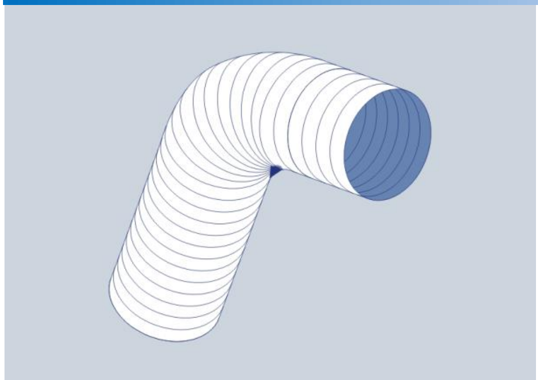


PRESSURE LOSS

FLEXIBLE DUCTING

The effect of a few parameters on the friction coefficient and the resistance coefficient in DEC International®-ducts and -bends has been investigated by TNO, report number 90-042/R.24/LIS. The following parameters have been examined: duct type, duct diameter, compressing (lengthwise), direction of flow, air velocity and the shape of the bends.

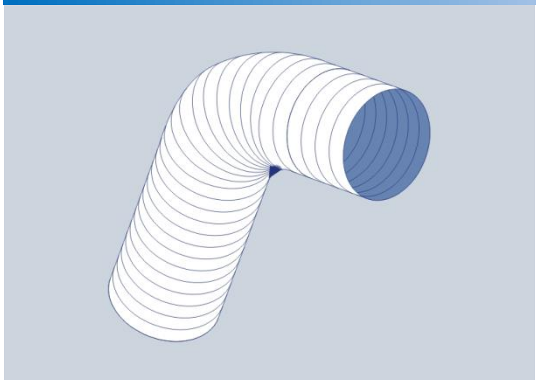
From this research the following became evident:

- The duct type affects the friction coefficient only in ducts which have been stretched completely (0% compressing). The measure of compressing has e great effect on the friction coefficient. A 5% compressing could already redouble the friction coefficient. The effect of the duct type can be neglected then.
- The effect of the duct diameter (102 mm - 305 mm), the air velocity (2 m/s - 6 m/s) and the direction of flow on the friction coefficient can be neglected.
- The resistance coefficients of the bends hardly depend on the duct type.

The results of the research will be given in pressure loss charts.

NOTATIONS:

D	duct diameter	[m]
f	friction coefficient	[-]
i	compressing percentage according to formula (3)	[-]
k	wall roughness	[m]
L	real duct length	[m]
Le	equivalent length according to formula	[m]
Li	length inflow section	[m]
Lm	maximal duct length	[m]
Δp	pressure loss	[Pa]
Pb	barometer pressure	[mbar]
Ph	pressure in test department	[Pa]
R	radius of a bend	[m]
Re	Reynolds number	[-]
T	temperature	[°C]
U	average velocity	[m/s]
ζ	resistance coefficient	[-]
ν	kinematic viscosity	[m^2/s]
ϱ	density	[kg/m^3]



PRESSURE LOSS

FLEXIBLE DUCTING

1. INTRODUCTION

The pressure loss in a duct, consisting of one or more straight parts and some bends, depends among other things on the friction coefficients of the ducts and the resistance coefficients of the bends.
In order to find the pressure loss in a duct, the coefficients must be known.
TNO measured the effect of some parameters on those coefficients.

While investigating the ducts the effect of the following parameters on the friction coefficients has been examined:

- Duct type
- Duct diameter
- Degree of compressing
- Direction of flow
- Air velocity

While investigating the bends the effect of the following parameters on the resistance coefficients has been examined:

- Shape of the bend
- Duct type

On behalf of the research a measurement setup has been built up (see fig. 3).

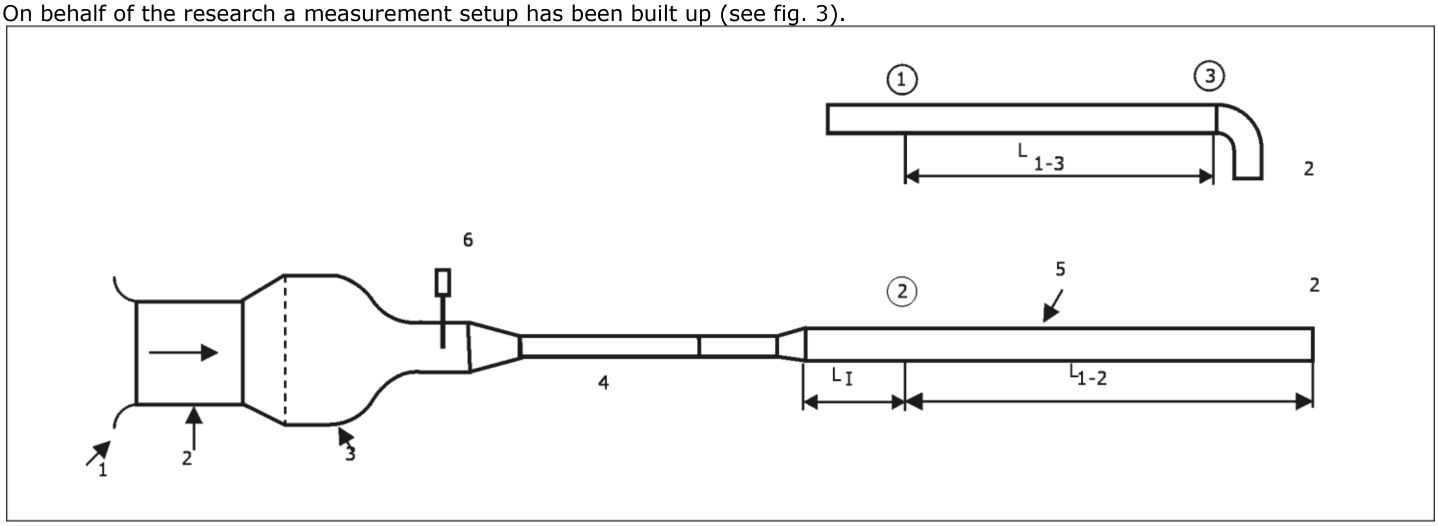
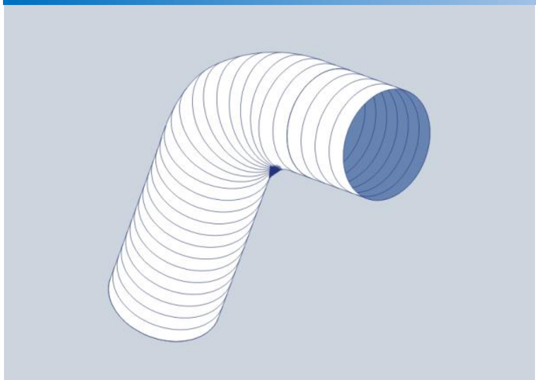


Figure 3

The formulas, making out the pressure loss of a straight part or a bend, will be given in chapter 2.

