Architectural Testing

Achieving Tight Buildings through Building Envelope Commissioning.

John Runkle P.E.
Director, Building Sciences

AIVC

Washington DC area - USA
18-19 April 2013

AIVC Airtightness Workshop

3rd TightVent Workshop on Building and Ductwork Airtightness

Learning Objectives

- Understand current code changes that dictate building envelope air leakage requirements.
- Learn the key steps within the BECx process to achieve a tight building.
- Review mock-up and testing strategies through case studies.

Commissioning the Building Envelope

- Importance of air tightness
- Guidelines and Standards
- Key Steps within BECx Process
- Functional Performance Testing
- Case Studies

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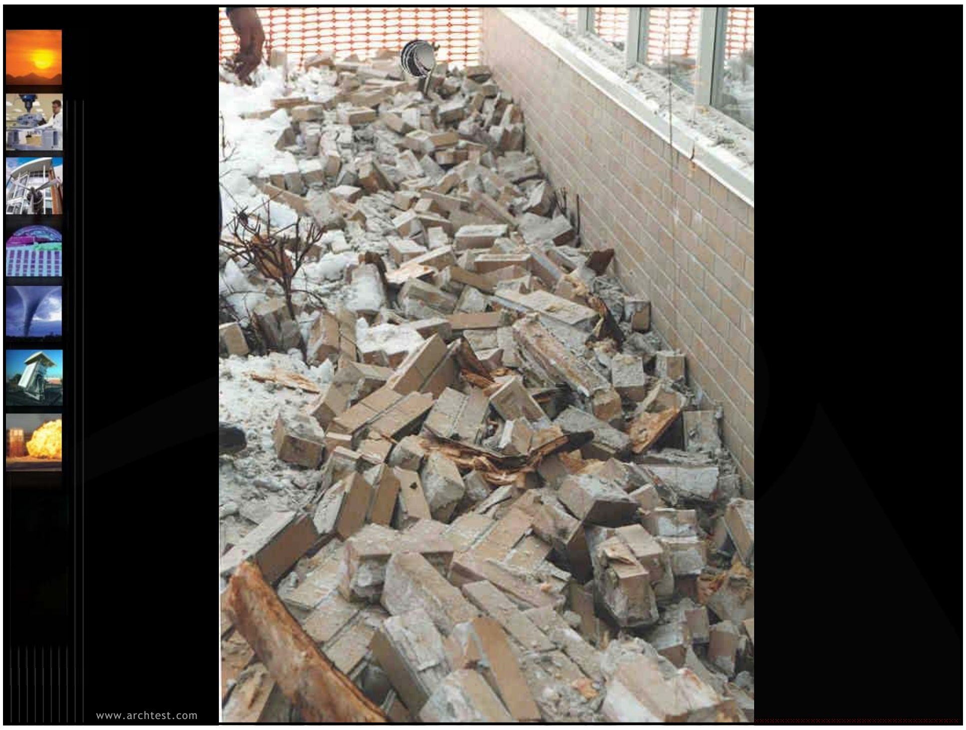
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1995 NBCC Requirements:

Material Requirements

- 0.02 L/s.m2 @75Pa

System Requirement

- Class 1 RH < 27% 0.15 $L/s/m^2$
- Class 2 RH 27-55 0.10 $L/s/m^2$
- Class 3 RH > 55% 0.05 $L/s/m^2$

- 1/8" x 1/8" hole in 1 yd^2 represents maximum leakage area to meet system requirement

History

Dr. Neil Hutcheon, 1953

Energy loss through air leakage

- Commercial buildings:
  15% - 35% of total energy use
- Residential buildings:
  30% of total energy use

History

2006:

- D.O.E. - Up to 40% of a building’s energy consumption is due to air leakage.

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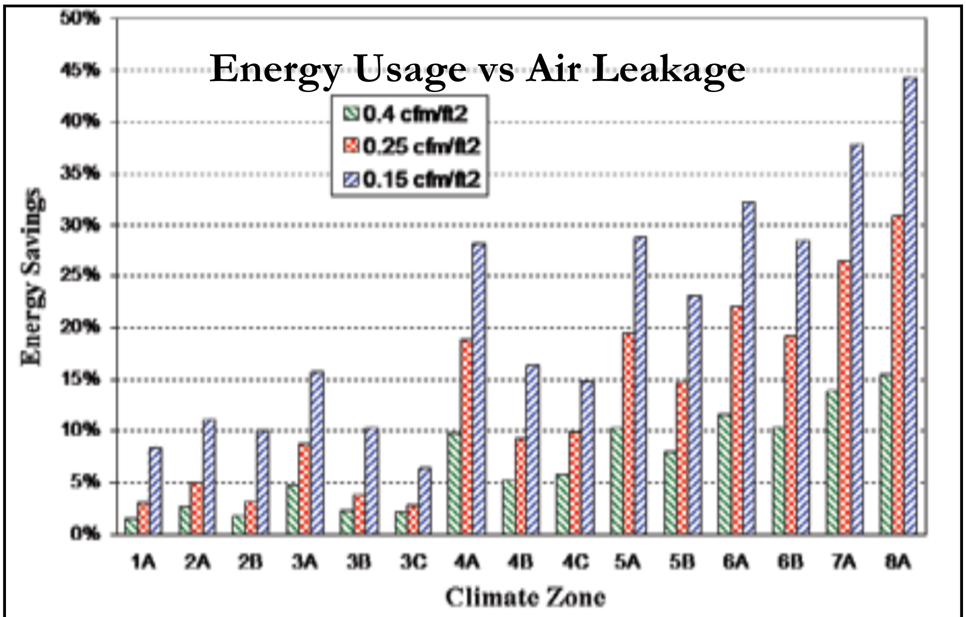

Credit: Journal of Building Enclosure Design Summer 2011
“Improvement of Air Tightness in U.S. Army Buildings” pgs. 11-13

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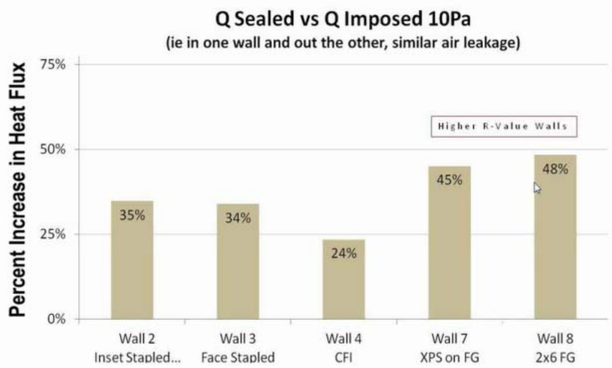
Oak ridge National Lab - Study

- Test full-scale walls w/ and w/o air leakage in hot box
- Leakage limited to joints at sheathings
- Heat flux increased 25 to 50%



Energy Modeling

Relationship with the Building envelope

Solar Heat Gain

U-Factor

Air Leakage

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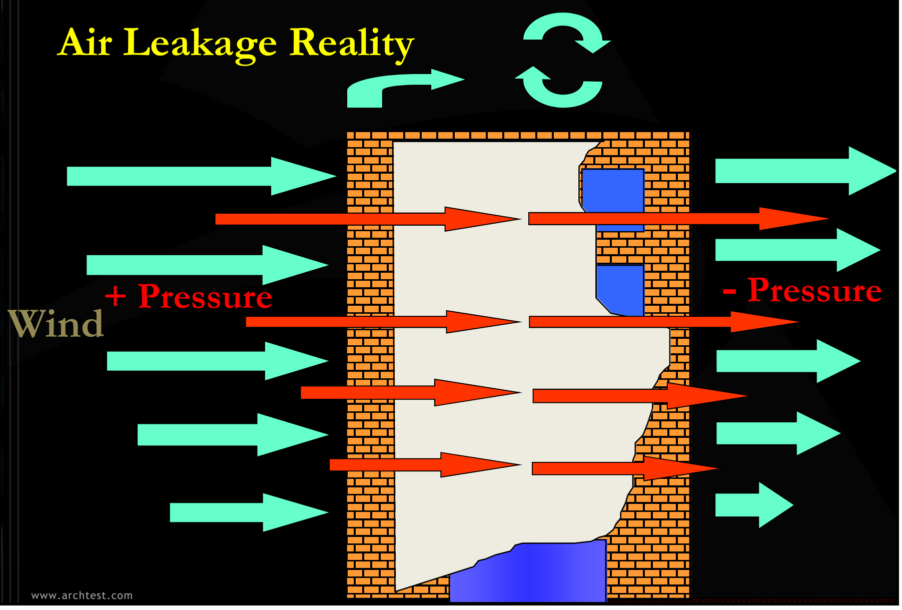
Energy Modeling

