3098

BLOWER DOORS: VARIATION IN LEAKAGE MEASUREMENTS

Blower-door derived estimates of leakage area can vary greatly under different wind and temperature conditions.

How accurate are blower door measurements? Although the rated accuracy of most available blower doors is 5 to 10 percent, the measurements vary greatly depending on weather conditions and the time of year. Current research shows that *blower door measurements on the same house can vary by as much as 45 percent between summer and winter.* Energy auditors, contractors, building officials, and weatherization agencies are now using blower doors to identify air leakage sites in houses and to quantify the amount of air leakage. With this increased use of blower doors to quantify whole-house air leakage, conservation professionals need to ask more questions about the accuracy of blower door measurements. (See the trend in this issue on the use of passive monitors to measure infiltration rates.)

The Technique

Typically, the blower door user measures the air flow rate necessary to create a pressure difference of up to 50 Pascals between the inside and outside of a house. This air flow rate must then be converted into a measure of the *natural air change rate* of the house. One common way to do this is to calculate the *effective leakage area* of the home—this is the combined area (in square inches or centimeters) of all the leaks and cracks in the house. The effective leakage area (ELA) represents the actual leakiness of the home under normal conditions.

Environmental conditions influence blower door test measurements through distortions in both pressure measurement and air flow measure-

Table 1. Guidelines for blower door measurements from several countries. (Source: P.J. Jackman, "Review of building airtightness and ventilation standards". From *Proceedings of the 5th Air Infiltration Conference*, 1984.)

Standard	Precision	Pressure range	Climatic limits
Canada (149-GP-10M)	Flow rate +/- 5% Pressure +/- 2 Pa Temperature +/- 1.8 °F	0 to -50 Pa	Windspeed < 12.5 mph
Norway (NS 8200)	Flow Rate +/- 6% Pressure +/- 2 Pa Overall +/- 8%	0 to +/- 55 Pa	Windspeed < 13.5 mph
Sweden (SS 02 15 51)	Flow Rate +/- 6% Pressure +/- 2.5 Pa Overall < +/- 8%	0 to +/- 55 Pa	Windspeed < 22.5 mph
USA (ASTM E779-81)	Flow rate +/- 6% Pressure +/- 2.5 Pa Temperature +/- 0.9 °F Overall +/- 10%	0 to +/- 75 Pa	Windspeed < 10.0 mph Indoor-outdoor temperature difference < 19 °F

