Applicability of a simple and new airtightness measuring method and further comparisons with blowerdoor measurements

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ABSTRACT

The building airtightness is essential to achieve a high energy performance. In most countries however, it is not mandatory to measure the airtightness. In the Netherlands it is common practice to just take a couple samples in a housing project. These samples do not give a good indication for all the buildings in a project. It is therefore important to measure the airtightness of all the buildings.

Current methods for airtightness measuring are too expensive and time consuming to make this feasible. A method with a new device , the AirTightnessTester (ATT), is tested. By using the buildings ventilation system, a reduction in price and time can be achieved. The ATT measures in compliance with RESNET-380-2016.

The ATT makes use of the ventilation system of the building. It will be explained when and how the ATT actually can cooperate with a ventilation system. We have looked at the different brands of ventilation systems in somewhat more detail to analyze the feasibility of our method in practice. It is concluded that several systems can be used as they are now. The systems that can't be used directly or easily could be modified by the manufacturer to accommodate our method, which is also to their advantage. Some ventilation systems cannot be turned on and off easily. For these ventilation systems a setting switching method has been developed. The theory behind this method, and some preliminary results using this method will be presented.

To validate measurements with the ATT, comparisons have been done to the blowerdoor. Preliminary results were already presented during the 2018 AIVC conference (Lanooy et al, 2018) but further validation was still necessary. The measurements with the blowerdoor are multi-point measurements and are all done in compliance with ISO9972. The measurements done with the ATT are all single-point The comparisons are done to the blowerdoor, because it is the most used method for airtightness measuring. To get a fair comparison, the uncertainty of both methods are taken into account.

Overall the blowerdoor and the ATT give similar results for the airtigthness. However, it has been observed that in most cases the ATT will measure a higher leakage in comparison to the blowerdoor.

KEYWORDS

Airtightness, Single-point, blowerdoor, RESNET

1 INTRODUCTION

The building airtightness is essential to achieve a high energy performance. In most countries however, it is not mandatory to measure the airtightness. In the Netherlands it is common practice to just take a couple samples in a housing project. These samples do not give a good indication for all the buildings in a project. It is therefore important to measure the airtightness of all the buildings.

Current methods for airtightness measuring are too expensive and time consuming to make this feasible. A method with a new device , the AirTightnessTester (ATT), is tested. By using the buildings ventilation system, a reduction in cost and time can be achieved.

The ATT makes use of the ventilation system of the building. Measuring the airtightness with the ventilation system of the building is not a new method, and has been described in the RESNET-380-2016[3]. What the ATT does different is the use of an indoor reference vessel. Instead of measuring the pressure differential inside and outside of the building, it is measured between the reference vessel and inside the building.

The use of an indoor reference vessel has some technical advantages. No opening in the building envelope is necessary, meaning the whole building envelope, including the exterior door, is measured. Another advantage is that the reference is an average of the pressure over the whole building, instead of a reference at one point, which is the case with a blowerdoor. The fact that the reference is an average of the whole building, and is measured indoors also makes the measurement with the ATT less susceptible to wind.

To validate measurements with the ATT, comparisons have been done to the blowerdoor. Preliminary results were already presented during the 2018 AIVC conference (Lanooy et al, 2018[1]). Some ventilation systems cannot be turned on and off easily. For these ventilation systems a setting switching method has been developed. The theory behind this method, and some preliminary results using this method will be presented. All measurements with the blowerdoor are done in compliance with the ISO9972 standard[2].

2 METHOD

2.1 General workings of the ATT

At the start of the measurement, the reference vessel is closed when the ventilation system is turned off and will remain closed for the duration of the measurement. The pressure inside the vessel is now equal to the pressure of the building with the ventilation system turned off.

