MagiCAD

Ventilation
Technical Specification

MAGICAD - VENTILATION
Technical Specification

1. Introduction

1.1 Purpose of this document

The purpose of this document is to provide specification of the computing methods that are used in **MagiCAD – Ventilation application.**

1.2 Scope of this document

This document consists of the following information about MagiCAD:
- duct sizing method
- balancing and pressure drop calculations
- sound calculations

1.3 Quantities and units used in this document

dp	Pa	pressure drop
v	m/s	velocity
ξ	-	single resistance coefficient
A	m2	area
d	m	diameter
ν	m2/s	kinematic viscosity
λ	-	drag coefficient of the flow in the pipe
k	m	absolute roughness of the pipe
Re	-	Reynolds number

2. Duct sizing

2.1 Which sizing method is the best one?

To understand the backgrounds of MagiCAD sizing principles, we will first briefly examine what kind of results we get using different duct sizing methods.

Constant pressure drop
Maximum pressure drop
In practice, these two methods are one and same, because both of these duct selection methods are based on the friction pressure drop defined for the duct(s).

Duct sizes in the system are well predictable, as there are no unexpected pressure drops or velocities. On the other hand, the duct sizes are selected one by one, which means that there may be more reducers than it is practical.

Constant velocity
Maximum velocity

These two methods are one and same, because both of these duct selection methods are based on the velocities defined for the duct(s).

The advantages and disadvantages are the same as with the pressure drop based sizing.

Static regain

Static regain method is somehow famous, and many designers who have not been working with this method would first think it the best one. But in practice, this method has some features that must be taken into account.

The velocity drop after branch should be at least 2 - 3 m/s (3 to 5 Pa of dynamic pressure) to compensate pressure drop in the next part. This means that the size of the main duct will remain the same from the fan to the last branch of the duct route.

After all, there will be very low velocities in most of the main ducts, and that means more space requirements and more costs. Therefore, ductwork designers do not use static regain method as much as it is generally thought.

Proportional air flow method

This method is probably used by a designer who has first tried to use the static regain method. The principle is that sizing proceeds from fan to rooms, and a reducer is used when the air flow has reduced x % from its original value (user can specify x, usually it is 30 to 60%). The reasons for using this method may be constructional.

If selection of the first duct is based on *vmax* or *dpmax*, the velocities are definitely below the limit, and then there are no problems. But there are situations when reducers appear at wrong places. For example: we have set x to 30%, and the air flow reduces 20% in the first branch and 1% in the next ten branches each – what is the result? A very long and large main duct. The optimal solution in this case would obviously be a reducer at the first branch.

As a summary, we cannot show any single method that could be used in a calculation program to select optimal duct sizes fast and efficiently in every possible case.

2.2 MagiCAD sizing method

The first step in MagiCAD sizing method is preliminary sizing. Duct sizes are selected one by one from the system-dependent, user-defined criteria.

User can define maximum velocities and maximum friction loss for different duct sizes. MagiCAD scans duct sizes of the series (each duct belongs to some duct size series) and takes the first one that is acceptable. With non-circular ducts program calculates the equivalent diameter.

Which method MagiCAD uses for preliminary sizing? It is up to user, because criteria can be defined so that we will get maximum/constant velocity- or maximum/constant pressure drop-based duct sizing.

The second step, which in fact takes place at the same session with preliminary sizing, checks that there will not be unnecessary reducers. The criterion is the distance between two T-branches in main duct direction. If the distance is shorter than one metre, the duct size is adjusted to the nearest duct in the fan side of the branch. There is also a rule that a duct can never be smaller than the previous duct when going towards the fan.

The third step allows user to customise sizing results. User may specify and lock size of an individual duct. Because MagiCAD never reduces duct size when going towards fan, it is easy to define size of main duct for the whole branch: just lock the size of the last duct.

3. Balancing

3.1. Balancing principles

As a default, MagiCAD balances ductwork to the minimum pressure level. As a result we get pressure drop demand for fan selection.

User can specify the minimum pressure drop for flow dampers and air devices, which makes it possible to get higher pressure level than minimum.

When there are several flow dampers in the same flow route, MagiCAD uses first the damper which is nearest to the fan. If all the required pressure drop is not achieved, MagiCAD adjusts the next flow damper(s), and finally the supply/exhaust device if necessary.
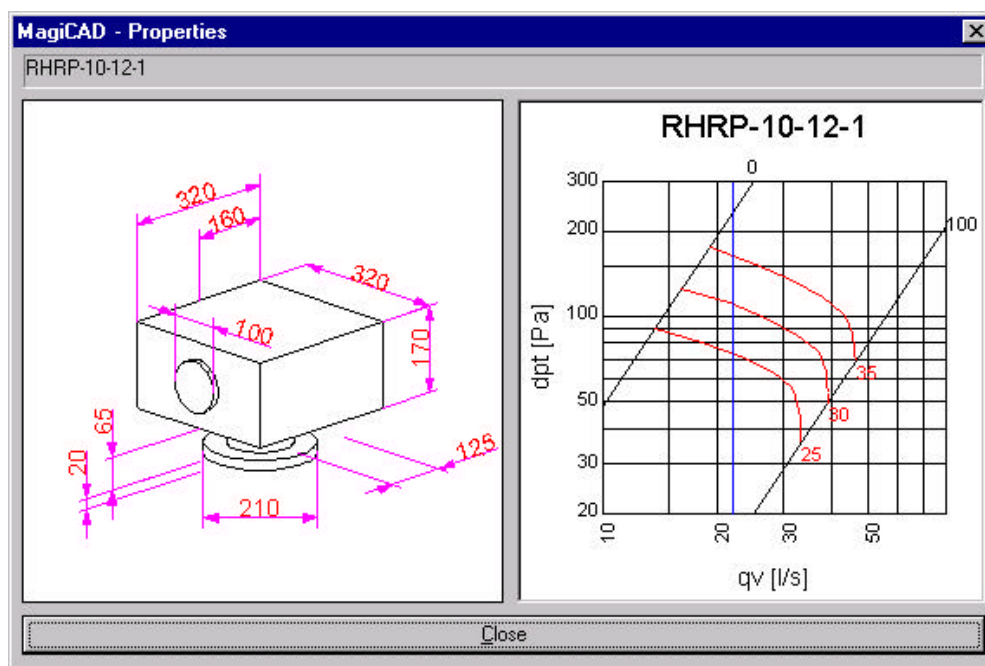If some route cannot be balanced, MagiCAD shows the supply/exhaust device where the pressure is out of limits.

