MEASURING VENTILATION AND AIR INFILTRATION IN BUILDINGS - SWEDEN

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"When you can measure what you are talking about and express it in numbers you know something about it"
Lord Kelvin (1824-1907)

Measuring air – compulsory or not?

In Sweden building requirements can be compulsory for two reasons:

It is either required of the proprietor by the authorities in building codes or of the contractor by the proprietor as specified in building specifications.

Building air tightness and leakage
Swedish building codes neither specifies quantified demands on tightness of buildings nor on measuring of leakage. This is thus normally only done in some research projects.

Instead tightness of a building's envelope (external walls, roof and floor) is indirectly regarded by the authorities to be covered by compulsory Swedish construction guidelines on **energy use** and **preventing moisture damages**. This aim and direction of the Swedish building authorities today is different from earlier codes as shown below.

Swedish building codes changed from detailed to functional demands

The Swedish building codes have changed from detailed requirements of e.g. building tightness and airflows for different types of buildings and premises to functional demands.
Gradual change from 1988 when:

- the (detailed) regulations and recommendations in the Swedish Building Code, **SBN**, published by The National Board of Physical Planning and Building were replaced by

- the mandatory provisions and general recommendations in Building Regulations (**BBR**) from the new authority The Swedish National Board of Housing, Building and Planning where the provisions are in the form of functional requirements.

Answer by Boverket to a common question:
Q: “Why are there no quantified demand values stated for the building envelope tightness?”
A: “There is an all-embracing functional demand on the energy use of the building. This demand can be fulfilled in many ways, e.g. with more or less heat insulation, different technical installations and a more or less airtight building envelope.

The building envelope needs to be so tight that the building can fulfil the energy use requirements for the whole building. Other relevant all-embracing demands to be fulfilled are installed electric power, ventilation, thermal comfort, moisture safety and noise. How tight the building envelope has to be is therefore something that has to be decided from case to case by the building proprietor/designer depending on the choice of ventilation systems, energy management solutions etc.”

Air Infiltration – detailed requirements in SBN

In the latest edition of SBN (1980) air infiltration in buildings were stated as maximum accepted air leakage (in $m^3/m^2,h$) for different building types:

SBN 33:3 - Maximum accepted air leakage (in $m^3/m^2,h$)

Building part	Pressure difference Pa	Building with height in floors		
		1 - 2	3 – 8	>8
Exterior wall	50	0.4	0.2	0.2
Exterior window and door (referring to the tightness of the chink between the frame and the window sash and door leaf respectively)	50	0.4	0.2	0.2
	50	1.7	1.7	1.7
	300	5.6	5.6	5.6
Roof and floor towards the outside or towards a ventilated space	50	0.2	0.1	0.1

Blower door
Building tightness, when measured, is normally controlled with a blower door installed either in a window frame or in the entrance door frame and tightened.
The size/volume of the building is limited by the airflow from the test fan and the system is used for smaller buildings, type one-family houses.

Case study: Leakage test of an office building

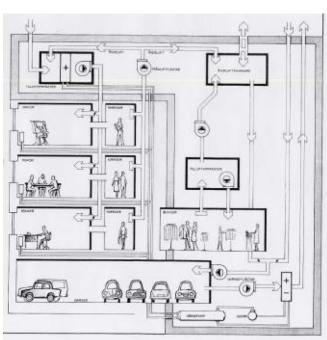
The author has been involved in tightness tests of two large buildings where the normal supply air fans were used for pressurizing the buildings :

(1): the R2 Reactor hall at Studsvik where the large free-standing reactor hall for safety reasons was pressure and tightness tested at 1000 Pa!

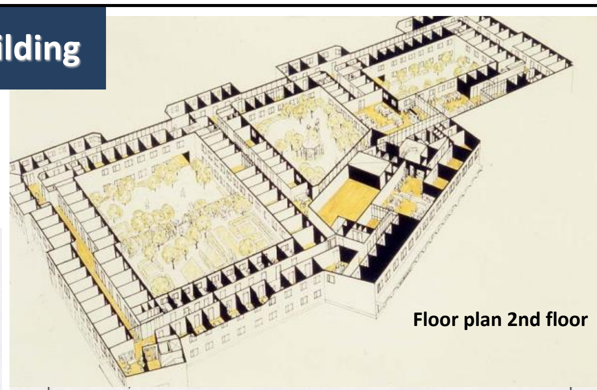
(2): an office building at Växiö which was constructed to obtain a high degree of tightness, low energy use and a building easy to maintain.

