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MORRISON HERSHFIELD

Critical Review of Whole Building Air Leakage Testing Requirement

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Abstract

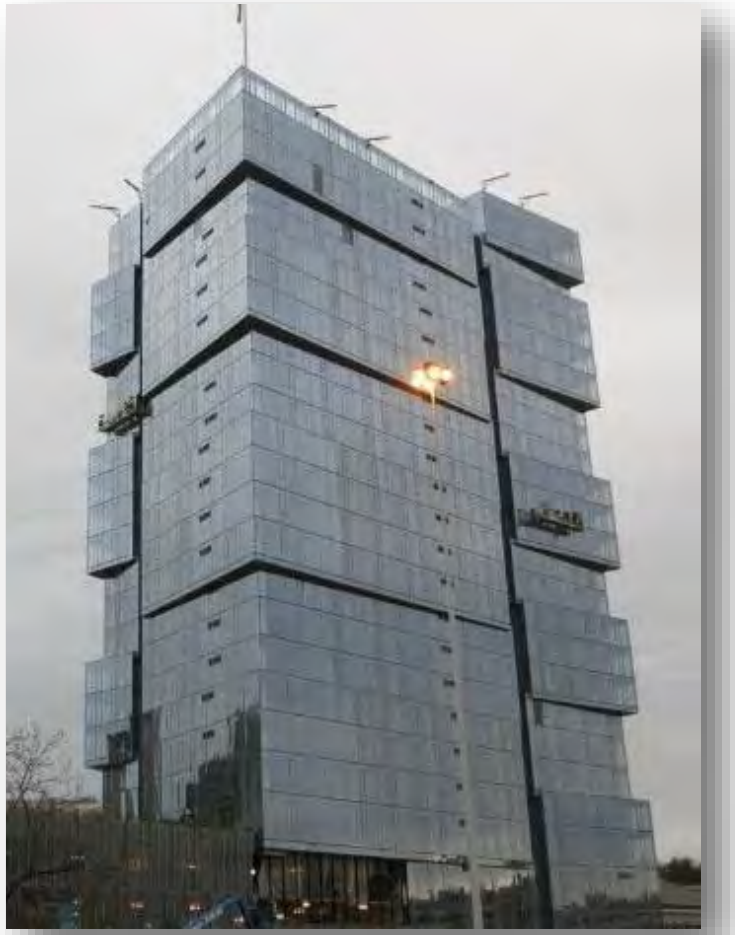
Over the past decades, energy codes have brought a number of changes with respect to improving the performance of the building envelope both in design and construction. With respect to the building enclosure, the most debatable is the increasing importance placed on air-leakage and how this often unknown value affects many of the energy efficiency metrics that define the performance of the building. Throughout the world, there are multiple codes and standards requiring varying levels of air tightness as well as varying performance levels and methods of verification. As the requirements and performance implications become better understood, common design and construction practices will experience shifts toward improved performance, as was experienced in the early years of the USACE requirements on which the private sector codes are based. However, variations between these standards and performance testing requirements have also brought about questions as to whether the testing is warranted and truly beneficial. Through a review of multiple case studies of past and current enclosure consulting and whole building air leakage testing, including high-rise, multi-family, and other commercial new and renovation construction, this presentation will provide a critical review of these codes and standards for validity, impact, and relevance.

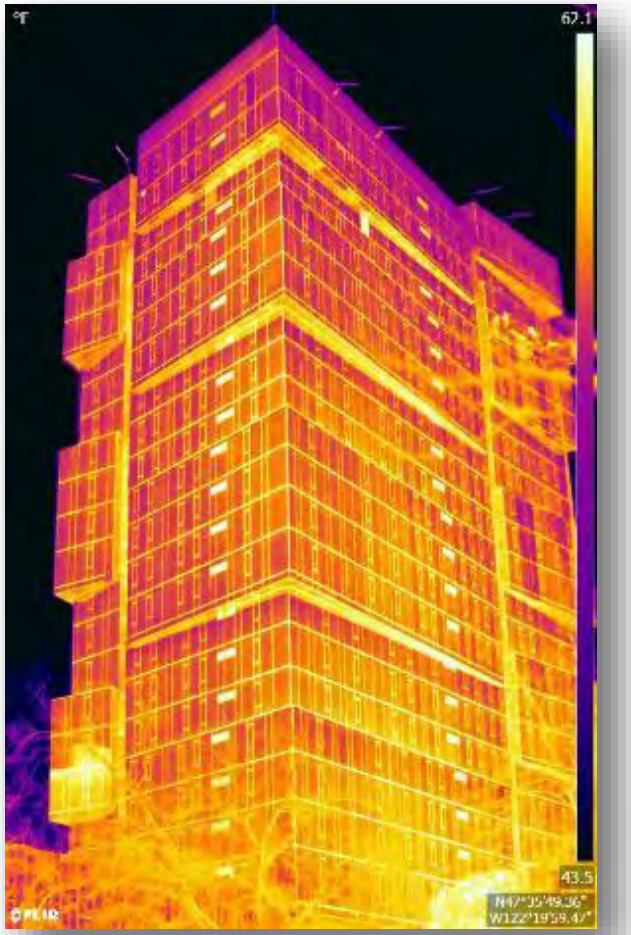
Learning Objectives

- Review the theory and historical progression of air tightness requirements and understand the metrics that provide the baseline for levels of air tightness.
- Understand the basic phases of holistic enclosure consulting related to air barriers.
- Understand validity, impact, and relevance of the wide range of air tightness codes and standards.
- Understand air leakage performance verification testing.

Whole Building Air Leakage Testing

Testing of ALL Buildings





Why Air Barriers and Why Now?

