



AABC Commissioning Group

AIA Provider Number: 50111116

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# Building Envelope Commissioning and Building Diagnostic Test: Case Studies

Course Number: CXENERGY1506

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April 29, 2015



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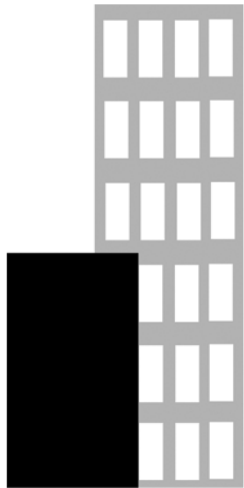
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# Course Description

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This session will make use of actual project data, photographs, and documentation to explore a variety of diagnostic test procedures related to the building envelope, including building air leakage tests, infrared imaging, forensic spray tests for windows and store fronts, and a unique application of theatrical smoke machine to demonstrate building air leakage. The presenters will focus on lessons learned from the real-world application of relevant ASTM, NIBS, ISO and other standards to verify delivery of reasonably airtight building envelope-air barrier systems in compliance with the Owner's Project Requirements.

# Learning Objectives

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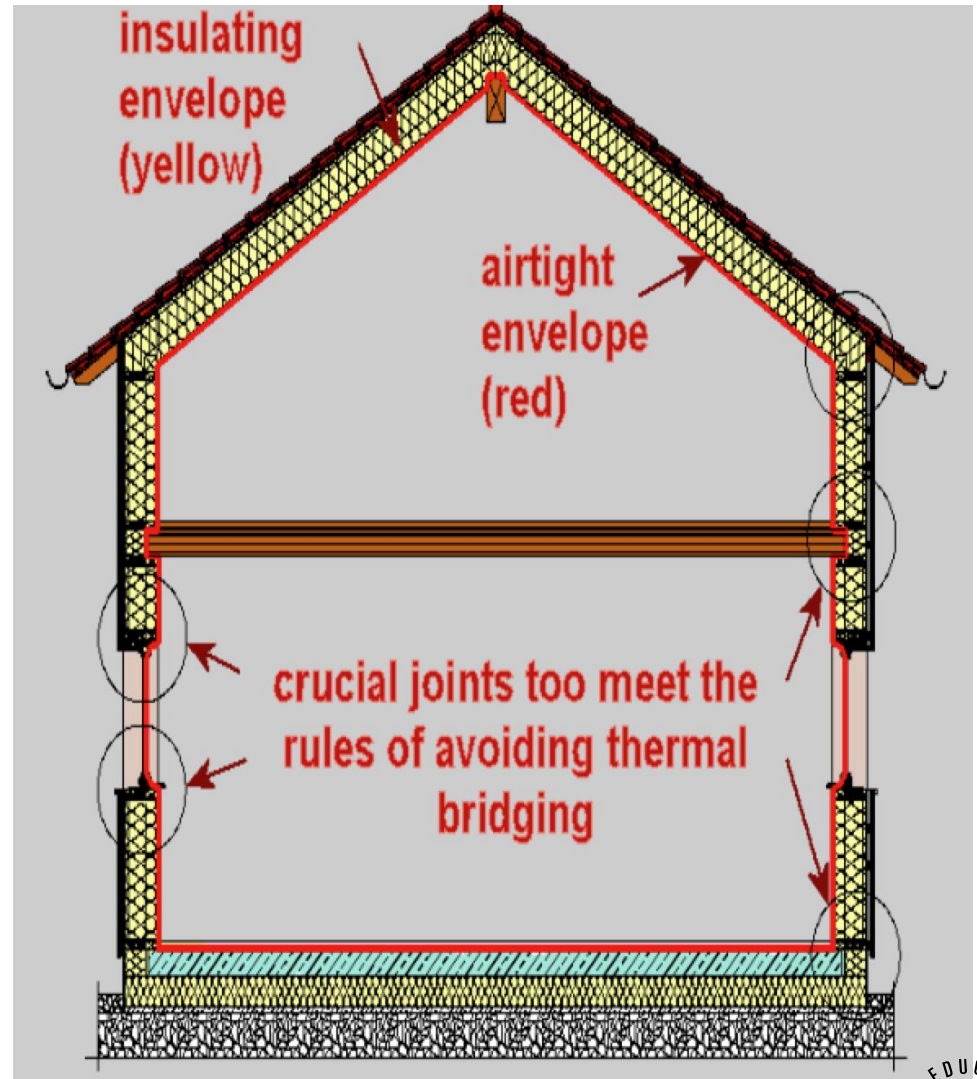
At the end of the this course, participants will be able to:

1. Understand how existing case studies in building envelope commissioning and diagnostic testing can be used to improve building commissioning practices.
2. Learn to use project data, photographs and documentation in diagnostic test procedures related to building envelope commissioning and testing.
3. Understand testing methods used to determine building air leakage including infrared imaging, forensic spray tests, and theatrical smoke machines.
4. Learn to apply relevant ASTM, NIBS, ISO and other standards to verify that building envelope barrier systems perform in accordance with owner project requirements.



