SWEDISH EXPERIENCE WITH AIR TIGHT TESTING: OVERALL SCHEME, TEST PROTOCOL, AND PRACTICAL EXAMPLES

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ABSTRACT

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

The HVAC-part of AMA included requirements for tight ventilation ductwork systems already in the early sixties. Sweden has thus a long and unbroken tradition of demanding 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.

But requirements and demands can be worthless unless they are controlled. The AMA requirements thus also include demands for tightness testing of the ductwork. The result of the tightness test has to be reported on standard protocol forms signed by the testing contractor.

And this has been shown to be very effective in raising the quality of ductwork. As e.g. shown in two EU-projects this long time focus on ductwork quality in Sweden has resulted in very low air leakage in normal Swedish duct installations.

And there are several reasons that justify the requirements for tight duct installations:

- 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.
- The supply air flow has to cover the sum of total nominal air flow and the leak flow. With leaky ductwork this will lead to a considerable and costly increase of the needed fan power.
- 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.

Swedish industries, building owners and authorities work together with the object to increase the quality of ventilation systems. Parallel with the voluntary AMA demands (i.e. voluntary until the contract has been signed) Swedish authorities 1991 thus started a compulsory system for ventilation control (OVK) in Sweden with aim to control and improve the function of ventilation installations. According to the ordinance (1991:1273) a control of the ventilation in most types of buildings has to be made before the installations are taken into operation and then regularly at recurrent inspections.

TESTING OF DUCTWORK AIR TIGHTNESS: OVERALL SCHEME

AMA – a sixty year old system, easy and accepted tool for specifying quality

The future building proprietor and his consultant use the AMA system (General Material and Workmanship Specifications) as a tool to specify the requirements for a new project. AMA covers all aspects of building and installation works of various kinds – e.g. buildings, installations, roads, and tunnels – and is split up in several parallel main parts covering these aspects, from building foundations to HVAC and electrical installations. The AMA requirements are made valid when they are referred to in the project contract between the owner and the contractor.

It all started way back in 1950 when AMA was born with "House AMA" and "Pipe AMA". During the following decades the group was extended with other AMA books for Ventilation, Ground works, Heating installations, Electrical installations and Refrigeration. Today these areas have been collected in four books, one of these is the HVAC AMA covering among many other aspects ventilation ductwork and e.g. protocol forms for reporting the result of tightness tests of ductwork.

Requirements in AMA are accompanied by advices in RA

Each of these AMA books (specifying the requirements) are accompanied by a parallel book (e.g. "RA – Advices and Instructions") comprising advices to the consultant on how to specify and quantify systems and components. In many cases they also give advice on how to choose a quality level. These RA-books serve also as check list for how to write a complete specification where the demands on the tenderer/future contractor are clearly shown in a way enabling him to calculate the cost for his contract commitments.

A common AMA-rule states that these requirements shall be expressed in measurable terms combined with control methods with known (and possible low) measurement errors. Another AMA-rule is that the cost for fulfilling the demands shall be calculable for the tenderers.
The AMA books are shown in Fig. 1.

Figure 1. The AMA family (VVS = HVAC), 1998 edition.

Requirements are raised in tact with technical progress and when economically motivated

The level of the AMA quality requirements are based on a kind of "80/20"-type rule. They should be suitable for most of the applications ("80 %") while for the rest they are either too high (the project, e.g. a building, has a very short planned life span and thus does not need the normal AMA quality) or too low (for projects where a higher quality is needed, e.g. laboratories and hospitals).

The AMA quality requirements are lifted when possible by technology progress and when found profitable for the owner on a Life Cycle Cost basis. Proposed increased requirements are established after they have been referred for consideration to a large number of owners, manufacturers, contractors, consultants and other

interested parties. Wherever possible, AMA refers to relevant national Swedish standards and European norms. Twice a year the AMA requirements can be updated through the AMA-nytt (AMA News) Journal and added to computer-based specification tool used by the consultants. AMA is published by The Swedish Building Centre, a non-profit organization).

