Passive House Institute

# Airtightness measurement of high-rise buildings

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## 1. Assistance in carrying out the measurement

Due to the strong wind and thermal effects on high-rise buildings, special rules must be observed for blower door measurements. The standards, EN 13829 and ISO 9972, do not provide sufficient information for the blower door measurement of such buildings.

In [Rolfsmeier/Simons 2017] practical experiences, from the measurement of a high-rise building with 16 floors (height approx. 60 m), are described. In the paper, the clear effects of wind gusts, as well as the pronounced thermal effects, with a natural pressure difference between ground floor and 16th floor of approximately 30 Pa (right picture), can be seen. In bad wind conditions (left picture), the pressure differences are highly unstable over the measurement time period. Depending on the location of the measurement, the measured results are influenced to varying degrees by the wind.

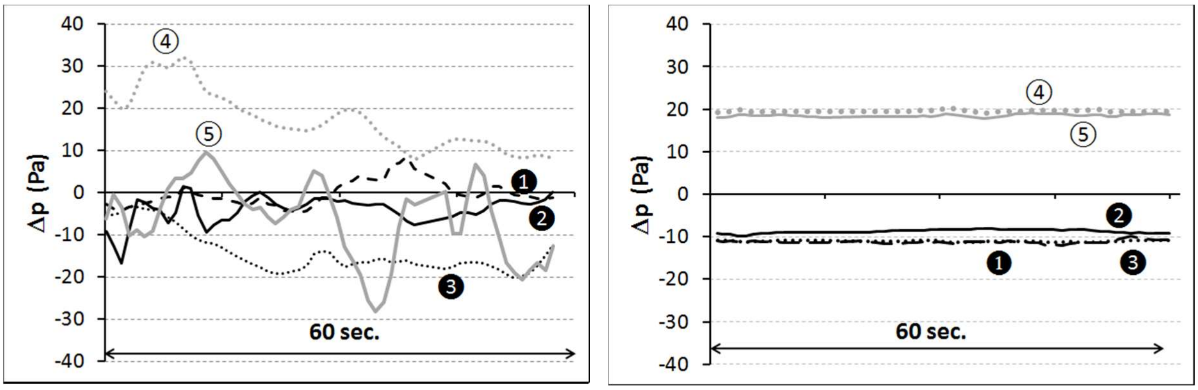


**Figure 1: Measurements of the natural pressure differences at the high-rise building, with 16 storeys. Measurements on three sides at the lowest floor (1, 2 and 3) and on two sides at the top floor (4 and 5).**
**Left: Wind force 4, temperature difference 9°C.**
**Right: Wind force 0-1, temperature difference 14°C. (from [Rolfsmeier/Simons 2017])**

The most favourable conditions for an airtightness measurement of a large building are, therefore, calm wind conditions and a small external to internal temperature difference. However, since the measurement must be integrated into the construction process, it is generally difficult to find an appropriate test point where these conditions exist.

The influence of the external to internal temperature difference and the height of the building on the magnitude of the pressure difference between the top and bottom (for differing thermal gradients) of a building is shown as an example in Figure 2. For example, the pressure difference for an 80 m high building and an external to internal temperature difference of 15 K is approximately 24 Pa. The starting point for this calculation is the pressure-neutral level, which in simplified terms is half the height of a building with uniform leakage distribution. From the ground floor to the top floor, the pressure difference is thus 2 x 24 Pa = 48 Pa. This results in a pressure difference that can no longer be neglected for the airtightness measurement.

According to the ISO 7792 and EN 13892 standards, five times the natural pressure difference is required for the lowest measuring point of the airtightness measurement series. For the case previously described this would be 5 x (-24 Pa) = -120 Pa, which is not feasible given standard testing equipment.