Energy models:

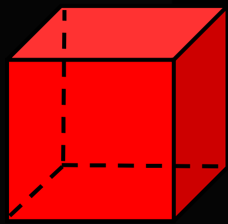
- Treat all air leakage as infiltration not exfiltration
- Leakage area is only wall, not roof/slab
- Does not account for stack effect

ENERGY MODELING



Energy Modeling

- Whole building air test results (ASTM E 779) are expressed as air flow through the wall, roof and floor not just the façade.
- CFM/SF rates must be adjusted accordingly (sometimes doubles flow the flow rate)



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Oak Ridge National Lab - Study

Finding relating to energy modeling and air leakage:

- Current Modeling software such as Energy Plus doesn't do a good job at accounting for energy loses due to air leakage.
  - Calculations are based on conductive losses that show smaller temperatures changes than the rapid temperature changes due to air leakage.
  - There is no interactive term within simulation tools and the magnitude of this term is currently unknown.
- Current models appear to underestimate the energy loss due to air leakage.
- Past studies focuses on lower R-value walls (minimizes energy loss due to leakage compared to higher R-values)

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Cost of Leaking Vs Tight Buildings

Cost	Past Poor Performance	High Performance	Planned High Performance
Design / Construction	X	X	X
BECx / Testing		X	X
Remediation	X		
Improperly sized mech. equip.	X	X	
Additional heating/cooling	X		
Unanticipated maintenance	X		
BECx impact on Architect and Contractor	As Architect and Contractor become familiar with BECx, extra costs are minimal		

History

2007:

US Army Corps of Engineers

- Air barrier material air permeance not to exceed 0.004 cfm/ft^2 at 0.3” wg (1.57 psf) (0.02 L/sm^2 @ 75 Pa)
- Whole building’s air leakage rate must not exceed 1.25 L/sm^2 @ 75 Pa (0.25 cfm/ft^2 at 1.57 psf) when tested according to ASTM E779

Case Study

- Approximate building air leakage rate @ 75PA cfm/ft² was in excess of 3 x the allowable leakage rate of 0.25 cfm/ft²
- A formal test was not performed
- A diagnostic evaluation was conducted in order to identify specific areas of leakage

Case Study

In the Details:

- The air barrier was not adequately transitioned between systems
- No air barrier was installed at the soffit of the entrances
- Building air leakage rate @ 75 PA = 0.82 cfm/ft²

2011 – CSA Z320-11

- **Standard that deals with commissioning of the building as a whole**
- **New construction and retro commissioning**
- Specific systems
  - **Architectural systems**
  - Vertical/horizontal transportation systems
  - Electrical systems
  - Mechanical systems
  - Control systems and integration
- Annexes for functional performance testing options

History

2006:

NIBS Guideline 3-2006

Exterior Enclosure

Technical Requirements

For the Commissioning Process

International Context

TABLE 2. AIR TIGHTNESS STANDARDS COMPARISON (FOR A FOUR-STORY BUILDING, 120 x 110Ft., N=0.65)			
Country	**Source**	**Requirement***	**Cfm/sq.ft .at 75 Pa.**
U.S.	ASHRAE 189.1-2009		0.40
UK	TS-1 Commercial Best Practice	5 m3/h/m2 at 50 Pa.	0.36
U.S.	LEED	1.25 sq. in. EqLA @ 4 Pa. / 100 sq. ft.	0.30
Germany	DIN 4108-2	1.5 1/h at 50 Pa.	0.28
UK	TS-1 Commercial Tight	2 m3/h/m2 at 50 Pa.	0.14
Canada	R-2000	1 sq. in. EqLA @10 Pa. /100 sq. ft.	0.13
Germany	Passive House Std	0.6 1/h at 50 Pa.	0.11

*USACE requirement is 0.25 cfm/sq. ft. at 75 Pa.

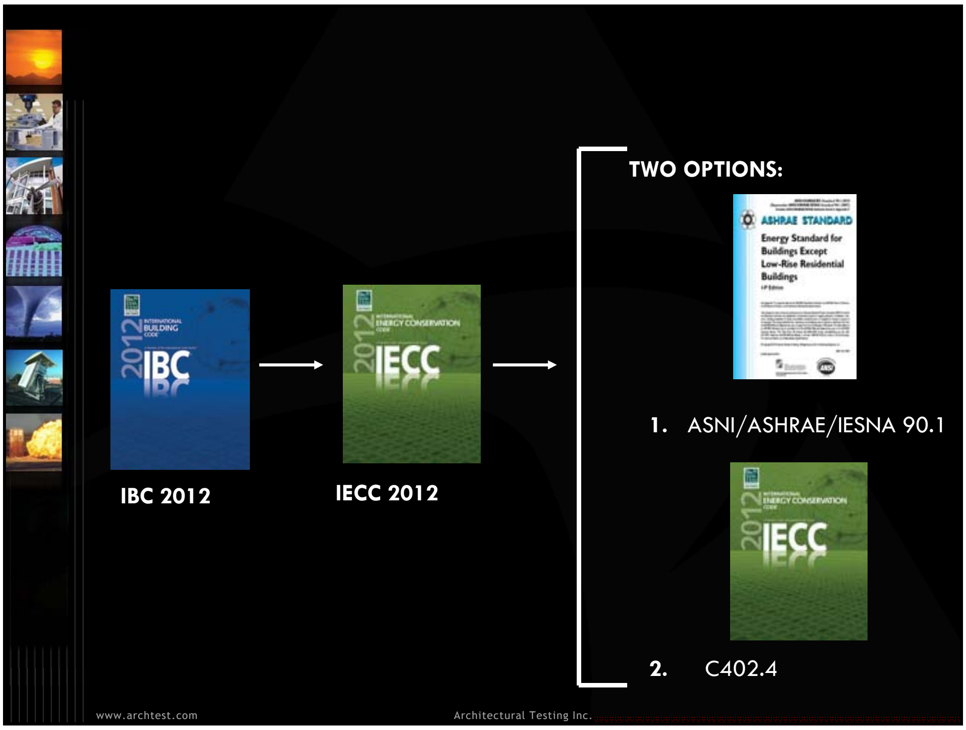
Credit: Journal of Building Enclosure Design Summer 2011
"Improvement of Air Tightness in U.S. Army Buildings" pgs. 11-13

History

2012:

ASTM

- E 2813 – Standard of Practice BECx
- NIBS Guideline 3 – Standard guide subcommittee formed
- Certification and Training subcommittee formed
  - ASTM certification, NIBS training
  - Based on ISO 17024 accreditation



	IECC	ASHRAE
Continuous AB	✓	✓
Continuous AB in Zones 1-3 (Southern States)		✓
Continuous AB in Semi-heated spaces	✓	
Construction Document Requirements		✓
Materials: air permeability ≤0.004 cfm/ft^2	✓	✓
Assemblies: air permeability ≤0.04 cfm/ft^2	✓	✓
Whole Building: air permeability ≤0.4 cfm/ft^2	✓	
Joints/seams resist negative/positive pressure	✓	✓
Joints, seams, transitions, and penetrations sealed	✓	✓
Fenestration Air Leakage Requirements	✓	✓
Door Air Leakage Requirements	✓	✓
Vestibule Requirements	✓	✓

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Fenestration Air Requirements

TABLE C402.4.3
MAXIMUM AIR INFILTRATION RATE FOR FENESTRATION ASSEMBLIES

FENESTRATION ASSEMBLY	MAXIMUM RATE (CFM/FT²)	TEST PROCEDURE
Windows	0.20[a]	AAMA/WDMA/ CSA101/I.S.2/A440 or NFRC 400
Sliding doors	0.20[a]	
Swinging doors	0.20[a]	
Skylights – with condensation weepage openings	0.30	
Skylights – all other	0.20[a]	
Curtain walls	0.06	NFRC 400 or ASTM E 283 at 1.57 psf (75 Pa)
Storefront glazing	0.06	
Commercial glazed swinging entrance doors	1.00	
Revolving doors	1.00	
Garage doors	0.40	ANSI/DASMA 105, NFRC 400, or ASTM E 283 at 1.57 psf (75 Pa)
Rolling doors	1.00	

For SI: 1 cubic foot per minute = 0.47L/s, 1 square foot = 0.093 m².

a. The maximum rate for windows, sliding and swinging doors, and skylights is permitted to be 0.3 cfm per square foot of fenestration or door area when tested in accordance with AAMA/WDMA/CSA101/I.S.2/A440 at 6.24 psf (300 Pa).

IECC 2012

What is an Air Barrier?

What is an Air Barrier?