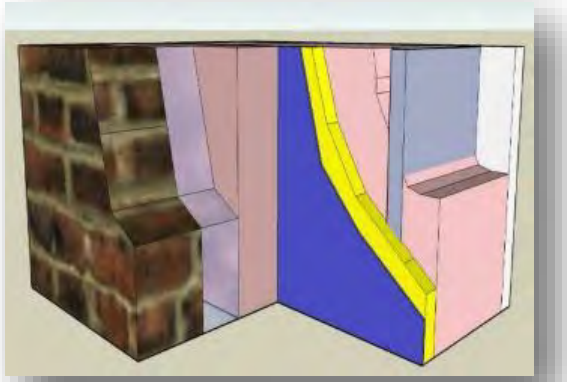
- Energy Conservation Measure
  - First Costs/Construction
  - Operational Costs

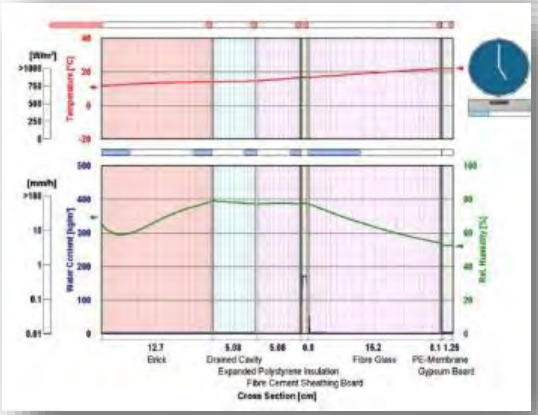
- Building Envelope Durability
  - H- Heat Barrier
  - A- Air Barrier
  - M_L- Moisture Liquid
  - M_V- Moisture Vapor

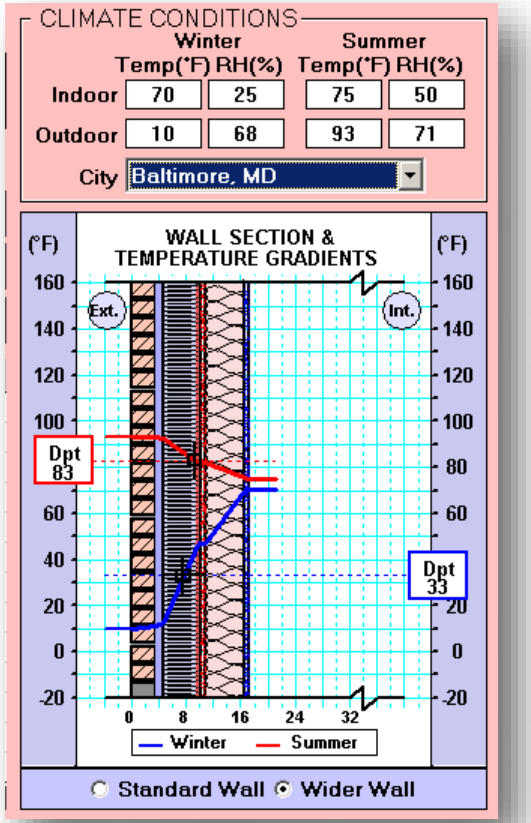
Energy

Photo credit BCRA Inc.