MagiCAD has also command, which highlights the most significant flow route.

3.2. Pressure drop calculations

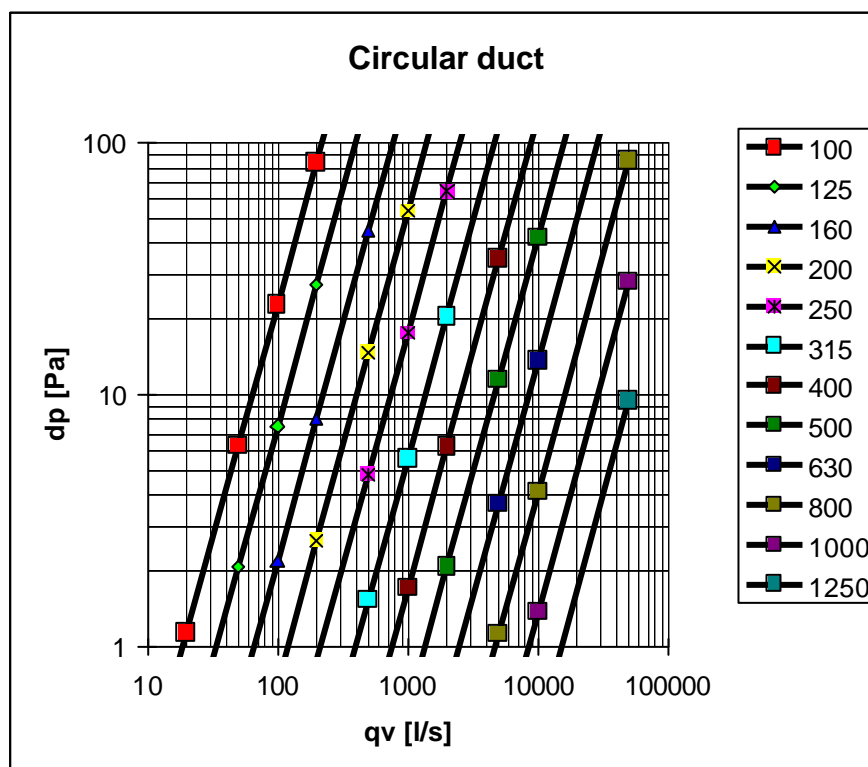## 3.2.1 Supply/exhaust devices, flow dampers, silencers etc.

Pressure drops and balancing are calculated using the manufacturers' product data.

3.2.2 Ducts

For friction pressure drop in ducts, MagiCAD uses Colebrook equation with the roughness value which can be specified for each duct size series by the user.

The following diagram specifies pressure drops [Pa/m] for roughness value 0.15 mm, which is normally used in steel ducts.

$$\frac{1}{\sqrt{l}} = -2 * Log_{10}\left(\frac{\frac{k}{d}}{3,71} + \frac{\frac{2,51}{Re}}{\sqrt{l}}\right) \qquad [1]$$

$$l = 0,11 * \left(\frac{\frac{k}{d}}{3,71}{d} + \frac{68,0}{Re}\right)^{0,25} \qquad [2]$$

$$dp = \frac{l}{d} * 0,6 * v^2 \qquad [Pa] \quad [3]$$

λ is iterated with the formula [1]. If the formula does not converge, the approximate formula [2] is used.
λ = drag coefficient of the flow in the pipe
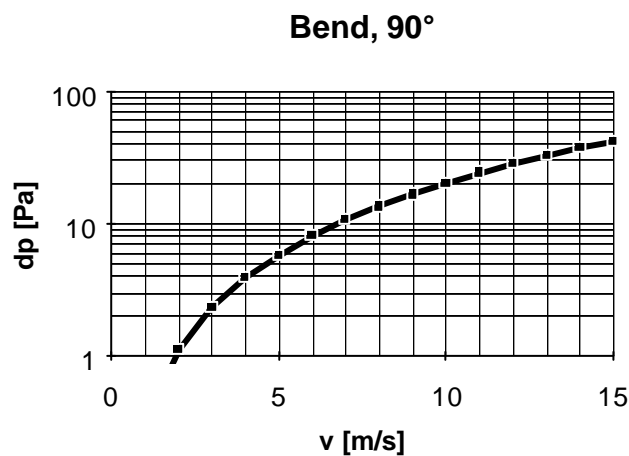k = roughness
d = inner diameter of the pipe [m]
Re = Reynolds number

$$Re\left(= r * v * \frac{d}{h}\right) = v * \frac{d}{n}$$

ν = kinematic viscosity of the air (+20°C) = 0,00001511 [m^2/s]
v = velocity [m/s]

