CMTA

10411 Meeting Street
Prospect, KY 40059

502.326.3085
cmta.com

Building Pressure Testing

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All buildings leak. Some more than others. Infiltration is uncontrolled: unconditioned outside air enters a building through gaps, cracks, and openings in the exterior envelope and is caused by mechanically induced pressure differentials, wind and stack effect. Leaky buildings can create indoor air quality issues leading to temperature, humidity, condensation, mold and mildew complaints from the occupants and will lead to higher energy costs for the building owner.

Think about how a great cooler works. They are constructed without seams, built with superior insulating materials, and are very tightly gasketed and sealed to keep items cold for days. Why can't your building be designed, constructed and operated with these concepts in mind? The good news is that it can be accomplished!

The purpose of this white paper is to discuss the importance of building pressure testing through discussions on factors that can lead to air infiltration. Solutions to minimize air infiltration through design, construction and operation will be presented. Methods for testing and compliance will also be described.

Why do you need building pressure testing (BPT)

Modern energy codes include prescriptive requirements for design and construction of the building envelope. The alternative is to perform a building pressure test. When testing is not performed, IECC 2015 and ASHRAE 90.1 2013 include mandatory design, installation and inspection requirements for continuous air barriers, acceptable construction materials and assemblies, requirements for doors and window construction, weather seals and vestibules. A building can be considered code compliant on paper with this prescriptive method; however, there is no guarantee of envelope performance without a building pressure test.

Code compliance through a pressure test is allowed in lieu of the prescriptive requirements stated mentioned previously. The building pressure test must be performed in accordance with ASTM E 799. The metric at which buildings are rated is airflow of leakage per square foot of exterior envelope surface (i.e. floors, walls and roofs) pressurized to 75 pascals. A building complies with code if the air leakage is less than 0.40 cfm/ft^2. The goal for a high performance building should be closer to 0.20 cfm/ft^2.

To have a successful envelope, the Owner, Architect, Engineer and Contractor all have to be active stakeholders for raised awareness and accountability. A blower door pressure test is inexpensive insurance compared to the total cost of a building. It provides a quick return on investment and will give you peace of mind that air leakage is minimal for your building. Knowledge of testing requirements will make all team members raise their level of awareness to ensure success. The true performance of an envelope cannot be truly confirmed without a building pressure test.

Design of buildings can be complicated and it will take extra care when it comes to the design of continuous air and vapor barrier of the envelope. The Architect is responsible for the envelope but the Engineer has a vested interest in the design and as a team can accomplish great results. Soffits, overhangs and eaves are notorious conditions for excessive air infiltration. Very close attention must be paid to the envelope details. Through thoughtful design of the envelope, the HVAC systems can be appropriately sized and will result in first cost and operational savings with reduced system sizes and runtime hours.

Building envelope construction techniques that utilize systems such as insulated concrete form walls (ICF), fluid applied vapor barriers and/or spray foam insulation are very successful strategies for well-designed air barriers. Additionally, design and constructability of difficult envelope conditions should be reviewed with the Contractor to ensure success. In the end, this will allow for a proactive design that will decrease reactive problems in the field. A blower door test will validate the design and expose issues that can be remedied during construction before Owner occupancy. Thermal imaging can also provide valuable information during construction. Specific examples will follow in the included case studies.

Timing the sweet spot – when and how do you need to do it?

There are lots of moving parts and many different subcontractors and suppliers involved when a building is being constructed. All of these different players and materials complicate the overall construction schedule and need to be considered when planning for a building pressure test. It is critical for the Prime Contractor to plan for and include time in the construction schedule for the building pressure test. This may seem obvious and straightforward; however, the timing of the test in relationship to construction critical path elements can prove to be challenging.

The ideal timing to perform the building pressure test is when the **entire** exterior envelope is sealed up **but** before the exterior and interior finish materials are applied. This means all window frames/glass and doors are installed, all door seals/gaskets/sweeps are installed and all penetrations are properly sealed. It is important to understand we are not testing the thermal performance of the exterior envelope, we are simply testing the air barrier to find the location of potential leaks.

If the objective is to identify the areas that are leaking and **fix** them, it is crucial to still have **access** to those systems to make the necessary repairs. If the exterior and interior finish skin is on the building, it limits what can be done to make repairs without destructive methods; thus, the building pressure test has to be performed before these finishes are installed. Alternative measures can be taken in order to mitigate issues as soon as possible.

Construction of large commercial buildings are rarely built in a linear fashion. The building is phased into sections and the elements of work are constructed as they are available. The various trades will leapfrog through the facility. This means one part of the building may have finished drywall and paint whereas other areas may be still open to environmental elements. This construction method goes directly against the timing sweet spot. The bottom line is to be flexible and engage the Contractor in the process as early as possible. Excellent results can still be obtained.

Case Study
Major Hospital

Major Health Partner's replacement hospital in Shelbyville, Indiana is a four story, 305,000 ft^2, acute care hospital. With energy efficiency in mind, the envelope was designed with exterior spray foam, which also aides in sealing the building. In the design process it was determined that envelope testing would be required and would include blower door pressurization/ depressurization and thermographic inspection.