Hereby we will go further into the effect of the duct diameter, the roughness of the inner duct wall and the Reynolds number on the friction coefficient. Secondly we will go further into the equivalent length of the bends.



PRESSURE LOSS

FLEXIBLE DUCTING

2. PRESSURE LOSS

In general a mounted duct has a few straight parts and a few bends. If a gas is flowing through the duct a pressure loss will occur in each straight part and each bend of the duct. When determining the conveying height of a fan, the pressure loss of each straight part and each bend of the duct has to be determinated.

2.1 STRAIGHT PART OF A DUCT

The pressure loss (also called pressure drop or resistance) of a straight part of a duct can be calculated with the next formula:

Δp = the pressure loss [Pa]
f = the friction coefficient of the duct [-]
L = the (real) length of the duct [m]
D = the diameter of the duct [m]
ϱ = the density of the gas [kg/m3]
U = the average velocity

$$\Delta p = f \cdot \frac{L}{D} \cdot \tfrac{1}{2}\varrho U^2$$

From this formula the following can be deducted:
- the pressure loss is proportional to the friction coefficient
- the pressure loss is proportional to the density of the gas. For (dry) air the density is:

$$\varrho = 1.293 \cdot \frac{P_b}{1013} \cdot \frac{273}{273 + T}$$

Pb = the barometer pressure in millibar
T = the temperature in °C

From the Moody-diagram [1] for ducts can be deduced that:
- The friction coefficient decreases slightly if the value of the Reynolds number (**Re = U.D/ϱ**) increases
- The friction coefficient decreases if the relative roughness decreases **k/D**

From this it follows that:
- The friction coefficient decreases slightly if the velocity increases (higher Re-number)
- The friction coefficient decreases if the diameter increases, if the wall roughness stays the same (higher Re-number and decreasing relative roughness)

The wall roughness is determined by:
- The duct type
- The extent of compression

The measure of compressing will be defined as follows:

$$i = \frac{L_m - L}{L_m} \cdot 100\%$$

Lm = the maximal duct length
L = the real duct length

The effect of the duct on the friction coefficient has been determined with a 0% compression.
The real length of the duct is then equal to the maximal length.

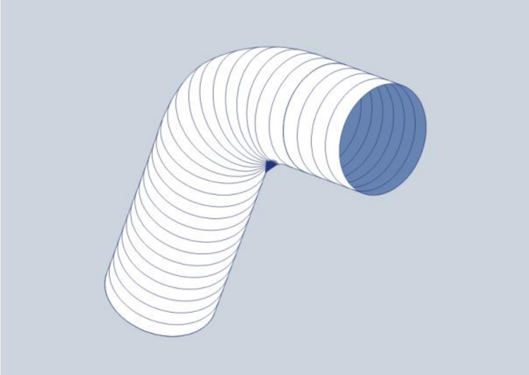
2.2 BENDS

The pressure loss of a bend can be determinated with the following formula:

$$\Delta p = \zeta \cdot \tfrac{1}{2}\varrho U^2$$

Δp = the pressure loss [Pa]
ζ = the resistance coefficient of the bend [-]
ϱ = the density of the gas [kg/m3]
U = the average velocity [m/s]

The pressure loss in a duct bend is greater than the pressure loss in a welded bend with the same diameter and radius of curvature. Because the friction losses in a bend are considerable greater. In a metal bend the inner wall is smooth in contrast to a duct bend. Especially the inner bend of the duct will compress intensely. Because of this the flow-through surface becomes smaller and the flow velocity higher.



PRESSURE LOSS

FLEXIBLE DUCTING

2.3 EQUIVALENT LENGTH

The equivalent length of a bend is the length of a straight duct, from which the pressure loss is equal to the pressure loss in the bend.

This equivalent length follows from:

$$\Delta p_s = f \frac{L}{D} \cdot \tfrac{1}{2}\rho U^2$$

$$\Delta p_b = \zeta \cdot \tfrac{1}{2}\rho U^2$$

To **Δps = Δpb** the formula is:

$$f \frac{L_e}{D} = \zeta$$

$$L_e = \frac{\zeta}{f} \cdot D$$

The equivalent lengths of the tested ducts of the Ø 102 mm Aludec 70 have been determinated with this formula.

3. DIAMETER

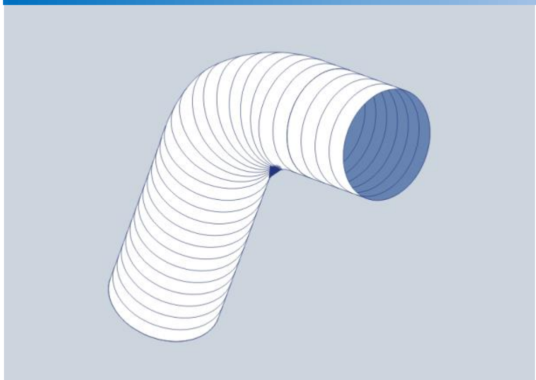
At four out of the five duct types, which have been investigated, the friction coefficient hardly depended on the duct diameter. Only the Greydec 100 had an increasing of the friction coefficient with the diameter. It appears that if the roughness of the duct wall stays the same, the friction coefficient decreases if the diameter increases. The increasing could be explained by presuming that the 203 mm and the 305 mm Greydec ducts must have had a certain degree of compressing. Although they have been stretched till maximum stated length. If we leave the measure results of the Greydec 100 out of consideration, the effect of the duct diameter on the friction coefficient could be neglected.

4. VELOCITY

In flexible ducts the friction coefficient slightly decreases if the velocity increases.
It appears that for DEC-ducts this is also the case with the Greydec 100, the Aludec 70 and the Aludec AA3, but in a less degree with the Aludec 112 and the Sonodec 25. In general the effect of the velocity on the friction coefficient is small. It can be neglected with respect to the effects of the duct type and the degree of compression.

5. DIRECTION OF FLOW

The friction coefficient of the Aludec 70 has been measured in both the flow directions. Due to the manufacturing method one flow direction provides a sudden (very small) narrowing at each overlap, whilst the other flow direction provides a sudden (very small) expansion. From the measurements it appears that the average value of the friction coefficient of the duct just in one case differs 5% from the other direction. In general this difference can be neglected.



PRESSURE LOSS

FLEXIBLE DUCTING

6. COMPRESSION

The compression of the ducts has a great effect on the friction coefficient (figure 4). It appears that, if a duct will be compressed only 5%, this already leads to a roughly double friction coefficient (figure 4).
Apparently, the roughness of the inner duct wall increases strongly if the compression is very small. Figure 4 also shows that the friction coefficient increases almost linear during compressing, provided that the compression is less than 20%. To each percent of compressing the increasing of the friction coefficient is ca. 0.01. If a duct has been compressed only 3% the friction coefficient will increase ca. 0.03. The increasing is the same as the differences of the five duct types, which have been measured.