3.2.3 Circular bends

For 90° circular bends MagiCAD uses equation that gives values presented in the following diagram
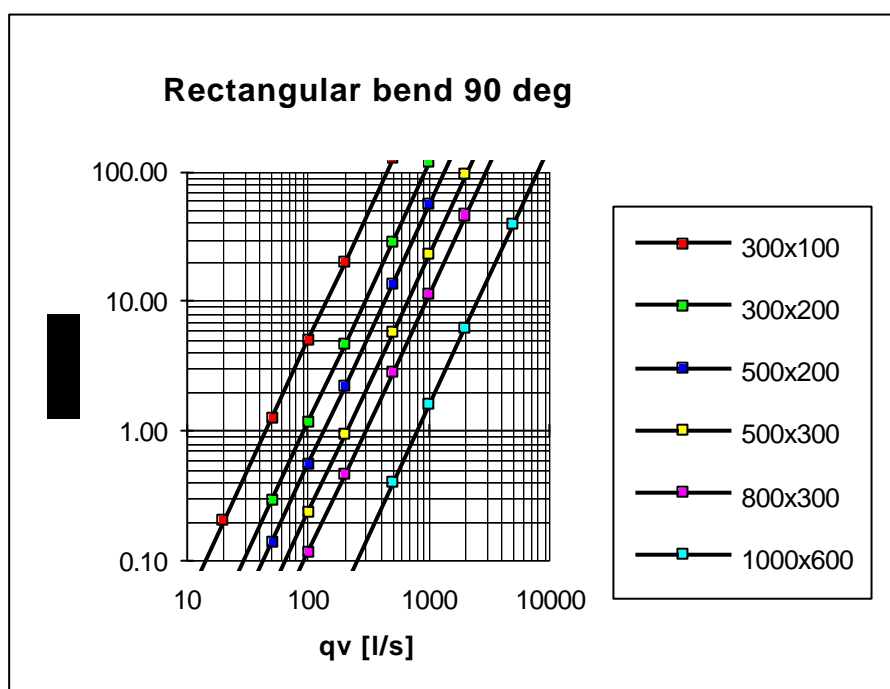
Bend, 90°

$$dp = 0,32 * v^{1,8} \quad [Pa]$$

v = flow velocity [m/s]

For 45° bend, the values are divided by 2.0 and for 30° bends they are divided by 3.0

3.2.4 Rectangular bends

For 90° rectangular bends MagiCAD uses equation that gives values presented in the following diagram.

Rectangular bend 90 deg

$$dp = \boldsymbol{x} * 0{,}6 * v^2 \quad \left[Pa\right]$$

ξ = single resistance coefficient
v = flow velocity [m/s]

Curved inside ξ = 0,33...1,4
With curved bend ξ = 0,35
With sharp bend ξ = 1,5

For 45° bend, the values are divided by 2.0 and for 30° bends they are divided by 3.0

3.2.5 Reduction

$$dp = 0,146 * \left(v_2 - v_1\right)^{1,9} \quad [Pa]$$

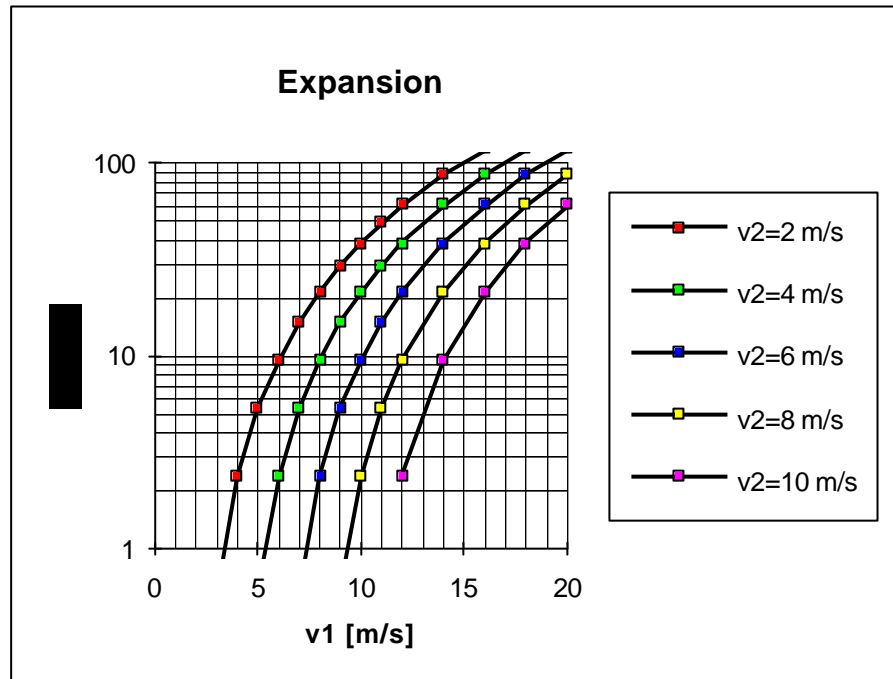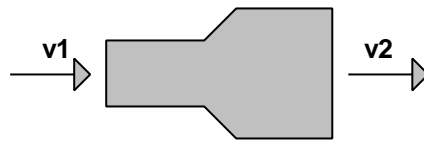v_2 = flow velocity at the outlet [m/s]
v_1 = flow velocity at the inlet [m/s]

The formulas are curve fittings, and match well Fläkt's curves. Fläkt has separate curves for circular and rectangular ducts, but they have identical values.