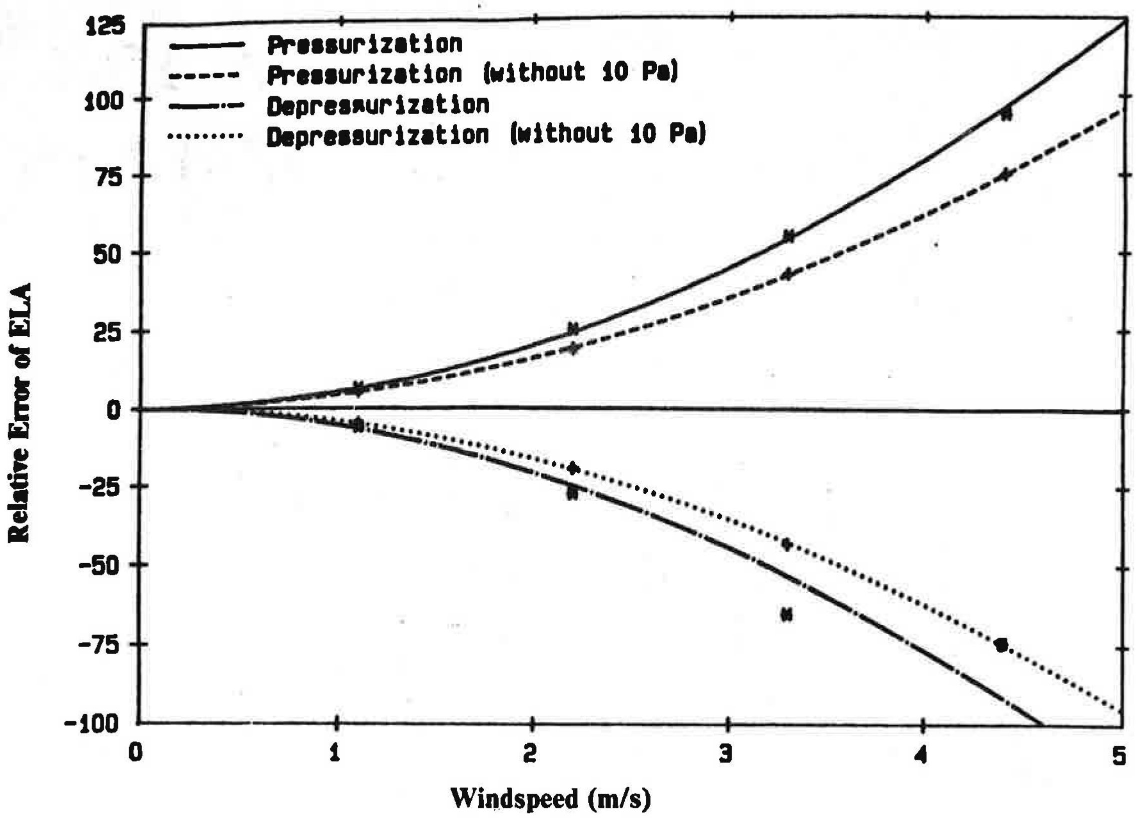


Figure 1. Relative error in effective leakage area (ELA) for different windspeeds.[1]

ment: 1) wind-induced pressure distorts inside-outside pressure difference measurements, and 2) air density differences affect air flow measurements. Wind on the building shell causes variation in the inside-outside pressure difference and affects the air flow through the fan itself. Air density varies with altitude and with inside-outside temperature differences at the time of the test.

In recent years at least four countries have developed measurement standards to provide guidelines for determining airtightness in buildings (see Table 1). Both the proposed Canadian standard and the U.S. standard incorporate air temperature and atmospheric pressure corrections for air flow measurements, while the Norwegian standard requires only a correction for air temperature. The Norwegian standard also forbids measurement when the wind speed is greater than 13.5 mph. The Canadian standard recommends a maximum wind speed of 12.5 mph, and the U.S. standard recommends a cutoff of 10 mph.

Variations Due to Wind

The effects of wind speed and indoor-outdoor temperature differences (the stack effect) can be minimized by performing both pressurization and depressurization measurements. Indeed, taking the average of pressurization and depressurization measurements provides a more accurate assessment of the leakiness of the house, since different leaks appear under each condition. Although the range of recommended wind speeds is reasonably broad, most contractors ignore these limits. Contractors regularly fail to record the actual wind speed, but instead record the weather as "calm" or "windy". Blower door measurements in the U.S., show an unbelievably large number of "calm" days.

The first blower door standard in North America (ASTM E779-81) established limits for wind speed, temperature difference, pressure difference and the accuracy of blower doors. The ideal measurement conditions are wind speeds of 5 mph or less and an indoor-outdoor temperature difference of no more than 20° F. The standard states that at wind speeds of 5 and 10 mph, the tests should be conducted "with caution"; unfortunately, it does not describe what this phrase means. The maximum wind speed allowed under the Canadian test standard (CGSB 149-GP-10M) is higher, 12.5 mph.

Bruce Dickinson and Helmut Feustel of Lawrence Berkeley Laboratory in California simulated the effects of wind on blower door measurements adhering to the U.S. and Canadian standards.[1] They found that single-direction blower door measurements performed on only one side of a building are susceptible to the effect of wind pressure on the side of the building. At wind speeds of 5 to 10 mph, the estimated leakage area (ELA) calculated for depressurization ranges from 24 to 74 percent lower than the ELA with no wind (see Figure 1). These errors are most severe when the pressure difference is measured on the windward side of the building. When both depressurization and pressurization measurements are averaged, the error at wind speeds of 5 to 10 mph drops to just 1 to 10 percent compared to the ELA with no wind.

