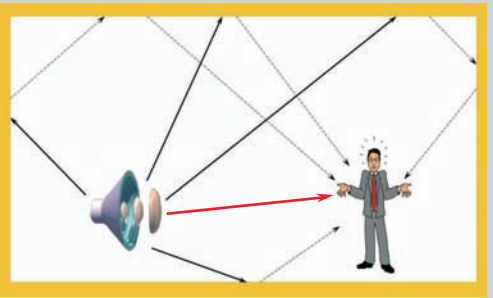
S_i is the sum of the area of the walls

'L_p' and 'L_w' values correspond to each frequency band.

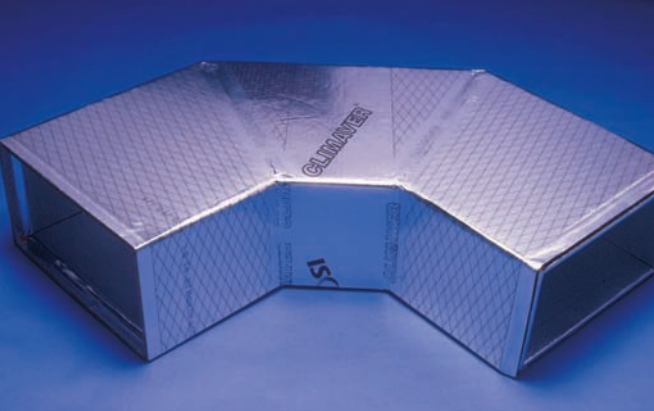
Sound levels in adjacent areas depend on how well separating structures are insulated acoustically. As a general rule, selection of the material acoustic insulation for an installation should also confer adequate thermal insulation on the installation.



In enclosed spaces sound is perceived as the audition of direct sound and the reflexion of sound in the walls.



Reflexion of the sound can be attenuated by using acoustic absorbent materials such as ISOVER mineral wools.



Air ducts made from glass wool ductboard contribute to significant noise reduction in the installation



4.2.2 Air distribution ducts

Noise generated in ducts is caused by the turbulence of the air flowing through them. Sometimes turbulence causes vibrations in duct walls, dramatically increasing the noise transmitted to the rooms they service. Sound propagation via ducts without internal insulation is not reduced (generally the potential dampening effect is negligible).

In order to significantly reduce the noise created by turbulence, the inner surface of the duct can be faced with a noise absorbing material (the ducting is metal) or made from glass wool ductboard. When the duct is sufficiently long, noise reduction can be estimated by the following expression:

$$\Delta L = 1.05 \cdot \alpha^{1.4} \cdot P/S$$

Where

ΔL represents noise dampening

α is the Sabine absorption rate for the material

P is the duct internal perimeter (m)

S is the duct free section

It can be deduced from the previous expression that attenuation is obtained more easily with small ducts (the P/S relation is increased for smaller ducts). This reasoning is, however, difficult to apply, as it would infer that higher flow speeds are required for smaller sections to maintain the same airflow. This could lead to a worsening of acoustic effects.

Attenuation is also determined by the absorption rate, which in turn depends on the nature and geometry of the material in contact with the airflow. With respect to the geometry, flat surfaces are usually used and the product thickness influences the Sabine coefficient: the greater the thickness, the greater the noise reduction, particularly with low and medium frequencies. Of the materials traditionally available, glass wool offers the best coefficients for acoustic absorption.

a) Glass wool ductboards

From the acoustic point of view, glass wool ductboards represent a favourable solution by reducing noise generated by air handling unit that then is transmitted throughout the building via the duct network.

ISOVER provides technical data for these types of product, with acoustic absorption coefficients as determined by agreed standardized laboratory testing.

The influence of the real noise spectrum

It should be noted that in most of the cases, the noise from the handling unit is predominantly in the low and medium frequency range. Therefore, the values of alpha Sabine at low and medium frequencies can determine the total acoustic attenuation.

EXAMPLE

Calculation of the noise reduction of a one metre long glass wool ductboard (350 x 350 mm). Two types of ISOVER ductboards are considered: one of them is **CLIMAVER** Neto, specifically designed with a black glass fabric to enhance acoustic insulation. The noise source is an axial fan producing an air flow of 5.5 m³/h (= 20.000 m³/h), and a pressure drop of 147 Pa (indicated by a manometer reading, 15 mm hydrostatic head). The resultant sound pressure reduction can be calculated using Madison-Graham's formula with correction for axial fan types.

F (Hz)	125	250	500	1,000	2,000
L _w (dB)	83.53	84.53	82.53	80.53	80.53

For **CLIMAVER** Plus R and **CLIMAVER** Neto, noise reduction is given by the formula:

$$\Delta L = 1.05 \cdot \alpha^{1.4} \cdot P/S$$

Where $P/S = \frac{4 \times 0.35}{0.35 \times 0.35} = 11,43$ in this example

And the ' α ' is taken from the technical datasheet.

	F (Hz)	125	250	500	1,000	2,000
CLIMAVER Neto	α	0.25	0.6	0.65	0.95	1
CLIMAVER Plus R	α	0.20	0.20	0.20	0.60	0.50

Acoustic attenuation is obtained from:

	F (Hz)	125	250	500	1,000	2,000
CLIMAVER Neto	L (dB/m)	1.72	5.87	6.56	11.16	12.00*
CLIMAVER Plus R	L (dB/m)	1.26	1.26	1.26	5.87	4.55

And the sound level at the exit will be:

	F (Hz)	125	250	500	1,000	2,000
CLIMAVER Neto	L _p (dB)	81.81	78.66	75.96	69.37	68.53
CLIMAVER Plus R	L _p (dB)	82.27	83.27	81.27	74.66	75.98

The global values are now given:

$$L_{wg} = 89.61 \text{ dB} \quad L_{pg} (\text{CLIMAVER Neto}) = 84.47 \text{ dB} \quad L_{pg} (\text{CLIMAVER Plus R}) = 87.66 \text{ dB}$$

Due to the interior material composition, a meter long **CLIMAVER** Neto ductboard can reduce sound by 5.1 dB and **CLIMAVER** Plus R by 1.9 dB.

Note: **CLIMAVER** Plus R is an ISOVER glass wool ductboard internally faced with aluminium.
CLIMAVER Neto is an ISOVER glass wool ductboard internally faced with a glass fabric (Neto)



Ductliners in metal ducts contribute to acoustic attenuation

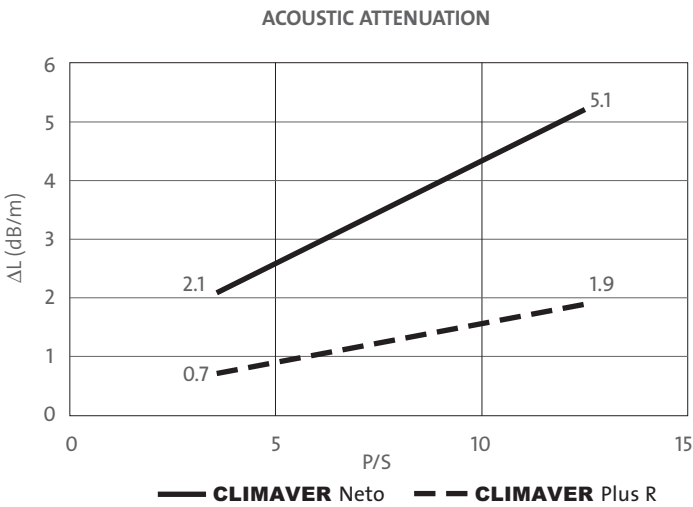


Influence of the duct geometry

The first sections of duct work connected to the air conditioning unit determine the acoustic attenuation until the first grids or diffusers can influence sound reduction. Not surprisingly, this is because they are the nearest to the noise emitting source, such as air handling units.