HAMM- Building Enclosure Design



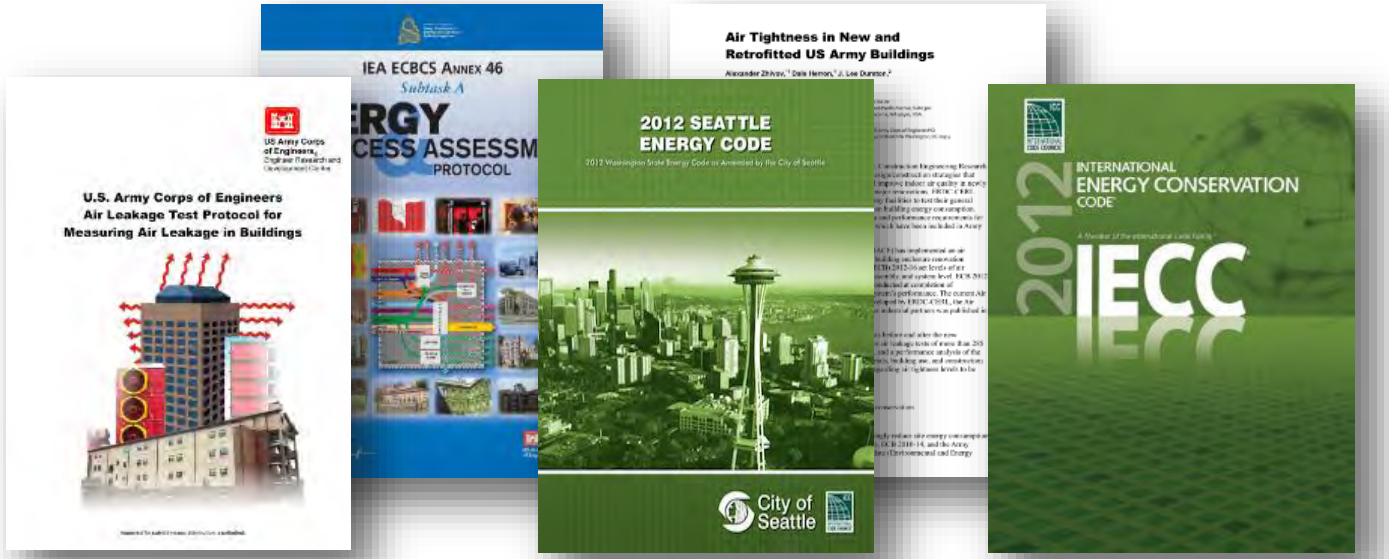




Durability

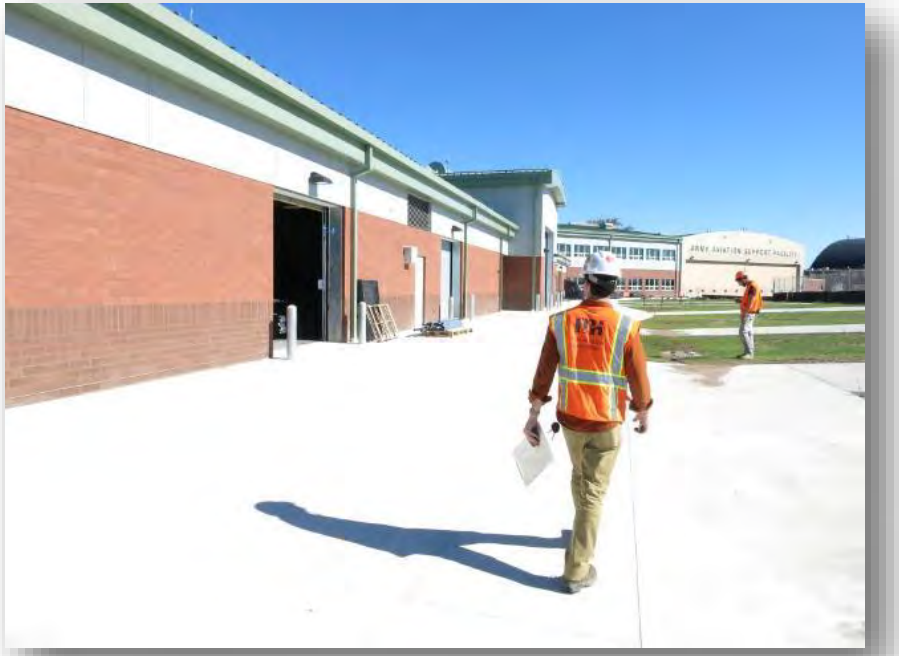
Photo credit BCRA Inc.

From Then to Now



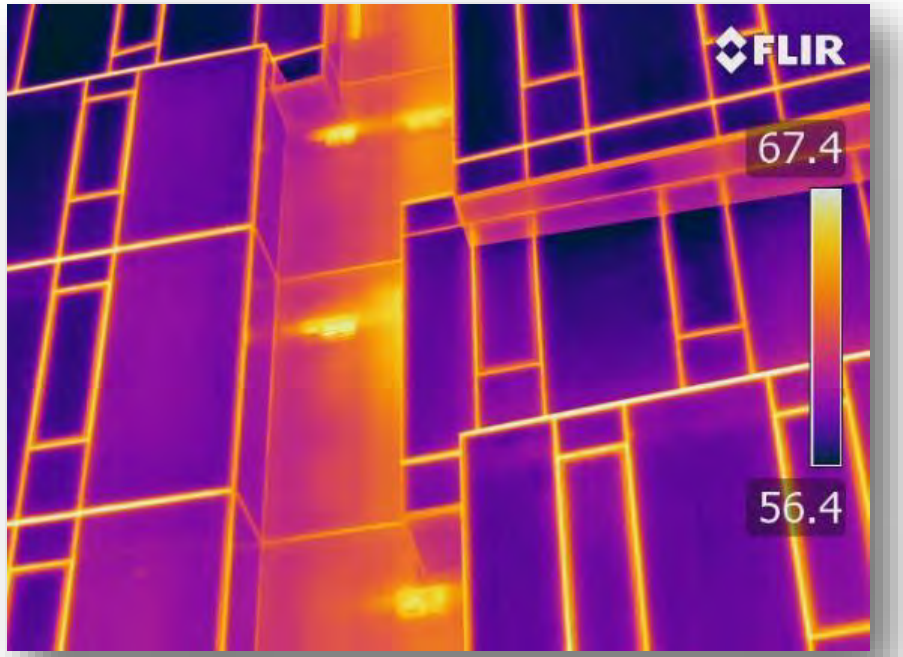
Energy Code Requirements

- United States Federal: Passing 0.25 cfm/ft^2 since 2009 (UFC)
  - Military Departments
  - Defense Agencies
  - DoD Field Activities
  - Federal Level Construction*
  - SOFA, HNFA, BIA, etc.



Energy Code Requirements

- Seattle/WA: The completed building shall be tested and the air leakage rate of the building envelope shall not exceed 0.40 cfm/ft^2 at a pressure differential of 75 Pa in accordance with ASTM E 779 or an equivalent method approved by the code official. (2012 WSEC C402.4.1.2.3 Building test).
- City of Fort Collins - UFC



Energy Code Requirements

- IECC 2012 - 0.4 cfm/ft^2 -coming at varying levels
  - Materials
  - Assemblies
  - WBALT
    - The 2012 IECC exempts buildings in Climate Zones 1through 3 and 90.1-2010 exempts semi-heated spaces in Climate Zones 1 through 6 in addition to single wythe concrete buildings in Climate Zone 2B
- Energy Models
  - Passive House
  - LEED
  - Etc.

A Look at Requirements Globally

			cfm/ ft²[L/s*m²]at 75Pa
US	ASHRAE / IECC	0.40 cfm/ft² at 75Pa	**0.40/2.02**
US	LEED	1.25 in² EfLA @ 4 Pa / 100 ft²	**0.30/1.52**
US	ASHRAE Average handbook of fundamentals	0.30 cfm/ft² at 75Pa	**0.30/1.52**
	U.S. UFC	**0.25 cfm/ ft² at 75Pa**	**0.25/1.27**
UK	TS-1Commercial Tight	2 m³/h/m² at 50 Pa	**0.14/0.71**
CAN	R-2000	1 in² EqLA @10 Pa /100 ft²	**0.13/0.66**
US	ASHRAE 90.1 Tight handbook of fundamentals	0.10 cfm/ft² at 75Pa	**0.10/0.51**

For a 4 story building, 120 x 110 ft, n=0.65

Looser

Tighter

Passive House 0.06 cfm/ft² at 75Pa

How Leaky Are Buildings?

