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Building **Better Together.**

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

Testing

Materials

ASTM E2178-13, *Standard Test Method for Air Permeance of Building 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*

ASTM E1827 – 11, Standard Test Methods for Determining Airtightness of Buildings Using an Orifice Blower Door

- *Single Point Method*
- *Two Point Method*

Typical Allowable Building Leakage:

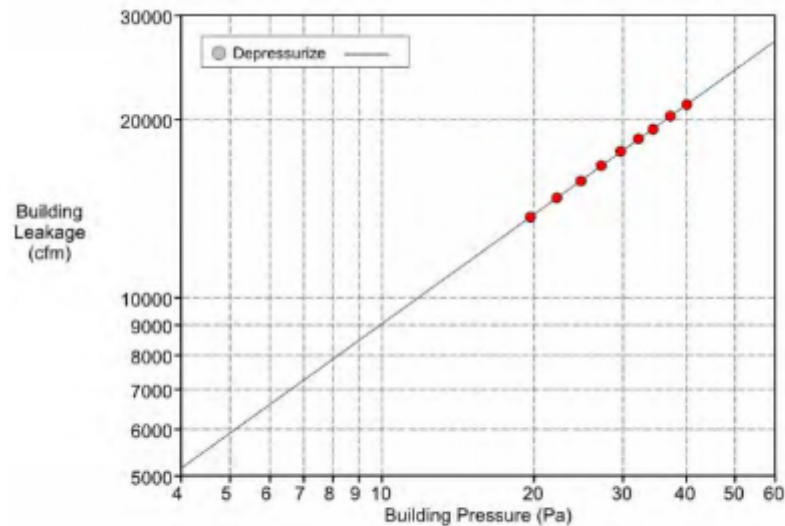
- 0.4 cfm/ft² @ 75 Pa (IBC, GSA)
- 0.25 cfm/ft² @ 75 Pa (USACE)
- 0.10 cfm/ft² @ 75 Pa (State of Utah)
- 0.6 ACH at 50 Pa (Passive House) or 0.05 cfm/ft² at 50 Pa

ACH (cfm/V) vs. cfm/ft²

- May work for small buildings (residential); ACH will likely allow less leakage than cfm/ft²
- 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



Induced Pressure vs. Flow Pressure, Depressurize Set

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:

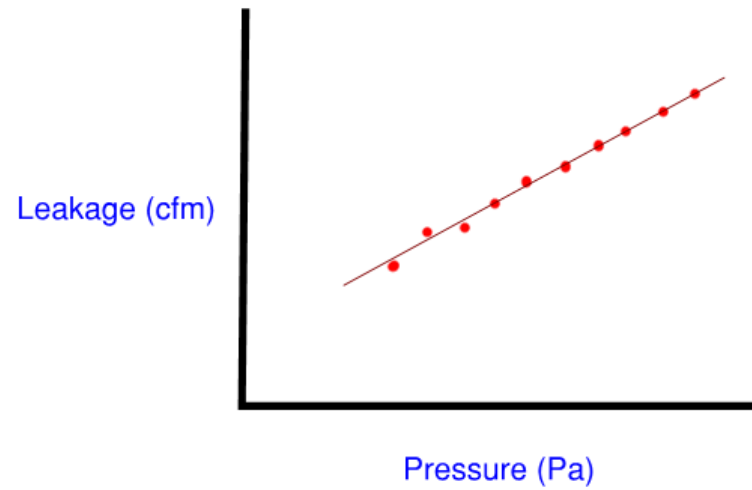
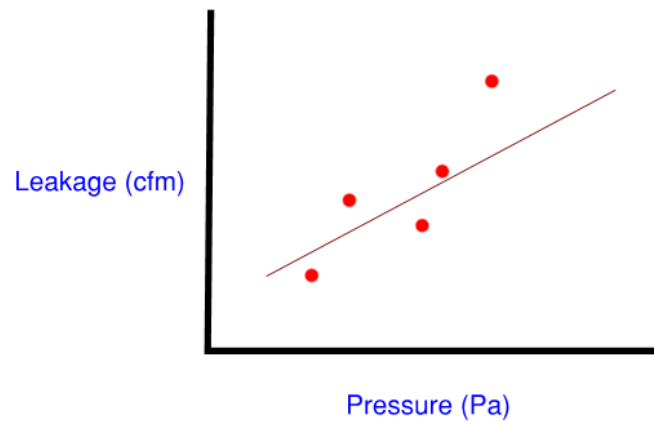
- Building preparation is more clearly defined
- Test procedure is clearly defined
- Requires positive and negative pressurization sets
- Defines acceptable induced pressure range
- Does not allow data extrapolation (10 data points and must measure at 75 Pa)
- Defines acceptable ranges the correlation 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

[Project]

[Date]

A. **General Information:** Commercial buildings can typically be tested to evaluate the air tightness of the building enclosure. Whole building air testing (WBAT) typically requires extensive preparation. WBAT can be performed on the whole building (i.e., single zone) or as split-zone or multi-zone testing. For the Los Angeles Federal Courthouse building, split-zone or multi-zone testing is impractical due to the light court extending through the center of the building. Typically, we utilize the "HVAC Excluded" building preparation and test guidelines. For additional information, refer to the ASHRAE study, "Protocol for Field Testing of Tall Buildings to Determine Envelope Air Leakage Rate 935-RR" (Sabrofieth, 1998). Our proposal was based on using the single-zone method with the "HVAC Excluded" building preparation guidelines. In the event "HVAC Excluded" building preparation is not initially achieved, access to mechanical systems is required to verify mechanical dampers are in the closed position and remain closed for the test.

B. General Test Area Description: [provide general description of test area]

Participants:	Name/Email/Phone
Intertek- ATI (ITK-ATI):	
Owner / Owner Reps (OR):	
Designer of Record (DOR):	
General Contractor (GC):	
HVAC Contractor (HVAC):	
Controls Contractor (CC):	
Electrical Contractors (EC):	

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

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C. Overview of Process

The following provides a schematic summary of the testing process:

- Pre-test meeting
- Pre-test preparation – review the official test boundary, enclosure area, and equipment requirements, etc.
- Preparation of building prior to testing
- Testing
 - Intertek-ATI stages equipment and reviews building preparation
 - Perform testing in accordance with specified standard(s)
- Demobilization 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**
 - Person in charge of scheduling test date (minimum 30 day notice): **DATE**
- Pre-test Meeting/Conference Call 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-ATI has assumed that all building preparations and test day requirements noted in Section E will be complete prior to arriving at the site, and that all required parties are present at the designated time prior to the start of testing. Intertek-ATI has assumed a specific amount of time at the site; delays from items not being completed and/or parties not present may increase the test duration and may require additional fees.

E. General Contractor & Designer Responsibilities

1. **Establish the Official Test Boundary (Enclosure Air Barrier):** It is the responsibility of the Designer of Record to provide, and for the Contractor to confirm, the official test boundary, typically delineated by the building enclosure air barrier. The official test boundary is required to determine the validity of the WBAT via error calculation and the pass/fail result of the WBAT. See Item G below for additional information on the calculation of the official test boundary.

Designated Party: **NAME**
Anticipated Date of Completion: **DATE**

2. **Access:** Unhindered access to inspect and observe ALL interior and exterior areas of the building, including access to mechanical rooms, air handlers, exhaust fans, and outdoor air and exhaust dampers, must be provided throughout the testing process to ensure proper test execution. If there are restricted areas of the building, additional coordination may be necessary to ensure the entire official test boundary reaches test pressures.

Designated Party: **NAME**

Intertek-ATI Project XXXXX.XX
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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

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3. Confirm the Allowable Leakage Rate (ALR) @ 75Pa: 0.25 cfm/ft² of enclosure area at 75 Pa
4. **Building Preparation:** In order to isolate "intentional" penetrations in the test boundary, the building must be prepared to the "HVAC Excluded" guidelines as follows:
 - Disable the HVAC system and exhaust fans.
 - Place the HVAC system in the correct mode for the pressure test(s). In some cases, recirculating air handlers may also need to be turned off.
 - Mask, seal, and close dampers to outside air and makeup air intakes.
 - Mask, seal, and close dampers to ventilation and exhaust outlets.
 - Close and lock all windows and doors on the limits of the official test boundary.
 - Fill all plumbing traps with water.
 - For suspended ceiling plenums, remove one tile for every 500 sq. ft. of ceiling area (minimum of one tile per room).
 - Disable vented and non-sealed combustion equipment.
 - Prop 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 spaces that are beyond, but adjacent to, the official test boundary to introduce ambient exterior conditions to 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
 - At conditions where the building elevator shaft(s) is/are included within the official test boundary, or in the event that even pressure cannot be obtained due to choke points, the elevator doors must be opened at each floor with the elevator car parked between floors. This requirement is project specific, and may not be necessary for this project.

