Practical Considerations for Whole-Building Air-Leakage Testing

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AS THE REQUIREMENT to complete whole-building air-leakage testing becomes more prevalent through both building codes and various voluntary energy standards, the industry is now grappling with the complexity of completing these tests, particularly in buildings that are fully occupied. Many nations, including Canada, have made commitments to achieve net-zero emissions by 2050. In Canada specifically, the focus has shifted from primarily addressing the energy efficiency of new buildings to also include expediting the rate of deep energy retrofits completed on existing buildings.[1]

While the inclusion of whole-building air-leakage testing in these projects is not yet mandated on a wide scale, it is one tool that can help new buildings and retrofits alike achieve the desired energy performance. This is highlighted in the *Illustrated Guide: Achieving Airtight Buildings*[2] where an archetype case study was modelled with varying levels of air airtightness, both above and below a theoretical target. In the cases where the airtightness target was "missed" the estimated energy associated with heating increased by as much as 70%. By planning for whole-building airtightness testing, the importance of the air barrier system will be emphasized to the entire project team.

So how does one go about testing a large building? Or an occupied building? There are three main components that need to be considered and communicated early in the planning stage: environmental conditions, setup requirements, and occupants.

ENVIRONMENTAL CONDITIONS

While the need to consider the environmental conditions for testing is not something exclusive to testing in occupied buildings, it can be especially important when buildings are occupied because any change in the date or timing of the testing will require significant additional effort and communication with the occupants. Before testing takes place, you must understand the requirements of the test standard you are applying; some have very specific limitations regarding environmental conditions.

For example, ASTM E779-19, *Standard Test Method for Determining Air Leakage Rate by Fan Pressurization*,[3] requires that you measure and record the indoor and outdoor temperatures at the beginning and end of the test and average the values for each to determine the interior and exterior temperature to be used in any calculations. Then the absolute value of the air temperature differential (the difference between the average interior and exterior temperature as measured on site) is multiplied by the height of the building. If the result is greater than 1180 ft•°F (200 m•°C), the pressure difference induced by stack effect is too large and will affect the accuracy of the test findings.

One way to address this problem on the day of testing is to adjust the interior temperature of the building to reduce the temperature differential. Depending on the season, this could mean using the HVAC systems or introducing exterior air before beginning the test to lower the temperature sufficiently

Figure 1. *Technicians running a series of blower doors connected through a central hub.*

before shutting down the system and closing or sealing all exterior openings.

Wind speed and direction should be recorded during the testing. It is best to avoid ASTM E779 testing on extremely windy days, when possible, as the wind can impact the ability of the blower door to achieve the desired test pressures. However, ASTM E779-19 does not provide a specific limit for wind speed. In any case, the pressure taps should be located at the base of leeward walls whenever possible; it is important to avoid both inside and outside corners as well as any other equipment or adjacent structures that could affect pressure readings. When a building is occupied, it is also important to protect the pressure taps (cordoning them off, if possible) to prevent intentional or accidental tampering.

SETUP REQUIREMENTS

Before beginning to plan any individual test, it is important to ensure that you have in place an internal program or process to maintain your equipment and supplies. Some of this is straightforward, like ensuring that after each test you replenish the consumable materials used like batteries, tape, plastic sheets, or fog fluid, while others (like full calibration of the blower door equipment) require more significant time and effort.

ASTM E1258, *Standard Test Method for Airflow Calibration of Fan Pressurization* Devices,[4] is one of the most commonly used standards for blower door equipment calibration. Since the calibration of blower fans requires a specially manufactured test chamber, it is typically performed by the manufacturer. The turnaround time for these tests is typically a couple of weeks; however, the total duration and cost of the testing will somewhat depend on how far the equipment needs to be shipped and whether it needs to be shipped to another country.