Example #1

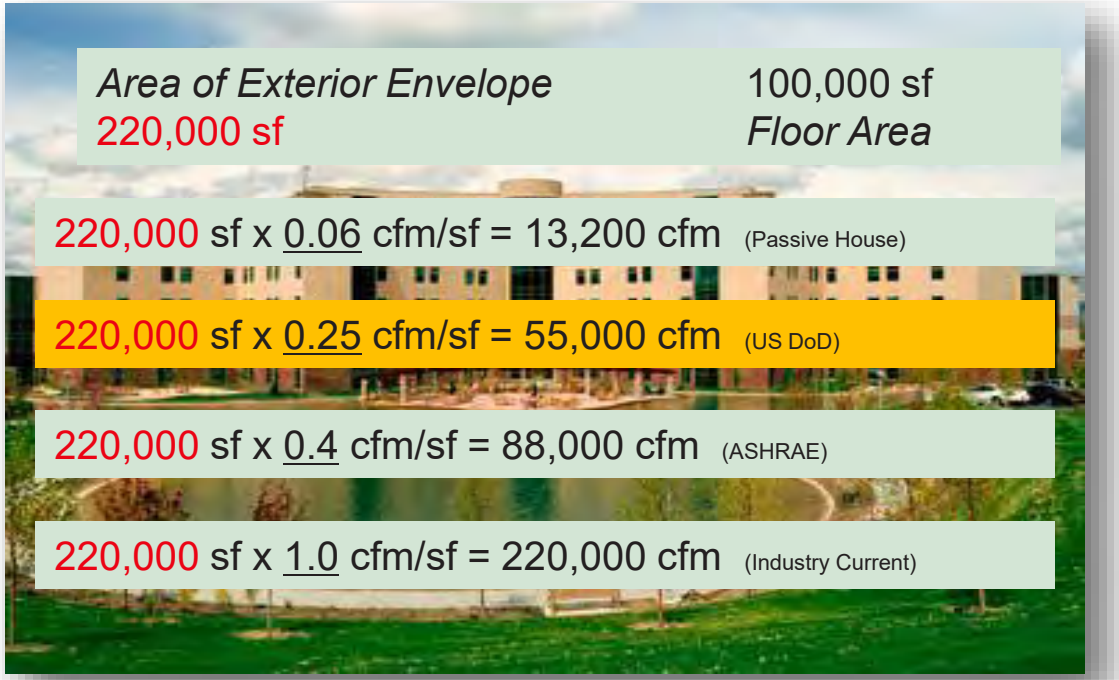
Standard
Commercial
Construction
Air Leakage Rate:

0.40 to 1.60 cfm/sf
@
0.3” wg

100,000sf of envelope =
40,000cfm to 160,000cfm

How Leaky Are Buildings?

Example #2



Area of Exterior Envelope 220,000 sf

100,000 sf *Floor Area*

220,000 sf x 0.06 cfm/sf = 13,200 cfm (Passive House)

220,000 sf x 0.25 cfm/sf = 55,000 cfm (US DoD)

220,000 sf x 0.4 cfm/sf = 88,000 cfm (ASHRAE)

220,000 sf x 1.0 cfm/sf = 220,000 cfm (Industry Current)

USACE Requirement/Study

- 285 DoD buildings
- Time range of 29 months
- 34+ DoD installations
- All climate zones in the United States *with some additional off shore*
- One to nine stories
- Building envelope areas ranging from 1,000 ft^2 to 370,000 ft^2
- All building types/uses

Air Tightness in New and Retrofitted US Army Buildings

Alexander Zhivov,[1] Dale Herron,[2] J. Lee Dunstan,[3] Matthew Hoese,[1] and George Lea[4]

Abstract

Keywords

1. INTRODUCTION

US Army Corps of Engineers

BCRA SCIENCE + ENGINEERING

Success of the Air Tightness Requirement

- Achievable
- Applicable
- Does not limit construction type
- Does not limit construction materials
- Building envelope discipline

US Army Corps of Engineers

Seattle – Leading the U.S.

- Seattle/WA: The completed building shall be tested and the air leakage rate of the building envelope shall not exceed 0.40 cfm/ft^2 at a pressure differential of 75 Pa in accordance with ASTM E 779 or an equivalent method approved by the code official. (2012 WSEC C402.4.1.2.3 Building test).

Seattle – Show the Pressure Boundary

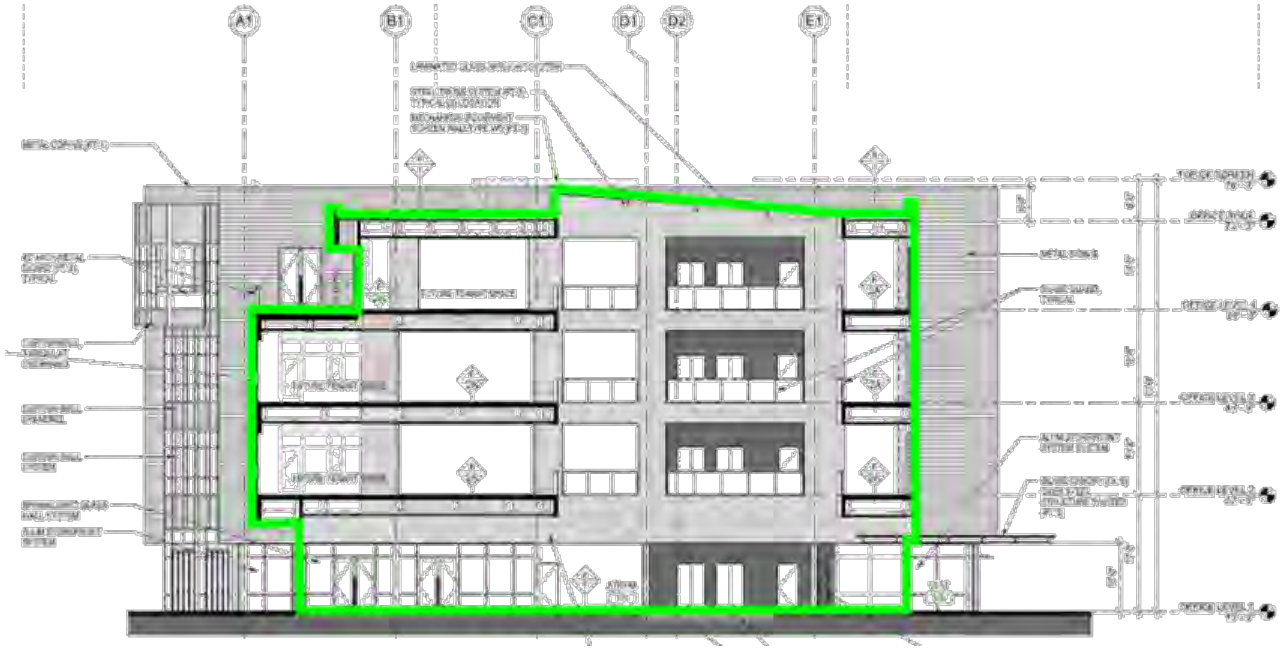
- Seattle: Construction documents shall contain a diagram showing the building's pressure boundary in plan(s) and section(s) and a calculation of the area of the pressure boundary to be considered in the test.
- Although not required in rest of Washington State, this is good practice and it will be required by the Contractor and Testing Agency to prepare and conduct whole-building air leakage test.

