Swedish experience with airtight ductwork

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Why is it important to have a tight ductwork?

Many studies have identified defective ventilation systems and insufficient airflows as a main reason for occurrence of sick buildings - the supply air needed to assure a good air quality should thus reach the areas where it is needed and not disappear along its transport through the building.

Duct systems account for a large fraction of the energy use in a building. This is further increased with a leaky duct system. The supply air flow has to cover the sum of total nominal air flow and the leaking flow. With leaky ductwork this will lead to a considerable and costly increase of the needed fan power.

There are several good reasons to reduce the air leaks from ductwork:

- Correct air flows to and from the rooms are dimensioned to ensure that emissions and heat loads are kept within set values and that air quality (AQ) and thermal quality (TQ) are acceptable.
- Duct leaks can result in disturbing noise.
- When leaky supply and extract air ducts are installed above a false ceiling part of the air will take the simplest way, from the supply duct direct to the extract duct without bothering to pass through the connected rooms.

In spite of these good reasons to use tight ductwork we found in two EU projects that designers, installers, building managers and owners in some countries often ignore the benefits of airtight duct systems. This has probably resulted in poor ductwork installations in a large fraction of the building stock. In these countries, installation is probably often undertaken using conventional in situ sealing techniques (e.g. tape or mastic), and therefore the ductwork airtightness is very much dependent upon the workers' skills.

AMA – an old and reliable Swedish system to ensure high quality ductwork

Starting already 1950 – i.e. for more than 60 years back in time – we have been using a quite unique quality assurance system in Sweden covering all aspects of building and installation technologies. Practically all buildings and their installations in Sweden are performed according to the quality requirements in the AMA specification guidelines (General Material and Workmanship Specifications). These requirements are made valid when they are referred to in the contract between the owner and the contractor.

The requirements for tight ventilation ductwork systems were included in AMA already in the early sixties. Sweden has thus a long and unbroken tradition of demanding and controlling tightness of ventilation ductwork. During this long period, since 1966, the AMA tightness requirements have been raised in tact with technology improvements and increased energy costs.

AMA is a tool for the employer (developer/future proprietor) to specify his demands on the new building and its installations. It is a work of reference – you use the parts that are relevant for your project by referring to these parts in your building specification. As an employer – you have to state what you want, check that you get it, and be prepared to pay the price for it!

The requirements are based on accepted demands – the requirements are regularly updated in accordance with technology development and (LCC-) costs. The technology development has probably to some extent been influenced by the regularly increased AMA demands.

Changes of the demands are prepared by a working group and discussed with – and accepted by – building owners, contractors and consultants. The demands are to be specified in measurable units and in such a way that the tenderers and contractors understand them and are able to calculate a price.

Ductwork airtightness demands in AMA 1966 – 1972

It started with the AMA version 1966 when two "tightness norms", A and B, were defined. It was also requested by the contractor to spot-check the tightness in a minimum of 10 m² duct perimeter area.

In AMA 1972 the requirements were transformed into two "tightness classes" A and B (same as the EUROVENT classes today). Class A was the basic requirement for the complete duct system in the air handling system (i.e. including dampers, filters, humidifiers and heat exchangers). It was advised to raise the requirement to meet Class B when the system operates for more than 8 hours/day and the air is treated (cooling, humidification, high class filters etc.).

A ductwork system is not specified to be tight – instead the permissible leakage rate at a specified test pressure is stated as a tightness class – that is possible to measure!

Tightness classes in Eurovent (AMA)

A: lowest class; B: 3 times tighter than A; C: 9 times tighter than A, and D: 27 times tighter than A. The tightness classes are defined by a leak factor in l/s, m². The AMA has 400 Pa as standard test pressure. See lines in **Figure 1**.

In the USA (ASHRAE) the classes are raised in steps of two times tighter: C_L48: lowest class, C_L24: 2 times tighter than C_L48 and so on till C_L3: 16 times tighter than C_L48 (**Figure 1**).

