Henri Fennell, CSI/CDT

Henri is an architect and building envelope specialist with over forty years of experience in the construction industry. He was a pioneer in the solar industry, introduced the installation technique for field-applied closed-cell closed-cavity-fill polyurethane foam and has designed and constructed a net-zero energy research structure in Antarctica. He has four energy-related U.S. patents.

HCF foam experience

1. First spray foam project was in 1971
2. Foam manufacturing from 1973 to 1979
3. Foam contracting and BE consulting from 1979 to 2009
   - Developed the method for injecting closed-cell foam on site
   - Installed ~ 5 million pounds of foam
4. Foam and BE commissioning from 2009 to present
5. Noteworthy foam projects include:
   - 1977 net-zero solar project in Boston, The Big Dig, 4 American Ski Grande Hotels in the Northeast, Net-zero energy weather station in Antarctica, The Guggenheim Museum
6. Two US patents and numerous technical papers related to foam & foam QA




Copyright Materials

Introductions

Resources posted on line

- Technical Resources on line
  - ASHRAE 9-2005 – Setting Airtightness Standards
  - Guidelines for air barrier implementation plans
  - HCFC Integrated design
- Program PowerPoint handouts

- How many of you know what a blower door test is?
- How many of you do blower door tests?
- How many of you use pressurized theatrical fog tests?

Outline

- Where are we in the US in terms of energy performance in our buildings?
- How do we size our HVAC systems?
- What do we do if the engineer's design doesn't work?
- How do we figure out the downsizing of the HVAC system?
- Model the air barrier - how much will it leak?
- Someone has to be willing to guarantee the leakage rate.
- Convince the engineer to use the aggressive air leakage guarantee number.
- Design to achieve the guarantee!
- Build to achieve the guarantee!
- Test compliance!
- Verify and track so we can improve the performance.

Where are we in the US in terms of energy performance in our buildings?

Rigid-foam board and air barrier?

Spray-applied Polyurethane Foam (SPF)

- Continuous monolithic air and vapor control system
- Drainage plane

- High R-value/inch

Where has the industry been?

Where are we now? Where can we go?

What is out there in the industry (CFM50/sq. ft. of shell)?

• NISTIR 7238 (1963 to 1995)*	1.90
• Current standard construction**	0.93
• ASHRAE 90.1 (5.4.3.1.3)	0.31
• IECC (C402.4.1.2.3)	0.31
• IRC (N1102.4.1.2, R402.4.1.2), 3 ACH50	0.45 to 0.60
• US Army Corp of Engineers (.25 CFM @ 75 pa)	0.19
• Target for high-performance construction**	0.10
• Ultimate designs we are achieving***	0.05

*NISTIR 7238 - *Investigation of the Impact of Commercial Building Envelope Airtightness on HVAC Energy Use-6/2005*

***Setting Whole Building Airtightness Standards*": ASHRAE Journal-10/2005

***Target for "cutting edge" structures – Better Buildings By Design 08

Convection control/performance

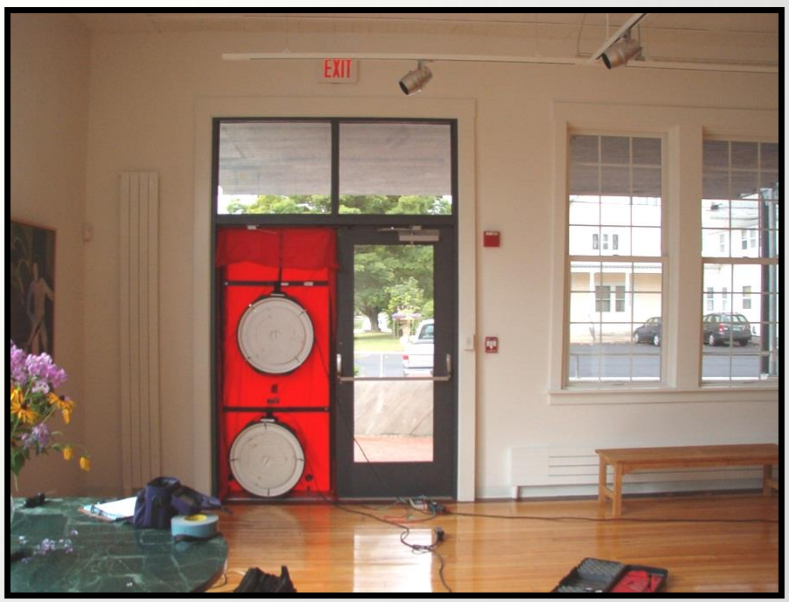
ASHRAE has 3 compliance options: Material, or Assembly, or Whole Building.

Codes & Regulations	**Compliance Requirements** cfm/ft^2 @ 0.30 in water (75Pa)		
	Material ASTM E2178	**Assembly** ASTM E1677	**Whole Bldg.** ASTM E779
NBC & MA Energy Code	**0.004**	**--**	**--**
WI Energy Code	**--**	**0.06**	**--**
MN Energy Code *(Proposal)*	**0.004**	**--**	**--**
ASHRAE 90.1	**0.004** *or*	**0.04** *or*	**0.4**

US ACE standard is .25CFM75/sq. ft. of shell

How do we know how a building performs?

- Industry-standard air leakage test method
- ASTM E799 (E1186)



These tests cost from
$.02 to $.06 / sq. ft.

Compliance Test – 63,000 sq. ft. school

Compliance Test – 104,000 sq. ft. building

What are the benchmarks?

- In 1984, very few people know what a blower door test is.
- The 2009 IECC still does not require blower door testing.
- The 2012 IECC finally mandates air tightness testing of buildings!

We need more predictable performance

If we can provide predictable BE performance, we can:

- Move toward achieving our net-zero energy and carbon goals
- Reduce overall up-front overall construction costs
- Assure durability
- Realize HVAC system savings – downsized to tested levels
- Easily cut operating costs (25% to 75%)
- Avoid failures (localized and general)

Bonus!

Improved indoor air quality

We need more predictable performance

LEED Performance variation*

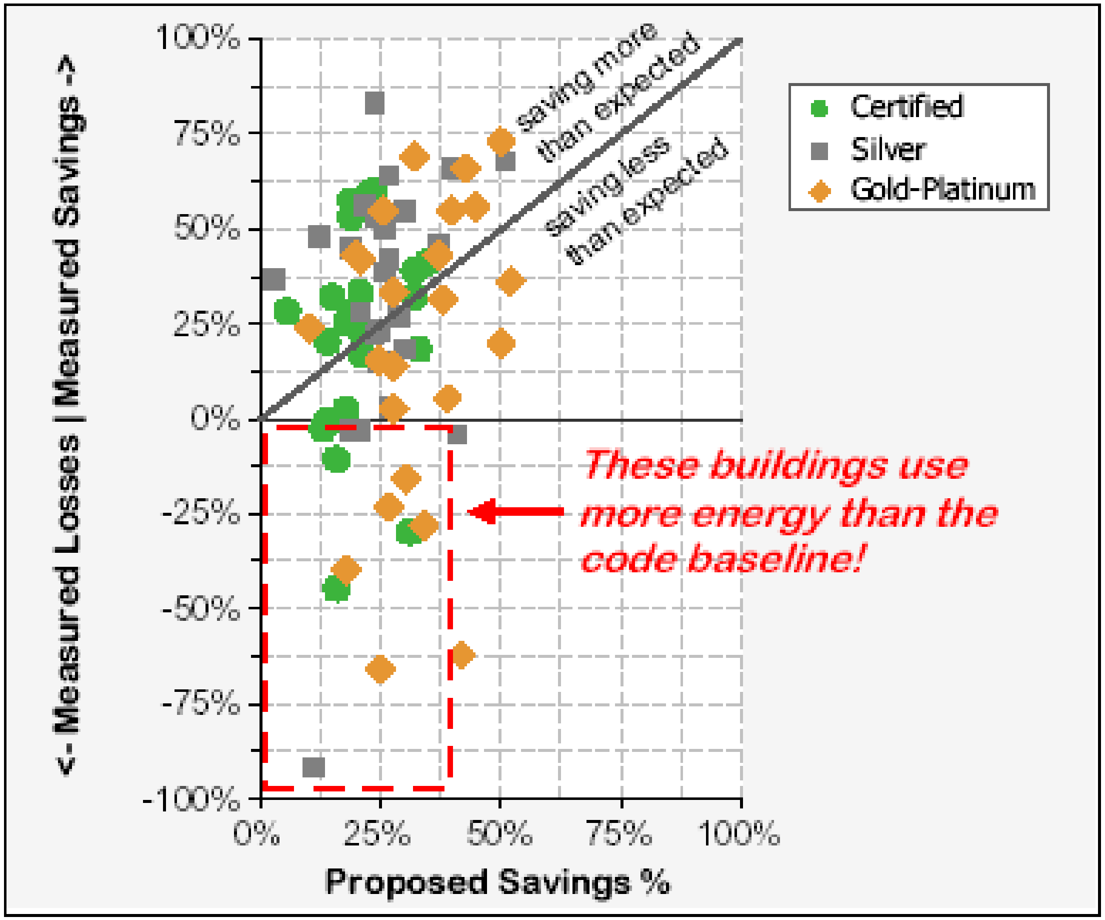
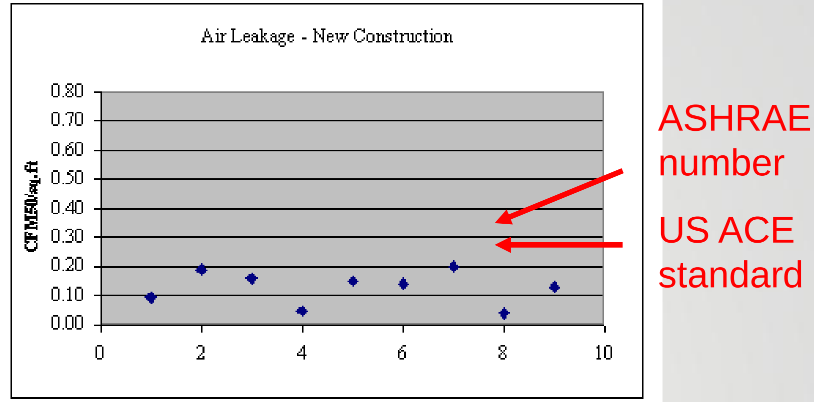