Reducing acoustic attenuation to the most common duct sections, involves reducing the application range of P/S from 11.4 to 4.

For the sound spectrum from the previous example, the potential for acoustic attenuation based on real geometries is shown in the following chart.



b) Comparison with other duct solutions

Metal ducts with no insulation are not a good solution for acoustic attenuation, due to their lower absorption coefficient, ‘α’.

- In the case of metal ducts, two possible approaches can be used to tackle this problem.
- Silencers or attenuators can be installed immediately post-air exit in a unit with characteristics similar to those described in the previous section. The subsequent calculation strongly depends on duct geometry and acceptable pressure drops.
 - Absorbent elements can be installed inside the duct, increasing the ‘alpha value’ in the whole frequency range. Glass wool boards or wraps can be used, so called ‘duct liners’.

Acoustic absorption is tightly bound to the thickness of the glass wool duct liner, especially for low to medium frequencies. Higher thicknesses provide greater acoustic attenuation in the duct, as well as higher thermal insulation. The following table shows the results of acoustic attenuation (dB/m) in a duct of 400 x 500 mm fitted with different insulation materials.

TYPE	ACOUSTIC ATTENUATION (dB/m)				
F (Hz)	125	250	500	1000	2000
Metal duct	0.07	0.07	0.19	0.19	0.1
Metal duct + duct liners, 15 mm	0.14	0.18	0.23	1.28	2.8
Metal duct + external wrapped insulation, 55 mm	0.14	0.14	0.38	0.38	0.2
Ductboard internally faced with aluminium	0.99	0.99	0.99	4.62	3.58
Ductboard internally faced with glass fabric	1.36	4.62	5.17	8.80	9.45

The distinctive zero sound attenuation of uninsulated metal ducting can, however, be improved using glass wool duct liners, conferring significant sound absorption, especially at low to medium frequencies as thickness increases.

As a reference, the alternative of a metal duct with duct wrap (exterior insulation to the metal duct) is also shown. In this case, there is a slight improvement of the attenuation compared to a non-insulated metal duct, though the result is still very poor, although thermal insulation is, of course, improved compared to the uninsulated metal duct. Optimum acoustic attenuation can be obtained with ductliner insulation in a metal duct or self supporting glass wool ducts, such as ISOVER **CLIMAVER** range, instead of metal ducts.

Summary – Chapter 4

HVAC installations are very complex in terms of acoustic design, as noise problems can arise from many points within the installation. Nevertheless, various different solutions are available for tackling acoustic problems in installations. These solutions are invariably more effective, simple and economical if they are considered at the design stage.

With reference to air distribution ducts, noise levels generated in the installation can be decreased using absorbent materials, either as part of the construction of the duct, or combined with silencers.

Finally, improvements in noise levels in air distribution ducts confirm that the best option is either glass wool ductboard, especially when faced internally with a glass fabric to allow acoustic absorption, or metal ducts with a glass wool duct liner installed in the air stream surface of the metal duct.



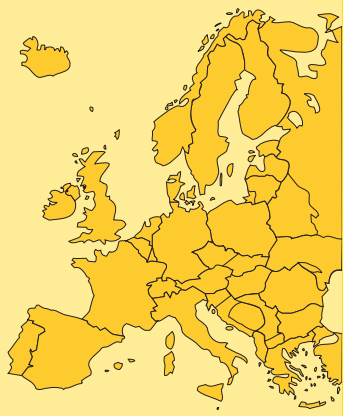
5. Fire Protection in HVAC duct work

Fire is one of the greatest risks for the occupants of any building. This is why fire protection regulations are becoming more and more stringent worldwide.

For instance, The 2004 Statistics Arson Control Forum calculated that in an average week in the United Kingdom there are:

- 2000 deliberately set primary fires
- 50 injuries
- 2 deaths
- £55m cost to society
- 20 fires in schools

Incorrect or poorly designed duct networks may contribute to the spread of fire and smoke throughout a building, as they offer direct physical access by which the fire can travel. Many different protection methods are available to avoid or minimize fire propagation: passive methods (where the fire propagation is minimized by the correct choice of building materials) and active (using mechanisms that try to reduce fire risks to a pre-designed level)



Euroclasses are a unique and harmonized system for all Europe



5.1. Reaction to Fire

When a material reaches its ignition temperature, it can start to burn, and this is therefore considered the starting point of a fire. From this moment, as combustion is an exothermic process, the temperature increases in the area around the starting point of the fire and the surrounding area may also start to burn. As long as combustible material is available the relationship between time and temperature becomes exponential. In a real fire scenario, when a certain critical temperature point is reached, all available combustible material suddenly begins to burn. If flashover occurs the possibility of leaving the room alive decreases dramatically. At the flashover point, the fire runs out of control. Combustion progresses until the temperature decreases due to the lack of combustible material.

Some factors determine the relationship between temperature and time:

- Fire load of the premises (materials): calorific value of existing materials as measured by surface unit. This characteristic depends on each material and cannot be modified artificially.
- Capacity and speed of fire propagation, also depends on the material, but can be artificially modified using flame retardants.

Example: Euro classification – European Standards of Reaction to Fire.

In Europe, the mandatory legal classification establishes 7 main classes and 6 sub-classes, according to EN 13501-1:

Classification		Additional classification (First level)				Additional classification (Second level)			
A1	The material will not contribute in any case to increase the fire	Not needed				Not needed			
A2	The material cannot significantly provide fire load, nor can it contribute to fire development.	s	Smoke production (smoke toxicity and opacity)	1	(nil or low smoke level)	d	Flaming Droplets / particles production	0	No fall
B	The material is a low combustible material that has not met the requirements demanded for the previous classes.			2	(average smoke production)			1	Delayed droplet fall
C	The material is combustible and has not met the requirements demanded by the previous classes.			3	(very high level of smoke production)			2	Fast droplet fall
D									
E									
F	Not classified								

This standard applies to all European countries. Depending upon country, the regulation establishes the minimum Euro classification a duct has to meet.

It should be noted that glass and stone wool products used for air conditioning ducts (either self-supporting pre insulated ducts or as lagging for metal ducts) are classified as mineral wools that neither contribute to the start nor propagation of fire.

All ISOVER materials exhibit the most stringent constraints concerning smoke emission, s1, and flaming droplets, d0, and represent low or zero fire load.

5.1.1. Smoke issues in fire safety

Generation and propagation of smoke in a fire may cause two different problems:


- Visual opacity
- Toxicity of smoke

Opacity is defined as the amount of light obscured by particulate pollution in the air. For instance, clear window glass has zero opacity and a brick wall is 100 percent opaque. In terms of fire safety, opacity is the visual darkening of evacuation areas that prevent people from escaping from a building where a fire has started. The greater the degree of darkening, the more difficult it will be to escape, increasing the risk of fatality.

Smoke from a fire are never healthy for humans. However, the chemical composition of the gases can vary depending on the type of material burnt. Two effects should be considered when exposed to fire smoke: toxicity of the smoke and opacity that would prevent people to find the exit ways.

European classification notes three levels of fire production: s1, s2 and s3, corresponding s1 to a null emission and s3 to a significant smoke production.

It is important to note that classification can be modified by the use of different facings.