Note: See Section H 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 overrides necessary to return the building to normal operation.

Designated Party and Contact(s):

- Disabling, masking and sealing of HVAC components: **NAME**
- HVAC controls: **NAME**
- Plumbing traps: **NAME**
- Fan electrical power: **NAME**
- Ceiling tiles, prop open interior doors, secure exterior doors and access: **NAME**
- Elevator: **NAME**

5. Test Day(s):

- An HVAC technician must be on site throughout the entire test duration to verify and assist with control operations. Oftentimes, the controls do not perfectly close all the dampers and adjustments must be made to properly execute the testing.

Designated Party: **NAME**

HVAC Excluded vs. Included



HVAC Excluded

Building Enclosure Area: 119,825 ft²

Performance: 0.137 cfm/ft²

HVAC Included

Building Enclosure Area: 119,825 ft²

Performance: 0.174 cfm/ft²

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-ATI) Responsibilities

1. Pre-Test Meeting/Conference Call

Approximately one (1) month prior to expected building enclosure air barrier construction completion, Intertek-ATI 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, commissioning agent, general contractor, and subcontractors associated with the performance of the building enclosure and mechanical systems (electrical, HVAC, control contractors, etc.). This meeting is imperative, as building preparation and assistance throughout the WBAT by the construction team must be coordinated to ensure the WBAT is performed correctly and without delays.

2. Pre Test Walk-Through

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

- Confirm building preparation is complete
- Note rain 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-ATI's scope of work.

3. Perform Whole Building Air Test

Prior to performing the WBAT, Intertek-ATI 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 concluded, and Intertek-ATI is satisfied with the building performance, the WBAT will be performed.

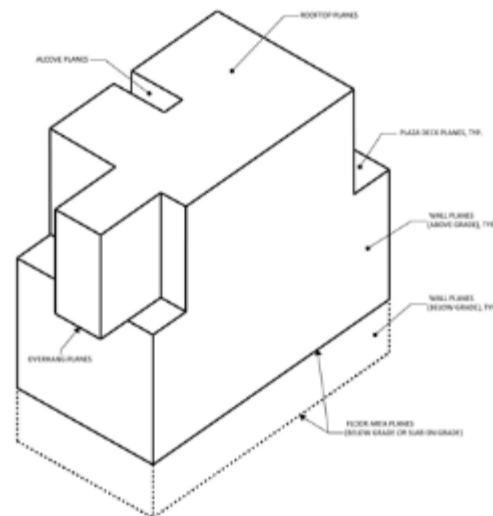
Test Preparation

- Provide Enclosure Area Calculation Guide

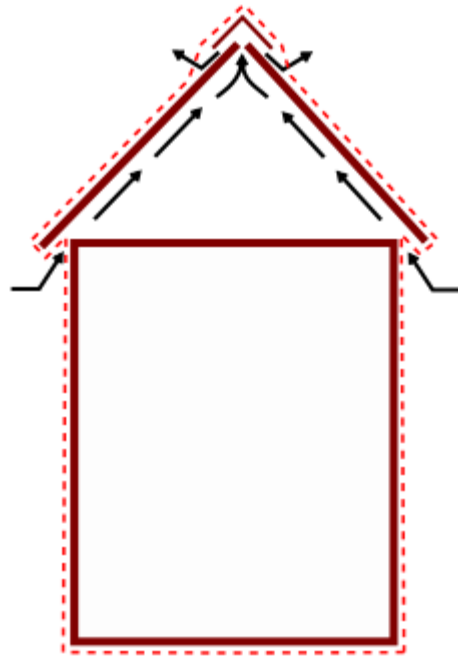


H. Enclosure Area Calculation Guide (WBAT)

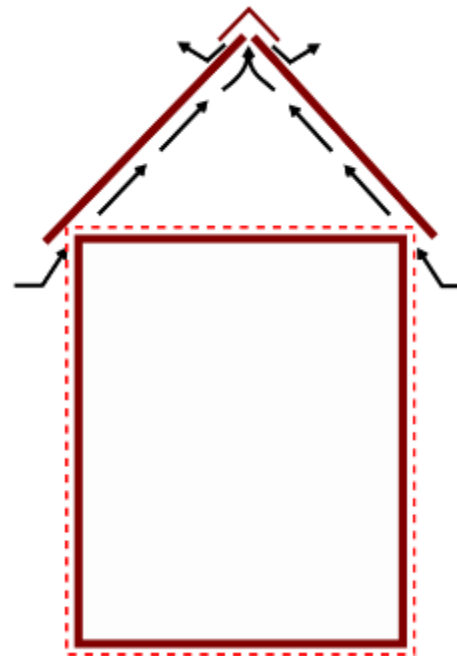
The test boundary shall be the sum of all building planes designed and constructed with an approved air barrier. This boundary typically encloses the conditioned space of the building, and must be designed and constructed such that it provides a continuous air control boundary. The boundary calculation 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



BAD



GOOD

Does the test boundary make sense?

Test Preparation

- Provide Default Preparation Guide



I. Default Preparation Guide

Intentional Openings	Air barrier systems enclosure test (HVAC-related openings excluded)	Operational enclosure test (air barrier systems and HVAC-related openings included)
Doors, hatches, and operable windows inside the test enclosure	Open	Open
Fire Dampers	Remain as found	Remain as found
Windows, doors, skylights, and hatches in the bounding enclosure	Closed and latched	Closed and latched
Identify windows, doors, hatches, and operable windows in Ancillary Spaces. See notes for Ancillary Spaces	Treat in accordance with additional notes for Ancillary Spaces	Treat in accordance with additional notes for Ancillary Spaces
Dryer doors and air handler access panels	Closed and latched	Closed and latched
Vented combustion appliance	Off, unable to fire	Off, unable to fire
Pilot light	As found	As found
Chimney or outlet for vented combustion device in a separate mechanical room	As found	As found
B-vent or other insulated chimney serving a vented combustion appliance located within the test enclosure	Sealed*, **	As found
Solid fuel appliances (fireplaces, wood burning stoves, pellet stoves)	No fires; dampers closed; chimney sealed*, **	No fires; dampers closed
Exhaust, outdoor air, make-up air fans, air handlers that serve areas inside and outside the test enclosure	Off	Off
Clothes dryers	Off	Off
Air intake inlet with motorized dampers	Dampers closed and sealed*, **	Dampers closed
Air intake inlet with gravity dampers	Sealed*, **	As found
Air intake inlet with no dampers	Sealed*, **	Open unless fan(s) serving inlet is operated greater than 8000 hours per year, then sealed*, **
Exhaust or relief air outlet with motorized dampers	Dampers closed and sealed*, **	Dampers closed
Exhaust or relief air outlet with gravity dampers	Sealed*, **	As found
Exhaust or relief air outlet with no damper	Sealed*, **	Open unless fan serving outlet is operated greater than 8000 hours per year, then sealed*, **
Active or passive smoke control systems - air reliefs and intakes	Sealed*, **	As found
Intended powered or non-powered openings for vented shafts/stairwells	Sealed*, **	As found



Waste or linen handling systems and equipment	Sealed*, **at rooftop chute vent opening.	Rooftop chute vent – open, chute intake doors – closed, chute intake room, and chute discharge room doors – closed and latched, fire dampers - left as found
Clothes dryer outlets	Sealed*, **	As found; sealed*, ** if dryers are not yet installed
Exhaust, outdoor air, or make-up air fan that runs >8000 hours per year	Sealed*, **	Sealed*, **
Ductwork that serves areas inside and outside the test enclosure	Sealed*, ** at supply and return	Sealed*, ** at supply and return
Floor drains and plumbing	Traps filled	Traps filled
<p>*Sealed means that an opening has been temporarily masked airtight (e.g. covered with self-adhering plastic film, taped polyethylene film, or rigid board stock). ** If the test result meets the passing criteria for the method used then the building is deemed to pass even if not all of the HVAC related openings were sealed during the test.</p> <p>Ancillary Spaces: Make a list of ancillary spaces that are not clearly included in the test enclosure by the test specifications or construction documents (such as mechanical rooms, elevator equipment rooms, loading docks, crawlspaces, basements, and attics).</p> <p>A. Include an ancillary space within the test enclosure if it is thermally separated from outdoors (i.e. by assemblies that include insulation and continuous air barriers) and is not thermally separated from adjoining indoor portions of the test enclosure. Windows and doors to the outdoors shall be closed and latched. Doors to the adjoining portions of the test enclosure shall be open during the test if it is an Air Barrier Systems Enclosure test and closed if it an Operational Enclosure Test.</p> <p>B. Do not include an ancillary space within the test enclosure if it is thermally separated from all adjoining portions of the test enclosure and is vented to the exterior by passive openings that do not include motorized or gravity dampers. Windows, doors and passive ventilation openings to the outdoors shall be open during the test and doors to all adjoining portions of the test enclosure shall be closed and latched if it is an Air Barrier Systems Enclosure Test. Many older commercial, institutional, and industrial buildings have separate mechanical rooms that contain boilers connected to multi-story chimneys; these spaces often include passive or fan powered make-up air inlets. In this case treat the boiler room as a separate space which is outside the test enclosure.</p> <p>After applying A and B if it is still unclear whether a space is inside or outside the test enclosure, consult with the designer, or close and latch doors and windows to both the test enclosure and the outside during the test.</p>		