The same equation is used both for circular and rectangular reducers.

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3.2.6 Expansion

$$dp = 0,864 * (v_1 - v_2)^{1,8} \quad [Pa]$$

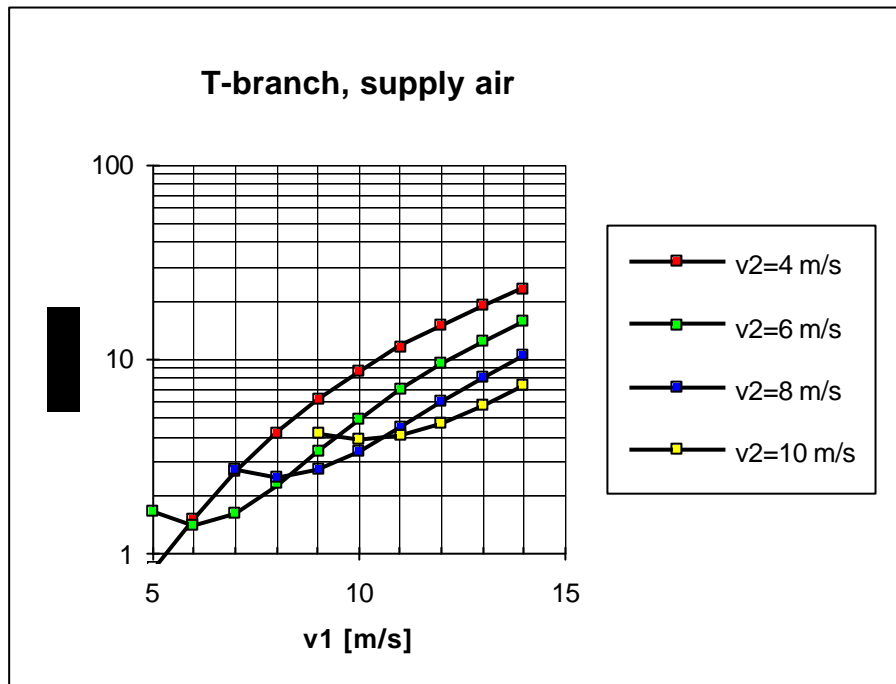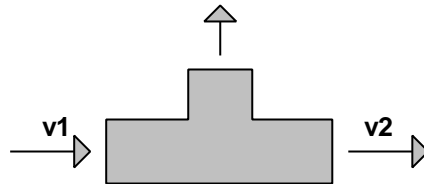v_2 = flow velocity at the outlet [m/s]
v_1 = flow velocity at the inlet [m/s]

The formulas are curve fittings, and match well Fläkt's curves. Fläkt has separate curves for circular and rectangular ducts, but they have identical values.

The same equation is used for circular and rectangular expansions.

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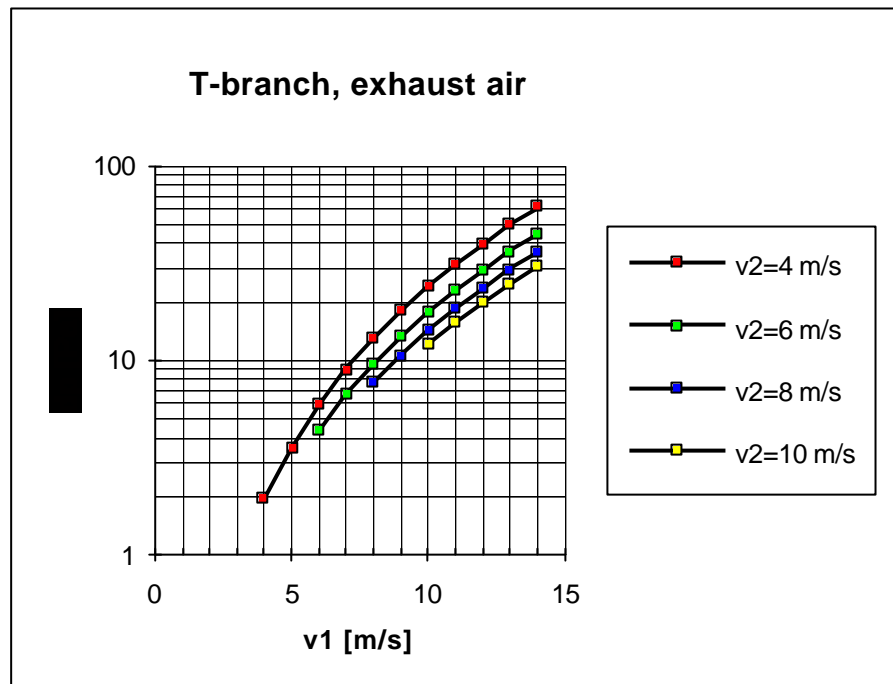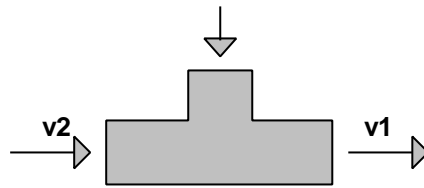www.progman.fi

