Characterizing Air Leakage in Large Buildings: Part II

By **Terry Brennan** and **Michael Clarkin**, Camroden Associates Inc.

In the Summer 2007 edition of JBED Terry Brennan and Michael Clarkin talked about what a fan pressurization test is, why it's important and how to go about completing one. In Part II of their article, they'll explain what the results of the test actually mean.

MEASURING PRESSURE DIFFERENCES

Electronic micromanometers designed for use in pressure testing buildings are available from the blower door manufacturers. A micromanometer has at least two air ports. A pressure sensitive transducer measures the air pressure difference between the two ports. Flexible tubing can be attached to each port so pressure differences between two locations that are distant from each other can be measured. **Figure 1** shows a two channel micromanometer. The green tubing runs to an outdoor measurement location. 2.1 Pascals air pressure difference is measured between the outdoor end of the tube and the open port at the bottom left. The building in this photo has none of the test fans operating—the pressure difference is due to a slight breeze. The blue tube runs to the flow nozzle on a blower door. The display switches between the two channels using the round knob below the display.

Wind and stack effect have important effects on pressure differences. Building air pressure is lower inside than outside on the windward side of the building; higher inside than outside on the leeward side. On sides parallel to wind usually the building is slightly lower air pressure than outside. When outdoor air is colder than indoor air the air pressure at the top of the building is higher than outdoor air and the air pressure at the bottom of the building is lower than outdoor air. The ASTM, ATTMA and CGSB standards provide guidance for dealing with these problems.

The wind and stack problems found while conducting tests on small single zone buildings are compounded in larger, more complex buildings. In addition, uneven depressurization or pressurization between floors or zones during the test can produce errors in larger, multi-zone buildings. For example, in a two story office building with the first and second floor connected mostly by open doors at the top and bottom of a stairwell, and entry doors on the first floor the only place to install blower doors, the pressure difference between the first floor and the outdoors may be significantly greater than the pressure difference between the second floor and outdoors. Sometimes this problem can be mended by placing a fan door in a window opening or a roof hatch. Sometimes exhaust fans or outdoor air fan on the second floor can be used to produce more uniform pressure differences across the enclosure.

In larger buildings there is a great advantage to simultaneously measuring the pressure difference between indoors and outdoors at several locations or between floors and zones. This gives immediate feedback on the effect wind, stack and interzonal airflow resistance is having on the pressure differences across all walls. Recording the data allows later analysis when data points with the smallest differences between orientations can be used. An eight channel micromanometer from the Energy Conservatory is shown in **Figure 2**. For this test four of the channels measure the pressure difference across four wall orientations, one channel measures the pressure difference between first and second floor and

Figure 1 – A two-channel micromanometer.

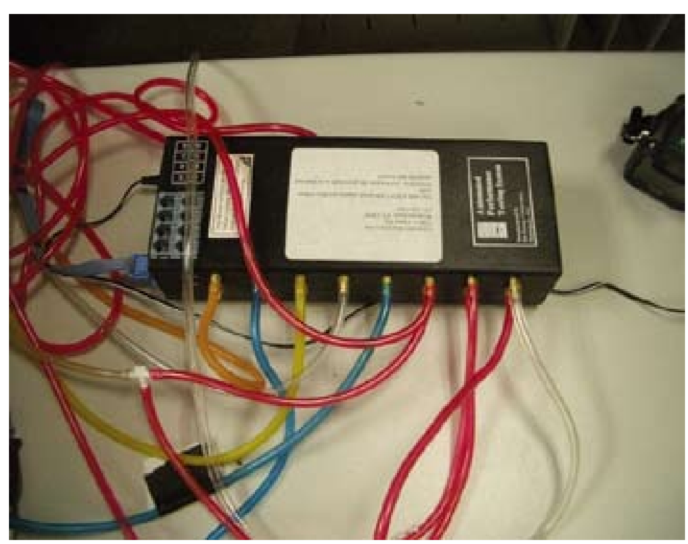

Figure 2 – An eight channel pressure difference datalogger.

