# Airtightness of buildings – Considerations regarding place and nature of pressure taps

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## ABSTRACT

This paper discusses two particular points of the buildings airtightness measurement method (ISO 9972) in relation with the pressure difference: (1) the nature of the pressure tap and (2) the place of the pressure tap outside.

The principle of the buildings airtightness measurement method is to measure the pressure difference induced by a given air flow rate generated by a fan. To that end, pressure measurements are made between inside and outside the building. However, with the increasing number of measurements and laboratories, more and more varied pressure taps such as pierced bottles or traffic cones are appearing. In addition, the place of the pressure tap outside largely varies; from very close to the building to very far away.

Although this may seem insignificant at first glance, the nature and the place of the pressure taps play a crucial role in the measurement uncertainty. This is mainly due to the effect of wind on the building and the dynamic pressure it generates.

This paper explains why it is necessary to use static pressure taps and place them away from the building and possible obstacles.

## KEYWORDS

Airtightness of buildings, pressure tap, pressure difference, wind, zero-flow pressure

## 1 INTRODUCTION

In European countries, increasing importance has been given to airtightness of buildings since the first publication of the directive on the energy performance of buildings in 2002. In some countries there are even requirements or financial incentives linked with the airtightness level. It is therefore more and more important to pay attention to the quality of airtightness measurements.

Following the increase in the number of measurements and laboratories, discrepancies are beginning to appear in some aspects of the test. This is the case, for example, for pressure taps for which some use drilled bottles or traffic cones. The location of the pressure tap outside also varies greatly, from very close to the building to very far away; some even take the pressure from inside their car.

Although this may seem insignificant at first glance, the nature and the place of the pressure taps play a crucial role in the measurement uncertainty. This is mainly due to the effect of wind on the building and the dynamic pressure it generates.

## 2 PRESSURE DIFFERENCE INDUCED BY THE FAN

In given climatic conditions (wind and temperature) and in the absence of fan, pressure differences $\Delta p_{0,j}$ are naturally generated across the envelope of a building. The equilibrium internal pressure is such that the air flow that enters the building is equal to the flow that leaves. The sum of the air flows through the building envelope is therefore equal to zero (formally we should talk about mass flow). Accordingly, parts of the envelope must necessarily undergo underpressure while others are in overpressure.

In the absence of wind or temperature difference, the action of a fan located in the building envelope induces an identical pressure difference $\Delta p$ across all points of the envelope. However, this is not quite true because the internal partitioning of the building may generate pressure drop (see 3.6). ISO 9972 requires opening all interior doors in order to minimize this effect and to consider the whole building as a single zone.

When adding the effect of a fan to that of the wind and of the temperature difference, each point (j) of the envelope is subjected to a pressure difference $\Delta p_{m,j}$ equal to the sum of those it would undergo for each of the two separate effects ($\Delta p$ and $\Delta p_{0,j}$) (Sherman 1990) (Figure 1 and Formula 1). Each point thus undergoes a similar change in pressure while keeping its relative difference compared to the other points. Note that this principle of addition is not true for air flow rates.