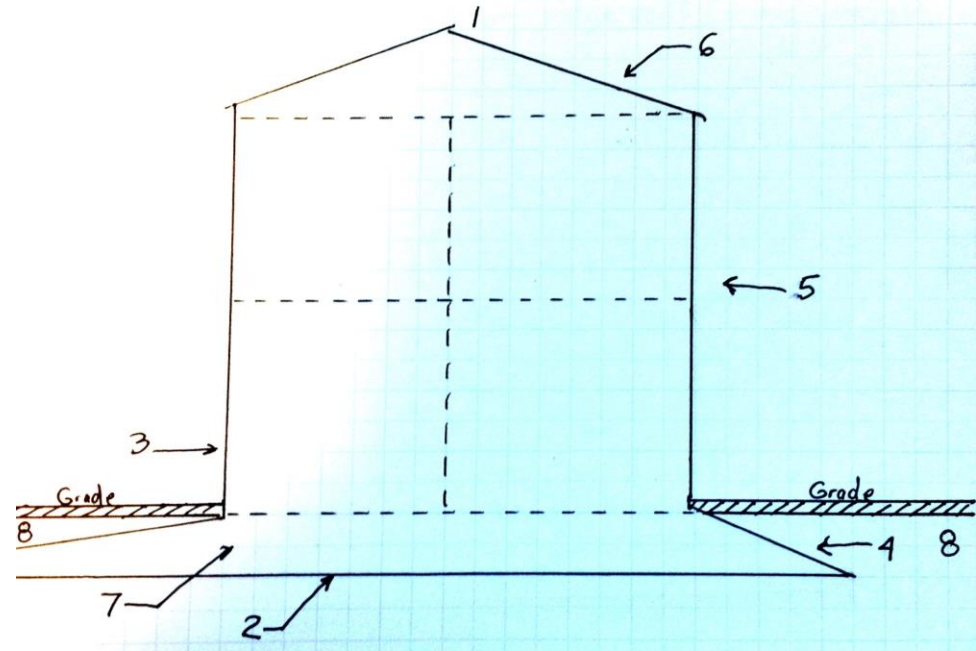
# Building Envelope

The boundary between conditioned spaces and various unconditioned spaces

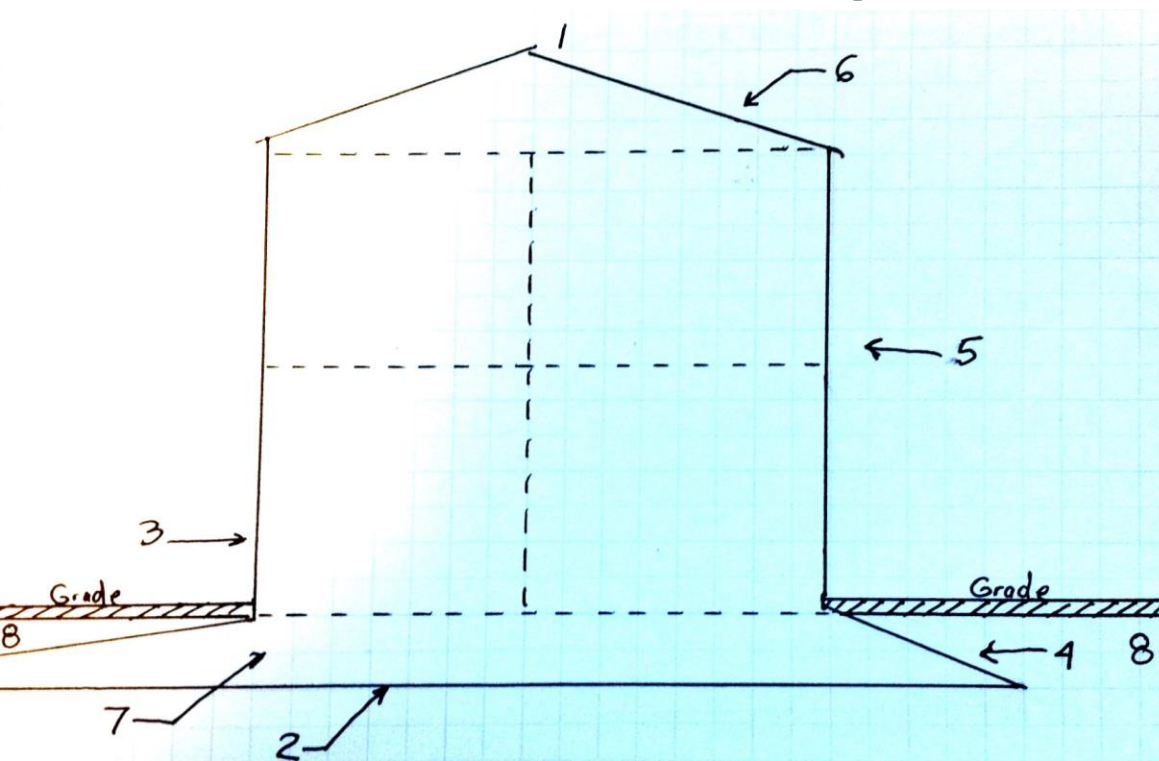


# Building Enclosure

systems separating one defined environment from another, including walls, fenestration, roofing and roof openings, floors and or ceilings, below grade perimeter walls, crawlspaces and attics from the interior, slabs-on-grade and interior walls and floor/ceiling assemblies separating interior zones with differing performance criteria



# Building Enclosure



- 1 – Ridge Vents or Roof Vents
- 2 – Floor Slab on/below grade
- 3 – Above Grade Wall Systems
- 4 – Foundation Wall System
- 5 – Windows, Doors, Curtain Walls, Storefronts, Hollow Metal Glazed Systems, etc.
- 6 – Roof System(s)
- 7 – Ventilated Crawl Space
- 8 – Backfill

\_\_\_\_\_ Continuous Air Barrier

----- Interior Space Separators



# Building Enclosure Provisions

- Insulation
- Continuous Air Barrier
- Thermal Bridges
- Moisture Barriers
- Vapor Barriers
- Gravity–Dead (Assemblies)
- Gravity–Live (People, Snow)
- Ground Movement
- Wind
- Explosion/Fire
- Rheological (Creep, Shrinkage)
- Sound
- Vermin
- Impacts (Vehicles)
- Solar Radiation
- Chemical Attack

# Continuous Air Barrier (Air Leakage Prevention)

- System design to control infiltration and exfiltration of airflow across the exterior enclosure of a building.
- Air pressures
- Air Barrier materials
- Combination “air and vapor barriers”
- Warm-side air and vapor barriers vs. cold-side air barriers
- ADA (Airtight Drywall Approach)
- Roof Air Barrier concepts

# Commissioning

A quality focused process... [for] verifying and documenting that the commissioned systems and assemblies are planned, designed, installed, tested, operated and maintained to meet the Owner's Project Requirements (OPR)

OPR – a written document that details the requirements of a project and the expectations of how it will be used and operated

– ASHRAE Standard 202

# Building Envelope

## Commissioning References

- ASHRAE Standard 202-2013 – *Commissioning Process for Buildings and Systems*
- NIBS Guideline 3-2012 – *Building Enclosure Commissioning Process BECx*
- ASHRAE Guideline 0-2005 – *The Commissioning Process*
- ASTM 2813-2012 – *Standard Practice for Building Enclosure Commissioning*
- National Institute of Building Sciences – *Whole Building Design Guide*
- US Army Corps of Engineers (USACE) and Air Barrier Association of America (ABAA) – *Air Leakage Test Protocol for Building Envelopes (Version 3 2011)*