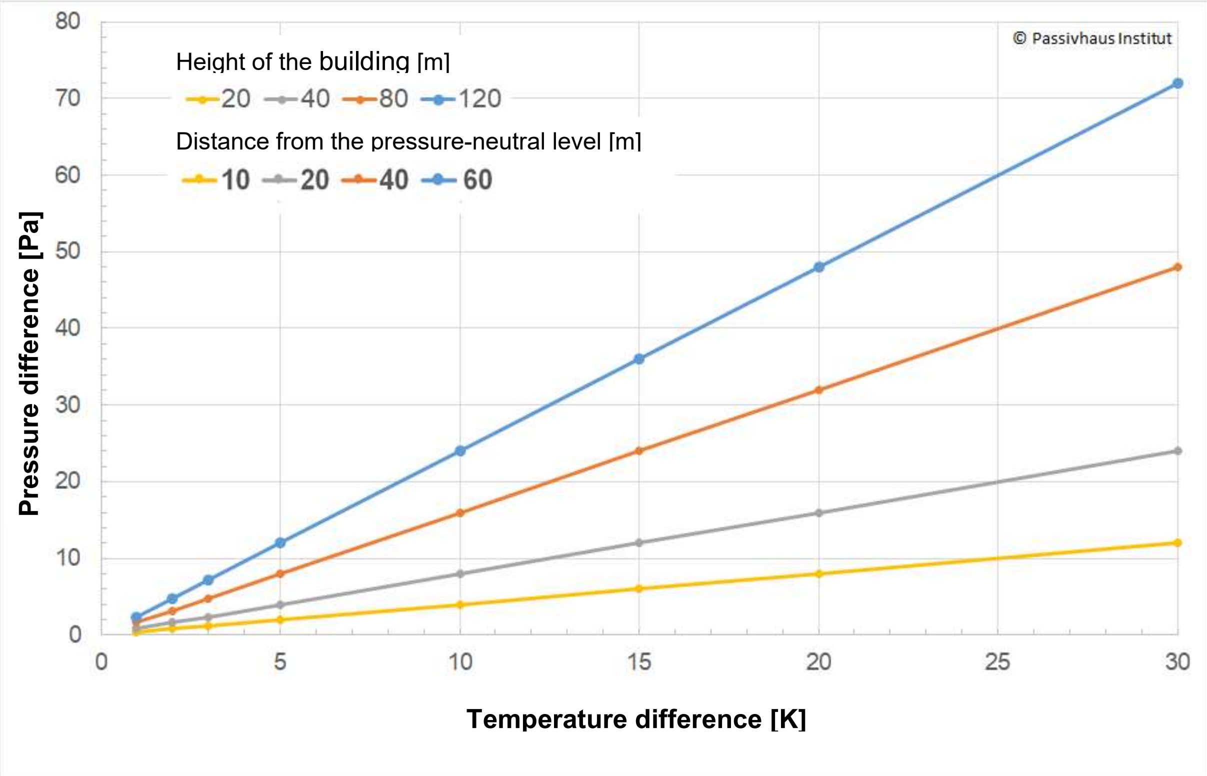


**Figure 2: Calculation of the external to internal pressure difference (starting point: pressure-neutral level) as a function of the temperature difference between inside and outside for different building heights.**

The formula used to estimate the natural pressure difference, due to thermal differences is [Zeller 2012]:

$\Delta p_{Th}$ = 0,04 Pa/(K m) * h * $\Delta T$

$\Delta p_{Th}$: Differential pressure between inside and outside, due to external to internal temperature differences, in Pa

h: Height from <u>the pressure-neutral level</u> in m

$\Delta T$: Temperature difference between inside and outside in K

A prerequisite for the validity of this formula is an open connection of the internal air spaces in the entire building, without any relevant pressure drop (treatment as "one room").

Under the simplified assumption of uniform air leakage distribution over the building envelope, the pressure-neutral level is set at the midpoint of the building height.

Without taking the external wind conditions into account, there is underpressure in the lower part and overpressure in the upper part of the building, (prerequisite: warmer internal conditions in relation to the external temperature) see Figure 3.

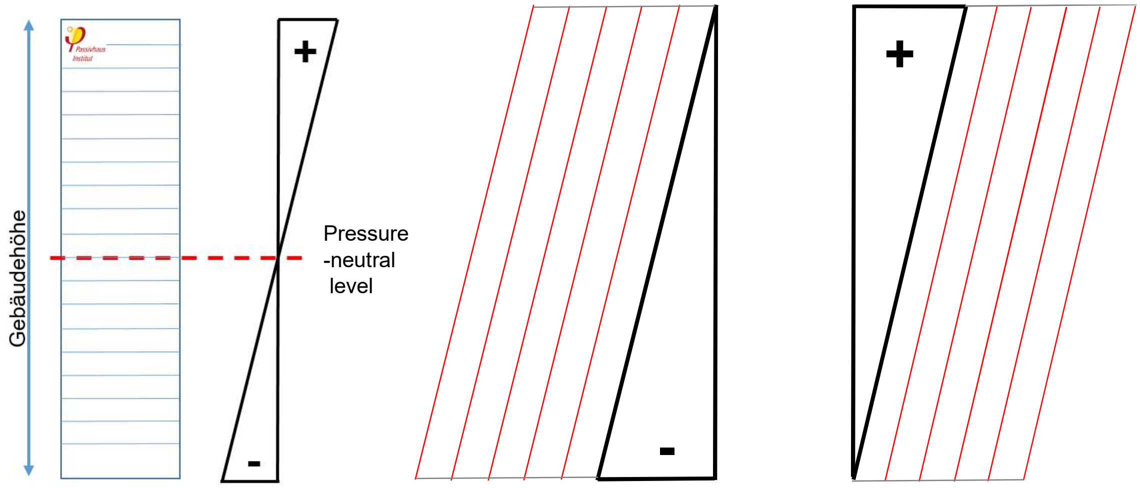


**Figure 3: Schematic illustration of the pressure conditions on a skyscraper due to the thermal conditions (left) and in the case of generated negative or positive pressure in the entire building (centre and right). The red solid lines represent the different pressure levels of a negative or positive pressure measurement**

## Important to note:

**For the airtightness evaluation, only those pressure measurement levels where an under- or over-pressure condition existed over the entire building height during the test duration may be used. The measurement points at which this is not true must be omitted. At these measurement points, some leaks will flow in the opposite direction to the test condition, and so the infiltration volume flow cannot be measured correctly.**

Important for all considerations is the distinction between the "measured" and the "generated" pressure difference:

**Measured pressure difference:** Value of the pressure difference between inside and outside, which is read off the measuring instrument. For example, a natural pressure difference of - 20 Pa.

**Generated pressure difference:** The pressure difference that the fan generates in addition to the natural pressure difference. If, for example, the natural pressure difference is - 20 Pa, and a pressure difference inside / outside of 0 Pa is read from the measuring device, the pressure difference generated is + 20 Pa.