Figure ES- 5: Measured versus Proposed Savings Percentages

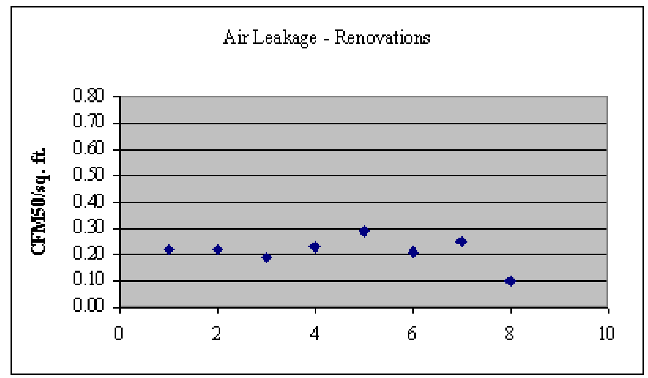
"Energy Performance of LEED® for New Construction Buildings," FINAL REPORT, March 4, 2008 (by: New Buildings Institute)*

We need more predictable performance

	BES - New Buildings, Major additions	CFM50/ Sq. ft.	ACH Nat	ACH 50	KWH / SM/Yr.
1	Logic Associates - Hartford, VT (84)	0.10	0.03	0.60	<100
2	Primex Office Bldg. – Concord, NH	0.19	0.06	1.15	
3	NRG Phase 1 – Hinesburg, VT	0.16	0.03	0.60	
4	Dartmouth – Kemeny (mockup)	0.05	0.02	0.27	
5	Champlain Valley Union HS	0.15	0.06	0.95	80
6	Richmond Middle School - No mech	0.14	0.04	0.88	
7	Randolph Development - Offices	0.20	0.06	1.15	
8	CRELL / NSF- Antarctica	0.04	0.01	0.25	65
9	Loudon Elementary (Addition)	0.13	0.04	0.80	
	Average	0.13	0.04	0.74	
	Standard Deviation	0.06	0.02	0.34	



	BES - Renovations	CFM50/ Sq. ft.	ACH Nat	ACH 50	KWH / SM/Yr.
1	Vermont Law School	0.22	0.06	1.26	
2	AVA Gallery	0.22	0.07	1.30	82
3	BES headquarters	0.19	0.02	0.50	
4	Phillips Exeter (Remodel)	0.23	1.70	1.45	
5	Williams College (Retrofit)	0.29	0.09	1.83	
6	Proctor Academy - Maxwell Savage	0.21	0.06	1.25	
7	Our Saviour Lutheran Church	0.25	0.07	1.50	
8	Waterbury Ice Center after air sealing	0.10	0.06	0.91	
	Average	0.19	0.26	1.03	
	Standard Deviation	0.05	0.58	0.28	



The minimal standard deviations of these projects demonstrate that it is possible to consistently meet industry targets for air barrier performance by using rigorous air barrier commissioning protocols.

Why do we need high-performance air barriers?

Why do we need high-performance building envelopes?

1. To avoid building failures
2. To improve energy performance of new and existing building stock
3. To meet or exceed building code requirements
4. To improve customer satisfaction
   - Lower operating costs
   - Indoor air quality and control
   - Environmental issues addressed
   - Improved comfort
5. To address LEED energy performance requirements

Since 2001, many states have adopted air barrier language into either their local energy code or building code and there are other states with pending proposals. In addition, Chapter 14 of the International Building Code (IBC) refers to mandatory air leakage control requirements in the International Energy Conservation Code (IECC).

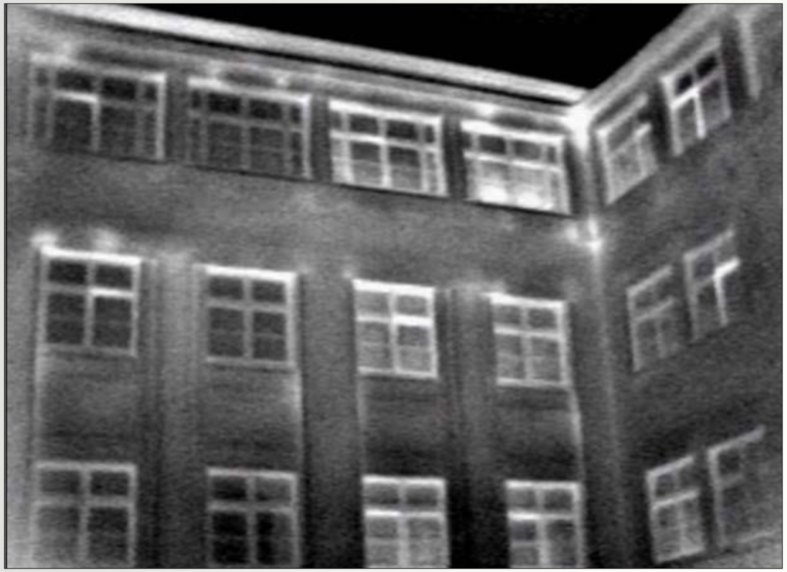
Avoid Building Failures

Figure 1: Efflorescence and spalling of bricks and mortar.

Figure 2: Ice forming on exterior of building.

Moisture-laden air driven out through masonry facades

Avoid Building Failures



IR survey shows hidden moisture-laden air being driven out through masonry facades.

How do we size our HVAC systems?

Calculate the design load

Modeling an HVAC system							
	Quantity	x	Rate 1	x	Rate 2	=	Load/T
Conductive losses	Area	x	U-value	x	temp. diff.	=	BTUs
Ventilation - fresh air	CFM	x	BTUs/cfm	x	temp. diff.	=	BTUs
Unintended ventilation	CFM	x	BTUs/cfm	x	temp. diff.	=	BTUs
Solar gain	Area	x	Trans. Coef.	x	Inc. rad.	=	BTUs
Less plug loads	Metered KWH			x	BTUs/W	=	-BTUs
People	Occupants	x	BTUs/Occ	x	Occupancy	=	-BTUs
							BTUs

Sample HVAC system sizing	Sq. ft. shell	BTUs/sfs	BTUs
Design	R=20	50F = T diff	
Surface area times heat loss rate due to conduction	123,210		308,025
Volume of building	1,080,000	0.02	
Air changes for fresh air ventilation requirements	2.00	1,080,000	2,160,000
Untentional air changes due to air barrier defects	3.00	1,080,000	3,240,000
Total building load - calculated			5,708,025
Safety factor - design load	50%		8,562,038

How do we figure out the right-sizing of the HVAC system?