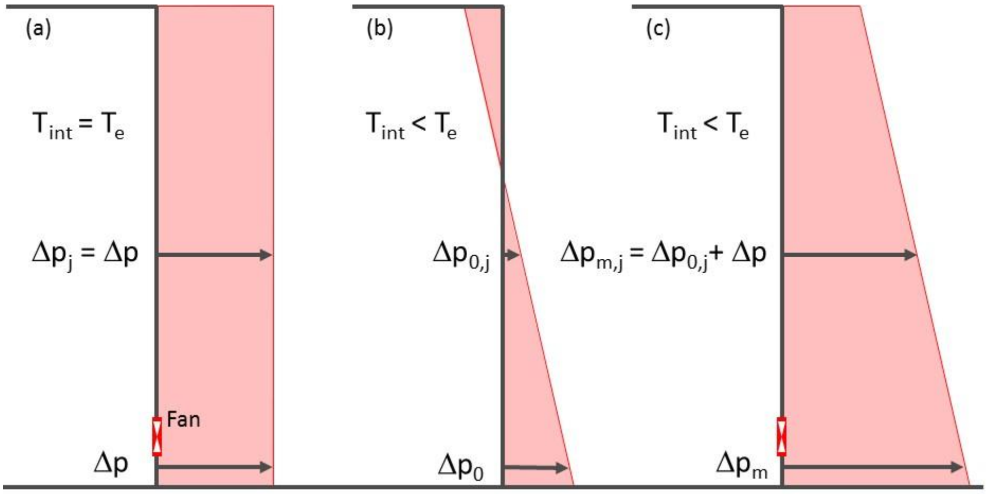

Figure 1: Example of pressure distribution over the height of a building (a) for a fan only, (b) for a temperature difference only and (c) for the combination of the fan and the temperature difference.

Additivity of pressure differences is used in ISO 9972 to indirectly measure the pressure difference induced by the fan:

1. Zero-flow pressure difference $\Delta p_0$: Pressure difference is measured between inside and outside the building when it is subject to natural conditions only (fan off and covered)
2. Measured pressure difference $\Delta p_m$: Pressure difference is measured between inside and outside the building when the fan is operating
3. Induced pressure difference $\Delta p$: Pressure difference induced by the fan is calculated by subtracting the first value from the second one (Formula 2)

$$\Delta p_{m,j} = \Delta p_{0,j} + \Delta p \tag{1}$$

$$\Delta p = \Delta p_m - \Delta p_0 \tag{2}$$

The principle of the buildings airtightness measurement method (ISO 9972) is then to make the link between the air flow rate generated by the fan and the induced pressure difference in order to characterize the airtightness of the building.

# 3 MEASUREMENT ERROR

## 3.1 Possible sources of error

Considering that the basis of the measurement method is to determine the induced pressure difference, a closer look into the way it is done is necessary.

At the start of the test, the building is subject to the equilibrium internal pressure. A stable pressure reference outside the building is necessary to measure this pressure with a differential manometer.

During the test, the fan is on and the building is subject to the sum of the induced pressure and the equilibrium internal pressure. This is measured with the same differential manometer and pressure taps at the same place.

While the measurement principle is very simple, there are different possible sources of error:

- Dynamic pressure inside the building;
- Dynamic pressure outside the building;
- Wind pressure on the building;
- Change in the equilibrium internal pressure;
- Measuring instruments (not included in this paper).

## 3.2 Dynamic pressure inside the building

Inside the building, there are inevitably places where air flows at a certain speed. At these places, part of the total pressure is dynamic pressure and the static pressure is therefore not representative of the sum of the induced pressure and the equilibrium internal pressure. Measuring the total pressure (sum of the static pressure and dynamic pressure) is no option in practice since the flow direction is unknown or disrupted.

These places are located

- next to the fan;
- in narrow spaces (e.g. corridor) or openings (e.g. door);
- or next to large leaks in the envelope.

Placing the pressure tap far away from all these places is good practice.

## 3.3 Dynamic pressure outside the building

In free field outside the building, there is atmospheric pressure (static pressure) and possible wind pressure (dynamic pressure). Since the pressure outside is taken as a stable reference pressure and wind is fluctuating in speed and direction, it is advisable to avoid the dynamic pressure.

To this end, it is necessary to use a special pressure tap that is not influenced by dynamic pressure and measures static pressure only. The principle of such a tap is to force the air flow in a given direction and measure the pressure perpendicularly to that direction (see examples in Figure 2). Note that a T-pipe fitted at the end of the tubing of the manometer is often used in practice.

Figure 2: Examples of static pressure taps (sources: Vaisala, Paragon Controls Incorporated, Micatrone)

### 3.4 Change in the equilibrium internal pressure

Another effect of the fluctuating wind is that it changes the equilibrium internal pressure in the building. Unfortunately, this change in internal pressure cannot be isolated from the induced pressure. Moreover, in practice it is not possible to calculate it from the pressure changes on the walls of the building.

During the test, a change in the temperature difference between inside and outside may occur for different reasons, e.g.:

- Change of outside temperature;
- Stopping of the heating system;
- Introduction in the building of large quantities of air from outside;
- Solar gains in the building.