- Materials with air permeability ≤0.004 cfm/ft^2
- Compliant Materials
  - Plywood ≥ 3/8 in. thick
  - Oriented Strand Board ≥ 3/8 in. thick
  - Extruded Insulation Board ≥ 1/2 in. thick
  - Foil-back Insulation Board ≥ 1/2 in. thick
  - Closed-cell spray foam (min. density 1.5 pcf and thickness ≥ 1-1/2 in.)
  - Open-cell spray foam with density 0.4-1.5 pcf and thickness ≥ 4-1/2 in.
  - Exterior or interior gypsum board ≥ 1/2 in.
  - Cement board ≥ 1/2 in.
  - Built-up roofing membrane
  - Mod-bit roofing membrane
  - Fully-adhered single-ply roofing membrane
  - Portland cement/sand parge or gypsum plaster ≥ 3/8 in. thick
  - Cast-in-place or precast concrete
  - Fully grouted concrete block masonry
  - Sheet steel or aluminum

Nature Wants Equilibrium

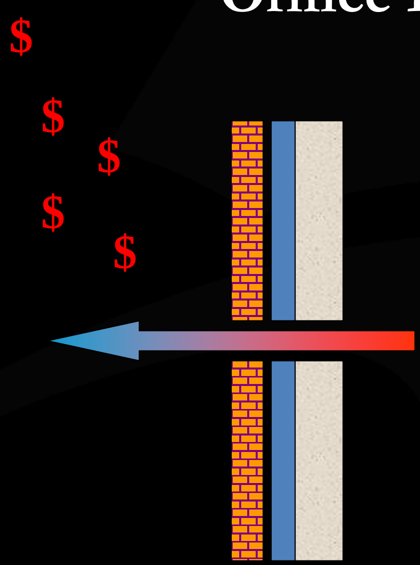
- High To Low
- Hot To Cold
- Wet To Dry

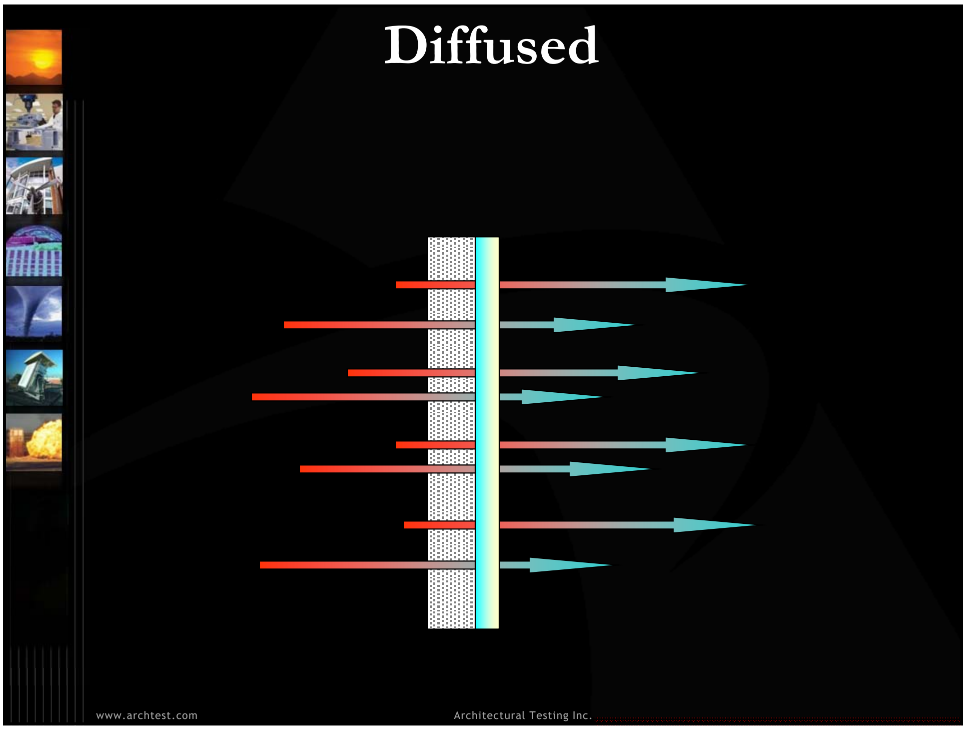
Air Flow

Air flow rate depends on:

- Pressure difference
- Size of hole
- Location of hole

Orifice Leak




Diffused
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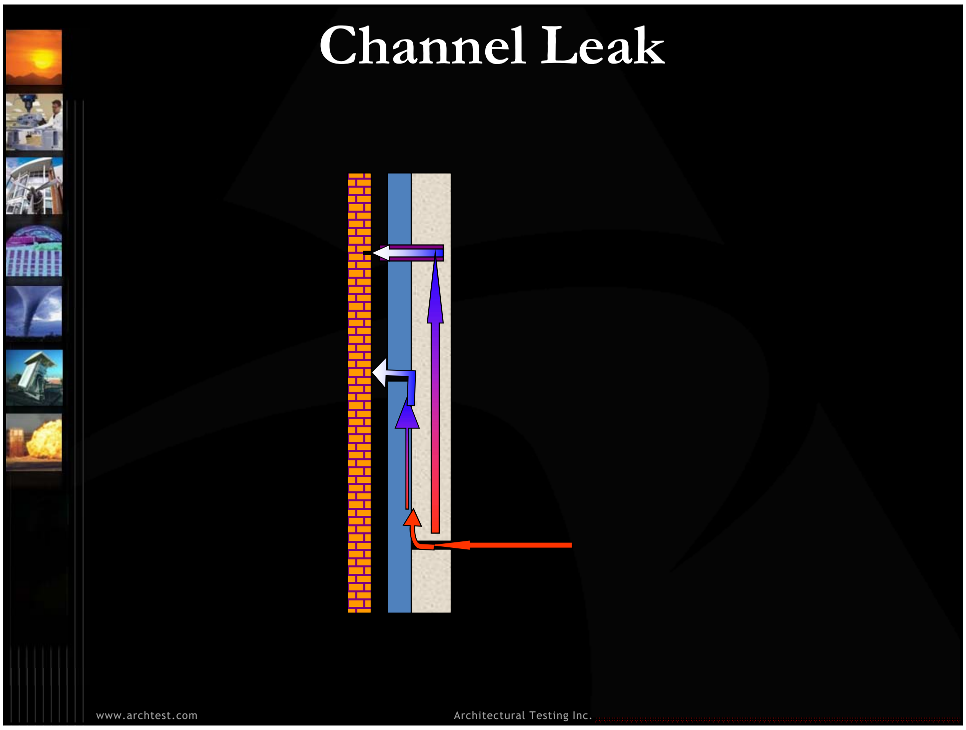
Channel Leak
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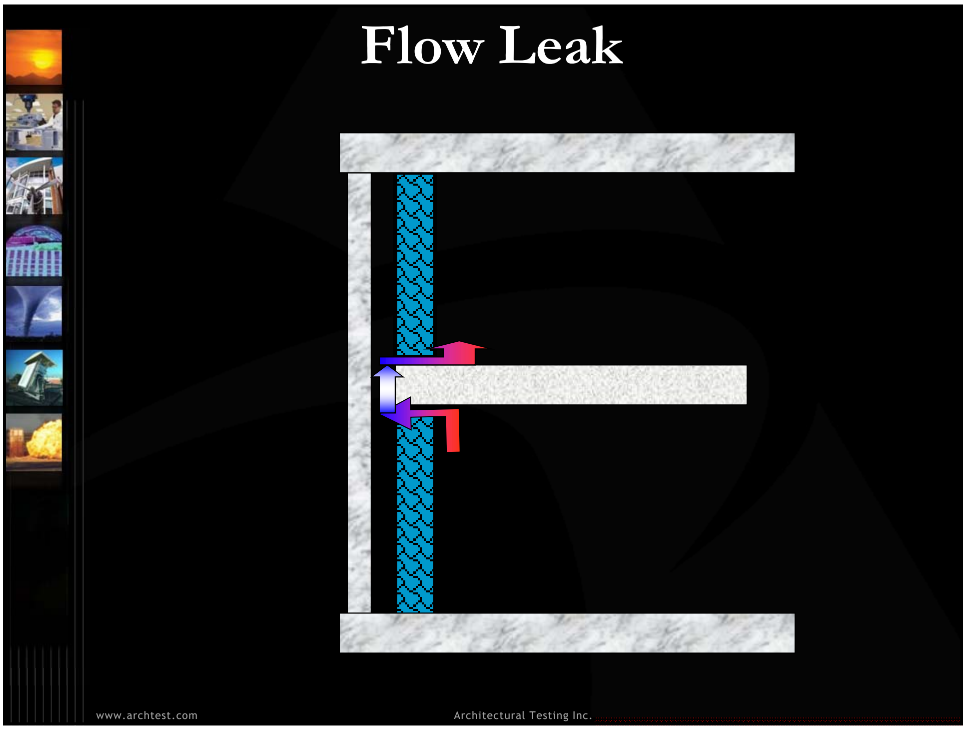
Flow Leak
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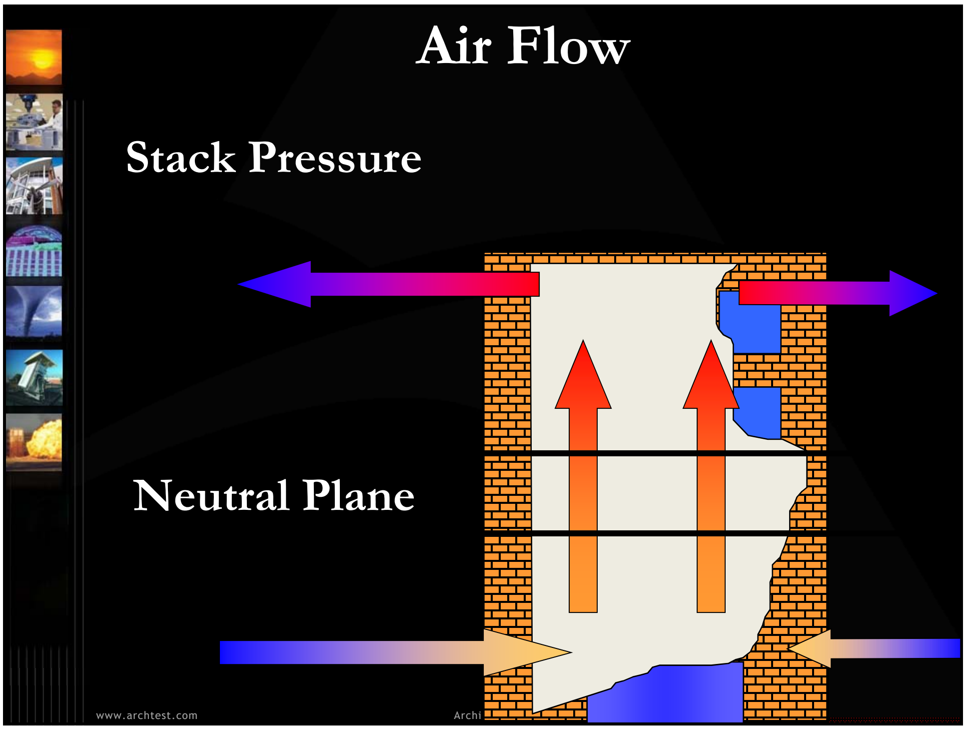
Air Flow
Stack Pressure
Neutral Plane
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ENVIRONMENTAL SEPARATION