Identifying Air Leakage Sites

Building Description: Two-Story Police Department

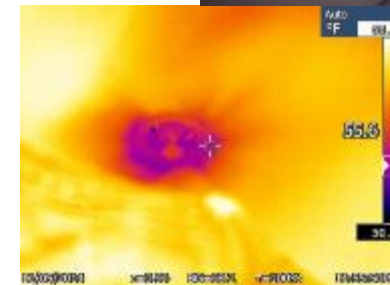
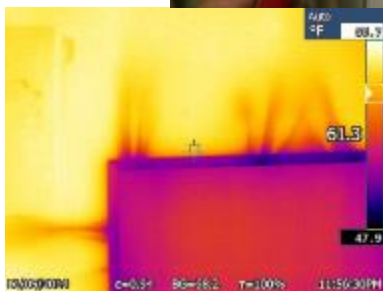
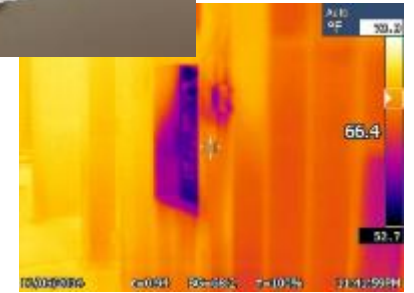
Building Enclosure: Basis of Design

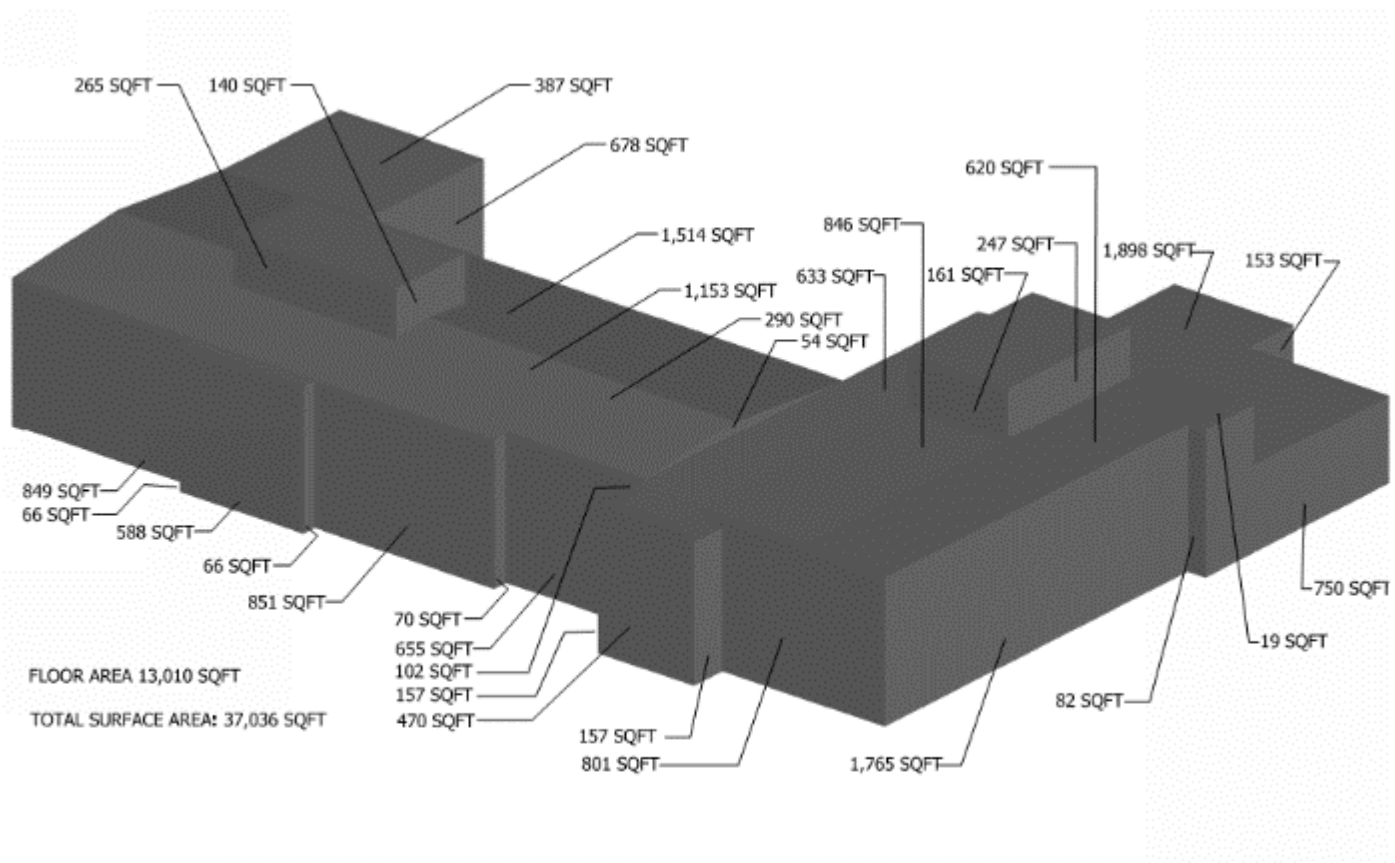
- Slab-on-Grade
 - *Air Control:* Slab on Grade/Vapor Barrier Membrane
- Walls: Rain Screen Cladding, Fin Windows employed at punched wall openings.
 - *Air Control:* Mechanically Fastened Membrane and Fenestration
- Roof Assembly: **Vented Steep-Sloped Asphalt Shingle Roof**
 - *Air Control:* **Second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

Building Enclosure Area: 37,036 ft²

Performance: 0.724 cfm/ft² *(extrapolated from 35 PA)







Building Description: Four-Story Apartment Building with Ground Floor Parking Space

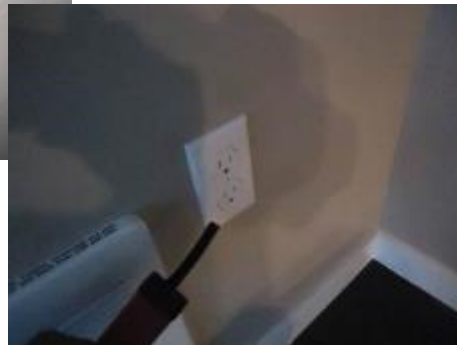
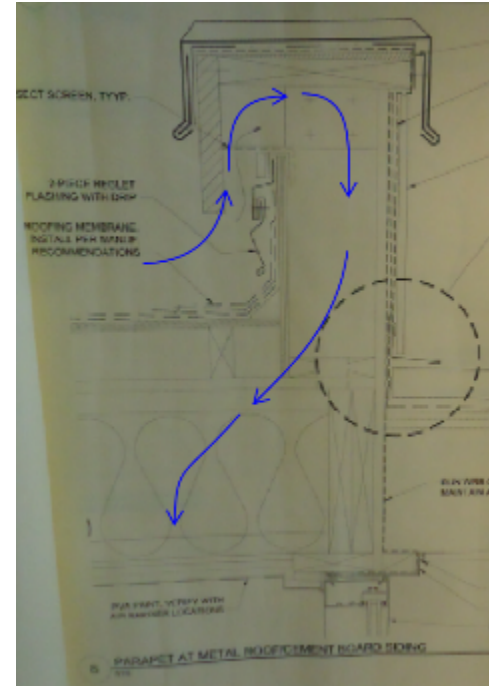
Building Enclosure: Basis of Design