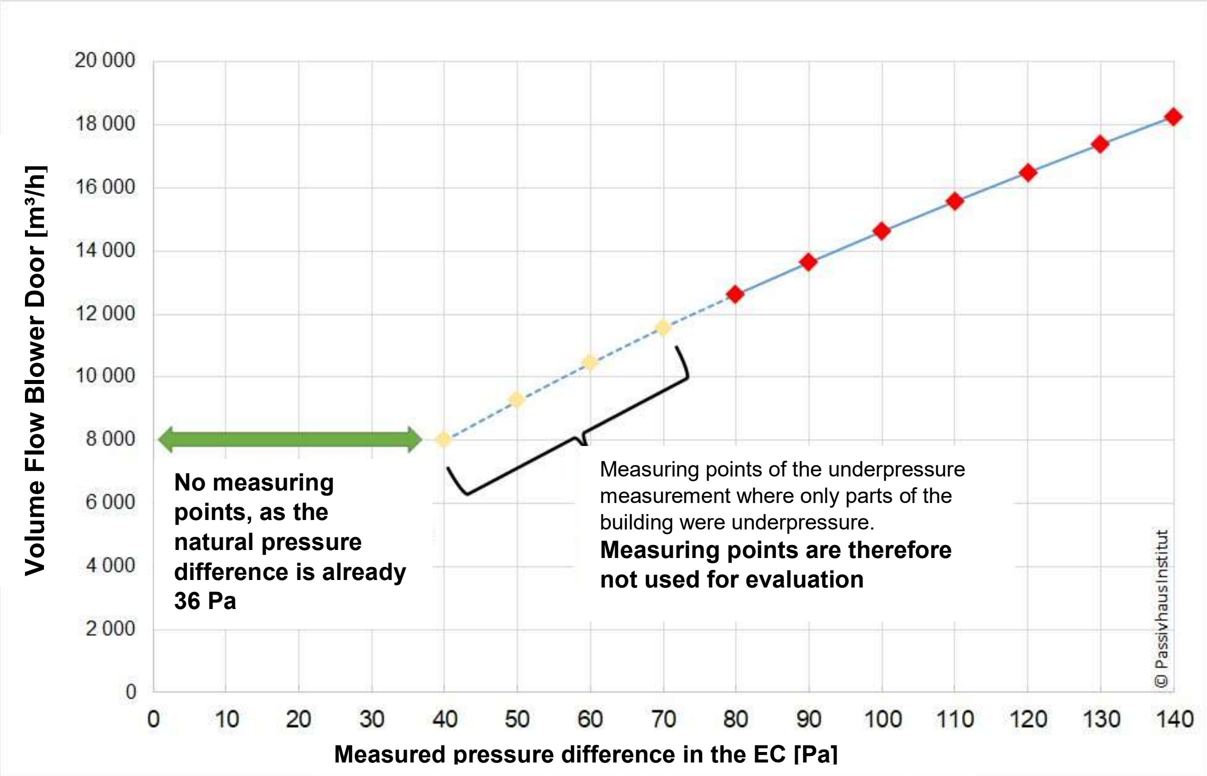


**Figure 4: Example measurement curve of an underpressure measurement at the example house from the next section. Due to the thermal conditions, the building is only completely underpressure from about -72 Pa (measured on the ground floor). Therefore, the measurement points may only be used from about -80 Pa onwards. The natural pressure difference in the ground floor is -36 Pa, therefore only measurement points with larger negative pressure values are acceptable.**

## 2. Calculation for an example skyscraper

A skyscraper with a height, H = 120 m, is measured in autumn with an external to internal temperature difference of 15 K. Due to the thermal effect, a pressure difference of about 72 Pa is created over the height of the building. If the pressure-neutral level is halfway up, the pressure difference will be -36 Pa on the ground floor and +36 Pa on the top floor. For the overpressure measurement procedure, the blower door should be adjusted so that the the lowest pressure measurement of the series applies an overpressure at the installation location on the ground floor, e.g. +5 Pa. For the rest of the pressure measurement series, up to 55 Pa for example, proceed as per the usual process. At the uppermost floor, due to the external to internal temperature differences, the following pressures will exist:

5 Pa + 72 Pa = **77 Pa** to

55 Pa + 72 Pa = **127 Pa**

When measuring the negative pressure test series, it must be ensured that there is also negative pressure at the top floor. If a "safety margin" of 5 Pa is applied for this case (as was done for the overpressure measurement), the result is the same as the overpressure case at the ground floor location:

-72 Pa - 5 Pa = -77 Pa to
- 72 Pa – 55 Pa = -127 Pa

Accordingly, there is a pressure difference of -5 to -55 Pa on the top floor and permanent negative pressure is ensured for the entire building envelope.

## 3. Practical tips for implementation

With the previous example it becomes clear that the requirement of the standard not to exceed a maximum internal pressure difference of 10% anywhere within the building envelope will not to be met under any case. However, in order to be able to carry out a high-rise measurement, the following practical instructions are derived[1].

1. The fan(s) can usually **all be installed at the ground level**. It is not possible to achieve the pressure difference at all heights of the building required for the pressure test simultaneously ("one room") by using additional fans distributed over the height of the building. From the ground floor, various stairwells / shafts can best be used for air distribution.

   If there are several areas in the building with significant pressure losses to be overcome (one after the other: door to the stairwell, door to the floor level and door to the apartment), **it may be necessary to utilise several devices to distribute the pressure over the internal volume of the building**. This is the only way to ensure that the pressure is distributed sufficiently well. The measurement then takes place according to the pressure difference generated at one of the devices (usually at ground level), which functions as a "control centre".

