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Raise the Standards within Ventilation

Background

Today the normal standards of duct systems for ventilation are air tightness class A or B. How does this correspond with the increased demand for energy efficiency presented by the European Commission? And what would be the effect if we raise the standards to class C or even D?

As an attempt to answer these questions we have gathered information from different sources. We start with a general discussion about ventilation and the effects it has on the indoor climate, health and productivity. This is followed by an article discussing a raise of standards against the background of increased global demands for energy efficiency. It is written by Fredrik Engdahl, PhD. We round up with general information about air tightness - tightness classes, why tightness is important and factors that can cause leakage in the system.

Why We Need Good Ventilation

Fresh air is one of the most important preconditions for life itself. However, all air contains pollutants, to different degrees, depending on time and place. Much is done to lower the emissions that make our outdoor air poor. Very little, however, is done to improve indoor air quality. This in spite of the fact that people in many parts of the world spend almost all their time inside. In Northern Europe, people spend as much as 90 percent of their time indoors.

People feel better if we have clean air to breathe. We become more effective and perform better, whether it is at work, in school or at home. Also, as a number of studies have shown, the number of sick days taken go down with increasing air flows. So it should be a given for everyone to demand good air quality in all of our surroundings.

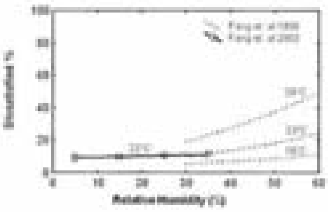
Factors Affecting Air Quality

Air Velocity

The indoor air must not be still if it is to maintain a high quality. The whole idea of ventilation is to take away the stale air and replace it with fresh air. When air is moving too fast, however, people experience negative effects. Draft is, for many people, as big a problem as stale air. It is therefore important to be able to control the air velocities in well-ventilated rooms.

Humidity

In recent years, "dry air" has become a buzzword and many people ask for air humidifiers. We think that the air is too dry and the solution frequently becomes to add humidity. Very often the diagnosis dry air is wrong. Instead it is usually a question of too high a temperature or too many pollutants in the air. A lowering of the temperature gives a higher relative humidity. Therefore, the best thing to do when the air feels dry is to lower the temperature.



The impact of humidity and temperature on perceived air quality expressed in percent dissatisfied is strong. Perception of clean air during whole-body exposure of persons to different levels of indoor air enthalpy (Fang et al., 1998a, 2003).

Temperature

Proper temperature during wintertime is 20-22°C, during summertime it is 22-24° C. There are many surveys that have shown that a temperature differential as little as a couple of degrees too high or low significantly decreases our performance. Not only is our effectiveness impacted but also our safety. Simply speaking, we get worse at doing what we do, our ability to think clearly goes down and our work result becomes totally different that if we had done it at better temperature conditions. If the environment is too warm, the ability to think clearly is diminished by 30-50 percent.

Air Pollution

The pollution of indoor air is the sum of pollutants from several different sources. Outdoor air that is not cleaned can get in, both through the ventilation system and through other openings in the building. Construction material and interiors can also emit pollutants. Surveys show that diseases such as lung cancer, asthma, and other lung disorders are more common among people who have lived in areas with high pollution levels. Increased fresh air volume and reduction of pollution sources give healthier people.

Indoor Climate and Health

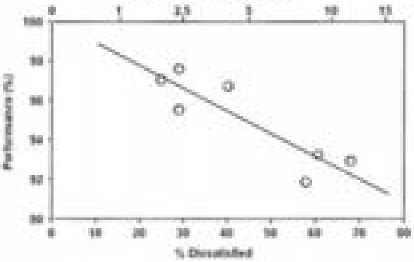
An adult breathes approximately 30 kilos of air, corresponding to 25 000 litres, every day. Compare this with 1 kg of food and 3 kg of water per day.

In Northern Europe, people spend as much as 90 percent of their time indoors. Yet we focus much more on outdoor air than indoor air. To make us feel well and stay healthy, it is important to lower the number of pollutants in the indoor air. We also need to lower the level of pollutants that are there in total. Various studies show that there is a correlation between bad indoor air quality and health problems and sick leaves.

Productivity

The impact of high indoor air quality compared with the mediocre air that is present in many existing office buildings worldwide may easily increase productivity by 5-10%. The actual cost of decreased productivity due to mediocre indoor air quality depends of course on local wages but can often be of similar magnitude or even higher than energy costs, capital costs, and the cost of operating the building. In life cycle cost analyses of office buildings, productivity needs to be included and will often be an important or even dominating factor compared to all other costs related to the construction and operation of a building.