Such a change also influences the equilibrium internal pressure in the building.

In order to have an idea of the possible change in equilibrium internal pressure during the test, ISO 9972 requires measuring it over a period of at least 30 seconds at the start and at the end of the test (zero-flow pressure difference).

Applying measured pressures differences much higher than the zero-flow pressure difference is therefore necessary in order to limit the influence of the possible changes in equilibrium internal pressure (ISO 9972 requires five times the value of the zero-flow pressure difference).

Note that a change in atmospheric pressure is equally felt by all points inside and outside the building. Therefore, it does not influence the equilibrium internal pressure.

**Example**

Assume a residential building (see Figure 3) with given characteristics.

At the start of the test, there is light wind (1 m/s) and no temperature difference between inside and outside. The equilibrium internal pressure is about 0,04 Pa (relative to the atmospheric pressure outside) and the pressure on the downwind façade is -0,15 Pa.

During the measurement of the first point of the test, the wind velocity remains at 1 m/s. The fan blows 700 $m^3/h$ which increases the equilibrium internal pressure by 10,9 Pa (for this example, this is calculated based on the characteristics of the openings).

During the measurement of the second point of the test, the wind velocity increases to 4 m/s which causes an increase of the equilibrium internal pressure to 0,60 Pa. The pressure on the downwind façade decreases to -2,42 Pa. The fan blows 950 $m^3/h$ which increases the equilibrium internal pressure by 20,10 Pa.

Taking the reference pressure outside the building in free field, close to the upwind roof or close to the downwind façade makes no difference as long as the wind does not change (Table 1 – First point) but it may have a large effect when the wind changes (Table 1 – Second point). For the second point, a pressure tap on the downwind façade and the increased wind speed give rise to 13% overestimation of the induced pressure which means underestimation of the air leakage rate. For the two other pressure taps, the increased wind speed gives rise to a 2% underestimation of the induced pressure.

