

NEGATIVE PRESSURE

FLEXIBLE DUCTING

1. INTRODUCTION

One of the major elements in a ventilation system is pressure. Air pressure is used absolutely as well as relatively for the density of molecules in a space. If the density is high, the pressure will be high and vice versa. If working with ductwork and ventilation systems, the density can be compared with a density of molecules somewhere else. This is called a difference in air pressure.

Since we live in a more or less standard air pressure of about 1000 hectopascal, pressures could be related to this standard pressure.

A ventilator, pulling air out of the atmosphere and pumping it into a volume, will create a certain pressure difference between the atmosphere and the volume. In this report we just mention pressure if it is related to standard pressure. Since the difference can be positive or negative we will mention positive and negative pressure. Both have been measured in relation to the standard air pressure.

Air ventilation systems can use both positive and negative pressures. This depends on the fact if air has been extracted from or pushed into a volume.

A ventilator, getting fresh air from outdoors, will at first cause a certain negative pressure in the ductwork, between the air inlet and the fan. This negative pressure causes an airflow from outdoors (where the pressure is higher) into the inlet. Depending on the air-resistance of the inlet and the power of the fan, this pressure could increase to dangerous values for our products. In this report we will explain what happens, if negative pressures occur in a duct and what protective action could be taken in order to prevent the ductwork from getting damaged.

2. THE DIFFERENCE BETWEEN POSITIVE AND NEGATIVE PRESSURE

It is very important to consider that positive and negative pressures do not have the same effect on ductwork. A positive pressure in a volume will yield a force of which the direction is pointed outwards. This force is caused by collisions of molecules to the wall of the volume.

3. NEGATIVE PRESSURE IN FLEXIBLE DUCTS

If air has been blown into a balloon, the volume will expand. The higher pressure inside the balloon will give a force and this force will push the wall of the balloon in all directions. Due to the fact that the wall increases in tension, thus causing a reverse force, a balance will be created and the expansion will be brought to a halt. Actually, a negative pressure inside a volume gives the same physical result. A force has been created, but now the direction points inwards the volume. The behavior of the volume depends on the size and the wall structure.

Large volumes appear to be more sensitive to pressure than small volumes. This is clarified by the fact that pressure is equal to a force, being applied to a certain area.

A 1000 Pa pressure would result in a force, caused by a 100 kg weight resting upon a 1m² area. Enlarging the volume (larger diameter) will result in a bigger total force, being applied to the wall surface. It needs no explanation that a flexible duct with a larger diameter has less resistance to negative pressures. A flexible duct could be damaged by negative pressure in two ways. The duct will either be squeezed or subjected to the, so called, domino effect.

Both ways of damaging duct will be explained below.

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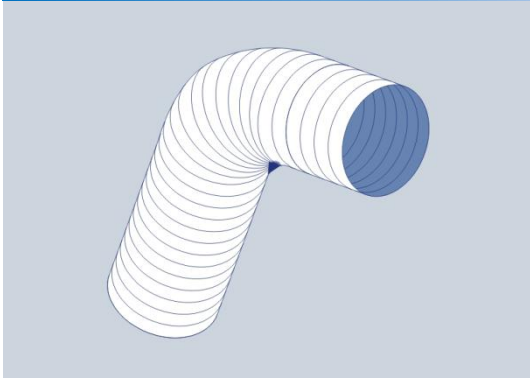
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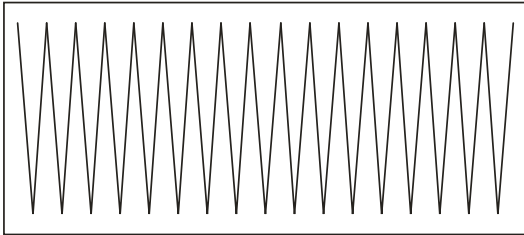
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4. THE DOMINO EFFECT

Depending on the structure of the flexible duct several effects can occur.
The most important effect to flexible ductwork will be shown in the next few drawings.



Drawing 1.

