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New findings on measurements of very airtight buildings

The trend in European countries is that the airtightness of buildings (Passive houses, certain large buildings, apartments) is getting better and better. This leads to new challenges when performing airtightness tests: Much more time than usual and patience is needed. This work shows the modified measurement procedure and gives recommendations how to achieve reliable test results.

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Over the last decades, airtightness has become a necessary and important characteristic of the building envelope. Many years of experience as well as growing know-how in the production of good air barriers frequently lead to building airtightness of excellent quality [Leprince]. Large buildings with specific airtightness requirements, for example oxygen reduction in warehouses for chemicals or food items, show air change rates (n_{50}-value) as low as 0.03 h^{-1}. Passive houses and apartments in some instances achieve n_{50}-values significantly below 0.6 h^{-1}.

It can be observed that the common measurement of these extremely airtight objects is reaching its limits. This leads to new challenges for measurement technology and measurement teams.

This article will look at the measuring procedure in such cases and give recommendations on how to achieve reliable and repeatable airtightness test results.

Description of the problem

There is little experience about how long it takes to build-up a stable and constant pressure difference in a building or apartment during an airtightness test with the BlowerDoor. When testing buildings with very low air change rates (n_{50}-values $\ll$ 0.6 h^{-1}) the normal automated test does not seem to work properly. One indication of this is when the readings fluctuate strongly around the target pressure and the measurement is interrupted after some time. If the individual measuring points are widely scattered around the line of best fit (the correlation coefficient in this case is significantly lower than 0.98), this is further indication.

Based on experience from measurements and calculations, the following sections will show which pressure build-up times can be expected in buildings with very low air change rates (n_{50}-values).

Testing very airtight objects

Real-time display and recording of all readings from an airtightness test

To investigate the reasons for the different measurement behaviour, we recorded the measurements of different buildings with low and extremely low air change rates with a data logger program (TECLOG from The Energy Conservatory). This program shows and records the building pressure difference and the readings of the BlowerDoor fan (airflow and fan pressure) over time in real time.

The characteristics of the measurement curves with sampling intervals of one second make it possible to trace the build-up of the building pressure [Brennan et al.]. This enables the measurement team to react appropriately to special measurement situations.

Example of a very slow pressure build-up

The following object shows an example of how the building pressure of one measuring point is built up in a very airtight building. **Figure 1** shows a warehouse with an interior volume of V = 46,600 m³. The impressively low air change rate n_{50} is 0.03 h^{-1}, in order to be able to keep the input of nitrogen into the hall, which is necessary for food technology reasons, as low as possible. This allows the system to be used for oxygen reduction can be held small and the power consumption minimized.

How the building pressure is built-up after turning on the measuring fan can be seen in the following diagram (**Figure 2**). The horizontal timeline runs the time during the measurement, and the y-axis shows the pressure difference in Pascal. The green curve shows the progression of the building pressure difference and the red curve the fan pressure at the measuring fan, resulting in the airflow depending on the fan configuration (ring).

Slightly before 9:51 a.m., the red curve for the fan pressure strongly declines from 0 Pa to ca. –350 Pa, indicating that the measuring fan (Minneapolis BlowerDoor Model 4, B Ring) has been turned on. The green curve for the building pressure increases comparatively slowly from the 0 Pa starting pressure to the target pressure of approx. 50 Pa. The closer the curve comes to the 50 Pa, the flatter it becomes (asymptotic progression).

At 9:56 a.m., **after** about **5 minutes** (**300 seconds**), both **measurement curves** run **parallel to** the **time axis**. This is the **sign** that the **target pressure has been reached** with sufficient accuracy and that no further serious changes are to be expected. Only from this point on we can assume stable and constant conditions.

Now, over at least 30 seconds, readings for this pressure stage can be recorded and averaged. This average value is one single test point of at least five measuring points (ISO 9972 / EN 13829) from which the leakage curve for this building is calculated.

Figure 1. Warehouse for herbs with an air change rate n_{50} = 0.03 h^{-1}, internal Volume V = 46,400 m^3 and airflow at 50 Pa V_{50} = 1.620 m^3/h.