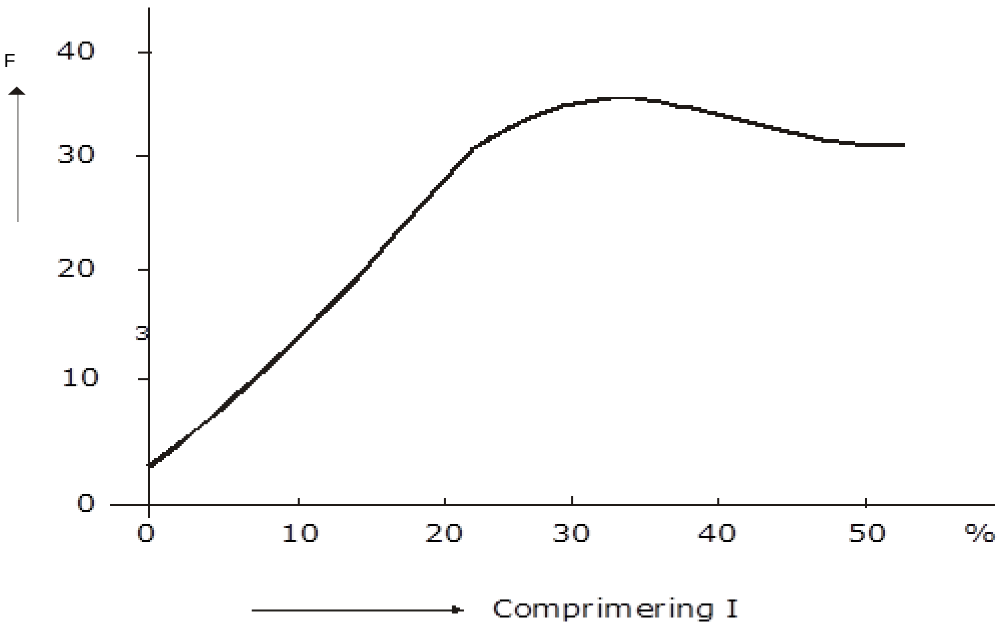
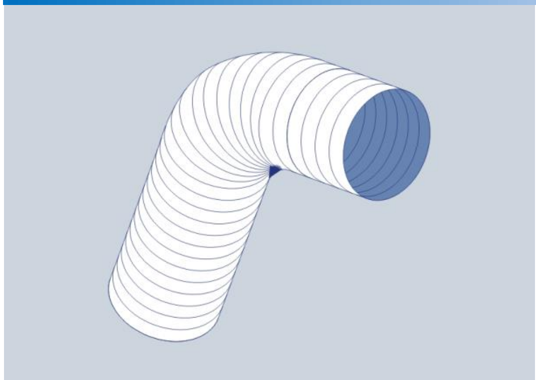


Figure 4

7. FRICTION COEFFICIENTS

From the above it follows that the effects of the duct diameter, air velocity and direction of flow on the friction coefficients of the ducts can be neglected. It also appears that the degree of compressing has more effect than the duct type. To determine the degree of compressing with formula 4, information on the maximal length of the concerning duct will be needed. The maximal length, however, depends on the size of the effort determining this length. Besides, a certain force at a duct with a small diameter, causes a greater tensile stress than at a duct with a larger diameter and the same wall thickness. In this research the friction coefficient for the different duct types only applies for ducts, which have been stretched to the same length as the ducts which have been tested.

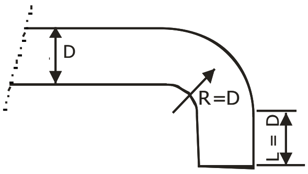


PRESSURE LOSS

FLEXIBLE DUCTING

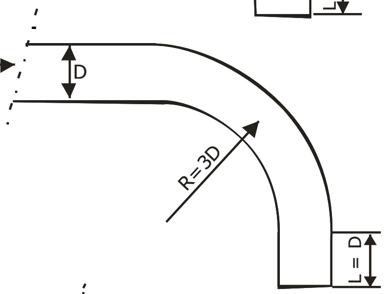
RESISTANCE COEFFICIENT OF THE BENDS

1a



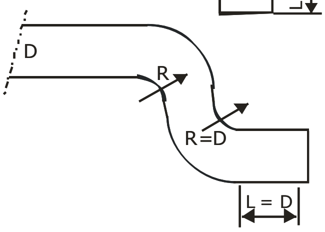
$\zeta = 3.6$

1b



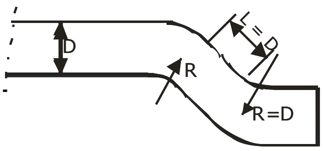
$\zeta = 3.0$

1c



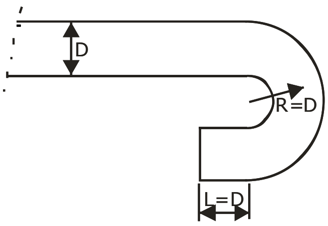
$\zeta = 6.2$

1d



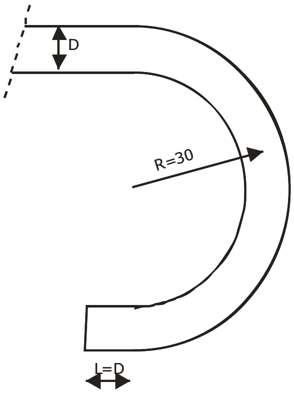
$\zeta = 4.1$

1e



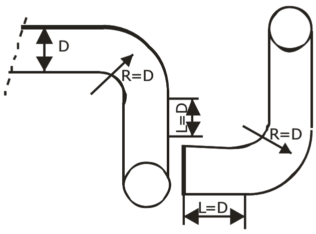
$\zeta = 4.7$

2a



$\zeta = 5.1$

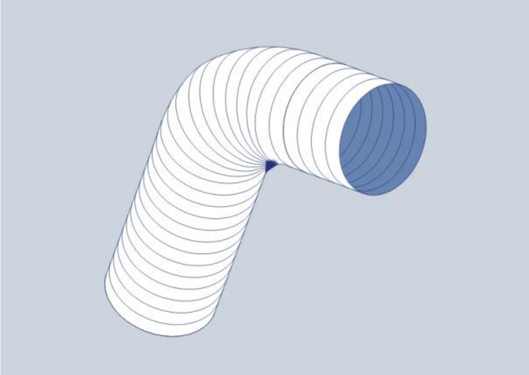
2b



$\zeta = 4.8$

2c

Greydec 100 $\zeta = 2.2$
Aludec 112 $\zeta = 2.5$
Aludec AA3 $\zeta = 2.7$
Sonodec 25 $\zeta = 2.7$



PRESSURE LOSS

FLEXIBLE DUCTING

8. RESISTANCE COEFFICIENTS OF THE BENDS

The resistance coefficients of the bends have been mentioned in the figures 1 and 2. It appears that the air velocity has hardly any effect on the size of the resistance coefficient. From the figures 1a, 1b, 2a and 2b it appears that an increasing of the curvature radius of the 90°-bend provides a decreasing of the resistance coefficient. The 180°-bend, however, shows an increasing. This is against all expectations. Probably this is due to the small differences of roughness of the bends, because the compression of the bends will differ from one another. A difference in flow model in both the bends could also be the cause. The duct type seems to have only a small effect on the resistance coefficient of the bends (figure 2c). This was to be expected. The inner bend is always compressed in such a way that its roughness is much larger than the roughness of the (maximally stretched) ducts.