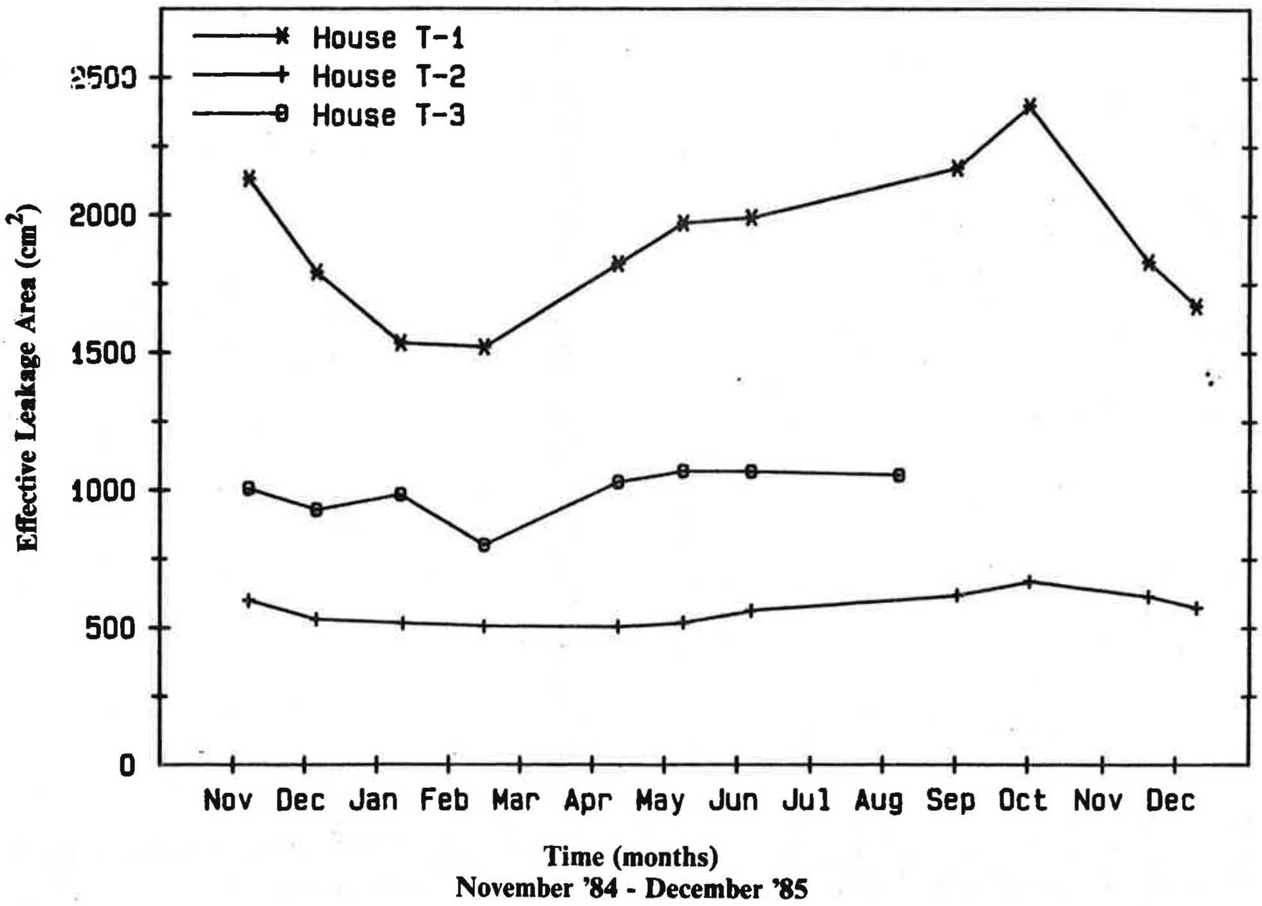
Seasonal Variations

Feustel and Dickinson also took blower door measurements in ten occupied houses over a year-long period to determine the extent of seasonal variations in leakage measurements.[2] The houses were located in three quite different climates—Reno, NV, Truckee, CA, Oakland, CA, and Martinez, CA. Reno is located on the semi-arid plateau on the eastern edge of the Sierra-Nevada mountain range at an elevation of 4400 feet. It has warm, dry summers and cool winters (an average of 6022 heating degree days and 329 cooling degree days at a base temperature of 65°F.) and 7.8 inches annual precipitation. Truckee is nestled in the Sierra-Nevada at an elevation of 6,500 feet. It has cold winters and mild summers (8208 heating and 33 cooling degree days). Annual rainfall

[1] Dickinson, J.B. and H.E. Feustel, "Influence of wind on the accuracy of blower door measurements: a numerical study." Unpublished report, 1986.

[2] Dickinson, J.B. and H.E. Feustel, "Seasonal variation in effective leakage area," Lawrence Berkeley Laboratory, LBL-19337, January 1986.

Figure 2. Effective leakage area vs. time for houses in Truckee, CA.



averages 31 inches. Oakland and Martinez are located on the San Francisco Bay, have mild winters and cool summers (2900 heating and 128 cooling degree days), and 19 inches annual precipitation.

Feustel and Dickinson measured the wood moisture content, wind speed, and inside and outside air temperatures in each house at the time of the test. They attempted to determine seasonal variation in leakage area for each climate and studied the effect of wood moisture content, postulating that seasonal differences in moisture content of the wood might be one explanation for variations in blower door measurements.

Their results indicate a seasonal variation in the leakage measurements for some, but not all of the houses. The greatest variations occurred in the Truckee houses (see Figure 2). ELA at 4 Pascals varied from 28 to 45 percent between winter and summer measurements, with the maximum ELA occurring during the summer. All of the Truckee measurements were taken at wind speeds of less than 2.3 mph, so the variation cannot be explained by wind-induced errors. In addition, the variations did not correlate with the moisture measurements of wood on the exterior and interior of the building. *These results are the opposite of the effect seen in similar studies conducted by other researchers in east coast climates, where the maximum ELA occurred during the winter.*