The interval at which the fans need to be tested varies depending on which standard you reference (manufacturer recommendations also vary), but most require calibration at least once every two to four years, at any point when you suspect the equipment has been damaged, or when the equipment fails your internal calibration checks. Most manufacturers provide a process for performing these interim checks within the product manuals. The process typically includes checking the motor and fan blade position and checking the flow sensor for leaks, and it is recommended that you complete an internal calibration check prior to each test.

When it comes time to look at preparing for a specific project, it is important to plan the entire setup to ensure that a sufficient amount of the correct equipment to complete the testing is available. Regardless of the test standard used, planning starts with understanding the number of blower door fans (**Fig. 1**) that will be required to successfully pressurize the space and determining where they will be positioned within the building to best distribute the pressure and combat stack effect.

Check with the blower door manufacturer to verify the operating range for the selected fan. For example, I know from the manufacturer's data that one of the fans I use can provide accurate measurements from 300 to 6300 cfm (141 to 2973 L/s) with the flow rings that were originally included at the time of purchase. However, for our Passive House and EnerPHit testing, we have also purchased additional flow rings that can go as low as 11 cfm (5 L/s).

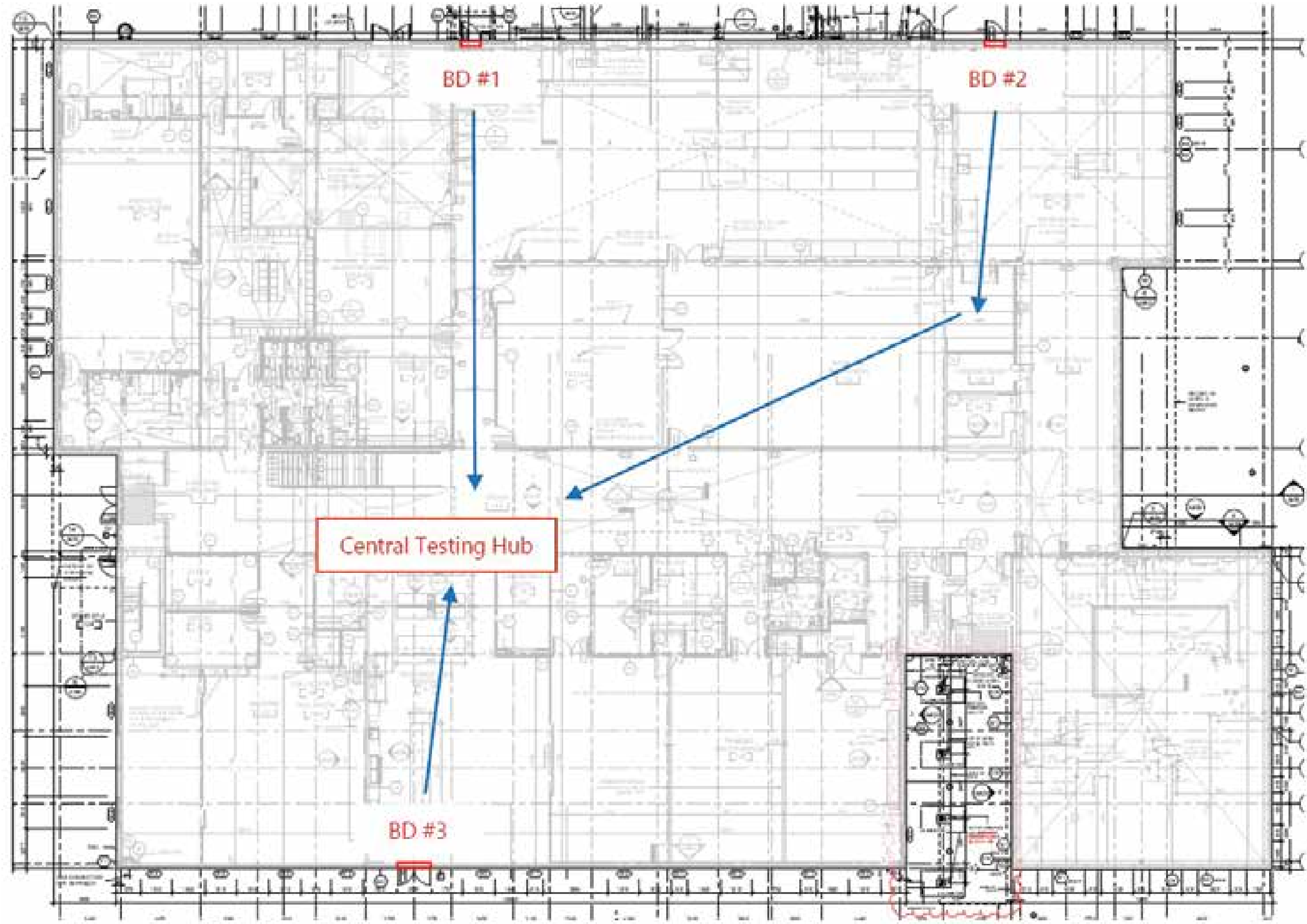

Figure 2. *Sample door and central hub layout.*

We then use the building enclosure area and the target air leakage rate to determine the volumetric flow rate required. The following are sample door calculations:

- Building enclosure surface area: 86,111 ft^2 (8000 m^2)
- Target air infiltration: 0.254 cfm/ft^2 (1.27 L/s-m^2) at 0.01 psi (75 Pa) of pressure.
- Total target leakage: 21,872 cfm (10,160 L/s)
- Total number of blower doors required: 3.42 at peak airflow.

Knowing that we will require a minimum of 3.4 blower doors to achieve the desired air-leakage rate gives us an excellent starting point for our planning. We can now review the floor plans, considering stack effect and building geometry, and identify our ideal locations to position the doors. In the real-life application of this example, we ended up using only four doors because the building was a large two-story rectangle. More complex forms or buildings with more floors would likely have necessitated operating more doors at a lower fan rate.