9. PRESSURE LOSS CHARTS

Pressure loss charts have been made for the different types of DEC-ducts and DEC-ends.
The charts show the pressure loss per meter duct for 0°C air.

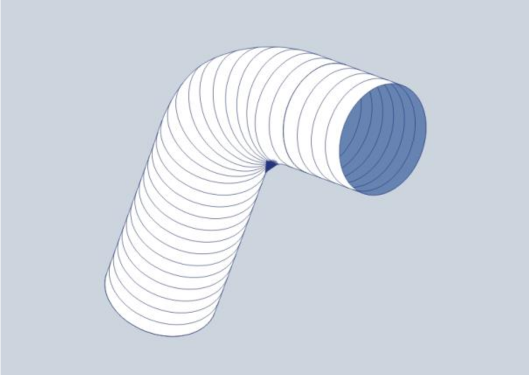
The charts for the different duct types have been given in the following figures

GREYDEC 100	(f=0.033)
ALUDEC 70	(f=0.037)
ALUDEC 112	(f=0.053)
ALUDEC AA3	(f=0.031)
SONODEC 25	(f=0.053)

The charts for the ALUDEC 112 and the SONODEC 25 are identical.
If the air has a temperature different from 0°C the pressure loss should be multiplied with a correction factor.
This correction factor is 273 / (273+T).

Emphatically it has been stated that the charts apply to ducts, which have been stretched maximally (**compression 0%**).

The pressure loss charts on the bends according to the figures 1 and 2, are given in 5.11a.
These charts apply to air with a temperature of 0°C. Also here it applies that, if the air has a temperature other than 0°C, the pressure loss has to be multiplied with the correction factor. In order to make the charts resistance coefficients have been applied, as mentioned in the figures 1 and 2. The average value of the measured coefficients has been used (2.6) for the bend according to figure 2c.

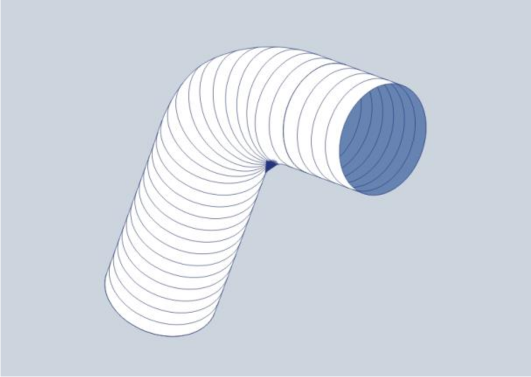


PRESSURE LOSS
FLEXIBLE DUCTING

10. CONCLUSIONS

- The friction coefficients of five different DEC-ducts have been determined in a measurement setup. The results have been given in a chart. The friction coefficients are applied to ducts, which have a 0% compression. On behalf of the effect of the compressing of the duct the effects of duct diameter, air velocity and direction of flow on the friction coefficients are to be neglected.
- Compressing a duct lengthwise, in some degree, will lead to a strong increasing of the friction coefficient. If compressing ca. 5% a redoubling of the friction coefficient appears.
- Charts have been made for the different duct types on the basis of the measured friction coefficients.
- The resistance coefficients of eight different bends have been measured. These coefficients seem to be independent of the air velocity and the duct type has only a small effect. The resistance coefficients of the duct bends have been given in the figures 1 and 2.
- Pressure loss charts for the bends have been made on the basis of measured resistance coefficients.
- If the air has a temperature different from 0°C the pressure loss should be multiplied with a correction factor. This correction factor is 273/(273+T)
- With respect to the wire distance the type of the tested ducts are a reflection of the several types of flexible ducts out of DEC International's delivery program. Compressing affects the pressure loss most seriously. The duct type has hardly any influence on pressure loss in bends. Therefore DEC International has deduced the pressure loss diagrams from the following duct types:

Duct type:	***Deducted from:***
Aludec (2)45	Aludec 112
Combidec 2000	Aludec AA3
Combidec 2100	Aludec 112
Combidec 2300	Aludec 112
PVC white	Aludec AA3
Isodec 25	Sonodec 25
Isodec 250	Aludec 112
Sonodec 250	Aludec 112
Sonodec GLX	Aludec 112
Sonodec TRD	Sonodec 25
CE-FLEX	Aludec AA3
Aludec 270	Aludec 112