Utilizing blower door assemblies, the building was pressurized and depressurized to determine if the building air barrier met the required specification for maximum air leakage of 0.20 cfm/ft^2. The initial testing showed that the building could not be pressurized and would not pass the test requirements. Several large voids were found where the new Hospital joined to an existing Cancer Center. These voids were repaired. Final testing ultimately showed the building leakage to be an incredibly low 0.11 cfm/ft^2. This result has had a significant impact on energy costs for the Owner.

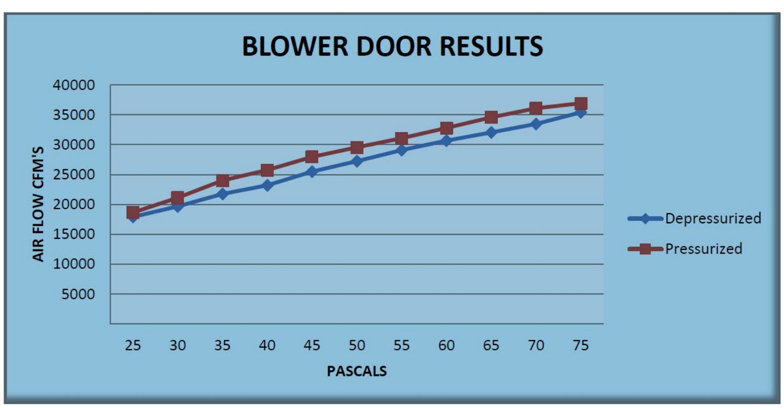

Chart 1 – Major Hospital Blower Door Test Results

Additionally, an infrared thermographic inspection using a fully radiometric infrared camera on the perimeter walls was conducted for the entire exterior of the building. This thermal inspection, which is normally performed during the building pressure test, was performed at a later date. Even without the simultaneous benefit of the pressure test, several openings were still identified. Some of the areas were confirmed due to localized temperature comfort issues reported after occupancy. The areas were all mitigated by sealing the cracks and voids further improving the tightness of the envelope.

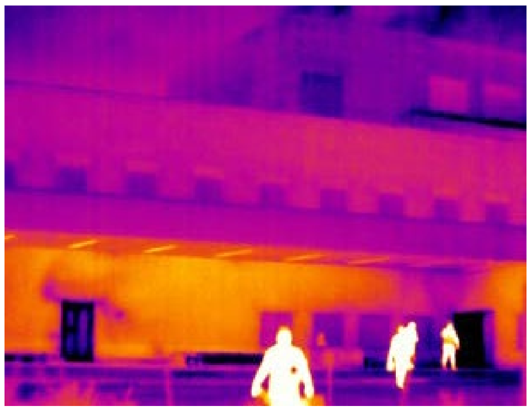

Figure 1 – Major Hospital Infrared Thermographic Inspection Image

These tests both occurred approximately two months before substantial completion. This was late in the construction process with the majority of building finishes already installed. The team learned that while a building can have phenomenal overall building performance, small leaks left undiscovered due to being hidden by finishes can ultimately still cause issues at a later date. The experiences with this ***project emphasize the need to find the correct timing for the sweet spot*** that follows the optimal construction process while still getting the most benefit from the building pressure. In the end the Owner still obtained phenomenal building envelope and results from these tests are proof. The Owner stated that this was some of the best money spent as it gave them the assurance that their building was sealed up properly.

Case Study
University of Louisville Thorntons Academic Center for Excellence

The UofL Thornton's Academic Center for Excellence is a two-story elevated building and features a total of 89,000 ft^2 of total test boundary surface area. The building is hanging from the existing structure of Cardinal Football Stadium. This construction is unique in that the envelope is exposed on all sides. The facade was primarily curtain wall with glazing and metal panels as seen in Figure 2.

Figure 2 – Thortons Academic Center for Excellence

For the initial testing attempt, the building could not hold any pressure which was a big issue. The tests were performed after almost all drywall was in place, making it difficult to pinpoint the cause. With a lot of time and exploration a two square foot opening above ceiling to the exterior of the building was found. This opening was difficult to locate as it was concealed with architectural elements and would have not have been found until pipes froze, condensation formed or the cooling system could not meet demand. A building pressure test was the only way this opening was able to be addressed and provided immediate return on the investment.

After repairing the large opening, the building test was attempted again. The test results ultimately showed the building leakage to be 0.25 cfm/ft^2. The primary cause of the building leakage was determined to be a large gap identified between the building slab and the curtain wall system. This occurred around the entire perimeter of curtain wall. This gap was discovered prior to construction during a review of the envelope design. The Architect's resolution was to fill this gap with expanding foam. During pressure testing, air could be felt infiltrating in this location. Figure 3 shows the picture of gap prior to applying expanding foam insulation. The team learned that while expanding foam is great at sealing a building envelope when used in a typical construction, it proved to be less effective than expected for filling large voids in the exterior envelope.