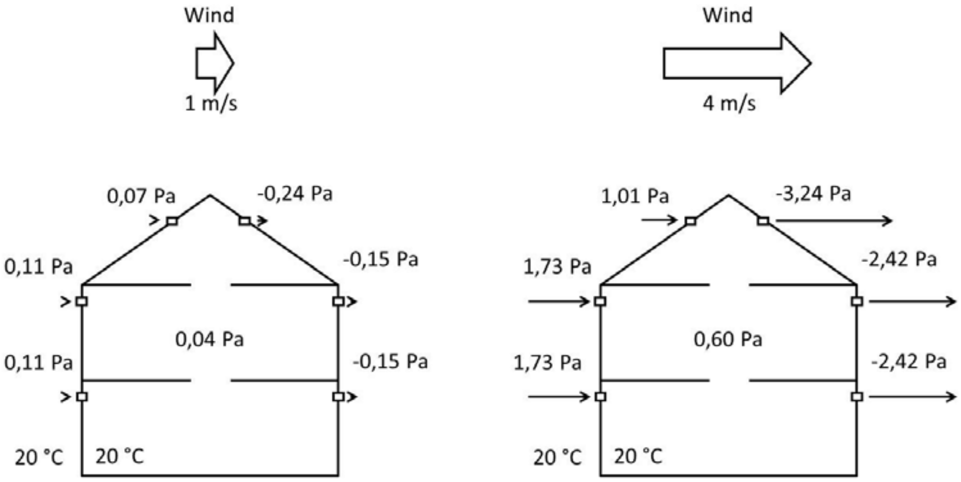

Figure 3: Example

Table 1 : Example

| | | Reference in free field outside | Reference on the upwind roof (left) | Reference on the downwind façade (right) |
|---|---|---|---|---|
| Wind 1 m/s<br>Fan covered | Zero-flow pressure difference | 0,04 – 0 = 0,04 Pa | 0,04 – (0,07) = -0,03 Pa | 0,04 – (-0,15) = 0,19 Pa |
| **First point**<br>Wind 1 m/s<br>Fan 700 m³/h | Measured pressure difference | 0,04 + 10,90 = 10,94 Pa | -0,03 + 10,90 = 10,87 Pa | 0,19 + 10,90 = 11,09 Pa |
| | Calculated induced pressure | 10,94 – 0,04 = 10,90 Pa | 10,87 – (-0,03) = 10,90 Pa | 11,09 – 0,19 = 10,90 Pa |
| | Error | 10,90 – 10,90 = 0 Pa | 10,90 – 10,90 = 0 Pa | 10,90 – 10,90 = 0 Pa |
| **Second point**<br>Wind 4 m/s<br>Fan 950 m³/h | Measured pressure difference | 0,60 – 0 + 21,10 = 20,70 Pa | 0,60 – 1,01 + 21,10 = 20,69 Pa | 0,60 – (-2,42) + 21,10 = 24,12 Pa |
| | Calculated induced pressure | 20,70 – 0,04 = 20,66 Pa | 20,69 – (-0,03) = 20,72 Pa | 24,12 – 0,19 = 23,93 Pa |
| | Error | 20,66 – 21,10 = -0,44 Pa (2%) | 20,72 – 21,10 = -0,38 Pa (2%) | 23,93 – 21,10 = 2,83 Pa (13%) |

Characteristics of the building:
Length x width x height: 14 m x 7 m x 7,6 m
Openings: 50 m³/h @ 2 Pa (flow exponent = 0,5)

| | |
|---|---|
| Upwind Façade: | 2 openings |
| Downwind Façade: | 2 openings |
| Upwind Roof: | 1 opening |
| Downwind Roof: | 1 opening |

Typical surface-averaged pressure coefficient $C_p$ are used

## 3.5 Wind pressure on the building

Close to the building or to obstacles (e.g. tree or car), flow pattern of the wind is disrupted and creates over- and underpressure zones (see Figure 4). Since the pressure outside is taken as a stable reference pressure and wind is fluctuating in speed and direction, it is advisable to avoid these zones (even with a pressure tap protected against dynamic pressure).

