Uncertainties due to steady wind in building pressurisation tests

This paper analyses the contribution of a steady wind to the uncertainties in building pressurisation tests, using the modelling approach developed in another paper (Carrié and Leprince, 2016). The uncertainty due to wind is compared to the uncertainties due to other sources of uncertainty (bias, precision and deviation of flow exponent). This article is based on a paper presented at the 38th AIVC - 6th TightVent & 4th venticool Conference, 2017 "Ventilating healthy low-energy buildings" held on 13-14 September 2017 in Nottingham, UK.

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With the increasing pressure of energy performance of buildings regulations, building pressurisation tests become more and more common. Yet, there remain unanswered questions regarding the quantification of uncertainties in practice. The sources of uncertainties include the model error due to wind, model error due to the deviation of the flow exponents, precision and bias error.

The objective of this study is to assess the impact of a steady wind on airtightness testing uncertainty and compare it to other sources of uncertainty. This paper uses the modelling approach proposed by (Carrié, et al., 2016).

This analysis assumes that:

- the building can be represented by a single zone separated from the outside by 2 types of walls: walls on the windward side of the building which are subject to the same upwind pressure; and walls on the leeward side which are subject to the same downwind pressure;
- the test is performed under isothermal conditions, and
- the airflow rate through the leaks of the envelope is given by a power-law with the same flow exponent.

To estimate combined uncertainty, we use a similar approach to that proposed by (Sherman, et al., 1995), which includes precision, bias and model error.

We have estimated the maximum error for a one-point measurement at 10 and 50 Pa and for a two-point measurement with the determination of flowrate at reference pressure 4 and 50 Pa. Constraints were applied to perform a test valid according to ISO 9972:2015. However, we have also plotted results without the constraint on the zero-flow pressure (named "constraint D") to see its impact. We assessed the uncertainties when averaging results of pressurisation and depressurisation tests. We analysed separately the maximum error likely to happen when testing a building zone with facades exposed to wind:

a) both upstream and downstream such as a detached house (called "restricted range")
b) either upstream only or downstream only (called "full range").

Results

The results are summarised in **Figure 1** to **Figure 4** and **Table 1**.