- 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 ft²

Performance: 0.541 cfm/ft²





Test Boundary

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

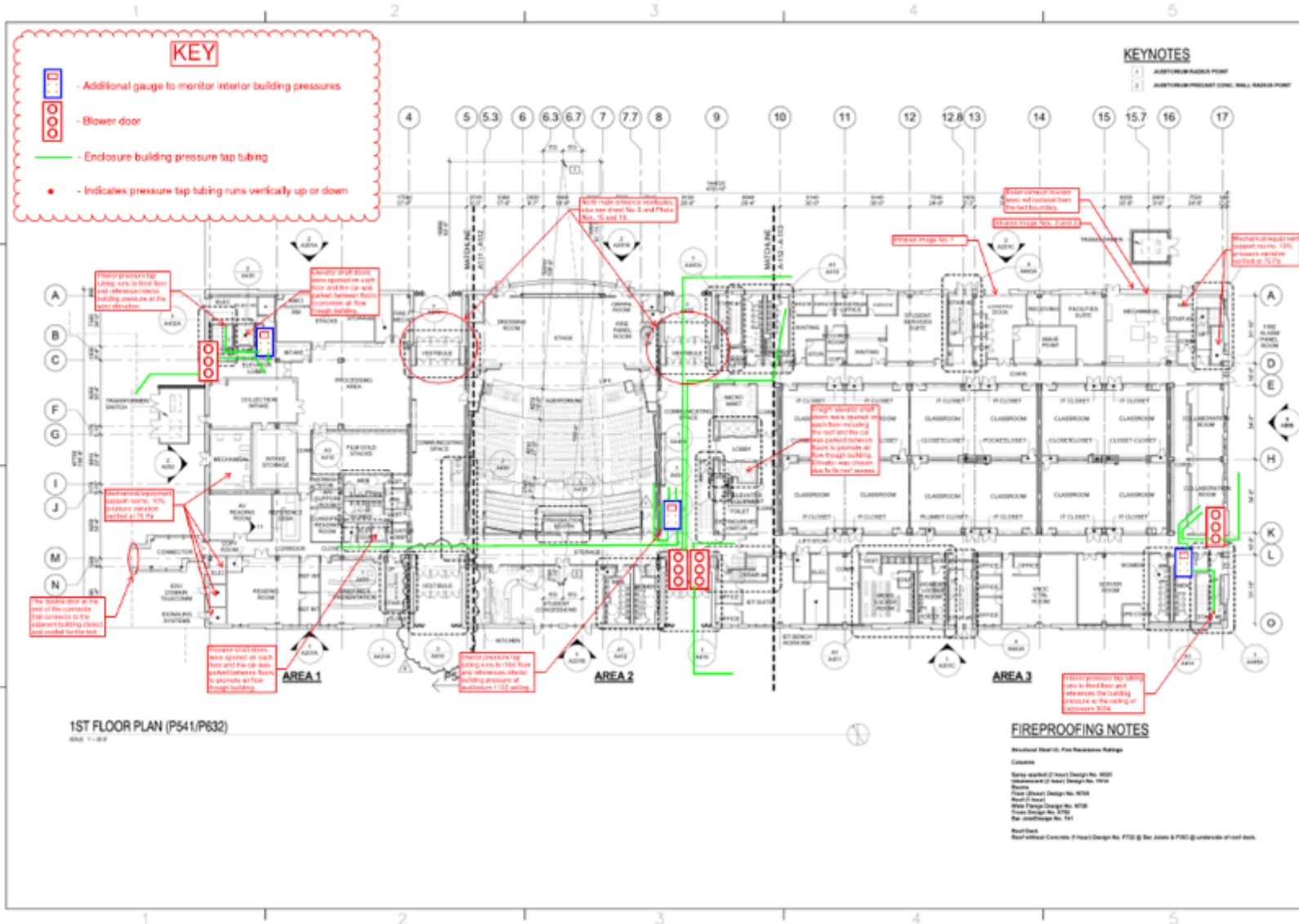
Building Enclosure: Basis of Design

- 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.

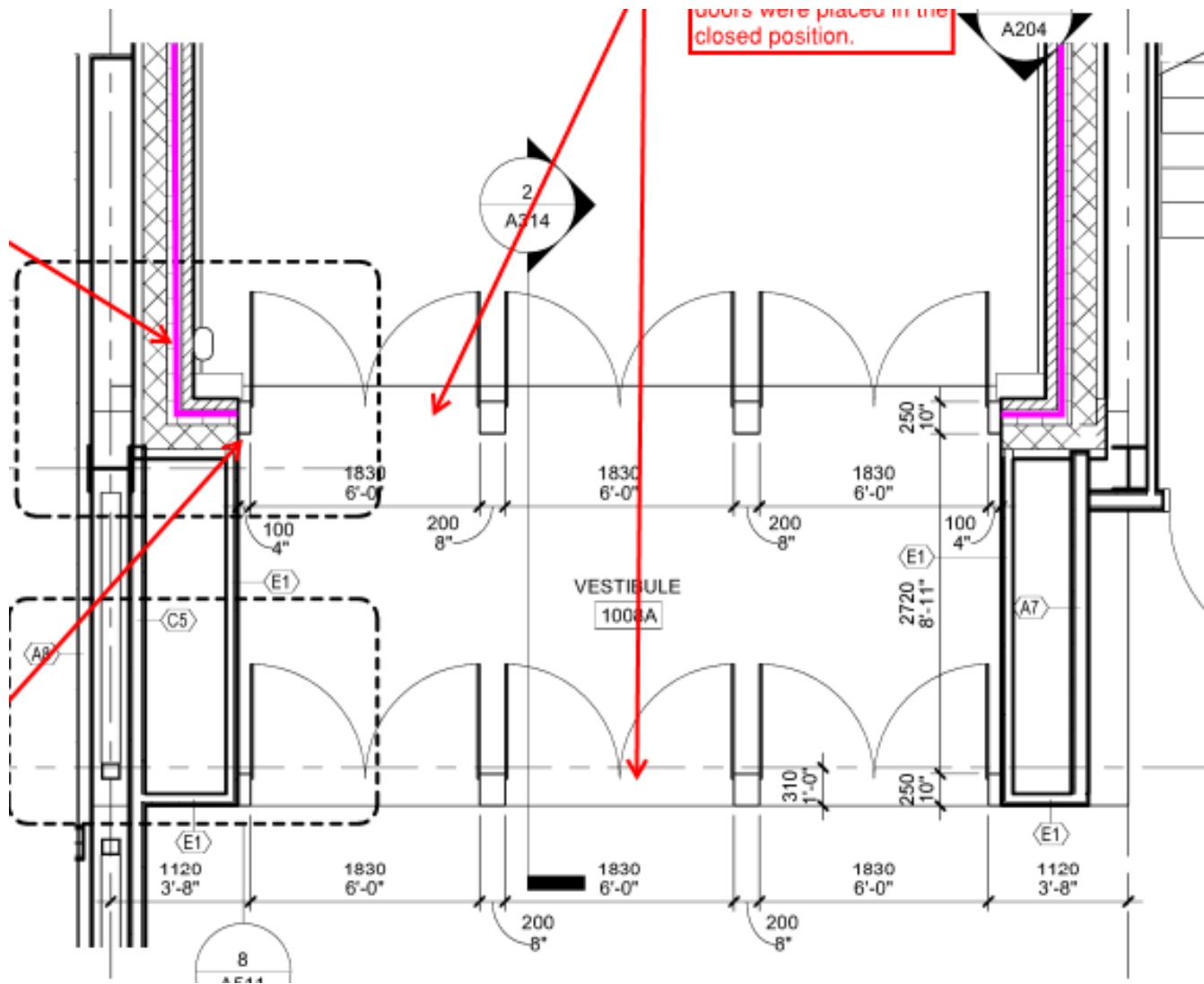
Building Enclosure Area: 216,300 ft²

Performance: 0.197 cfm/ft² *





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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