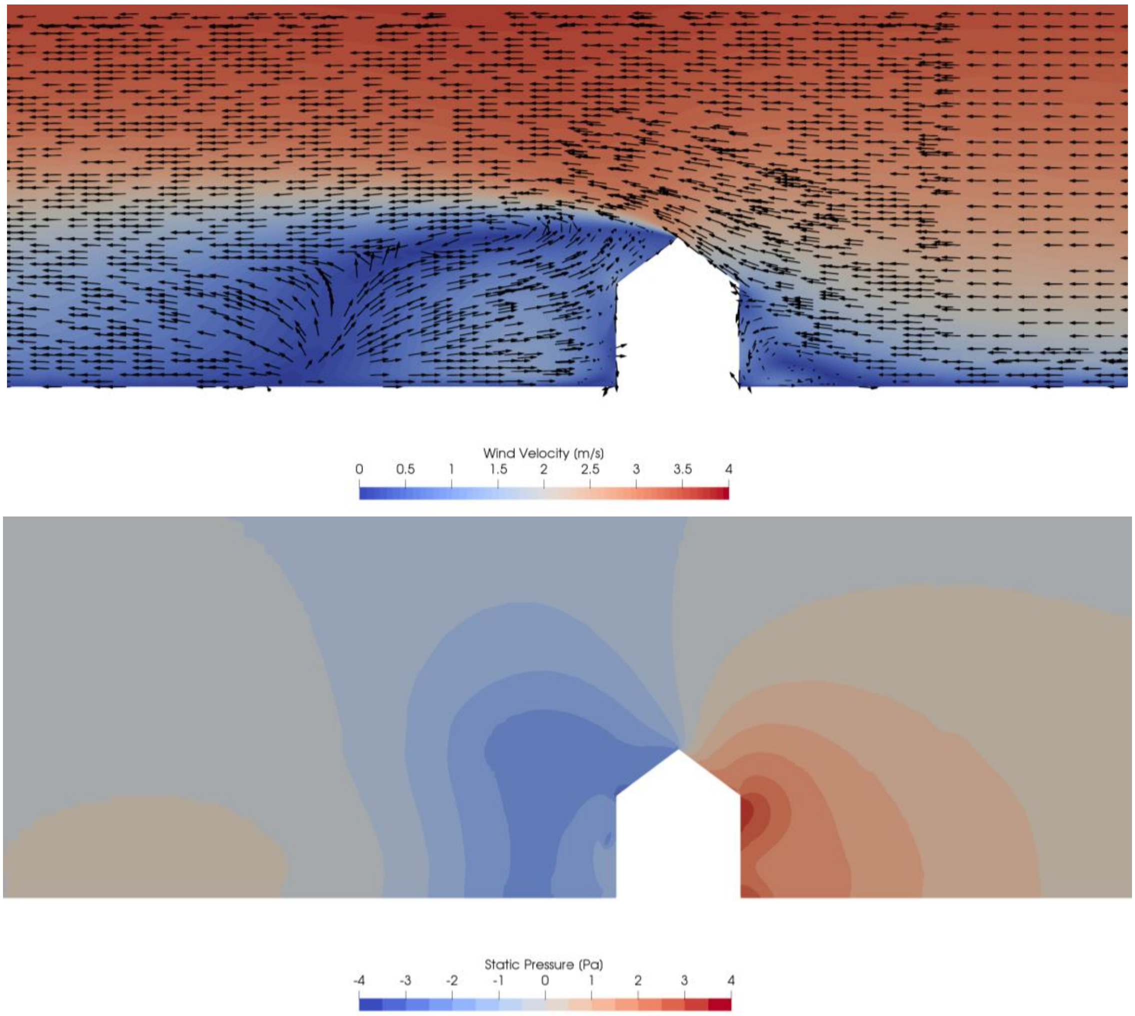

Figure 4: Example of wind velocity and static pressure distribution around a building
(3 m/s wind velocity at 10 m height – 5 m building height under cornice)

The previous example shows however that there may be places around the building (e.g. the upwind roof in this particular example) where over- or underpressure changes in the same way as the equilibrium internal pressure. These places would show low variation of pressure difference between inside and outside the building and may be a good location for pressure reference outside the building.

### 3.6 Vertical position of manometers or pressure taps

The pressure difference between inside and outside the building is usually measured on the ground floor of the building. This is quite practical during the test and it is a good place to measure the stack effect. In practice, it means that the differential manometer itself is on the ground floor. The vertical position of the pressure tap (connected to the manometer with a plastic tubing) plays no role because the column of air above the manometer acts on it with or without tubing.

When the pressure tap is located in another room than the manometer, it may show a difference due to the pressure drop between the rooms. If there is large difference, it means that the building does not really react as a single zone as assumed by the ISO 9972 test method. In that case, changing the location of the fan or adding one or more fans at different locations may help.

## 4 RECOMMENDATIONS

Regarding the place and nature of pressure taps, ISO 9972 says:

- *"Ensure that interior and exterior pressure taps are not influenced by the air moving equipment."*
- *"The exterior pressure tap should be protected from the effects of dynamic pressure"*
- *"Especially in windy conditions, it is good practice to place the exterior pressure tap some distance away from the building, but not close to other obstacles."*

These recommendations are relevant and could be clarified as follows:

- Ensure that interior and exterior pressure taps are not placed within the draught caused by the air moving equipment;
- Ensure that the interior pressure tap is not placed in a zone of possible draught (e.g. corridor or door opening);
- Especially in windy conditions, ensure to place the exterior pressure tap some distance away from the building, but not close to other buildings or obstacles; Alternatively, place the exterior pressure tap where zero-flow pressure variation is very low compared to other locations;
- Ensure the exterior pressure tap is designed to measure static pressure only.

## 5 NOMENCLATURE

$i, j$ = element of a series

$T_{int}$ = Internal air temperature

$T_e$ = External air temperature

$\Delta p$ = Induced pressure difference

$\Delta p_0$ = Zero-flow pressure difference

$\Delta p_m$ = Measured pressure difference

## 6 REFERENCES

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