# Building Envelope Commissioning Pre-Design Phase

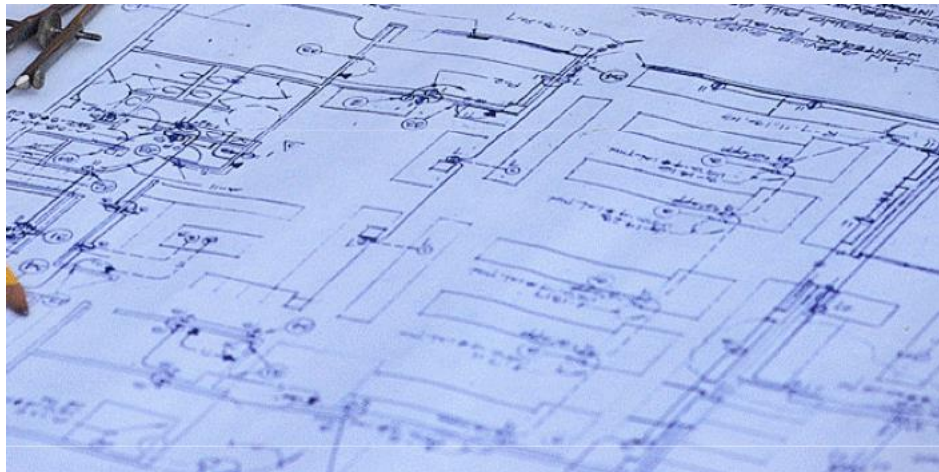
- Owner's Project Requirements (OPR)  
Workshop with Owner and design team
- Review OPR to develop checkout and testing procedures and to be utilized during the design review
- Review the Basis of Design (BOD) for consistency with the OPR, completeness and clarity of information

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# Building Envelope Commissioning Design Phase

- Review design documents (plans and specifications)
  - 100% DD's
  - Pre-100% CD's
- Provide written comments related to the building envelope components for the team's consideration



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# Building Envelope Commissioning Design Phase

- Provide specifications pertinent to envelope components for inclusion in construction documents
- Identify any factory testing, mockups, field testing, or other testing requirements for commissioned systems and the building envelope components
- Prepare envelope components System Verification Checklists (SVCs) based on OPR, BOD, specs, and manufacturer's requirements

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# Building Envelope Commissioning Construction Phase

- Participate Kick-off and Pre-Con meeting with owner, design team, GC, and subcontractors in trades connected to the building envelope components
- Review contractor's submittals and shop drawings against OPR, BOD, and construction documents
- Provide written comments related to commissioning requirements to be considered by project team
- Discuss SVCs, construction checklists, construction sequencing, submittals, mock-ups, testing, site visits, coordination of trades, and record keeping

# Building Envelope Commissioning Construction Phase

- Conduct a pre-installation conference with GC and respective subcontractors regarding each trade connected to the building envelope components
- Discuss critical construction items, coordination, checklists, observations, testing, and record keeping
- Periodic site visits, as necessary, to witness:
  - Components and systems installations
  - Field-verify completion of checklists
  - Attend occasional project meetings
  - Provide reports from each visit to Cx Team

# Building Envelope Commissioning Construction Phase

- Conduct a pre-installation conference with GC and respective subcontractors regarding each trade connected to the building envelope components
- Perform site visit with Owner, design team, GC and related subcontractors to observe mockup construction and witness mockup testing
- Observe field testing and review testing results
- Make recommendations based on observation and results to Owner for proceeding or for requesting remedial action



# Building Envelope Commissioning Construction Phase

- Field testing may include:
  - Water penetration
  - Drainage plane performance
  - Air leakage
  - Roofing
  - Sealant adhesion

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ASTM D 4541 adhesion pull testing  
(NIBS Guideline 3)

# Building Envelope Commissioning Construction Phase Observations

- Steel Beams, Angles or Bracing Penetrations
- Daylight
- Walls with Voids
- Roof Air Barrier Flashing/Membrane Not Extended Over Edges and Wrapped Down to Exterior Wall
- Failed/Improperly Installed Adhesives or Sealants
- Fenestration Installations not per Details or Manufacturer's Recommendation
- Compound Joints or Complex Junctions

# Building Envelope Commissioning Post-Construction Phase

- Substantial completion inspection of envelope components with the Owner, design team, and GC to observe and document completed components and systems
- Provide a comprehensive final commissioning report and punch list including findings, deviations and recommendations, supported by photographs
- Review contractor's close-out documents with Owner as it pertains to envelope components

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# Building Envelope Commissioning Post-Construction Phase

- Substantial completion inspection of envelope components with the Owner, design team, and GC to observe and document completed components and systems
- Provide a comprehensive final commissioning report and punch list including findings, deviations and recommendations, supported by photographs
- Review contractor's close-out documents with Owner as it pertains to envelope components

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# Building Envelope Commissioning Post-Construction Phase

- Close-out documents may include project- specific warranties with contact info and required maintenance instructions
- Commissioning report contains all aspects of commissioning process:
  - Design review
  - Submittal reviews
  - Completed checklists
  - Meeting minutes
  - Site visit reports
  - Field test results
  - Outstanding issues that require actions

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# Building Air Leakage Test

American Society for Testing and Materials

- ASTM E779: *Standard Test Method for Determining Air Leakage Rate by Fan Pressurization*
- ASTM 1827: *Standard Test Method for Determining Airtightness of Buildings Using an Orifice Blower Door*



# System Verification Checklist

## Title of Project

System: **ASTM E779 Air Barrier Leakage Test Preparation Prerequisites**

Service: **Building Envelope**

<b>Contractor: Unnamed Construction</b>	
<b>Floor(s): Ground, First &amp; Second</b>	
<b>Items to be provided by Contractor to FCG prior to Air Barrier Testing</b>	<b>Date/</b>
Provide copies of drawings of site plans (with sea level elevations), floor plans, building elevations and wall sections with dimensions and Building Numbers and addresses at least a week prior to the testing date	5/13/13 DRA
Provide a copy of the Air Barrier Specification and Testing Criteria for the project BE/AB & IR Testing requirements	5/21/13 DRA
Provide contact names, cell phone numbers and e-mail addresses for the building	12/29/14 DRA
Provide after hours contact information for security purposes	12/29/14 DRA
Provide after hours contact information for Building Automation Controls (BAS) contractor	12/29/14 DRA
Provide verification that the building envelope-air barrier RTF items have been mitigated to provide a building envelope-air barrier system that does not have sources of air leakage	12/29/14 DRA
Coordinate with FCG's for a pre-test observation walk-through of BE/AB & IR surfaces	12/29/14 DRA
Scheduled date for the BE/AB & IR Test with FCG based on acceptable weather conditions	12/29/14 DRA
Provide a Construction schedule indicating temperature controls and TAB work being completed	12/29/14 DRA
Provide verification that the weather barriers membrane system has been installed in accordance with Section 072500 and sealed to the other air barrier systems	12/29/14 DRA
Provide verification that the spray-applied foam cavity wall insulation air barrier system has been installed in accordance with Section 072100 and sealed to the other air barrier systems	12/29/14 DRA
Provide verification that the roof air barrier membrane system has been installed in accordance with Section 075400 and sealed to the other air barrier systems	12/29/14 DRA