With the Swedish AMA version 1983 Tightness Class C was added for round ductwork larger than 50 m² while Class B was required for round duct systems with a surface area smaller than 50 m² and also for rectangular ductwork. Class A, the lowest class, was only accepted for visible supply and exhaust ducts within the ventilated room. In AMA 1998 Tightness Class D was added (D is 3 times tighter than Class C). The use was not specified. It is an optional requirement for larger circular duct systems and where leakage can lead to hazards. AMA 2007 raised the requirements still another step – now also rectangular ductwork has to meet tightness Class C.

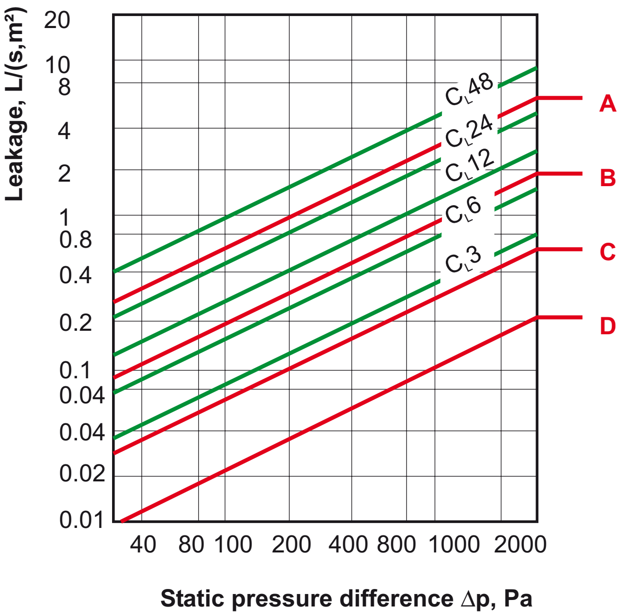

Figure 1. Comparison between European (Eurovent and AMA) Tightness Classes A – D and American (ASHRAE) Tightness classes C_L3, C_L6 etc.

How is the tightness tested – and by whom?

Requirements and demands can be worthless unless they are controlled. AMA thus also states the demands and the requirements for tightness testing of the ductwork. The leakage rate at a specified test pressure is stated – this is possible to measure! – and it is compared to the permissible value for the prescribed tightness class.

This control is normally done by the contractor as a spot check where the parts to be checked are chosen by the owner's consultant. This is specified in AMA and thus being a part of the contract (i.e. the cost for the test is normally included in the contract lump sum). AMA also states the first part of the ductwork to be tested to be 10% of the total duct area for round duct systems and 20% for rectangular ducts.

The control of whether the leak factor value is acceptable is measured by the contractor normally under the supervision of the owner's consultant. The contractor is required to hand over a filled in and signed AMA protocol to the owner.

The tightness of the ductwork is controlled in the following manner: The consultant points out which part of the ductwork he wants controlled.

The test fan ("provfläkt") is connected to the ductwork where all openings are sealed ("täcklock") (**Figure 2**). The fan is started and the airflow ("läckflöde") needed to keep test pressure ("provtryck") at e.g. 400 Pa is measured. The actual leak factor is calculated by dividing the airflow (l/s) by the in situ measured (or taken from drawings) surrounding area of the tested duct system. The result is then compared with the leak factor for the prescribed tightness class as found in the AMA tables.

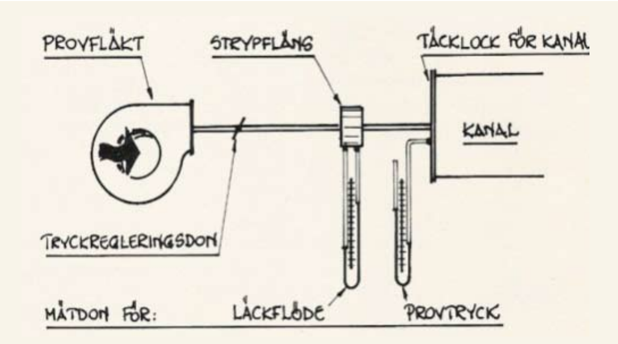

Figure 2. The test equipment for measuring the ductwork leakage from an article in 1966 by same author as this article – when AMA first required ductwork tightness. The principle is still the same!

