Building Enclosure Airtightness Testing

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Why is building enclosure air tightness important?

- Energy Savings
- Smaller more Efficient Mechanical Systems
- Moisture Control
- Comfort
- Air Quality
- Building Life Expectancy
How are projects meeting airtightness requirements?

• Passive House
• Energy Star
• Building Enclosure Commissioning (NIBS, ASTM, etc.)
• Building Enclosure Consulting
• Building Code Requirements
• Others
Materials


*Typical Allowable: 0.004 cfm/ft² at 75 Pa (1.57 lb/ft²)*

Assemblies

ASTM E2357-11, *Standard Test Method for Determining Air Leakage of Air Barrier Assemblies*

*Typical Allowable: 0.04 cfm/ft² at 75 Pa (1.57 lb/ft²)*

ASTM E283 – 04 (2012), *Standard Test Method for Determining Rate of Air Leakage Through Exterior Windows, Curtain Walls, and Doors Under Specified Pressure Differences Across the Specimen*

*Typical Allowable: 0.06 cfm/ft² at 300 Pa (6.24 lb/ft²)*

Building Testing

This is where it can get tricky…….
Building Testing

ASTM E779-10, Standard Test Method for Determining Air Leakage Rate by Fan Pressurization

- Multipoint Regression Method


- Single Point Method
- Two Point Method

Typical Allowable Building Leakage:

- 0.4 cfm/ft² @ 75 Pa (IBC, GSA)
- 0.25 cfm/ft² @ 75 Pa (USACE)
- 0.10 cfm/ft² @ 75 Pa (State of Utah)
- 0.6 ACH at 50 Pa (Passive House) or 0.05 cfm/ft² at 50 Pa
ACH (cfm/V) vs. cfm/ft$^2$

- May work for small buildings (residential); ACH will likely allow less leakage than cfm/ft$^2$
- ACH is problematic when comparing small buildings to large buildings
- Volume to surface area ratio increases substantially as building size increases (ACH allows more leakage)
- Materials and Assemblies tested based of surface area
- ACH does not affectively evaluate construction of large buildings
Testing Protocol

ASTM E779-10, Multipoint Regression Method

ASTM E779-10 Limitations:

- Building preparation not clearly defined
- Test procedure is not clearly defined.
- Allows for testing at lower pressure ranges that are more susceptible to error due to weather events.
- Allows data extrapolation (only requires 5 data points)
- Lack of clarity and guidance creates inaccuracy and issues with repeatability
Testing Protocol

USACE, Air Leakage Test Protocol for Building Envelopes

Provides clear guidelines for how ASTM E779 is performed:
• Building preparation is more clearly defined
• Test procedure is clearly defined
• Requires positive and negative pressurization sets
• Defines acceptable induced pressure range
• Does not allow data extrapolation (10 data points and must measure ar 75 Pa)
• Defines acceptable ranges the correlation coefficient squared, $r^2$, in addition to the pressure exponent, $n$
• Defines diagnostic procedures to help determine air leakage sites

Just published….

ABBA, Standard Method for Building Enclosure Airtightness Compliance Testing
• Similar to USACE, but further defines methods for testing
• Includes multipoint regression, single point, and two point methods
• Is to become ASTM standard. ASTM E779 will likely be phased out in the future.
Testing Protocol

- Wind
- Building prep
- Equipment issues
Test Preparation

• Planning is imperative to ensure testing is a smooth process. Know what your getting into before you arrive.

• Create a test plan.

• Organize conference meetings. Don’t be afraid to suggest a site visit to walk the building a few weeks before testing. It is worth it in the end.

• Be sure to document responsibilities for all parties involved. This is not always included specification
Test Preparation

• Include General Building Description

• Contact Information:
  • Testing Agency
  • Owner/Owner’s Rep
  • HVAC Representative
  • Electrician
  • General Contractor
  • Architect

Whole Building Air Test (WBAT)

Pre-Test Meeting Agenda

A. General Information: Commercial buildings can typically be tested to evaluate the air tightness of the building envelope. Whole building air testing (WBAT) typically requires extensive preparation. WBAT can be performed on the whole building (i.e., single side) or as Subtrone or Multisite testing. For the Los Angeles Federal Courthouse building, subtrone or multisite testing is impossible due to the tight court opening through the center of the building. Typically, it utilizes the HVAC excluded building requirements and test guidelines. For additional information, contact the SWBAT study, Protocol for Field Testing of Tall Buildings to Determine Envelope Air Leakage Rate (National Laboratories, 1995). Our proposal was based on using the single side method with the HVAC excluded building preparation guidelines.