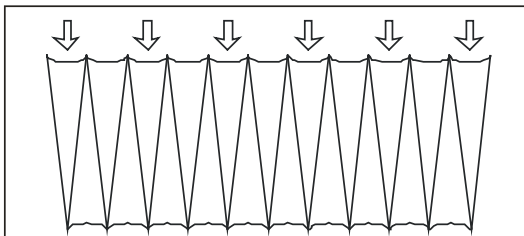
(Drawing 1) This is the normal position of the wire helix inside the wall of a flexible duct, as seen from the side.
The wires of two neighboring windings are connected with the laminate of the duct. Depending on the nature of this material, the wire spacing can be different. The wire prevents the duct from dents etc.

The laminate, however, gives an either stiff or souple behavior to the duct.

We already explained that the force, caused by a negative pressure inside the duct, points inwards the duct. Normally, the direction is perpendicular to the duct wall. In that case the wire, as well as the laminate, will have to resist the force.

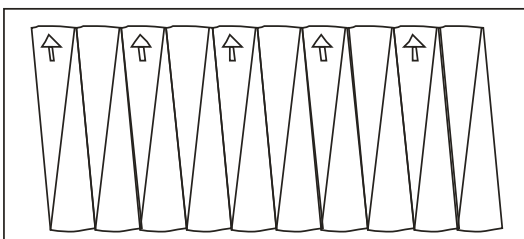
The force has been indicated by arrows, in drawing 2.

The tear resistance of the wall material will now determine the maximum applicable force.



Drawing 2.

This would, more or less, be the same as the maximum positive pressure, of which the arrows point in the reverse direction (drawing 3).



Drawing 3.

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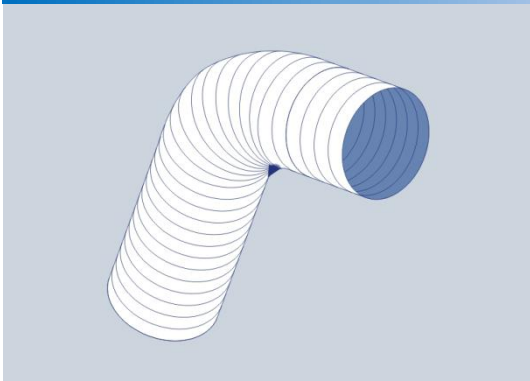
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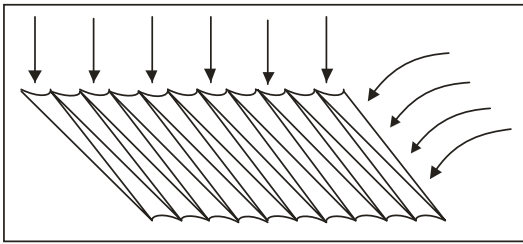
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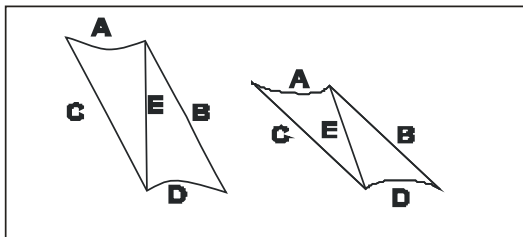
Unfortunately this is not the case. What in fact happens is that the windings will fall like a row of domino stones (see drawing 4). With this movement the volume, inside the duct, has been decreased by the pressing force from outside.



Drawing 4.

For this effect a force with much less strength is enough. It is useful to know which of the important parts of the duct determine the resistance to this domino-effect.

We will have a close view at what is happening.



Drawing 5.

Let us assume that a small piece of duct, drawn at the left, is more or less rectangular. If this has been deformed into the shape of the drawing at the right, the shape becomes a rhomboid. Two major effects will counteract such a movement:

Effect 1 - The wire E will be shortened and the wires B and C will get slightly longer. This has not been done by stretching and shrinking, of course, but a piece of 'E' has been given to B and C. One can imagine that this has been caused by shifting in the warp direction of the wire in the overlap. The wire E will get a sharper curve, the wires B and C will have a less sharp curve. This deforming of the original form of the wire has been counteracted by the wire itself.