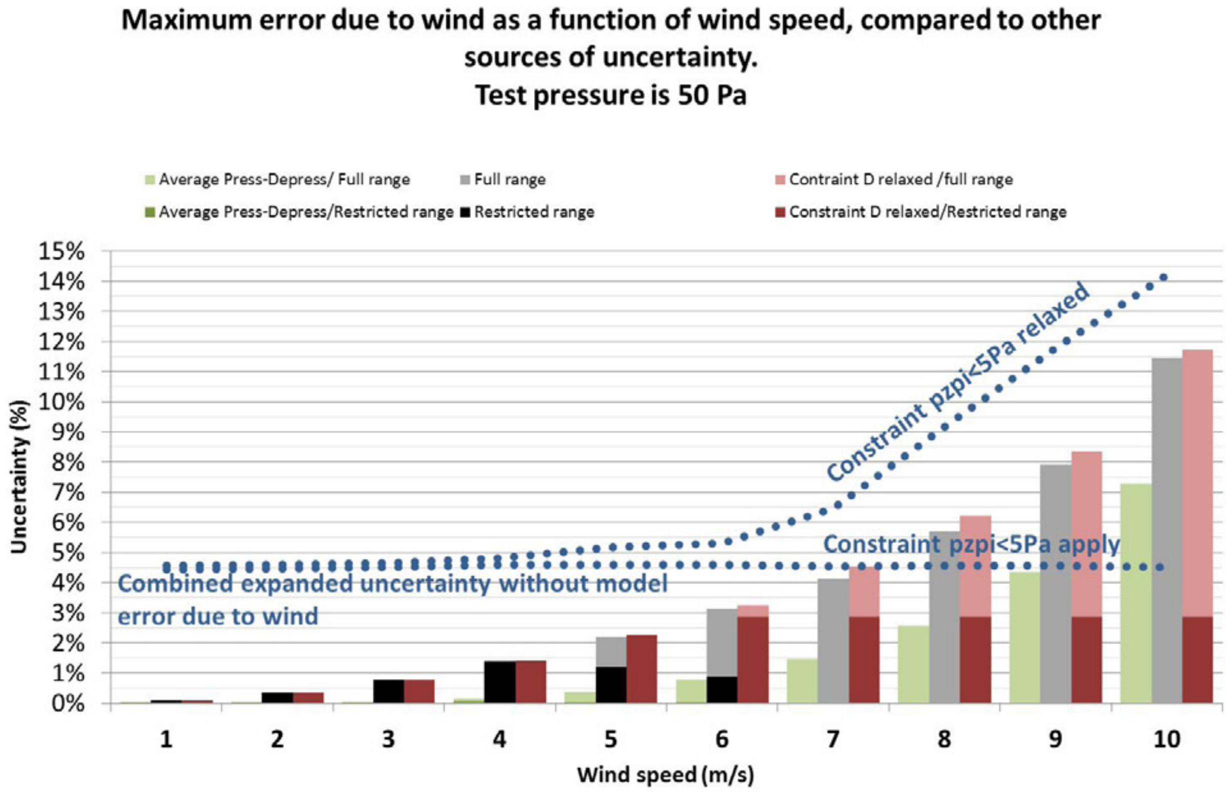

Figure 1. Model error due to wind at 50 Pa, one point measurement.

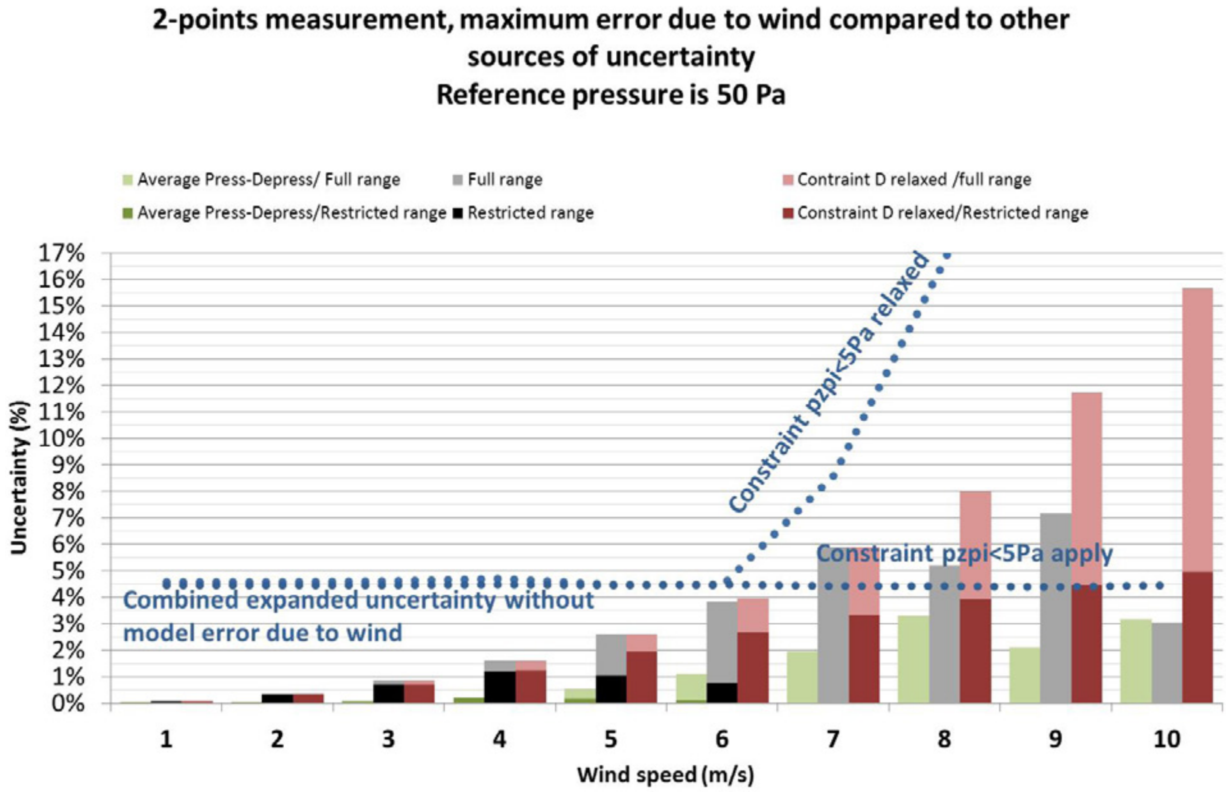

Figure 2. Model error due to wind at a reference pressure of 50 Pa with 2-points measurements.