3.2.7 T-branches

For T-branches, the same equations are used for both the circular and rectangular branches:

T-branch, supply air

v1 [m/s]

v2=4 m/s
v2=6 m/s
v2=8 m/s
v2=10 m/s

$$dp = \left(0,4408 * \left(\frac{v_2}{v_1} \right)^2 - 0,7619 * \frac{v_2}{v_1} + 0,3785 \right) * 0,6 * v_1^{\,2} \quad [Pa]$$
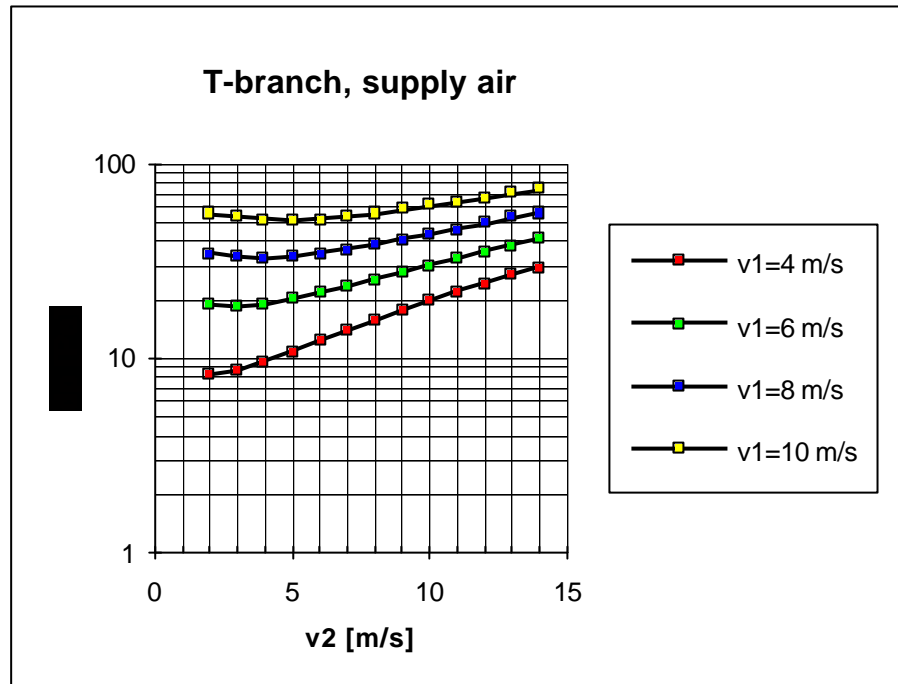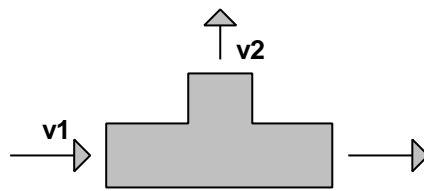
v_2 = flow velocity at the outlet [m/s]
v_1 = flow velocity at the inlet [m/s]

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T-branch, exhaust air

■ v2=4 m/s	
■ v2=6 m/s	
■ v2=8 m/s	
■ v2=10 m/s	

v1 [m/s]

$$dp = 0,2 * \left(\frac{v_2}{v_1} \right)^{-0,76} * 0,6 * v_1^{\,2} \quad [Pa]$$
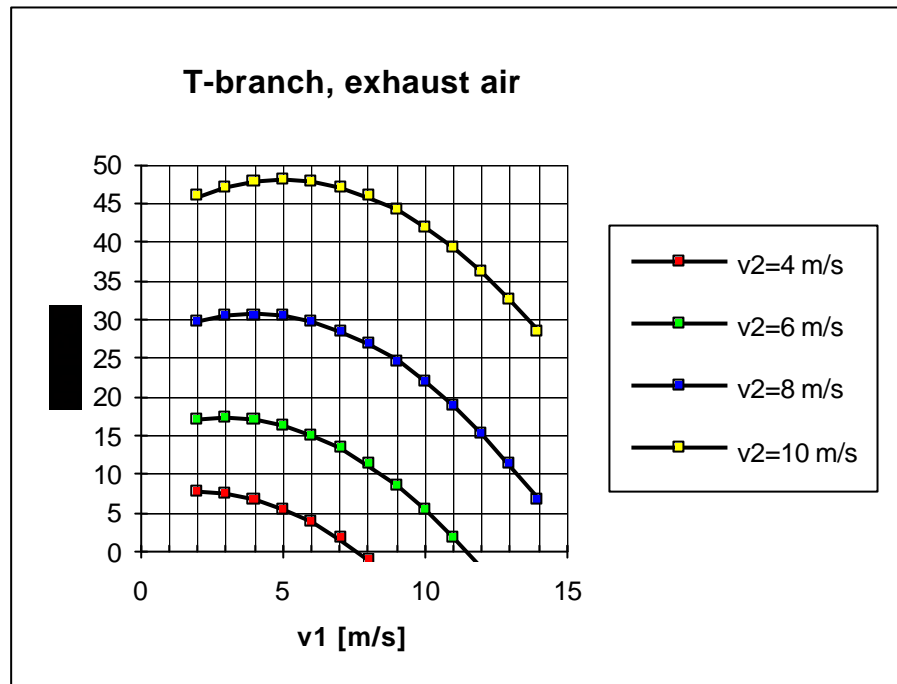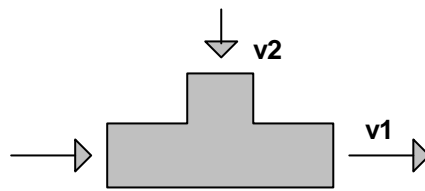
v_2 = flow velocity at the inlet [m/s]
v_1 = flow velocity at the outlet [m/s]

v2

v1

T-branch, supply air

v1=4 m/s	
v1=6 m/s	
v1=8 m/s	
v1=10 m/s	

v2 [m/s]

$$dp = 1,07 * \left[0,8 + 0,4 * \left(0,4 * \left| \frac{v_2}{v_1} - 0,5 \right| \right)^{1,5} \right] * 0,6 * v_1^2 \quad [Pa]$$

