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NOISE CONTROL FOR A BETTER ENVIRONMENT

Acoustic behaviour of air aconditioning facilities with mineral wool

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ABSTRACT

In air conditioning installations, noise, vibrations and turbulence caused by equipment, and by the flow of air circulating through the air distribution network, can generate noise that is transmitted to living spaces.
If the inner surface of the ducts is made of a material that easily reflects the sound (for example, sheet metal), these turbulences can cause the walls of the ducts to vibrate, thus transmitting the noise through the network of conduits to the rest of the enclosure.
The mineral wools are excellent acoustic absorbers, and for this reason, they effectively solve the acoustic problems in the air conditioning installations.

Keywords: Noise, Environment, Annoyance
I-INCE Classification of Subject Number: 30

1. INTRODUCTION

The problems of noise in an installation of air conditioning generally have different origins, therefore, the solutions are also diverse and should be focused on each of the different identified problems, but in any case, they should always be considered from the phase initial project of the installation.

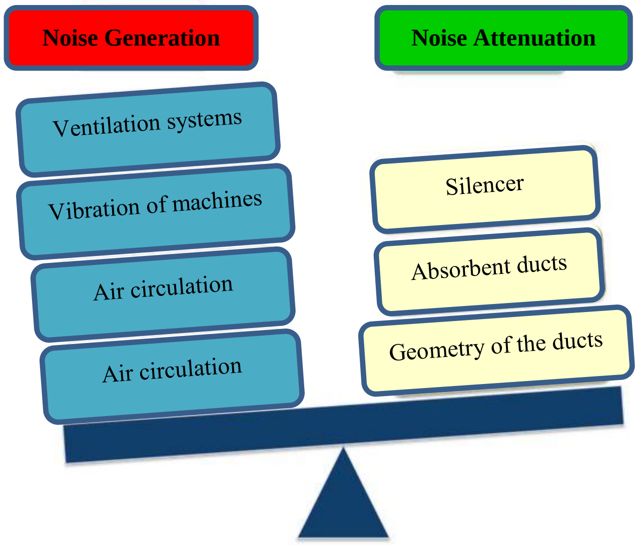
The availability of a technical study allows acoustic behaviour to be modelled in an air conditioning installation, applied at the project level, and all measures aimed at guaranteeing users' acoustic comfort.

In an air conditioning installation, noise, vibrations and turbulence caused by the flow of air circulating through the air distribution network can generate noise that is transmitted to living spaces.

If the inner surface of the ducts is made of a material that easily reflects the sound (such as steel), these turbulences can cause the walls of the ducts to vibrate, thus transmitting noise through the network of conduits to the rest of the enclosure.

The mineral wools are excellent acoustic absorbers, and therefore, effectively solve the problems of conditioning and acoustic insulation of the enclosures in buildings.

Taking into account the sound sources and the attenuation elements present in an air conditioning installation, it is possible to model the acoustic behavior of said installation along the network of conduits, by means of mathematical algorithms.



In this document the mathematical algorithms that govern the acoustic behavior of the elements of an air conditioning installation and that allow modeling the sound behavior of the installation will be presented and analyzed.

2. MINERAL WOOLS

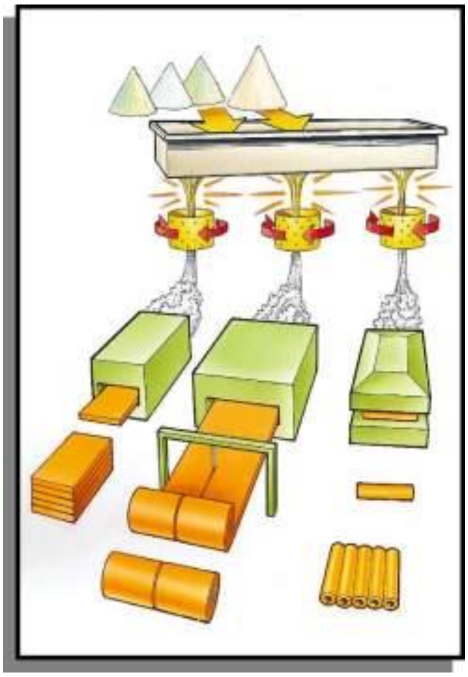
2.1 Definition

According to the product standard EN 13162, *Manufactured products of mineral wool (MW)*, Specification, the mineral wools are insulating materials or products of woolly consistency obtained by melting rock (basaltic / volcanic minerals) or glass (siliceous sands).