If a tall building is to be tested, it is necessary to monitor the interior pressure approximately every few floors to ensure that the pressure distribution is uniform. It is also best practice to monitor the pressure drop across the roof throughout testing to ensure that the entire building remains either pressurized or depressurized. Additionally, there must be compensation for stack effect. The stack effect can be mitigated by reducing the temperature difference between the building's interior and exterior, as noted previously. However, that is not always possible; for example, on an extremely cold winter day reducing the interior temperatures to near freezing could damage interior finishes or cause pipes to freeze.

Generally, test pressures will need to be shifted, so that they allow all test points to be at negative pressure during a depressurization test. For example, if the stack pressure at the top of the building is 0.0029 psi (20 Pa), all the test pressures should be below −0.0029 psi (−20 Pa) to ensure that even the top floor achieves a negative pressure. At some buildings it will not be possible to overcome the impact of stack effect with fans (the pressures would be too high, preventing the necessary number of readings from being possible); in such cases, the building will need to be split into multiple zones. For example, a 50-story building would likely need to be split into at least two test areas of 25 floors each.

Beyond the technical requirements for door positioning, there are also practical and installation considerations that should be factored into the planning. For example, you will need to confirm that the door frame size is compatible with the blower door frame. If one of the locations selected is a double door and your blower door assembly is only suitable for a single door frame, it may be necessary to construct a temporary frame to properly seal one of the doors and provide an edge against which to install the blower door frame. It is helpful to identify this need early, and to request help from a qualified contractor when necessary.

There is also a need to consider the interconnectivity of the blower doors. While there are wireless options available, it is not always practical or possible at an existing building to connect all blower doors to a single Wi-Fi network. Therefore, you may need to rely on wired connections. Choosing your door locations relative to the central hub and ensuring that the cables are long enough is critical. **Figure 2** shows a sample blower door and central hub plan. The wires should be taped down, preferably along the outside edge of any corridors, so that they are not tripping hazards for occupants who move throughout the space during testing.