	Unfaced mineral wool	Faced mineral wool						Foam	
A ₁		Glass veils	Alu	Painted					
A ₂									
B				Vinyl	Alu/Kraft	PES			
C									
D									
E									Kraft
F									

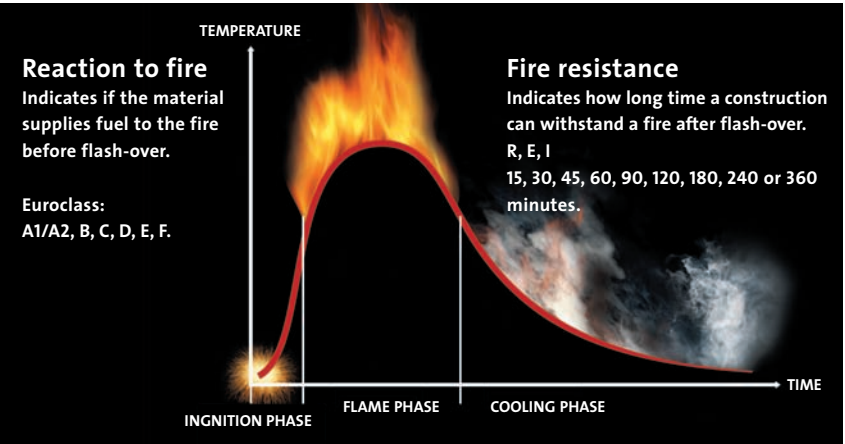
5.1.2. Flaming Droplets and/or particles production

Another parameter to consider in reaction to fire is the production of flaming droplets and/or particles. Since ducts are typically installed over suspended ceilings, proliferation of these droplets or particles in a fire scenario is most important, not only for safety but also for restriction of fire propagation (for example, the combustion of furniture due to falling droplets).

European classification establishes three levels of flaming droplets: d0, d1 and d2, corresponding do to the minimum emission and d2 to a high level of flaming droplet and particles emission.



ULTIMATE insulation provides optimum values for fire resistance with lower weight than traditional solutions



5.2. Fire resistance

The fire resistance of a building component is defined as the time during which this component is able to fulfil conditions of stability, display an absence of flammable gases, provide no passage to flames and minimize the temperature of the unexposed face.

Ducts can be designed to meet the fire resistance requirements of the regulation. For example, when ducts pass through separating walls designed to function as fire-breaks, they must also be designed with a minimum level of fire resistance.

Two solutions are available:

- The use of fire resistant ducts.
- The use of fire dampers.

Fire resistant ducts can be created by in several different ways. The most common method is to insulate metal ducts with a mineral wool that, making it resistant, in addition to providing thermal and acoustic insulation.

For fire resistance ducts, ISOVER has developed a unique solution called **ULTIMATE** PROTECT, based on the **ULTIMATE** mineral wool. This solution combines:

- Optimum fire resistance values for duct work
- Lower weight than traditional stone wool insulation solutions
- Reduction of thickness for equivalent fire resistance compared to traditional stone wool solutions
- Ease of installation

The **ULTIMATE** range of products designed for this application is U Protect and can achieve the following fire resistance in ducts:

Rectangular ducts – up to 2 hours fire resistance for fires located inside or outside of the duct, both horizontally and vertically. The U Protect Slab is used for rectangular ducts.
Circular ducts – up to 2 hours fire resistance for fires located inside or outside of the duct, both horizontally and vertically. U Protect Wired Mat is used for circular ducts.

See tables below for exact thicknesses of U Protect:

Insulation thickness needed (mm)						
Fire position	Fire class					Duct Orientation
	EI 15	EI 30	EI 60	EI 90	EI 120	
▼ Fire inside duct ▼						
Inside	30	40	60	70	80	Horizontal
	35	60	80	90	100	Vertical
▼ Fire outside duct ▼						
Outside	30	30	30	70	80	Horizontal
	30	30	30	70	80	Vertical
▼ When both fire positions are required ▼						
Both	30	40	60	70	80	Horizontal
	35	50	80	90	100	Vertical
▼ To use 1 product for both duct orientations ▼						
Outside Inside	30 35	30 50	30 80	70 90	80 100	Both
▼ To use 1 product for all cases ▼						
Both	35	50	80	90	100	Both

Rectangular duct

Insulation thickness needed (mm)						
Fire position	Fire class					Duct Orientation
	EI 15	EI 30	EI 60	EI 90	EI 120	
▼ Fire inside duct ▼						
Inside	35	50	75	95	115	Horizontal
	35	50	75	95	115	Vertical
▼ Fire outside duct ▼						
Outside	30	30	60	90	100	Horizontal
	30	30	60	90	100	Vertical
▼ When both fire positions are required ▼						
Both	35	50	75	95	115	Horizontal
	35	50	75	95	115	Vertical
▼ To use 1 product for both duct orientations ▼						
Outside Inside	30 35	30 50	60 75	90 95	100 115	Both
▼ To use 1 product for all cases ▼						
Both	35	50	75	95	115	Both

Circular duct

Summary of Chapter 5

Fire is one of the main causes of accidents in buildings as measured in both material damage and loss of life. For fire safety in buildings, the appropriate method and materials need to be selected to prevent fire propagation.

This is especially important in terms of duct networks. When selecting the constituent materials of any duct their behaviour relative to fire must always be considered, especially calorific content, smoke production and flaming droplets when burning.

ISOVER's products are a safe option for HVAC duct work as they produce neither smoke nor incandescent drops in a fire. They also contribute negligible calorific input for a fire.

*Duct design also needs to take fire stability into account, for which ISOVER has developed **ULTIMATE**, a new generation mineral wool that increases the fire resistance of duct work and has considerable advantages, such as lower weight and ease of installation, compared to traditional solutions. **ULTIMATE** also contributes significantly to thermal and acoustic insulation.*



6. Pressure losses in air ducts

Air flowing inside a duct network receives impulse energy from a fan. The amount of energy has to be sufficient to distribute the airflow to all outlets at the volume, temperature and speed required.

Duct dimensions need to be designed to obtain the required airflow inside the duct and to ensure that the energy supplied is sufficient to overcome pressure losses during normal operation of the installation.

Pressure loss can occur for two reasons:

- Frictional losses, caused by fluid resistance to flow against the surface of the duct, the duct's internal surface roughness.
- Dynamic energy losses which depend on the geometry, directional changes and the type of air movement (turbulence).

This chapter describes how to calculate and evaluate these pressure losses

6.1 Static, dynamic and total pressure

General Concepts

Energy provided by the fan creates a motive force, or pressure, divided into two components: static pressure and dynamic pressure as defined below.

a) Static pressure, P_s , is the result of compressing fluid (air) within a duct. It is measured with reference to atmospheric pressure. Static pressure reaches a peak at the fan unit and decreases throughout the duct due to frictional pressure losses and declines to almost zero at the exit. The same occurs in the exhaust duct, although in this case the value is negative. It is 'positive' during suction and 'negative' during 'discharge'.

b) Dynamic pressure, P_d , is the energy component due to fluid velocity and is calculated using following formula:

Where:

ρ = airflow density (kg/m^3)

v = airflow velocity (m/s)

$$P_d = \frac{\rho v^2}{2}$$

Dynamic pressure is always positive. The velocity varies with changes in duct geometry, size etc along the duct length, as the air mass at any point in time is the same throughout the duct. This is the case until its exit point or when air is distributed into various branches of the duct network.

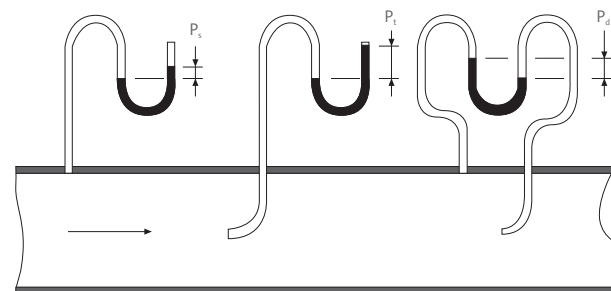
c) Total pressure, P_t , is the algebraic sum of $P_s + P_d$. P_t is positive in supply duct and negative in the discharge duct.

Units and measuring equipments

The international unit of pressure is the Pascal ($1 \text{ Pa} = 1 \text{ N/m}^2$).

However, calculations relating to pressure in HVAC systems is conventionally expressed in mm of manometer hydrostatic head. The conversion factor is $1 \text{ mmwg} = 9.81 \text{ Pa}$ ('mmwg', or sometimes expressed 'mmca', is the measurement in millimetres of water measured in the manometer).