2. At ground level it makes sense to not install just one measuring point for the differential pressure. Depending on the circumstances, there are different possibilities (see Figure 5):
   **a)** Measurements, for example, with a capillary tube through the window seals **in different compass directions.** Mathematical averaging of the values during evaluation.
   **b)** If **several devices** are used on the ground floor, they can be positioned on different facades. This allows several internal to external pressure difference measurements to be recorded. These can be averaged during the evaluation.

[1] **Note**: A section-by-section measurement of 6-8 storeys each is also a possible solution for the measurement of tall buildings. These measurements can be conducted analogously to a standard measurement. However, this requires that the building can be sealed horizontally at the boundaries of the sections (also elevator shaft, staircase, etc). As a general rule, this will not be possible at reasonable cost.

3. At least one additional measuring point is required to determine **the pressure difference at the upper floor** (capillary tube through the window seal, see Fig. 6). This pressure difference value must be measured and recorded for all of the test points of the measurement series.
   In case of significant **wind influence**, it is advisable to carry out the measurements at the top floor in at least 2 different directions.
   This measurement can be used to verify the required pressure distribution in the building (see Section 4 for an explanation).
4. A simple **help sheet** (MS Excel) is available for calculating the necessary pressure differences, which can be used for setting pressure test levels.
5. The **room air temperature** in a high-rise building is usually not homogeneous, especially not during the construction phase. It is therefore advantageous to measure and average the room air temperature at least on the ground floor and on the top floor.
6. If it is technically feasible, it can be helpful to reduce the temperature difference between inside and outside by long, **massive ventilation** (overnight, all windows open). This procedure is only expedient if, not only the internal air volume, but also the building masses are cooled or warmed.
7. It can be assumed from the thermal conditions that **the values of the natural pressure** difference are considerably higher than those of non high-rise buildings.
8. **An underpressure AND overpressure** measurement must be conducted. These may differ more clearly than in the case of small buildings. Only the mean value can be used as the result.
9. At **higher wind** speeds it is to be expected that the measurement will not lead to accurate results
10. When evaluating large buildings, it is always necessary to calculate the surface area of the envelope (according to ISO 9972), to determine the **leakage value q50, related to the envelope area** and to enter it in the test protocol.
11. For the negative pressure measurement, only those measurement points may be used at which negative pressure existed for the entire building volume (correspondingly in the case of positive pressure).
12. As usual, the pressure differences corrected **by zero pressure are** used for the evaluation.

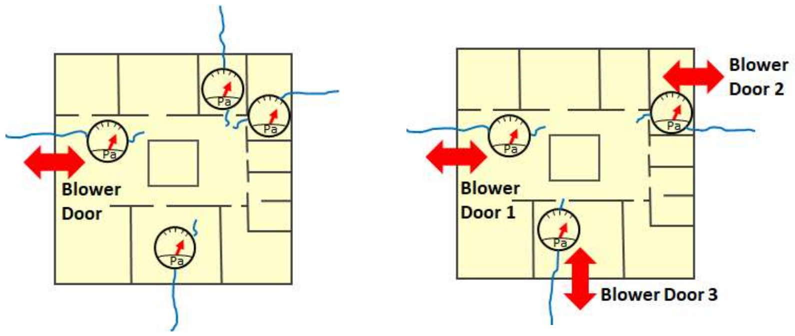


**Figure 5: Building floor plan with different options for measuring the pressure difference between exterior and interior:**
**Left: Measurements in four directions with e.g. capillary tubes through the window seals.**
**Right: Measurement with three Blower Door devices. Each has its own integrated internal/external pressure differential measurement.**


**Figure 6: Capillary tube with hose connection for pressure difference measurement through a window seal (e.g. for measurement on the top floor).**

## 4. Control of the maximum deviation of the pressure distribution

According to the EN 13829 and ISO 9972 standards, a blower door measurement must ensure that the pressure difference between inside and outside is present everywhere in the building. A maximum deviation of 10% must be observed. Due to the thermal influences described in the previous sections, this is generally not possible in high-rise buildings, even when there is no wind.

A check of the equal pressure distribution in the building can also be carried out for high-rise buildings. For this the influence of the thermal conditions is considered, whereby there are two different methods (see figure 7)

## 4.1 Procedure 1:

**Measurement between critical space and environment (see Fig. 7, left image)**

1. For the zero pressure measurement with closed fan, the natural pressure difference $p_{nat}(0)$ shall be measured and documented at the blower door (ground floor) and $p_{nat}(h)$ at the top floor.
2. *For the plausibility check, this value can be compared with the expected natural pressure difference at this altitude (see formula in previous section). With this difference applying over the total height of the building the natural pressure difference, $p_{nat}(h)$, can be calculated theoretically at each point of the building's height (uniform leakage distribution and homogeneous temperature distribution assumed).*
3. If a room is to be checked at any height for compliance with the maximum deviation, the natural pressure difference $p_{nat}(h)$ is first measured with the aid of the capillary tube (with the fan closed). The blower is then put into operation and a pressure value is set at the ground floor ($p_{mess}(0)$). In the critical space at height h, the pressure inside / outside $p_{mess}(h)$ is then measured.
4. The pressure difference $p_{nat}(h)$ - $p_{nat}(0)$, caused by the thermal effect is subtracted from the measured value $p_{mess}(h)$ in the analysed room. In addition, the pressure difference $p_{BD}$ caused by the fan at the ground floor is subtracted. What remains is the pressure deviation, which should not exceed 10% of $p_{BD}$.
   $P_{divergence} = p_{mess}(h) – (p_{nat}(h) - p_{nat}(0)) - p_{BD}$
5. In this test, the influence of the wind on the facade must be taken into account. Thus the measurement in the critical room/area can be carried out on different facades if necessary in order to exclude large test values (windward or leeward side).