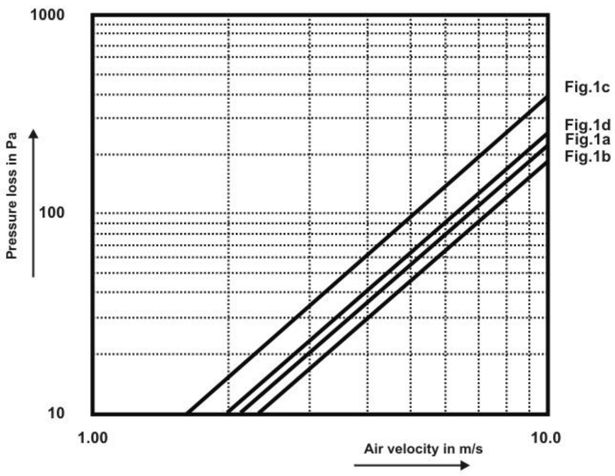


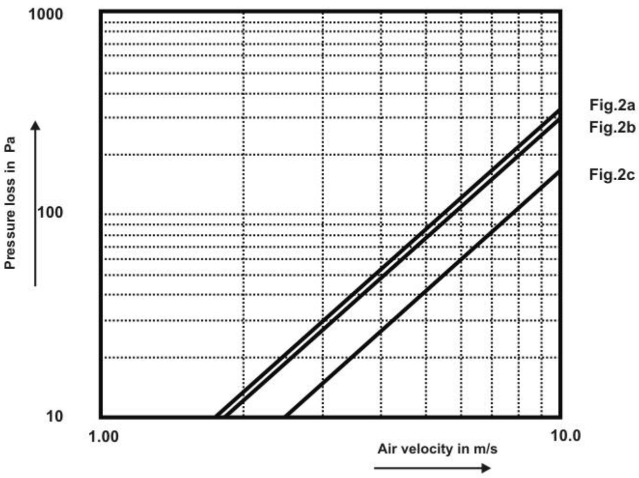
PRESSURE LOSS

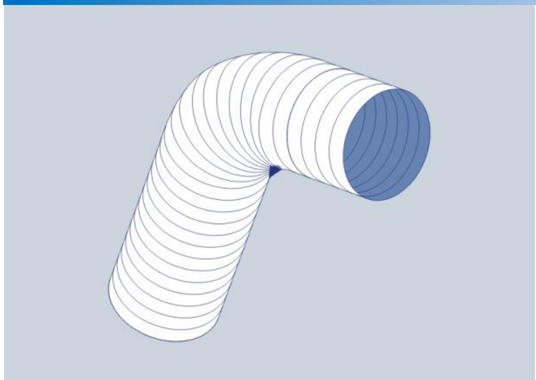
FLEXIBLE DUCTING

11 GRAFICS

11a PRESSURE LOSS OF THE BENDS







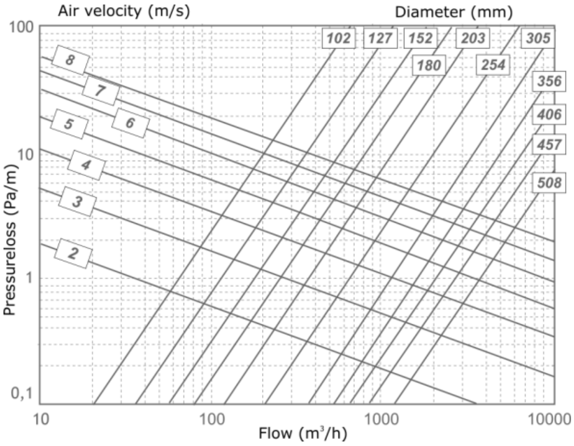
PRESSURE LOSS

FLEXIBLE DUCTING

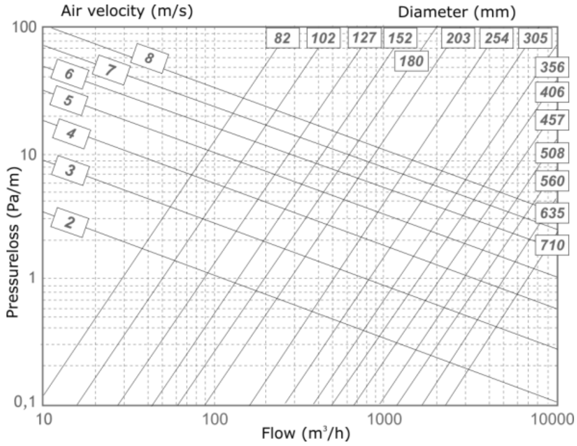
11 GRAFICS

11b PRESSURE LOSS DEC DUCTING

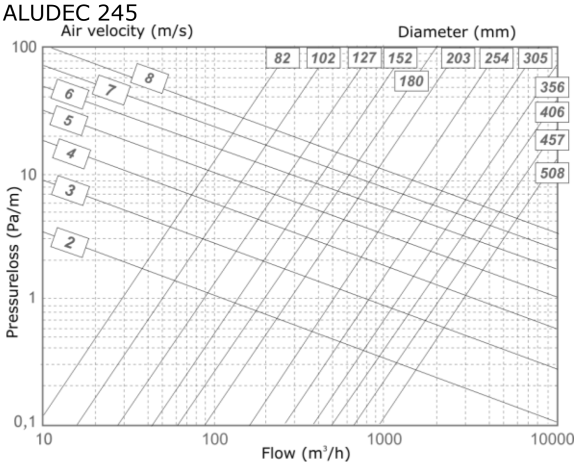
ALUDEC AA3



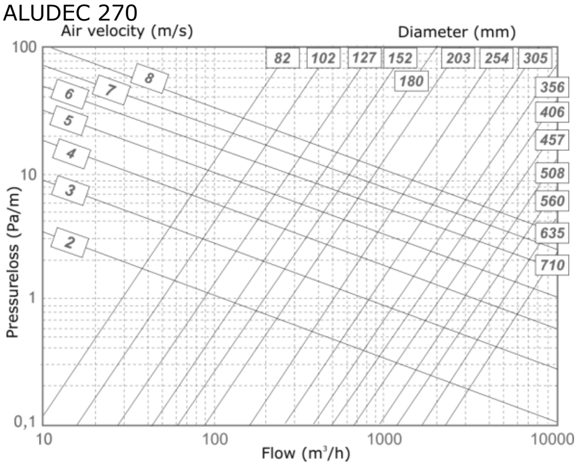
ALUDEC 112



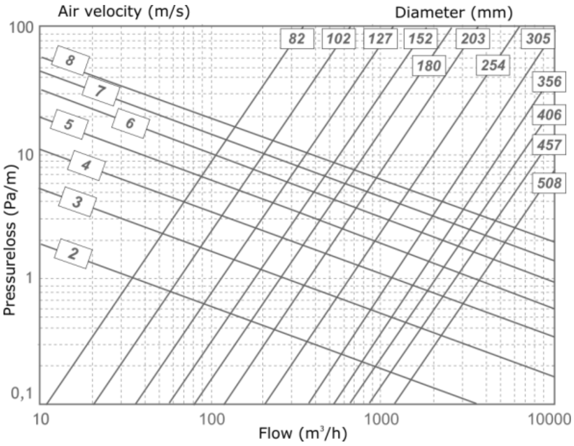
ALUDEC 245



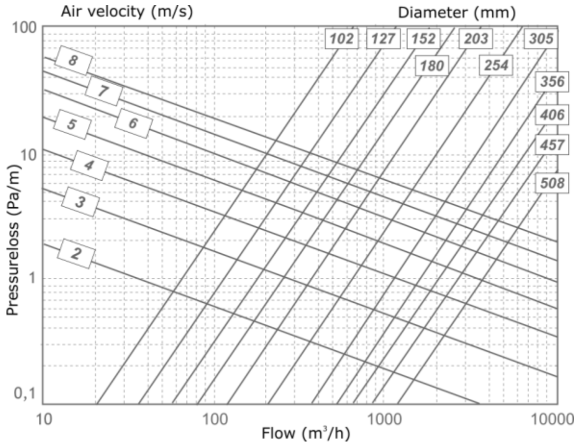
ALUDEC 270