The AMA system follows the project through all phases of the building project – from design (supplying advices to the designer), to tender documents with specifications (these include references to relevant AMA clauses and advices on how to quantify), to installation (stating quality requirements for material/components and workmanship e.g. for duct connections, insulation of ducts or soldering of copper pipes), testing (e.g. measurement methods, protocols, e.g. for tightness test of ductwork), and maintenance (e.g. labelling and marking of components, cleaning of ductwork).

AMA vs. regulations

AMA is a voluntary complementary to Swedish statutory rules, regulations and specified building standards laid down by the authorities. Even if AMA and the regulations have common interest areas in securing sustainability and low energy use there is a difference between the two - the statutory rules are normally mostly focussed on reducing the risk of injuries to workers and users while AMA (not having to deal with those aspects) is focussed on reducing property damages and LCC-costs.

The AMA demands on ductwork tightness

Specifying requirements on ductwork tightness has a long story in Sweden; it has been specified as part of building specifications since the AMA edition 1966.

As described the AMA quality requirements are raised when possible by technology progress and when found profitable for the owner on a Life Cycle Cost basis. This is also true for ductwork tightness requirements:

In AMA version 1966 two “tightness norms” A and B, were defined. They were to be spot checked by the contractor; minimum tested duct surface area was 10 m².

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 installation (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 or the air is treated (cooling, humidification, high class filters etc.).

In AMA 1983 a new tightness Class C was added to be used round ductwork larger than 50 m². Class B was to be used for round duct systems having a surface area smaller than 50 m² and also for rectangular ductwork.
Class A was accepted for visible supply and exhaust ducts within the ventilated room (i.e. not hidden above false ceiling).

In AMA 1998 a new tightness Class D was added being 3 times tighter than Class C. The use is not specified. It is an optional requirement for larger circular duct systems and where leakage can lead to hazards.

In AMA 2007 also rectangular ductwork has to meet tightness class C.

In AMA 2011 the ductwork tightness requirements are the same as in 2007.