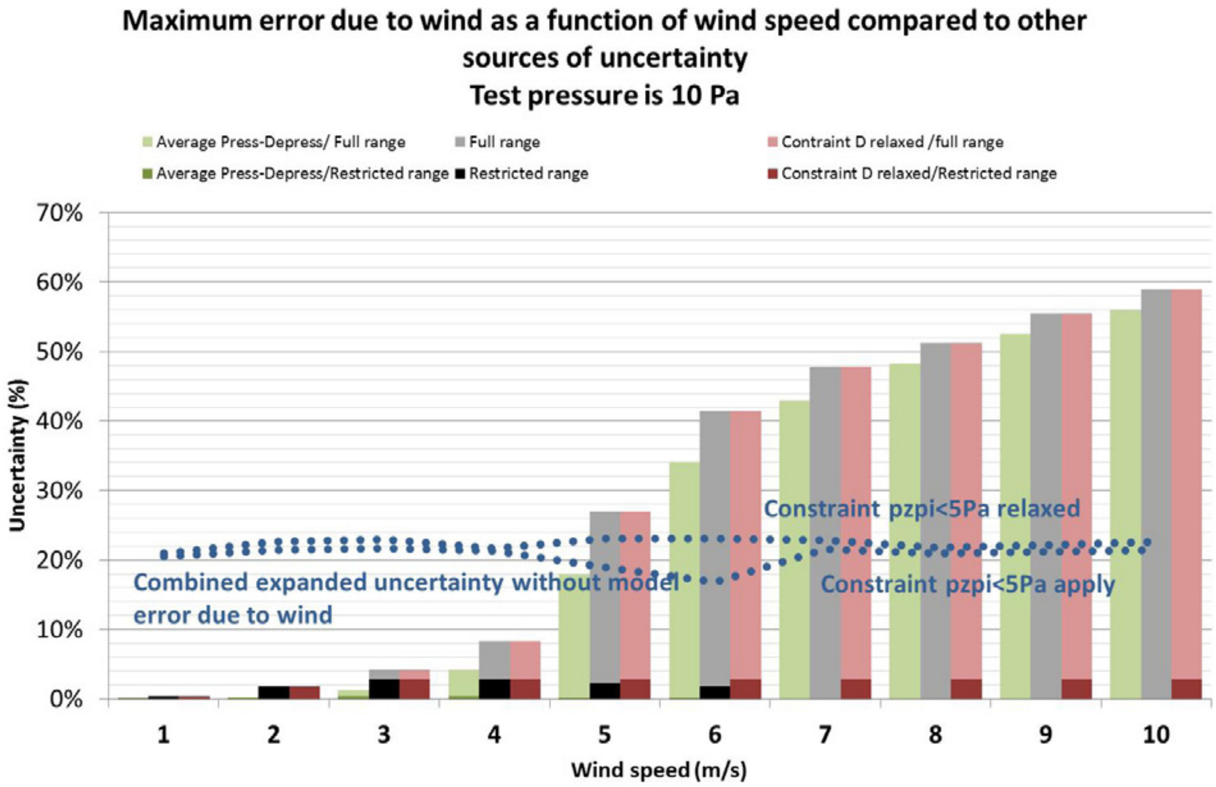

Figure 3. Model error due to wind at 10 Pa, one-point measurement.