Reduce the design load

Sample HVAC system sizing	Sq. ft. shell	BTUs/sfs	BTUs
Design	R=20	50F = T diff	
Surface area times heat loss rate due to conduction	123,210		308,025
Volume of building	1,080,000	0.02	
Air changes for fresh air ventilation requirements	2.00	1,080,000	2,160,000
Untentional air changes due to air barrier defects	3.00	1,080,000	3,240,000
Total building load - calculated			5,708,025
Safety factor - design load	50%		8,562,038
Actual	R=20	50F = T diff	
Surface area times heat loss rate due to conduction	123,210		308,025
Volume of building	1,080,000	0.02	
Air changes for fresh air ventilation requirements	2.00	1,080,000	2,160,000
Untentional air changes due to air barrier defects	1.50	1,080,000	1,620,000
Total building load - calculated			4,088,025
Safety factor - design load	10%		4,496,828
% of design			52.5%

Insulation is important, but air barriers are the key to high-performance building envelopes

		R-value	ACH	UA	Total Btus	%
Standard R-value with standard air leakage						
	Conduction				34,851,600	
	Air leakage				38,237,184	
	Total	19	0.50	60	73,088,784	100.00%
Standard air leakage with high R-value						
	Conduction				23,234,400	
	Air leakage				38,237,184	
	Total	42	0.50	40	61,471,584	84.11%
					Improvement	15.89%
Standard R-value with low air leakage						
	Conduction				34,851,600	
	Air leakage				2,676,603	
	Total	19	0.05	60	37,528,203	51.35%
					Improvement	48.65%

What do we do now if the engineer's design doesn't work?

1. We add more heat, we don't reduce the load.
2. We waste more energy!

Someone has to be willing to guarantee an aggressive H-P air leakage rate!

Then someone has to convince the engineer that they can build the aggressive H-P air leakage rate

H-P Air Leakage Rates

What are the means of assuring that a given air leakage rate can be delivered for a new building?

- Track the performance of your buildings to prove you can set and meet an aggressive standard.
- Indemnify the engineer against a too-small HVAC system.
- Produce an air barrier model that the Engineer trusts.
- Assign responsibility for non-compliance.

What can we guarantee?

BES - New Buildings, Major additions, Renovations	ACH Nat	CFM50/ Sq. ft.	ACH 50	KWH / SM/Yr.
Logic Associates - Hartford, VT	0.03	0.10	0.63	5
Primex Office Bldg. – Concord, NH**	0.06	0.19	1.15	
Vermont Law School	0.06	0.22	1.26	
NRG Phase 1 – Hinesburg, VT	0.03	0.16	0.60	
Dartmouth – Kemeny (mockup)***	0.02	0.05	0.27	
Champlain Valley HS	0.06	0.15	0.95	80
Richmond Middle School - No mech	0.04	0.14	0.88	
Richmond Middle School w/mech	0.06	0.19	1.20	
Randolph Development - Office Building	0.06	0.20	1.15	
CRELL - ARRO prototype - Antartica	0.01	0.04	0.25	65
Kennett High School (Area A)	0.08	0.25	1.58	
Loudon Elementary (Addition)	0.04	0.13	0.80	
AVA Gallery	0.07	0.22	1.30	82
BES headquarters	0.02	0.19	0.50	
Phillips Exeter (Remodel)	1.70	0.23	1.45	
Williams College (Retrofit)	0.09	0.29	1.83	
Proctor Academy - Maxwell Savage Holland Hall	0.06	0.21	1.25	
Waterbury Ice Center after air sealing work	0.06	0.10	0.91	
Average		0.15		

Project/Client Name	AVA Gallery	Merrimack Valley High School	Merrimack Valley Middle School	Loudon Elem. School	Richmond Middle School*	Champlain Valley Union HS*	Logic Associates
Location	Lebanon, NH	Penacook, NH	Penacook, NH	Loudon, NH	Hanover, NH	Hinesburg, VT	Hartford, VT
Date project completed	Sep-07	Aug-07	Feb-07	Apr-07	Jan-06	Aug-05	Jan-84
Type of construction	Wood-framed - 3 stories	Metal Backup - 1 & 2 stories	Metal Backup - 2 stories	Metal Backup - 1 to 2 stories	Metal Backup - 1 to 3 stories	Metal Backup - 1 to 3 stories	Timber Frame - 2.5 stories
Total sq. ft. - Useable floor area	40,104	90,000	14,887	18,806	104,991	220,000	7,800
Building cost (excluding site develop.)	$4,000,000	$9,404,546	$2,046,686	$2,499,118	$13,190,136	$13,303,000	$702,000
Initial Construction Cost Savings	$34,274	$945,807	$233,957	$112,537	$432,694	$1,272,059	$5,200
Savings % of total building cost	1.02%	10.06%	11.43%	4.50%	3.28%	9.56%	0.74%
Savings - $/sq.ft. of floor area	$0.85	$10.51	$15.72	$5.98	$4.12	$5.78	N/A
Savings - $/sq.ft. of wall area	$2.08	$25.16	$26.23	$8.01	$9.17	$45.56	N/A
Savings - $/sq.ft. of shell area	$1.12	$7.68	$13.65	$3.92	$3.07	$5.06	N/A
Operating Cost / Savings (actual)							
Fuel Cost Winter 2007-2008	$13,810	$24,500			$14,000	$57,240	Net Zero
Unit fuel use (btu/sq.ft. /HDD)	2.13	4.01			5.56	7.38	N/A
Unit cost ($/sq.ft.)	$0.34	$0.10			$0.13	$0.26	$0.68
Performance Data							
Air Leakage Rates (CFM50/Sq. Ft.-shell)							
Compliance Test Result	0.22	0.10	0.15	0.13	0.14	0.15	0.09
ASHRAE Recommended Max.	0.31	0.31	0.31	0.31	0.31	0.31	0.31
Conventional - US average	0.93	0.93	0.93	0.93	0.93	0.93	0.93
Air Leakage Rates (in ACH/Hr Nat)							
Compliance Test Result	0.06	0.06	0.04	0.03	0.04	0.04	0.02
ASHRAE Recommended Max.	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Conventional - US average	0.23	0.23	0.23	0.23	0.23	0.23	0.23

What can we guarantee?

School Projects	Sq. Ft.	Year Tested	CFM 50/ Sq. Ft.
Proctor Academy	5,000	2003	0.21
Vermont Law School - Oakes Hall	50,000	2004	0.22
Champlain Valley Union HS new classroom wing	220,000	2005	0.15
Dartmouth Kemeny Hall - Mockup	1,600	2005	0.05
Richmond Middle School - Entire project	104,991	2006	0.22
Richmond Middle School East Wing	37,000	2005	0.14
Phillips Exeter (Retro)	36,124	2006	0.23
Merrimack High School (with air handlers masked)	90,000	2007	0.10
Kennett High School (not complete, not tested yet)	205,000	2006-07	0.27
Vermont Technical College - Shape Hall addition	13,389	2008	0.25
Total	763,104	Avg.	0.18

There is a story that goes with each of these regarding what building assembly was used or not having control of some of the trades, but the standard deviation is still only about 5%.

Model the air barrier

1. How much will it leak?
2. We just have to beat .31 CFM50/sfs.

Model the air barrier

Modeling the air barrier system for a Model House					
	Area	x	CFM50/sq. ft.	=	CFM50
Framed Walls	828		0.050		41.4
Attic floor	768		0.120		92.2
Windors	180		0.350		63.0
Dampers	20		1.100		22.0
Foundation walls	896		0.025		22.4
Slab	768		0.025		19.2
	3460				260.2
	Lin. Ft.	x	CFM50/lin. ft.	=	CFM
Ducts & fittings	55		0.100		5.5
Transitions	582		0.185		107.7
					113.2
Shell surface area =	3460				
CFM50/sq. ft. =	0.10	Target		Actual	0.108
Max. CFM =	346 ←				373.3 ←

Assign responsibility for each air barrier component!

Model the air barrier

Air Leakage Rates in Typical Air Barrier Assemblies ORNL/TM-2015/639

Table 1. Air leakage rates from test walls with mechanically-fastened membrane as the air barrier.