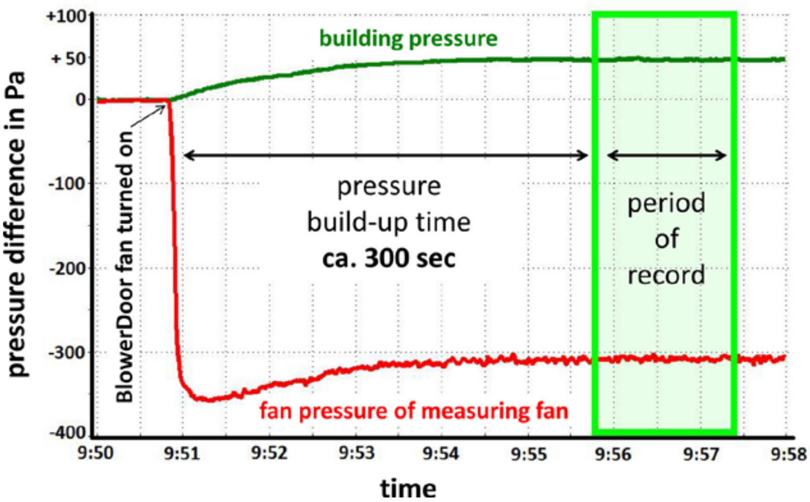

Figure 2. Approx. 300 seconds build-up time from 0 Pa starting pressure to 50 Pa building pressure (green curve from approx. 9:51 to 9:56).

Calculation of the pressure build-up time

In order to control the measurement optimally, it is necessary to know the pressure build-up times for very airtight objects. Calculations by [Zeller] show that the **pressure build-up time is inversely proportional to the air change rate at 50 Pa (n_{50}-value).** Basis of his calculations are the ideal gas equation, the equation for the leakage curve of a building, and assuming a constant airflow (independent of the building pressure). **Figure 3** shows the pressure build-up times for different air change rates when the building pressure is controlled from 50 Pa starting pressure to 40 Pa target pressure. An air flow exponent of 0.67 is assumed for this calculation.

The diagram clearly shows that with decreasing air change rates the pressure build-up times increase until a constant building pressure is achieved. The 40 Pa building pressure is built-up within a few seconds if the n_{50}-value is 3 h^{-1}. The build-up time is around 15 seconds at an n_{50} of 0.6 h^{-1} (green curve, Passive House requirement) and much more than approx. 300 seconds if the n_{50} is 0.03 h^{-1} (grey curve).

For the measuring practice, the following equation [Zeller] helps to estimate the minimum pressure build-up time for each single test point of a multipoint airtightness test that must be planned for achieving repeatable and reliable tests results.

$$t(\mathrm{s}) = \frac{9(\mathrm{s/h})}{n_{50}(\mathrm{h}^{-1})}$$

Where

t = pressure build-up time in seconds

n_{50} = air-change rate in h^{-1}

Boundary conditions:

- Pressure stages in increments of approximately 10 Pa
- Airflow exponent around 0.67
- Target pressure is reached with a tolerance of ±0.5 Pa.

Example:

The desired air change rate at 50 Pa: $n_{50} \leq 0.1\ h^{-1}$.

$$t(\mathrm{s}) = \frac{9(\mathrm{s/h})}{n_{50}(\mathrm{h}^{-1})} = \frac{9(\mathrm{s/h})}{0.1\ (\mathrm{h}^{-1})} = \mathbf{90\ s}$$

The pressure build-up time for this example is ca. 90 seconds per pressure stage.

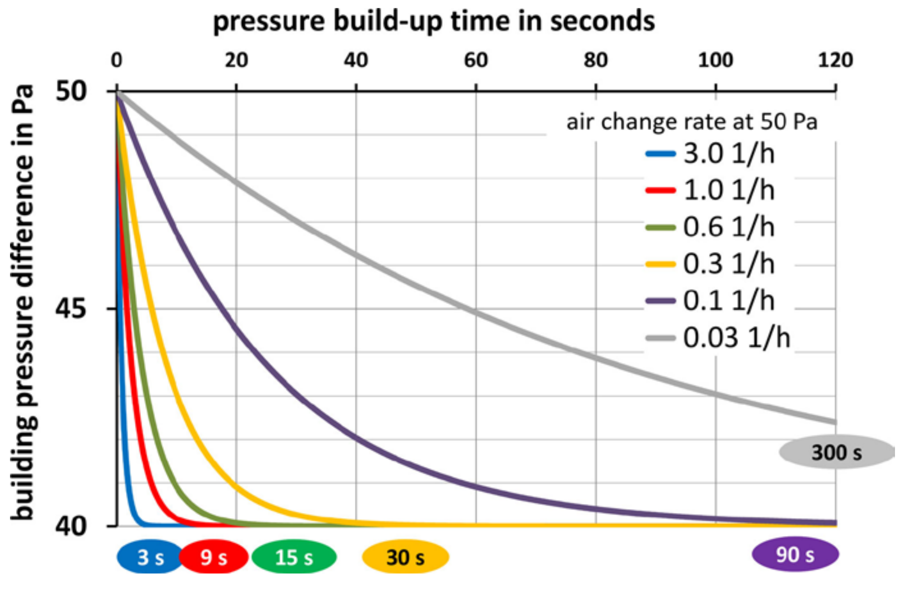

Figure 3. Pressure build-up times for different air change rates at 50 Pa (n_{50}-value). The starting pressure is 50 Pa and the target pressure 40 Pa. The airflow exponent n of the leakage curve is 0.67 [Zeller].