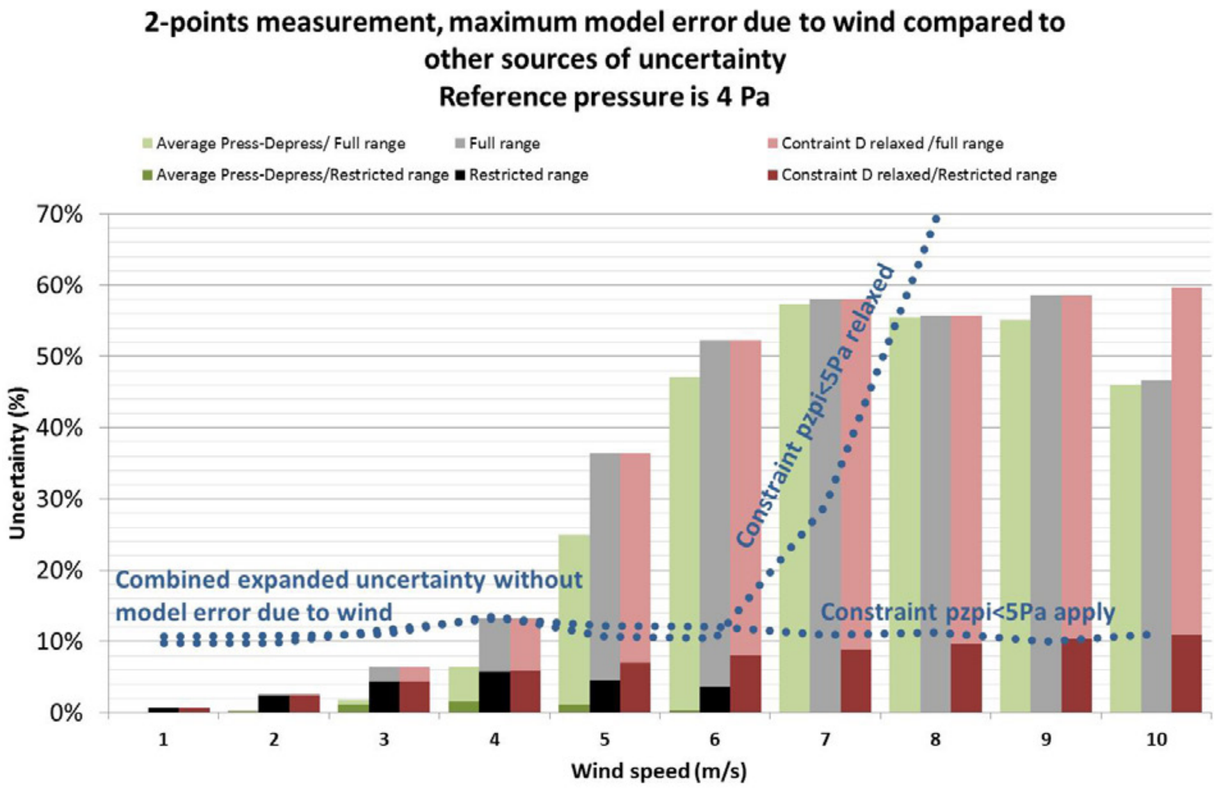

Figure 4. Model error due to wind at a reference pressure of 4 Pa with 2-point measurements.

Table 1. Summary of the result: maximum error due to steady wind.

		At 4 Pa				At 50 Pa			
		Constraint D		No constraint D		Constraint D		No constraint D	
	Range of z	Full	Restr.	Full	Restr.	Full	Restr.	Full	Restr.
1-point	6 m s^{-1}	3%	1%	3%	3%	3%	1%	3%	3%
	10 m s^{-1}	11%		12%	3%	11%		12%	3%
1-point combined	6 m s^{-1}	32%	30%	33%	32%	6%	5%	6%	6%
	10 m s^{-1}	34%		45%	44%	12%		15%	14%
2-point	6 m s^{-1}	52%	4%	52%	8%	4%	1%	4%	3%
	10 m s^{-1}	47%		60%	11%	3%		16%	5%
2-point combined	6 m s^{-1}	53%	15%	53%	42%	6%	5%	6%	5%
	10 m s^{-1}	48%		151%	139%	5%		44%	39%

Discussion

One key result is that alone, the model error due to the wind on the estimated airflow rate is relatively small for the high-pressure point, but it can become very significant with a low-pressure point. While the error lies within 12% for wind speeds up to 10 m s^{-1} at 50 Pa, it can reach 60% at the low-pressure point (10 Pa).

However, there are other sources of uncertainty that are not taken into account in this study such as:

- wind fluctuations,
- leaks that have different flow exponents,
- the linear regression,
- thermal draft,
- uncertainty on building preparation.

What happens over 6 m/s?