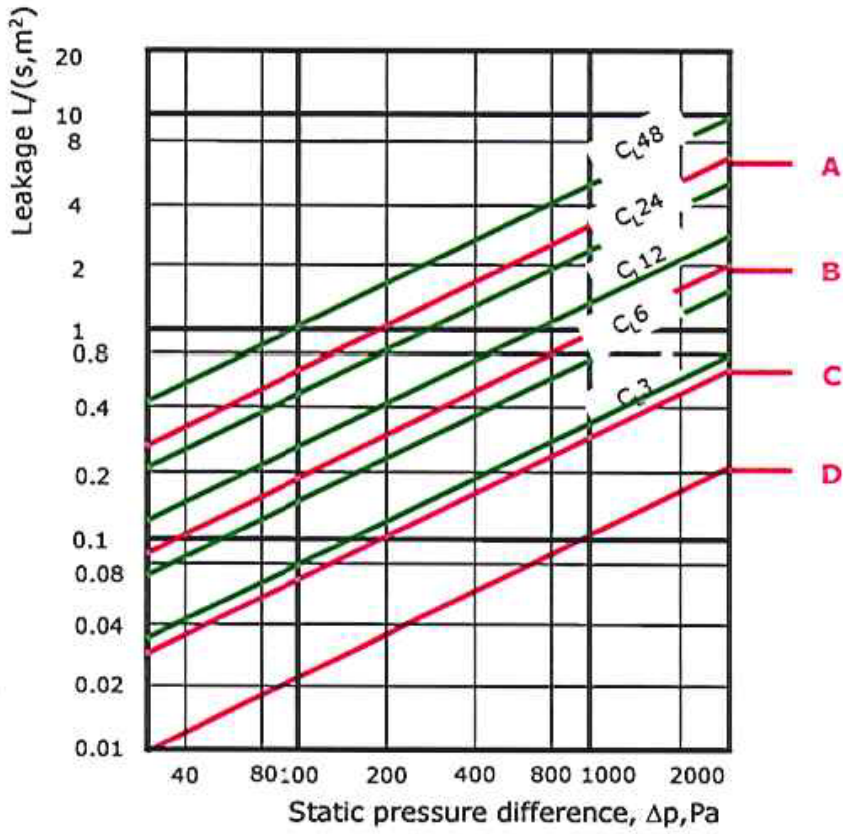

Figure 2. Eurovent Tightness Classes A – D and ASHRAE Classes C_L 48 - 3.

Often the duct manufacturers initially objected to these increased demands but as soon as one of them quickly announced that e.g.: “We can meet the new AMA requirements”, the rest of the gang was forced to follow.

Specify what you can control – and do it!

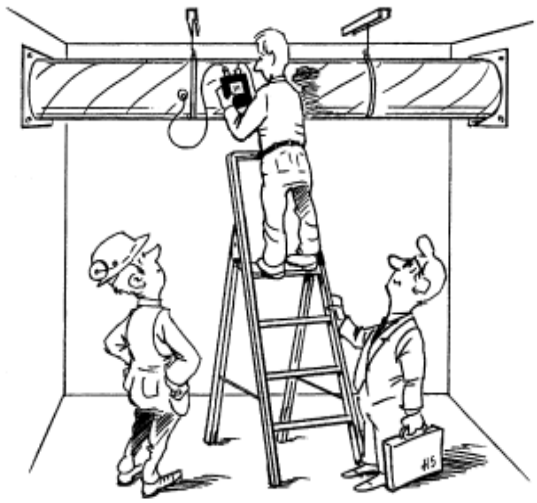

Figure 3. Express your demands in measurable units and measure it! The building owner’s consultant points out what part of the ductwork that shouyld be tested by the contractor

A ductwork system should not be specified to be tight – instead the permissible leakage rate at a specified test pressure is stated – that is possible to measure! Unless otherwise specified the tightness classes are to be in accordance with AMA demands (as stated above). AMA also states the requirements for the testing of ductwork tightness.

The general AMA rules stated above are thus relevant for ductwork tightness: “Express your requirements in measurable terms and control that you have got it!” and the other: “The costs and risks for the contractor to fulfil the requirements in the contract should be possible to calculate”.

To ensure the quality of the duct system the leakage has to be verified; this is normally done either by the contractor himself or by a specialist engaged by the contractor. This is included in the contract and the cost is thus covered by the contractor. This test is undertaken as a spot check where the parts to be checked are chosen by the owner's consultant. For round duct systems 10 % and for rectangular ducts 20 % of the total duct surface normally has to be verified as specified in AMA.

Should the result of this test however show that the leakage is higher than allowed for the tightness class specified the contractor has first to tighten the leak points until the tightness requirement is fulfilled as verified by a new test of the same part of the ductwork – the contractor has consequently to redo his job until found OK! But in addition to this, another part of the same duct installation (e.g. another 10 % of a round duct installation) has to be checked. If this is also shown to be leakier than allowed the whole duct installation (i.e.100 %) has to checked and tightened until accepted.

And this increased testing, tightening and retesting can be costly for the contractor who is responsible for delivering an installation fulfilling the specification requirements. Quite naturally this has led to high quality tight ductworks – instead of risking this costly and time-consuming additional work the contractor aims to do a good job right away. Even though the tightness requirements have been raised during the past years, the new types of rubber gasket provided ducts and duct components have made the duct installation job easier, cheaper and more reliable than before.

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.

In summary: the costs for the tests – the first 10 %, then another 10 % if not accepted and then at the end the whole system - is part of the contract and thus to be covered by the contractor. The mechanical contractor can either make the tightness test with his own personnel, provided he has equipment and skilled personnel to do that, or he can have it done by another 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. The result of the leakage test shall be reported on AMA standard protocols and handed over to the owner.