The mineral wools have a fibrillar structure, with open porosity, with applications of thermal insulation, absorbent / acoustic insulation and passive protection against fire.

For its manufacture. the raw materials, once mixed, are introduced into the melting furnace, and by the contribution of primary energy, the melting of the mixture at high temperatures is obtained.

The melt is mechanically stretched for the generation of wool, and finally, by polymerization and cutting, transform it into commercial products, in the form of rolls, panels or molded elements.



2.2 Acoustic Properties

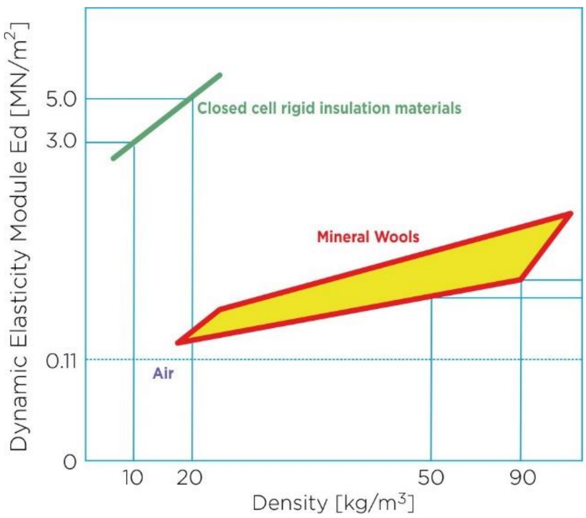
The products intended for building and that contribute to protection against noise are characterized by:

• **Resistivity to air flow**, r, in kPa.s/m^2: it is the capacity of products to reduce the transmitted acoustic energy, decreasing the speed of sound inside it.

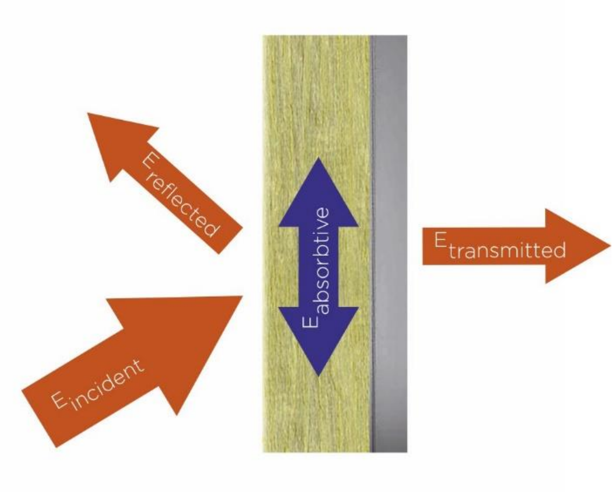
• **The dynamic stiffness**, s', in MN/m^3: indicates the capacity of the same to act as a spring and consequently, its capacity to act as an acoustic damper.

$$S' = \frac{E_d}{d}$$

S´ Rigidez dinámica del material (MN/m^3)
E_d Módulo de elasticidad dinámica (MN/m^2)
d Espesor del material (m)



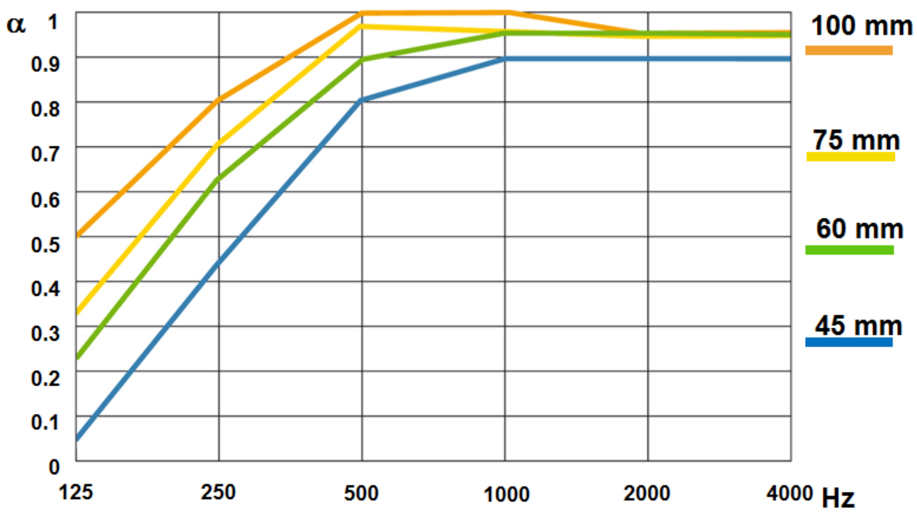
• **The acoustic absorption coefficient**, α: is the ability to absorb part of the acoustic energy incident in a material.