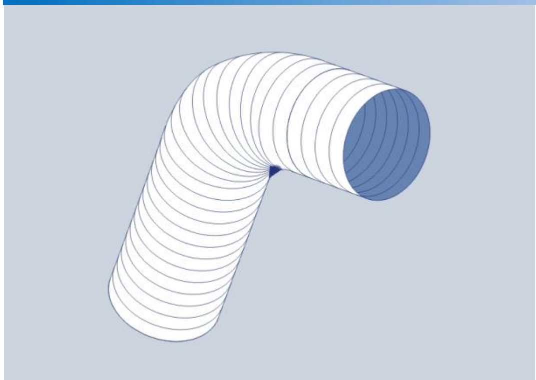


ALUDEC CLASSIC



CE-FLEC





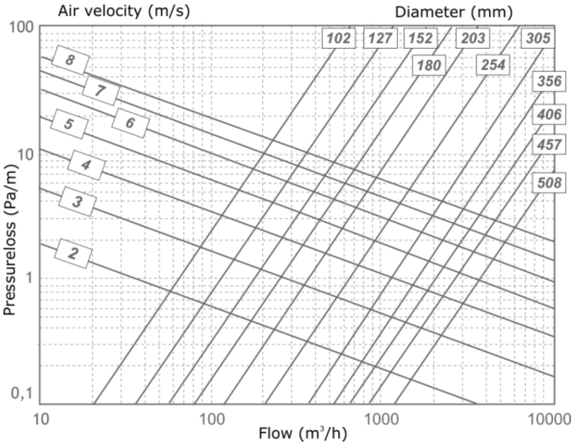
PRESSURE LOSS

FLEXIBLE DUCTING

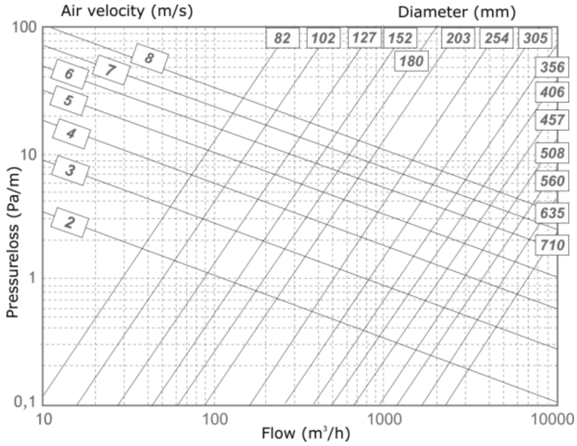
11 GRAFICS

11b PRESSURE LOSS DEC DUCTING

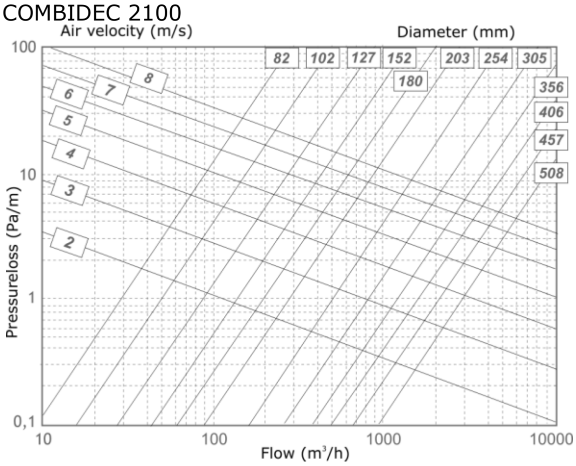
COMBIDEC 2000



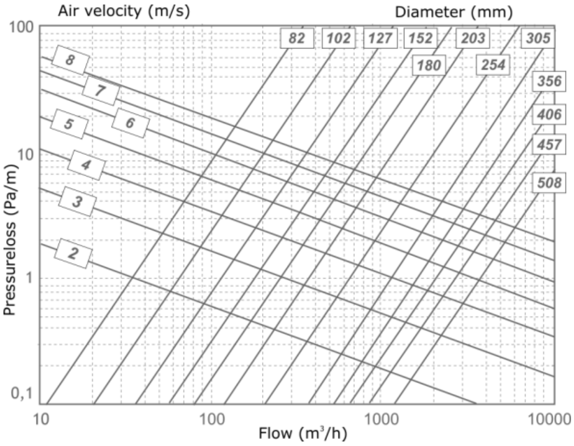
COMBIDEC 2300

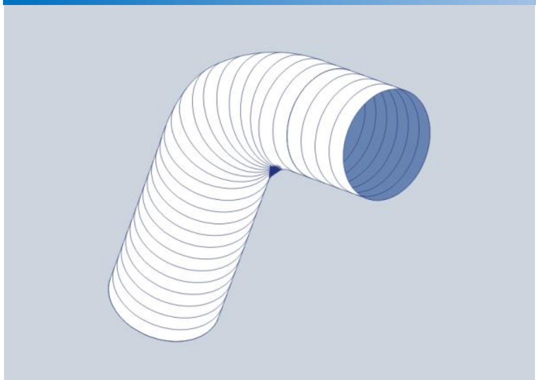


COMBIDEC 2100



COMBIDEC CLASSIC





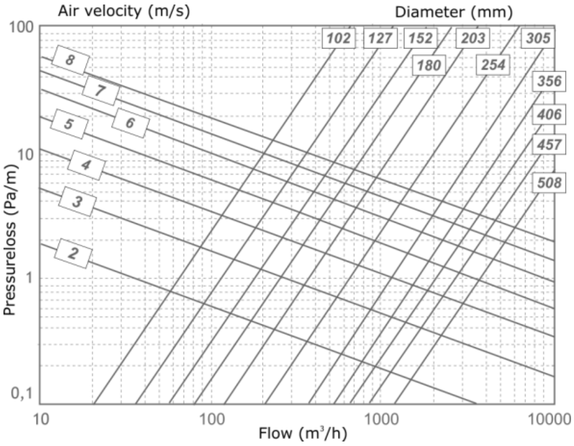
PRESSURE LOSS

FLEXIBLE DUCTING

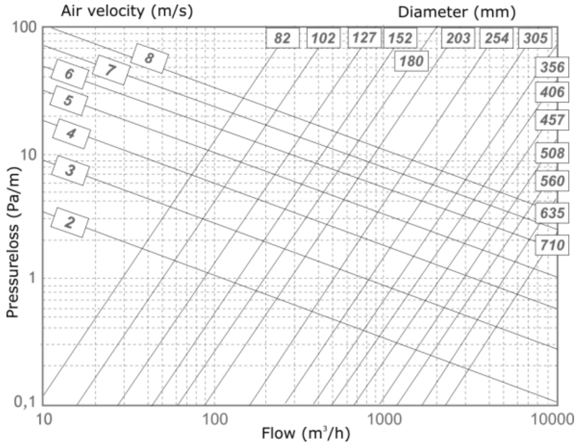
11 GRAFICS

11b PRESSURE LOSS DEC DUCTING