Effect 2 - The laminate A, in drawing 5, will not result in any effect, since the distance between the windings at this place remains the same. The same goes for the laminate D at the bottom. The material in the middle of the duct, between B and C, will cause a certain resistance against this movement. This resistance can be compared by taking a piece of paper in a 'portrait' position, while pressing the four corners of the paper against the table with both hands. Use thumbs and forefingers. Now move the left hand away from you, while pressing the two left corners against the table. The paper starts to fold in the middle. You have tried to make a rhomboid out of a rectangular. The same effect occurs with the laminate between each of the two windings, at the side of the duct. Depending on the nature of this material the deforming can be easy or difficult.

Depending on the nature of the materials, mentioned in 1 and 2, the movement in drawing 5, will be counteracted with more or less force. However, this force is much less than the force needed to tear the material itself. This will be done when too high a positive pressure is applied. Therefore the maximum negative pressure, which a flexible duct can resist, is much less than the maximum positive pressure.

With this conclusion, we come to one of the determining elements of the behavior of a flexible duct with negative pressures.

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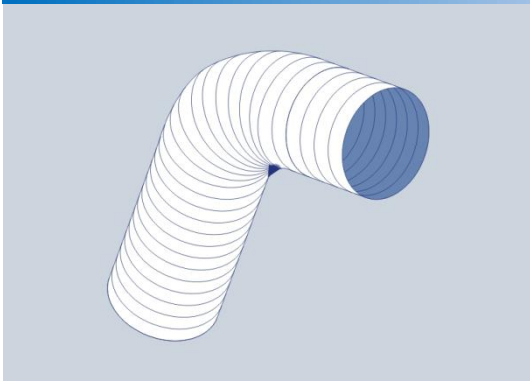
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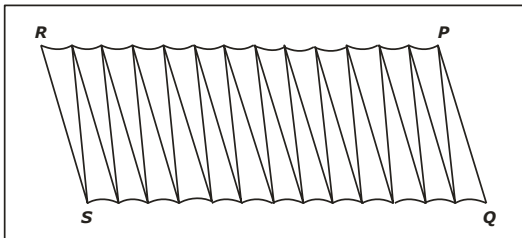


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How can we give optimal resistance to negative pressures?

To achieve this, it is necessary to minimize the chance of the domino effect. There are several possibilities of minimizing the chance:

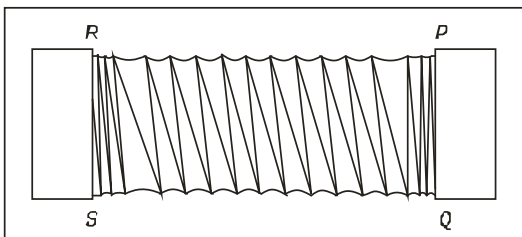
- 1** Stiffer material could be used for the duct wall. The stiffer material will not fold easily and therefore it would be more difficult to deform the rectangular of drawing 5. A less flexible product, however, would be the consequence. In practice it has been shown that an Aludec 112 has a better resistance against negative pressures than a PVC duct has.
- 2** Thicker wire could be used. The toughness of the wire will give resistance to the deforming in 'effect 1'.
- 3** When the pitch of the wire helix has been decreased, it will be more difficult to deform the rectangular of drawing 5. 'A' and 'D' have become shorter and this results in a closer contact between 'C' and 'B'. It will be less easy to move 'C' in relation to 'B'. Decreasing the wire spacing is a very good method of achieving a better resistance to negative pressures. The price of the duct, however, will increase accordingly.
- 4** The last possibility is one of major importance! The first three methods have to be performed by the manufacturer, because of the differences in the structure of the duct wall. The last one could be done by the user of the duct, without making any changes to the actual duct structure. Since this last method has a big influence on the capability of the duct to resist negative pressures, we will give much attention to explaining how and why. Referring to drawing 6, we see a duct, subjected to the domino effect.