<u>Legend:</u>
$p_{nat}(0)$: Natural pressure difference at the installation location of the blower
$p_{nat}(h)$: Natural pressure difference at height h (measurement with capillary tubes)
$p_{mess}(0)$: Measured pressure difference at the blower installation location
$p_{mess}(h)$: Measured pressure difference at height h (measurement with capillary tube)
$p_{BD}$: Calculated by $p_{BD} = p_{mess}(0) - p_{nat}(0)$

## 4.2 Procedure 2:

**Measurement of uniform pressure distribution within the building**
(see Fig. 7, right image)

For measuring the deviation of the generated pressure difference within the building, e.g. in a "critical room":

Installation of a pressure hose from the ground floor through the stairwell into the "critical room" (here for example in the attic) and measurement of the pressure difference between the ground floor and the “critical room”. Since the thermal influence on the hose is the same as for the building internal volume, the thermal effect is not considered. Only the deviation of the pressure distribution is measured.

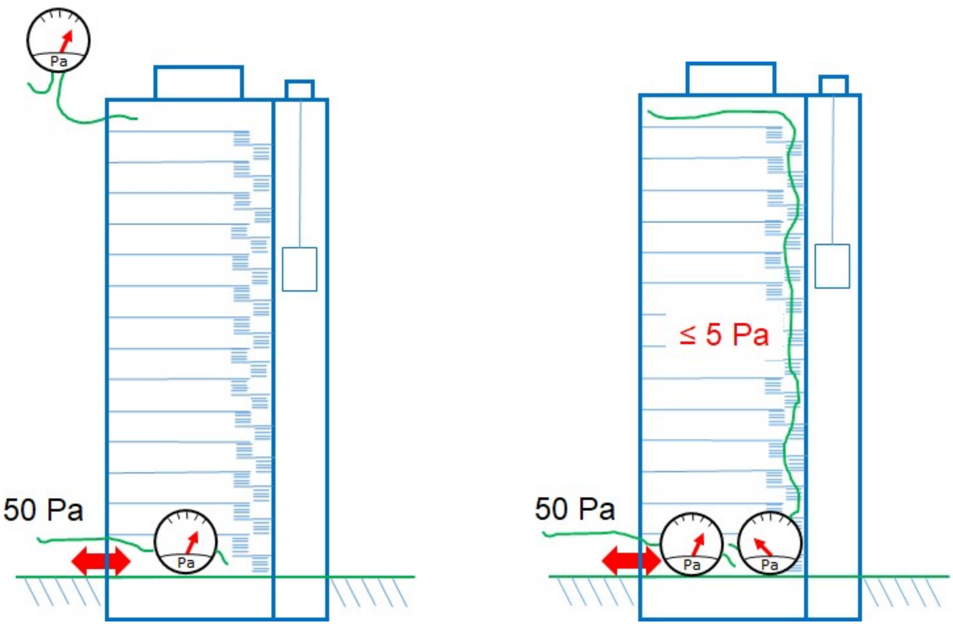


**Figure 7: Two possibilities for measuring the pressure deviation in a high-rise building, for an example with the pressure difference inside / outside of 50 Pa at the ground floor.**
**In the picture on the left, the maximum permissible deviation in the "critical room" (here for example the attic) is checked by measuring the pressure difference to the environment. The influence of the thermal effects must be deducted.**
**In the other variant (right), the pressure difference in the building is measured by a pressure hose from the ground floor to the attic (critical room). Since the hose is located inside the building, no correction is necessary here.**

## 5. Measurement error due to the non-linearity of the flow formula

Due to the fact that the generated pressure in a high building cannot be produced uniformly in the entire building, there are influences on the leakage volume flow. At an overpressure of 50 Pa on the ground floor, the leaks on the 16th floor are subjected to 122 Pa - in the previous example. The leakage volume flow will be correspondingly greater at that location due to the higher pressure difference. In the case of an underpressure measurement, the opposite is true. However, the leakage volume flow does not depend linearly on the pressure difference. According to the flow formula,

$V_L = C_L \times (dp)^n$

$V_L$: leakage volume flow [m³/h]
$C_L$: coefficient [m³/(h Pa$^n$)]
dp: Pressure difference inside-outside [Pa]
n: flow exponent [-]

The leakage volume flow rate is non-linear in relation to the pressure difference, as seen in the above equation, but assumed to be the same for both an overpressure and underpressure. This is based on the assumption that there is no dominant valve effect at the leak locations, which causes a direction-dependent flow. This non-linearity results in a deviation from the ideal case, which excludes the interior to exterior thermal effects.

As long as - as described above - only measurement points which are underpressure or overpressure for the entire building envelope are used for the calculations, the resulting error is not relevant to the other measuring errors. Thus it can be neglected.

The derivation of the defect size, using the non-linear volume flow formula, and the measured test volume flow leakages is shown in the appendix.

## 6. Measurements of large, not tall houses

The special features for airtightness measurements described in this document apply to tall buildings. If buildings are tested which have a large volume, but are not tall, e.g. schools, the thermal effects are negligible. Then, as required by the standard, it must be verified whether the deviation, from the applied pressure, does not exceed 10% in at the most unfavourable location in the building.