$$\alpha_s = \frac{\text{Absortive energy}}{\text{Incident energy}}$$

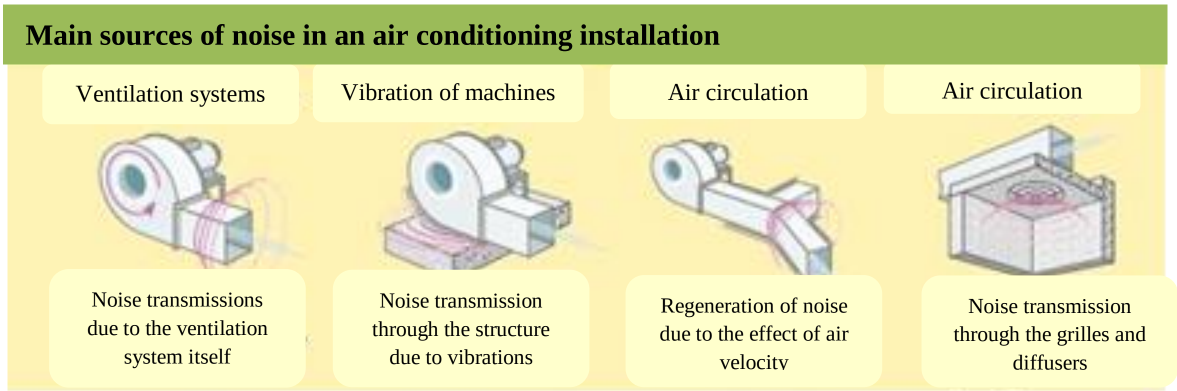
For mineral wool, the acoustic absorption coefficient depends mainly on the thickness of the products, and to a lesser extent on other factors such as the density or type of fiber.

Mineral Wool, 16 kg/m^3



3. SOUND SOURCES

The classification of the different types of noise generated in an air conditioning installation in the design phase is essential prior to proposing corrective measures aimed at the elimination or minimization of the causes of the acoustic problem.



Regarding the type of generated noise, it will be necessary to differentiate airborne noise from structural noise, since its treatment will be different:

- Air borne noise: transmission in the air (for example, the noise generated by the blades of a fan). It will be treated with absorbent materials based on Mineral Wool.
- Structural borne Noise: it is transmitted through the solid medium and dissipates in the air environment. Must be treated with damping systems (antivibration, banks of inertia).

3.1 Ventilation systems

Ventilation systems emit noise throughout the frequency spectrum due to the displacement of the air and the movement of the fan blades at a certain speed (as the speed increases, the noise level emitted increases).

To project the installation, it is necessary to know the sound pressure levels of the fan. This information can be obtained by means of a laboratory test or by means of expressions, tables and abacuses that allow to have an order of magnitude of this variable. One of the most used expressions is Madison-Graham:

$$L_W = 10 \log Q + 20 \log P + 40$$

Where:

L_W: Sound pressure level of the fan (dB)

Q: Air flow (m^3/s)

P: Static pressure (Pa)

From the previously calculated value, we can obtain the spectral sound power levels by applying the following corrections:

Spectrum corrections on Lw							
	125	250	500	1000	2000	4000	Hz
Axial fan	-5	-6	-7	-8	-10	-13	dB
Centrifugal fan	-7	-12	-17	-22	-27	-32	dB

Each one of the elements of the Ventilation System will have a behavior in front of the generation, attenuation and propagation of the noise.

Outdoor Units

The reference legislation establishes that the maximum power level of certain equipment located in roofs and outdoor areas must not exceed the levels of acoustic quality set according to the type of acoustic area.