<table>
<thead>
<tr>
<th>Participant</th>
<th>Name/Contact/Phone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intertek Field Test (FT)</td>
<td></td>
</tr>
<tr>
<td>Owner/Owner Rep (OR)</td>
<td></td>
</tr>
<tr>
<td>Designer of Record (DC)</td>
<td></td>
</tr>
<tr>
<td>General Contractor (GC)</td>
<td></td>
</tr>
<tr>
<td>HVAC Contractor (HVAC)</td>
<td></td>
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<tr>
<td>Contract Contractor (CC)</td>
<td></td>
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<tr>
<td>Electrical Contractors (EC)</td>
<td></td>
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</tbody>
</table>
Test Preparation

- Overview of Process
- Schedule and Timing
- General Contractor Responsibilities
  - Site coordination
  - Access
  - Coordination with Subcontractors
- Designer Responsibilities
  - Define air barrier system boundary
  - Provide boundary calculation

C. Overview of Process

The following provides a schematic summary of the testing process:

- Pre-test meeting
- Final test preparation — review the official test boundary, envelope area, and equipment requirements, etc.
- Preparation of building prior to testing
- Testing
  - Perform air tightness testing equipment and review building preparation — perform testing in accordance with specified standards
  - Demolition and return building to normal operation.
- Reporting

D. Schedule and Timing

- Expected date of building completion: DATE
- Expected date (range) test may be performed: DATE
- Final test meeting (not more than 10 days prior to test): DATE
- Final test day date (approximately one month prior to test): DATE
- Expected time of day for test preparation & setup: DATE
- Expected time of day for performing test: DATE

Note: Intertek has assumed that all test preparations and test day requirements noted in Section D will be completed prior to arriving at the site, and that all required parties are present at the designated time prior to the start of testing. Consequently, if such requirements are not completed on test day, Intertek will assume a portion of the test day unless otherwise noted.

E. General Contractor & Designer Responsibilities

1. Establish the official test boundary (erosion & exclusion) is the responsibility of the designer of record. The designer of record provides, and for the contractor to confirm, the official test boundary, typically determined by the building envelope air barrier. The official test boundary is required to ensure the validity of the AAMA air barrier test result. See form for additional information on the calculation of the official test boundary.

   Designated Party: NAME
   Anticipated Date of Completion: DATE

2. Access: Unobstructed access to inspect and observe all interior and exterior areas of the building, including areas accessible to mechanical rooms, air handlers, exhaust fans, and exterior air and exhaust dampers, must be provided throughout the testing process to ensure proper test execution. If these are obstructed areas of the building, additional delays or may be necessary to ensure the entire official test boundary is within test pressure.

   Designated Party: NAME
Air Barrier System Boundary

• Typically Defined by the Designer of Record
  • Always review and verify calculation
  • Should be within 5% - 10%
  • Does designer understand concept of continuous air control layer?
Test Preparation

- Document Allowable Leakage Rate
- Building Preparation
  - HVAC Excluded vs. Included
  - Interior Doors
  - Ceiling Tiles
  - Drain traps
  - Elevators

1. Confirm the allowable leakage rate (AILR) @ 0.5 psf (0.25 dm³/s) of enclosure area at 75 Pa

4. Building preparation: In order to mimic "intentional" preparation in the test boundary, the building must be prepared to the "HVAC Excluded" guidelines as follows:
   - Disable the HVAC system in all exhaust fans.
   - Place the HVAC system in the correct mode for the pressure test(s). In some cases, recirculating air systems may also need to be turned off.
   - Seal, seal, and close dampers to outside air and makeup air intakes.
   - Seal, seal, and close dampers to ventilation and exhaust outlets.
   - Close and lock all faucets and drains on the limits of the official test boundary.
   - Fill all plumbing traps with water.
   - For suspended ceiling plenums, remove one tile for every 200 sq. ft. of ceiling area (minimum of one tile per room).
   - Disable vented and non-vented combustion equipment.
   - Drop open all interior doors within the official test boundary, including elevator doors if within the established test boundary. (Note: Refer to Elevator Section below for additional information regarding elevator preparation, if applicable.)
   - Open windows or doors of interior areas that are beyond, but adjacent to, the official test boundary to introduce ambient interior conditions to some exterior side of the official test boundary.
   - Secure and ensure all doors in the plane of the official test boundary will remain closed throughout the test duration.

