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# PRACTICAL RECOMMENDATIONS FOR AIRTIGHTNESS TESTS IN HIGH-RISE BUILDINGS

AIVC/TightVent Webinar – 26 January 2024

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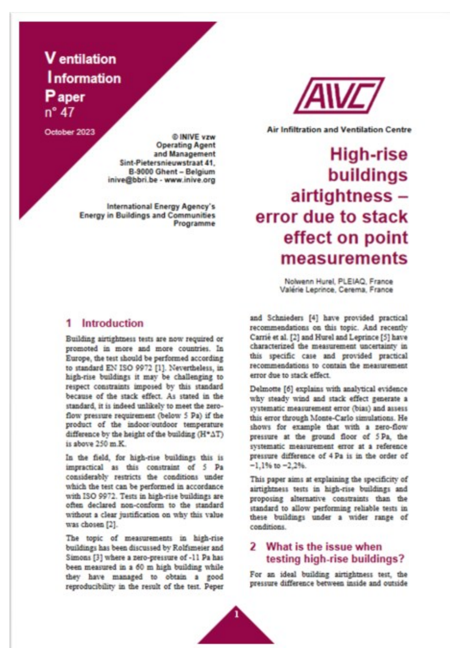
## AIVC PUBLICATION

**VIP 47: High-rise buildings airtightness – error due to stack effect on point measurements**
*(Hurel & Leprince, 2023)*

- **New criteria** for high-rise buildings
- **Analysis of the error** due to stack effect
- **New test methodology**
- **Practical recommendations**

**Focus of this presentation**



Ventilation Information Paper
n° 47
October 2023

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International Energy Agency's Energy in Buildings and Communities Programme

AIVC
Air Infiltration and Ventilation Centre

High-rise buildings airtightness – error due to stack effect on point measurements

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1 Introduction

Building airtightness tests are now required or promoted in more and more countries. In Europe, the test should be performed according to standard EN ISO 9972 [1]. Nevertheless, in high-rise buildings it may be challenging to respect constraints imposed by this standard because of the stack effect. As stated in the standard, it is indeed unlikely to meet the zero-flow pressure requirement (below 5 Pa) if the product of the indoor/outdoor temperature difference by the height of the building (H*ΔT) is above 250 m.K.

In the field, for high-rise buildings this is impractical as this constraint of 5 Pa considerably restricts the conditions under which the test can be performed in accordance with ISO 9972. Tests in high-rise buildings are often declared non-conform to the standard without a clear justification on why this value was chosen [2].

The topic of measurements in high-rise buildings has been discussed by Rolfsmeier and Simons [3] where a zero-pressure of -11 Pa has been measured in a 60 m high building while they have managed to obtain a good reproducibility in the result of the test. Peper and Schnieders [4] have provided practical recommendations on this topic. And recently Carrié et al. [2] and Hurel and Leprince [5] have characterized the measurement uncertainty in this specific case and provided practical recommendations to contain the measurement error due to stack effect.

Delmotte [6] explains with analytical evidence why steady wind and stack effect generate a systematic measurement error (bias) and assess this error through Monte-Carlo simulations. He shows for example that with a zero-flow pressure at the ground floor of 5 Pa, the systematic measurement error at a reference pressure difference of 4 Pa is in the order of −1,1% to −2,2%.

This paper aims at explaining the specificity of airtightness tests in high-rise buildings and proposing alternative constraints than the standard to allow performing reliable tests in these buildings under a wider range of conditions.

2 What is the issue when testing high-rise buildings?

For an ideal building airtightness test, the pressure difference between inside and outside

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New criteria

Error due to stack effect

Test methodology & practical advices



## CONFLICTS WITH STANDARD ISO 9972

Some criteria are difficult to meet:

- **Zero-flow pressure measurements:** $|\Delta P_{0,ground}| < 5$ Pa
  - 50 m high building, $|\Delta P_{0,ground}| < 5$ Pa → $\Delta T < 4.5$°C
- **Lowest pressure station** > 5 x$|\Delta P_{0,ground}|$
  - 50 m high building, $\Delta T = 15$°C → $|\Delta P_{s,ground}| > 82$ Pa
- **Single zone:** "*The entire building or part of the building to be tested shall respond to pressurization as a single zone*"
  → Challenging as for any large building


FINAL DRAFT

INTERNATIONAL STANDARD

ISO/FDIS 9972

Thermal performance of buildings — Determination of air permeability of buildings — Fan pressurization method

Please see the administrative notes on page iii

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## NEW CRITERIA SUGGESTED

### Standard ISO 9972

- **Zero-flow pressure measurements:** $|\Delta P_{0,ground}| < 5$ Pa
- **Lowest pressure station** $|\Delta P_{s,ground}| > 5 \times |\Delta P_{0,ground}|$

