Measurement issues of air flow at air terminal devices and perspectives

Samuel Caillou*[1]

1 Belgian Building Research Institute
Street address
Address, Country
**Corresponding author: samuel.caillou@bbri.be*

SUMMARY

The different methods for air flow rate measurement at air terminal devices are presented in this overview, such as van anemometer with a cone, small velocity probe (thermal probe or small vane anemometer), compensation method, etc. Several measurement methods are available on the market at highly variable cost. However some of these methods are suspected to lack reliability.
Some of these measurements methods are not really appropriate for the measurement of flow rates at air terminal devices, with errors up to more than 50% in some cases!

This overview paper aims at identifying the main problems of measurement at ATD and possible solutions to overcome these problems. This is based on the lab measurement tests and on site measurement campaigns carried by different research team the last years: BBRI in Belgium, BSRI in the UK, Cetiat in France and LBNL in the USA.

KEYWORDS

air flow rate, vane anemometer, compensation method, measurement cone, measurement hood, measurement error

1 INTRODUCTION

The measurement of the ventilation air flow rates is necessary for the adjustment of the flow rates in the different rooms, as part of the commissioning. Flow rate measurement is also of primary importance in the context of compliance with the regulation or other requirements. For small and residential applications, the measurement of air flow rates at air terminal devices (ATD) is a very common measurement method. The advantage of the measurement at the ATD is also to measure the flowrate really delivered in the room itself.

Several measurement methods at ATD are available on the market at highly variable cost. The different methods for air flow rate measurement at air terminal devices are presented in this overview, such as van anemometer with a cone, small velocity probe (thermal probe or small vane anemometer), compensation method, etc.
However, some of these methods are suspected to lack reliability.

This overview paper aims at identifying the main problems of measurement at ATD and possible solutions to overcome these problems. This is based on the lab measurement tests and on site measurement campaigns carried by different research team the last years: BBRI in Belgium, BSRI in the UK, Cetiat in France and LBNL in the USA.

2 OVERVIEW OF THE MEASUREMENT METHODS

One of the most common method used to measure the flowrates at ATD is the vane anemometer where the air speed is measured thanks to a propeller. In this first case, the propeller covers the whole section of the cone.
An alternative measurement method consists of using a small probe (thermal or vane anemometer) in as specific cone. In this case, the air speed measurement occurs only at one central point of the section of the cone, where the small probe is positioned.
Larger hoods are also frequently used, especially for large ATD and high flow rates in commercial buildings. In this case, a large hood is used to bring the flow rate toward a measurement instrument, where different flow rate or air speed measurement principles can be applied.
The compensation method is a specific measurement method where an additional fan inside the measurement instrument is used to compensate the pressure drop of the measurement instrument itself so that the instrument is not "seen" by the ATD and ductwork.
Finally, many alternatives of these methods also exists and are continuously developed by manufacturers.

Figure 1: Overview of common measurement methods for flowrates at air terminal devices, from top left to bottom right: vane anemometer, small probe in a specific cone, larger hood, and compensation method.

3 MAIN PROBLEMS FOR THE MEASUREMENT AT ATD

Different studies have been recently carried out to check the measurement error of different methods to measure the airflow rates at ATD.
Different approaches have been followed, such as: (1) in lab measurement, comparing the method to be tested with a reference flow rate measurement, (2) on site measurement, comparing the method to be tested with a reference measurement instrument known to be reliable or previously tested in lab.

The aim was mainly to test different measurement methods rather than to test specific trademarks of instruments. Therefore, where possible, different trademarks for a same measurement principle have been tested.

3.1 Systematic error rather than random error

First of all, this is important to note that the measurement error observed with some measurement methods is most often a problem of systematic error rather than a problem of random error. In other words, if the measurement is repeated several times with the same instrument, the deviation of each measurement against the average of the measurements (random error) is limited while the deviation of the average of the measurement against the reference value (systematic error) is bigger, up to more than 50% in some cases.

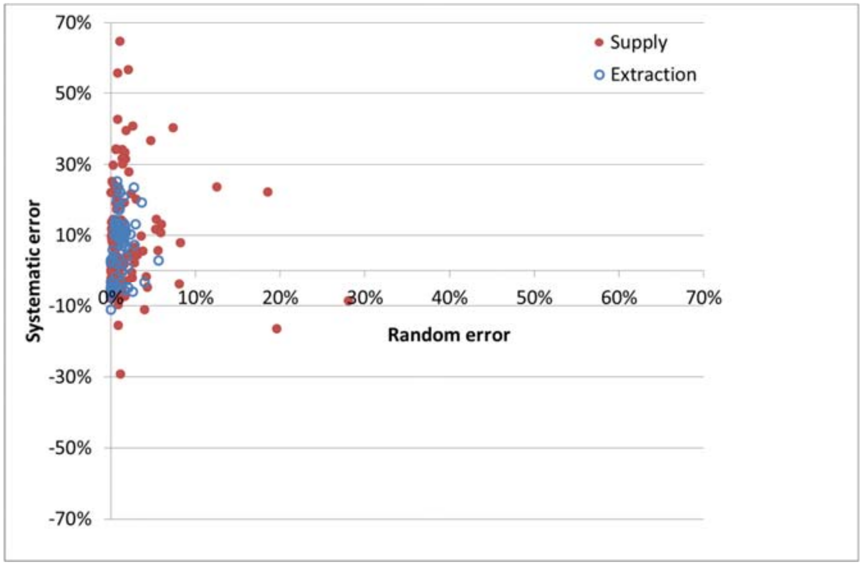

Figure 2: Comparison of systematic error and random error for the tested measurement methods at ATD carried out in BBRI, Belgium.