- Air barriers
- Vapor barriers
- Drainage layers
- Thermal barriers

Commissioning Phases

- Pre-Design Phase
- Design Phase
- Pre-Construction Phase
- Construction Phase
- Operations & Maintenance Phase

Building Enclosure Commissioning Selection Guide

Select all options that apply to specific project

	Performance	Functional Performance Testing
	--------------------Service Life in Years--------------------	
☐	Beyond code minimum fire protection required	
☐	Within 5 miles or 65 dBA or higher contour curve of airport	
☐	Interior dBA levels less than 45	
☐	Within 1000 ft of freeway, fire station, sports arena, racetrack	
☐	Within 3000 ft of active railway, helicopter pad	
☐	School, hospital, theater, mixed use residential/commercial	
☐	Beyond code minimum energy efficiency desired	
☐	Blast, forced entry or security performance required	
☐	Basic wind speed in excess of 100 mph	
	--------------------Tolerance to Water Intrusion--------------------	Enter applicable option from drop down box
	--------------------Thermal Conditions--------------------	Enter applicable option from drop down box
☐	LEED V3 2009 innovation point for Building Envelope Cx	
	--------------------Building Pressurization--------------------	Enter applicable option from drop down box
☐	No time loss facility (e.g. data center)	
☐	Functional performance layers are non-maintainable	
	--------------------Project Delivery--------------------	Enter applicable option from drop down box
	--------------------Project Schedule--------------------	Enter applicable option from drop down box
	--------------------Intererior Rh and climate--------------------	Enter applicable option from drop down box
	Recommended Level of Thermal FPT	No FPT Required
	Recommended Level of Acoustical FPT	No FPT Required
	Recommended Level of Water FPT	No FPT Required
	Recommended Level of Air FPT	No FPT Required
	Recommended Level of Solar FPT	No FPT Required
	Additional Miscellaneous Testing (Fire)	No Additional Testing Required
	Additional Miscellaneous Testing (Blast)	No Additional Testing Required
	Additional Miscellaneous Testing (Structural)	No Additional Testing Required
	Recommended Level of Commissioning	Basic Commissioning

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Design Phase

- Review design against OPR and BOD
- Perform hygrothermal computer modeling (WUFI & Therm)
- Review construction sequencing and scheduling
- Write BECx and functional performance testing specifications

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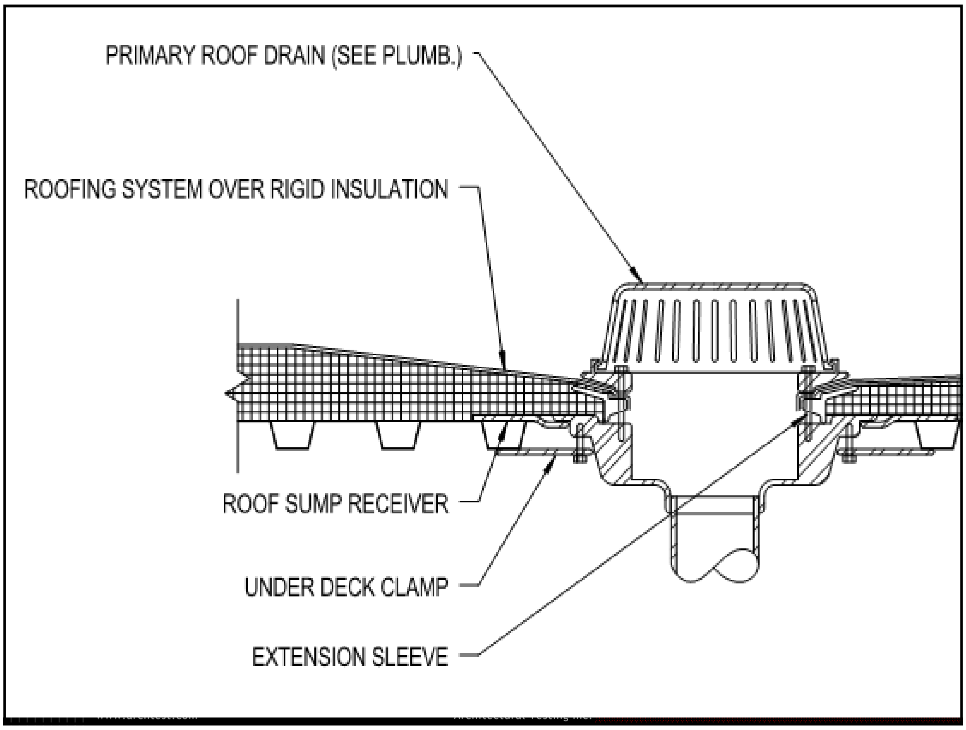
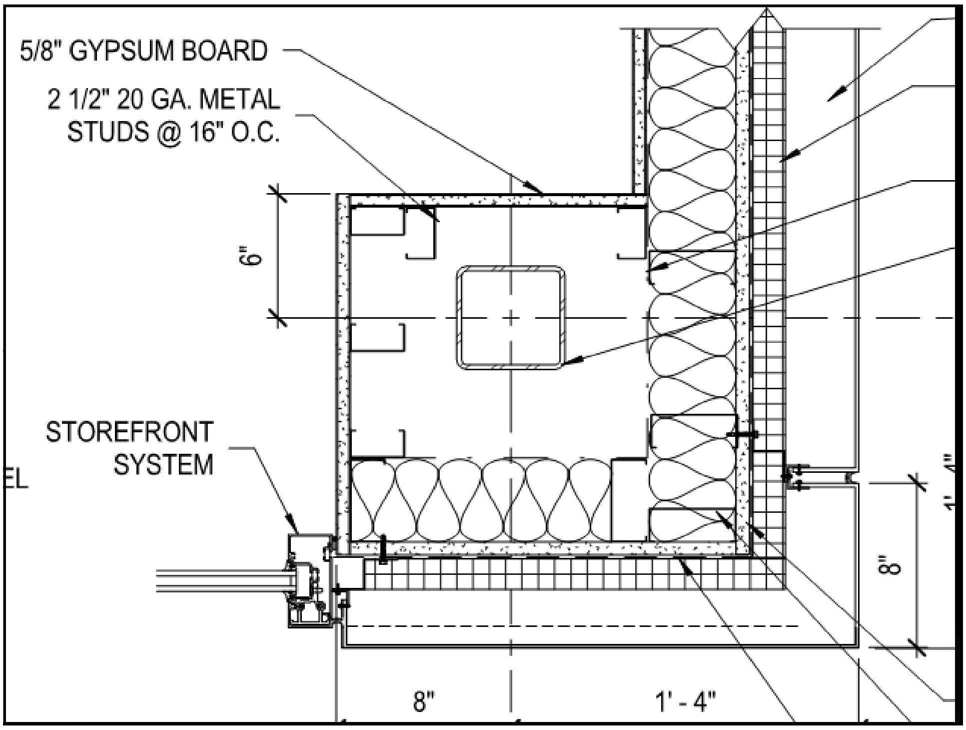
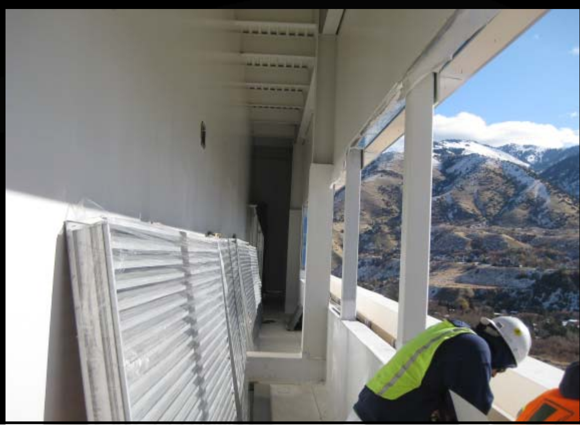