If the contents of the inner brackets is zero or near zero, the following formula is used:
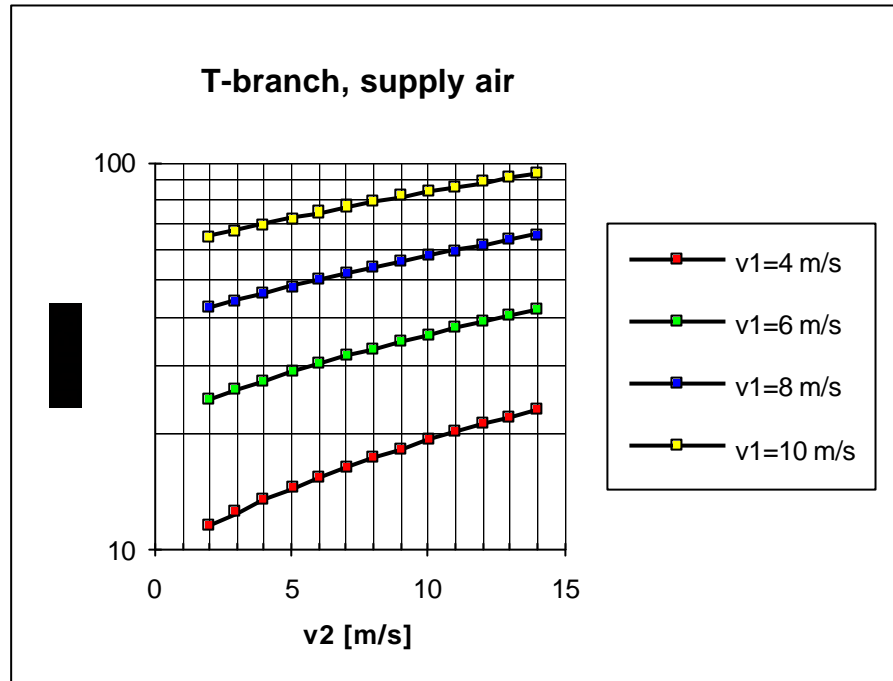
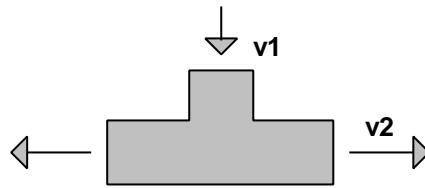$$dp = 1,07 * 0,8 * 0,6 * v_1^2$$

T-branch, exhaust air

$$dp = \left[0,7 * \left(\frac{v_2}{v_1} \right)^2 + 0,4 * \frac{v_2}{v_1} - 0,4 \right] * 0,6 * v_1^{\ 2} \quad [Pa]$$

v_2 = flow velocity at the inlet [m/s]
v_1 = flow velocity at the outlet [m/s]

Note that the negative values are set zero to avoid infeasible situations.

T-branch, supply air

$$dp = \left(0,4 * \frac{v_2}{v_1} + 1,0\right) * 0,6 * v_1^{\,2} \quad [Pa]$$

v_2 = flow velocity at the outlet [m/s]
v_1 = flow velocity at the inlet [m/s]

$$dp = \left(0{,}56 * \frac{v_2}{v_1} + 0{,}6\right) * 0{,}6 * v_1^2 \quad [Pa]$$

v_2 = flow velocity at the inlet [m/s]
v_1 = flow velocity at the outlet [m/s]

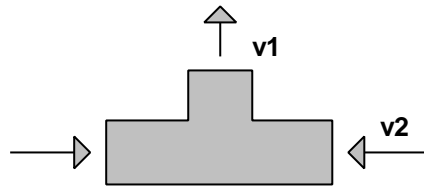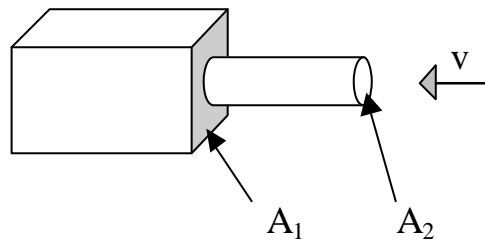## 3.2.8 From duct to distribution box

$$\mathbf{x} = 0{,}25 * \left(\frac{A_1}{A_2} - 1\right) \qquad if \; \frac{A_1}{A_2} < 2$$

$$\mathbf{x} = 0{,}25 + 0{,}2 * \left(\frac{A_1}{A_2} - 2\right) \quad if \; \frac{A_1}{A_2} < 3$$

$$\mathbf{x} = 0{,}45 + 0{,}15 * \frac{\dfrac{A_1}{A_2} - 3}{4{,}5 - 3} \quad if \; \frac{A_1}{A_2} < 4{,}5$$

$$\mathbf{x} = 0{,}6 + 0{,}1 * \frac{\dfrac{A_1}{A_2} - 4{,}5}{6 - 4{,}5} \quad however \; \mathbf{x} \le 1$$

$$dp = \mathbf{x} * 0{,}6 * v^2 \quad [Pa]$$

A_1 = The area of the box side where the duct connects [m²]
A_2 = cross-sectional area of the duct [m²]
ξ = single resistance coefficient
v = flow velocity [m/s]