Leakage Site	Test Wall									Avg
	1	2	3	4	5	6	7	8	9	
Infiltration										
Wall-to-roof joint (Q_{wr}, cfm50/ft^2)	0.02	0.09	0.04	0.02	0.03	0.03	0.04	0.05	0.05	0.04
Wall-to-ceiling joint (Q_{wc}, cfm50/ft^2)	0.03	0.05	0.17	0.02	0.03	0.03	0.09	0.02	0.06	0.06
Wall-to-foundation joint (Q_{wf}, cfm50/ft^2)	0.08	0.12	0.03	0.04	0.05	0.04	0.01	0.04	0.04	0.05
Electrical outlet w/ cover (Q_{eo}, cfm50/ft^2)	0.09	0.10	0.10	0.07	0.06	0.08	0.08	0.07	0.05	0.08
Total ($Q_{unsealed}$, cfm50/ft^2)	0.10	0.16	0.18	0.12	0.13	0.12	0.12	0.14	0.13	0.13
Total ($Q_{unsealed}$, cfm75/ft^2)	0.32	0.39	0.4	0.24	0.23	0.22	0.23	0.22	0.25	0.28
Exfiltration										
Wall-to-roof joint (Q_{wr}, cfm50/ft^2)	0.01	0.12	0.05	0.03	0.05	0.03	0.02	0.05	0.04	0.04
Wall-to-ceiling joint (Q_{wc}, cfm50/ft^2)	0.02	0.05	0.17	0.01	0.04	0.04	0.03	0.03	0.06	0.05
Wall-to-foundation joint (Q_{wf}, cfm50/ft^2)	0.08	0.15	0.05	0.06	0.09	0.07	0.02	0.06	0.09	0.07
Electrical outlet w/ cover (Q_{eo}, cfm50/ft^2)	0.10	0.09	0.09	0.08	0.06	0.08	0.06	0.06	0.07	0.08
Total ($Q_{unsealed}$, cfm50/ft^2)	0.08	0.20	0.18	0.11	0.12	0.13	0.10	0.14	0.11	0.13
Total ($Q_{unsealed}$, cfm75/ft^2)	0.36	0.44	0.4	0.26	0.24	0.22	0.26	0.26	0.23	0.30

Measurements obtained from 2’×8’ test walls.

Model the air barrier

Other Sources - Air Leakage Rates in Typical Air Barrier Assemblies

- Most manufacturers of building materials now list air permeability figures (ASTM E 2178) in their TDSs
- DOE and NIST studies
- Manufacturer's TDSs for Air Leakage Rate for Fenestration Assemblies (ASTM E 283)
- SPF technical data sheets (TDSs)
- Most sheathing product TDSs
- International Masonry Institute technical data
- Your data from tracking the leakage through assemblies you design and/or build with

The financial model

How the CRP works

The financial model

1. The additional design costs of H-P projects
    - H-P detailing and air barrier specifications (Architect, AB Commissioning agent)
    - BE commissioning fees (Comm. agent)
    - Additional pricing – General Contractor
    - Additional HVAC modeling with aggressive airtightness levels (ME)

How the CRP works

The financial model

2. Standard construction vs. H-P construction
   - H-P construction may require better insulation materials and systems (GC/Subs).
   - H-P construction may require better air barrier materials and systems (GC/Subs).
   - QA protocols are required for H-P construction (Commissioning Agent, Subs).
   - Compliance tests are required for performance verification (Comm. Agent or third-party).
   - H-P construction will have lower mechanical system costs.

How the CRP works

The financial model

3. The source of the savings
   - There will be about a 3% increase in design costs.
   - There will be about a 3.5% increase in construction costs.
   - The building will be at least 50% tighter than ASHRAE recommendation for air leakage.
   - This will result in a 25% reduction in mechanical system costs.
   - Mechanical systems cost about 25% of the total building cost.
   - Net savings = 3% to 8% of total project cost.

Therefore, an H-P project with a right-sized HVAC system costs less to build and to operate!

How the CRP works

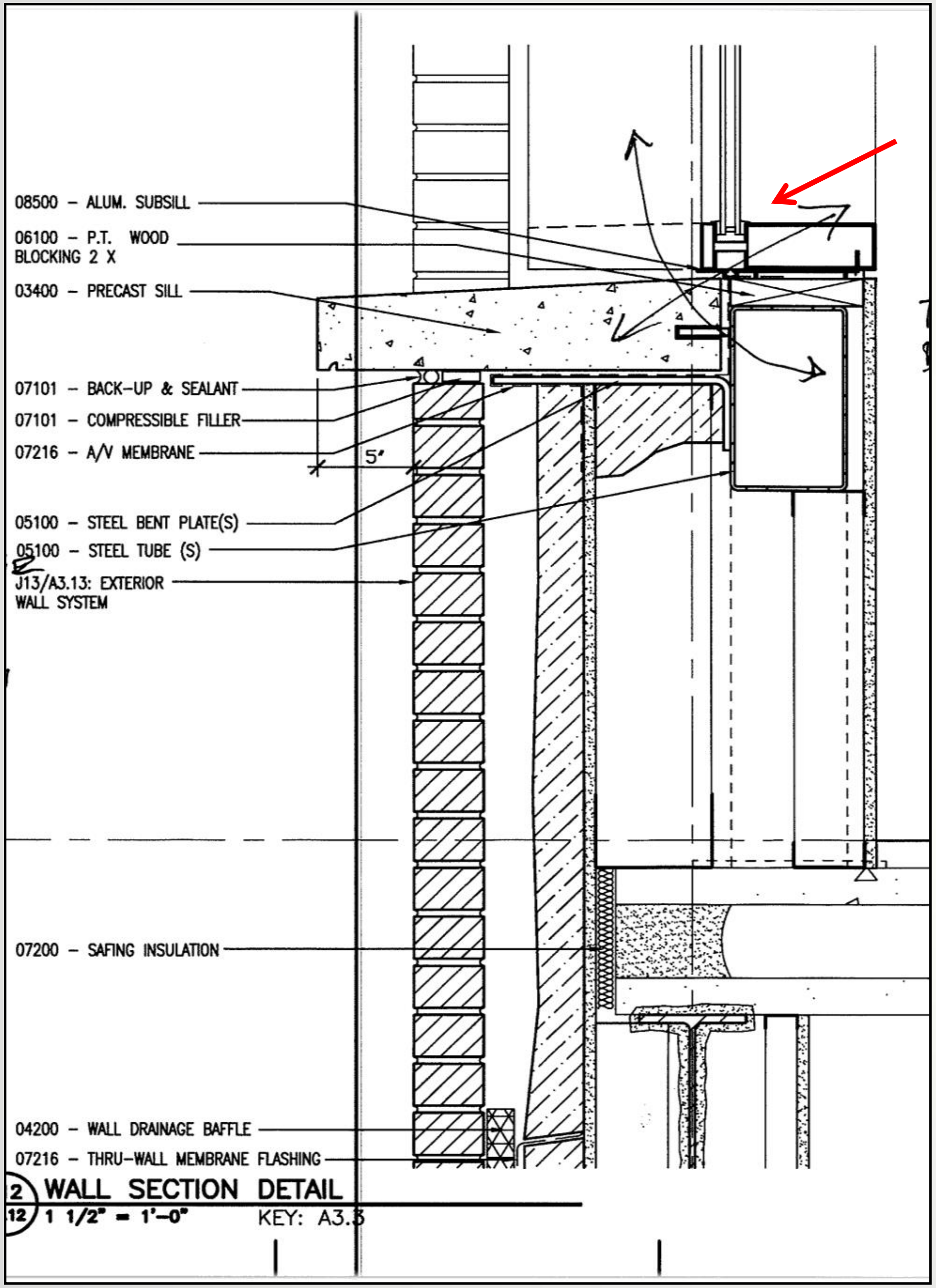
Sample project comparison	Standard	H-P
Design (@ 6.5%)	$650,000	$650,000
3% increase in CRP-related design costs		$19,500
Construction (including QA and compliance testing)	$6,850,000	$6,850,000
3.5% increase in CRP-related construction costs		$239,750
Mechanical system (about 25% of the total building cost)	$2,500,000	$2,500,000
25% reduction in CRP-related mechanical system costs		-$625,000
Total building cost, including design	$10,000,000	$9,634,250
Net construction cost savings = 3% to 8% of total project cost		$365,750
Percent construction savings		3.7%
Operation savings		25% to 50%

This is key! After every presentation on the CRP someone says too bad it costs more!