The instrument for such measurements is the Pitot-Static Tube, illustrated in the adjacent figure.



6.2 Pressure losses

The movement of the air (akin to the movement of a fluid) inside ducts causes two types of pressure loss: friction losses and dynamic losses.

a) Pressure losses by friction

Frictional losses are influenced by the viscosity of a fluid (in this case, air), changes in the direction of the air and the behaviour of air molecules as part of the turbulent effect; 'normal' operating conditions in HVAC systems.

Losses take place along the length of the duct and are expressed in Pa/m or mmwg/m (total pressure by the length of the duct).

The formulaic calculation of the pressure losses is complex, since it depends on a considerable number of factors including exponential equations, established by Darcy-Weisbach and Colebrook. These formulae can be calculated with computing tools and the appropriate software.

If no software is available, a more convenient method is to use friction graphs already created to describe a duct's geometry. Material type (using only the friction coefficient), air conditions of density and temperature, as well as the atmospheric pressure are also taken into account.

If considering another type of installation, corrective factors have to be applied to the data from the graph, which provide values for the real pressure losses of the system.

Pressure losses in ISOVER's glass wool ductboards

Laboratory investigations and practical experience of duct assemblies with diverse cross-section sizes and types have established the following:

- Real pressure losses are practically equal to the theoretical values predicted by ASHRAE's friction graphs for cylindrical galvanized metal ducts, for air speeds from 0 to 15 m/s.
- Elbows with two 135°-angles, that is to say, those made from straight duct sections, have similar or slightly inferior pressure losses compared to curved elbows made of glass wool ductboards.



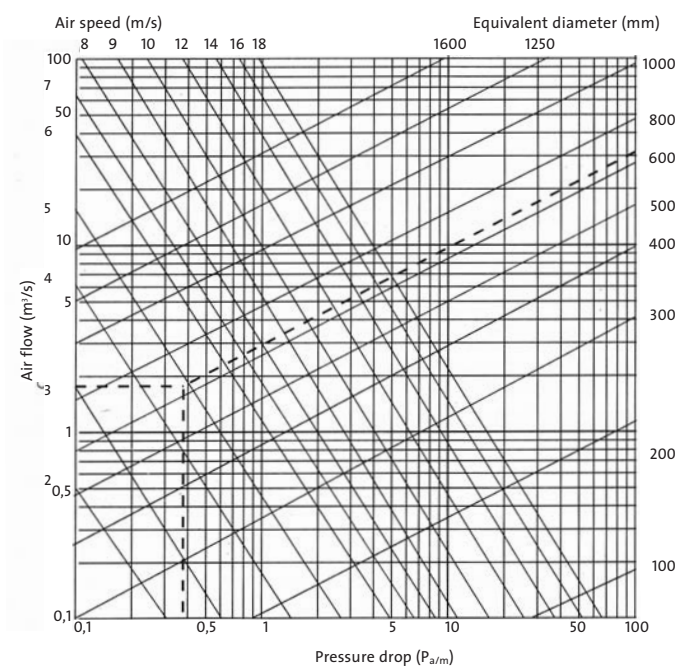
Under these conditions, pressure losses can be evaluated using the ASHRAE friction graph.

- a) Firstly, it is necessary to establish what would be the equivalent circular section for the rectangular duct (D_e) studied, to ensure the same pressure losses for equivalent airflow rates.
The following equation is used:

$$D_e = 1,3 \frac{(a.b)^{0.625}}{(a+b)^{0.25}} \text{ (mm)}$$

With 'a' and 'b' as the sides of the rectangular duct (mm)

- b) Given the airflow (m^3/s) and ' D_e ', the pressure loss can be determined by the friction graph corresponding to those ducts.



EXAMPLE

Evaluation of the pressure losses in a glass wool ductboard **CLIMAVER** with a section of dimension 600 x 600 mm with an airflow rate equal to 1.70 m^3/s . Thermal and pressure conditions are: STP (Standard Temperature & Pressure), 20 °C, 760 mmwg (101.325 kPa).

$$D_e = 1,3 \frac{(600.600)^{0.625}}{(600+600)^{0.25}} = 656.3 \text{ (mm)}$$

The corresponding value for pressure loss can be read off from the ASHRAE graph, which indicates a pressure loss equal to 0.37 Pa/m (0.037 mmwg/m see section 6.1 for more details)

b) Local or dynamic pressure losses

They occur at the points or sections where the airflow undergoes speed disruption because of direction change or variations in its absolute values.

Although dynamic losses take place along the whole length of the duct, they are assumed to be localized to areas where the speed is actually modified, making the calculation easier.

This calculation is valid if it assumed frictional pressure losses affect sufficiently long straight sections of the duct (lengths greater than 6 times the diameter).

If a straight section between two joints (assumed to create localized pressure losses), is less than this value, then this type of calculation is invalid and pressure losses have to be evaluated by direct measurements.

Values for local pressure losses

These are dimensionless values that give a relationship between pressure losses in relation to the total pressure and the dynamic pressure in the duct:

$$C = \frac{\Delta P_t}{P_v}$$

With:

C = rate of pressure loss (dimensionless)

ΔP_t = total pressure loss in the duct (Pa)

P_v = dynamic pressure in the duct (Pa)

These coefficients correspond to geometric configurations of duct assemblies, as well as to the duct's dimensionless characteristic.

When there is a change of direction of airflow inside a duct, the geometric considerations must be complemented by another coefficient that affects the specific characteristics of the airflow, by means of corrections with the Reynolds number (R_e):

$$R_e = \frac{\rho \cdot D \cdot v}{\mu}$$

With:

R_e = Reynolds number (dimensionless)

ρ = air density (kg/m^3)

D = equivalent diameter (m)

v = air velocity (m/s)

μ = air viscosity (m.Pa/s)

Under normal conditions, applicable to HVAC:

$R_e = 6.63 \times 10^4 D.v$

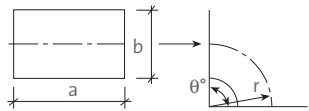
Under these conditions, the rate of loss is given by:

$C = C'.K_{Re}$

Where:

C' = Geometric characteristic rate of pressure loss (dimensionless)

K_{Re} = Flow loss rate (dimensionless)



Elbow with constant radius and rectangular section

a) elbow 90°

$C = C'.K_{Re}$

Values for C'											
a/b	0.25	0.5	0.75	1.0	1.5	2.0	3.0	4.0	5.0	6.0	8.0
r/b											
0.5	1.3	1.3	1.2	1.2	1.1	1.1	0.98	0.92	0.89	0.85	0.83
0.75	0.57	0.52	0.48	0.44	0.40	0.39	0.39	0.40	0.42	0.43	0.44
1.0	0.27	0.25	0.23	0.21	0.19	0.18	0.18	0.19	0.20	0.27	0.21
1.5	0.22	0.20	0.19	0.17	0.15	0.14	0.14	0.15	0.16	0.17	0.17
2.0	0.20	0.18	0.16	0.15	0.14	0.13	0.13	0.14	0.14	0.15	0.15

Values for K _{Re}									
Re · 10 ⁻⁴	1	2	3	4	6	8	10	14	20
r/b									
0.5	1.40	1.26	1.19	1.14	1.09	1.06	1.04	1.0	1.0
≥ 0.75	2.0	1.77	1.64	1.56	0.46	1.38	1.30	1.15	1.0

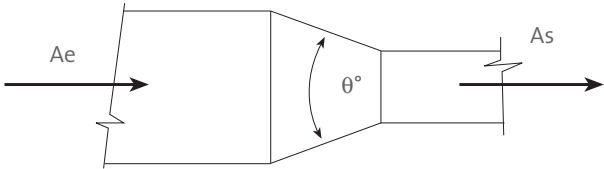
b) elbow θ°

$C = C'.K_{Re} \cdot K_{\theta}$

c' and K_{Re} according to a)