- Performance of simulated office work is estimated to increase on average by 1.5% for every 10% decrease in the percentage of persons dissatisfied with the air quality.
- The overall performance of office tasks is estimated to increase by 1.9% for every twofold increase in the ventilation rate at constant pollution load or for every two-fold decrease of the pollution load at constant ventilation rate.

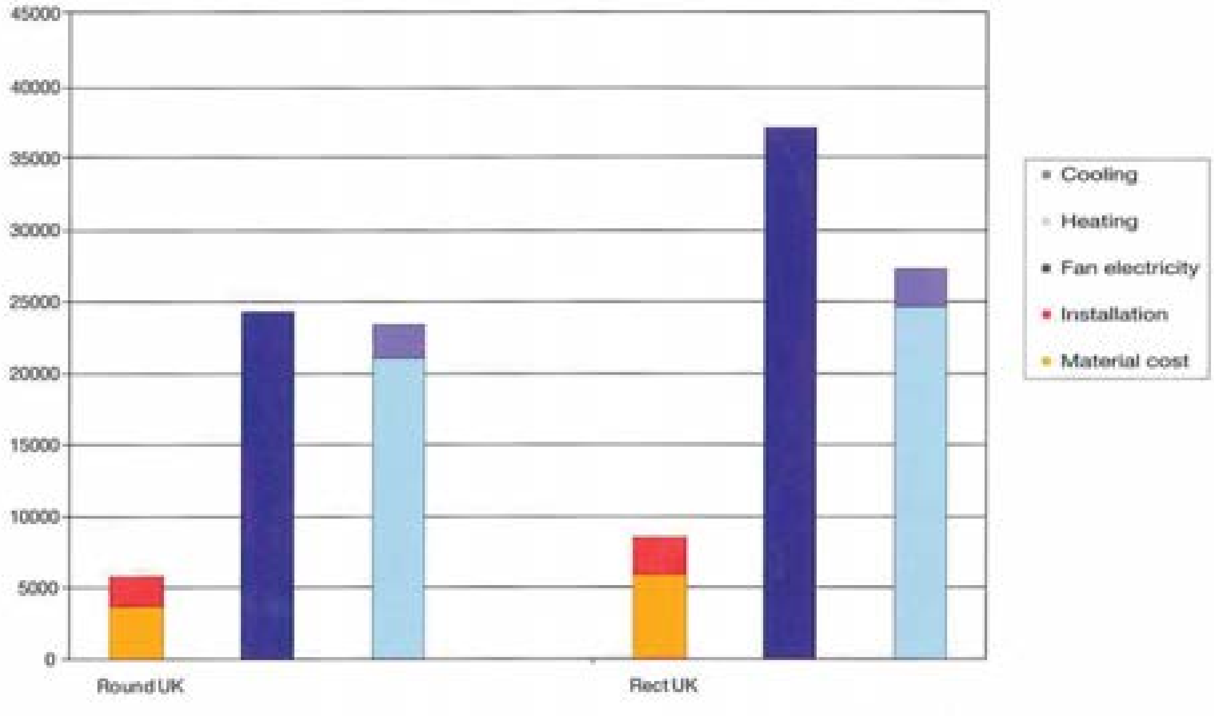


Relation between perceived air quality and productivity (Wargocki et al., 2000b)