3.2 Problem of back pressure or insertion loss

One of the problem of the air flowrate measurement at ATD is the pressure drop created by the instrument itself, possibly influencing the working of the ventilation and then the delivered flow rate.

This source of error depends mainly on the type of ductwork (branched or not), the pressure drop of the ductwork and the type of fan (axial or centrifugal). Roper et al. reported large measurement errors when a measurement method without compensation (for example vane anemometer) was used to measure decentralized ventilation system (mounted on wall or ceiling), with very low pressure difference and axial fans.

One of the solution to overcome this problem is to use an instrument with compensation method where the pressure drop created by the instrument itself is compensated by the fan integrated in the instrument itself.

3.3 Problem of non-uniformity of the flow rate

A second common problem for the measurement of air flow rate at ATD is the non-uniformity of the flow pattern at the ATD.

Several situations can cause this non-uniformity, such as specific flow pattern at the ATD, swirl, directional flow, high local velocities, presence of an elbow before the ATD, ATD adjusted too closed.

Several authors reported that such non-uniformity of the flowrate at the ATD can degrade drastically the reliability of the measurement with van anemometer, larger hood and small probe in a specific cone.

The problem is probably that the flow rate and the air velocity pattern is not homogeneous at the point of measurement, generating measurement error. For example with a small probe in a specific cone, the measurement occurs only at one point at the centre of the flow section while the air velocity can be very different from on point to another of this section.

Measurements using different instruments with pressure compensation have proven that the compensation method can largely overcome this problem of non-uniformity of the flow rate at ATD. However, some instrument equipped with a fan for compensation gave also bad results and larger measurement errors. The key point with the compensation method is probably not only the compensation itself with the fan, but rather the fact that these instruments are equipped with a stabilisation device, such as a grid with very small holes, that help to stabilize the flow pattern before the measurement point. Of course, such stabilisation devices create generally higher pressure drop and the compensation fan is then very useful to compensate this additional pressure drop created by the instrument itself.

Alternative stabilisation methods also exist to overcome this problem of non-uniformity of the flow rates. One example is the use of an additional duct piece with a length of about 30 cm developed by the manufacturer of a vane anemometer. Such device is well suited to overcome the non-uniformity of the flow at the ATD, but not to overcome the problem of back pressure.

3.4 Problem of non-centering of the instrument on the ATD

Another possible problem is the centering of the instrument on the ATD to be measured. Additional measurement errors have been reported when, for example a vane anemometer with a large cone, is used at different position related to the ATD to measure the flow rate.

Again, the method with pressure compensation has proven its effectiveness to overcome this problem.

4 CONCLUSIONS AND PERSPECTIVES

The compensation method with sufficient stabilisation of the flow gives reliable measurements at the air terminal device in all the tested conditions (less than 10% error). This method uses a flow hood and combines a grid for the stabilisation of the flow and an auxiliary fan for the compensation of the pressure drop of the device, mainly due the stabilization grid (zero pressure differential). It has also been shown that the principle of pressure compensation as such is not enough to assure reliable results. The stabilisation grid plays probably also an important role given that another instrument with pressure compensation but without stabilisation grid gives bad results in certain measurement conditions.

For vane anemometer combined with a flow hood, the following conditions can have a dramatic effect on the measurement error: air terminal device with asymmetric flow rate, air terminal device adjusted in nearly closed position, measurement instrument not perfectly centred on the air terminal device, etc. Some new development shows that a stabilisation of the flow is also possible with vane anemometers.

Finally, another problem is the influence of the pressure drop created by the measurement instrument itself. Again, the compensation method presents also the advantage of neutralizing this additional pressure drop.

Based on these results, more attention should be paid from the commissioner over the choice of the measurement instrument in terms of reliability. As there are only very few reliable instrument on the market, there is a real need for the development of such instruments for the measurement of flow rates at the air terminal device.

The different measurement problems and errors identified in this overview highlight also the problem of the choice of a reliable measurement method and how a method could be declared as reliable or not. The identified measurement problems are mainly caused by the combination of a given measurement instrument with a specific type of ATD, flow rate pattern or measurement conditions. Because of the

large number of different ATD on the market and measurement conditions in practice, the calibration of a given instrument in standardized lab conditions is not enough to overcome these problems.
One possible solution would be to develop a standardized methodology to test the reliability of measurement instrument in different standardized measurement conditions (type of ATD, flow rate, flow pattern, centering, etc.) in order to determine with instrument is reliable in which measurement conditions.

5 REFERENCES

NBN EN 12599:2012. *Ventilation for buildings - Test procedures and measurement*

methods to hand over air conditioning and ventilation systems

Pr EN 16211 (to be published). *Ventilation for buildings - Measurement of air flows on site – methods*

G. Hawkins (2013). *Domestic ventilation systems – A guide to measure airflow rates.* A BSRIA Guide, BG 46/2013. www.bsria.co.uk

A. Gilbert, Ch. Knights (2013). *Quality of ventilation systems in resiedential buildings : statut and perspectives in the UK*, AIVC International Workshop, Brussels, Belgium, 18-19 March 2013

I.S. Walker, C.P. Wray, D.J. Dickerhoff, M.H. Sherman (2001). *Evaluation of flow hood measurements for residential register flows.* Lawrence Berkeley National Laboratory

C.P. Wray, I.S. Walker, M.H. Sherman (2002). *Accuracy of flow hoods in residential applications.* Lawrence Berkeley National Laboratory

I. Carré, P. Chaffois, P. Henry (2013). *Guide des bonnes pratiques des mesures de débit d'air sur site pour les installations de ventilation.* Cetiat, France.

I. Caré (2013). *Measurement of flow rate at air terminal device*, Congrès international de Métrologie, Paris, October 2013