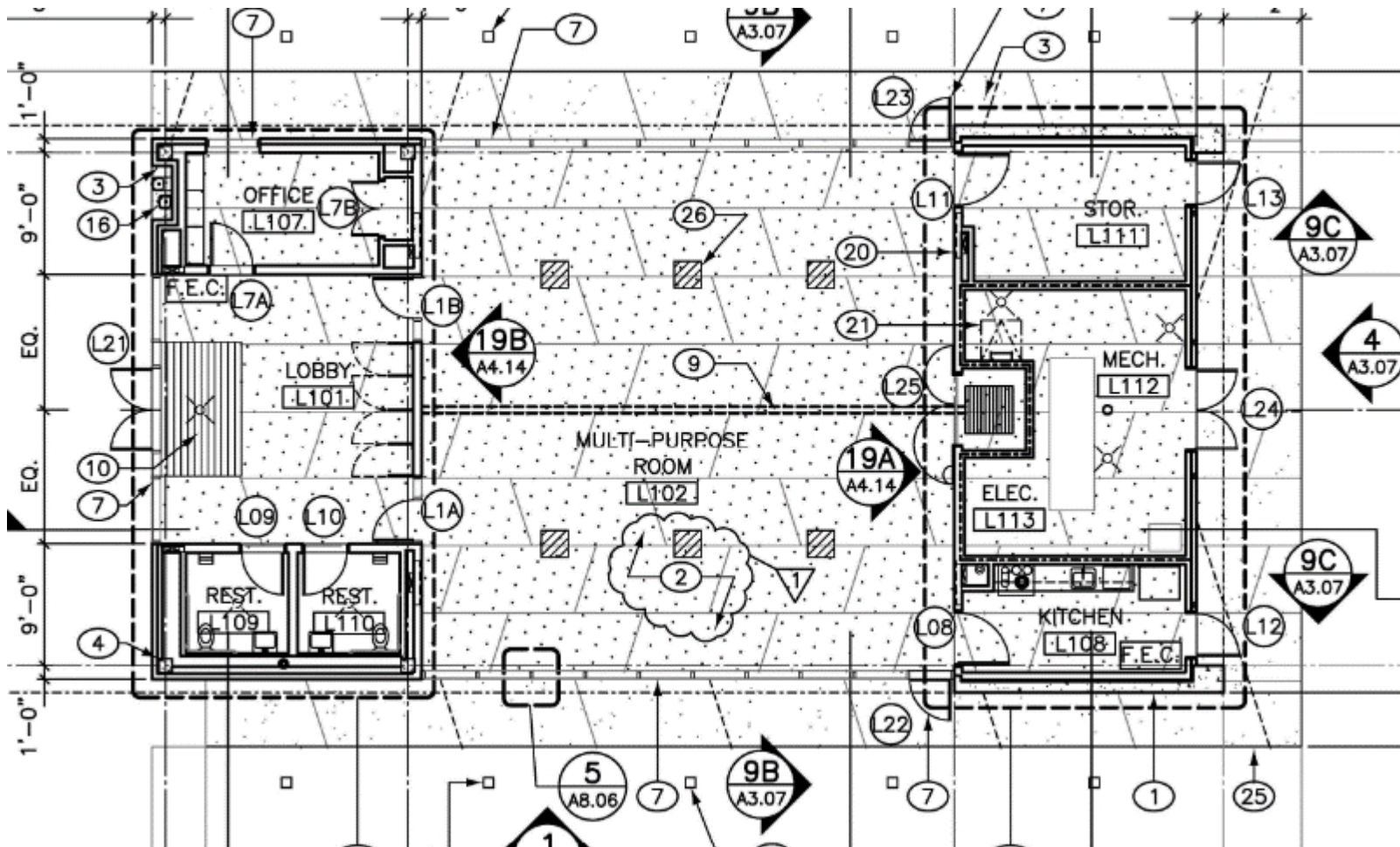
Building Enclosure: Basis of Design

- 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

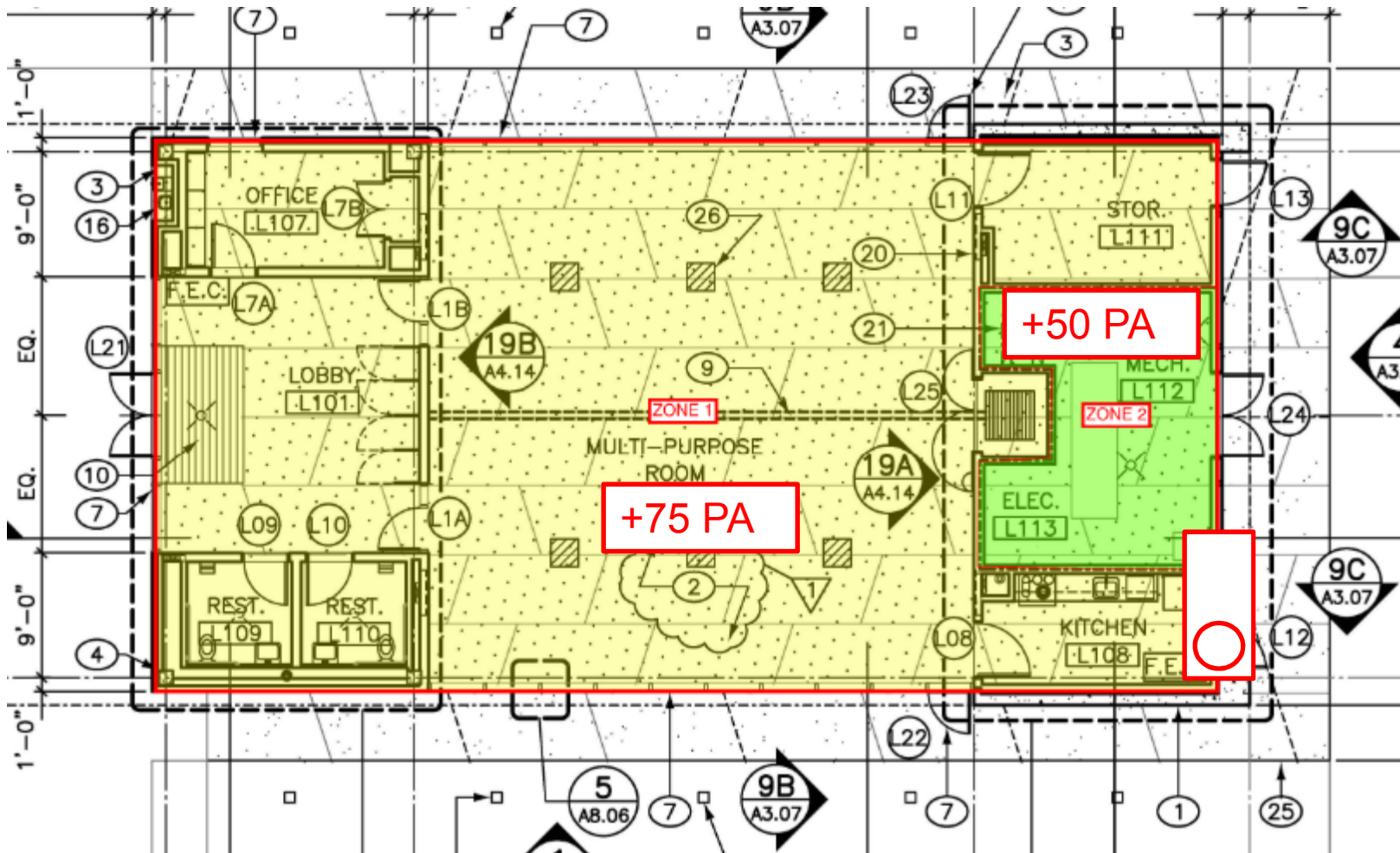
Building Enclosure Area: 9,130 ft²



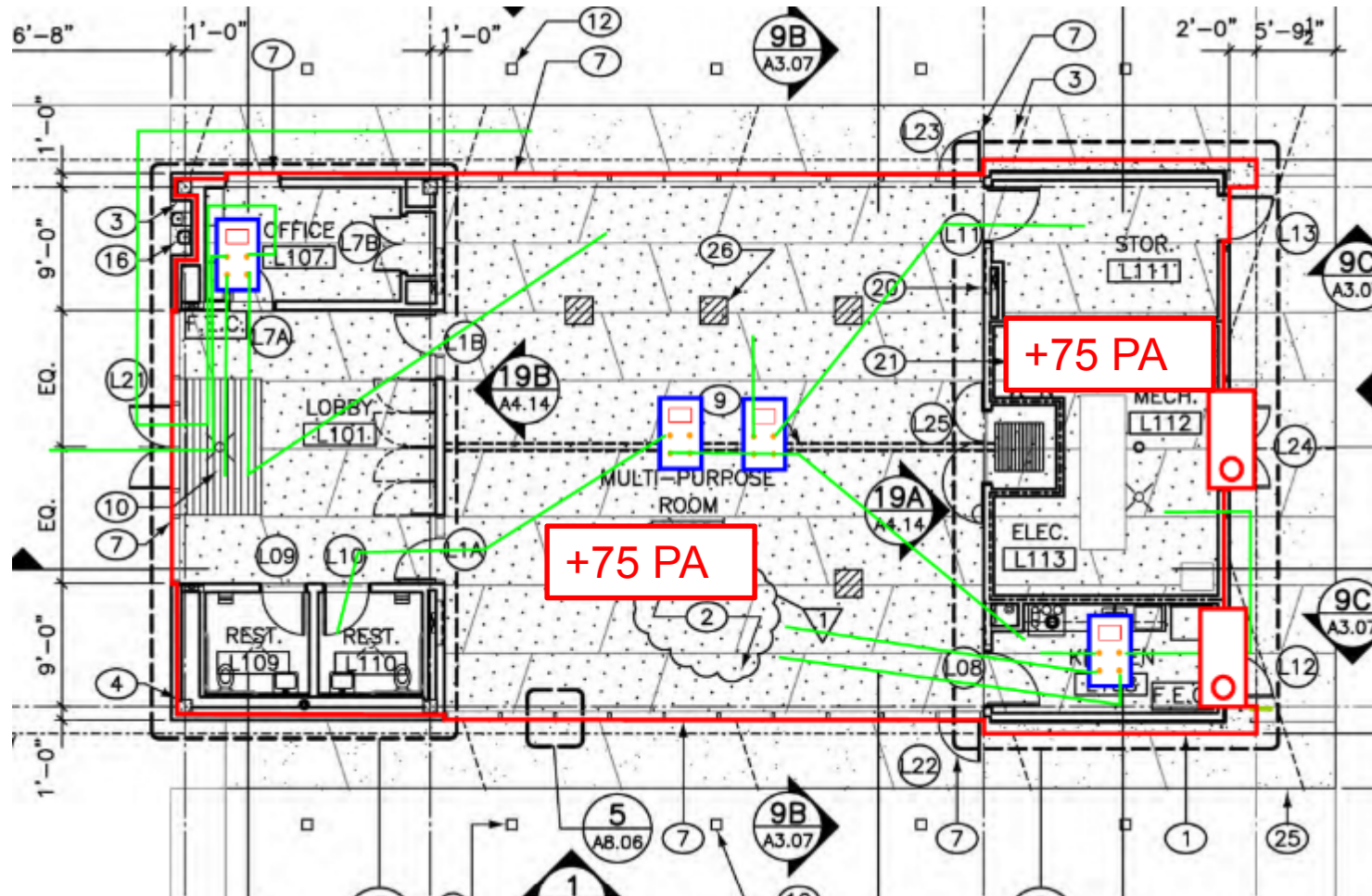
Single Zone Testing with Multiple Zones



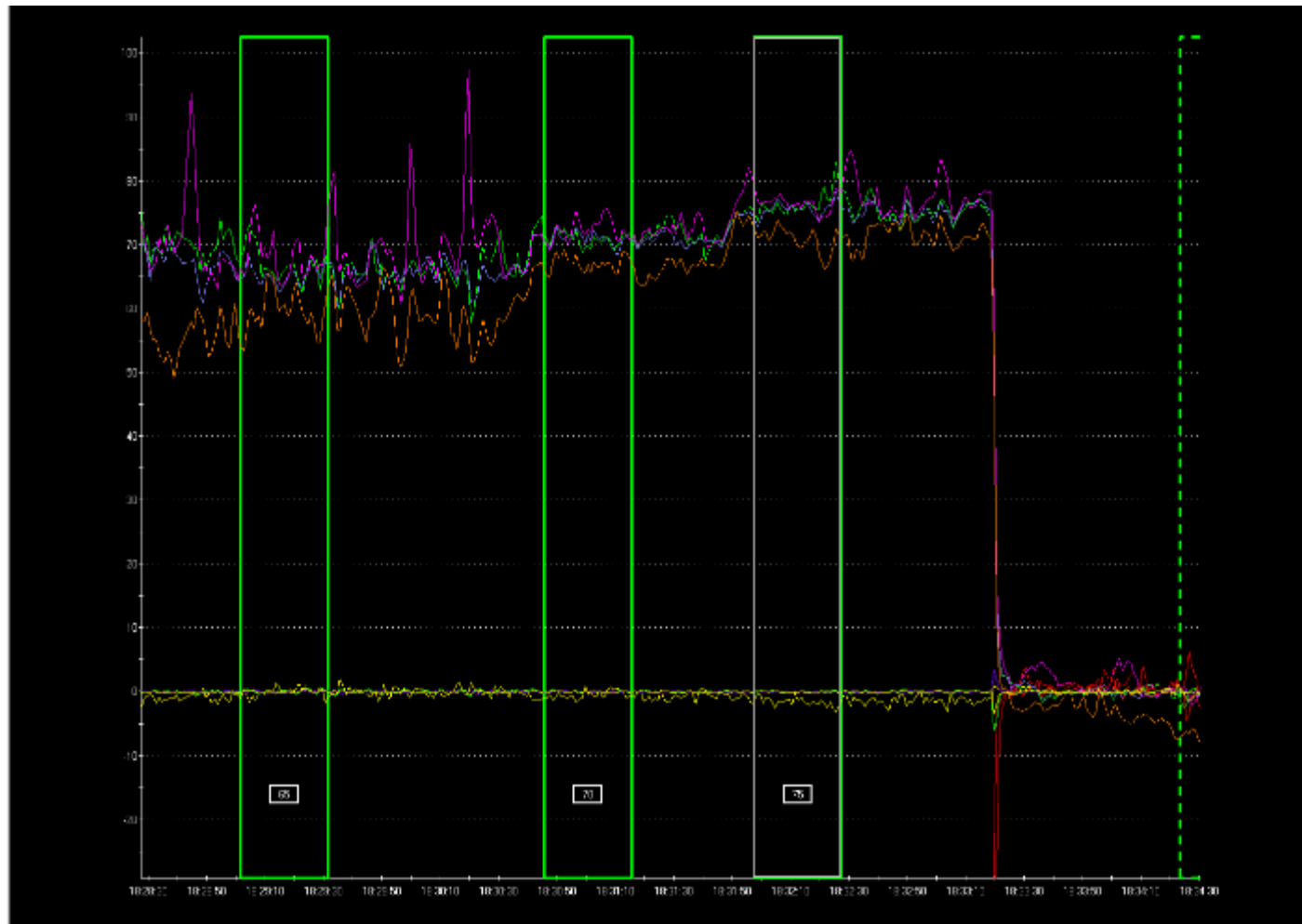
Single Zone Testing with Multiple Zones



Single Zone Testing with Multiple Zones



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

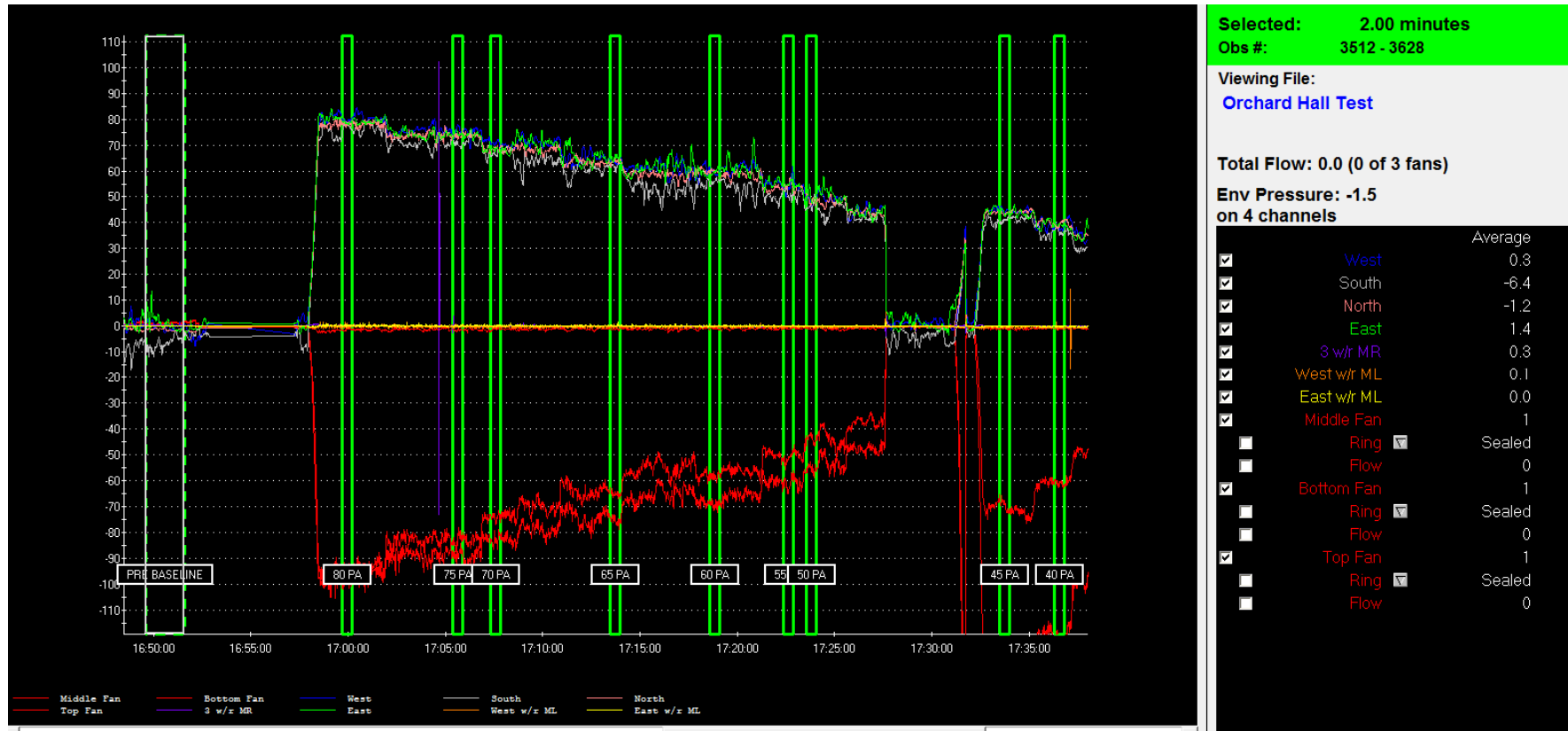
	Average
<input checked="" type="checkbox"/> NORTH ELEV	76.5
<input checked="" type="checkbox"/> EAST ELEV	75.6
<input checked="" type="checkbox"/> SOUTH ELEV	76.4
<input checked="" type="checkbox"/> WEST ELEV	70.8
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<input checked="" type="checkbox"/> N W/R LC	-0.1
<input checked="" type="checkbox"/> N W/R WEST	0.0
<input checked="" type="checkbox"/> N W/R NW	-0.1
<input checked="" type="checkbox"/> N W/R SE	0.0
<input checked="" type="checkbox"/> N FAN	-110
<input type="checkbox"/> Ring	Ring A
<input type="checkbox"/> Flow	1883
<input checked="" type="checkbox"/> Mech Fan	-151
<input type="checkbox"/> Ring	Ring C
<input type="checkbox"/> Flow	281