Energy and cost

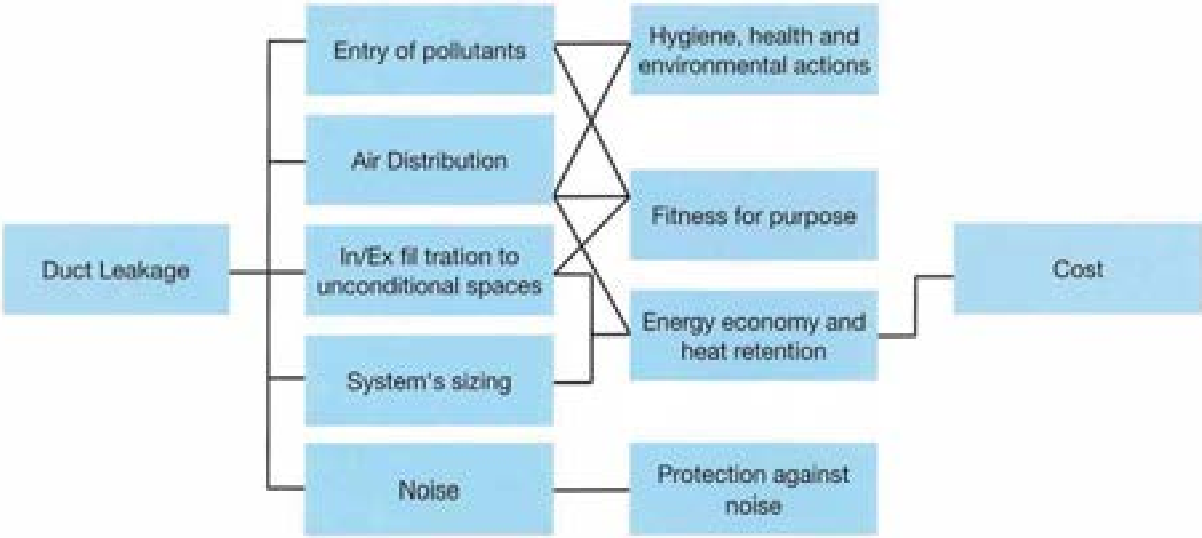
A good ventilation system does not require a large energy investment. On the contrary, a good ventilation system lowers energy use compared to a natural draft system. Natural draft doesn't use any additional energy to work like fan controlled systems. However, natural draft ventilation still uses a lot of energy since all heat disappears with the exhaust air. Instead of heating a building you wind up heating the entire neighbourhood. The most energy efficient systems are those were fans give you control over both the supply and exhaust air flows and where the heat recovery system is installed to make use of the heat content in the exhaust air.

Before making the investment it is important to calculate LCC, or Life Cycle Cost. That is what it costs to invest in, to run and maintain and to eventually perhaps take away and destroy. If you calculate LCC for a ventilation system the cost of purchase is a very small portion of the total, while the cost of heating/cooling and ventilating is a considerable part of the running cost for a building. To lower that cost it is important to focus on an effective ventilation system.



Investment analysis comparing a rectangular and a circular (equivalent) system.

It is important to minimise the leakage in the system. Leakage has different consequences, and a majority of them in the end lead to increased costs:



Duct systems for ventilation, heating and air conditioning can be divided into four air tightness classes. The most airtight class is D, and the least airtight duct system is categorised in the A class. Most modern systems rarely achieve air tightness class B. Thus, there is much potential for improvement here. In Europe, more airtight systems would mean an annual energy saving of approx. 10 TWh, which is comparable to the annual production of three nuclear power plants.

Another aspect on energy and ventilation is the Kyoto protocol, which came into effect in February 2005, which means that all undersigned countries promise to decrease their outlet of greenhouse gas to 8 % below the level of 1990. The only way to reach this target is to decrease our total energy use. This, however, shall not have a negative influence on indoor climate.

Today's Research and the Demands of Tomorrow

Professors and students at the Technical University of Denmark (DTU), the world's leading research institute for indoor environment, health and comfort, are working with research to better understand how important the indoor air is for our well-being. A number of different studies have been made. For example:

Study: Dampness in Buildings and Health (including The Värmland Study)
Issue / Problem: Why do people get sick in damp buildings? (How does indoor air affect children?)
Facts: Study over 4 years, but will probably continue for decades. 11 000 children in survey. 400 in extended survey. Extensive medical examination. Home environment studied in detail.
Result: Condensation indicates bad ventilation. A lot of dampness indicates a higher risk for children to develop allergies or asthma.
Research Institute: Made by DTU in cooperation with Universities and approx. 20 other institutions in Denmark, Sweden, Norway, Holland and USA.

Study: The Bamse Study
Issue / Problem: Why do children become allergic?
Facts: One of the largest researches made of children ever. 4000 children born in 1994 and 1996 have been followed since they were born. Made in Stockholm, Sweden.
Result: At 4 years age 40 % of the children had some type of allergies. Risk factors found: poor indoor climate, smoking, short period of breast feeding. More than one risk factor present gives large increase.
Research Institute: Cooperation between Labour and Environmental Medicine, Astrid Lindgren's children hospital and Karolinska Institutet, Sweden.

Study: The Massachusetts Study
Issue / Problem: Is performance affected by the air flow?
Facts: Study over 4 years, but will probably continue for decades. 11 000 children in survey. 400 in extended survey. Extensive medical examination. Home environment studied in detail.
Result: Condensation indicates bad ventilation. A lot of dampness indicates a higher risk for children to develop allergies or asthma.
Research Institute: Made by DTU in cooperation with Universities and approx. 20 other institutions in Denmark, Sweden, Norway, Holland and USA.