HVAC or building Envelope?

- Air intake, but interior room forms the duct.
- Floor is waterproofed with roofing membrane.
- Room hemorrhages air.



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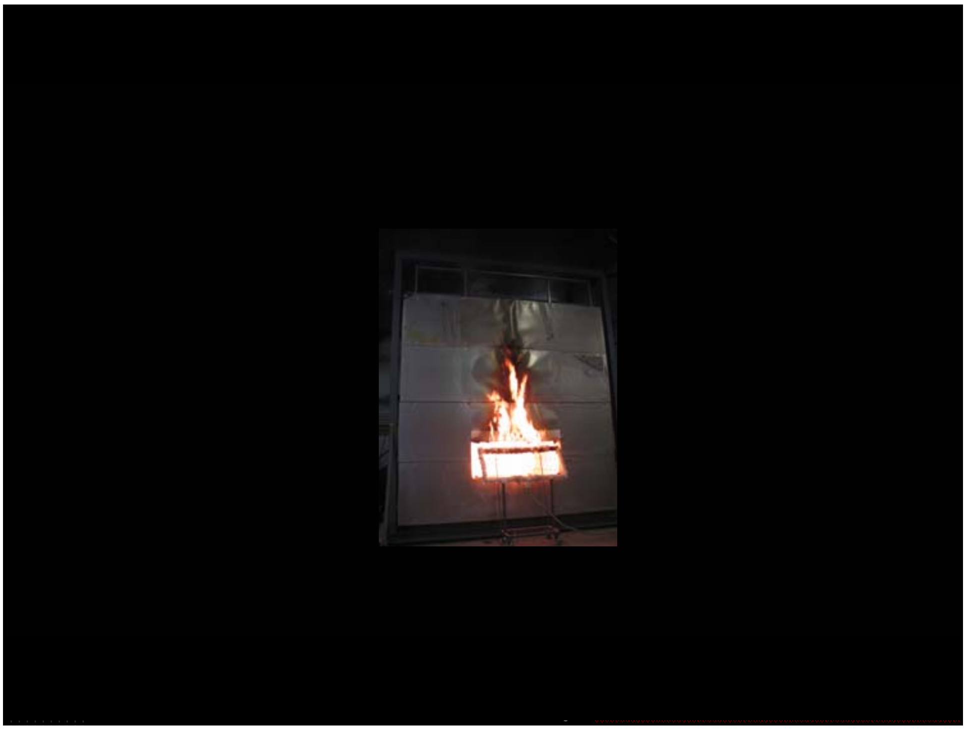
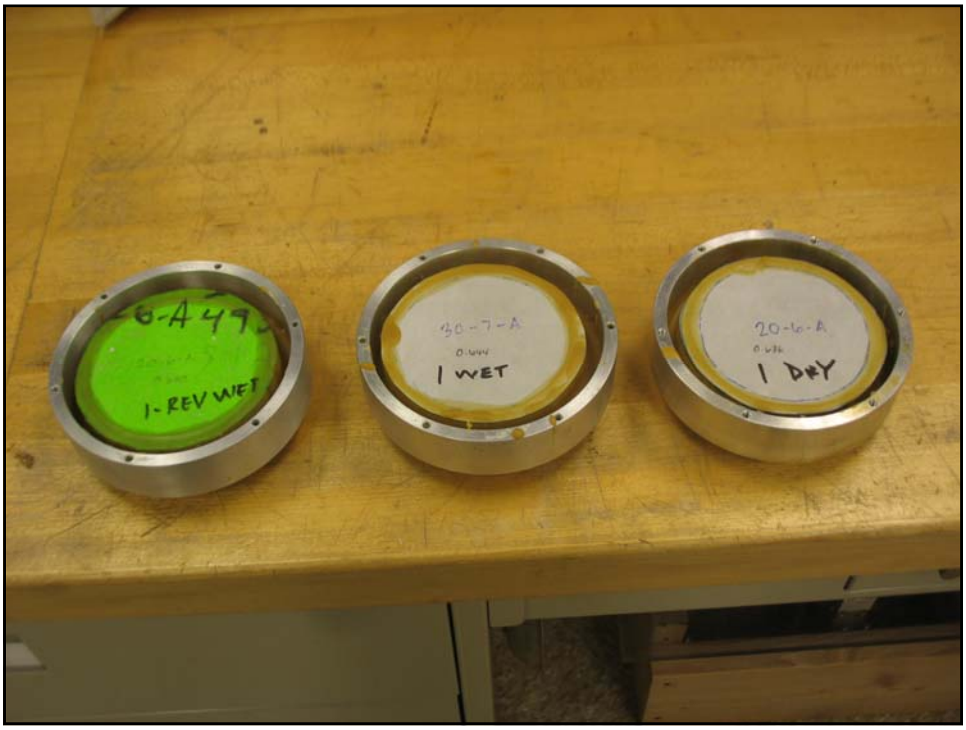
Testing Considerations

- Difficulty in achieving the OPR
- Complexity of the design – How wild is the Architect's dream and what's the climate
- Number of systems - cladding Matrix
- Are all interior spaces conditioned the same?
- Expectations of trades.

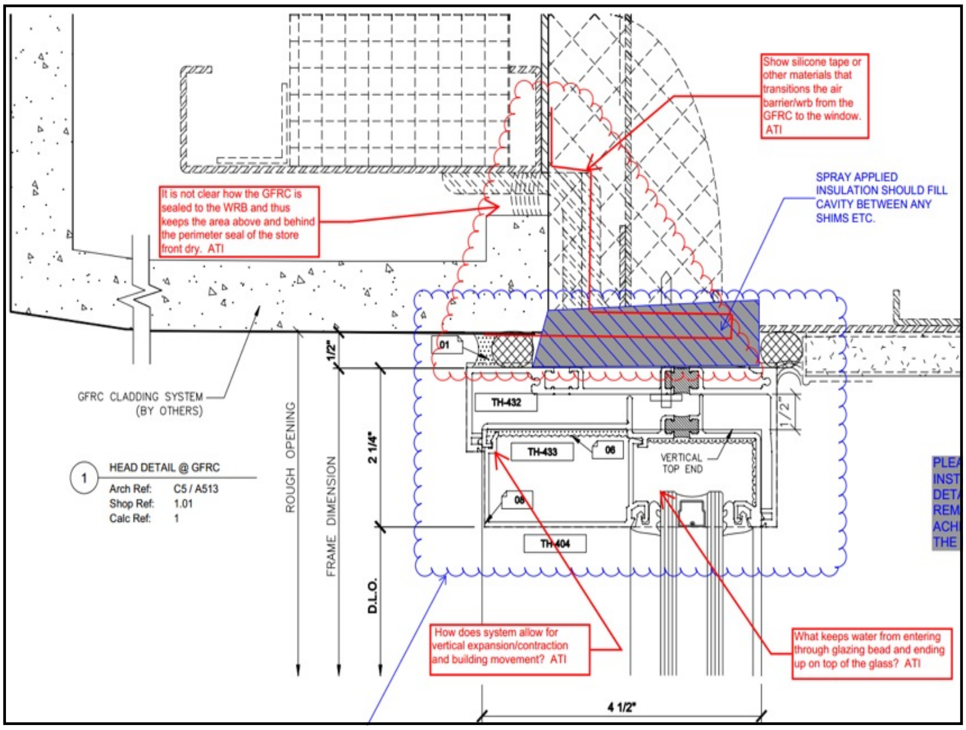

ASTM E2357 Product Installation
Post Applied Brick Ties





Pre-construction Phase

- Start-up meeting with all parties involved
- Review of shop drawings
- Review of proposed materials for compatibility
- Review of ownership/sequence
- Finalize testing protocols
- Document mock-up construction and testing.



