Unmasking Commercial

Building Energy Loss

Building enclosure tightness testing reveals HVAC damper leakage.

BY DAVE BOHAC, P.E., PETER BURNS AND PAUL MORIN

Images courtesy of The Energy Conservatory.

The need to achieve high-performance buildings has prompted design changes that incorporate efficient use of energy and resources. One of these changes, the design, installation and testing of the building air barrier, has driven a dramatic increase in the demand for blower-door testing of large buildings.

The 2012 International Energy Conservation Code (IECC) requires testing of multifamily buildings less than three stories. The General Services Administration (GSA) requires testing of new government buildings. Washington state requires that commercial and multifamily residential buildings of greater than five stories have the completed air-barrier tested. The United States Army Corps of Engineers (USACE) has an air-tightness requirement and all new buildings and major renovations must be tested for air leakage. The USACE has found that consultants that work with the contractors through the design and construction phases are able to pass the blower-door test at levels greater than 50% tighter than the standard. As more consultants learn these techniques, this emerging technology will move more quickly from the public sector to the private sector.

Until recently, most blower-door testing was performed on small, non-residential and residential structures. However, there is now a demand for consultants with the knowledge and equipment necessary to test large facilities, usually using multiple-fan blower-door systems.

Preparing the building by sealing HVAC openings and unsealing them after the test will often be the most time-consuming part of the entire test process.

Two research projects on non-residential buildings were completed in 2013. One was initiated to develop and test envelope air-leakage screening protocols, investigation protocols, measure the change in building leakage due to air sealing, model the effect of leakage reduction on space-conditioning loads, and generate cost and savings estimation procedures. Project staff conducted air-leakage investigations on

26 existing commercial and institutional (C&I) buildings, including whole-building air-leakage tests before and after air sealing on seven of those buildings, and leakage tests on one building that was not sealed. This project was conducted by the Center for Energy and Environment (CEE) and was supported in part by a grant from the Minnesota Department of Commerce, Division of Energy Resources through a Conservation Applied Research and Development program.

The project also included continuous building indoor-to-outdoor pressure measurements merged with building-automation system trend data to evaluate the effect of the HVAC system on building pressure. Those results are being used to develop CONTAM multi-zone air-infiltration models that include HVAC pressure effects. The models will be used to evaluate the effect of the air sealing on building air-infiltration energy use.

The second project, conducted by the American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE) 1478, was a research project designed to measure enclosure airtightness of mid- and high-rise buildings in the U.S. Data was collected from 16 non-residential buildings in six different climate zones across the U.S. constructed since the year 2000. Major air-leakage sites were identified in the course of testing. Air leakage through HVAC-related penetrations was measured in a subset of the buildings. Factors that are associated with the most air-tight enclosures include air-barrier continuity detailed in construction documents and precast concrete panel construction. Damper air leakage turned out to be a significant portion of the total enclosure air leakage in some of the buildings. The significance of air leakage by HVAC systems is reviewed in relation to building air tightness.

Intentional holes in the building

Most test protocols will include some level of sealing of intentional holes in the test boundary. The USACE's standard has specific requirements pertaining to masking HVAC openings. Air leaks around windows and doors are not considered intentional holes. Remember that chimneys for combustion appliances should not be sealed as part of the test. Mechanical dampers may be sealed or left unsealed, however, mechanical damper leakage may be significant and you may choose to do some level of diagnostic testing with dampers sealed and unsealed. Preparing the building by sealing all of these openings and unsealing them after the test will often be the most time-consuming part of the entire test process. When testing a new building, this may be the responsibility of the builder. However, you will want to make sure that their sealing technique will withstand the pressures that will be applied to the building. You may want to also confirm that all dampers are working properly.

When ventilation systems are operating and dampers are opened to regulate air flow, damper leakage is typically not a concern. However, when air handlers and exhaust fans are off, the dampers become part of the building's air barrier and damper leakage causes additional building air infiltration or exfiltration. This includes outside air, relief air and exhaust fan dampers. Damper leakage is more of a concern for buildings where the HVAC systems are off a greater amount of time.

Whole-building air-leakage tests are typically conducted with temporary seals on the mechanical dampers or penetrations. For these projects, they also conducted a single-point test with the seals removed. The Minnesota study found that the mechanical system leakage increased the enclosure leakage by 17% to 103% (see Figure 1). There was a trend for higher mechanical leakage in older buildings. For the four buildings built before 1985, the average mechanical leakage as a percentage of envelope leakage was 64%, where it was only 25% for the four buildings built after 1985. Moreover, the three buildings with the greatest mechanical leakage were built before 1968. The ASHRAE study conducted similar tests for 14 buildings and found that the mechanical leakage ranged from 2% to 51% of the envelope leakage. The average mechanical leakage of 27% for these buildings built since 2000 is consistent with the average of 25% for the four newer buildings in the Minnesota study. These results suggest that improving damper tightness offers a significant energy-efficiency opportunity to existing buildings.

Methodology

The building air-tightness tests generally followed the requirements of the American Society for Testing and Materials (ASTM) E779-10, with additions to address the complexities of testing larger buildings. The key additions to or clarifications of the test protocol are outlined below.

→**Indoor/outdoor pressure sensors—**The average of four ground-level indoor/outdoor pressure measurements placed on different sides of the building was used to indicate the building indoor with respect to outdoor pressure difference.

→**Baseline pressures—**Building baseline pressures were measured for at least five minutes before and after both the pressurization and depressurization tests.