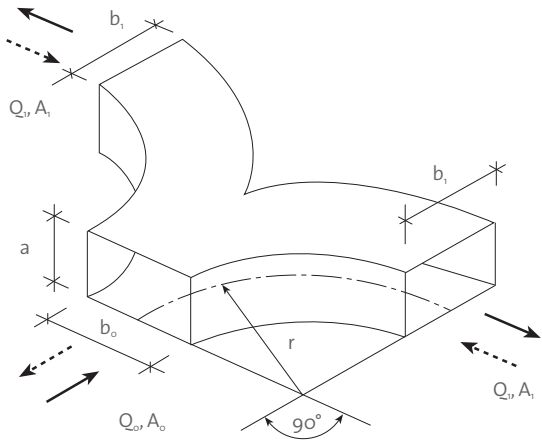
Values for K _θ										
θ°	20	30	45	60	75	90	110	130	150	180
Kθ	0.31	0.45	0.60	0.78	0.90	1.00	1.13	1.20	1.28	1.40

Reduction and rectangular section:



Values for C							
θ°	10	15-40	50-60	90	120	150	180
Ae/As							
2	0.05	0.05	0.06	0.12	0.18	0.24	0.26
4	0.05	0.04	0.07	0.17	0.27	0.35	0.41
6	0.05	0.04	0.07	0.18	0.28	0.36	0.42
10	0.05	0.05	0.08	0.19	0.29	0.37	0.43

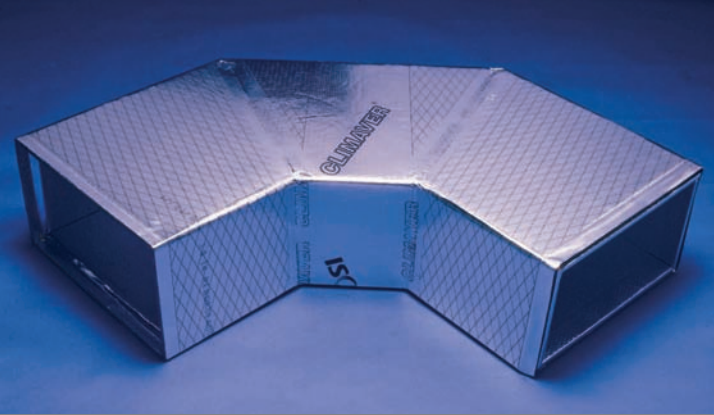
Double branch and rectangular section



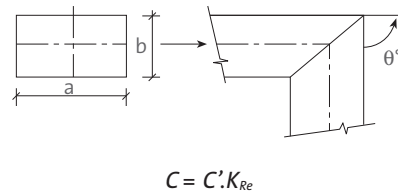
Only for r/b₀ = 1.5

$Q_1 = Q_0/s$

Values for C		
A ₁ /A ₀	0.5	1'
Air stream		
Convergent	0.23	0.07
Diverging	0.3	0.25



Elbow with an angle θ° and rectangular section:

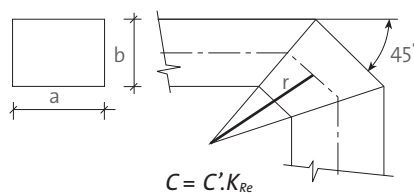


with:

Values for C'											
a/b	0.25	0.5	0.75	1.0	1.5	2.0	3.0	4.0	5.0	6.0	8.0
θ											
20	0.08	0.08	0.08	0.07	0.07	0.07	0.06	0.06	0.05	0.05	0.05
30	0.18	0.17	0.17	0.16	0.15	0.15	0.13	0.13	0.12	0.12	0.11
45	0.38	0.37	0.36	0.34	0.33	0.31	0.28	0.27	0.26	0.25	0.24
60	0.60	0.59	0.57	0.55	0.52	0.49	0.46	0.43	0.41	0.39	0.38
75	0.89	0.87	0.84	0.81	0.77	0.73	0.67	0.63	0.61	0.58	0.57
90	1.3	1.3	1.2	1.2	1.1	1.1	0.98	0.92	0.89	0.85	0.83

Values for K_{Re}								
$Re \cdot 10^{-4}$	1	2	3	4	6	8	10	≥ 14
K_{Re}	1.40	1.26	1.19	1.14	1.09	1.06	1.04	1.0

Elbow 90°, bevel edged 45° and rectangular section:

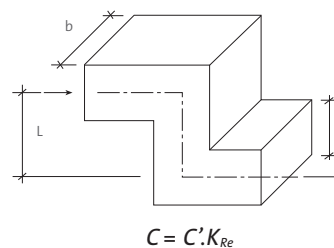


with:

Values for C'							
a/b	0.25	0.5	0.75	1	1.5	2	3
R/b							
0.5	1.3	1.3	1.2	1.1	1.1	1.1	0.98
0.75	0.9	0.85	0.78	0.72	0.65	0.64	0.64
1	0.49	0.47	0.44	0.40	0.36	0.34	0.34
1.5	0.47	0.45	0.43	0.39	0.34	0.32	0.32
2	0.46	0.45	0.43	0.39	0.34	0.32	0.32

Z fittings or elbows at 90° and rectangular section:

a) for $a = b$



with:

Values for C'											
L/a	0.4	0.6	0.8	1	1.4	1.8	2	2.4	2.8	3.2	4
C'	0.62	0.9	1.6	2.6	4	4.2	4.2	3.7	3.3	3.2	3.1

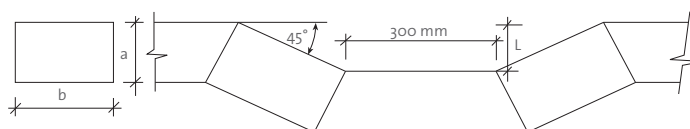
b) For $a \neq b$

$$C = C' \cdot K_{Re} \cdot K_{Ge}$$

being C' and K_{Re} , equal to a) and:

Values for K_{Ge}								
b/a	0.25	0.5	0.75	1	1.5	2	3	4
K_{Ge}	1.1	1.07	1.04	1	0.95	0.9	0.83	0.78

Offset with rectangular section:

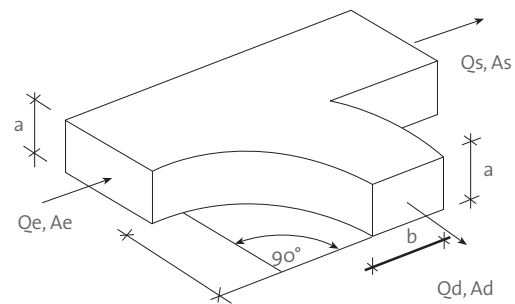


$a/b = 0.5$

$L \geq 1.5 \cdot a$

Values for C					
V (m/s)	4	6	8	10	12
C	0.18	0.22	0.24	0.25	0.26

Branch:

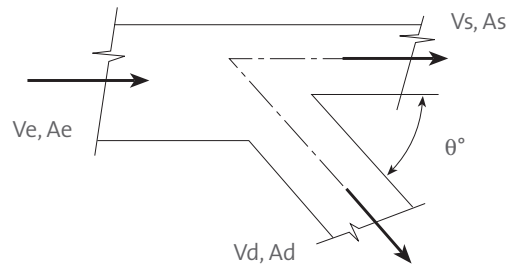


Note: only for $\theta = 90^\circ$ and $r = b$
Qe, Ae: Air stream and entrance area
Qs, As: Air stream and exit area
Qd, Ad: Air stream and deviation area