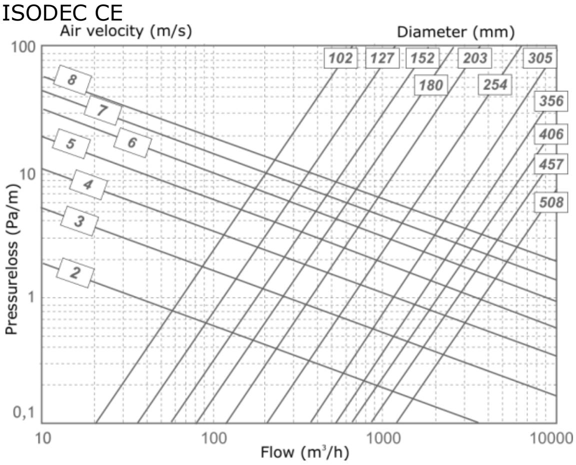
ISODEC 25



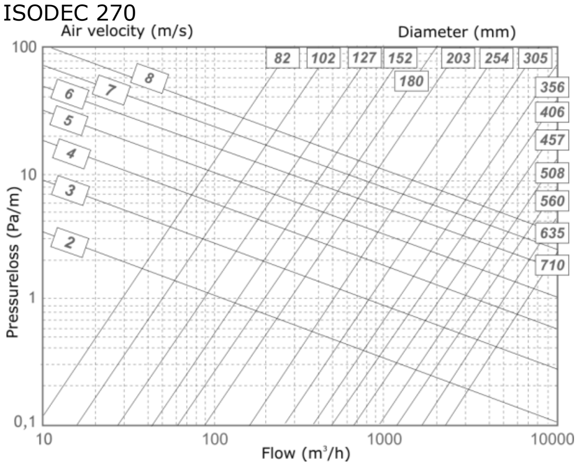
ISODEC 250



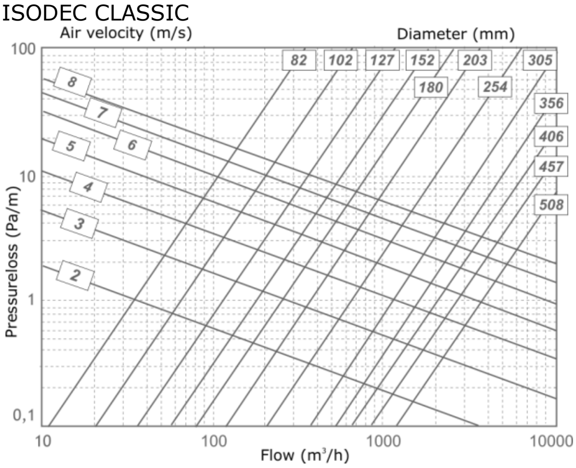
ISODEC CE

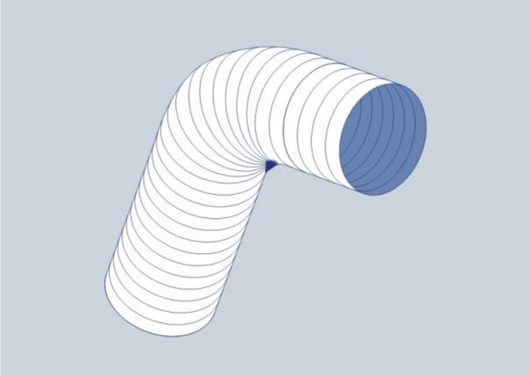


ISODEC 270



ISODEC CLASSIC





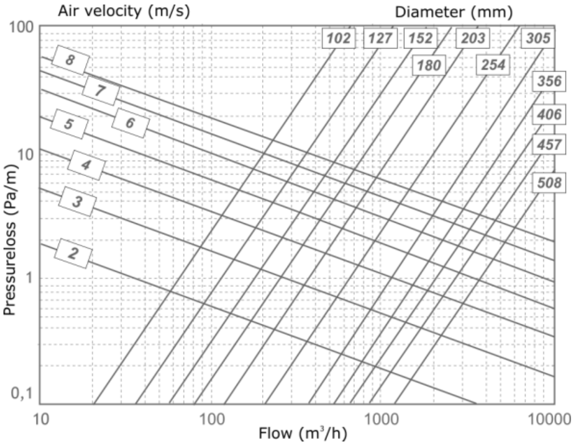
PRESSURE LOSS

FLEXIBLE DUCTING

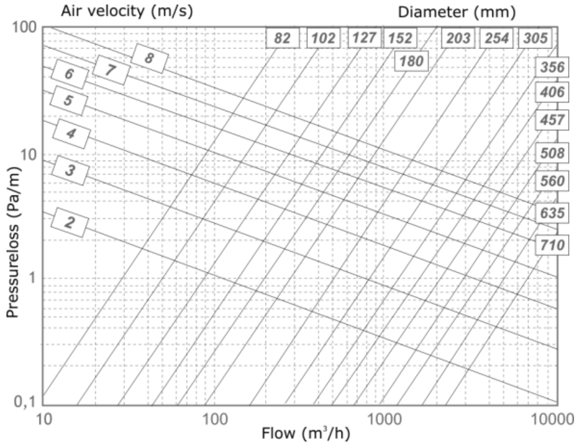
11 GRAFICS

11b PRESSURE LOSS DEC DUCTING

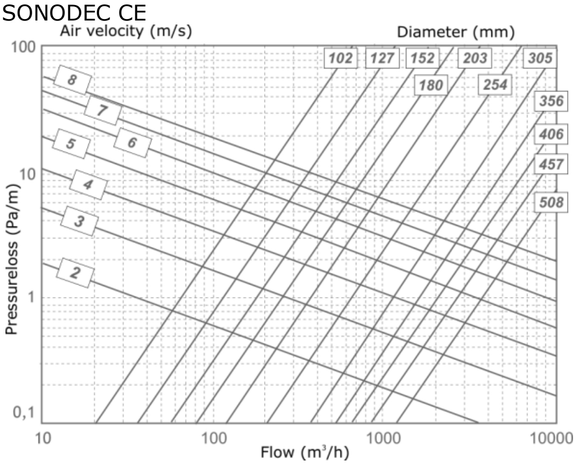
SONODEC 25 / TRD



SONODEC 250 / GLX



SONODEC CE



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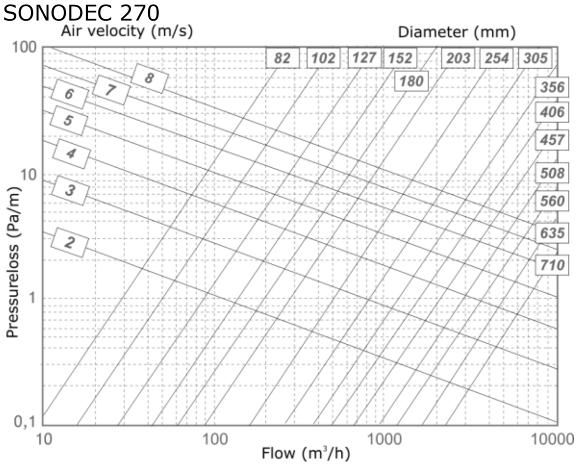