If this result is equal or lower than required the system is accepted. If not the contractor has to tighten the leak points and measure this part anew. He is now also required to check a new system part of the same size. (This is specified in AMA to be a 10% part of the system for round duct systems and 20% for rectangular systems). If also this second measurement shows an unsatisfactory result he has to check the whole system until everything is accepted.

Is the testing worth the money?

The costs for the tests – the first 10%, then next 10% if not accepted and then the whole system - is part of the contract, i.e. covered by the contractor.

The mechanical contractor can either make the tightness test with his own personnel, provided he has equipment and skilled personnel, or he can use a specialized contractor. In both cases he has to cover the costs which can be quite considerable if the tests have to be repeated due to bad test results.

This has certainly led to high quality ductwork standard in Sweden for the following reasons.

The contractors do their best to avoid costly setbacks from inferior duct quality, the duct manufacturers are competing in inventing and marketing tight duct systems that are easy to install. Both circular and rectangular duct connections are provided with rubber gaskets that are very tight compared to older (and foreign) systems. New types of duct joints have reduced earlier laborious installation works.

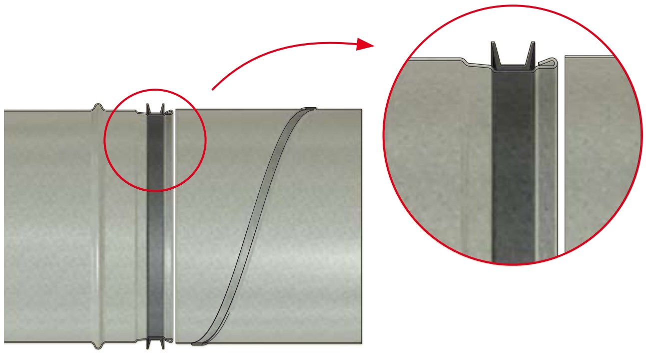

Figure 3. An example of a duct connection fulfilling Class C requirements. The rubber seal is compressed and tightens the gap.

Comparison of test results in three EU countries

The EU-project SAVE-DUCT found that duct systems in Belgium and in France were typically 3 times leakier than EUROVENT Class A, see **Figure 4**. Typical duct systems in Sweden fulfilled the requirements for EUROVENT Class B and C and were thus between 25 – 50 times tighter than those in Belgium and France.

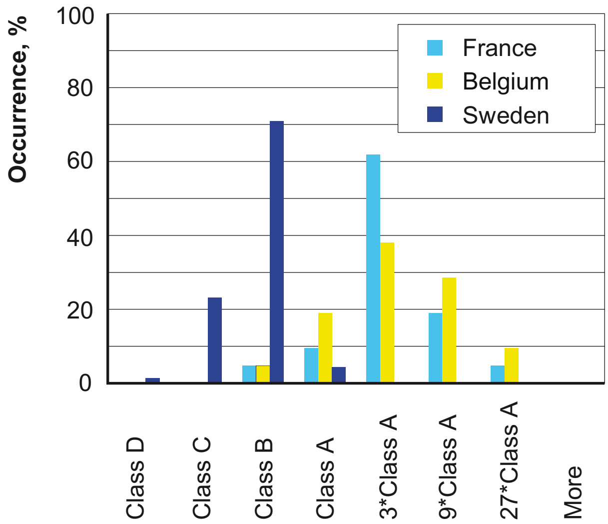

Figure 4. Results from the EU-project Airways. In the figure the bars show the percentage of tested ductworks in each tightness class. The tightness class 3 x Class A etc. had to be expanded to fit the results from leaky ductworks in the evaluation.

Figure 5. The supply air duct for the flat is fixed to a light framework at the ceiling. The duct is hidden behind a cladding fixed to the same framework – everything is done, quickly, by the duct fitter.