Seasonal variations in the air flow and ELA estimated at 4 Pascals in the Reno houses were about 20 percent. The variations seen in the Oakland homes were the lowest, around 10 percent. Dickinson and Feustel surmise that the variation may be lower in the Oakland houses because the temperature is more constant year round in Oakland. Ten percent is within the range of error expected for blower door measurements.

Recommendations

Our understanding of the dynamics of air leakage in buildings is not complete, and more basic research is needed on the use of blower doors to estimate air infiltration (and heating savings). Auditors and retrofitters should be cautious in the way they use blower door measurements to quantify whole-house air leakage and present these leakage measurements to the homeowner.

Also, taking the average of both pressurization and depressurization measurements will provide a more accurate assessment of leakiness than just conducting either a pressurization or depressurization test. It is essential to record the wind speed to ensure accurate and comparable leakage measurements of houses. Blower door users cannot expect accurate leakage measurements with wind speeds greater than 5-10 mph. In light of this, it would be useful for blower door manufacturers would include an inexpensive anemometer with their blower door.

Seasonal variations cannot be readily predicted by building design, climate or age of the home. There may be greater seasonal variation in climates with extreme temperatures (e.g., Truckee) than in more moderate climates (e.g., Oakland). Clearly, blower door measurements on the same house must be taken within a few weeks of each other in order to be comparable.

– Peter duPont

An article in the next issue of **EA&R** *will discuss the use of a passive infiltration monitor to measure the integrated infiltration rate into a house over longer periods of time.*