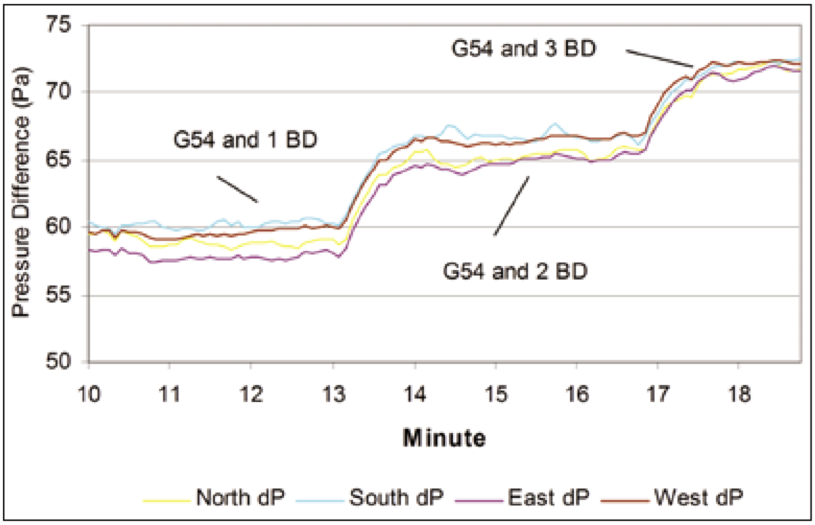

Figure 3 – Continuous pressure difference data reveals the impact of changing pressurization air flows and the effect wind has on the pressure differences.

the remaining three channels measure the pressure drop across the flow orifices for three blower doors. NOTE: If using tubing longer than 100 feet, the tiniest airleaks cause erroneous pressure difference measurements. Accuracy must be verified across each wall if tubing longer than 100 feet is used.

Figure 3 shows a time series of pressure difference data across four walls during a test. At the beginning of the trace the building is being pressurized using a trailer mounted G54 and one blower door—a total of around 66,000 cfm. A second blower door is turned on at 13 minutes adding another 6,000 cfm and increasing the indoor/outdoor pressure difference by 6 to 8 pascals. A third blower door is turned on at around 17 minutes, increasing the indoor outdoor pressure difference again. Notice the time lag between when the additional air was supplied and when the pressure difference stabilizes. This is due to the data collection time interval and the rather large 32,000,000 cubic foot volume of the warehouse being tested.

During the test the wind was from the northeast. The pressure difference across the north and east walls are usually within a pascal of each other. The pressure difference across the south and west walls are usually within a pascal of each but are generally 1 to 2 pascals greater than the north and east wall. This is consistent with the wind direction. With the graph plotting on the computer screen in real time, data at each new flow can be collected long enough to assure small wind effects are noticed, and fan flows can be adjusted to maintain uniform pressure differences for multiple zones.

If you are testing the building at multiple airflow-pressure points, it is a good idea to plot the data and do the regression analysis as the data is collected. Outliers become obvious and can be retested. At the very least, plot the data while the test equipment is still setup. It's an expensive mistake to discover consistent data when everything is taken down and you're back at the office.

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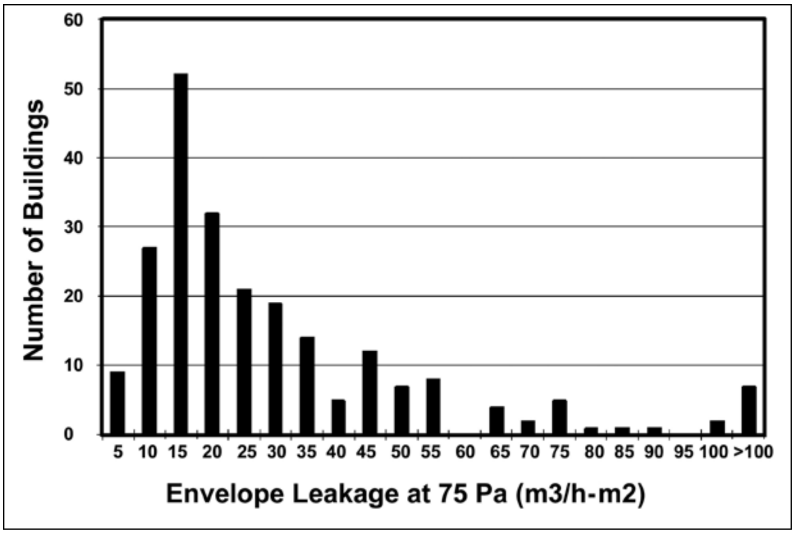