### New criteria suggested (high-rise)

- **Zero-flow pressure measurements:** standard deviation < 5 Pa
- **Averaging pressurization & depressurization tests**
- **Entire building pressurized/depressurized** with a margin of 10 Pa (ideally)
- **Limit on the stack effect:** H x ΔT < 2000 m.K (Ideally < 1250 m.K for multiple points < 100 Pa)

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New criteria

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# ERROR DUE TO STACK EFFECT

**Maximum error:** on the **1st pressure** measurement station

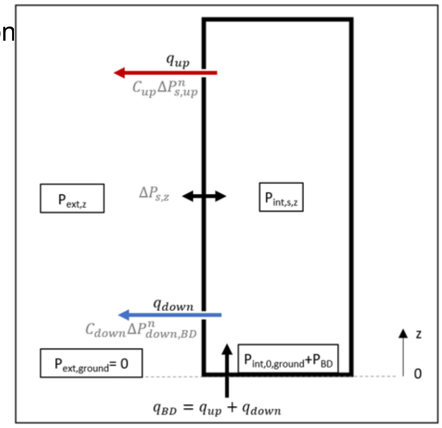
**Parameter study:**

- ISO criteria
- New criteria

**Leakage distrib.** ($C_{up}/C_t$)
**Min:** 0
**Max:** 1
**Step:** 0,01

**Stack effect** (H x ΔT)
**Min:** 50 m.K
**Max:** 2000 m.K
**Step:** 50 m.K

- Pressurization
- Depressurization
- Average






# ERROR DUE TO STACK EFFECT

**Main results:**

## Standard ISO 9972

- H*ΔT > 1000 m.K. : Test possible for **< 20%** of simulated configurations

## New criteria suggested

- Test possible for **every leakage distribution**

**→ Increased possibilities of tests**

- Maximum error **always higher** for a given repartition

- Maximum error < 10%

**→ Reduced maximum error**

New criteria

Error due to stack effect

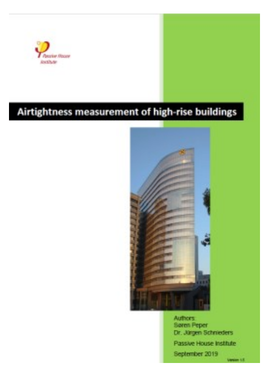
Test methodology & practical advices

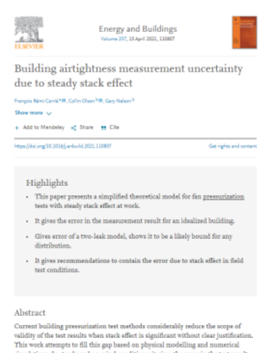


# TESTING METHODOLOGY

**Two main references:**

- Passive House Institute Guideline
  (Peper and Schnieders 2019)
- "Building airtightness measurement uncertainty due to steady stack effect"
  (Carrié, Olson and Nelson 2021)





Energy and Buildings
Volume 237, 15 April 2021, 110807

Building airtightness measurement uncertainty due to steady stack effect

François Rémi Carrié, Collin Olson, Gary Nelson

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Highlights

- This paper presents a simplified theoretical model for fan pressurization tests with steady stack effect at work.
- It gives the error in the measurement result for an idealized building.
- Gives error of a two-leak model, shows it to be a likely bound for any distribution.
- It gives recommendations to contain the error due to stack effect in field test conditions.

Abstract

Current building pressurization test methods considerably reduce the scope of validity of the test results when stack effect is significant without clear justification. This work attempts to fill this gap based on physical modelling and numerical simulations. In steady and no-wind conditions, it gives the error in the test result

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## TESTING METHODOLOGY

**1) Reduce as much as possible the temperature difference between inside and outside**

- massive **airing and ventilation** before the test
- **closing shutters** or other solar protections
- performing the test during the **night** (sunny weather) and/or in **mid-season**
- etc.

Credit: Trendsideas

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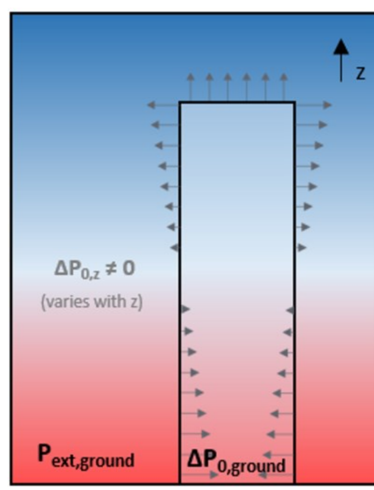
## TESTING METHODOLOGY

**2) Measure the zero-flow pressure $\Delta P_{0,ground}$ and check that:**

- standard deviation < 5 Pa
- $H*\Delta T$ < 2000 m.K

  (Ideally < 1250 m.K for multiple points < 100 Pa)