Building's Pressure Boundary

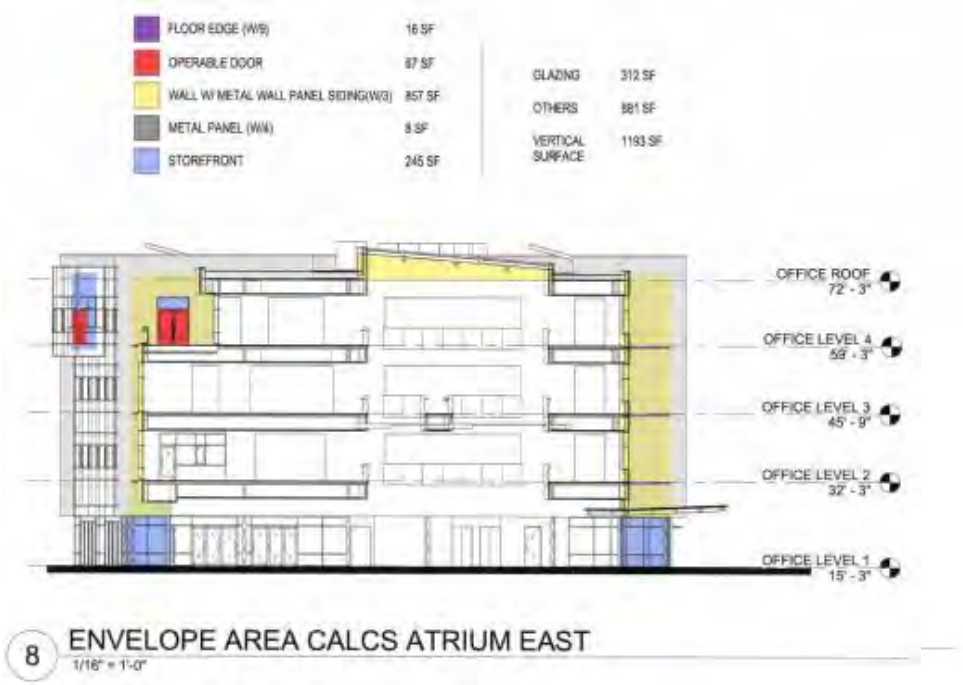
- In plan show the plane of the continuous air barrier
- For clarity consider showing thumbnail plans on one sheet

Building's Pressure Boundary

- In section show the plane of the continuous air barrier
- For clarity show thumbnail sections on one sheet



Air Barrier Area Calculations/Budget

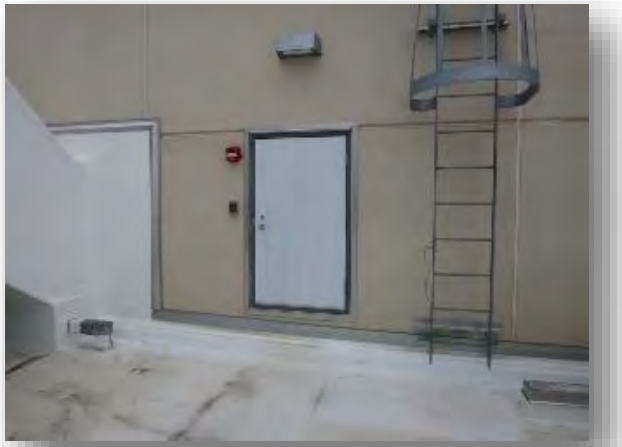


Pay special attention:

- Vestibules
- Wing walls
- Soffits & eaves
- Roof-to-wall
- Parapets
- Elevators & stairs
- Loading docks
- Parking garage
- Utility rooms