Values for C_d (branch)										
Qd/Qe		0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
Ad/As	Ad/Ae									
0.25	0.25	0.55	0.50	0.60	0.85	1.2	1.8	3.1	4.4	6.0
0.33	0.25	0.35	0.35	0.50	0.80	1.3	2.0	2.8	3.8	5.0
0.5	0.5	0.62	0.48	0.40	0.40	0.48	0.60	0.78	1.1	1.5
0.67	0.5	0.52	0.40	0.32	0.30	0.34	0.44	0.62	0.92	1.4
1.0	0.5	0.44	0.38	0.38	0.41	0.52	0.68	0.92	1.2	1.6
1.0	1.0	0.67	0.55	0.46	0.37	0.32	0.29	0.29	0.30	0.37
1.33	1.0	0.70	0.60	0.51	0.42	0.34	0.28	0.26	0.26	0.29
2.0	1.0	0.60	0.52	0.43	0.33	0.24	0.17	0.15	0.17	0.21

Values for C_s (main duet)										
Qd/Qe		0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
Ad/As	Ad/Ae									
0.25	0.25	-0.01	-0.03	-0.01	0.05	0.13	0.21	0.29	0.38	0.46
0.33	0.25	0.08	0	-0.02	-0.01	0.02	0.08	0.16	0.24	0.34
0.5	0.5	-0.03	-0.06	-0.05	0	0.06	0.12	0.19	0.27	0.35
0.67	0.5	0.04	-0.02	-0.04	-0.03	-0.01	0.04	0.12	0.23	0.37
1.0	0.5	0.72	0.48	0.28	0.13	0.05	0.04	0.09	0.18	0.30
1.0	1.0	-0.02	-0.04	-0.04	-0.01	0.06	0.13	0.22	0.30	0.38
1.33	1.0	0.10	0	0.01	-0.03	-0.01	0.03	0.10	0.20	0.30
2.0	1.0	0.62	0.38	0.23	0.13	0.08	0.05	0.06	0.10	0.20

Simple branch and rectangular section:



Note: only for $15^\circ < \theta < 90^\circ$ and $ae = as + ad$
Ve, ae: Velocity and entrance area
Vs, as: Velocity and exit area
Vd, ad: Velocity and deviation area

Values for C_d													
Vd/Ve	0.1	0.2	0.3	0.4	0.5	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0
θ°													
15	0.81	0.65	0.51	0.38	0.28	0.20	0.11	0.06	0.14	0.30	0.51	0.76	1.0
30	0.84	0.69	0.56	0.44	0.34	0.26	0.19	0.15	0.15	0.30	0.51	0.76	1.0
45	0.87	0.74	0.63	0.54	0.45	0.38	0.29	0.24	0.23	0.30	0.51	0.76	1.0
60	0.90	0.82	0.79	0.66	0.59	0.53	0.43	0.36	0.33	0.39	0.51	0.76	1.0
90	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Values for C_d							
Q 15-60 90							
Vs/VE	As/AE	0-1.0	0-0.4	0.5	0.6	0.7	≥ 0.8
0		1.0	1.0	1.0	1.0	1.0	1.0
0.1		0.81	0.81	0.81	0.81	0.81	0.81
0.2		0.64	0.64	0.64	0.64	0.64	0.64
0.3		0.50	0.50	0.52	0.52	0.50	0.50
0.4		0.36	0.36	0.40	0.38	0.37	0.36
0.5		0.25	0.25	0.30	0.28	0.27	0.25
0.6		0.16	0.16	0.23	0.20	0.18	0.16
0.8		0.04	0.04	0.17	0.10	0.07	0.04
1.0		0	0	0.20	0.10	0.05	0
1.2		0.07	0.07	0.36	0.21	0.14	0.07
1.4		0.39	0.39	0.79	0.59	0.39	—
1.6		0.90	0.90	1.4	1.2	—	—
1.8		1.8	1.8	2.4	—	—	—
2.0		3.2	3.2	4.0	—	—	—

Summary of Chapter 6

When designing a duct network, it is best to consider the duct as if it were acting in resistance to the airflow. This resistance has to be evaluated, as do the pressure losses caused by it. To evaluate this, pressure loss computer software and ASHRAE tables are available to provide the relationship between air-flow, duct section size and type, velocity and pressure losses. The ASHRAE chart is described in this handbook.



7. Air Quality – the role of HVAC Ducts

European Standard EN-13779 ‘Ventilation for non-residential buildings. Performance requirements for ventilation and room-conditioning systems’ discusses some aspects of indoor air quality and the influence of air ducts and the such like on air distribution.

- Air replenishment in a building should be delivered by a correctly filtered ventilation duct network. A set of established minimum filtration classes exists, based on outdoor air quality and required indoor air quality.
- During the design phase of a project it is necessary to specify all necessary controls, checks and cleaning points for the filtration system, to ensure maintenance procedure is correct.
- In most cases, air-conditioning devices are used that ensure hygroscopical conditions match the expectations of a building’s occupants.

Air ducts are static elements of the installation through which air flows into the building, connecting all the system: supply, air handling units, return and evacuation of exhaust air.

Considering indoor air quality and the desired level of comfort, ducts can be designed to influence indoor air quality and comfort. Such as:

- by varying the physical dimensions of the air
- noise control
- external factors that influence in Indoor Air Quality (IAQ)

The following sections explain different aspects related to this issue.

7.1 Air ducts factors influencing IAQ

a) Humidity and temperature variations

The aim of a duct network is to distribute air to the building within the parameters originally foreseen for the project, including temperature and humidity. Air at the machine exit has different temperature and humidity characteristics to those of the surroundings, which is why unwanted heat transfer through the duct’s walls will always occur. The thinner the duct’s insulation, the greater the heat transfer.

Energy losses caused by air leakage at duct work joints also has to be added to that via heat transfer.

These two effects are illustrated by the data in the “Air duct performance and cost comparison” table (reference NAIMA AH 109). This table presents the results of a test carried out by NAIMA (North America Insulation Manufacturers Association) on the energy losses in different types of HVAC ducts, for the following conditions:

Ductwork 20 m long
Cross section: 40 cm x 20 cm
Temperature inside the duct: 15 °C
Temperature outside the duct: 25 °C

With reference to this table, if a non-insulated duct is assumed to be the worst case scenario for thermal loss and, therefore a benchmark for the highest energy loss, it is strikingly apparent that glass wool ductboards equate to massive energy savings.

Air duct performance and cost comparison				
	Unsealed metal (uninsulated)	Unsealed metal lined with 15 mm	Unsealed metal wrapped with 55 mm	Glass wool ductboard CLIMAVER
Leakage				
- Air flow (m³/h)	223	223	223	28
- Energy (Kwh)	1.28	1.28	1.28	0.19
Walls				
- U (W/h.m²)	3.70	2.10	0.80	1.10
- Energy (Kwh)	1.66	0.97	0.35	0.57
Total energy losses (Kwh)	2.94	2.25	1.63	0.76

These energy losses have two different effects:

- 1) They increase the energy consumption of the system (the equipment has to provide greater air flow to compensate for the losses).
- 2) The airflow passing through the duct loses its original hygrometric characteristics and reaches the target areas with a humidity and temperature different to that anticipated by the original design.

The effective solution for avoiding such losses is a combination of two measures:

- 1) Provide the duct network with effective thermal insulation, (for example, either constructed from insulating panel material – such as ISOVER glass wool ductboards, or adding insulation, either as duct wrap or duct liner from ISOVER glass wool or **ULTIMATE**.
- 2) Minimize air leakage at ducts joints. When glass wool ductboards are used, the joints are tightly sealed, thus minimizing thermal via this route. If metal ducts insulated with mineral wool insulation are planned, then joints need to be sealed to prevent air leakage.

b) Condensation

Another important characteristic, linked to appropriate thermal insulation, is the possibility of condensation in ducts (see chapter 2).