Study: Perceived air quality, sick building syndrome (SBS) symptoms and productivity in an office with two different pollution loads.
Issue / Problem: Does the quality of indoor air affect productivity?
Facts: Altogether three studies were made. A well-controlled normal office (field lab) was used in which two different air qualities were established by including or excluding an extra pollution source, invisible to the occupants. The two cases corresponded to a low-polluting and a non-low-polluting building as specified in the European guidelines for the design of indoor environments (CEN, 1998). The same subjects worked for 4 ½ hours on simulated office work in each of the two air qualities. The ventilation rate and all other environmental factors were the same under the two conditions.
Result: The productivity of the subjects was found to be 6.5% higher ($P<0.003$) in good air quality and they also made fewer errors and experienced fewer SBS

symptoms. The productivity increased significantly with increased ventilation.

Research Institute: DTU (Wargocki et al., 1999, Wargocki et al., 2002a, Wargocki et al, 2000b) in Denmark and Sweden.

Study: a) Upper limits for air humidity to prevent warm respiratory discomfort enthalpy.

b) Sick building syndrome symptoms caused by low humidity.

Issue / Problem: How does temperature and humidity of indoor air affect us?

Facts: a) 36 subjects judged the acceptability of air polluted by different typical building materials in a climate chamber. The enthalpy was changed in the room while the chemical composition of the air was constant and the thermal sensation for the entire body was kept neutral by modification of the subjects' clothing. The acceptability did not change with time, i.e. no adaptation took place.

b) Humidity studies in a climate chamber.

Result: The air should preferably be offered rather cool and dry. People perceive the indoor air quality better at 20°C and 40% RH and a small ventilation rate of 3.5 l/s per person than at 23°C and 50% RH at a ventilation rate of 10 l/s per person. Studies at very low air humidities between 5 and 35% RH have demonstrated that lower humidities than hitherto assumed can be used with positive effect on perceived air quality. At 5% the blinking rate of the eye increased, however, and the productivity decreased significantly. A humidity level of 15 or 20% RH can, however, be endured without negative effects and has still the above-mentioned positive effects on perceived air quality.

Research Institute: DTU, Denmark (a) Fang et al., 1998a, 2003 b) Wyon et al., 2002 Fang et al., 2003)

Checklist for an Adequate Ventilation System

To construct a proper ventilation system you should be able to tick all the boxes in the checklist below:

- ✓ Good indoor climate
  - Lack of draft
  - Low noise level
  - Appropriate temperature
  - Good air quality
- ✓ Low energy use
- ✓ Simple adjustments
- ✓ Low life cycle cost (total cost)
  - Material cost
  - Installation cost
  - Heating/cooling cost
  - Fan electricity cost
- ✓ Easy to operate and maintain and supplied with detailed instructions.

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Airtight duct systems – a simple way of improving a building's energy efficiency without increased investment

Europe can save energy equivalent to three nuclear reactors

Against the background of increased global demands for energy efficiency, Fredrik Engdahl believes that property owners should raise the standards of duct systems for ventilation, heating and air conditioning. This would not only save energy but also mean lower installation costs, shorter assembly times and better air quality thanks to less leakage.

The importance of energy-efficient buildings will increase in the future, not only due to rising electricity prices, but also due to increased environmental awareness. One example of this is the Kyoto Agreement, which indirectly forces countries to review their energy use with the aim of reducing carbon dioxide emissions. A current example of the latter is the energy directive from the EU, which basically increases the demands on energy planning and on the energy performance of buildings. One way of satisfying the stricter energy rules can be to make demands of duct systems for ventilation.

Four classes

Duct systems for ventilation, heating and air conditioning can be divided into four air tightness classes. The most airtight class is D, and the least airtight duct system is categorised in the A class. Most modern systems rarely achieve air tightness class B. Thus, there is much potential for improvement here. In Europe, more airtight systems would mean an annual energy saving of approx. 10 TWh, which is comparable to the annual production of three nuclear power plants.