When the ventilation system is turned on, a pressure difference will occur between the reference vessel and the building itself. This pressure difference, together with the flow rate of the ventilation system, is a measure for the airtightness (equation 1).

$$q_{v,P_r} = q_{v,sys} \cdot \left(\frac{P_r}{\Delta P} \right)^n \tag{1}$$

where:

$q_{v,Pr}$:	airtightness at the reference pressure P_r	[l/s]
$q_{v,sys}$:	flow of the ventilation system	[l/s]
P_r:	reference pressure	[Pa]
ΔP:	pressure differential between the reference vessel and building	[Pa]
n:	air flow exponent.	[-]

Because the airtightness is measured at only one pressure difference and flow rate, it is not possible to determine the flow exponent. This means that an assumption must be made on the flow exponent. The flow exponent in houses typically ranges between 0,55 and 0,75. The average flow exponent is determined to be 0,66.

Multiple cycles of turning the ventilation system on and off are done. This way an uncertainty can be calculated and errors caused by pressure variations reduced. The total uncertainty of a measurement done with the ATT is calculated through propagation of error. All uncertainties involved in this calculation are independent.

$$\sigma_{q_{v,P_r}} = \sqrt{\left(\frac{\delta q_{v,P_r}}{\delta q_{v,sys}}\right)^2 \cdot \sigma_{q_{v,sys}}{}^2 + \left(\frac{\delta q_{v,P_r}}{\delta \Delta P}\right)^2 \cdot \sigma_{\Delta P}{}^2 + \left(\frac{\delta q_{v,P_r}}{\delta n}\right)^2 \cdot \sigma_n{}^2} \qquad (2)$$

The uncertainty of the flow of the ventilation system is dependent on the device that is used to measure this flow. The uncertainty of the air flow exponent is an assumed value of ±0,10[1]. The uncertainty is of the pressure differential is the deviation of the average block signals. This uncertainty contains the most information in terms of the measured signal itself. The deviation between block signals can be caused by various sources.

One of the factors that can cause a variation in the signal is a change in the bias pressure. A constant bias cannot be observed by the ATT, as the pressure difference between the vessel and the building at the start of a measurement is 0 Pa. However, when measuring the block signal, a change in the pressure difference whilst the ventilation system is turned, could be caused by a change in bias.

Another factor that could be the cause of a variation in the pressure signal is a variation in the flow of the ventilation system. It cannot be determined which of the factors is the cause for a variation in the block signal, and the most likely scenario is that it is a combination of the factors, but for the calculation of the total uncertainty it is not necessary to know which of the factors is the cause for this variation, as long as the variation is taken into account in equation 2.

2.2 Equations for the adjusted ATT measurement method

In practice it has been noticed that it is not always possible to turn the ventilation system on and off without causing a long start up sequence. This sequence can negatively impact the measured signal, making it impossible to get a proper pressure signal for the calculation. For systems where this is the case, an alternative method has been theorized.

Instead of measuring between the ventilation system turned on and off, a measurement can be done by switching the settings of the system between a high and a low flow. This way a long start up sequence can be avoided. The equation to calculate the airtightness will need to be altered to accommodate an extra flow.

$$q_{v,P_r} = \left(q_{v,high}{}^{\frac{1}{n}} - q_{v,low}{}^{\frac{1}{n}}\right)^n \cdot \left(\frac{P_r}{\Delta P}\right)^n \qquad (3)$$

It can be observed that when $q_{\mathrm{v,low}} = 0$ is filled into this equation, the original ATT equation (equation 1) is regained. The extra flow also brings an extra uncertainty, making the total uncertainty, calculated through propagation of error:

$$\sigma_{q_{v,P_r}} = \sqrt{\left(\frac{\delta q_{v,P_r}}{\delta q_{v,high}}\right)^2 \cdot \sigma_{q_{v,high}}{}^2 + \left(\frac{\delta q_{v,P_r}}{\delta q_{v,low}}\right)^2 \cdot \sigma_{q_{v,low}}{}^2 + \left(\frac{\delta q_{v,P_r}}{\delta \Delta P}\right)^2 \cdot \sigma_{\Delta P}{}^2 + \left(\frac{\delta q_{v,P_r}}{\delta n}\right)^2 \cdot \sigma_n{}^2} \tag{4}$$

Because of an extra flow uncertainty and multiple occurrences of the flow exponent in equation 1 (in general the largest uncertainty of measurement done with the ATT), it is expected that the total uncertainty with this method will be higher in comparison to a measurement done where the ventilation system is turned on and off.