An H-P project with a right-sized HVAC system costs less to build and to operate!

Design to achieve the guarantee

- The air barrier has to be buildable
- The air barrier has to be continuous



- Thermal bridges
- Missing or difficult transitions
- Structural Gymnastics
- Missing pan flashings

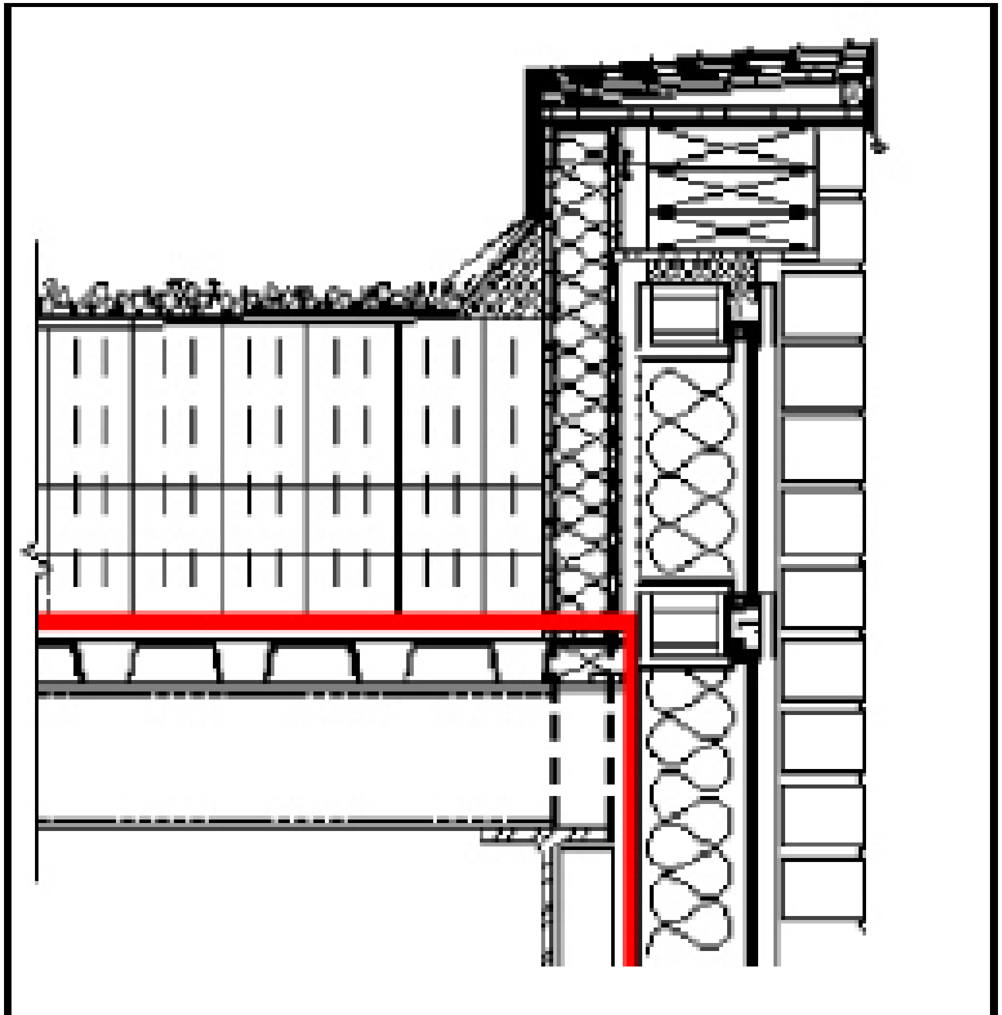
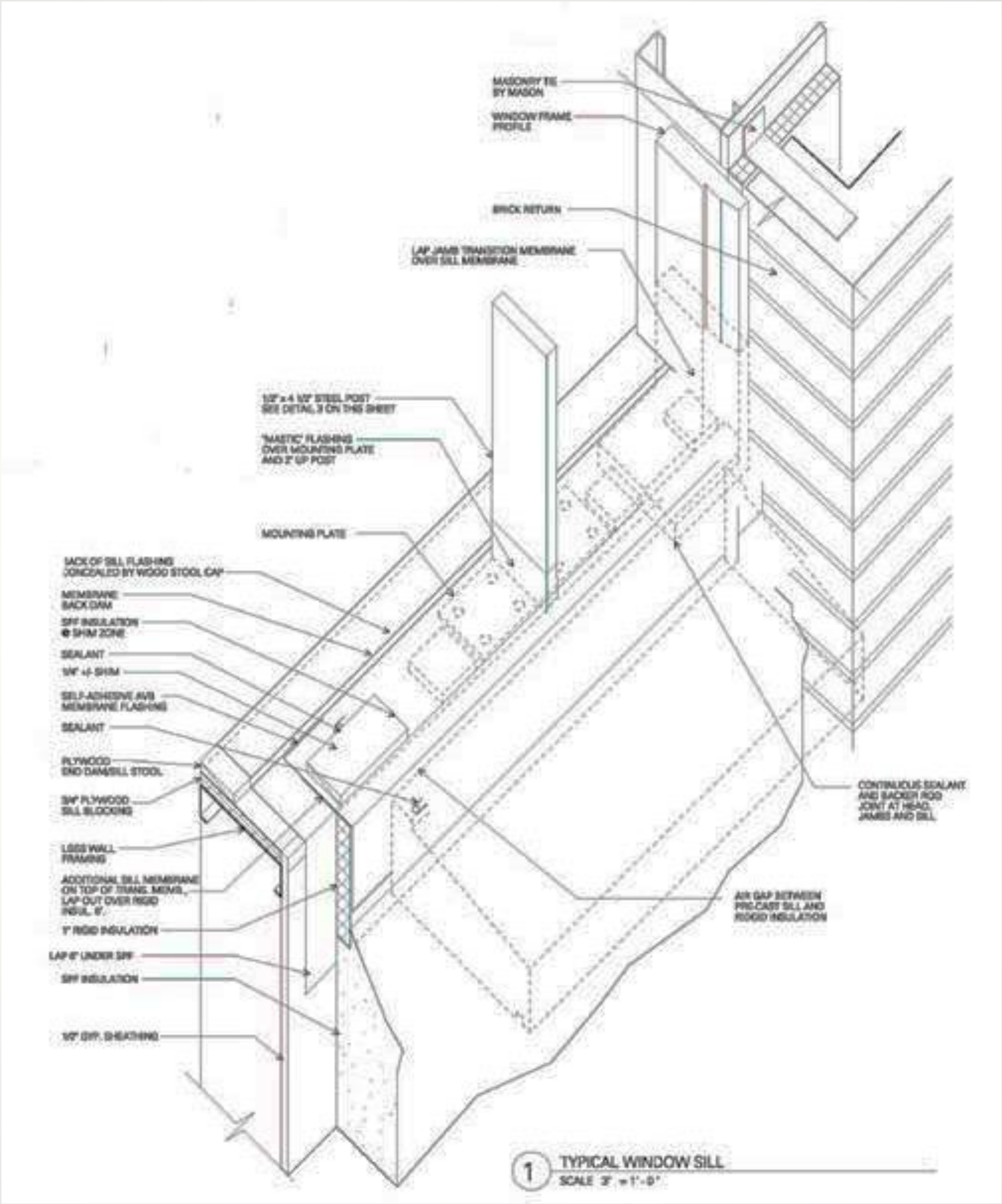


Figure 3: Roof/wall air barrier detail that cannot be built.