3.2.9 From distribution box to duct

$$\boldsymbol{x} = 0,5 - \frac{A_2}{A_1} * 0,5$$

$$dp = \boldsymbol{x} * 0,6 * v^2 \quad [Pa]$$

$$\boldsymbol{x} = 0,7 - \frac{A_2}{A_1} * 0,7$$
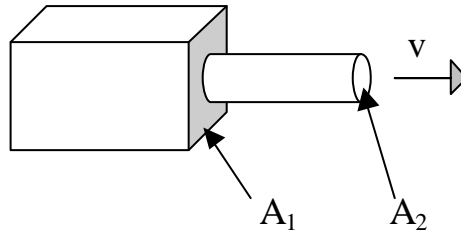
$$dp = \boldsymbol{x} * 0,6 * v^2 \quad [Pa]$$

A_1 = The area of the box side where the duct connects [m²]
A_2 = cross-sectional area of the duct [m²]
ξ = single resistance coefficient
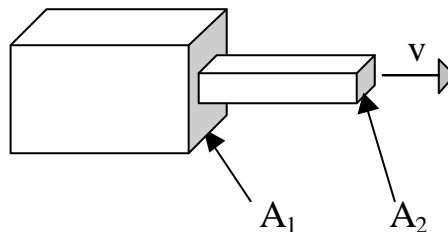v = flow velocity [m/s]

3.2.10 Other

Dynamic pressure

$$dP_{dyn} = \frac{1,2}{2} * v^2 \quad [Pa]$$

v = flow velocity [m/s]

4. MagiCAD sound calculations

4.1. From fan to rooms

Sound calculation proceeds from the root of the ductwork towards the fans. The fan sound level, which is given in the general information, is used as the initial sound level.

User specifies the supply/exhaust device where calculation is routed. On the route, MagiCAD calculates noise levels and attenuation for each device. Finally the room attenuation (usually 4 dB) and A-filter are taken into account.
It is possible to have calculations for every part of the route.

4.2. Sound level and sound attenuation calculation methods

4.2.1 Supply/exhaust devices, flow dampers, silencers etc.

Sound levels and attenuation values are calculated using manufacturers' product models.

4.2.2 Ducts

Noise generated by the duct is calculated from the following equation:

Lw = 10 + 50*Lg(v) + 10*Lg(A) + kFz

v = Velocity [m/s]
A = Area [m2]

kFz depends on the octave band and is presented in the following table:

F [Hz]	kFz
63	-5
125	-6
250	-7
500	-8
1000	-9
2000	-10
4000	-14
8000	-21

Sound attenuation in ducts are presented in the following tables:

SOUND ATTENUATION [dB/m] IN CIRCULAR DUCT

D [mm]	dLw 63	dLw 125	dLw 250	dLw 500	dLw 1000	dLw 2000	dLw 4000	dLw 8000
75 - 200	0.1	0.1	0.15	0.15	0.3	0.3	0.3	0.3
200 - 400	0.06	0.1	0.1	0.15	0.2	0.2	0.2	0.2
400 - 800	0.03	0.06	0.06	0.1	0.15	0.15	0.15	0.15
800 - 1600	0.03	0.03	0.03	0.06	0.06	0.06	0.06	0.06

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SOUND ATTENUATION [dB/m] IN RECTANGULAR DUCT

a [mm]	dLw 63	dLw 125	dLw 250	dLw 500	dLw 1000	dLw 2000	dLw 4000	dLw 8000
75 - 200	0.6	0.6	0.45	0.3	0.3	0.3	0.3	0.3
200 - 400	0.6	0.6	0.45	0.3	0.2	0.2	0.2	0.2
400 - 800	0.3	0.6	0.3	0.15	0.15	0.15	0.15	0.15
800 - 1600	0.45	0.3	0.15	0.1	0.06	0.06	0.06	0.06

4.2.3 Rectangular bends

Noise generated by a 90° rectangular bend is calculated using the following equation:

Lw = Lwb + 10*Lg(df) + 30*Lg(Dg) + 50*Lg(v)
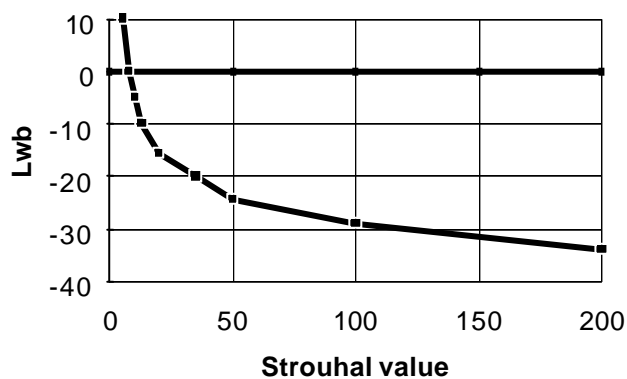
v = velocity [m/s]
Dg = sqrt(4*A/pi), where A = Area [m2]
df = width of the octave band and is presented in the following table:

	63	125	250	500	1000	2000	4000	8000
df	44	88	176	352	704	1408	2786	5600
10*Lg(df)	16	19	22	25	28	31	34	37

Lw = Base level which can be seen in the following diagram:

Base noise for rectangular bend

Str = fm*Dg/v, where fm = frequency (63,125,...)