2.3 Uncertainty of a measurement with the blowerdoor

All measurements with the blowerdoor are done in compliance with the ISO9972 standard. With regards to the uncertainty, this standard only gives a recommended procedure for estimating the uncertainty in the air leakage coefficient and air flow exponent. This procedure does not take into account the uncertainty in the flow and the pressure measurement.

A method to calculate the total uncertainty of a blowerdoor measurement, taking into account all variables, has been described before (Delmotte, 2013[4]). These variables include the bias pressure, external temperature and internal temperature. It also correlates the errors in the air leakage coefficient and air flow exponent. Two equations are derived, one for depressurization (equation 5) and one for pressurization (equation 6).

$$\sigma_{q_{v,P_r}} = \sqrt{\left(\frac{\delta q_{v,P_r}}{\delta a}\right)^2 \cdot \sigma_a{}^2 + \left(\frac{\delta q_{v,P_r}}{\delta b}\right)^2 \cdot \sigma_b{}^2 + \left(\frac{\delta q_{v,P_r}}{\delta T_e}\right)^2 \cdot \sigma_{T_e}{}^2 + 2\left(\frac{\delta q_{v,P_r}}{\delta a}\right)\left(\frac{\delta q_{v,P_r}}{\delta b}\right)\sigma_a \sigma_b r(a,b)} \tag{5}$$

$$\sigma_{q_{v,P_r}} = \sqrt{\left(\frac{\delta q_{v,P_r}}{\delta a}\right)^2 \cdot \sigma_a{}^2 + \left(\frac{\delta q_{v,P_r}}{\delta b}\right)^2 \cdot \sigma_b{}^2 + \left(\frac{\delta q_{v,P_r}}{\delta T_i}\right)^2 \cdot \sigma_{T_i}{}^2 + 2\left(\frac{\delta q_{v,P_r}}{\delta a}\right)\left(\frac{\delta q_{v,P_r}}{\delta b}\right)\sigma_a \sigma_b r(a,b)} \tag{6}$$

where:

a:	air flow exponent	[-]
b:	natural log of the air leakage coefficient	[l/s/Pa^n]
T_i:	internal temperature at the time of measurement	[K]
T_e:	external temperature at the time of measurement.	[K]

All blowerdoor uncertainties in this paper are calculated according to these equations. To determine the uncertainty in a and b, a weighted least-square calculation is used. This calculation takes into consideration the uncertainties in the flow and pressure measurement in the regression calculation for a and b (Cantrell, 2008[5]). This method requires an iterative calculation, which is done via Excel.

3 RESULTS

All measurements were done in the same order. First a blowerdoor measurement is done in compliance with ISO9972, including closing off the buildings own ventilation system. After the blowerdoor measurement is done, the blowerdoor remains setup, with the blowerdoor fan closed off. This is done to get the situation as comparable as possible and because the new buildings measured did not always have a front door yet. The buildings own ventilation system was then connected back up and a measurement ATT was done, either by switching the ventilation system on and off or by switching between a high or a low setting.

3.1 ATT measurements done by switching the ventilation system on and off

Most of the collected data was done via the original ATT measurement method, switching between a flow and zero. The results of the collected dataset of comparison are split into two figures for readability, figures 1 and 2.