Drawing 6

Normally, P, Q, R and S would have been fit to an accessory, which has been attached to the main ventilation system. Therefore P should be straight over Q, the same goes for R and S.

In reality the duct in drawing 6 would have been mounted like drawing 7.



Drawing 7

P is straight over Q now and R over S. The first and the last winding of the wire helix will have to be positioned vertically. The windings in the middle are collapsed, due to the negative pressure inside. The windings in the middle, however, can only be subjected to the domino effect, if there is enough clearance in the material at point P and S. The material at Q has been compressed and the material at P has been extracted, in order to give the wire the possibility of moving according to the domino effect.

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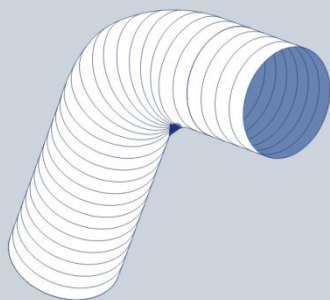
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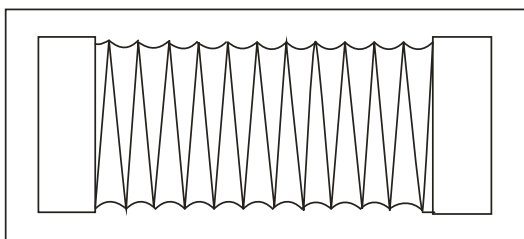
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To achieve this, it is necessary to minimize the chance of the domino effect.

When no clearance is available, the laminate will keep the wire in position (drawing 8). This will be done if the flexible duct has been stretched completely and connected between the accessories with a slight tension. It could be said that each winding of the wire has been pulled from both sides and therefore it is not able to move.

This will prevent the domino effect! This installation method will be more difficult if there have to be curves, formed by the duct. Despite of this it is important to mount the duct in the optimal position and to stretch and connect it properly.

We have discussed the first one of two ways of damaging a flexible duct by negative pressures. The second one is squeezing.



Drawing 8

5. SQUEEZING

This effect occurs if the wire helix of the duct is less strong than the wall structure. This means that the wall structure of the duct has a better resistance against the domino effect, than the wire helix has against squeezing.

The deforming, which occurs if a duct has been squeezed, would be the same as if a heavy object should be placed on the duct. The duct will simply become flat. For this action it will be necessary to deform all helix windings to an oval, or even a flat shape.

The wire will be bent at two places in each winding. It is easy to consider that the resistance against this squeeze-effect improves, if the wire thickness increases or the wire spacing decreases. In the latter case there are more windings to resist the force.

This explains why a vacuum cleaner-duct has a thick wire and a very small wire spacing.

It is very important to consider that the resistance of a flexible duct decreases very much, if the diameter is enlarged. Forces on the surface of a duct with a bigger diameter, will put more strain on the wire helix and therefore the duct will squeeze more easily. When too thin a wire has been used for a very big diameter, e.g. 710 mm, the duct will almost be squeezed by its own weight. A very small pressure can be the key to a full collapse.

A user cannot do much to improve the resistance against squeezing. When a duct reaches the end of its capacity, starts to deform and becomes oval, there is nothing the user can do, except from applying less negative pressure or use a better duct.

6. CONCLUSIONS

We have discovered that the behavior of a duct to negative pressure is worse than to positive pressure. Depending on the diameter and the construction of the duct wall the domino or the squeeze effect will occur. If the domino effect occurs first, the user can take some steps to enlarge the ducts behavior greatly by installing it in a proper way. But as soon as the squeeze effect occurs you can be sure that the end limit of the possibilities of the duct has been reached.

A test laboratory can examine the behavior of a flexible duct with negative pressures, but the results will always refer to the test situation and the form of the duct in that particular situation. Transformation during mounting because of treating the material roughly as well as the way of mounting can be of such a great influence that it would not be correct to give values.

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