There are a few other key pieces that require planning, and these relate to the interconnectivity of spaces and the sealing of openings. Most standards for whole-building air-leakage testing will require that all interior spaces are interconnected during the testing to ensure uniformity of interior pressure distribution. Typically, you must deploy a surprising number of door stoppers to fulfill this requirement. Confirming the number of interior doors in advance of the testing ensures that there are enough door stoppers on hand. A local hardware store will only have so many, and you might even garner a few funny looks at the checkout when you clean out the entire shelf. The implications of opening all doors are further discussed later in this article.

OCCUPANTS

Most of the challenges in testing occupied spaces come down to the doors and their dual function of facilitating movement and providing security. When the testing is in progress, the doors that are meant to facilitate movement are blocked, and those providing security must remain open.

When interior doors need to be open within a building, it is often necessary to provide additional security to set occupants at ease. In residential buildings, where each unit entry door into the corridors will remain open for the duration of the testing, residents need to be reassured that their space and their belongings will be protected. Depending on the comfort level of the occupants, you might need to station a security guard on each floor to monitor the activity in the corridors.

Meanwhile, the exterior doors (and windows) need to remain in the closed position while the air flow readings are recorded at each test pressure. ASTM E779-19 requires a minimum of five readings at intervals of 0.00072 to 0.0014 psi (5 to 10 Pa) (**Fig. 3**).

Special interest

Looking for Meaningful Work?
Look Outside

Which workers find their jobs the most meaningful and the least stressful? According to self-reported data, the answer is workers in the agriculture, logging, and forestry sector.

Since 2010, the US Bureau of Labor Statistics' American Time Use Survey has asked workers to rate their happiness and stress at work and how meaningful their work is on a scale from 0 (low) to 6 (high). Compared with workers in other industries, workers in agriculture, logging, and forestry had the highest self-reported level of happiness and the lowest-self-reported level of stress, and they gave their work the highest rating in meaningfulness. Respondents in the finance and insurance industries were the most stressed and least happy of all participants, and they gave their work the lowest rating of any sector in the meaningfulness category. Collectively, the data for all industries "paint a simple picture," wrote Andrew Van Dam. "A white collar appears to come with significantly more stress than a blue one."

Analysts hypothesize that relatively high degree of worker satisfaction in agriculture, logging, and forestry may be linked to the locations where these types of work occur. "We found that while your workplace looms as the single most stressful place in the universe, the great outdoors ranks in the top three for both happiness and meaning," Van Dam said. "Researchers across the social and medical sciences have found a strong link between mental health and green space or being outdoors. Even seeing a tree out your window can help you."