<b>Number</b>	<b>Date</b>	<b>Remarks</b>
1	12/29/14	Dan R. Adam, CxA Jim Fitzpatrick, CxT, Certified Level II Thermographer Clay Kissick, BE Assistant David Dial, BE Assistant

# System Verification Checklist

## Name of Project

System: **ASTM E779 Air Barrier Leakage Test Post Preparations**

Service: **Building Envelope**

<b>Contractor: Unnamed Construction</b>	
<b>Floor(s): Ground, First &amp; Second</b>	
<b>Items to be completed after the Building Air Leakage and Infrared Testing</b>	<b>Date/</b>
FCG remove BE/AB & IR Testing Door Signs from the doors.	12/30/14 DRA
Contractor to restore HVAC exhaust air devices, outside air opening, louvers, rooftop unit dampers, etc. have removed temporary covering to pretest conditions	12/30/14 DRA
Contractor to reset HVAC AHU's, outside air equipment and exhaust, supply & return fans to normal operation	12/30/14 DRA
FCG remove and store door stops	12/30/14 DRA
FCG remove tape where used to assist seal procedures	12/30/14 DRA
FCG uncover drier vents	12/30/14 DRA
FCG uncover kitchen hood exhaust grilles and louvers	12/30/14 DRA
FCG dispose of trash generated during test procedures (tape, plastic, etc.)	12/30/14 DRA
FCG remove and store BDF's and accessories	12/30/14 DRA
Contractor turn off lights used during test	12/30/14 DRA
Contractor secure building egress locations	12/31/14 DRA
FCG prepare and submit Air Barrier Test Report	TBD

<b>Number</b>	<b>Date</b>	<b>Remarks</b>
1	12/30/14	Dan R. Adam, CxA Jim Fitzpatrick, CxT, Certified Level II Thermographer Clay Kissick, BE Assistant David Dial, BE Assistant

# System Verification Checklist

## Title of Project

System: **ASTM E779 Air Barrier Leakage Test Day Preparations**

Service: **Building Envelope**

<b>Contractor: Unnamed Construction</b>	
<b>Floor(s): Ground, First &amp; Second</b>	
<b>Contractor completed items and confirmed by FCG prior to BE/AB &amp; IR Testing</b>	<b>Date/</b>
Install BE/AB & IR Testing Door Signs on the appropriate doors to be kept closed and <u>used</u> for access in and out of building during testing	12/29/14 DRA
Remove at least four (4) sq ft of the acoustical ceiling tile panels for every 500 sq ft of ceiling area (1850 sq ft / 500 sq ft) x 4 sq ft =14.8 or 15 ceiling tiles	N/A
Install blank covers or seal open electrical and data/communication junction boxes in the BE/AB & IR test area	N/A
Voids and penetrations have been sealed and/or fire-stopped per specifications	12/29/14 DRA
Schedule controls contractor to be on site the day of BE/AB & IR testing to coordinate with FCG as to what equipment control settings are to be made	12/29/14 DRA
HVAC system is to operate the day prior to and the day of testing to cool or heat the building so there is a minimum of 20°F differential temperature between the interior and the exterior	12/29/14 DRA
Outside air, exhaust and return air fans are under BAS control by control contractor and able to be overridden to a closed 0% position	12/29/14 DRA
Identify what HVAC dampers are not motorized and connected to the BAS and fans to be turned off and sealed during testing or cover at each exhaust air device, outside air opening, louvers, rooftop unit dampers, etc.	12/29/14 DRA
Door weather stripping and sweeps installed and adjusted as required by specifications	12/29/14 DRA
The interior doors of conditioned rooms are propped open	12/29/14 DRA
The closets and other non-conditioned room doors are closed	12/29/14 DRA
Sealed windows are closed and locked	12/29/14 DRA
Contractor & FCG coordinate blower door fan (BDF) installation locations for BE/AB & IR testing	12/30/14 DRA
FCG to wear Personal Protective and Safety Equipment (PPE); Eyewear, Footwear, Hearing Protection, Safety Vest, and adhere to project safety requirements	12/29/14 DRA
Disconnect specific door closures for the BE/AB & IR equipment as designated by FCG	12/30/14 DRA
Seal each dryer vent	12/29/14 DRA
Seal kitchen hood exhaust grilles and/or louvers	12/29/14 DRA
Plumbing traps are filled with water or sealed to block plumbing drain lines from air leakage	12/29/14 DRA
Provide separate 20AMP non-GFCI receptacles available for each BDF within 100LF from the BDF locations and there is adequate lighting at the BDF locations	12/30/14 DRA
Coordinate with subcontractors so that no workmen are mobilizing in and out of the building during the BE/AB & IR Tests to not disrupt the tests results	12/30/14 DRA

<b>Number</b>	<b>Date</b>	<b>Remarks</b>
1	12/30/14	Dan R. Adam, CxA Jim Fitzpatrick, CxT, Certified Level II Thermographer Clay Kienick, BE Assistant



# Building Air Leakage Test



- Test Pass/Fail Criteria
- Door Stops
- Repurposing Stops
- Adhesive Plastic/Tape
- HVAC Dampers/Openings
- Dryer Vents
- Roof Vents
- Open cell fire batt insulation
- 2'x4' wood block jigs for power cords, etc.
- Wood blocks to stabilize temporary mullion
- 2'x4' temporary vertical mullion @ sliding doors
- TAB Status