To determine if these quality objectives are exceeded, at a certain distance, the algorithm is used:

$$L_{pr} = L_w + 10 \log \left(\frac{\Phi}{4\pi d^2} \right)$$

Where:

L_W: Sound pressure level of the fan (dB)

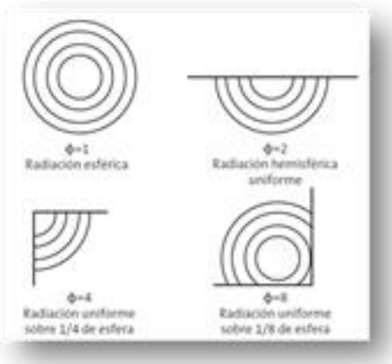
Φ: directivity factor of point sources emitting in open field

d: Distance to the source (m)

Indoor Units

The airborne noise generated by a machine affects the place where the equipment is located, and from this it is transmitted to the rest of the building.

The level of sound pressure at a distance r from the source can be determined through the expression:



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

Where:

L_{pr}: Sound pressure level at a distance r from the source (dB)

L_W: Acoustic power level of the source (dB)

d: Distance to the source (m)

Φ: Directivity factor of the sound source

The directivity factor is the measure of the degree to which the sound energy is concentrated in a certain direction of space.

As the absorption area increases, due to the presence of absorbent materials, such as mineral wool, the sound pressure level decreases.

Due to its nature, fibrous products with open porosity, the mineral wools decrease the reverberation, and therefore, reduce the value of the sound pressure level at a certain point.

Knowing the level of sound pressure at a distance r, it must be ensured that the levels specified in the reference legislation are met. Likewise, if this level is known, inside a room and depending on the separation enclosures, it will be necessary to guarantee that the difference of standardized levels weighted A in interior D_{nT} enclosures.

$$D_{nT,A} = -10 \cdot \log \sum_{i=1}^{n} 10^{(L_{Ar,i} - D_{nT,i})/10}$$

Where:
$D_{nT,i}$ is the standardized difference in levels in the frequency band i (dB)
$L_{Ar,i}$ is the value of the normalized pink noise spectrum, weighted A, in the frequency band i (dBA)
i travels all the third octave frequency bands from 100 to 5000 Hz.

Metallic ducts and end elements

The non absorbent ducts and the grids or end elements of an air conditioning system are sources of noise generation produced by variations in the speed and direction of the air flow.

The designer must study the characteristics of the distribution network to be projected, taking into account the noise generated in:

- Straight sections
- Output terminal elements, grids and diffusers
- Other sources of noise

The power generated by these systems must be provided by the manufacturers, or be estimated from the following expressions:

In the case of metallic ducts:

$$L_W = 50 \log V + 10 \log S + 7 \quad [dB]$$

$$L_{WA} = -25 + 70 \log V + 10 \log S \quad [dBA]$$

Where:

L_W: Sound power generated in straight

V: Speed in m/s

S: Duct section in m^2

Spectrum corrections on Lw						
F(Hz)	125	250	500	1.000	2.000	4.000
	-4	-6	-8	-13	-18	-23

Lw is the level of generated sound power to which the following correction must be made by frequencies to perform calculations in Octave bands.

In the case of grilles and diffusers:

$$L_{WA} = -4 + 70 \log V + 30 \log \zeta + 10 \log S \text{ [dBA]}$$
$$L_{WA} = -40 + 10 \log Q + 60 \log v + 10 \log \zeta \text{ [dBA]}$$
$$L_{WA} = -33 + 10 \log Q + 30 \log \Delta P \text{ [dBA]}$$

Where:

V: Blowing speed (m/s)

ζ: Coefficient of resistance to the flow of the diffuser

S: Duct section (m^2)

Q: air flow (m^3/h)

ΔP: Loss of charge (Pa)

The air that circulates through the ducts produces a noise regeneration that adds to the sound power generated by the fan.

Producing changes of sections and branches is adequate to reduce the sound energy coming from the source, but it can be harmful if a turbulent regime is generated that generates new sources of noise.

ACOUSTIC ATTENUATION THROUGH THE USE OF ABSORBING DUCTS

Straight Sections

Attempts to quantify the loss by insertion of conduits and silencers have a long history.

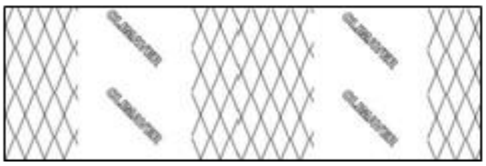
The first articles appear in 1940 in the Journal of the Acoustical Society of America published by researchers as relevant as H.J. Sabine ("The Absortion of Noise in Ventilating Ducts", JASA, vol.12, pp. 53-57, 1940) and L.L. Beranek ("Sound Absortion in Rectangular Ducts", JASA, vol.12, pp 228-231, 1940).