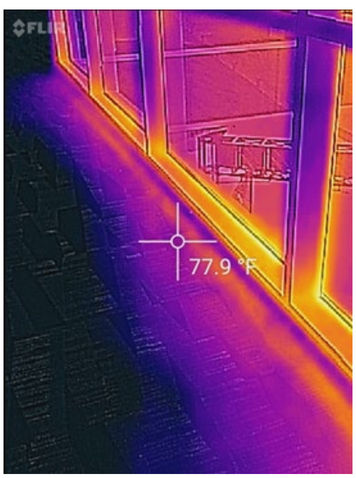

Figure 3 – Images of curtain wall gap and thermal imagery of gap.

The building envelope likely could have performed better had the large gap been detailed differently during the design process. However, even with the intricacies of the architecture, the building still performed 35% better than IECC code minimum (0.40 cfm/ft^2).

CASE STUDY
GOODRICH C. WHITEHALL BUILDING
EMORY UNIVERSITY

Goodrich C. Whitehall Building is an existing 48,000 ft² concrete building constructed in the mid-1970s. Emory University is performing a study to inform the design for a major renovation to the classroom building including all new MEP systems. It was decided to perform a "pre-design" building pressure test and thermal imaging of the existing building. The results of the test showed the building leakage to be 0.30 cfm/ft² – which is much better than expected. The results of this test provided a benchmark for any improvements to the envelope made during the renovation. The results also inform the energy modeling being performed and help guide the design team when studying possible new HVAC systems. The test and thermal imaging also provide focus on where envelope improvements need to be targeted.

During the test, a handheld infrared camera and a drone with infrared camera were utilized to locate problem areas in the current envelope. It was discovered that exterior can lights located in the soffit were acting like air diffusers during the positive pressure test. Whistling was even heard and seen on the thermal camera at windows and doors. Thermal bridging was observed at mullions for the windows. See Figures 4 and 5.

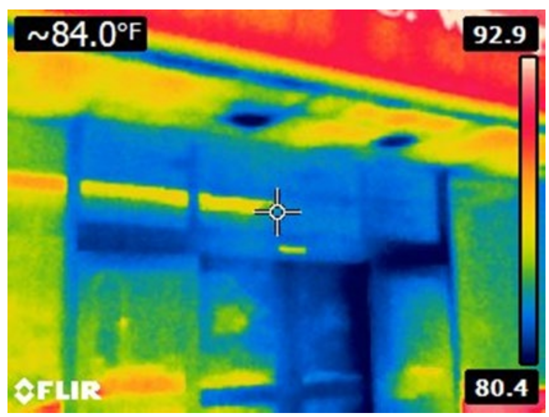

Figure 4 – Exterior image showing leakage at curtain wall and soffit lighting

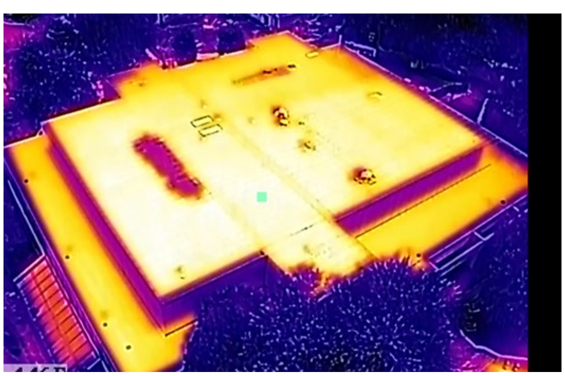

Figure 5 – Thermal imaging of the classroom building roof utilizing drone technology

All of these observations provide valuable information and will be utilized by the design team to target specific areas for improvement for the existing envelope to meet requirements needed for a high-performance building. Money can be specifically applied to the areas that have the biggest impact on comfort and energy usage. This will also assist in "right-sizing" the HVAC system and create confidence in the building's performance.

Summary

These case studies demonstrate the value of building pressure testing to not only meet code compliance, but to ensure the performance of the building systems. Thoughtful design of the envelope together with a pressure test means the HVAC systems can be appropriately sized and will result in first cost and operational savings with reduced system sizes and runtime hours. The ideal timing to perform the building pressure test is when the entire exterior envelope is sealed up but before the exterior and interior finish materials are applied. This means all window frames/glass and doors are installed, all door seals/gaskets/sweeps are installed and all penetrations are properly sealed. The true performance of an envelope cannot be truly confirmed without a building pressure test.

Jeff Williams, Vice President for Facilities at Major Hospital said, *"The building pressure test was some of the best money we spent. We now know that the building is tight."*

About the Author

Jess E. Farber, PE, LEED AP, CxA

Mr. Farber joined CMTA in 1999 and has worked in consulting engineering since his graduation from the Georgia Institute of Technology (Georgia Tech). He is the director of the mechanical department in the Louisville office and assists in the overall management of the Louisville office. He has a reputation of providing excellent service to his clients and is well respected for his responsiveness to project related issues. As the leader of CMTA's Mechanical Engineering Department, he works on daily basis with the senior and junior members of the staff. He is a strong proponent of mentoring and places special emphasis on training and developing younger engineers.