*A first check a few days before the test according to the weather forecast is recommended to reschedule the test if necessary*

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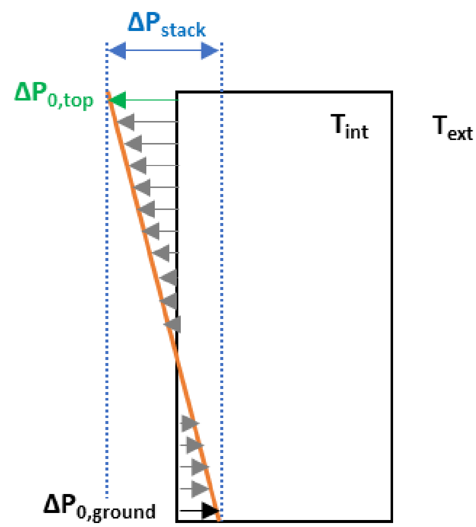
## TESTING METHODOLOGY

3) **Calculate $\Delta P_{stack}$ :**

$$\Delta P_{stack} \approx 0.044 \times H \times (T_{int} - T_{ext})$$

**and estimate the zero-flow pressure at the top of the building $\Delta P_{0,top}$ :**

$$\Delta P_{0,top} = \Delta P_{0,ground} + \Delta P_{stack}$$





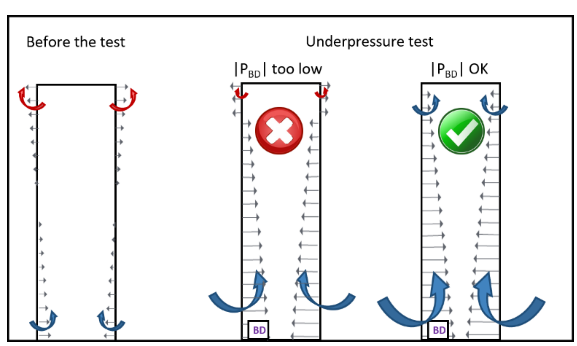

## TESTING METHODOLOGY

4) **Determine the minimum absolute pressure that shall be generated to guarantee that the building is fully pressurized**

$$|P_{BD,min}| = \max(|\Delta P_{0,top}|; |\Delta P_{0,ground}|) + margin$$

*Recommended margin: **10 Pa** to compensate for:*
- *The pressure measurement uncertainty*
- *The pressure fluctuation in time and around the building's envelope (wind)*

*For **winds ≥ 3** (Beaufort scale) : measure the zero-flow pressure all around the building's envelope to make sure that the margin is high enough*



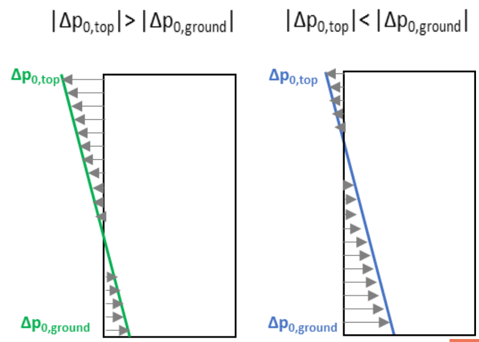
# TESTING METHODOLOGY

**5) Calculate the pressure difference at the ground floor to be reached for the first test pressure difference**

To ensure same absolute values in pressurization and depressurization:

| $\Delta p_{s,ground}$ | $\lvert\Delta p_{0,top}\rvert > \lvert\Delta p_{0,ground}\rvert$ | $\lvert\Delta p_{0,top}\rvert < \lvert\Delta p_{0,ground}\rvert$ |
|---|---|---|
| Press. | $\Delta p_{stack} + 2 \times \Delta p_{0,ground} + 10$ | 10 |
| Depress. | $-\Delta p_{stack} - 10$ | $2 \times \Delta p_{0,ground} - 10$ |

*Alternative (≠ absolute values):*
- ***pressurization:*** $\Delta ps,ground,p+ = margin$
- ***depressurization:*** $\Delta ps,ground,p- = -\Delta pstack - margin$





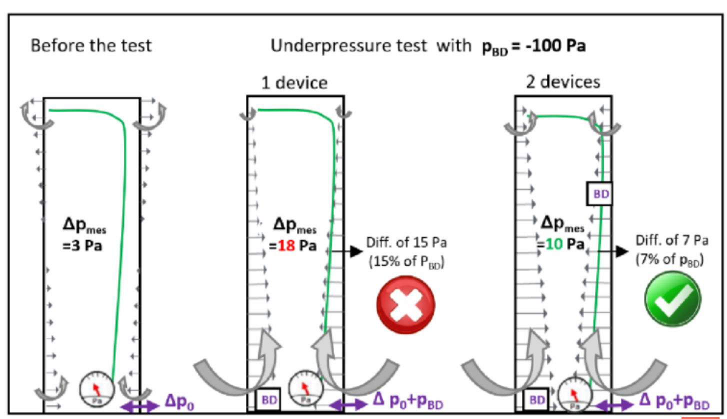

# TESTING METHODOLOGY

**6) Check the pressure homogeneity inside the building**

Verify that the **pressure difference between the top and bottom of the building does not vary by more than 10% of $p_{BD}$** when comparing before and during the test (pressure deviation)

