Wind speed in building airtightness test protocols: a review

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INTRODUCTION

Since the 1970s, many authors have discussed the impact of poor airtightness on building energy use, indoor air quality, building damage, or noise transmission (Carrié and Rosenthal, 2008) (Tamura, 1975) (Sherman and Chan, 2006) (Orr and Figley, 1980). Nowadays, because poor airtightness affects significantly the energy performance of buildings, and even more significantly with low-energy targets, many countries include requirements for building airtightness in their national regulations or energy-efficiency programs. Building pressurization tests are increasingly used for compliance checks to energy performance requirements and may result in severe penalties (Mees and Loncour, 2016). Therefore, the uncertainty of the measurement results has become a key concern in several countries over the past few years.

1 OBJECTIVES OF THIS PRESENTATION

The goal of our work is to improve the reliability of airtightness test results regarding wind impact with better uncertainty estimates and protocols. In this presentation, we will focus on the effect of wind and the provisions set in airtightness protocols to limit the uncertainty in the results.

2 WHEATHER CONDITIONS IN PAST AND CURRENT PROTOCOLS

In the 1970s, research teams elaborated first experimental prototypes and performed building airtightness measurements. The influence of the weather effects led to recommendations concerning the wind velocity: not higher than 8 $m.s^{-1}$ (Nevander and Kronvall, 1978). Kronvall (Kronvall, 1978) determined a lower wind speed limit at 5 $m.s^{-1}$ using “static wind loads and simplified load distribution models”. He defined this limit as the wind velocity (for static wind load models) which induced a pressure difference of 5 Pa (with simplified load distribution models). 5 Pa corresponds to 10% of the 50 Pa reference used in Sweden.
In 1984, 4 standards used a test pressurization method (Jackman, 1984): the Swedish standard SS 02 15 51, the Norwegian standard NS 8200, the American standard ASTM E779-81 and the Canadian General Standard (limited to depressurization tests). Whereas each of these four

standards described a method for a fan pressurization test, some significant variations existed (Jackman, 1984). Table 1 gives requirements regarding the wind included in those standards.

Table 1: Requirements regarding wind of the 4 first fan pressurization tests standards

Standard Requirements	**Swedish standard SS 02 15 51 (1980)**	**Norwegian standard NS 8200 (1981)**	**American standard ASTM E779-81 (1981)**	**Canadian standard (1983)**
Climatic limits: wind speed	< 10 $m.s^{-1}$	< 6 $m.s^{-1}$	< 4.4 $m.s^{-1}$	< 5.5 $m.s^{-1}$

Nowadays, two major standards regarding fan pressurization method for determining building air leakage are commonly used: the US ASTM 779-10 and the ISO 9972 (2015). Both standards describe a fan pressurization multi-point test method to characterize air leakage of building envelope. Although the basic principles remain the same, there are significant differences between these standards that affect the uncertainty in the test results, including the building preparation and the meteorological conditions. Table 2 compares requirements of these two standards regarding wind speed, temperatures, and zero-flow pressures.

Table 2: ASTM 779-10 and ISO 9972 requirements regarding meteorological conditions

	ASTM 779-10	ISO 9972
Wind speed	Strong winds shall be avoided	Strong winds are to be avoided It is recommended that - wind speed near the ground ≤ 3 $m.s^{-1}$ - meteorological wind speed ≤ 6 $m.s^{-1}$ or ≤ 3 on the Beaufort scale
Temperatures	Large indoor-outdoor temperature differences shall be avoided Product of the indoor/outdoor air temperature difference by the height of the building shall be ≤ 200 m.°C	Large indoor-outdoor temperature differences are to be avoided It is recommended that the product of the indoor/outdoor air temperature difference by the height of the building ≤ 250 m.K
Zero-flow pressures		The test is not valid if one zero low pressures average (in absolute) ≥ 5 Pa

3 SOME ISSUES TO CONSIDER AND RELATED RESEARCH WORK

In our presentation, we will discuss more specifically the following issues:

- The number of points: ASTM 779-10 and ISO 9972 are multi-point test methods (Figure 1c). In 2013, Walker (Walker et al. 2013) applied a one-point test method (Figure 1a) considering a default value for the flow exponent n=0.65. He evaluated the uncertainty of this method results and compared it to the uncertainty of results obtained with a multi-point test technique for about 6,000 tests performed on 6 houses. He found that the one-point test method is less sensitive to wind pressure fluctuations when wind speed is higher than 6 $m.s^{-1}$ (error due to *n* approximation is less significant than error due to the wind), whereas he recommended performing a multi-point test for wind speeds lower than 6 $m.s^{-1}$. Carrié and Leprince (Carrié and Leprince 2016) proposed a numerical evaluation of the impact of the wind from a simplified isothermal model. They tested a one-point test method and a two-point test method (Figure 1b). They suggested choosing a one-point test method when the wind speed is above 5 $m.s^{-1}$ at the building level, especially for an indicator at 4 Pa.

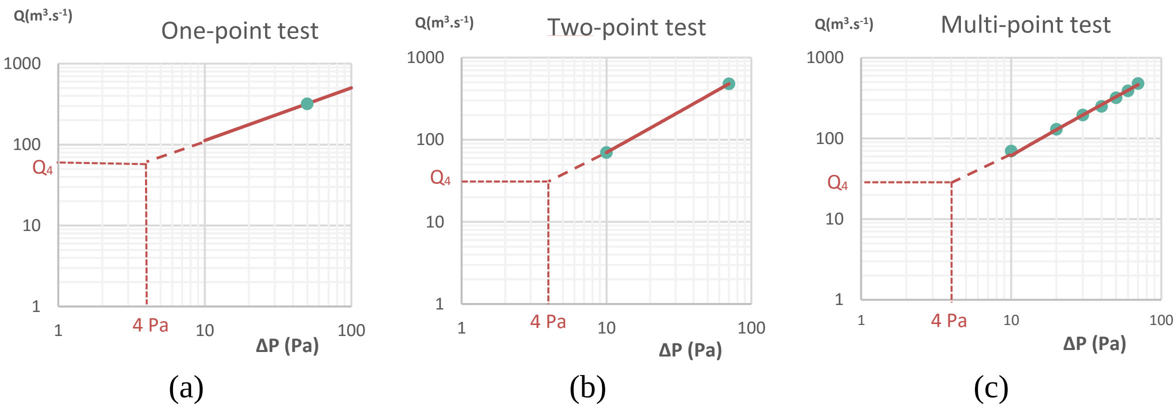

Figure 1: 1-point test (a), 2-point test (b) and multi-point test (c) methods

- The reference pressure measurement and the zero-flow pressure measurement: because the wind-induced pressures are not the same on upwind façade and others façades of the building, the position of the pressure probe has an impact on the test result. In order to reduce these effect, Modera and Wilson (Modera and Wilson, 1990) experimented with time averaging and spatial averaging of pressure. They obtained scatters below 11% for wind speeds lower than 5 $m.s^{-1}$.

- The wind speed measurement: in the literature, the definition of wind speed is hardly ever properly given. Indeed, we can identify 2 main different wind speeds: the meteorological wind speed (at 10 meters from the ground) and the local wind speed: (at the height of the building), which can be very different. Moreover, EN ISO 9972 gives a recommendation regarding wind speed near the ground, which is a third wind speed reference. It occurs that there are often confusions with regard to the definition of the wind speed which can lead to significant differences in the wind speeds measured or calculated with a common reference.

- The fluctuations of the wind: Most of the studies we have analyzed consider steady wind (numerical studies) and low wind speed (experimental studies). However, we often have to perform airtightness measurement under unsteady and not so low wind. These fluctuations may induce significant uncertainties on measurement results because they induce time variations in the measured pressures and flows.

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