# Building Air Leakage Test



# Building Air Leakage Test



# Building Air Leakage Test





# Building Air Leakage Test



# Building Air Leakage Test



# Building Air Leakage Test





# Building Air Leakage Test





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# Building Air Leakage Test



# Building Air Leakage Test



# Building Air Leakage Test





# Building Air Leakage Test





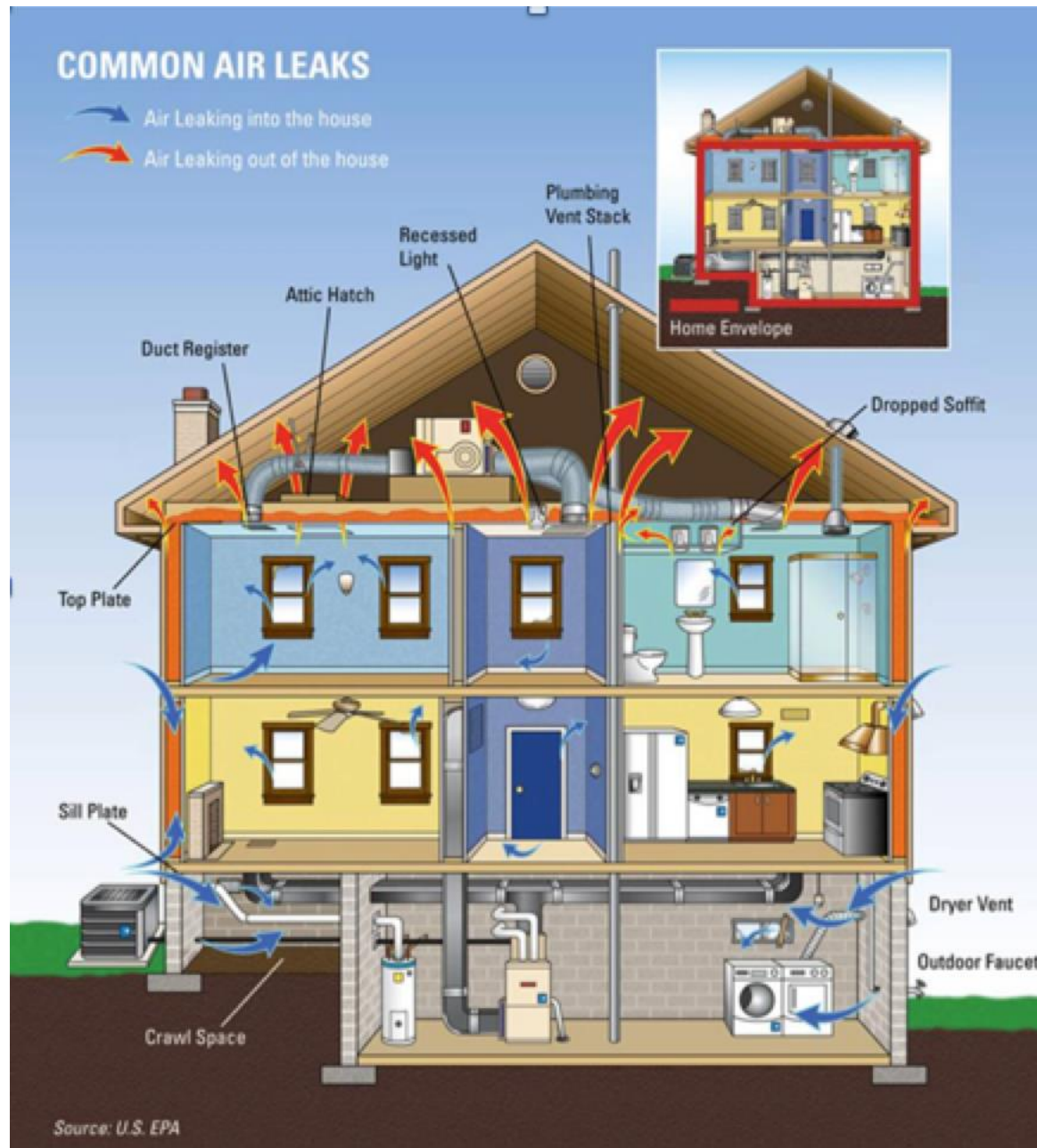
# Building Air Leakage Test



# Building Air Leakage Test



# Building Air Leakage Test

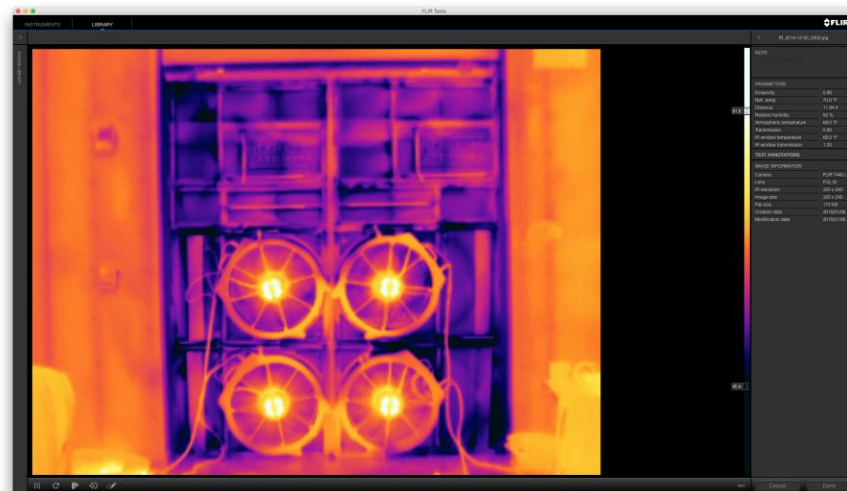




# Infrared Thermography

American Society for Testing and Materials  
International Standards Organization

- ASTM C1060:  
*Standard Practice for  
Thermographic  
Inspection of Insulation  
Installations in Envelope  
Cavities of Frame  
Buildings*
- ISO Standard 6781:  
*Thermal Insulation –  
Qualitative Detection of  
Thermal Irregularities in  
Building Envelopes –  
Infrared Method*

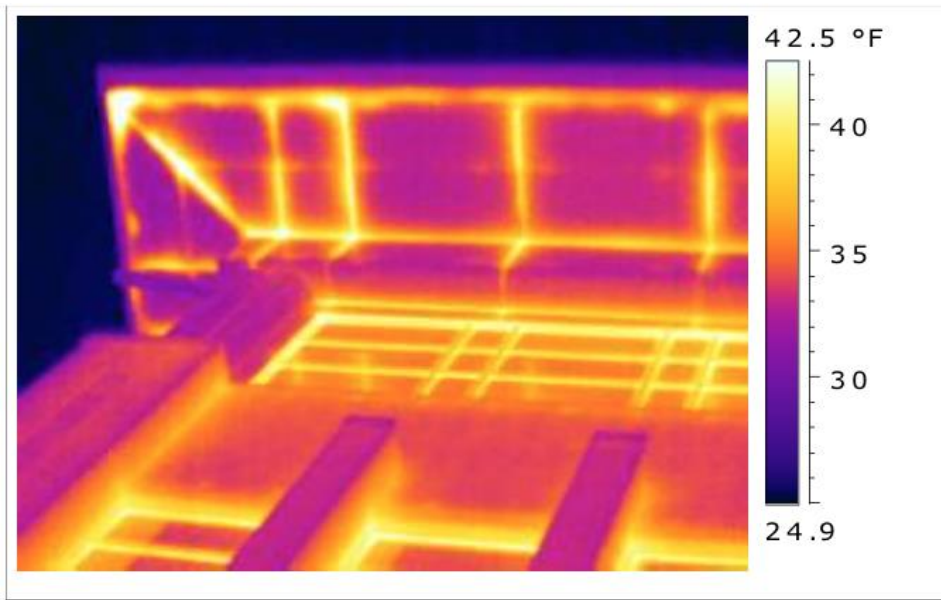


# Infrared Thermography

- Test Conditions
- Temperature Differential
- Wind Velocity
- Solar Load
- Heat Sources
- Pressurization/De-Press.