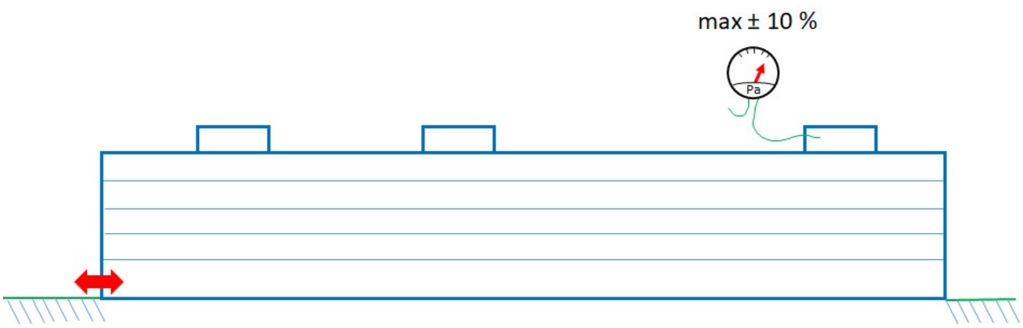


**Figure 8: Sectional view of a building with large horizontal dimensions. The red double arrow indicates the Blower Door. With such a test configuration, it must be verified at the most unfavourable pressure location whether at least 90% of the generated pressure difference between inside and outside exists. Thermal effects play only a minor role here.**

## 7. Sources

[Arena/Pratt/Brennan 2017] Arena, Lois; Pratt, Carmel; Brennan, Terry: Whole Building Blower Door Testing Results to Determine Compliance withe Passive House Airtightness, Requirements at Cornell NYCTech – H/R Residential. Steven Winter Associates, Inc and Camroden Associates, Inc, Juni 2017

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[Zeller 2012] Zeller, J.: Messung der Luftdurchlässigkeit der Gebäudehülle. In: Fachverband Luftdichtheit im Bauwesen e. V. (Hrsg.), Gebäude-Luftdichtheit. Band 1, zweite aktualisierte Auflage, Berlin: Selbstverlag, 2012

## 8. Annex: Influence of nonlinearities on the measurement results

### 8.1 Overview

In high-rise buildings, the chimney effect can lead to significant pressure differences between inside and outside. The differences in static pressure can vary from 0.5 to 1 Pa/m in winter. For a building height of 100 m, for example, this can result in a pressure difference at the ground floor and the top floor that exceeds the usual applied pressure of 50 Pa for a building airtightness test.

This topic will be examined in more detail below.

Important Note: The correct measurement result will be determined by following the appropriate procedure and minimizing the impact of the external conditions. With the same temperature inside and outside as well as no wind, the pressure test results in the **$n_{50}$**-value, which can be used to characterise the airtightness of the building.

### 8.2 Assumptions and conventions

Some of the formula nomenclature used here differs from the main body of this document. The following assumptions are made:

- The building has a homogeneous **internal temperature Ti**.
- The building has a **total height of H**.
- During the pressure test, there is no significant pressure drop in the building due to the air flow, it is treated like a single room. The installation location of the Blower Door is therefore irrelevant. *For orientation: A typical blower with 7,000 m³/h causes a pressure drop of less than 2 Pa at a 2 m² door opening. With two blowers, with a combined volume flow rate of 14,000 m³/h, the pressure loss already rises to approximately 6 Pa. As a result it would be necessary to install second blowers elsewhere in the building.*
- The external wind speed is negligibly small.
- Leaks are of the same type and evenly distributed over the height of the building. In particular, there are no significant leaks in the area of the roof or floor slab.

- Overpressure in the building is calculated positively.
- The external to internal temperature difference is positive if the inside temperature is higher than the outside temperature.
- The volume flow through the leaks depends on the pressure difference according to the following formula

  $\dot{V} = c(\Delta p)^n$ with 0,5 < $n$ < 1

  Positive values therefore indicate an air flow from the inside to the outside of the buiding through the leaks, or from the outside to the inside at the blower door test site.

The pressure difference between inside and outside is measured during the measurement at height ***$h_p$*** above ground. This measured value of the pressure difference is called $\Delta \boldsymbol{p_0}$.

## 8.3 Air change during measurement

The static pressure difference between inside and outside increases with height according to

$$\Delta p = \rho g \frac{\Delta T}{293\,K} \Delta h$$

or

$$\Delta p = 0{,}04 \frac{Pa}{K\,m} \Delta h\, \Delta T$$

At a temperature **difference ΔT** of 20 K, for example, approx. 0.8 Pa/m is the resulting value. The **pressure increase per metre** is referred to below as $\frac{dp}{dh}$.

The pressure difference across the building envelope is thus

$$\Delta p(h) = \Delta p_0 + \left(h - h_p\right) \frac{dp}{dh}$$

If the pressure difference does not depend on the height, the well-known correlation applies for the pressure test air exchange

$$n_{mess} = n_{50} \left(\frac{\Delta p}{50 Pa}\right)^n$$

with 0,5 ≤ n ≤ 1. This can also be specified per metre of building height, whereby the pressure difference can depend on the height. The result is a differential contribution to the exfiltration air exchange at height, h, above the ground:

$$n'(h) := \frac{n_{50}}{H} \left(\frac{\Delta p(h)}{50 Pa}\right)^n \qquad \text{for } \Delta p(h) > 0$$

$$n'(h) := -\frac{n_{50}}{H} \left(\frac{-\Delta p(h)}{50 Pa}\right)^n \qquad \text{for } \Delta p(h) < 0$$

Then the total air change measured at the Blower Door is:

$$n_{mess} = \int_0^H n'(h)dh$$

If the leaks are evenly distributed as assumed, the following applies for the **height, $h_0$, of the pressure-neutral level**

$$0 = \Delta p_0 + \left(h_0 - h_p\right)\frac{dp}{dh}$$

and thus

$$h_0 = h_p - \frac{\Delta p_0}{\frac{dp}{dh}}$$

This also applies to operation of the Blower Door. Even during the measurement, the pressure-neutral level can possibly be located inside the building, which means that one part of the building (for ΔT>0) is under overpressure, the other underpressure.