Pre-construction Phase

Mockup:

- To be built by the trades
- Represent project design and materials
- May be stand-alone or part of the final construction
- To include as many typical details as possible
- To be tested for compliance
- Sets the standard of care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Testing
Link-Belt


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ASTME 283


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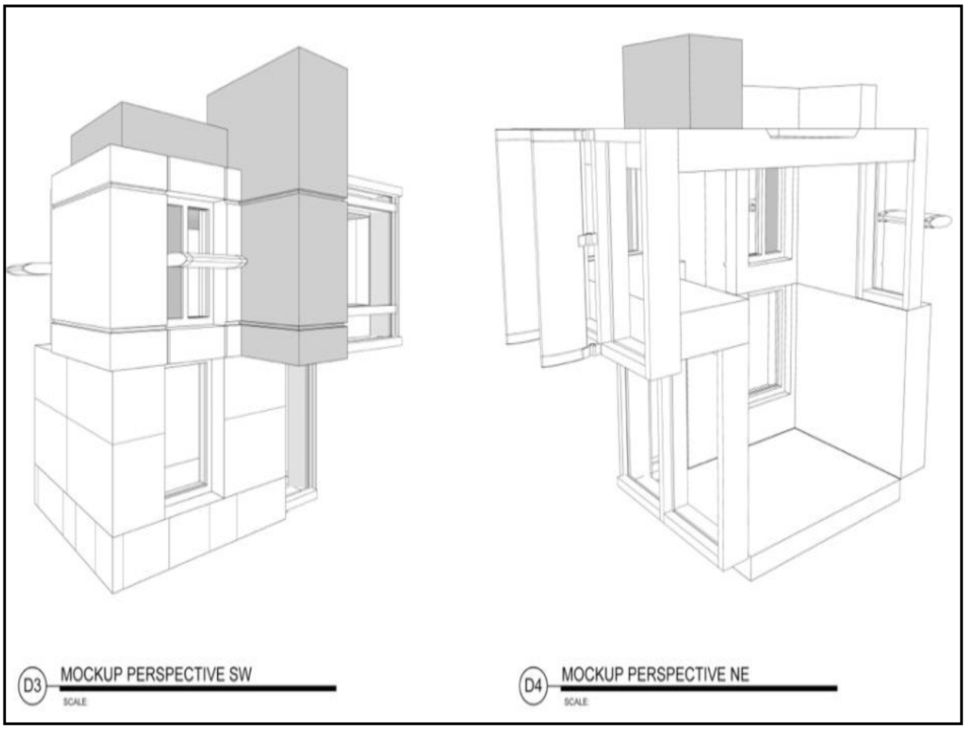
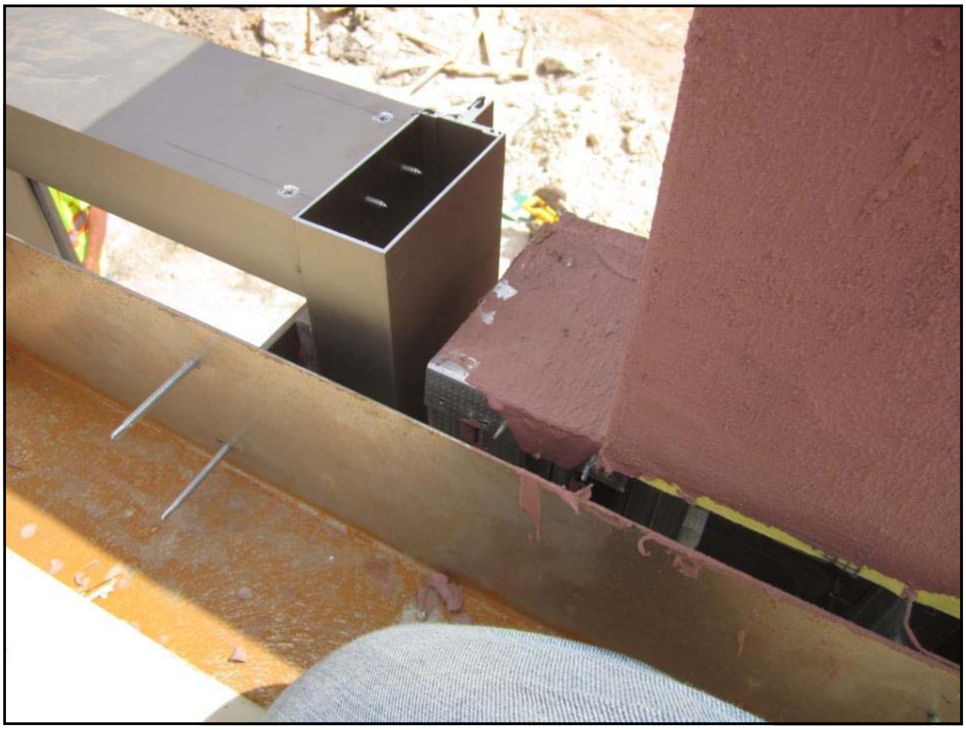
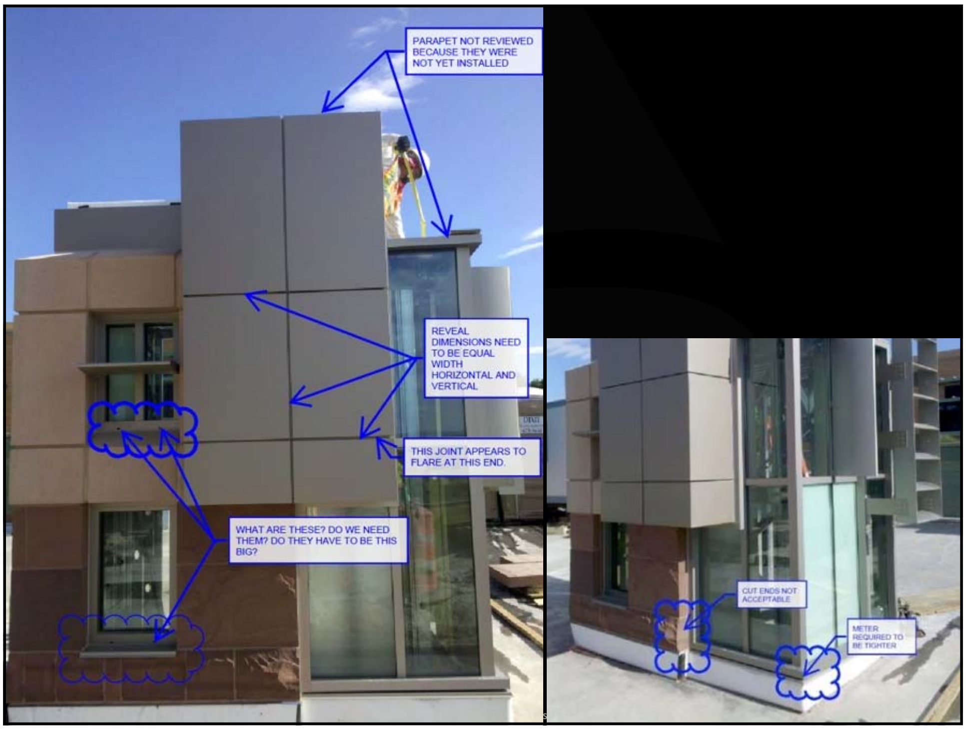
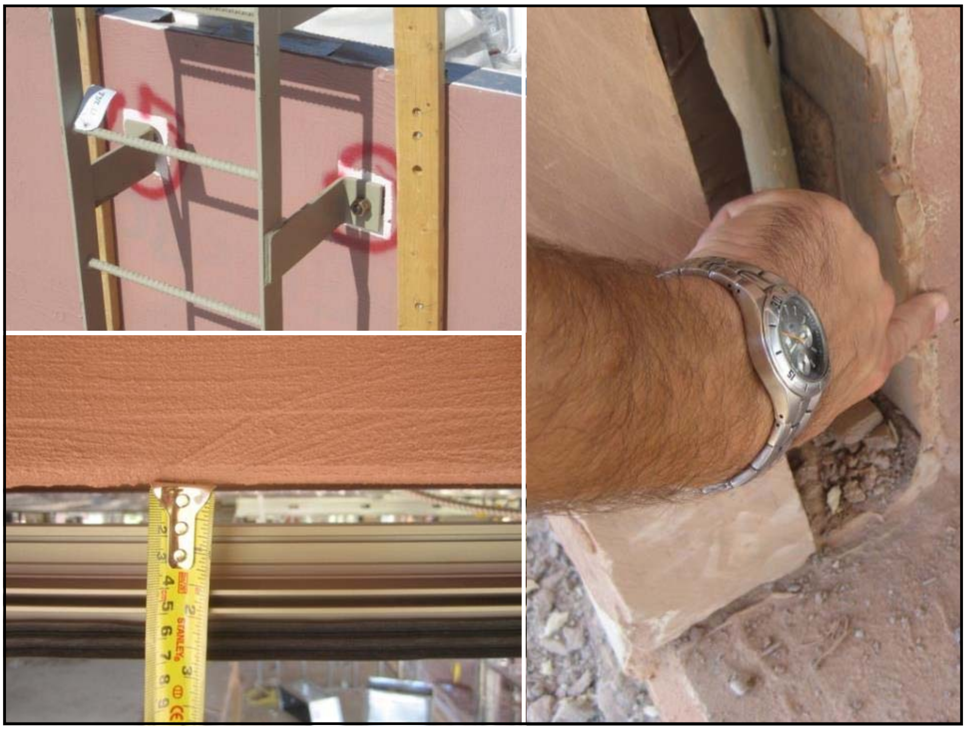