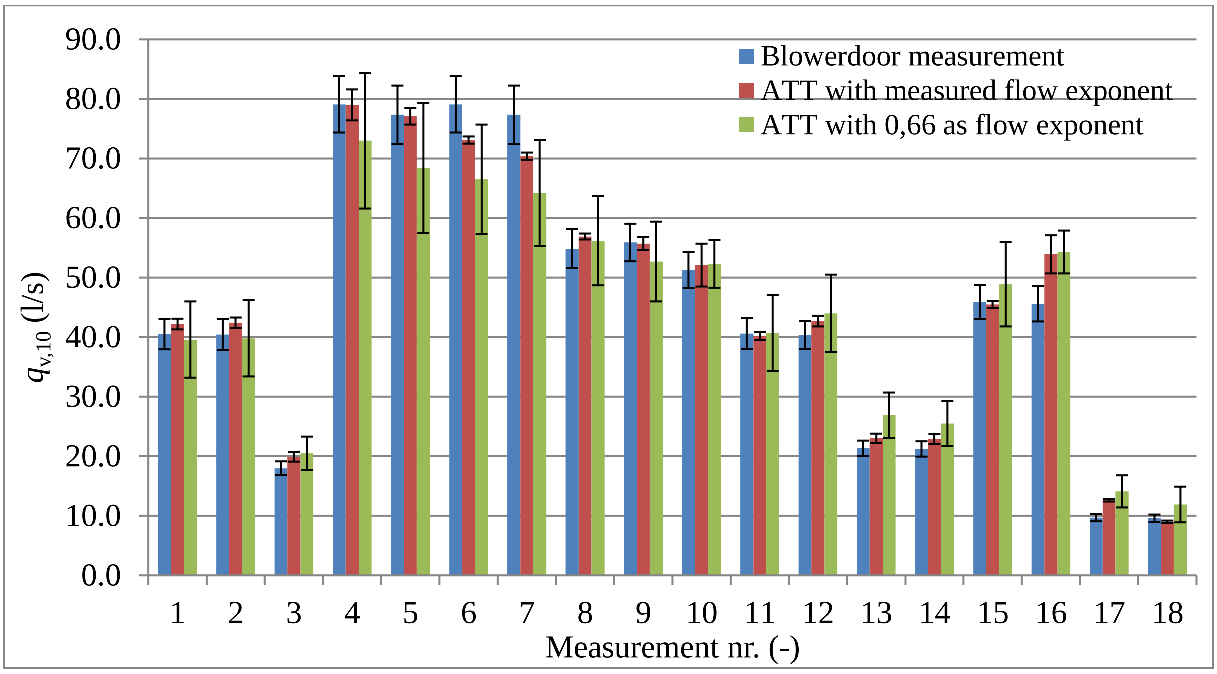

Figure 1: ATT measurement with a measured and fixed flow exponent compared to the blowerdoor.