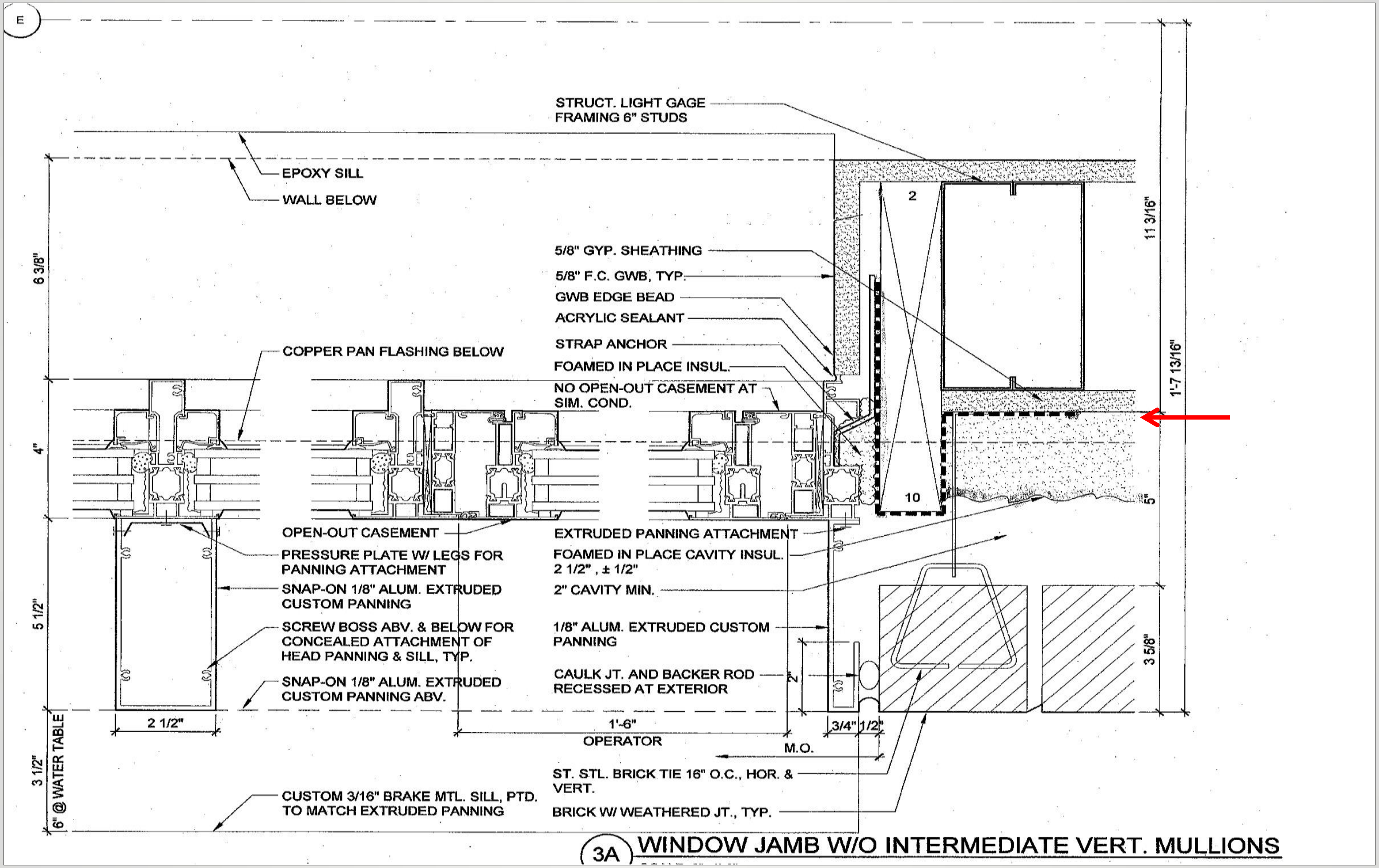
Through-wall and Pan Flashing complexity