***Fan location:***
- *In a large room as close as possible to the stairwell(s)/lift.*
- *Usually: easier at the ground floor, Ideally: at neutral pressure plane*

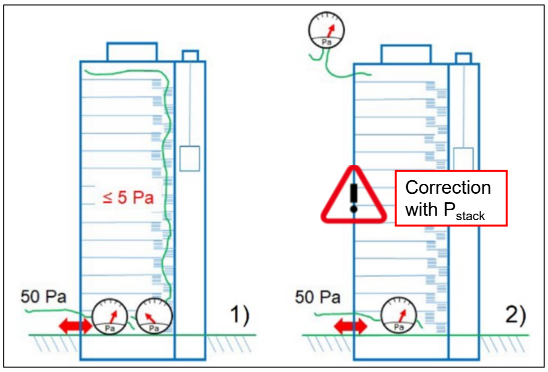
***Homogeneity NOT verified:***
*→ Try to install additional fan(s) distributed along the envelope*



## TESTING METHODOLOGY

**6) Check the pressure homogeneity inside the building**

Two possibilities for measuring the pressure deviation :




*(Peper and Schnieders 2019)*

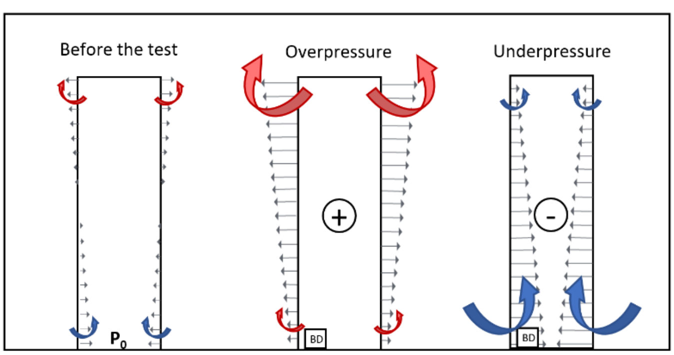
*__To avoid the wind impact__ on the upper measurement, __option 1) is preferable.__ When only option 2) is possible, the pressure can be measured on several façades and averaged (if possible)*





## TESTING METHODOLOGY

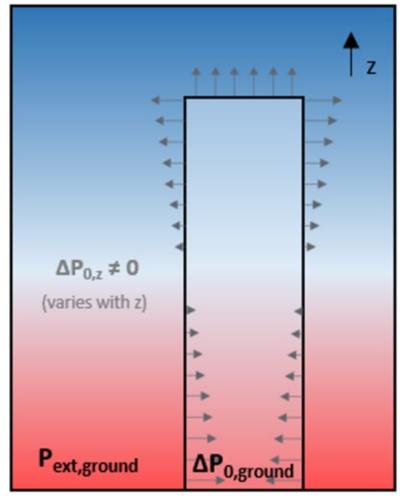
**7) Conduct the air leakage measurement at several pressure stations in pressurization and depressurization modes**




*As recommended by standard ISO 9972, __the highest test pressure difference__ should be above 25 Pa and as high as possible up to 100 Pa.*

## TESTING METHODOLOGY

8) **Measure the the zero-flow pressure $\Delta P_{0,ground}$ after the test and check that its standard deviation is less than 5 Pa**

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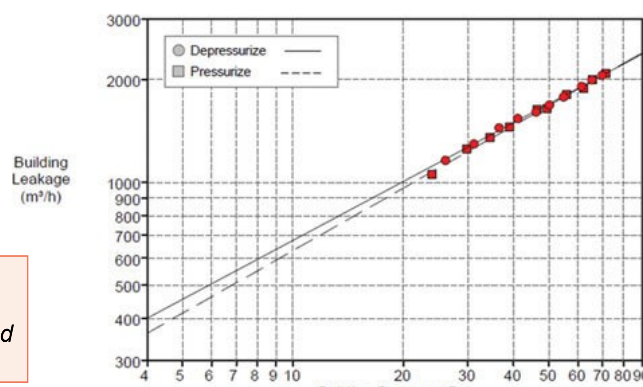
## TESTING METHODOLOGY

9) **Calculate the result by averaging the pressurization and depressurization tests results after regression**




*(Yongming & Duanmu, 2016)*

*If this methodology cannot be followed: consider dividing the building for the test (sampling allowed in some countries as UK & France)*

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## THANK YOU FOR YOUR ATTENTION

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