All such projects are required to avoid condensation in the duct network, as this invariable leads to mould or bacterial infestation of the system. At this point it should be noted that neither ISOVER mineral wool nor **ULTIMATE** new generation mineral wool encourage the development or proliferation of moulds.



c) Balancing pressures

Within any form of fluid transportation there is always some pressure drop off in the system due to a combination of two factors:

- Friction of the fluid moving across the walls of the duct – which depends on flow type, internal face’s geometry and the friction coefficient.
- Dynamic drop due to variations in duct geometry and/or the direction of the air flow.

In order to achieve correct perfusion, ducts must have a correctly defined section, with a balanced average air velocity and defined static pressure.

Inadequate duct network design or defects in material installation will change the operating conditions, giving rise to thermal loads in the target areas and insufficient air replenishment (with a decline in perceived comfort for the building’s occupants).

d) Noise in duct network and acoustic attenuation

Another aspect independent of material which plays a fundamental role in a duct is acoustic attenuation of the noise produced by the HVAC system itself (air handling units, airflow in the ducts, diffusers etc. ...), as well as from ‘transmission noise’ produced in the building and that transmitted to neighbouring buildings via the duct system. As noise is considered ‘unwanted sound’, it is evident that reducing noise results in better indoor air quality & comfort. To achieve the desired level of attenuation, ducts made from or insulated using a material with high acoustic absorption properties, such as glass wool need to be installed. The most effective solution would be based on glass wool ductboards. Alternatively, the application of glass wool duct liners might also be recommended. If **ULTIMATE** mineral wool is to be used, due to fire resistance requirements, it also significantly attenuates noise produced in the installation. The following table shows the results of the studies carried out by NAIMA on duct noise attenuation for different ducts solutions:

Description	Duct noise attenuation loss (dB/m)				
	Frequency (Hz)				
Section (mm)	125	250	500	1.500	2.000
Bare sheet metal (no perceived noise reduction)	0.1	0.1	0.1	0.1	0.1
Wrapped sheet metal (no perceived noise reduction)	0.2	0.2	0.2	0.2	0.2
Lined sheet metal (Significant perceived noise reduction)	0.2	0.5	1.4	3.0	2.4
Glass wool duct (Very significant noise reduction. Perceived noise reduction to less than 50 % original level)	0.4	1.4	3.3	3.9	5.0

As a particular case, significant attenuations can be achieved with glass wool ductboards: The following table shows the results of a test carried out to measure the acoustic attenuation by

linear, meter of a duct network, for two types of ISOVER products: **CLIMAVER** Neto (a glass wool ductboard with an internal face with glass fabric especially developed to increase noise absorption), and **CLIMAVER** Plus R (also a glass wool ductboards with an internal face made of aluminium foil).

Acoustic Attenuation in a CLIMAVER Neto Straight Duct (dB/m)					
Frequency (Hz)					
Section (mm)	125	250	500	1000	2000
200 x 200	3.71	11.09	12.26	19.70	21.00
300 x 400	2.17	6.47	7.15	11.49	12.25
400 x 500	1.67	4.99	5.52	8.86	9.45
400 x 700	1.46	4.36	4.81	7.74	8.25
500 x 1000	1.11	3.33	3.68	5.91	6.3

Acoustic Attenuation in a CLIMAVER Plus R Straight Duct (dB/m)					
Frequency (Hz)					
Section (mm)	125	250	500	1000	2000
200 x 200	2.81	2.81	2.81	11.09	8.33
300 x 400	1.64	1.64	1.64	6.47	5.15
400 x 500	1.26	1.26	1.26	4.99	3.97
400 x 700	1.10	1.10	1.10	4.36	3.47
500 x 1000	0.84	0.84	0.84	3.33	2.65

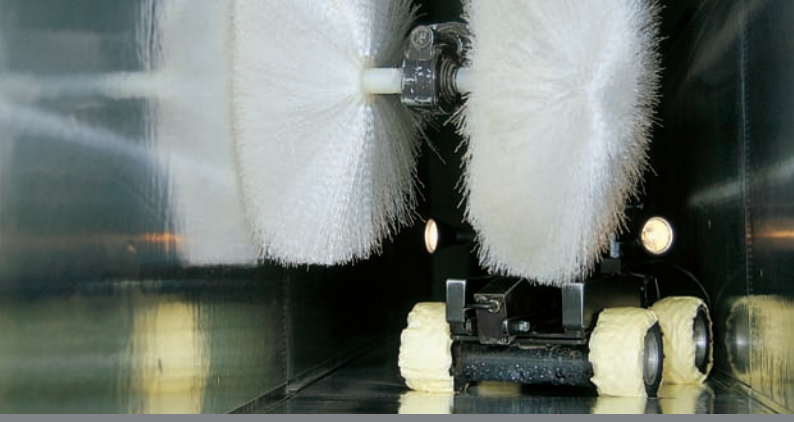
For typical HVAC system frequencies, attenuation in glass wool ductboards is higher than in metal ducts with no insulation:

- 20 times higher for **CLIMAVER** Neto
- 10 times higher for **CLIMAVER** Plus R

e) Exogenous and endogenous factors determining Indoor Air Quality.

Designers of air conditioning equipment are fully aware that dirt is likely within the air duct, derived from several different sources. For example, it might be produced during assembly of the duct system (such as dust left from the building materials during installation), or during operation of the system with contaminated outer air that has entered the network, or the filtration system is inadequate.

Furthermore, daily use of the building might well contribute to the accumulation of dirt inside ducts. Sweat, tobacco or kitchen smoke, even fibres from carpets or curtains can contribute to dirt inside air ducts, all of which lead to a decline in indoor air quality.



Outer air can also represent a source of organic and inorganic material which enters the system if filtration is inadequate.

However, in order to disarm any possible alarmist arguments, it is worth remembering that according to a study carried out by Health Building International on a total of 11 million square meters of duct work, only 10 % of occupants' complaints concerning inadequate indoor air quality were due to contamination inside ducts.

Causes of discomfort on HBI Study, IAQ

- Maintenance operations: 76 %
- Inefficient filtration: 56 %
- Low levels of ventilation: 54 %
- Inadequate air distribution: 21 %
- Pollution inside the ducts: 12 %

Nevertheless, it is obvious that duct network has to be designed with the prospect of being cleaned during its future operational life.

Initial cleaning of ducts should be done before the installation is made operational. During operation, in addition to suitably adapted air replenishment, it is necessary to have efficient filters and to undertake cleaning and proper maintenance of the installation.

7.2 Duct cleaning

This section is based on "Recommended Best Practices for inspection, opening, cleaning and closing of air ducts", edited by the North American Insulation Manufacturers Association (NAIMA).

The process of cleaning air ducts is divided into:

- Inspection and evaluation of the HVAC system as to whether it is necessary to clean the ducts or not, and if necessary, the measures needing implementation.
- opening ducts
- cleaning methods
- closing of ducts after cleaning, final inspection and starting

a) Installation inspection

Cleaning a duct network can be expensive and ineffective in providing a solution to problematic indoor air quality if the cause of the contamination cannot be identified. For this reason, all potential causes of the problem should be fully explored before embarking on duct cleaning.

A guide list of tests to perform might include the following:

- What are the symptoms? The study should specify the type of discomfort experienced by occupants, such temperature, dust, smells etc. Their reactions require analysis to identify the cause of discomfort.
- Where and when does the problem occur? The frequency of problem needs to be identified, intermittent or constant, to detect the contamination source.
- How is the building maintained?
- How is air distribution managed? Is it efficient and with sufficient air replacement?
- Are the air handling units working correctly? Equipment needs to be inspected to determine if batteries, filters and humidity systems work correctly and are properly maintained. Excessive humidity is especially relevant.
- Is supply air properly filtered? Are fans positioned correctly?
- Are there any irregular indoor contamination sources?
- Is building use consistent with that intend in the initial design? It is important to check that decoration materials, furniture and working material (printing and copying machines for instance) are not a source of excessive contamination.

Although Indoor Air Quality issues are usually due to some of the above, contaminated ducts can also be a source of problems. That is why the interior of the ducts has to be carefully inspected.