Case study: Office building

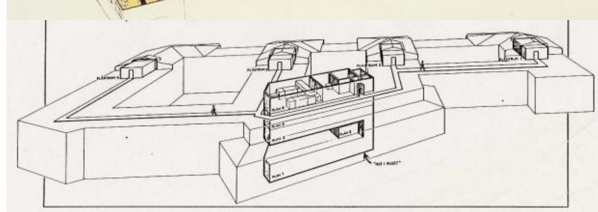
Building data:
Building volume: 74,000 m^3
Floor space: 21,000 m^2



The closed energy circuit – VAV and heat pump reduces energy use



Floor plan 2nd floor



Building within building containing all central HVAC systems and own elevator from basement to attic to simplify maintenance – compare with a ship!

Case study: Office building

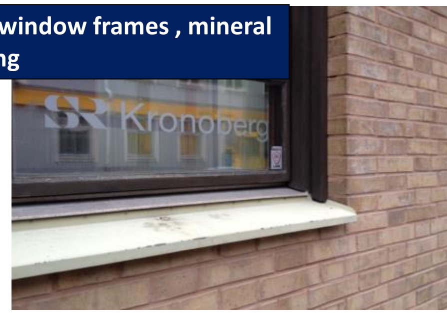
One of the HVAC supply fans was used for the leak test

Measured leakage for whole building:
Measured leak flow at +50 Pa : 2.6 m³/s

Corresponding to: ≤ 0.12 ACH at +50 Pa

Normal value at 10 Pa: 1.2 m3/s

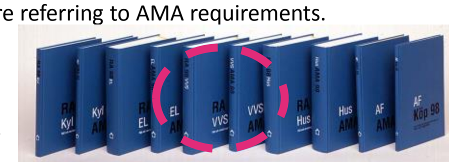
Concrete wall with window frames , mineral wool and brick facing



Measuring air flows and ventilation ductwork tightness

Measuring air flows for system adjustment and control of ductwork tightness

Practically all building specifications in Sweden are referring to AMA requirements.



AMA has detailed requirements on airflow measurement and ductwork tightness control. These demands cover e.g. methods, instruments, calculation of measurement error and reports.

AMA (General Material and Workmanship Specifications) – 65 years of quality system

The reference to **AMA** requirements in the building specification thus makes measuring of air flows and tightness of ventilation ductwork normally compulsory for the contractor.

Air flows (both for adjustment and tightness tests) shall be measured with recommended methods described in Formas Report **T9:2007**, ("Methods for measuring air flow in ventilation installations"). Results are to be presented on AMA forms. AMA 83 referred to a previous edition T32:1982 which was based on a work from the early 1970's by NVG, the Nordic Ventilation Group, mostly financed by Swedish Council for Building Research.

Recommended air flow measurement methods

Method group A – Airflow measurement in duct
A1. Velocity measurement with Prandtl pipe
A11. Circular cross section
A12. Rectangular cross section

Now being transferred to prEN 16211:2011
Measurement uncertainty increased from 67% to 95% - i.e. instrument error doubled.

A2. Fixed airflow measuring device
A21. Without damper
A22. With damper

A3. Velocity measurement with hot wire anemometer
A31. Circular cross section
A32. Rectangular cross section

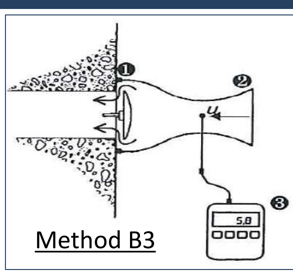
A4. Tracer gas measuring

A5. Total airflow measurement at fan inlet

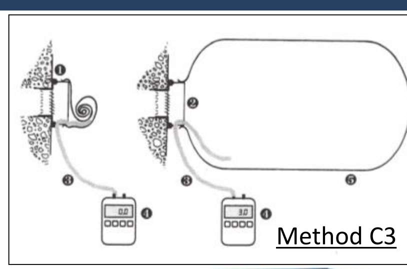
Method group B – Airflow measurement at exhaust registers and intake grilles (7 methods)