In the following we will only consider the most frequent case, ΔT>0.

This also includes, $\frac{dp}{dh}>0$.

For the measured volume flow during operation of the blower door, however, several cases have to be identified:

a) $0 < h_0 < H$

$$n_{mess} = -\int_0^{h_0} \frac{n_{50}}{H}\left(\frac{-\left(\Delta p_0 + \left(h - h_p\right)\frac{dp}{dh}\right)}{50\,Pa}\right)^n dh + \int_{h_0}^{H} \frac{n_{50}}{H}\left(\frac{\Delta p_0 + \left(h - h_p\right)\frac{dp}{dh}}{50\,Pa}\right)^n dh$$

$$= \left[\frac{n_{50}\,50\,Pa}{H(n+1)\frac{dp}{dh}}\left(\frac{-\left(\Delta p_0 + \left(h - h_p\right)\frac{dp}{dh}\right)}{50\,Pa}\right)^{n+1}\right]_0^{h_0}$$

$$+ \left[\frac{n_{50}\,50\,Pa}{H(n+1)\frac{dp}{dh}}\left(\frac{\Delta p_0 + \left(h - h_p\right)\frac{dp}{dh}}{50\,Pa}\right)^{n+1}\right]_{h_0}^{H}$$

$$= \frac{n_{50}\,50\,Pa}{H(n+1)\frac{dp}{dh}}\left\{\left(\frac{-\left(\Delta p_0 + \left(h_0 - h_p\right)\frac{dp}{dh}\right)}{50\,Pa}\right)^{n+1} - \left(\frac{-\left(\Delta p_0 - h_p\frac{dp}{dh}\right)}{50\,Pa}\right)^{n+1} + \left(\frac{\Delta p_0 + \left(H - h_p\right)\frac{dp}{dh}}{50\,Pa}\right)^{n+1} - \left(\frac{\Delta p_0 + \left(h_0 - h_p\right)\frac{dp}{dh}}{50\,Pa}\right)^{n+1}\right\}$$

Because

$$0 = \Delta p_0 + \left(h_0 - h_p\right)\frac{dp}{dh}$$

this expression is simplified to

$$n_{mess} = \frac{n_{50}\ 50\ Pa}{H(n+1)\frac{dp}{dh}} \left\{ \left( \frac{\Delta p_0 + (H - h_p)\frac{dp}{dh}}{50\ Pa} \right)^{n+1} - \left( \frac{-\left(\Delta p_0 - h_p \frac{dp}{dh}\right)}{50\ Pa} \right)^{n+1} \right\}$$

b) $h_0 < 0$. There is overpressure everywhere in the building, the first sum and integral under a) is omitted. It remains

$$n_{mess} = \int_0^H \frac{n_{50}}{H} \left( \frac{\Delta p_0 + (h - h_p)\frac{dp}{dh}}{50\ Pa} \right)^n dh$$

$$= \frac{n_{50}\ 50\ Pa}{H(n+1)\frac{dp}{dh}} \left\{ \left( \frac{\Delta p_0 + (H - h_p)\frac{dp}{dh}}{50\ Pa} \right)^{n+1} - \left( \frac{\Delta p_0 - h_p \frac{dp}{dh}}{50\ Pa} \right)^{n+1} \right\}$$

c) $h_0 > H$. There is negative pressure everywhere in the building, the second sum is omitted. It remains

$$n_{mess} = -\int_0^H \frac{n_{50}}{H} \left( \frac{-\left(\Delta p_0 + (h - h_p)\frac{dp}{dh}\right)}{50\ Pa} \right)^n dh$$

$$= \frac{n_{50}\ 50\ Pa}{H(n+1)\frac{dp}{dh}} \left\{ \left( \frac{-\left(\Delta p_0 + (H - h_p)\frac{dp}{dh}\right)}{50\ Pa} \right)^{n+1} - \left( \frac{-\left(\Delta p_0 - h_p \frac{dp}{dh}\right)}{50\ Pa} \right)^{n+1} \right\}$$

## 8.4 Correction calculation

### 8.4.1 Calculation of $n_{50}$

The results for $n_{mess}$ under a), b) and c) contain the desired value for $n_{50}$ a function of $n_{mess}$. The determination of $n_{50}$ is therefore possible from these relations. In principle, a correction calculation for all conceivable pressures would be possible; however, since the assumptions made for the derivation will not usually apply in practice, this is discouraged. The application, for the following example, also shows that the resulting corrections are of negligible magnitude if one follows the above recommendations for practical implementation of the evaluation.

### 8.4.2 Example

A skyscraper is measured, 100 m high, dp/dh = 0,7 Pa/m, $n_{50}$ = 0,6 $h^{-1}$, exponent n = 0,66. The blower door is installed at the ground floor, where the pressure difference measurement also takes place.