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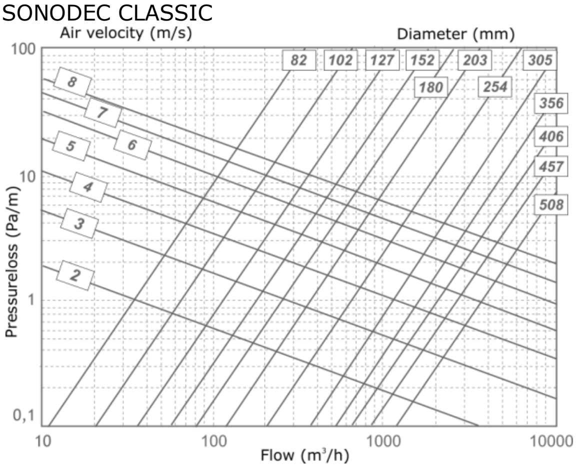
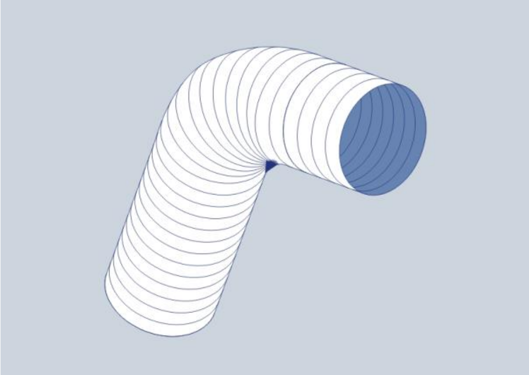




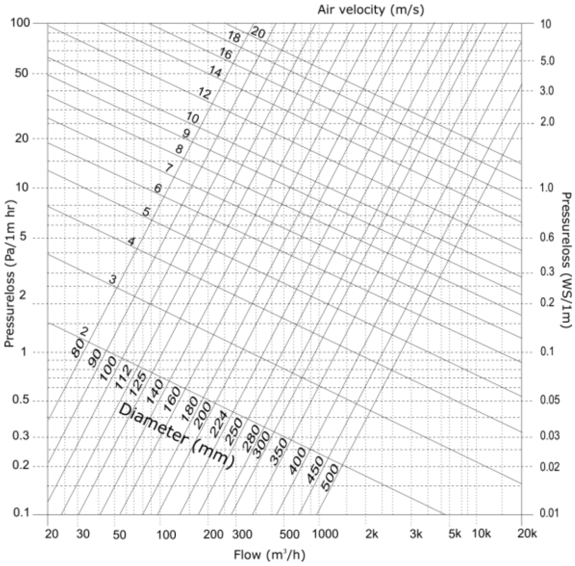
PRESSURE LOSS

FLEXIBLE DUCTING

11 GRAFICS

11b PRESSURE LOSS DEC DUCTING

STRETCHDEC / SEMIDEC



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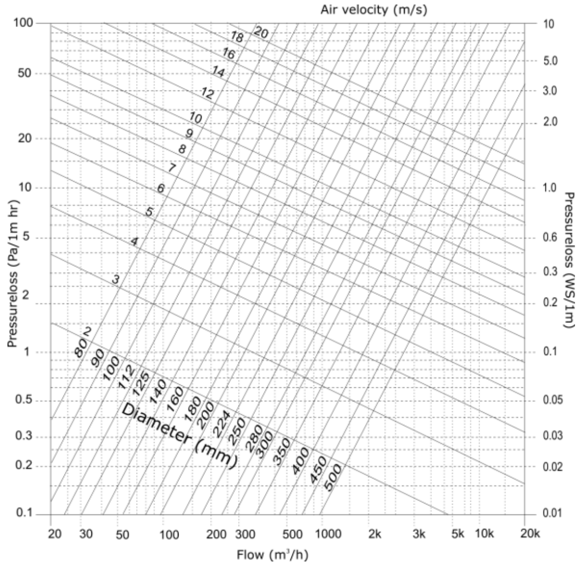
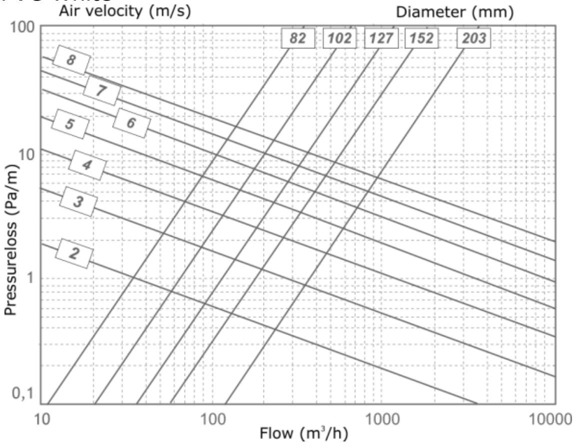
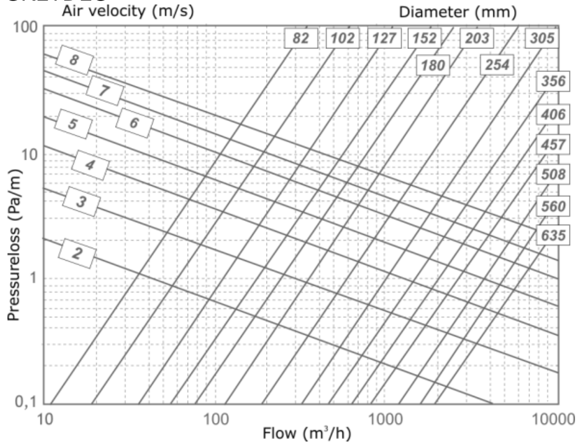


PVC White



GREYDEC



LIABILITY:
The information contained in this brochure was current on the publication date. DEC INTERNATIONAL reserves the right to make changes in details at any time without prior notice. In order to avoid misunderstandings, any interested party is advised to contact DEC INTERNATIONAL checking for any changes in materials and/or information after this brochure was published.

PLEASE NOTICE:
The consultant is responsible for the actual installation and mounting of the product. The mentioned values with respect to temperatures are not appropriate to be used to determine the physical properties. These properties are also dependent on humidity and the temperature of the air inside and outside of the H.V.A.C. system.