D3
MOCKUP PERSPECTIVE SW
SCALE:
D4
MOCKUP PERSPECTIVE NE
SCALE:

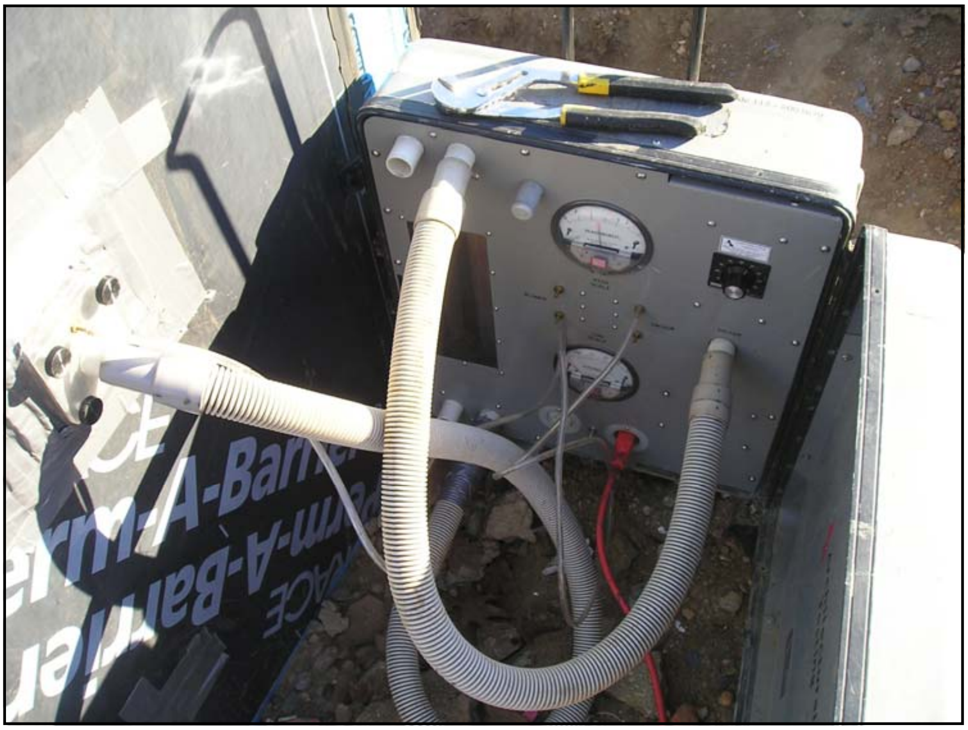



PARAPET NOT REVIEWED BECAUSE THEY WERE NOT YET INSTALLED
REVEAL DIMENSIONS NEED TO BE EQUAL WIDTH HORIZONTAL AND VERTICAL
THIS JOINT APPEARS TO FLARE AT THIS END.
WHAT ARE THESE? DO WE NEED THEM? DO THEY HAVE TO BE THIS BIG?
CUT ENDS NOT ACCEPTABLE
METER REQUIRED TO BE TIGHTER




GRACE
Perm-A-Barrier


GRACE
Perm-A-Barrier
11/30/2010




PERM-A-BARRIER


02/08/2011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Layton


GRACE


USG
SECUROCK
Glass-Mat Sheathing
DANGER


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Construction Phase

- Review Quality control by contractors Q/C
- Observe/perform functional performance testing
- Construction observations/inspections
- As-needed BECx meetings
- Update BECx plan

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SURFACE PREPARATION
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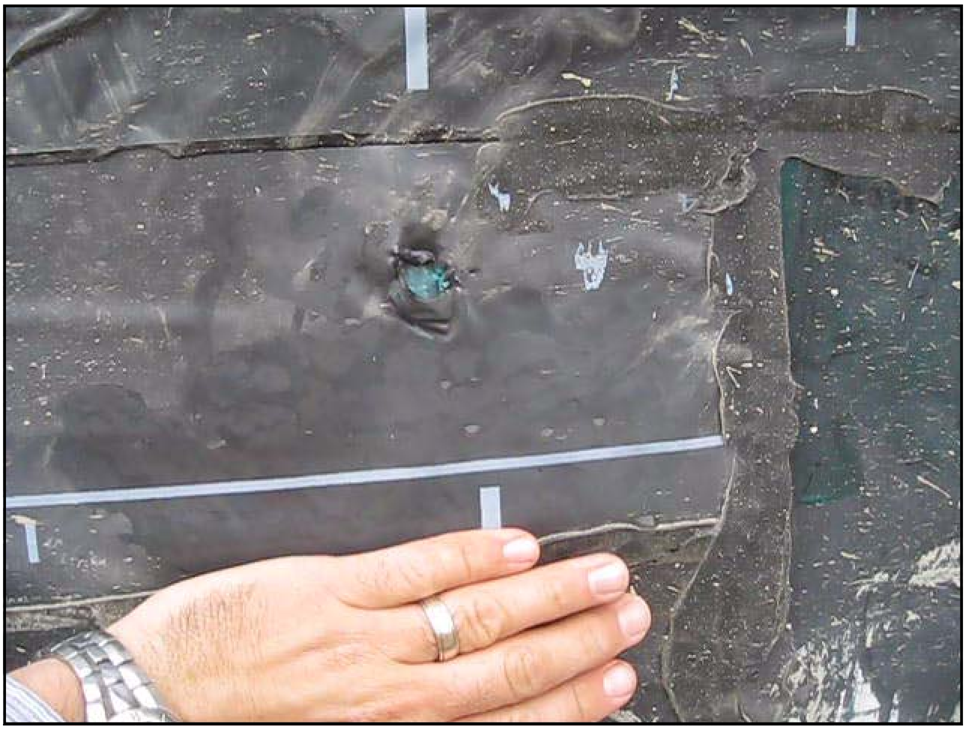
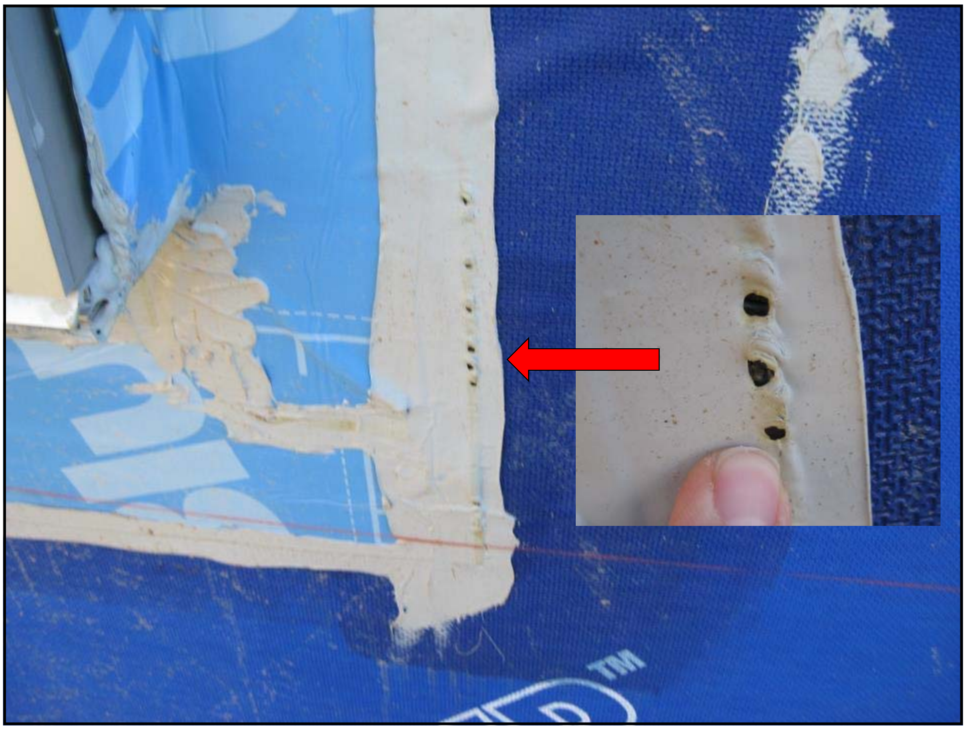
07/04/2004