At 50 Pa, up to 6 m/s uncertainty due to wind remains below "other combined uncertainty". Therefore, the uncertainty due to wind has almost no impact on the quadratic sum. It is seen on one- and two-point measurement graphs.

The uncertainty due to wind becomes dominant at 5 m/s for 10 Pa (**Figure 3**) and at 4 m/s for 2-point test extrapolated at 4 Pa (**Figure 4**).

Therefore, 6 m/s is a relevant limit value for the high-pressure station (50 Pa) but is too high for low-pressure measurements.

Can we relax the zero-flow pressure constraint ("constraint D" on graphs) to allow testing in windy places?

The difference between with and without the zero-flow pressure constraint is the difference between the grey/black and the red bars on figures 1 to 4. Up to 6 m/s, there is not much difference between with and without applying this constraint. Constraint D limits the wind speeds for which the test can be performed to about 6.2 m s^{-1} with a restricted range of leakage distribution (see **Figure 1**, **Figure 2**, **Figure 3**, **Figure 4**) which is consistent with ISO 9972:2015 stating that constraint D is unlikely to be met above 6 m s^{-1}. Relaxing the constraint on the zero-flow pressure would allow one to perform a test above 6 m/s in detached houses.

In detached houses (restricted range of leakage distribution), the uncertainty due to wind remains low even with wind speeds up to 10 m/s and without constraint on zero-flow pressure. However, for 2-point tests above 6 m/s, the combined uncertainty without wind increases rapidly without constraint D; it passes over 10% at 7 m/s for a reference pressure at 50 Pa.

These results suggest it is necessary:

- either to have a constraint on wind speed (maximum 6 m/s); or
- to have a constraint on zero flow pressure (maximum 5 Pa)

Does averaging pressurisation and depressurisation have a significant impact on results?

The difference between green and grey bars in figures 1 to 4 shows the effect of averaging pressurisation and depressurisation tests. This averaging can decrease the uncertainty due to wind up to 5 percentage points. At low wind speed, when averaging, the uncertainty due to wind is negligible; therefore other sources of uncertainties dominate.

At high wind speed, averaging is not enough to make uncertainty due to wind in the same range of other sources of uncertainties.

Averaging is mostly beneficial at intermediate wind speed (around 4 m/s) when reference pressure is 4 Pa. It keeps the error due to wind far below the “other” combined uncertainty.

Is the uncertainty different between tests in detached houses and single-sided dwellings?

The maximum uncertainty in detached houses (restricted range) is given by dark bars in the figures, and the maximum uncertainty without restriction on the leakage distribution is given by light bars. The uncertainty in detached houses remains below 12% even for wind speeds up to 10 m/s with constraint D relaxed at 4 Pa, whereas for a single-sided dwelling the uncertainty due to wind may reach 60% at high wind speed. Therefore, the uncertainty due to wind is mostly critical for single-sided buildings or zones.

To calculate the infiltration air flowrate at 4 Pa and 50 Pa is it better to perform a 2 or a 1 point of the test (and extrapolate with constant n for 4 Pa)?

According to (Carrié, et al., 2016) ; figure 6), the uncertainty for a reference at 4 Pa (with $n = 2/3$) when testing at a single pressure station of 50 Pa remains between 31 and 34% up to 10 m/s when constraint D applies. When constraint D is relaxed, it increases from 5 m/s to reach 47% at 10 m/s.

Comparing this result with **Figure 4** suggests that, for a result at 4 Pa, up to 5 m/s, it is better to perform a 2-point test and extrapolate with a calculated flow exponent and above 5 m/s it is better to perform a test at 50 Pa and extrapolate with a default flow exponent ($n = 2/3$).

For detached houses, **Figure 4** suggests that a 2-point test is preferable up to 7 m/s (whether constraint D is relaxed or not).

If the reference value is 50 Pa, there is much less uncertainty due to wind if the test is performed at only one pressure point close to 50 Pa.

Still, it may be useful to test envelopes at multiple pressure stations to identify suspicious results, e.g. due to moving valves.

What is the impact of steady wind on uncertainty compared to other sources of uncertainty?

On figures 1-4, for detached houses (restricted range), the impact of steady wind is quite low compared to the other sources of uncertainty, but for a single-sided building (full range), it is important to check wind speed and/or pressure difference at zero flow to perform a reliable test. ■

References

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