Is it worthwhile to require and control the ductwork tightness? Yes!

There are several reasons that justify the requirements for tight duct installations:

Many studies of SBS, the Sick Building Syndrome, have identified defective ventilation systems and insufficient airflows as a main reason for the occurrence of sick building problems. The required supply air flow needed to assure a good indoor air quality should of course be delivered to the areas where it is needed and not be allowed to disappear along its transport through the building. This requires tight ducts!

In order to guarantee that the correct air flow is delivered to the room the supply air flow from the fan has to cover both the sum of the total nominal air flow and the disappearing leak flow. With leaky ductwork this will lead to a considerable and costly increase of the needed fan power (that has to be raised with up to third power of air flow increase).

Ductwork leak points can result in disturbing high frequency noise.

If leaky supply and extract air ducts are installed above a false ceiling part of the supply air will take the simplest way, from the supply duct with overpressure direct to the extract duct with underpressure without bothering to pass through the connected rooms.

And the AMA system has been shown to be very effective in raising the quality of ductwork. When compared to the result of tightness test of ductwork in Belgium and France as shown in two EU-projects this long time focus on ductwork quality in Sweden has resulted in very low air leakage in normal Swedish duct installations.

Comparison of the results from an EU project – Ductwork in Sweden was 25-50 times tighter!

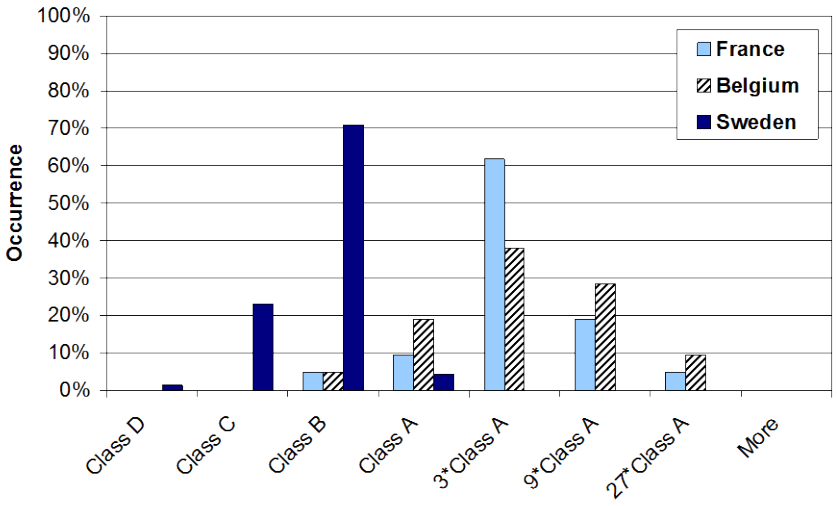

Figure 4. Comparison of the results from an EU project – Ductwork in Sweden was 25-50 times tighter!

As shown above duct leakage is detrimental to energy efficiency, comfort effectiveness, indoor air quality, and sometimes even to health. However, in most countries designers, installers, building managers and building owners, often ignore the benefits of airtight duct systems. Furthermore, as there are no incentives in most countries, over the years, this has (probably) lead to poor ductwork installations in a large fraction of the building stock.

In these countries ductwork installation is 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..

The measurements and literature review performed within the EU-project SAVE-DUCT found that duct systems in Belgium and in France are 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.

The answer to the question "Why this large difference between the countries?" is most probably that Sweden has required tight ducts, i.e. specifying how much they are allowed to leak at a certain test pressure, since the early sixties whereas in the two other countries tightness of ductwork is normally neither required nor tested.

CONCLUSION

Duct leakage is detrimental to energy efficiency, comfort effectiveness, indoor air quality, and sometimes even to health.

The Swedish long-time experience of quality approach to ductwork airtightness has shown that tight ductwork systems are cost effective and sustainable.

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KEYWORDS

AMA, Ductwork, Tightness,