Gaps in the insulation



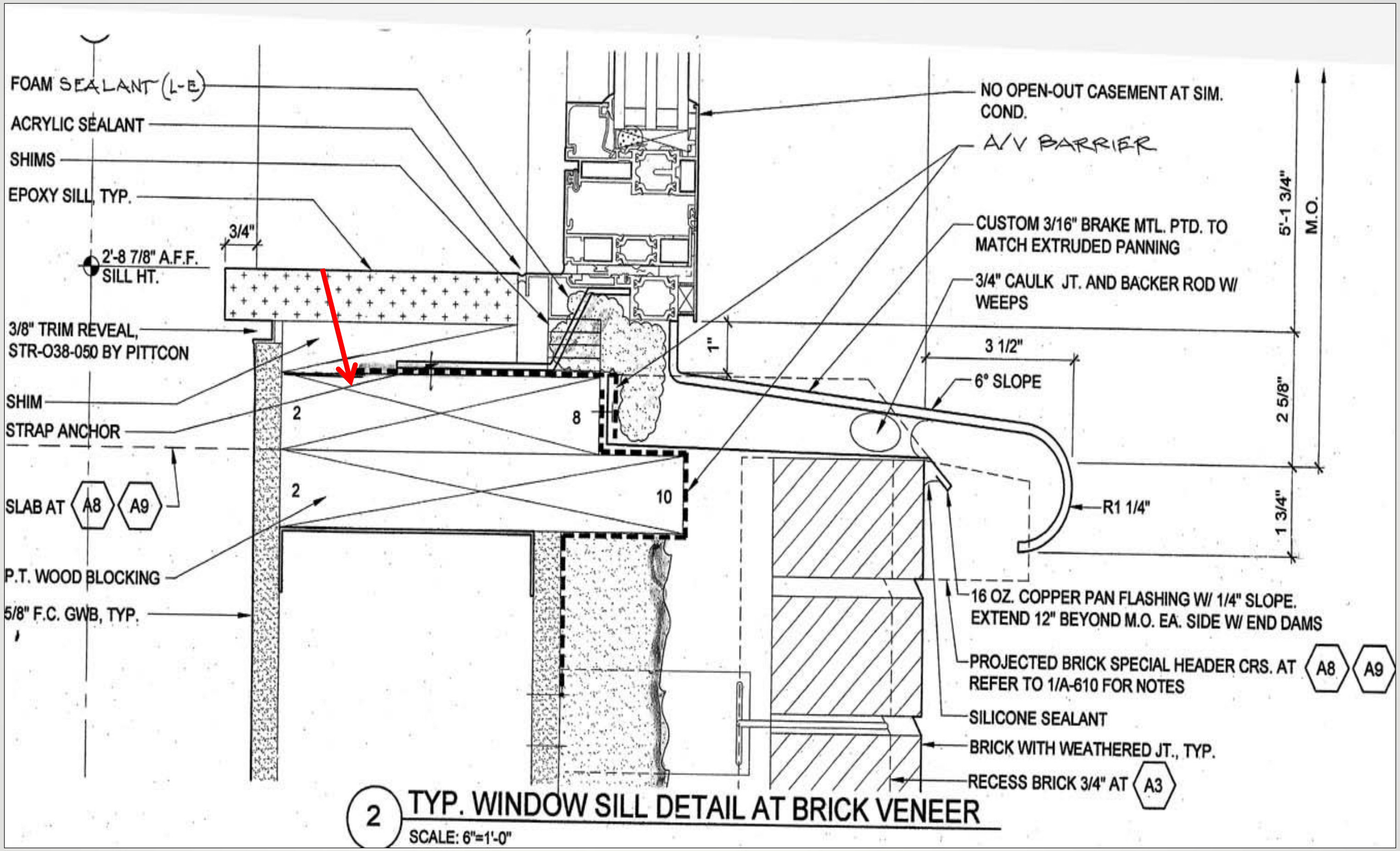
Pan Flashing

Window Jamb Detail



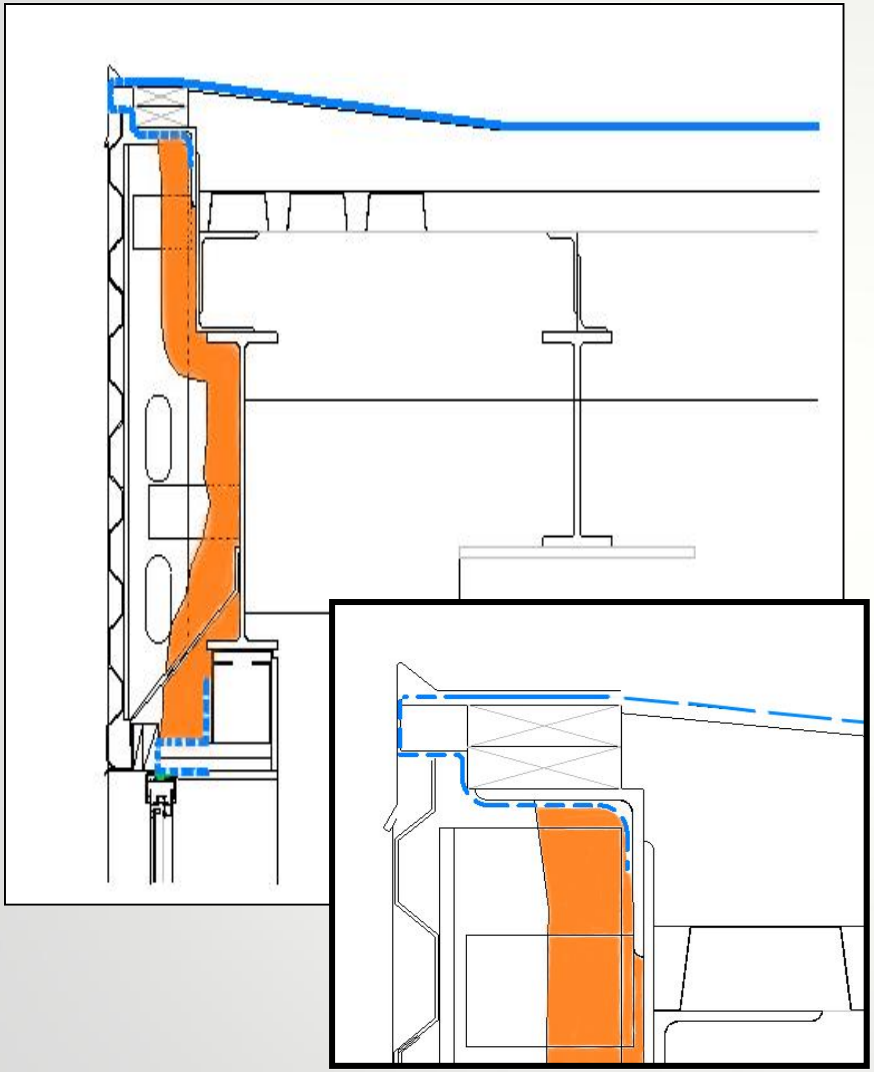
Transition membranes

Window Sill Detail



Transition membranes can also act as the pan flashing, but the inside must be higher than the outside to drain

Air barrier continuity



In this detail, the roof membrane (for flat roofs) is wrapped down around the edge of the roof and attached to the top of the back-up wall.

Roof to wall transitions can be complex

Build to achieve the guarantee

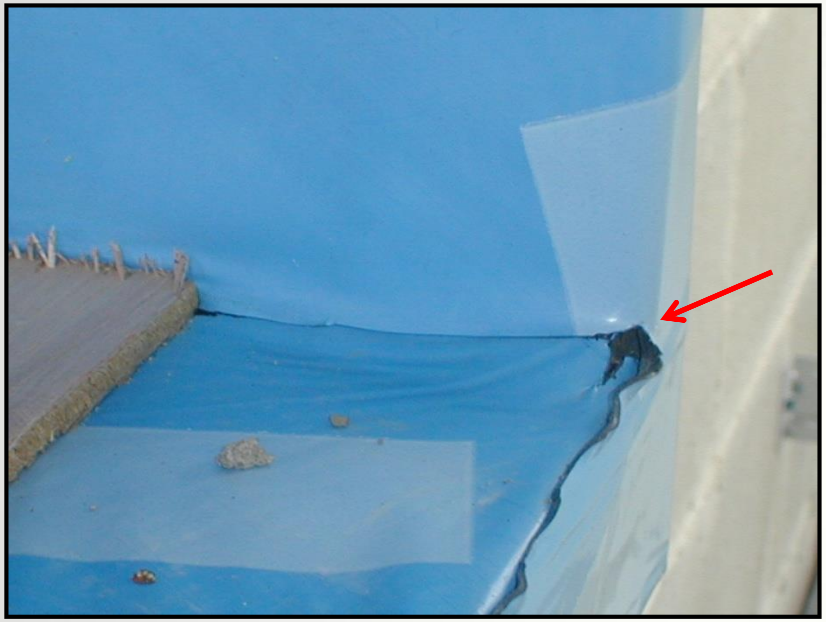
Use mockups to fine tune air barrier details

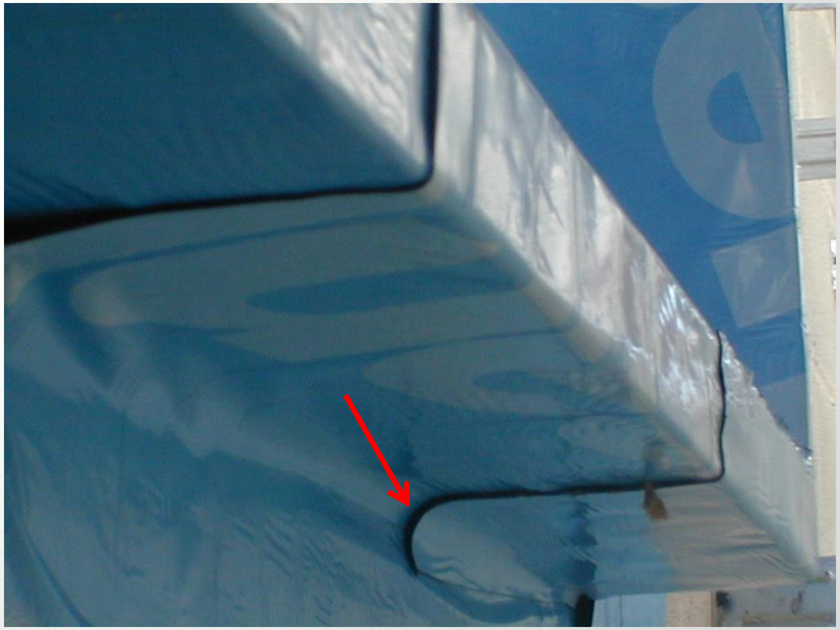
Transition membrane joints

Brick ties failed

Relieving angle and through-wall flashing detail

Peel-and-stick Membrane





Liquid-applied Membrane (LAM)

What can we achieve?

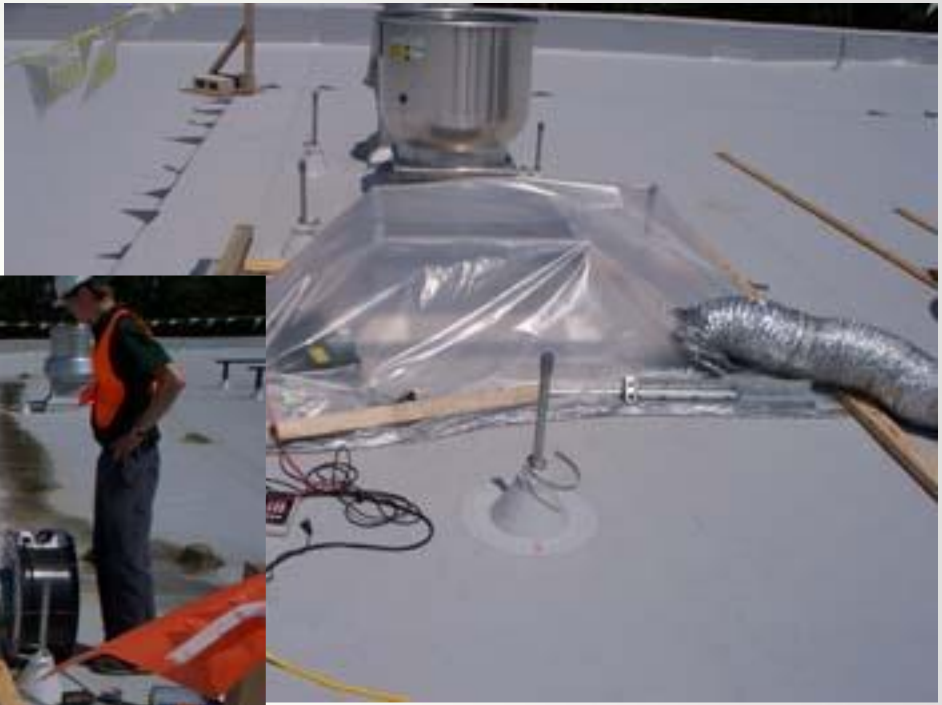
First Instance Testing – window opening

What can we achieve?

First Instance Testing – window opening

What can we achieve?

First Instance Testing – Roof-top units



Quality-assurance testing – Air barrier

Air leakage test methods

Quality-assurance testing – Air barrier

First Instance Testing - window unit

Occurs long after window opening test

Pressurized smoke analysis

Figure 15: ASTM E 1186 4.2.6 smoke test being performed on a window.