28/04/2003






Eau Claire
NEWS
18


GlasRoc
1-800-UR-RENTS


Henry
BlueskinVP


Henry
BlueskinVP
Blueskin


Henry
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Blueskin


USB DATA LOGGING
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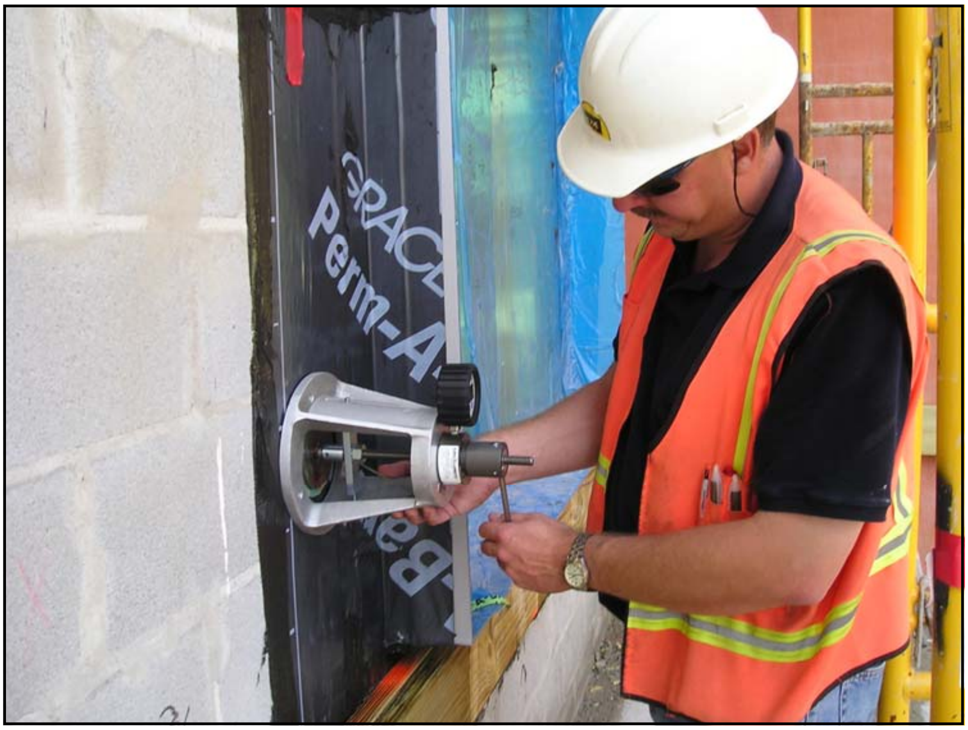
BlueskinVP


Perm-A


01/08/2013

Architectural Testing

Project Name: U Penn Fisher Translational Research Center
Location: Philadelphia, PA
ATI Project No.: 84941.01-115-27

Reported by: B. Monahan - Architectural Testing Inc. (ATI)
Reported to: G. Swallow - UPHS

Weather: Clear - 42° F
On/Off Site Time: 8:45 AM 1:00 PM

Client: University of Pennsylvania Health System (UPHS)

Present:

B. Monahan	ATI
G. Swallow	UPHS
J. DeFelice	LF Driscoll (LFD)
K. Whalen	National Glass and Metal Co. (NGMC)

Work In Process: Stip window glazing installation at northwest corner, snap covers at north elevation
Insulation and vapor barrier installation at west elevation, 4th floor
Louver pan flashing completed at 5th floor, north, east and west elevations

Field Report No.: 4
Site Visit Date: 03/12/09

Item:	Observation:	Attention Required By:	Floor:	Elev.:	Location:	Photo No.:
11	The sealant applied between the back leg of the sill starter and the sill frame is adhered to the window sticker of the sill frame. All sealant substrates are to be cleaned and prepared in accordance with the manufacturers recommended installation procedures. NGMC removed the sealant and sticker, prepared the sealant substrates and reapplied the sealant prior to ATI leaving the site.	None	3	North	Column Q-2	1194
12	The joints between the back leg and end dam of the metal pan located below the louvers are unsealed at several locations. ATI notified LFD that sealing the joints of the metal pan is required to properly drain water collecting in the pan.	DeMeyo	5	North and West	Column P.6-5, Adjacent to columns L-2 and H-2	1188, 1189, 1191
13	Two fasteners penetrating through the metal pan flashing below the louvers were unsealed. ATI notified LFD that all fastenters through the flashing are to be sealed as indicated in the shop drawing detail.	DeMeyo	5	West	North of column E-2	1192

Additional Comments:
The above conditions represent discrepancies that we observed in the installed work compared to construction documents, installation instruction, shop drawings and good industry practice. Additionally, we noted conditions that are repairs or steps that are repairs or steps that they installers took in reaction to our observations. This report does not include our opinion regarding the merits of the remedial efforts, but we would be pleased to provide our opinion or other consulting services upon request. Unless the condition above states that it was repaired during our site visit, the condition remains outstanding. Our inspections do not constitute 100% inspections and Contractors are responsible to carry out 100% inspections of their work and corresponding repairs. Repeat conditions are indicative that this inspection is not being performed by the contractors.

O & M Phase

- Whole building testing
- Infrared scanning
- Warranty package
- Final BECx record

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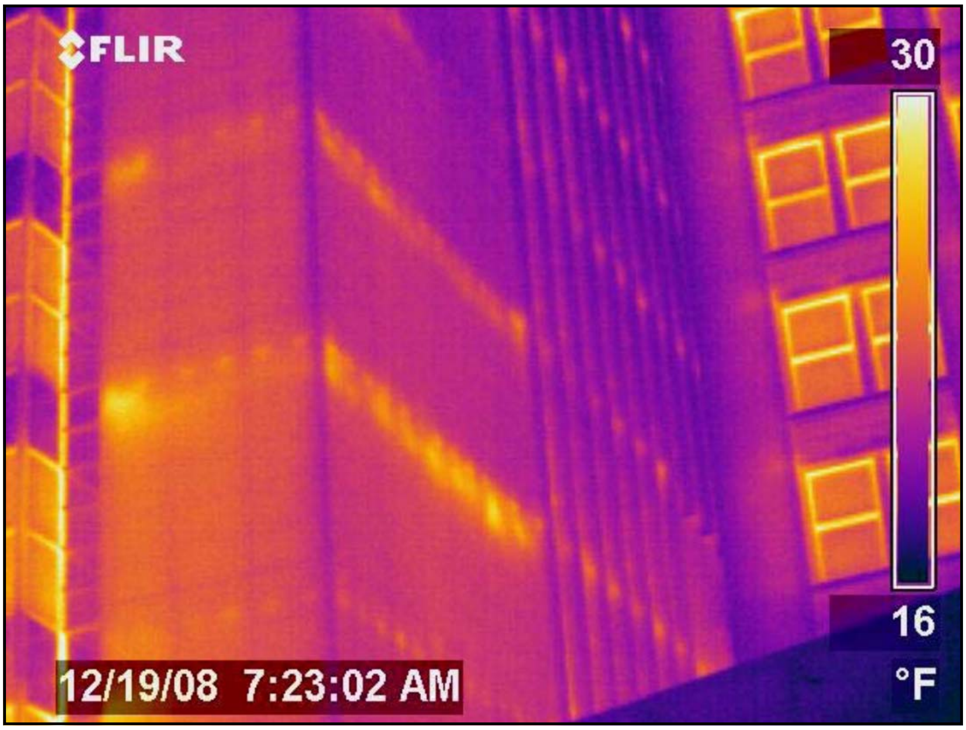
EXIT
EXIT


FLIR
30
16
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12/19/08 7:23:02 AM


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QUESTIONS?
COMMENTS?
INSULTS?
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