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Sound attenuation in 90° rectangular bends are presented in the following table

SOUND ATTENUATION [dB] IN 90° RECTANGULAR BEND

a [mm]	dLw 63	dLw 125	dLw 250	dLw 500	dLw 1000	dLw 2000	dLw 4000	dLw 8000
125	0	0	0	0	6	8	4	3
250	0	0	0	6	8	4	3	3
500	0	0	6	8	4	3	3	3
1000	0	6	8	4	3	3	3	3

4.2.4 Circular bends and T-branches

Noise generated by 90° rectangular bend is calculated using the following equation.
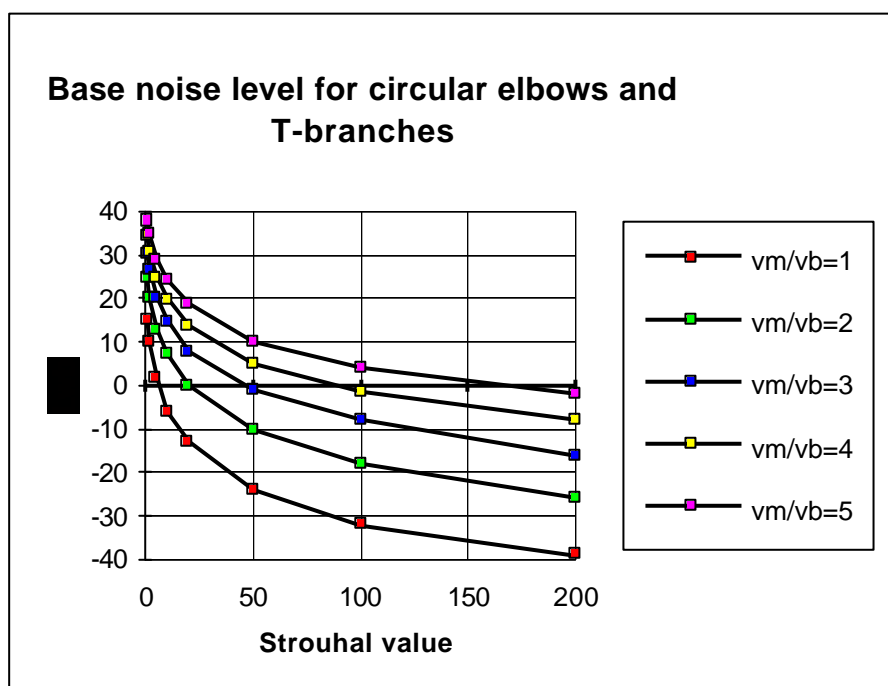
Lw = Lwb + 10*Lg(df) + 30*Lg(Db) + 50*Lg(vb)

vb = velocity in branching duct [m/s]
Db = diameter of branching duct
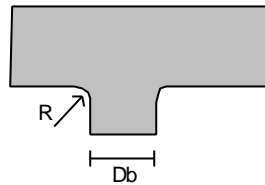df = width of the octave band; described in chapter 5.2.3

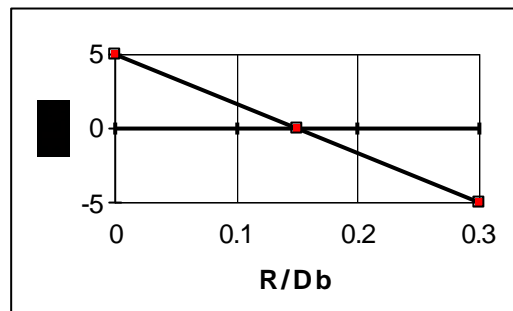Lw = Base level which is read from the following diagram

Str = fm*Db/vb, where fm = frequence (63,125,...)
vm = velocity in main duct [m/s]
Values of the diagram are valid, when radius R/Dh is about 0.15...

... otherwise, correction factor read from the following diagram must be used.

R/Db

Sound attenuation in T-branches consists of two components. First one depends on the area ratio of the branching ducts, and can be calculated using the following equation:
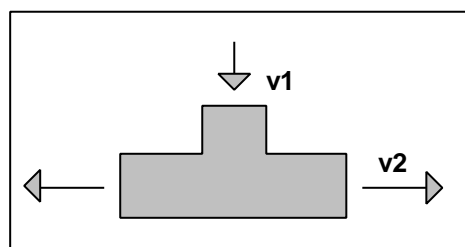
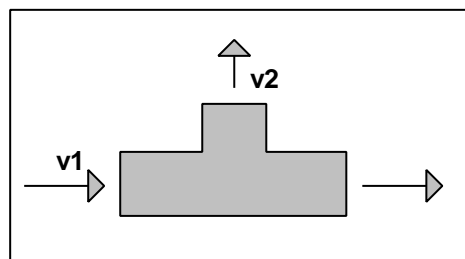**dLw = 10*Lg(Ax/(Ax+A2))**

Ax = area of the branch to be calculated
Ax+A2 = Sum of all branching ducts

Attenuation is independent of octave band.

In addition, attenuation of the bend can be calculated in the following cases:

Attenuation of the bend can be added

In this case, half of the attenuation of the bend can be added.