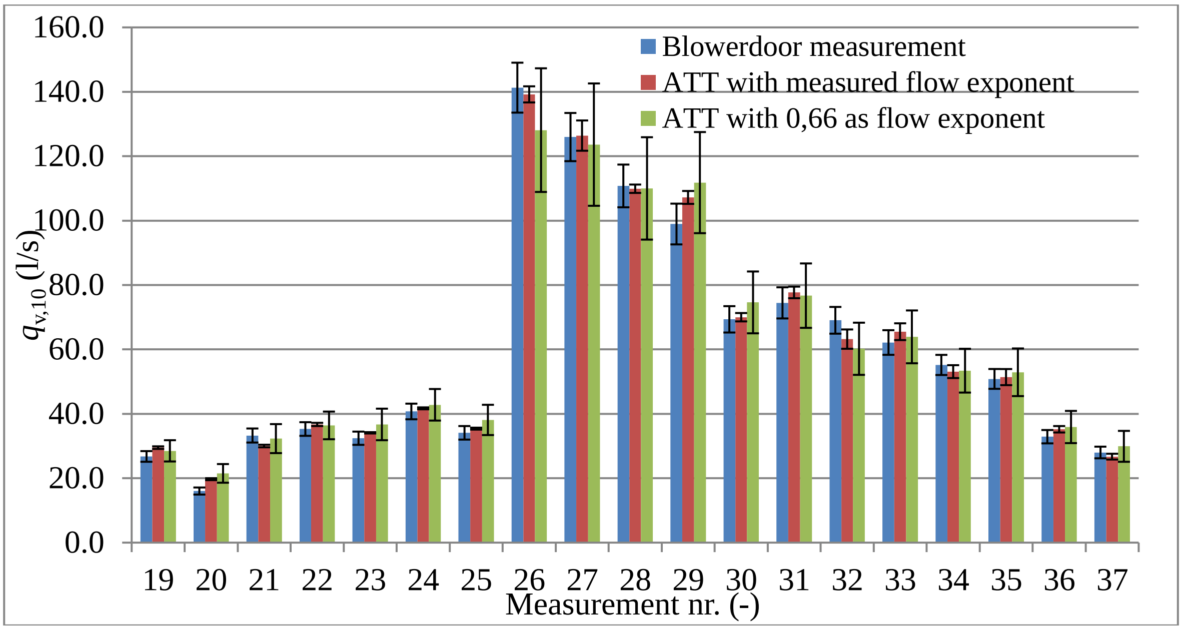

Figure 2: ATT measurement with a measured and fixed flow exponent compared to the blowerdoor.

In 23 of the 37 measurements it was found that the measured airtightness with the ATT was slightly higher than the measurement with the blowerdoor. Together with the data collected and presented in the first paper regarding the ATT[1], it can be concluded that this increase appears to be systemic needs to be researched further.

3.2 ATT measurements done by switching the ventilation system high and low

In figure 3 the results of measurements done with the ATT using a high and a low ventilation system flow are plotted, together with the blowerdoor measurement. To give an indication of the impact of using a fixed air flow exponent of 0,66, the calculation with the ATT has been done with both the flow exponent as measured with the blowerdoor and a flow exponent of 0,66. The uncertainty has also been plotted as error bars.

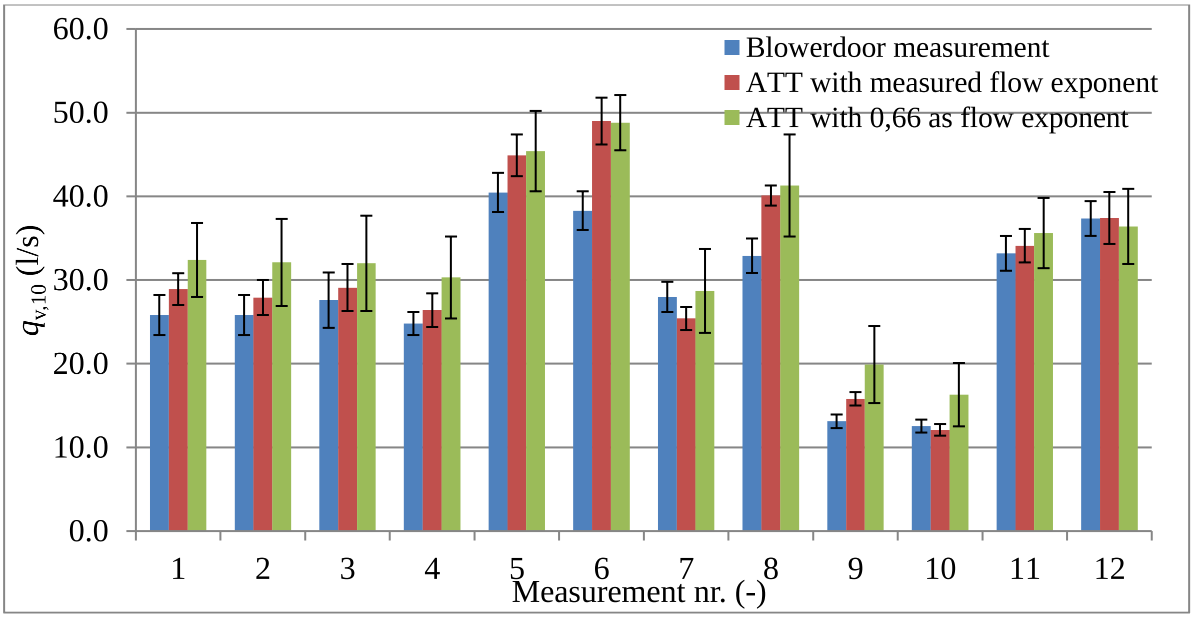

Figure 3: ATT new calculation with a measured and fixed flow exponent compared to the blowerdoor.

The airtightness value as measured with ATT with a measured flow exponent is higher in 10 of the 12 cases. The airtightness when using a fixed flow exponent is higher or lower depending on whether the measured flow exponent is higher or lower than 0,66.