Zero pressure with the blower door closed results in -35 Pa. The measured volume flows deviate significantly from each other at overpressure and underpressure:

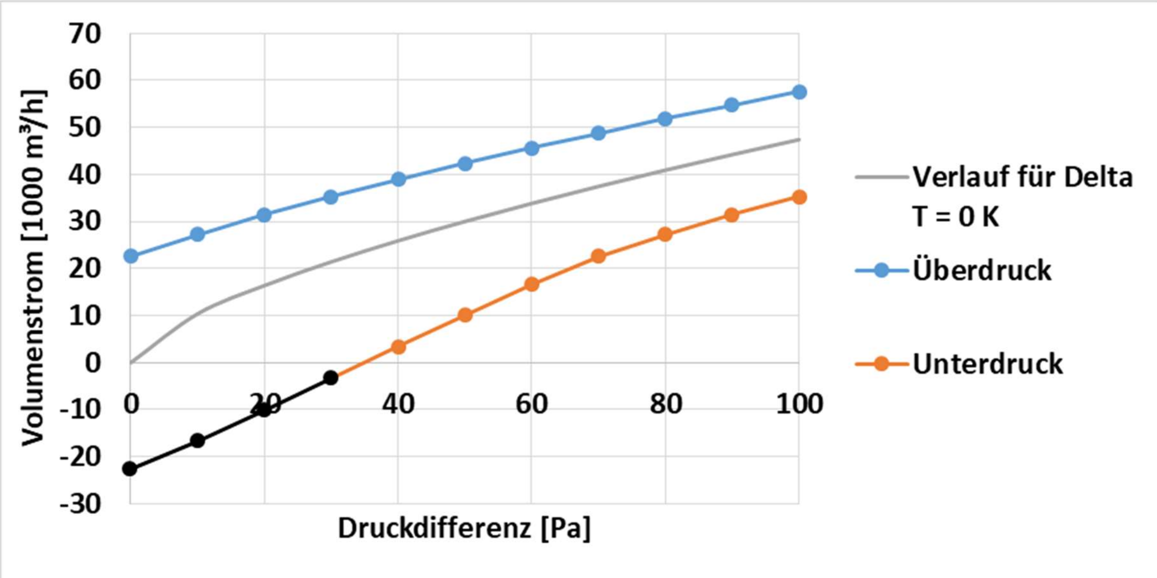


**Figure 9: Measured volume flow and measured pressure difference if blower door installation and measurement take place at the ground floor. Since the zero pressure is already -35 Pa, the Blower Door would have to draw air into the building (black dots) to achieve lower negative pressures.**

If, on the one hand, the applied pressure difference is corrected by the zero pressure, as shown in Figure 10, the measurement can be evaluated immediately. According to the above calculation, there are certain deviations from the results that would occur if there was zero temperature difference between inside and outside ("Delta T = 0 K"), but, however, they are insignificant for the evaluation of the airtightness of the building. The prerequisite is that the building is completely underpressure or overpressure; this is the case here from 35 Pa.

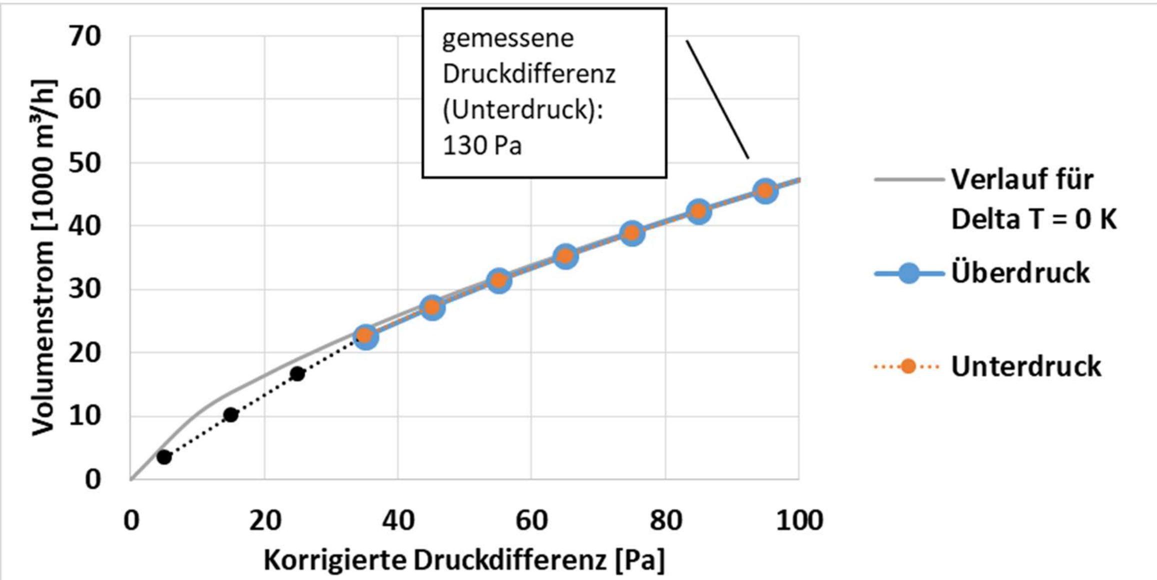


**Figure 10: Measurement, as in Figure 6, the pressure difference is corrected by the zero pressure. If the corrected pressure difference is less than 35 Pa, the building is simultaneously under and over pressure (black dots).**

During the measurement, it must be ensured that sufficiently high pressure differences are generated for later result's evaluation. For example, in order to measure the points shown in Figure 10, up to 130 Pa must be generated during the underpressure measurement.

With larger building heights and temperature differences, the measuring point with 50 Pa (corrected) overpressure or underpressure may possibly not be used at all, because no complete underpressure or overpressure in the building can be achieved. In this case, the number of measurement points must be extrapolated to determine $n_{50}$.