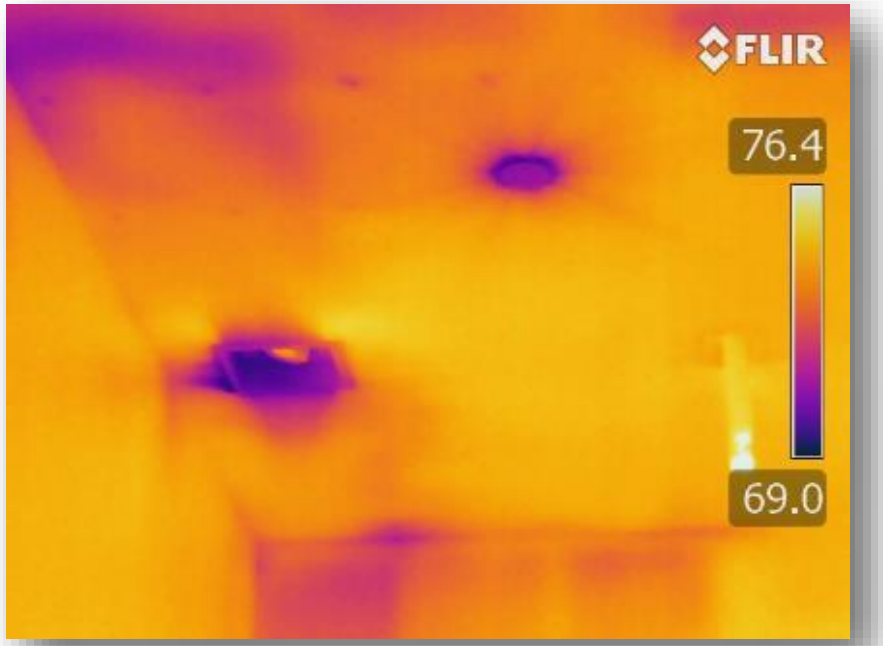
Envelope System Decisions

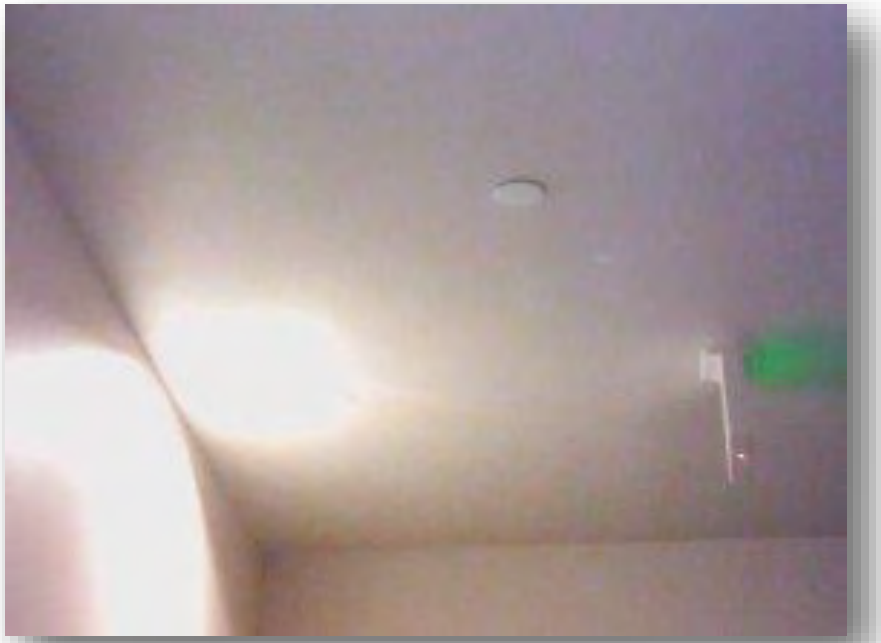
- Location of the Air Barrier
- Material selections



Envelope System Decisions

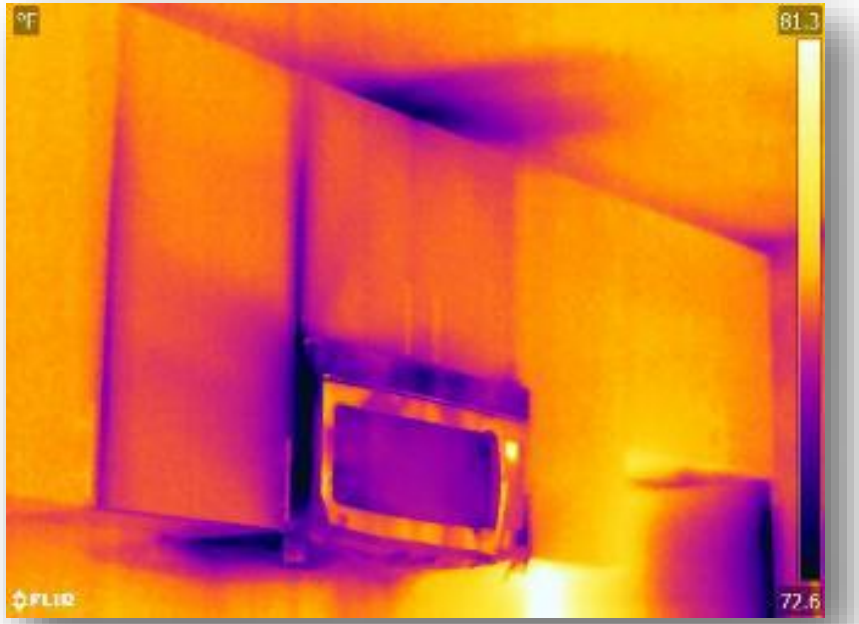
- Air barrier at GWB ceiling



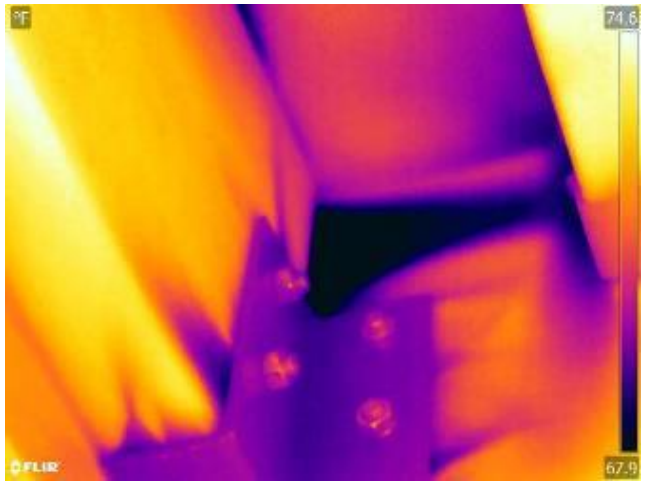


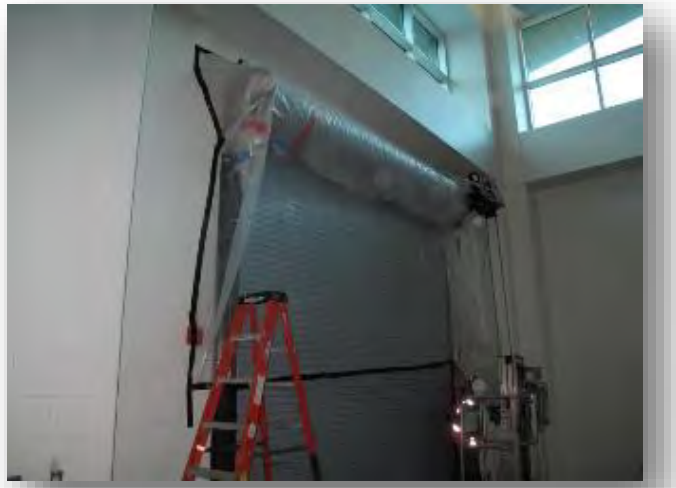
Envelope System Decisions

- Openings: doors, windows, elevators, vestibules
- Penetrations: Drier vent locations, Microwave unit leakage