Troubleshooting

Troubleshooting

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



Troubleshooting

Building Description: Two-Story School

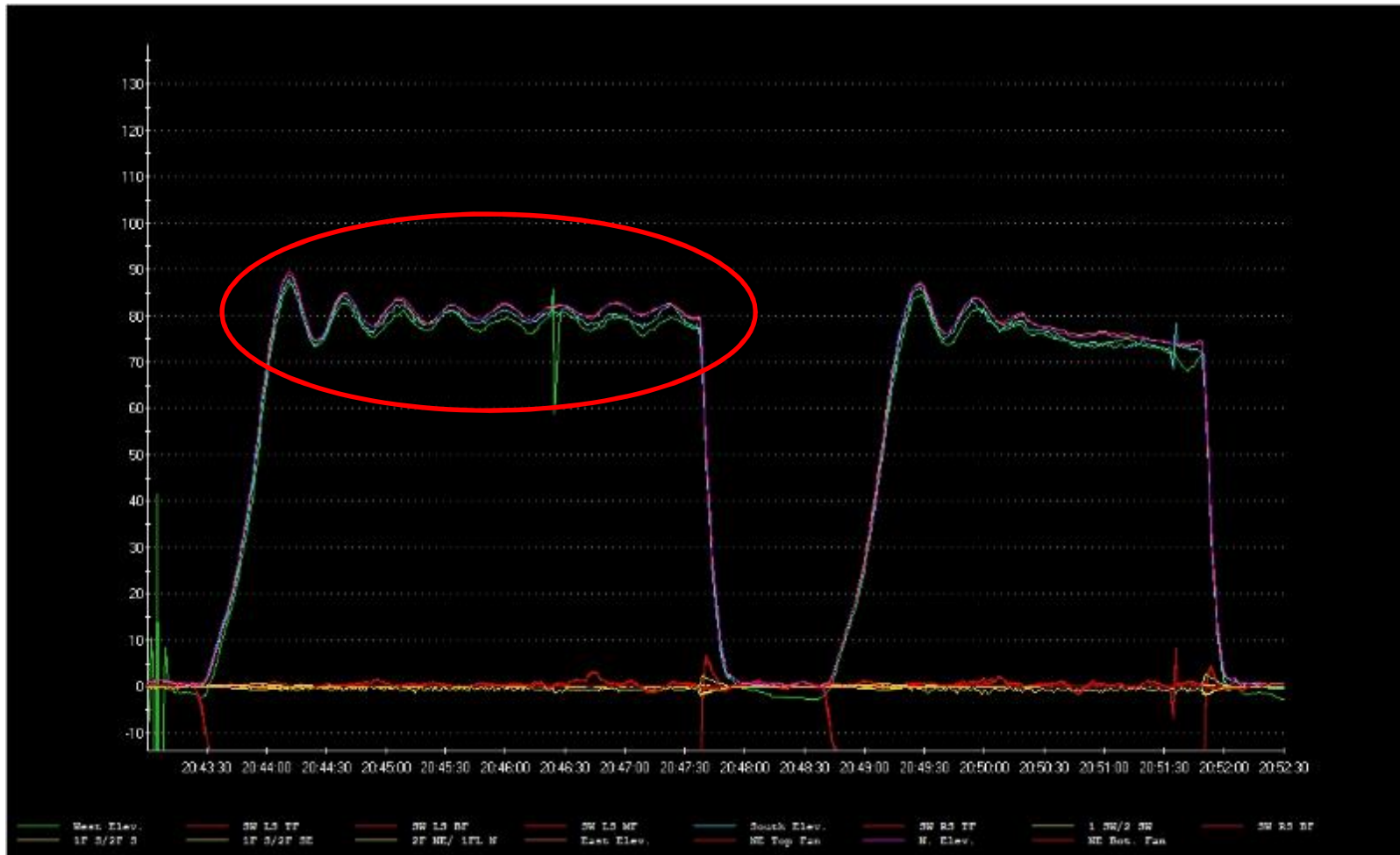
Building Enclosure: Basis of Design

- 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

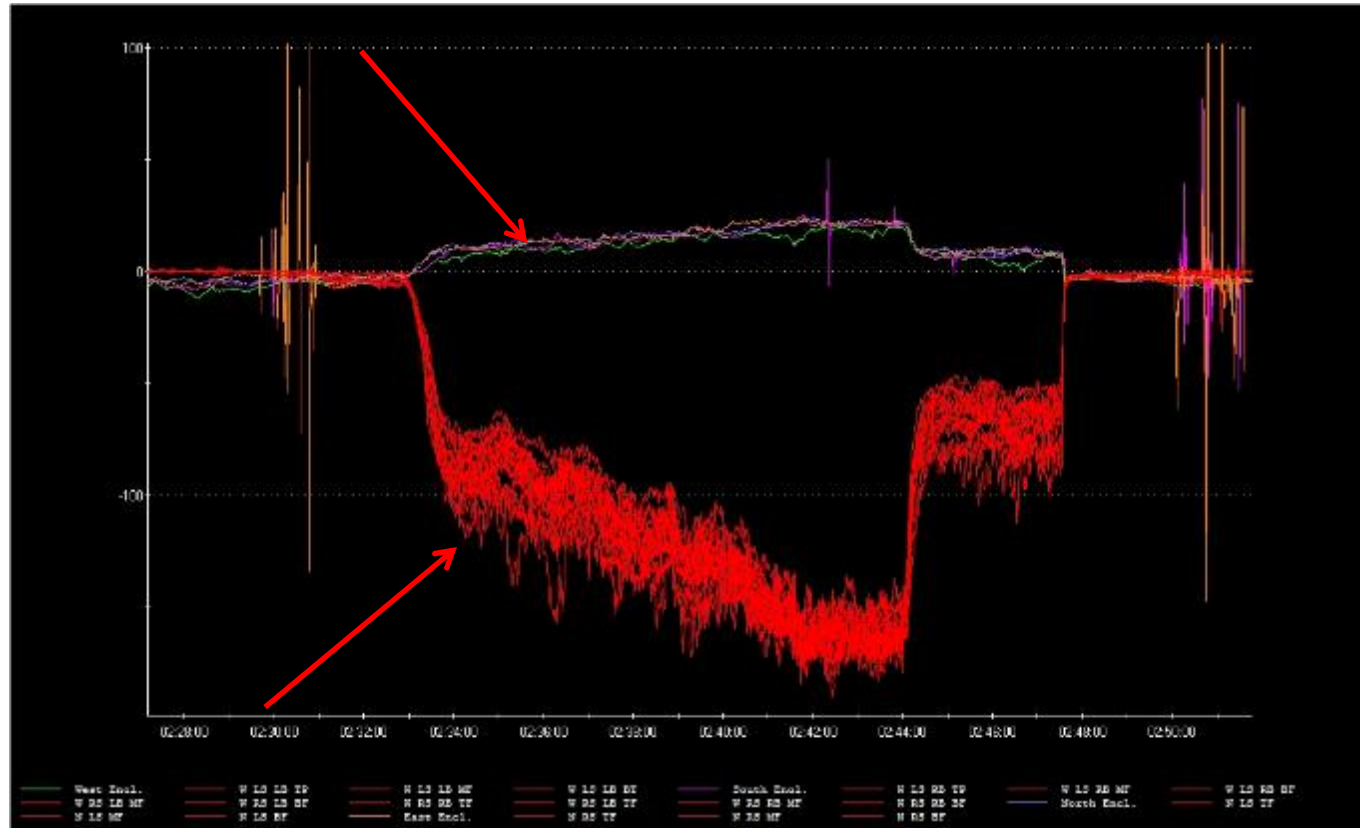


Troubleshooting



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

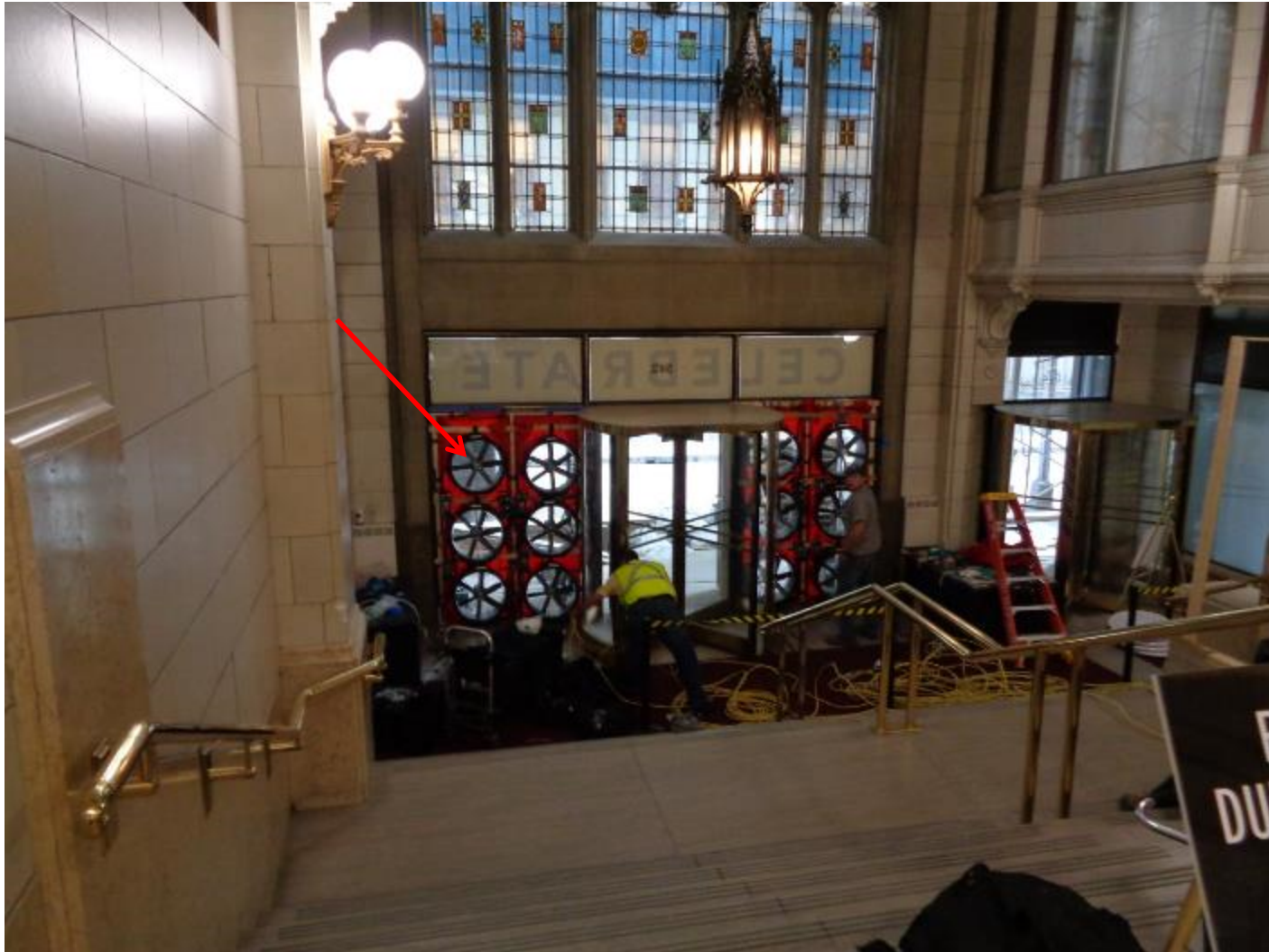
Troubleshooting



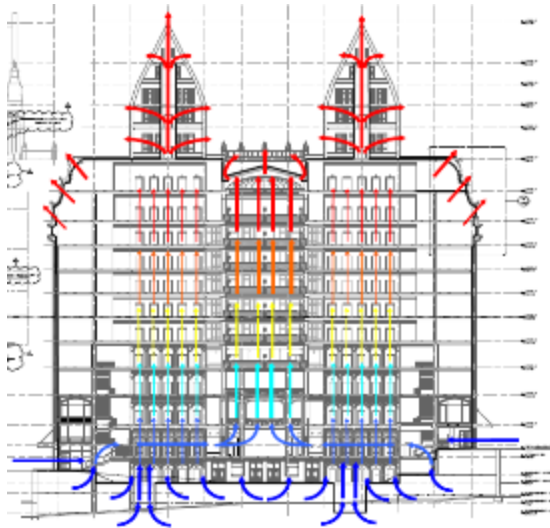