It can be observed that when using a measured flow exponent, the ATT and the blowerdoor have similar uncertainties. The uncertainty when using a fixed flow exponent is always higher, which was expected.

From this dataset is can be concluded that measuring by changing the flow between high and low does not give any big differences with the blowerdoor measurement and could be used as an alternative in case of a situation where the ventilation system cannot be turned on and off without causing disturbances in the measured signal.

3.3 ATT measurement with on/off compared to measurement with high/low

Six measurements have been done where a building was measured twice with the ATT, once by switching the ventilation system between on and off and once by switching between high and a lower setting. The results from these measurements are in table 1.

Table 1: Measurements done with the ATT with both methods.

Measurement	$q_{v,10}$ on/off (l/s)	ΔP_{on-off} (Pa)	$q_{v,10}$ high/low (l/s)	$\Delta P_{high-low}$ (Pa)
1	30,9±3,2	27,5	32,4±4,4	22,4
2	28,2±3,5	34,6	32,0±5,7	20,2
3	27,4±2,9	28,7	30,3±4,9	15,9
4	29,9±4,8	48,6	28,7±5,0	25,1
5	30,9±3,2	27,5	32,1±5,2	17,8
6	35,9±5,0	39,5	41,3±6,1	27,5

As expected, the uncertainty is higher when using switching between a high and a low setting in comparison to switching the system on and off. This is caused by the second flow and the lower pressure signal. In measurement 4 the difference in uncertainty is small. This is caused by the reference pressure. Since the airtightness is calculated to a reference pressure of 10 Pa, the uncertainty caused by the flow exponent will be bigger when the measured pressure signal is further away from 10 Pa. When switching between a high and low setting, the generated pressure signal will be lower than when the ventilation system is switched between on and off.

4 CONCLUSIONS

In this paper a methodology for airtightness measurements through fan pressurization is described. This methodology measures the airtightness through the ventilation system of the building itself. Instead of measuring the pressure between inside and outside the building, the ATT measures the pressure differential between inside the building and an indoor reference vessel. This makes it possible to measure the entire building envelope, including an exterior door.

Measurements with the ATT were further validated by comparing measurements done with the ATT with a blowerdoor measurement. In general it can be concluded that a measurement with the ATT gives a slightly higher airtightness value then a blowerdoor measurement. More research is still being done to determine the cause of the difference. The current theory is that this is caused by the difference in reference pressure, as the blowerdoor takes the reference in one place and the ATT takes its reference as an average over the whole building.

In this paper an adjusted method for measuring was also presented. Instead of switching the ventilation system on and off, it is possible to switch between a high and low flow. Switching between high and low is not the preferred method of testing, because of the increase in the uncertainty, caused by the extra flow in the calculation and the low pressure signal. The increase in uncertainty is however not that large that the measurement becomes unusable to judge whether a building passes its airtightness requirement. It can therefore be used when it is not possible to do a measurement by switching between on and off.

5 REFERENCES

[1] Lanooy, T., Kornaat, W., Bink, N.J., Borsboom, W., (2018). *A new method to measure building airtightness*. Juan-les-Pins, France, Proceedings of the 39th AIVC Conference, 18-19 September 2018.

[2] International Organization for Standardization (ISO). *ISO 9972:2006*: *Thermal performance of buildings – Determination of air permeability of buildings -- Fan pressurization method*. Geneva, Switzerland.

[3] Residential Energy Services Network (RESNET). *RESNET 380-2016: Standard for Testing Airtightness of Building Enclosures, Airtightness of Heating and Cooling Air Distribution Systems, and Airflow of Mechanical Ventilation Systems.* Washington, USA.

[4] Delmotte, C., (2013). *Airtightness of buildings - Calculation of combined standard uncertainty*. Athens, Greece, Proceedings of the 34th AIVC Conference, 25-26 September 2013.

[5] Cantrell, C. A., (2008). *Technical Note: Review of methods for linear least-squares fitting of data and application to atmospheric chemistry problems*. Atmos. Chem. Phys., 8, 5477-5487.