   Note: See Section 11 below for additional information on default conditions for building preparation. Also note that building preparation performed by others includes removal of temporary masking, sealing, and HVAC system barriers necessary to return the building to normal operation.

   designated party and contacts:
   - Distilling, masking and sealing of HVAC components: NAME
   - HVAC contractor: NAME
   - HVAC engineer: NAME
   - Fan electrical power: NAME
   - Ceiling tiles, prop open interior doors, secure exterior doors and access: NAME
   - Elevator: NAME

5. Test Day(s):
   - HVAC technician must be onsite throughout the entire test duration to verify and assist with test operations. (Note: The technician, or technician, must be present at all times while testing and must also complete the testing.

Designated Party: NAME
HVAC Excluded vs. Included

HVAC Excluded
Building Enclosure Area: 119,825 ft\(^2\)
Performance: 0.137 cfm/ft\(^2\)

HVAC Included
Building Enclosure Area: 119,825 ft\(^2\)
Performance: 0.174 cfm/ft\(^2\)

Over 4000 cfm of air leakage through dampers!
Test Preparation

- Document Testing Agency Responsibilities
  - Pre-Test Walk-Through
  - Test Procedure
  - Reporting
  - Diagnostic Evaluation (IR and Smoke)

- Project Specific Notes:
  - Door dimensions for blower door frame
  - Perimeter isolated rooms
  - Access limitations
  - Etc.

- ASTM E779 requires that all interconnecting doors of the interior of the building be propped and remain open within the official test boundary during the test.

  Designated Party: NAME

- An electrician must be on site throughout the entire test duration to ensure sufficient, continuous power supply is provided for pressurizing the building. Power supply for the fans will be significant for this test. Requirements include continuous power at each fan, power to be supplied on separate circuits for each fan, and access to circuit breakers during the test.

  Designated Party: NAME

f. Testing Agency (Intertek-AAT) Responsibilities

1. Pre-Test Meeting/conference call

   Approximately one (1) month prior to expected building enclosure air barrier construction completion, Intertek-AAT will schedule a conference call with the construction team to establish a test date and review the pre-test checklist. This conference call shall include the designer of record, contractor/site agent, general contractor, and subcontractors associated with the performance of the building enclosure and mechanical systems (electrical, HVAC, control systems, etc.). This meeting is imperative as building preparation and existence throughout the WBT by the construction team must be coordinated to ensure the WBT is performed correctly and without delay.

2. Pre-Test Walk-through

   Intertek-AAT will perform a building walk-through upon arriving on site to verify all building preparations have been completed.

   • Confirm building preparation is complete
   • Note environmental conditions that may cause the leakage rate to be less than in dry conditions.
   • Confirm all areas outside of the official test boundary are at ambient conditions.

   Note: Completion of the required building preparation is outside of Intertek-AAT's scope of work.

3. Perform Whole Building Air Test

   Prior to performing the WBT, Intertek-AAT will perform a confidence assessment on the building to verify that the required test pressures can be achieved. The confidence assessment will be performed by attempting to reach the maximum air flow capacity required to meet the specified testing protocol. Once the confidence assessment is completed, and Intertek-AAT is satisfied with the building performance, the WBT will be performed.
Test Preparation

• Provide Enclosure Area Calculation Guide

H. Enclosure Area Calculation Guide (WBAT)

The test boundary shall be the sum of all building planes designed and constructed with an approved air barrier. This boundary typically encloses the conditioned space of the building, and must be designed and constructed such that it provides a continuous air control boundary. The boundary calculation is required to determine the validity of the test via error calculation, as well as determining the pass/fail result of the WBAT.
Air Barrier System Boundary

Does the test boundary make sense?