Figure 4 – Histogram of enclosure tightness measurements for large buildings.

WHAT DOES IT MEAN?

Analysis of the data and interpretation depends on the purpose of the test. If the purpose is to compare the enclosure tightness to a target—for example specified as performance criteria by owner, designer or regulation—then the analysis must report the result in the same measurement units as the target specification. The measurements must be made so the uncertainty in the result is small compared to the target tightness level. For example, if the target is the same as the British normal practice of 6 m^3/hr@50pascals per m^2 of enclosure (where enclosure area includes the top, bottom and exterior sides of the building), then the results must be converted to these units. The British ATTMA standard (multi-point test), ASTM E-779-03 (multi-point test) and ASTM E-1827-96 (single-point and two-point test) each provide criteria for bias and uncertainty, corrections for air density and accounting for environmental conditions.

The tightness of an enclosure can also be compared to similar buildings that have been previously tested. Figure 4 shows a histogram of the measured airtightness of 229 large building enclosures collected by the National Institute of Science and Technology from a number of data sources (Emmerich 2005). The results are reported in m^3/hr@75 pascals per m^2 surface area (where the surface area includes the roof, bottom floor and exterior walls of the enclosure). Enough data has been collected to see that the distribution is log-normal. To give some perspective on the data:

- British Part L energy requirements require office buildings to be air sealed to an airtightness of 10 m^3/hr@50 pascals per m^2 surface area; for comparison to the NIST data set this is converted to 13 m^3/hr or 3.6 L/s @75 pascals per m^2 surface area—assuming n=0.65 (Potter 2007). Just over 28 percent of the buildings in the dataset meet this target.
- British normal practice for office buildings is 5 m^3/hr@50 pascals per m^2 surface area (6.5 m^3/hr or 1.8 L/s @75 pascals per m^2 surface area—assuming n=0.65) (ATTMA, BSRIA). Just over 6 percent meet this target.
- British best practice for office buildings is 2 m^3/hr@50 pascals per m^2 surface area (2.6 m^3/hr or 0.72 L/s @75 pascals per m^2 surface area—assuming n=0.65) (ATTMA, BSRIA). Two of the buildings in the dataset are within 10 percent of this target, but none definitively meet it.
    - For commercial buildings Henri Fennell suggests a State of the Art target of 2.7 m^3/hr@50 pascals per m^2 surface area (3.5 m^3/hr or 0.97 L/s @75 pascals per m^2 surface area—assuming n=0.65) (Fennell 2005). Just over 2 percent of the buildings meet this target.
    - ASHRAE Addendum z to 90.1 2004 allows 2 L/s @ 75 Pa per m^2 surface area.
    - US Army Corps of Engineers airtightness requirement is set at 1.25 L/s @ 75 Pa per m^2 surface area.

The challenge to those designing high performance buildings is to meet the airtightness target values listed above, placing their buildings in the tightest few per cent of the building stock. To routinely achieve these target levels the construction documents must contain drawings and specifications detailing continuity of an air barrier system in all sections. It must be clear enough that contractors can understand what must be done. Pressure testing is an important tool in helping those who design and build to learn what is needed to air seal to meet airtightness target levels. ■

Terry Brennan and Michael Clarkin are building scientists who work at Camroden Associates Inc. They have been pressure testing buildings since 1981.