Envelope System Decisions





The Building is a Patchwork

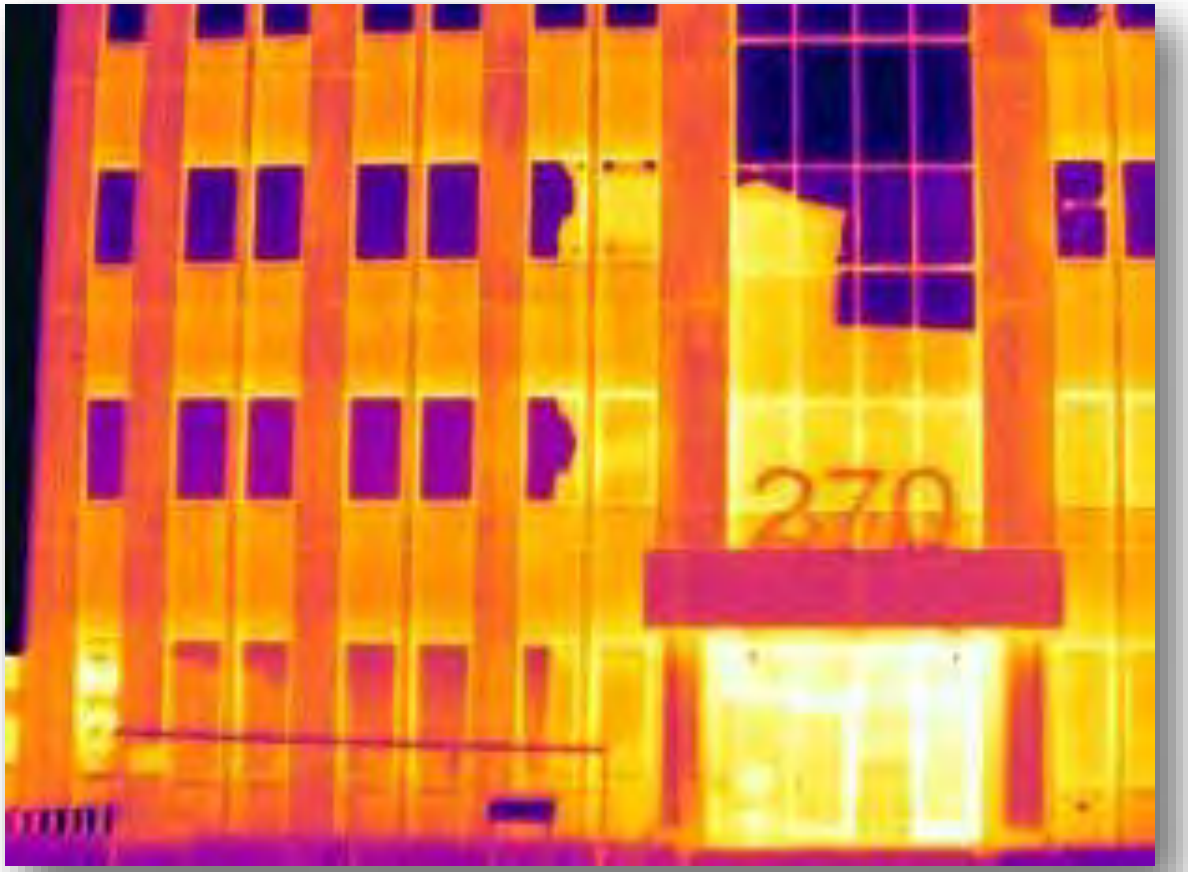


Photo credit BCRA Inc.

Seattle – What Went/Is Going Well?

- Air Barrier is being thought about
- Air Barrier is in the design documents
- Air Barrier is being approached as a system, not just a material or an assembly
- Large (50+ story) buildings are being completed
- All buildings are being completed
- A suitable workforce is being developed

Seattle – The Trouble Points

- The acceptable air leakage rate is 0.4cfm @ .3” w.c.
- At least for the first few years, the requirement has lacked teeth. Billed as a fact finding period. This is changing
- The code official is not the same entity as the owner/developer/contractor
- Deals, testing for show, ultimatums, junk testing
- Tall building challenges
- Public vs. Private sector

Seattle – Recent Updates

C402.5 Air leakage – thermal envelope (*Mandatory*). The thermal envelope of buildings shall comply with Sections C402.5.1 through C402.5.8.

C402.5.1 Air barriers. A *continuous air barrier* shall be provided throughout the *building thermal envelope*. The air barriers shall be permitted to be located on the inside or outside of the building envelope, located within the assemblies composing the envelope, or any combination thereof. The air barrier shall comply with Sections C402.5.1.1 and C402.5.1.2.