The expression used here should be associated with Sabine, who found empirically, that at low frequencies the attenuation of a conduit could be expressed by mathematical algorithms that related it to the value of the acoustic absorption coefficient of the material used.

A straight section is a system that produces an attenuation on the noise generated by the installation, and whose efficiency will be determined by the acoustic absorption coefficient of the walls that constitute the conduit.

In the case of straight sections, the estimation of insertion losses in rectangular ducts can be made taking into account the following algorithm:

$$L = 1{,}05 \cdot \alpha^{1{,}4} \cdot \frac{P}{S} l$$



Where:

L: Acoustic attenuation (dB)

α: Sabine acoustic absorption coefficient of the material

P: Interior perimeter of the duct (m)

S: Free section of the duct (m^2)

l: Duct length (m)

When using this expression, we must consider that the acoustic absorption coefficient depends on the frequency, and therefore, the resulting damping depends on the frequency analyzed. The modeling has to be done for all frequencies.
In addition, we must use the weighting indexes A, because the human ear has a sensitivity to sounds depending on the frequency.

To adapt the level of sound pressure to the sensitivity of the human ear it is necessary to make a series of corrections, obtaining the so-called weighted levels. This is due to the need to make a global subjective assessment of noise by measurement, applying the corrections corresponding to the so-called weighting curve A, which consists, in the same way as what the human ear does, in making corrections of levels of noise. sound pressure by frequencies by means of compensation values given in decibels.

There are different weights, but the most used is the weighting curve A, since it is the one that best reflects the response of the human ear for habitual levels of noise, for which the following adaptation values are used:

Weight adjustment A					
Frequency (Hz)	125	250	500	1000	2000
Weighing	-16.1	-8.6	-3.2	0.0	1.2

And to obtain the global weighted value, the expression is used:

$$L_{total} = 10 \cdot \log \sum_{i=1}^{n} 10^{Li/10}$$

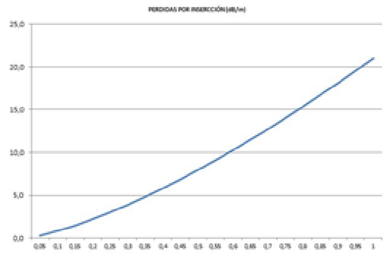
In general, it is found that in those metallic conduits, without an interior acoustic coating, the sounds propagate barely without attenuation due to the low coefficient of acoustic absorption of said material.

From the estimation of insertion losses in rectangular ducts it can be deduced that in addition to the length of the section, there are two factors that influence the acoustic attenuation provided by an air duct:

a) Perimeter-Section Relationship: The greater this relationship, the greater insertion losses.

b) Coefficient of acoustic absorption of the conduit material:
It depends on the nature and geometry of the material in contact with the air flow. Since flat surfaces are usually used, the variable that most influences is the acoustic absorption coefficient, alpha Sabine (α).
The greater the thickness, the higher α, and therefore, greater attenuations.

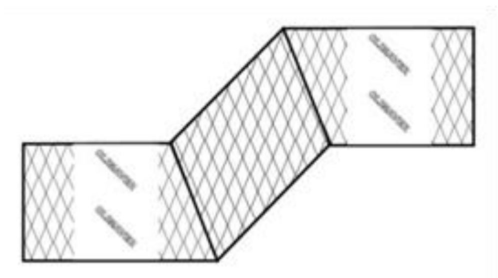
The following graph shows the insertion losses produced, per linear meter, based on the acoustic absorption coefficient of the material used for a 20 x 20 cm rectangular duct.

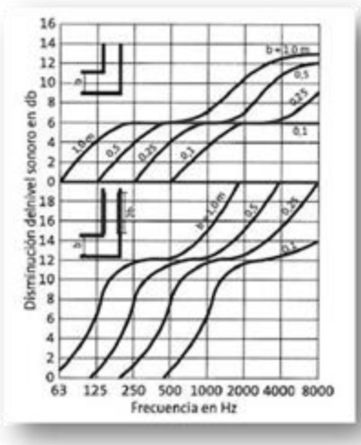


There are absorbent conduits in the market, based on mineral wools whose acoustic absorption coefficients reach values of up to 0.9.
In many cases, through the use of this type of absorbent ducts, the attenuation values are obtained high enough, so as to guarantee the acoustic comfort of the users without the need to use specific additional silencers.