# Infrared Thermal Irregularities

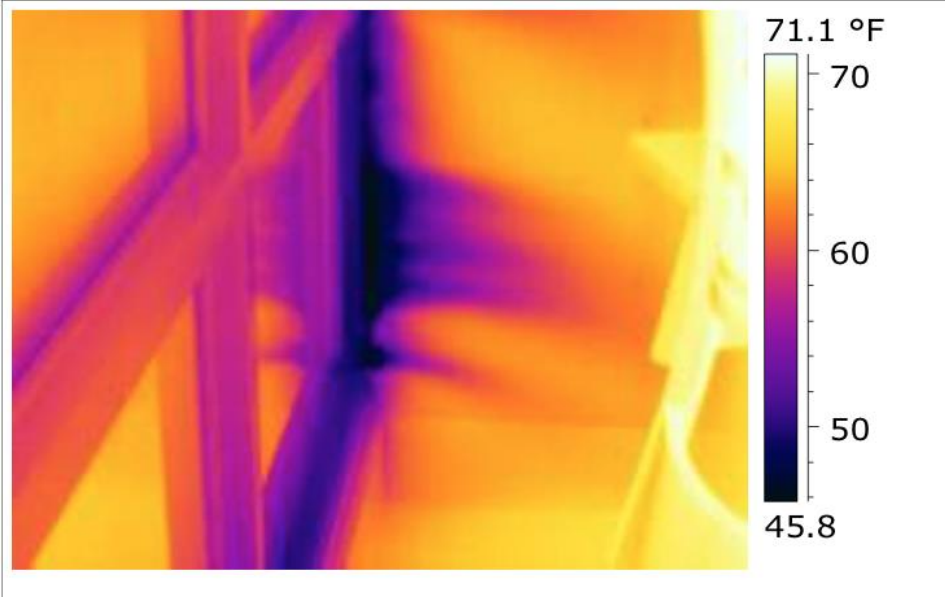


## Comment:

The thermogram appears to indicate thermal irregularities in the building envelope at the exterior insulated panel seems / reveals, which indicates thermal bridging and possibly air exfiltrating at the inconsistent temperature coloring of the thermogram.



# Infrared Thermal Irregularities

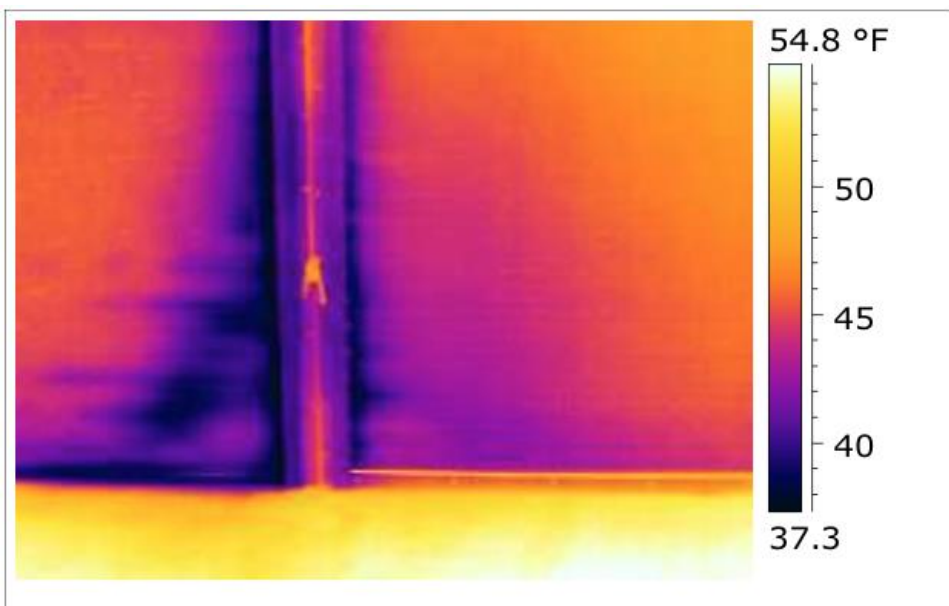


## Comment:

The thermogram appears to indicate thermal irregularities in the building envelope at the seal from the exterior wall to curtain wall.



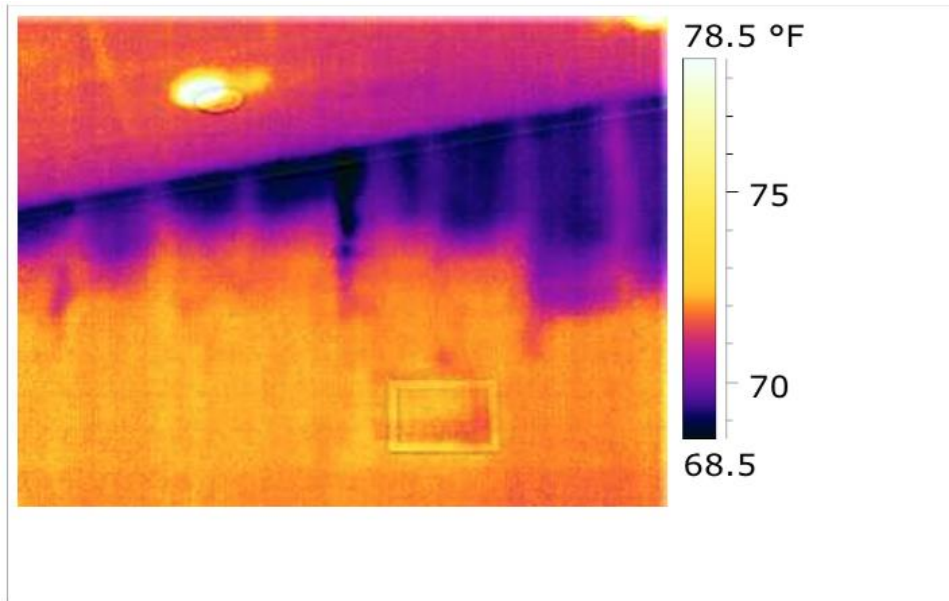
# Infrared Thermal Irregularities



## Comment:

The thermogram appears to indicate thermal irregularities in the building envelope at the seal to the overhead doors.