→**Test pressures—**Multiple calibrated fans were used to vary the baseline adjusted building indoor/outdoor pressure at 5-pascal increments from approximately 15 to 75 pascals. Measurements were conducted at 13 to 16 pressure levels for 60 seconds at each level.

→**Mechanical systems—**All mechanical dampers were closed and the dampers or terminations of the outside air ducts, exhaust air ducts and exhaust fans were temporarily sealed. After the depressurization test was completed, the temporary seals were removed sequentially from the mechanical

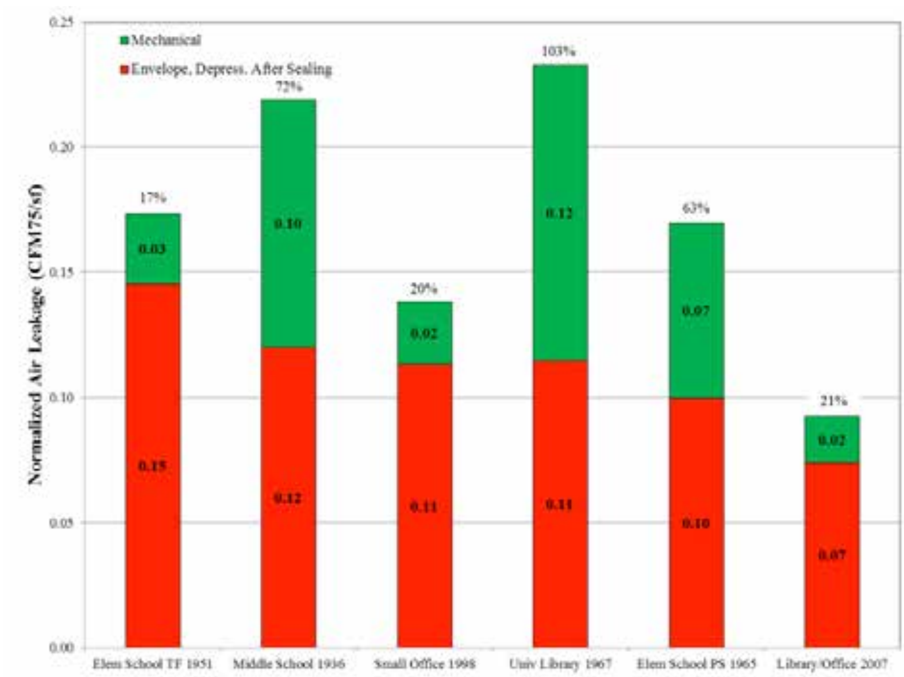

Figure 1 Whole-building leakage tests were conducted with mechanical penetration sealed (red bars) and unsealed. The green bars show the additional leakage due to the mechanical systems.

equipment, while the test fans were used to depressurize the building to a baseline adjusted pressure of approximately -75 pascals. One minute of measurements were recorded at each stage of the unsealing. The measured fan flow rate and building pressure were used with the depressurization test baseline and flow exponent to compute a total building leakage for a reference pressure of 75 pascals. The "envelope only" building leakage was subtracted from that value to determine the additional leakage due to the mechanical systems.

Project staff used commercially available software to record building pressure differences, record fan flow rates, control test fan speeds, graphically display the measurements and compute air-leakage values. They improved data quality by using distributed gauges to minimize tube lengths and real-time regression analysis to identify erroneous measurements. A new standard is currently under development for testing large buildings and should be available by the end of 2014.

Conclusions

There is a large amount of air leakage associated with HVAC-related penetrations. The largest air leaks were through undampered exhaust fans serving kitchens, toilets, elevator shafts and dampers that did not cycle to the closed position when instructed to do so by the control system. These problems can be fixed, but must be located first. Leakage through fans that operate continuously (such as electrical room exhaust) has little effect on energy use. On the other hand, leakage through fans that almost never run (such as smoke-evacuation fans) behave as any other enclosure leakage site.

›› During the test, all mechanical dampers are closed and the dampers or terminations of the outside air ducts, exhaust air ducts and exhaust fans were temporarily sealed.

›› With the dampers closed, this RTU revealed an opening for inevitable leakage and air infiltration.

The buildings in the Minnesota study were much tighter than the U.S. average reported by previous studies, even though many of the buildings were built before 1970 and none were required to meet a tightness standard at its time of construction. Previous studies have suggested that buildings in colder climates are tighter and these buildings follow that trend. The air-sealing results indicate that it is possible to reduce the leakage of already tight buildings. However, the sealing potential is better for leakier buildings, unless investigators can identify concentrated leaks that are inexpensive to seal. The contractor estimates of physical leakage area that would be sealed were less than one-third of the measured reduction in leakage area. Infrared scans and smoke puffer investigations confirmed that the specified leaks were successfully sealed, which suggests that it is necessary to improve methods for estimating leakage areas.

The type of test and mechanical system leakage has a significant effect on building-tightness results that must be considered for tightness-performance standards. The leakage for pressurization tests was an average of 21% greater than that for depressurization. It is unclear which test is a more valid indicator of leakage under typical conditions. HVAC systems are often designed to positively pressurize buildings, but one of the leakage paths (such as loose door latches) only occurred at pressures above 25 to 45 pascals. For one-half of the buildings, including the mechanical system, leakage increased the total building leakage by more than 50%. Since the mechanical system is part of the envelope when it is not operating, that leakage can significantly impact air infiltration, and leakage reduction presents an opportunity for energy savings.

There is a large range in building air tightness. However, with appropriate detailing and HVAC control, a tighter building can be achieved. This knowledge must be incorporated into all of our buildings to ensure energy efficiency and human comfort.

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