The calculated build-up times may deviate from a real test. The following factors affect the pressure build-up time, among others:

- The build-up time is decreased if the increment between the measuring points is reduced from 10 Pa (70 Pa, 60 Pa, 50 Pa, etc.) to 5 Pa (70 Pa, 65 Pa, 60 Pa, etc.).
- A higher airflow exponent of the leakage curve will reduce the build-up time.

Comparing the calculations with the real-test example

For comparisons, the pressure build-up time for the building presented before is calculated. The air change rate is 0.03 h^{-1} and the airflow exponent of the leakage curve n is 1. The diagram in **Figure 4** shows the calculated pressure build-up time from 0 Pa starting pressure to a target pressure of 50 Pa.

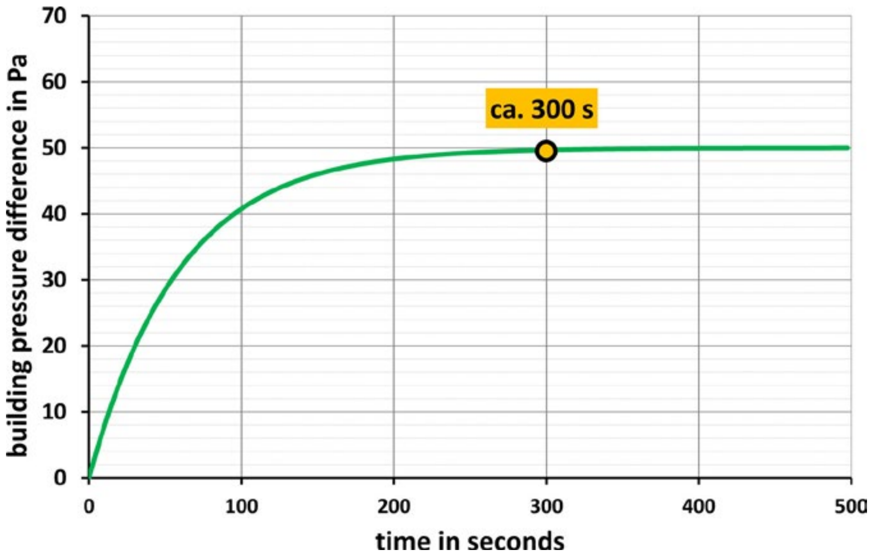

Figure 4. Calculated pressure build-up time for a building with n_{50} = 0.03 h^{-1}, airflow exponent n = 1 and increasing the building pressure from 0 Pa to ca. 49.5 Pa.

The calculation shows that 49.5 Pa building pressure is reached after approx. 300 seconds. During the real airtightness measurement, the target pressure had been built up sufficiently after about 300 seconds (see Figure 2).

This means that the calculations correspond very well to the experience in real life.

Conclusions

Measurement experiences show, that airtightness tests of very airtight buildings such as warehouses with air change rates at 50 Pa of 0.03 h^{-1} (e.g. due to oxygen reduction), passive houses or apartments with n_{50}-values lower or much lower than 0.6 h^{-1} take longer than tests in buildings with common air change rates.

This is due to the fact that the **pressure build-up time** for one building pressure difference during a depressurization or pressurization test **is inversely proportional to the air change rate at 50 Pa** (n_{50}-value) of the building [Zeller]. The smaller the n_{50}-value, the longer it takes for the required target pressure to build up (e. g. the build-up time for an n_{50} of 3 h^{-1} is approx. 3 seconds, for 0.3 h^{-1} approx. 30 seconds or for 0.03 h^{-1} approx. 300 seconds).

The comparison between the pressure build-up times actually achieved and the theoretical calculations result in a very good agreement.

With the help of the formula for estimating the pressure build-up time [Zeller] and the use of data logger software with display of the building pressure differences and the airflow of the test equipment in real time, traceable and reliable measurement results can be achieved even in very airtight buildings. ■

References

Brennan, T., Clarkin, M. Nelson, G., Olson, C., Morin, P. (2014): Beyond single family residential. The Energy Conservatory, Minneapolis US.

Leprince, V. (2018): Mesure d'étanchéité à l'air à petit débit.

Zeller, J. (2019): unpublished study on temporal progress of pressure build-up (in German language).

EN 13829 (2001): Thermal performance of buildings – Determination of air permeability of buildings – Fan pressurization method (ISO9972:1996, modified)

ISO 9972 (2015): Thermal performance of buildings — Determination of air permeability of buildings – Fan pressurization method (ISO 9972:2015).

Reference Guide BlowerDoor Standard and Reference Guide BlowerDoor MiniFan (2018) as well as Reference Guide BlowerDoor MultipleFan (2018).