Step 7 - Quality Assurance
First Instance Test

Quality-assurance testing – Air barrier

Window gaskets and AHUs both failed

Quality assurance testing – air barrier

Pressurized theatrical fog test

Quality-assurance testing assures compliance

Project Sequencing relies on first-instance tests to assure compliance

Before, During, and After – test as you go or it will be too late

Test compliance!

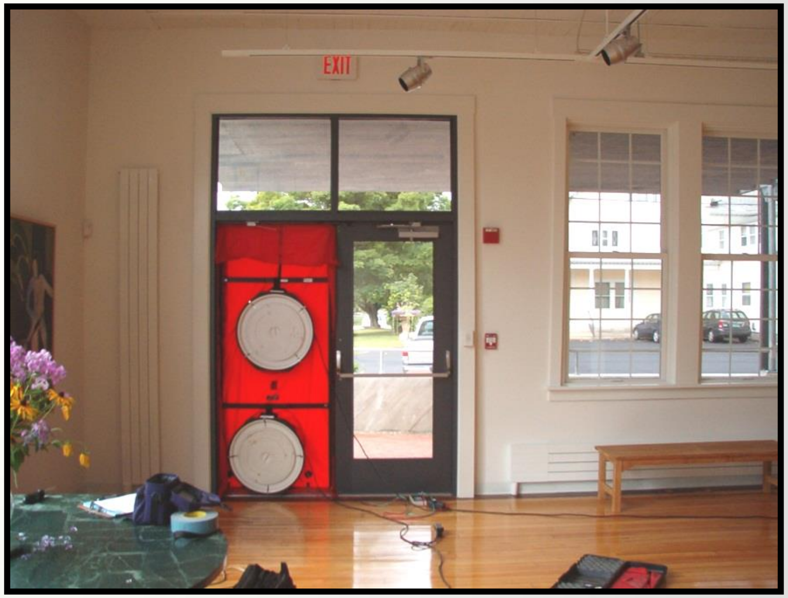
Post-work performance verification

1. Whole-building airtightness compliance test
   - Blower door testing 101
   - Locating leaks and assigning remediation responsibility
   - Final compliance verification
2. Initial and long-term fuel-use monitoring

How do we know how a building performs?

- Industry-standard air leakage test method
- ASTM E799 (E1186)

These tests cost from
$.02 to $.06 / sq. ft.



40,104 sq. ft. Mill building
conversion

Compliance Test – 63,000 sq. ft. school

Only one fan was used

Compliance Test – 104,000 sq. ft. building

~200,000 complex – 3 zones

Compliance Test only required 6 fans

Case Study

Merrimack Valley Middle & High Schools
(60,000 & 90,000 SF)

Merrimack Valley High School

Merrimack Valley High School

Metal stud and Densglas backup wall at new corner access addition

Extensions/stops at the punch-out openings

Extensions/stops at the punch-out openings

Merrimack Valley High School

Masonry backup wall

Merrimack Valley High School

LAM application at multiple window openings

SPF on backup wall

SPF on backup wall

SPF & LAM on backup wall

Typical Window – LAM

LAM installed after the SPF

Air sealing LAM to windows

Merrimack Valley High School

Brick Cladding

Note: Lintel and wall-roof transition issues

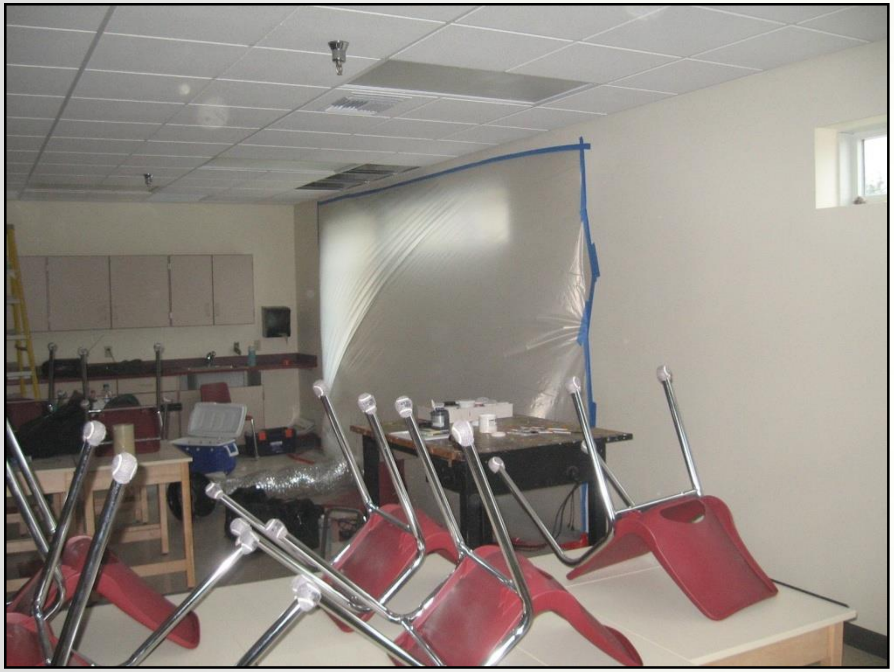
Compliance Test – No masking of Mechanicals

The Post-construction Phase

Performance Verification

- Determine the leakage sites in the case of non-compliance, responsibilities, and the best ROI for remediation.
- Plan and oversee any BE upgrades required to meet the standard.
- Repeat the compliance test.

Last-Instance Test – Merrimack Valley High School



Post-compliance Test – Addressing leakage

Merrimack Valley High School

Merrimack Valley High School

“Right-sized” Wood Chip Plant

- Smaller central plants
- Eliminates Hydronic distribution systems all together
- Model the mechanical system and estimate the cost for the most effective options.

Project Summary

Summary	Estimated Standard Construction	Actual H-P Construction
Total floor area	90,000	90,000
Total HVAC system cost	$4,266,667	$3,200,000
Total Shell	$33,320	$133,280
Total HP design and commissioning	$0	$1,500
Total Additional work by BE related trades	$0	$19,400
Total Shell & HVAC system cost	$4,299,987	$3,354,180
Total net additional cost or savings		$945,807
Total Building cost (excluding site development)	$10,350,353	$9,404,546
Percentages		
HVAC systems	41.22%	34.03%
HP Shell	0.32%	1.42%
Subtotal	41.54%	35.44%
Balance of construction costs	58.46%	64.56%
Savings		10.06%
Square foot costs ($/sq. ft. of floor area)		
Building	$115.00	$104.49
HVAC systems	$47.41	$35.56
HP Shell including all related costs	$0.37	$1.71
Subtotal	$47.78	$37.27
Savings		$10.51

Merrimack Schools
energy improvement vs. construction cost*

The Addition and Renovation	90,000 sq. ft.
Total campus	255,000 sq. ft.
Building envelope installation	$112,000.
Reduction in air leakage	50% less
The HVAC system	25% less
Construction savings (net)	$945,806
The first winter fuel cost (2007-2008)	$21,000
	$.10/sq. ft.

Comments:

Standard insulation values	R=38 roof, R=21 walls
Vs. Local conventional schools	$.86/sq. ft.

**Bill Root, GWR Engineering*

Airtightness test data

Comparative air barrier performance by component

Performance Data	Other Construction	Actual H-P Construction (tested)
Air Leakage Rates (in CFM50/Sq. Ft.)		
Compliance Test (with masking on AHUs)	-	0.100
Compliance Test (no masking on AHUs)	-	0.175
ASHRAE Recommended Max. Leakage	0.31	-
Conventional Construction - US average	0.93	-
By building component		
% - air leakage due to HVAC openings		42.86%
Rest of shell (including HVAC)		57.14%

How important are mechanical penetrations?

Fuel Use Data

Performance Data	Original Construction	Actual H-P Construction (tested)
Cost Savings reported		
$30 per (wet) ton		
Calculated load = 1,400 tons		
Use = 700 tons (2007-2008 season)	$85,500	$24,500
Square feet (HS + MS + WCP combined)	186,165	186,165
$/sq. ft. annual heating cost	$0.46	$0.13
HS, MS, Bus, & Chip on central plant		
US Census vs. actual - 1,000 btus/sq. ft.	90.0	24.3

Conclusion

- High-performance buildings can cost less to build. The payback period is “0” years.
- The savings that offset the high-performance design, insulation, air barrier systems, and quality assurance protocols are in the mechanical systems.
- BE performance guarantees make the savings possible.

Verify and track performance so we can convince more engineers to right-size their HVAC systems

Thank you for your time!

QUESTIONS??

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