Method group C – Airflow measurement at supply air registers (10 methods)

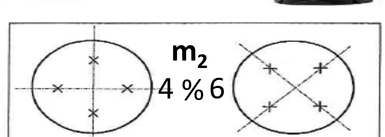
Recommended measurement methods – some examples



Method B3



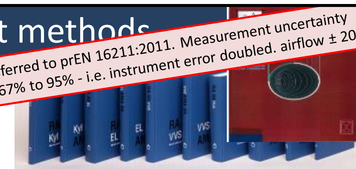
Method C3



Method A11

Accuracy of air flow measurement methods

Now being transferred to prEN 16211:2011. Measurement uncertainty increased from 67% to 95% - i.e. instrument error doubled. airflow ± 20%.



Accuracy of adjusted airflows as required by **AMA**

Designed airflow ± 15% incl. probable measure error.

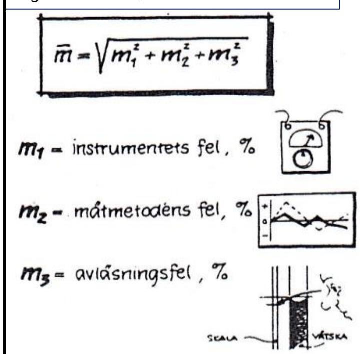
Probable measure error m_m

$m_m = (m_1^2 + m_2^2 + m_3^2)^{1/2}$

m_1 = instrument error, %

m_2 = method error, %

m_3 = reading error, %



Example

m_1 - instrument error for manometer; m_1 = 3 %

m_2 - method error for A11. Velocity measurement with Prandtl pipe in rectangular cross section; m_2 = 4 %

m_3 = reading error, m_3 = 3 %

m_m $= (m_1^2 + m_2^2 + m_3^2)^{1/2} = (3^2 + 4^2 + 3^2)^{1/2} =$

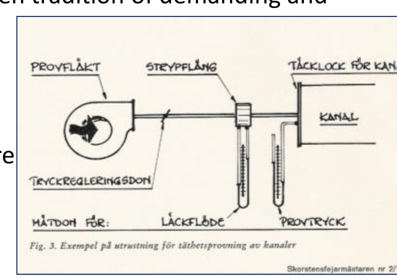
$= (9 + 16 + 9)^{1/2} = (34)^{1/2} =$ 5.8 %.

Thus, airflows in this case have to be adjusted to an accuracy of measured vs. designed values of: ± (15 – 6) = ± 9 %

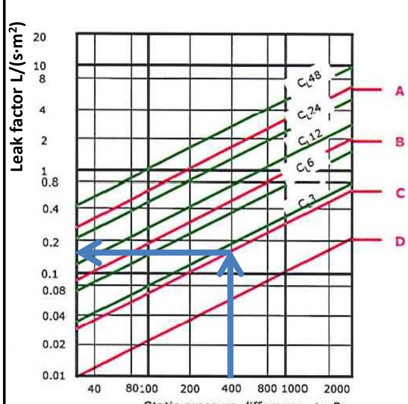
Measuring ductwork air tightness

The requirements for tighter ventilation ductwork systems were included in AMA already 1966. Sweden has thus a long and unbroken tradition of demanding and controlling tightness of ventilation ductwork.