However, two important points should be noted:

- Mould will not develop inside ducts unless specific conditions of dirt and humidity exist.
- A dust layer may occur on the inner surface (in contact with airflow) of all types of ducts, including metal ones. However, if the inspection reveals the presence of more than a thin layer, it is time to clean the duct.

Personal Protection

During inspection the HVAC system should be switched off. To prevent potential exposure of the building's occupants to dirt or cleaning products, the cleaning teams have to proceed with caution (and whilst at work, wear gloves, eye protection and masks).



Inspection procedures

This procedure is followed:

- Check if air is correctly distributed to all the occupied rooms of the building.
- Inspect the air filtration equipment.
- Inspect the refrigeration coils.
- Check central heat equipment and refrigeration (including humidity regulators).

Inspection of the ducts is done through existing openings, such as access doors, or grid openings, inspection panels etc.

Visual inspection is done first: If mould or any 'unusual' material is detected, samples are gathered for further analysis. Inspection openings must be closed before proceeding with cleaning.

b) Duct openings

Regardless of building type and insulation material used with the duct, openings should be made to ensure the best air tightness when cleaning operations are finished.

c) Duct cleaning methods

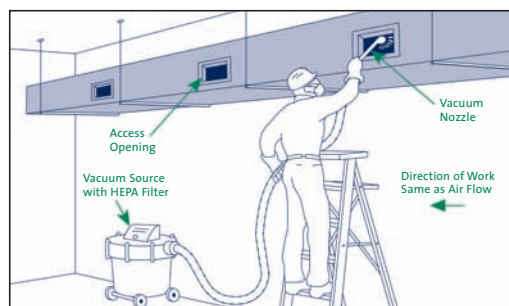
Several methods are used to clean insulated ducts. The most common ones, also considered the most effective, are briefly described in this handbook:

- Contact vacuum method
- Air sweep method
- Mechanical brush method

Contact vacuum method:

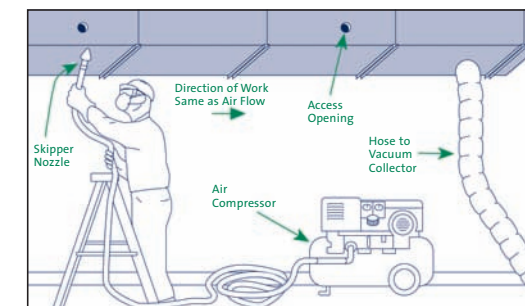
Vacuuming the faces of the ducts in the air stream can be completed with good results only if it is done with the right equipment. The risk of damaging the surfaces is very low. Only HEPA (High Efficiency Particle Collector) vacuuming equipment may be used: conventional equipment may release extremely fine particles into the atmosphere, instead of gathering them.

Contact vacuuming usually requires larger access windows than other methods, in order to allow the cleaning equipment to reach into the last corner of the duct. The distance between access hatches depends on the hoovering equipment and the target distance from the opening. The head of the vacuum cleaner is introduced into the duct using the nearest opening at the beginning of the duct network. Hovering then starts, following the direction of airflow, and sufficiently slowly to capture and gather up all the dirt.



Air sweep method

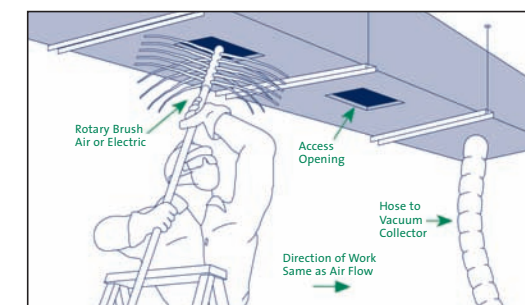
A dust vacuum collecting device is connected to an opening in the duct. It is recommended that the insulated area of the duct for cleaning has a minimum static pressure of 25 mm c.a., to ensure correct transport of the material for collection. Compressed air is introduced into the duct with a hose. The vacuum head is introduced into the duct using the nearest opening at the beginning of the duct network. Hoovering is started, following the airflow, sufficiently slowly to allow the vacuum cleaner to gather all the dirt.



Mechanical brush method

A hoovering device is connected to the most extreme point of the network. To evacuate dirt and dust particles suspended in the air, rotary brushes are used, with electric or pneumatic power. Dirt particles are dragged into the airflow direction inside the duct and are then collected by vacuum cleaner.

Brushing operations will usually require larger access openings than the previous method. Nevertheless, fewer openings are needed. Certain types of mechanical brushes can reach up to 7 m in both directions.



Summary of Chapter 7

- A suitably designed and correct duct assembly will guarantee there are no problems likely to cause modifications of the physical characteristics of indoor air and other aspects related to comfort.
- Dirt inside the ducts is the main reason of endogenous air contamination. Therefore it is essential to consider initial cleaning, proper filtration of the airflow and appropriate maintenance.
- Glass wool insulation does not contribute to the development of polluting agents inside air ducts.
- Inspection of the air-conditioning system determines the possible problems that reduce Indoor Air Quality. The following are required:
 - Visual inspection of the ducts. The air distribution network must have access panels in order to access the inside of the ducts.
 - Suitable cleaning system

ISOVER products contribute to thermal and acoustic insulation in different countries.

The following reference projects include ISOVER products in the HVAC installations:

Germany

- Klinikum Minden
- Zeche Zollverein (Historic Building), Essen
- Sky-Office, Düsseldorf
- RTL Television Building, Cologne
- Universitätsklinik Mainz
- Schloss-Arkaden Shopping Centre, Brunswick
- Hoch 4 / Palais-Quartier Shopping Centre, Frankfurt
- Allianz Arena, Munich



Hoch 4 / Palais-Quartier Shopping Centre, Frankfurt



Hunter Medical Centre



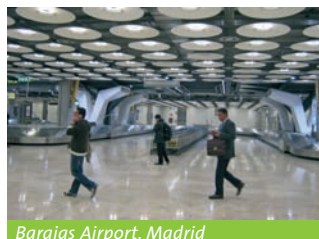
Adam Smith University Building

France

- Cité des Sciences et de l'Industrie
- Headquarters, LVMH
- St André Hospital (Bordeaux)
- Paris Airport
- LEP, Volvic
- CAMECA offices



CAMECA offices, Paris



Barajas Airport, Madrid



Barajas Airport, Madrid



Repsol Tower, Madrid



National Statistics Office, Madrid

UK

- Hunter Medical Centre
- Adam Smith University Building

Spain

- Barajas Airport
- Concert Hall Santander
- National Statistics Office
- Financial district Banco de Santander
- Santander
- Isozaki Towers
- Repsol Tower
- Training centre Real Madrid
- NH Hotels
- Zara shopping centres
- Hospital del Norte, Tenerife

Sweden

- Nacka forum shopping centre
- Fräsaren office
- Gränby centrum Uppsala shopping centre
- Kista Tower office
- Rica Talk Hotel Älvsjö hotel
- Stockholms mässan exhibition centre
- Blåmannen office
- Arlanda airport



Stockholms mässan



Blåmannen



Rica Talk Hotel

Poland

- Cracow Cloth Hall
- Slowackiego Theatre, Cracow
- Blue City Shopping Center
- Askana Shopping Center
- Złote Tarasy Shopping Center
- Alfa Shopping Center
- University of Economics, Cracow
- Rondo ONZ 1 Offices



University of Economics, Cracow



University of Economics, Cracow



Blue City Shopping Center



Blue City Shopping Center

Bulgaria

- Sunset Resort
- Shopping mall Stara Zagora



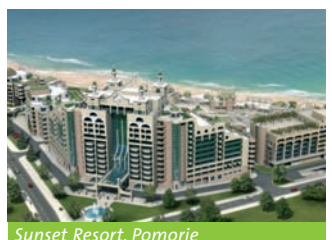
Shopping mall Stara Zagora

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