Source: washingtonpost.com Tridsanu Thopet/shutterstock.com

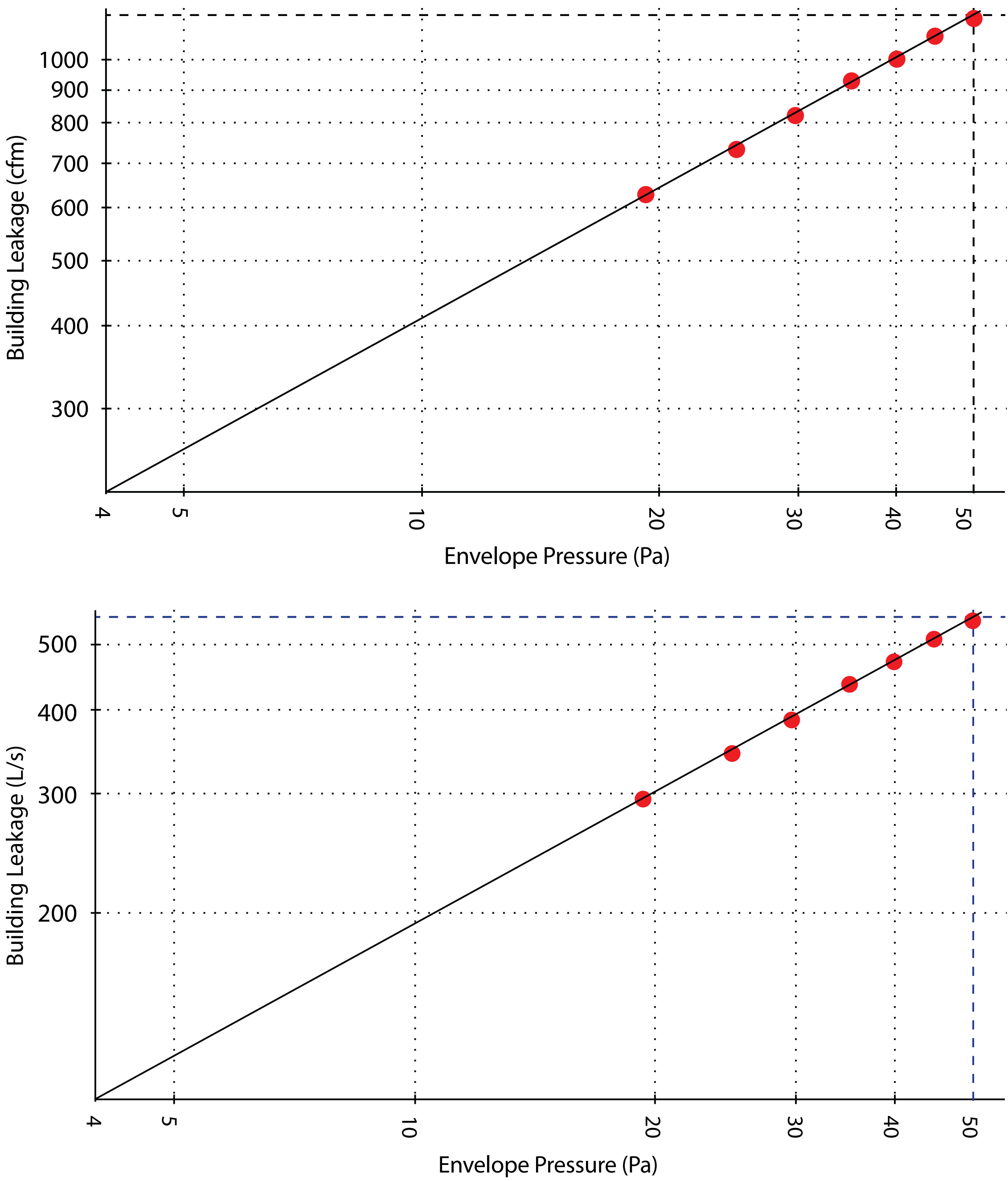

Figure 3a/3b. *Building leakage measurements at 5 Pa increments as collected using TECLOG 4 software. Note: 1 Pa = 0.00014 psi; 1 cfm = 0.47 L/s.*

The day of the test will require cooperation from 100% of the people within the building, and the best way to ensure that is to build buy-in by communicating the plan clearly and concisely. For example, during the planning stage for a high-rise residential project, we understood that the building occupants, primarily seniors, would not be able to go without access in and out of the building for the duration of the testing. All the team members agreed that it would be necessary to provide breaks between readings to allow residents to exit or support personnel to enter the building. This arrangement would increase the overall duration of the testing but minimize the inconvenience to the residents. To streamline the process, the team selected a single door to be identified as the testing access door, and residents were informed that a stop-sign system would be implemented: During the test readings, the stop sign would be posted. Once the reading was complete, the door manager would be notified by walkie-talkie, and the door would be open for approximately two to three minutes to allow individuals to exit or enter. All other exterior doors would need to remain fully closed and would be monitored on a roving basis.

In high-rise buildings, the elevator should be treated in one of two ways. When the building is being tested as a single compartment, it is beneficial to open the elevator doors to allow the air to flow through all the floors more easily and help pressurize everywhere equally. Guards should be installed at each elevator door for the full duration of the test, and use of the elevators is not possible.

Alternatively, if the building is being split into multiple zones, the elevator doors must be sealed and the area of the elevator shaft must be excluded from the test. To allow use of the elevators between readings, they can be sealed with a dust containment door that can be opened and closed as needed without having to reseal the elevator doors.