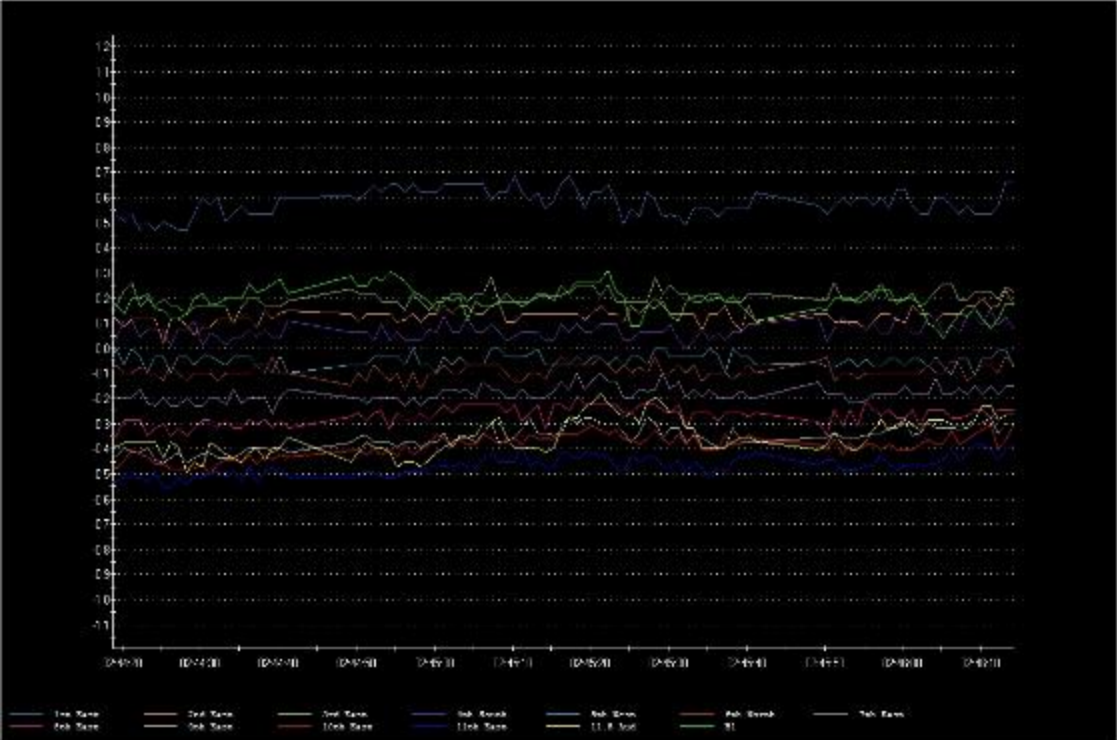
Use graph to trouble shoot equipment and building conditions

- Monitor fan pressures (Fan spinning backwards)
- Monitor enclosure pressures
- Monitor interior building pressures

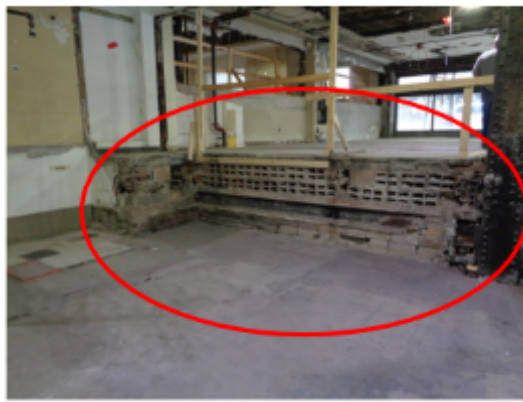
Troubleshooting



Interior Pressure and Stack Pressure Monitoring



Stack Pressure Monitoring



Intertek



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Questions?



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