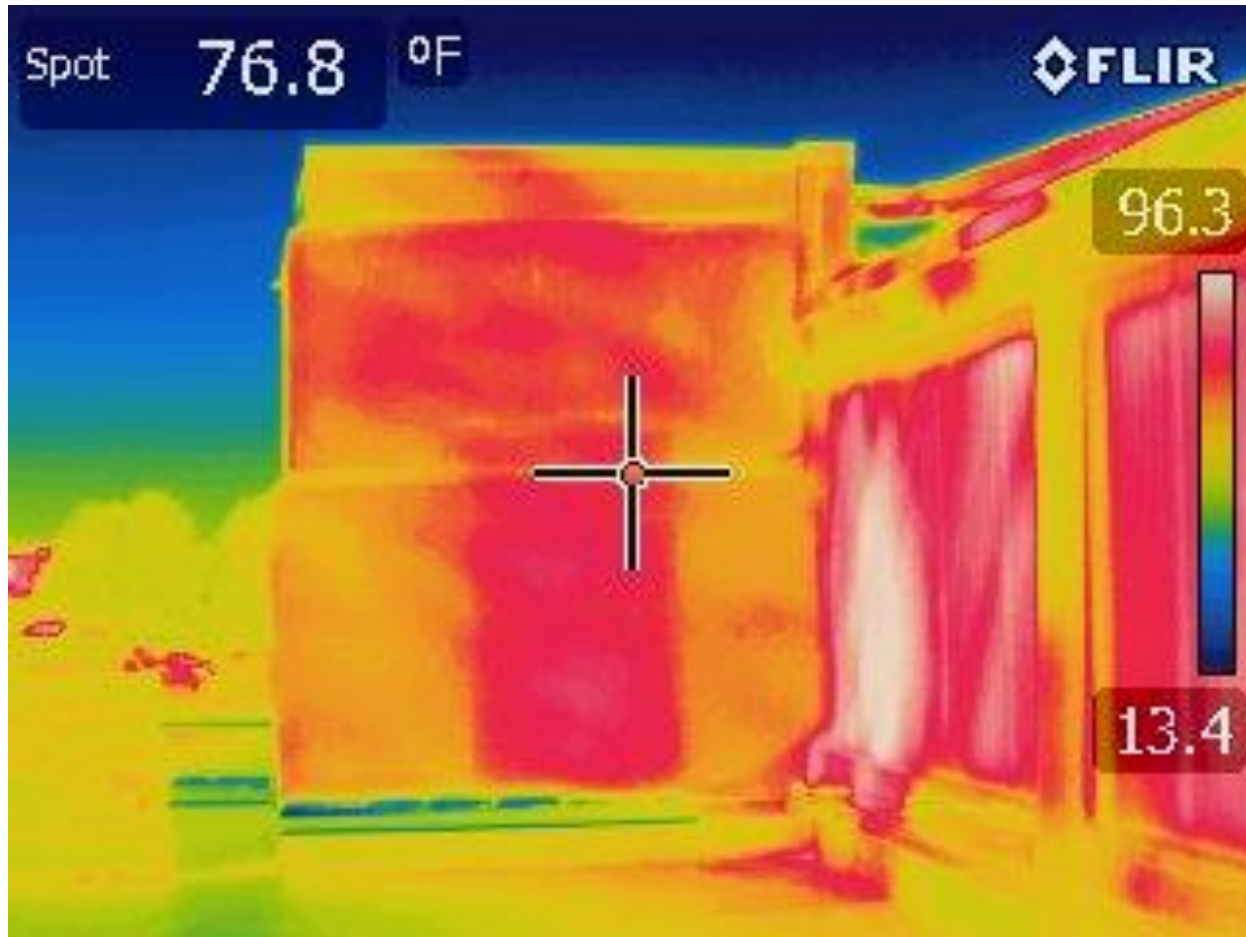
# Infrared Thermal Irregularities



## Comment:

The thermogram appears to indicate thermal irregularities in the building envelope at the anomaly in the wall cavity and insulation at the exposed wall in the roofing offsets. The dark spot could possibly indicate moisture in the wall and may warrant further investigation.

# Infrared Thermal Irregularities



Doorway infill without insulation

# Forensic Spray Testing

## American Architectural Manufacturers Association

- AMMA 501.2-03: *Quality Assurance and Diagnostic Water Leakage Field Check of Installed Storefronts, Curtain Walls, and Sloped Glazing Systems*
- Type B-25, #6.030 brass nozzle with a 1/2" FPT as manufactured by Monarch Manufacturing Works, Inc./Newton Tool & Mfg. Company