Why this large difference?

The most probable reason for this large difference is that Sweden has required tight ducts since the early sixties whereas in the two other countries tightness of ductwork is normally neither required nor tested.

Renovation of ventilation systems

During the period 1965 – 1975 it was decided by the Swedish Parliament that a large number of dwellings should be built to solve the acute crisis and reduce the housing queue and improve the dwelling standard. Statistics show that 1 006 000 dwellings (thus the name "The Million Program") were built during this period mostly in multi-family buildings but also to some extent in row houses. These houses have now reached an age when most of them are in acute need of renovation, not least when it comes to their installations. A standard ventilation principle in those buildings was extract ventilation with air being supplied from the outside through grilles in the external walls.

A common renovation solution today to improve the ventilation is to install a supply air system, keep – but clean and tightness test – the extract ducts and connect both duct systems to a new air-handling unit installed in the attic space. This provides several important improvements: the air intake is thus placed high up toward the back side of the building instead of at low level toward the street, the supply air (even though it is much cleaner than in the previous case) passes through a high class filter (Class F7 is a common standard), a heat exchanger reduces the energy use. The noise from the fans in the unit is attenuated to reduce the noise transmitted through the ducts to the flats.

To install a new supply air ductwork in an existing occupied building requires new installation methods. The inhabitants of the house should be disturbed as little as possible and for a very short time, preferably only during one day. This is of course a new and interesting market for the suppliers and several similar methods to solve this have been designed.

The illustrations show one of these systems where all the necessary components are prefabricated.

Another example when an old ventilation installation was replaced can be found in a high-rise office building in downtown area of Stockholm.

This building was the first of five rather identical high-rise office buildings in the City Centre of Stockholm (**Figure 6**). The architecture of the building was the result of an architectural competition (all five buildings, similar in height and dimensions, had its own architect). They were the result of a drastic reconstruction of a large part of the downtown area of the city when most of the old 18th and 19th century buildings were torn down and replaced with new office and commercial buildings.

The building was inaugurated in 1959, which was an extremely hot summer in Sweden. As typical for the time, the window/wall ratio was high, 76%. Following the normal design in Sweden at that period, the building was not equipped with any comfort cooling.

The supply and exhaust air was distributed through concrete shafts connected on each floor to branch duct systems. As there was no shadowing from other buildings the indoor temperature during the hot summer 1959 raised to above 35°C and the top floors of the building had to be abandoned for a few weeks.

After nearly thirty years of operation the building was thoroughly renovated in 1997. All installations were refurbished and the old ventilation system replaced with a modern air-conditioning system. New plant rooms were built on the roof of the building connecting to the old concrete shafts.

Instead of using the shafts as plenums for supply and exhaust air respectively, the shafts were literally filled with circular ducts as each floor plan was provided with its own separate supply and extract ducts. As each floor represents its own fire cell, the supply and exhaust ducts are provided with fire dampers (and regulating dampers) in the rooftop plant room as shown in **Figure 6**.

This technical solution required that fifteen ducts were installed in each of the shafts. This was possible by using circular ducts. The ducts were also delivered in 6-m lengths thus reducing the number of vertical joints considerably. The very compact installation reduced the necessary space for the vertical shafts and increased thus the floor area that could be let.

The design of the duct systems had to be studied in detail on how the supply and extract ducts were entering to or emerging from the shafts to prevent unnecessary collisions and facilitate the installation work. The ducts were tightness tested in turn as they were installed to prove that they were fulfilling the tightness requirements of Class C.

Conclusion

This Swedish way of working has been shown to be very effective in raising the quality of ductwork. Our long time focus on ductwork quality in Sweden has resulted in very low air leakage in normal Swedish duct installations which has promoted air quality, thermal comfort and sustainability.

Figure 6. Ducts for the different floors pass down through common shafts, one for supply and one for extract air. The photo shows part of the supply ducts with their fire dampers.

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