Reducing Uncertainty in Air Tightness Measurements

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SUMMARY

There are several methods for measuring air tightness that may result in different values and sometimes quite different uncertainties. The two main approaches trade off bias and precision errors and thus result indifferent outcomes for accuracy and repeatability. To interpret results from the two approaches, various questions need to be addressed, such as the need to measure the flow exponent, the need to make both pressurization and depressurization measurements and the role of wind in determining the accuracy and precision of the results. This article used a large dataset of blower door measurements to reach the following conclusions. For most tests the pressure exponent should be measured but for wind speeds greater than 6 m/s a fixed pressure exponent reduces experimental error. The variability in reported pressure exponents is mostly due to changes in envelope leakage characteristics. It is preferable to test in both pressurization and depressurization modes due to significant differences between the results in these two modes.

KEYWORDS

Pressure testing, air tightness evaluation, air leakage, measurements, error analysis.

1 DATA SOURCES

We used a dataset from the Alberta Home Heating Research Facility (AHHRF) located south of Edmonton, Alberta, Canada. The facility consists of six test houses, each constructed in a different way in order to examine different heating and ventilating strategies. The houses were unoccupied and the fan pressurisation test system was automated, and in this study we used over 6000 of the resulting tests. Wind speed, wind direction, and ambient temperature data were taken from meteorological towers at the test site. The flow rates were measured using a laminar element flowmeter, and were corrected for pressure and temperature changes. Offset pressures due to stack and wind effects with the fan not in operation were measured between each data point. The houses were tested in a total of 97 configurations of open and closed flues, windows and passive vents, pressurization and depressurization, resulting in a wide range of total envelope air leakage, leakage distribution and air flow paths. Typically there were 30 to 100 tests in each configuration. The best test in each configuration was determined by first looking for low wind speed (less than 1.5 m/s) tests to reduce the uncertainty in the test results from fluctuating wind pressures. A total of 301 tests met this low wind speed criterion. For each configuration, these low wind speed tests were analyzed to find the test with the least wind-induced variability (a combination of minimal least squares fitting error and visual observation of the data) in the measured pressures and flows. This test was then used as the reference for all the other tests in a given configuration. The C, n, Q_{50}, ELA_4 and NL from the low wind speed test were the reference for other tests for comparison.

2 ANALYSIS AND DISCUSSION

The mean pressure exponent from the AHHRF data is 0.649 with a standard deviation (SD) of 0.073. The variability represented by the standard deviation includes both noise due to measurement uncertainty and differences between leakage configurations from home to home.

To estimate the fraction of this variability due to different home leakage configurations, we can examine the low wind speed tests only. For low wind speed tests the mean and standard deviation were 0.631 and 0.063, respectively. The standard deviation for the low wind speed tests is almost entirely due to the true variability in pressure exponent between different house configurations. These results indicate that the standard deviation in pressure exponent due to wind effects is 0.037 – or about one half of that due to true leakage variation. Examining differences between open/closed flue and pressurization/depressurization results showed that the variability in pressure exponent due to changes in building leakage configuration is significant (0.075) which implies that assuming a fixed pressure exponent can introduce significant errors. The extrapolation error from 50 Pa down to 4 Pa was estimated by adding or subtracting 0.075 from the fixed pressure exponent of 0.65 and extrapolating with these higher and lower pressure exponents. The resulting extrapolation errors in estimating ELA_4 for using the higher and lower exponents based on exponent variability 15% to 21%, with a typical value of 18%. Similarly, we can use the estimate of wind-induced exponent variability of 0.037 to estimate extrapolation errors for getting the wrong pressure exponent due to wind pressure fluctuations. The resulting errors are 9% and 10%.

There may also be a difference in the physical size of the holes in the envelope (ELA_4) between pressurization and depressurization due to valving action. On average, there was a 24% RMS difference between the pressurization and depressurization ELA_4. In general, the average ELA of pressurization and depressurization will be the quantity of interest since in normal operation the envelope will have areas of both pressurization and depressurization. Because the mean difference is small compared to the RMS difference a reasonable estimate of the uncertainty due to performing only pressurization or depressurization rather than averaging both together is half of the RMS difference, or 12%.

3 GUIDANCE FOR TEST METHOD SELECTION

The fixed pressure exponent errors do not change much with wind speed but the fitted exponent results show lower errors at low wind speed and increasing error with wind speed. The fitted n results give lower RMS errors up to about 6 m/s, after which the fixed exponent gives less variability. This implies that an optimum would be to use fitted C and n for wind speeds below 6 m/s and a fixed exponent at higher wind speeds. Only 7% of the tests were above 6 m/s so if we had to choose one method we would choose the fitted C and n as they give lower errors for the majority of tests. If we want to estimate uncertainty for a typical test we can look at the uncertainties for the wind speeds that are most common: 2-4 m/s. In this range the wind-induced RMS errors for fitted C and n are about 10%, and for fixed exponent, about 17%.

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