Changes of direction

Any change of direction in an elbow-shaped absorbent duct causes acoustic damping, which depends on the frequency. Although the singularities of this phenomenon are not well known, different empirical studies show that insertion losses in this type of figures can be determined through empirical graphs, as shown in the attached graph, where we obtain the sound attenuation produced by an elbow in a distribution network according to the dimensions and geometric characteristics of the connection for materials with absorbent interior coverings.





The attenuation is due to a "labyrinth or barrier" effect that enhances the acoustic absorption of the material in this type of zone.

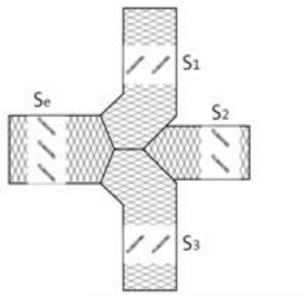
It must be borne in mind that this type of fiures may be inadequate, from the acoustic point of view, if an aerodynamic transition is not achieved, which could generate undesirable noise, due to the turbulence generated in this area.

Derivations

A derivation is a branch of a conduit in others that can be symmetrical or asymmetric.

In the derivations of flow, an acoustic attenuation is produced that is given by the expression:

$$\Delta L = 10 \log \frac{S_e}{S_i}$$



Where:

S_i*: is the section of the conduit considered*

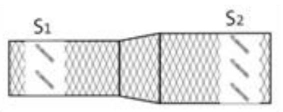
S_e*: is the primary conduit section (input)*

Section extensions

The sectional extensions are elements of the air distribution network that connect adjacent conduits of different section.

In this type of elements, when acoustic conduits are used, an acoustic attenuation occurs that can be determined through the following expression:

$$\Delta L = 10 \log \frac{(m_s + 1)^2}{4m_s}$$



Where:

m_s*: is the relationship between the sections before and after the widening (*S_1/S_2*)*

S_1*: is the section before the widening (*m^2*)*

S_2*: is the section after the widening (*m^2*)*

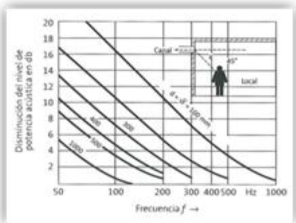
Air vents/air oulets

The air outlets generally reduce the acoustic power transmitted by the distribution network.

Because the air outlets usually have a small dimension in relation to the wavelength of the sound, reflecting in the conduit part of it.

In the same way, this reduction of the section can cause turbulent flow areas, an aspect that will lead to the generation of new sound levels that have to be taken into account.

For the estimation of both factors, the data provided by the manufacturer must be taken into account, although in the absence of them, graphs can be used that specify the reduction of the product as a function of the frequency and the square root of the output section , in addition to the situation of said element in the premises:



4. CONCLUSIONS

The most efficient way to design a distribution network in an air conditioning installation is by using absorbent ducts made of materials with high sound absorption values and always taking into account all the elements that are part of the installation.
A good projection, taking into account all the elements, will guarantee the desired acoustic levels without the need to integrate additional systems such as specific silencers.
When studying and choosing the most appropriate solutions for each installation, it will be essential to analyze the sound pressure levels in each frequency band, taking special care with low frequencies, which are the most complicated to treat.
The sound pressure level at each point of the distribution network will be equal to the logarithmic sum of the sound power of each of the noise sources minus the sum of the attenuation of each of the existing attenuating elements:

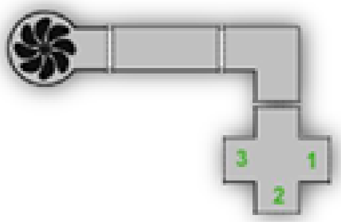
$$L_{w,\,salida} = 10 \log \left(\sum 10^{L_m/10} \right) - \Delta L_T$$

After taking into account the sound spectrum of the emission sources within the pipeline network, the sound spectrum is modeled at each point of the network, to obtain at the end, a prediction of the sound power level at the output of the network. grid, taking into account the insertion losses that occur in the network, due to the presence of absorbent ducts and the existence of certain figures.

To obtain the global levels, the levels for each frequency are taken into account:

$$L_{total} = 10 \cdot \log \sum_{i=1}^{n} 10^{Li/10}$$

In the market there are several free access computer tools that allow modeling the acoustic behavior of AIR CONDITIONING installations.
The CLIMCALC ACOUSTIC program, from ISOVER, applies the algorithmic expressions indicated in this paper, being a powerful software, but simple and intuitive.



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