Lower investments costs with a round shape

At present ventilation ducts are usually rectangular or circular. There are circular duct systems with integral sealing systems that can guarantee the highest air tightness class, D. A ventilation system often consists of a mixture of circular and rectangular ducts, in which the latter often find it more difficult to satisfy strict demands on air tightness. If we strive to ensure that as much of the duct system as possible consists of circular ducts of air tightness class D, the whole system can ultimately achieve air tightness class C and generate the as mentioned, savings to the order of 10 TWh. We should therefore as far as possible replace rectangular ducts with circular ones. The cost of purchasing and assembly is lower than a rectangular solution, meaning that the payback is immediate. This also means that no payback calculation is necessary.

Shorter assembly time

The round shape is better in terms of flow technology. A round shape will also always create the smallest possible circumference for a cross-section. A circular duct has a circumference that is approx. 20% smaller than a rectangular one with a height/width ratio of 1:3. This results in the round duct requiring approx. 20% less sheet metal and insulation, producing a lower weight. All in all, these factors mean that the purchase costs of sheet metal, insulation and brackets are reduced, while also reducing the assembly time. If you also have an integral sealing system, the assembly time for the circular solution is approx. 20% shorter. The conclusion is therefore that the total investment for an airtight C system is lower than for the poorer quality A system, on the condition that there is a greater proportion of circular ducts. System planners should strive for a solution that is circular as far as possible, and in some cases this may also produce new, innovative alternatives and close interaction with the architect about the installation areas.

Smaller fans

In order for the right flow (and air conditioning effect) to reach the ventilated areas, the fans must transport the total flow, i.e. not only the air that passes to and from the various areas in the building, but also the air expelled out of or drawn into the ventilation system. A system that leaks a lot thus requires larger, more expensive fans and more space in the building.

Improved health and internal environment

Besides the purely financial benefits of more efficient ventilation based on a circular duct system, there can also be a positive effect on people's health. This is because a higher-quality duct system creates the conditions for buildings being well ventilated with the lowest possible energy use. Much current research indicates that the air quality in our buildings has a major impact on people's health and well-being. Improved air quality reduces absence through illness and increases productivity. And if the air is supplied in an energy-efficient way, this reduces the impact on the external environment.

Act now!

Stricter demands on duct systems thus produce nothing but positive effects. We should therefore define the requirements for air tightness as soon as possible, as early as the planning stage of a property. Otherwise we can expect unnecessarily high and escalating energy costs!

Fredrik Engdahl, PhD

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8. Kost p 54 airways
9. weight p 53 (Tsal et al
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Why is air tightness important?

If the ventilation system is not airtight, the leakage must be compensated with an increased fan flow.

This requires an over-dimensioning of the unit's parts such as fans, filters, heater/cooling-coil batteries, heat exchangers, etc. All of this causes increased energy consumption and hence increased costs and a greater impact on the environment than necessary.

It is also not entirely uncommon for the leaking air to cause a disturbing hissing sound.

Reduced comfort

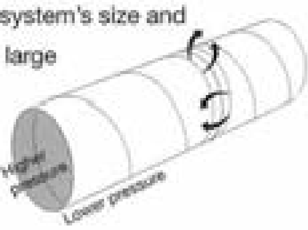
If the leakage is *not* compensated with an increased flow, the consequence will be reduced comfort combined with poorer air quality and the wrong temperature. Furthermore, the planned air flows will not be achieved.

Different types of air tightness

We talk about two types of air tightness. Air tightness to the surroundings and air tightness past damper blades.

Air tightness to the surroundings

Leakage is a function of the system's size and of the pressure difference. A large system leaks more than a small one. Higher pressure also entails greater leakage. Leakage is specified in the unit l/s.

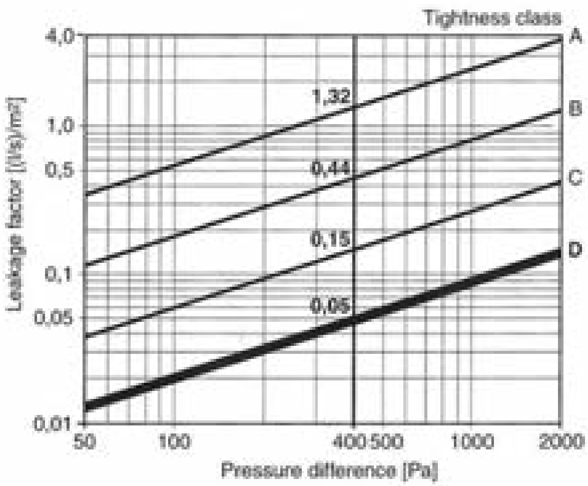


The leak factor incorporates the system's size by specifying the leakage per unit of area. This is calculated as the system's total leakage divided by its total casing area, and is written (l/s)/m². One complication is that it is not the system's area that leaks, rather its joints and connections etc., which is why systems with unusual ratios between components and ducts can produce peculiar results.