BAD

GOOD
# Test Preparation

- Provide Default Preparation Guide

## I. Default Preparation Guide

<table>
<thead>
<tr>
<th>Intentional Openings</th>
<th>Air barrier systems enclosure test (air barrier systems and HVAC-related openings included)</th>
<th>Operational enclosure test (air barrier systems and HVAC-related openings included)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Doors, windows, and operable windows inside the test enclosure</td>
<td>Open</td>
<td>Open</td>
</tr>
<tr>
<td>Fire dampers</td>
<td>Retained as found</td>
<td>Retained as found</td>
</tr>
<tr>
<td>Windows, doors, shutters, and frames in the bounding enclosure</td>
<td>Closed and latched</td>
<td>Closed and latched</td>
</tr>
<tr>
<td>Access, windows, doors, and operable windows in Anxillary Spaces</td>
<td>Test in accordance with additional notes for Anxillary space</td>
<td>Test in accordance with additional notes for Anxillary space</td>
</tr>
<tr>
<td>Spray doors and an handle access points</td>
<td>Tested and passed</td>
<td>Tested and passed</td>
</tr>
<tr>
<td>Raised or extended bumper</td>
<td>Fail, unable to close</td>
<td>Fail, unable to close</td>
</tr>
<tr>
<td>Minimum air pressure</td>
<td>As found</td>
<td>As found</td>
</tr>
<tr>
<td>Air damper assembly for exhaust distribution device in a separate mechanical room</td>
<td>As found</td>
<td>As found</td>
</tr>
<tr>
<td>8 inches of other standard materials around a vent or ventilation apparatus located within the test enclosure</td>
<td>19%</td>
<td>19%</td>
</tr>
<tr>
<td>Vent and flue apparatus (fireplace, wood burning stoves, pellet stove)</td>
<td>No Leaks, damper closed</td>
<td>No Leaks, damper closed</td>
</tr>
<tr>
<td>Exhaust, outdoor air, makeup air fan, all handles that serveinside the enclosure and outside the test enclosure</td>
<td>OFF</td>
<td>OFF</td>
</tr>
<tr>
<td>Yard ventilators</td>
<td>OFF</td>
<td>OFF</td>
</tr>
<tr>
<td>Air Intake with manual dampers</td>
<td>Dampers closed</td>
<td>Dampers closed</td>
</tr>
<tr>
<td>Air Intake with gravity dampers</td>
<td>19%</td>
<td>19%</td>
</tr>
<tr>
<td>Air Exhaust with no dampers</td>
<td>19%</td>
<td>19%</td>
</tr>
<tr>
<td>Air Exhaust with air relief</td>
<td>19%</td>
<td>19%</td>
</tr>
<tr>
<td>Air Exhaust with fume relief dampers</td>
<td>19%</td>
<td>19%</td>
</tr>
<tr>
<td>Air exhaust with fume relief</td>
<td>19%</td>
<td>19%</td>
</tr>
<tr>
<td>Intentional powered or non-powered open for various disturbances</td>
<td>19%</td>
<td>19%</td>
</tr>
</tbody>
</table>

### Inside or Blown-Out Rooms and Equipment

- 30% for air relief
- 19% for supply

### Inside or Blown-Out Rooms and Equipment

- 30% for air relief
- 19% for supply

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- 30% for air relief
- 19% for supply

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- 30% for air relief
- 19% for supply

### Inside or Blown-Out Rooms and Equipment

- 30% for air relief
- 19% for supply

### Inside or Blown-Out Rooms and Equipment

- 30% for air relief
- 19% for supply
Identifying Air Leakage Sites

**Building Description:** Two-Story Police Department

**Building Enclosure:** Basis of Design

- **Slab-on-Grade**
  - *Air Control:* Slab on Grade/Vapor Barrier Membrane
- **Walls:** Rain Screen Cladding, Fin Windows employed at punched wall openings.
  - *Air Control:* Mechanically Fastened Membrane and Fenestration
- **Roof Assembly:** Vented Steep-Sloped Asphalt Shingle Roof
  - *Air Control:* Second Floor Drywall Ceiling

**Building Enclosure Area:** 37,036 ft²

**Performance:** 0.724 cfm/ft² *(extrapolated from 35 PA)*
FLOOR AREA 13,010 SQFT
TOTAL SURFACE AREA: 37,036 SQFT
**Building Description:** Four-Story Apartment Building with Ground Floor Parking Space

**Building Enclosure:** Basis of Design
- **First Floor Slab/Slab-on-Grade**
  - *Air Control:* Concrete Slab
- **Walls:** Rain Screen Cladding, Aluminum Windows employed at punched wall openings.
  - *Air Control:* Mechanically Fastened Membrane and Fenestration
- **Roof Assembly:** Vented Low-Sloped Built-up Roof supported by Wood Deck
- **Air Control:** Fourth Floor Drywall Ceiling