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

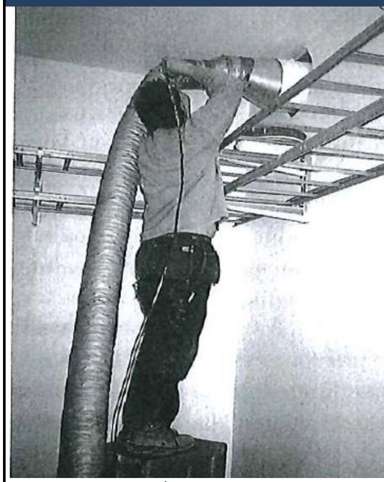


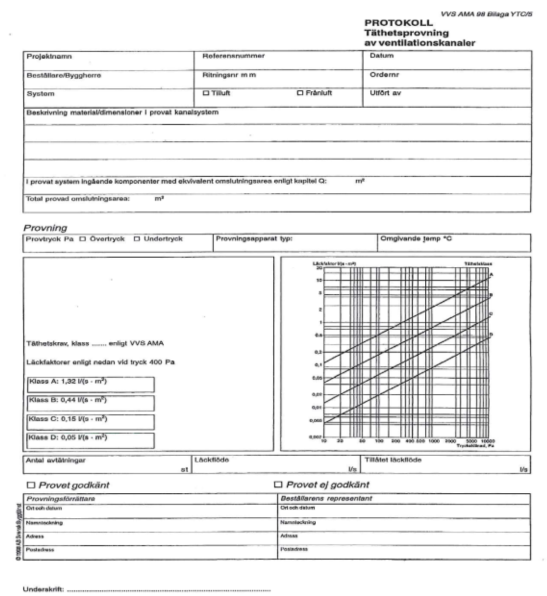
(1967) The principle is still the same!



$q_{max} = A \cdot 0.15$ L/s

Measuring ductwork air tightness





VVS AMA 98 Bilaga YTC/5

PROTOKOLL
Täthetsprovning av ventilationskanaler

Projektnamn	Referensnummer	Datum
Beställare/Byggherre	Ritningsnr m m	Ordernr
System	☐ Tilluft ☐ Frånluft	Utfört av
Beskrivning material/dimensioner i provat kanalsystem		
I provat system ingående komponenter med ekvivalent omslutningsarea enligt kapitel Q: m²		
Total provad omslutningsarea: m²		

Provning

Provtryck Pa ☐ Övertryck ☐ Undertryck	Provningsapparat typ:	Omgivande temp °C

Täthetskrav, klass .... enligt VVS AMA

Läckfaktorer enligt nedan vid tryck 400 Pa

Klass A: 1,32 l/(s · m²)
Klass B: 0,44 l/(s · m²)
Klass C: 0,15 l/(s · m²)
Klass D: 0,05 l/(s · m²)

Antal avtätningar st	Läckflöde l/s	Tillåtet läckflöde l/s

☐ *Provet godkänt* ☐ *Provet ej godkänt*

Provningsförrättare	*Beställarens representant*
Ort och datum	Ort och datum
Namnteckning	Namnteckning
Adress	Adress
Postadress	Postadress

Underskrift: ....

Measuring ⬆ Reporting ➡

If not OK – new tests to be done at contractor's expense until OK!

OVK – Swedish compulsory inspection of ventilation systems

In 1991 a compulsory system for ventilation control (OVK) started in Sweden with aim to control and improve the function of ventilation installations.
The ordinance (1991:1273) requires that the ventilation in most types of buildings has to be controlled before the installations are taken into operation and then regularly at recurrent inspections.

The OVK control at these recurrent inspections are not intended to check whether the systems are fulfilling the requirement of today. Instead the OVK inspector controls if the systems are fulfilling the demands that were compulsory at the time when the systems were built.

The most common faults found at the OVK inspections are that the **airflows** are lower than those prescribed when the building was built; the next most common fault are dirt collected in fans and ductwork.

OVK – Swedish compulsory inspection of ventilation systems

Regular inspection intervals

The stipulated inspection intervals depend on the type and use of the building and type of ventilation system:

Type of building and ventilation system	Inspection intervals
Day nurseries, schools and hospitals	3 years
Block of flats and offices with FT-ventilation	3 years
Block of flats and offices with F-ventilation	6 years
Block of flats and offices with S-ventilation	6 years
One and two dwelling-houses with FT-ventilation	only first inspection (new buildings)

S = Natural ventilation; F = Exhaust ventilation; FT = Supply and exhaust ventilation

The result of the OVK inspection shall be reported on a special protocol. The owner of the building shall as soon as possible rectify faults and defects found at the inspection.

A copy of the inspection protocol is sent to the municipality who is responsible for monitoring that the building owners fulfill their duties.

Thank you!