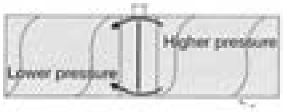
The pressure difference is retained as a separate parameter. The diagrams that are used have the leak factor on one axis and the pressure difference on the other.

Air tightness is divided into the classes A, B, C and D, where class D is the most airtight. It is three times as airtight as class C, which in turn is three times as airtight as class B, and so on. Classes A–C were first defined in the publication EUROVENT 2/2. For Sweden they have been included in VVS-AMA (Swedish Standard for Building Services), to which class D has also subsequently been added. The classification is intended for entire ventilation systems. In other words, it is not meant to be applied to individual products.

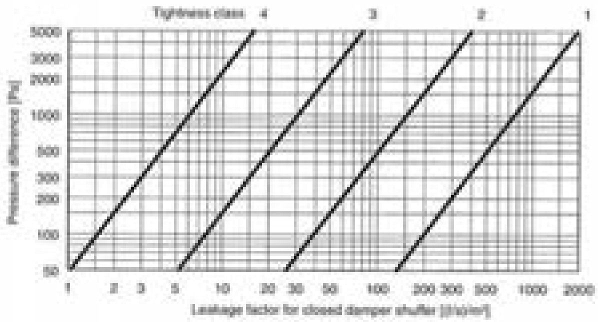
Testing air tightness normally takes place at a 400 Pa pressure difference. This is not a requirement, however, so testing may take place at any suitable pressure difference(s).



Air tightness past damper blades



Class 4 is the most airtight. The various classes are differentiated by a factor of 5. Air tightness past damper blades is often tested at different pressures. The area is the cross-section, but here too it is not the area that leaks, rather the gap along the blade's circumference. At increasing diameters, the area increases more rapidly than the circumference (quadratically and linearly respectively), which is why larger dimensions cope better and smaller dimensions worse.



What can go wrong?

The most common causes of leakage are incorrect assembly, reduced product quality and products that have been reused

Product

General

- Inaccessible points are often leakage points. This is due either to the fact it has not been possible to access these points to screw in properly, or that the product must be specially built at the installation location in order to be assembled.
- Components that have been reused or moved/turned often have old, non-airtight holes created by screws or blind rivets. These holes cannot be seen from the outside of the system, but require an internal inspection in order to be discovered.
- Components that are "produced" or adjusted/converted at the actual installation location often leak.
- Quite naturally, components that are used outside of their intended function have difficulty remaining airtight. For example, where 60° bends are used where there is a 45° change of direction.
- Certain components, such as saddles, T-pieces and inlet tubes, also have a different connection for securing to a panel surface. This connection is a potential leakage source.

Silencers and dampers

Silencers and dampers are products that are usually specified separately. You should stipulate that the manufacture of the products you use reports which air tightness class they satisfy - this means less worry for you.

Inferior components can cause greater leakage. In particular components with some type of opening (such as doors or slits/bushings) tend to leak. The same applies to “sharp, right-angled” components.

Installation

Remember that...

- Air tightness class D places **very high** demands on the installation and on the fitters.
- The sealing strip's lips can be folded backwards and forwards if the components are inserted in the ducts incorrectly.
- Screw Holes must be sealed if components and ducts have been reused or moved. Otherwise the result will be leaking screw holes.
- Installation using blind rivets that are not airtight must be avoided. The rivets' pull-stems can otherwise fall out of the rivets, resulting in leaking holes. This happens particularly with low-price blind rivets.
- Self-tapping screws are occasionally tightened so hard that they lose grip and simply spin around. They are then not so airtight.
- Knives are often used as a guide when aligning the components in the ducts. There is then a risk of causing indentations on the end of the components resulting in leakage.

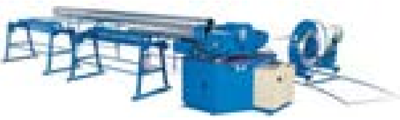
Testing

Remember to...

- Check the hydrostatic tester's professional expertise.
- Plug holes that have been made in the ducts during earlier measurements.
- Replace the caps on the measuring nipples in the measuring device.

THE COMPLETE SOLUTION

We welcome you to visit our demonstration centre to see the machines in action.



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