**Building Enclosure Area:** 37,250 ft\(^2\)

**Performance:** 0.541 cfm/ft\(^2\)
Test Boundary

**Building Description:** Three-Stories; with Offices, Lecture Halls, Classrooms, Auditorium

**Building Enclosure:** Basis of Design
- **Slab-on-Grade**
  - *Air Control:* Slab on Grade/Vapor Barrier Membrane
- **Walls:** Brick Cavity Wall, Aluminum Windows at punched wall openings, and portions of Curtain Wall.
  - *Air Control:* Closed Cell Spray Foam in conjunction with Self-adhered Sheet and Fluid Applied Air Barrier Membranes at transitions, wall openings, penetrations, control joints, substrate transitions, etc. and Fenestration
- **Roof Assembly:** Fully Adhered Single-Ply Membrane supported by Concrete Deck
  - *Air Control:* Concrete Deck/Single Ply Membrane.

**Building Enclosure Area:** 216,300 ft²

**Performance:** 0.197 cfm/ft² *
Single Zone Testing with Multiple Zones

*Similar procedures can be used to perform partial building tests through beginning stages of construction or forensic investigation.*
Single Zone Testing with Multiple Zones

**Building Description:** Single Story Visitor’s Center

**Building Enclosure:** Basis of Design

- **Slab-on-Grade**
  - *Air Control:* Slab on Grade/Vapor Barrier Membrane

- **Walls:** Rain Screen Wall Assembly, Concrete, Window Wall,
  - *Air Control:* Mechanically Fastened Membrane, Concrete, Fenestration

- **Roof Assembly:** Fully Adhered Single-ply Membrane supported by Concrete Deck
  - *Air Control:* Concrete Deck/Single ply Roof Membrane

**Building Enclosure Area:** 9,130 ft\(^2\)
Single Zone Testing with Multiple Zones
Single Zone Testing with Multiple Zones

+75 PA

+50 PA
Single Zone Testing with Multiple Zones

+75 PA

+75 PA
Single Zone Testing with Multiple Zones

Selected: 30.00 seconds
Obs #: 2219 2248
Viewing File: F93 Test LC

Total Flow: 2164 (2 of 2 fans)
Env Pressure: 74.8 on 4 channels

Average
- NORTH ELEV 76.5
- EAST ELEV 75.6
- SOUTH ELEV 76.4
- WEST ELEV 70.8
- M w/ LC -1.6
- N w/ R LC -0.1
- N w/ R WEST 0.0
- N w/ R NW -0.1
- N w/ R SE 0.0
- N FAN -110
- Ring A
- Flow 1893
- Mech Fan -151
- Ring C
- Flow 281
Additions
Troubleshooting
Troubleshooting

- Testing with Relatively High Wind Speeds
- Solar and Rain Effects on Tubing
Troubleshooting

Building Description: Two-Story School
Building Enclosure: Basis of Design
  - Slab-on-Grade
    - Air Control: Slab on Grade/Vapor Barrier Membrane
  - Walls: Precast Concrete Wall Panels and Back-up Wall with Air Barrier Membrane
    - Air Control: Self Adhered Air Barrier Membrane and Fenestration
  - Roof Assembly: Single-Ply Roof Membrane and IRMA supported by Concrete Deck
    - Air Control: Vapor Barrier Membrane/ Waterproofing

Building Enclosure Area: 119,825 ft²
Troubleshooting
Troubleshooting
**Troubleshooting**

**Building Description:** 100 Year Old, 15 Story Office Building with 3 Basement Levels

**Building Enclosure:** Basis of Design

- **1st Floor Slab:**
  - *Air Control:* First Floor Slab
- **Walls:** Stone Mass Wall with Wood Windows at punched wall openings
  - *Air Control:* Stone and Fenestration
- **Roof Assembly:**
  - *Air Control:* Mansard Roof Assembly with Terra Cotta Dormers, Built-up Roof Assembly, and Fenestration

**Building Enclosure Area:** 119,825 ft²
Troubleshooting
Troubleshooting
Troubleshooting

- Door openings may not always accommodate blower door frame.
  - 100 year old door with offset hinge.
  - Added 3 hours to site time
Troubleshooting

Use graph to trouble shoot equipment and building conditions
- Monitor fan pressures (Fan spinning backwards)
- Monitor enclosure pressures
- Monitor interior building pressures
Troubleshooting
Interior Pressure and Stack Pressure Monitoring
Stack Pressure Monitoring
Questions?
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