# Forensic Spray Testing



# Forensic Spray Testing





# Forensic Spray Testing



# Forensic Spray Testing



# Forensic Spray Testing





# Forensic Spray Testing





# Forensic Spray Testing



# Forensic Spray Testing



# Forensic Spray Testing



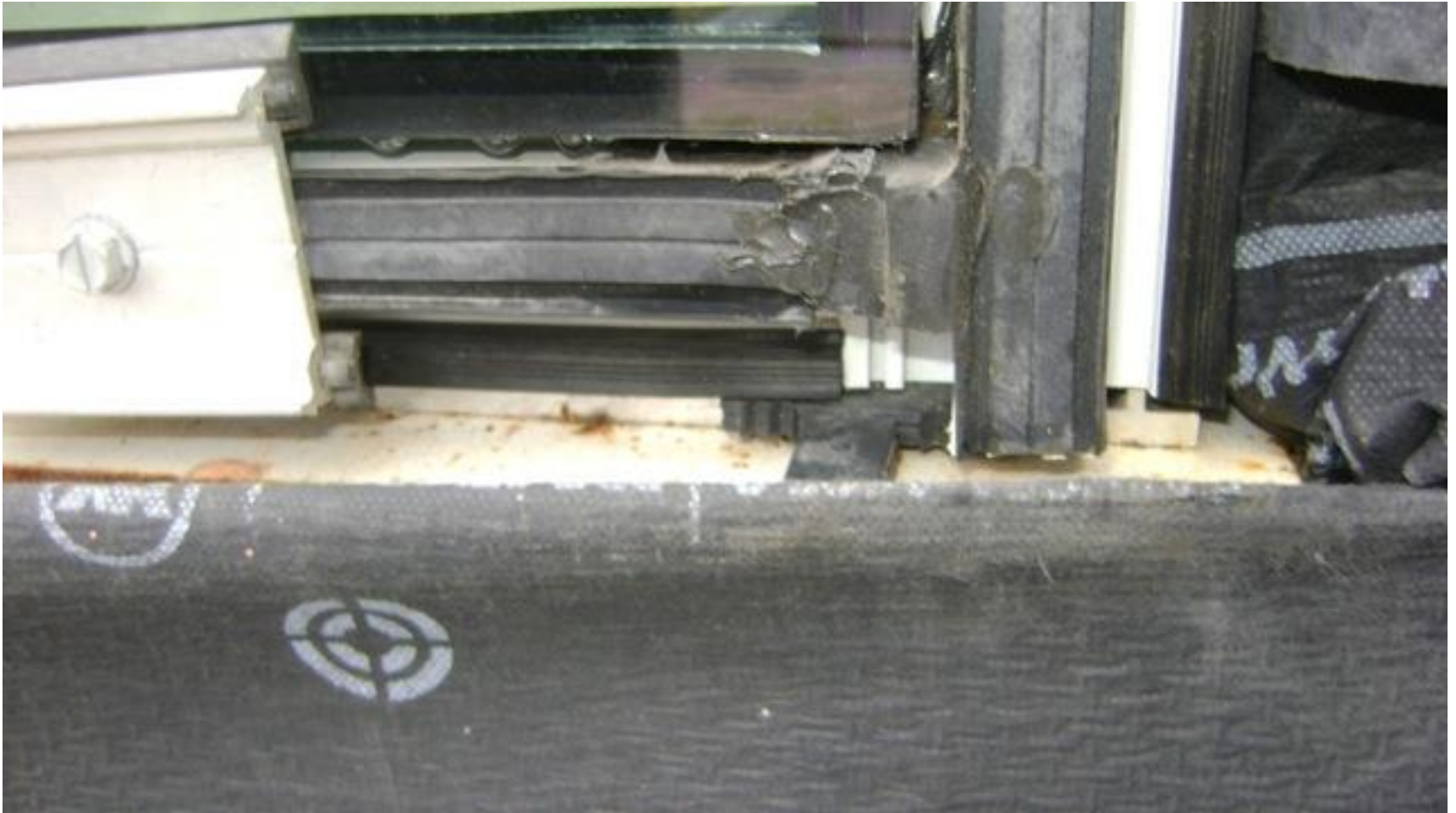


# Forensic Spray Testing





# Forensic Spray Testing



# Forensic Spray Testing



# Theatrical Smoke Testing

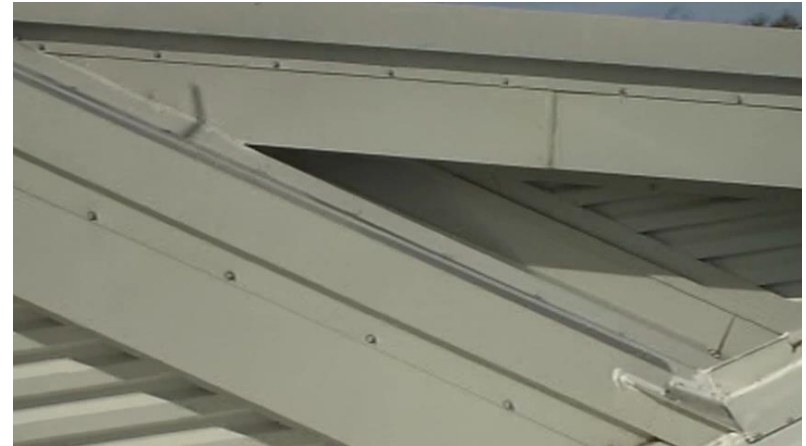
American Society for Testing and Materials

- ASTM-E 1186-09:  
*Standard Practices for Air Leakage Site Detection in Building Envelopes and Air Barrier Systems*
  - Paragraph 4.2.2  
*Smoke Tracer in conjunction with Building Pressurization and Depressurization,*
  - Paragraph 5.5  
*Smoke Tracers – Local Leak Detection*
  - Paragraph 7.3  
*Smoke Tracer Practice*



# ASTM-E 1186-09

## Paragraph 4.2.2 Smoke Testing





# ASTM-E 1186-09

## Paragraph 4.2.2 Smoke Testing



# Additional Diagnostic Tests



**ASTM E 783 test with exterior chamber, testing a window and its perimeter window-to-wall joint**

**Sub-Annex U.2a: Field Testing Case Study Example NIBS Guideline 3-2006**

# Additional Diagnostic Tests



**Dynamic Water Test**

**Sub-Annex U.2a: Field Testing Case Study Example NIBS Guideline 3-2006**



# Additional Diagnostic Tests



**Strain gauges for measuring inter-story drift**

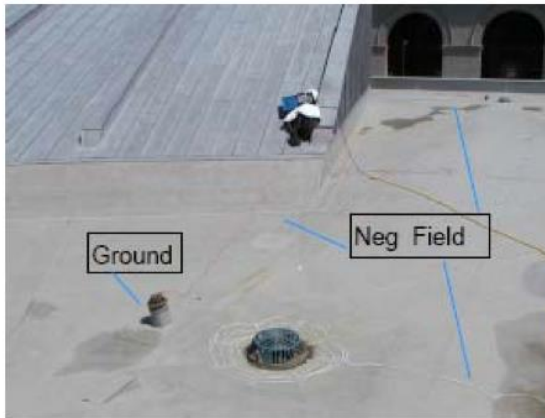
**Sub-Annex U.2a: Field Testing Case Study Example NIBS Guideline 3-2006**



# Additional Diagnostic Tests

Sub-Annex U.2a: Field Testing Case Study Example

NIBS Guideline 3-2006



Figures 15 through 17 for roofing, waterproofing and vegetated roofs, Electric Field Vector Mapping is an extremely useful and accurate tool for pin-pointing leaks.

# Visual Evidence





# Visual Evidence



# LEED

- **EA Prerequisite 1: Fundamental Commissioning of Building Energy Systems**
- Owners are encouraged to consider including water-using systems, building envelope systems, and other systems in the scope of the commissioning plan as appropriate. The building envelope is an important component of a facility that impacts energy consumption, occupant comfort and indoor air quality. While this prerequisite does not require building envelope commissioning, an owner can achieve significant financial savings and reduce risk of poor indoor air quality by including it in the commissioning process.
- **ID Credit 1: Innovation in Design – Path 2 Exemplary Performance (1-3 points)**



# Specifications and Construction Drawings

- Building Air Leakage Pass/Fail Criteria
- Continuous Air Barrier Requirement
- Closed Cell Materials
- Relate Air Barrier Performance to HVAC Performance
- Reference Building Enclosure Commissioning Requirements with Close-Out Requirements
- Continuous Air Barrier Indicated on Construction Docs
- Continuous Air Barrier Design Intent Notes on Docs
- Rigorous Details Included on Construction Documents

This concludes The American Institute of Architects  
Continuing Education Systems Course  
Building Envelope Commissioning and Building  
Diagnostic Test: Case Studies

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