C402.5.1.1 Air barrier construction. The *continuous air barrier* shall be constructed to comply with the following:

1. The air barrier shall be continuous for all assemblies that are the thermal envelope of the building and across the joints and assemblies.
2. Air barrier joints and seams shall be sealed, including sealing transitions in places and changes in materials. The joints and seals shall be securely installed in or on the joint for its entire length so as not to dislodge, loosen or otherwise impair its ability to resist positive and negative pressure from wind, stack effect and mechanical ventilation.
3. Penetrations of the air barrier shall be caulked, gasketed or otherwise sealed in a manner compatible with the construction materials and location. Joints and seals associated with penetrations shall

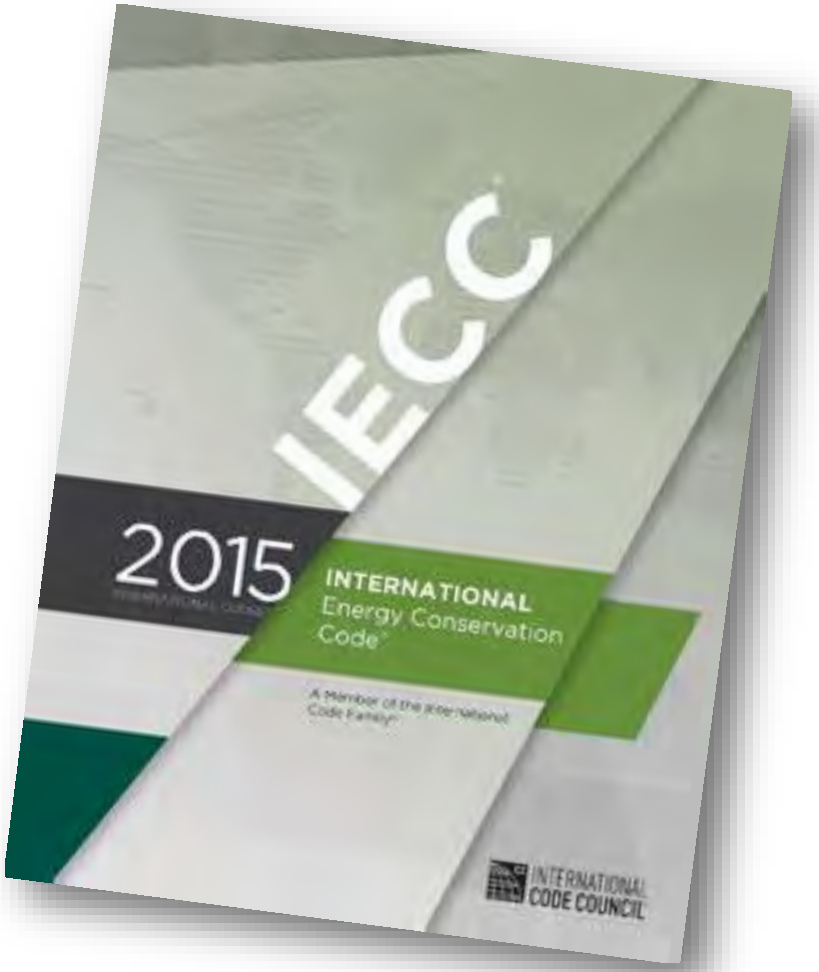
the pressure boundary for conducting the air leakage test. However, unheated spaces are not included when determining the pressure boundary.

C402.5.1.2 Building test. The completed building shall be tested and the air leakage rate of the *building envelope* shall not exceed ((~~0.40~~)) 0.30 cfm/ft^2 at a pressure differential of 0.3 inches water gauge ((~~(2.0 L/s x m^2 at 75 Pa)~~)) (1.5 L/s x m^2 at 75 Pa) at the upper 95 percent confidence interval in accordance with ASTM E 779 or an equivalent method *approved* by the code official. A report that includes the tested surface area, floor area, air by volume, stories above grade, and leakage rates shall be submitted to the building owner and the Code Official. If the tested rate exceeds that defined here, a visual inspection of the air barrier shall be conducted and any leaks noted shall be sealed to the extent practicable. An additional report identifying the corrective actions taken to seal air leaks shall be submitted to the building owner and the Code Official and any further requirement to meet the leakage air rate will be waived.

1. Test shall be accomplished using either (1) both pressurization and depressurization or (2) pressurization alone, but not depressurization alone. The test results shall be plotted against the correct P for pressurization in accordance with Section 9.4 of ASTM E779.
2. The test pressure range shall be from 25 Pa to 80 Pa per Section 8.10 of ASTM E779, but the upper limit shall not be less than 50 Pa, and the differ-

IECC – 2012, 2015

- IECC - 0.4 cfm/ft^2
  - Materials
  - Assemblies
  - WBALT
    - The IECC exempts buildings in Climate Zones 1through 3 and 90.1-2010 exempts semi-heated spaces in Climate Zones 1 through 6 in addition to single wythe concrete buildings in Climate Zone 2B



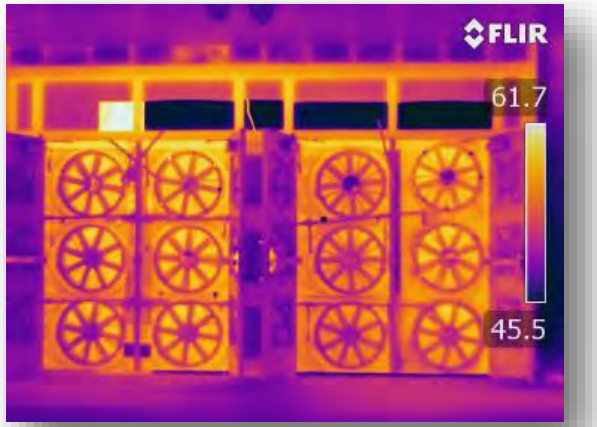
Specified Air Leakage Rates

	ASHRAE 90.1 Append. Z / IECC	US Army Corps Engineers	Canada NBC
	(cfm/ft^2 @ .3" w.c.)		(L/(s*m^2 @75Pa)
Material	**0.004**	**0.004**	**0.02**
Assembly	**0.04**	**0.04**	**0.2**
Building	**0.4**	**0.25**	**2.0**

Materials or Assemblies or WBALT

ASTM 2178

ASTM 2357



ASTM e779….

Shouldn't it be and, and

What is the Right Number?

- Energy
- Durability

			cfm/ ft²[L/s*m²]at 75Pa
US	ASHRAE / IECC	0.40 cfm/ft² at 75Pa	**0.40/2.02**
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For a 4 story building, 120 x 110 ft, n=0.65

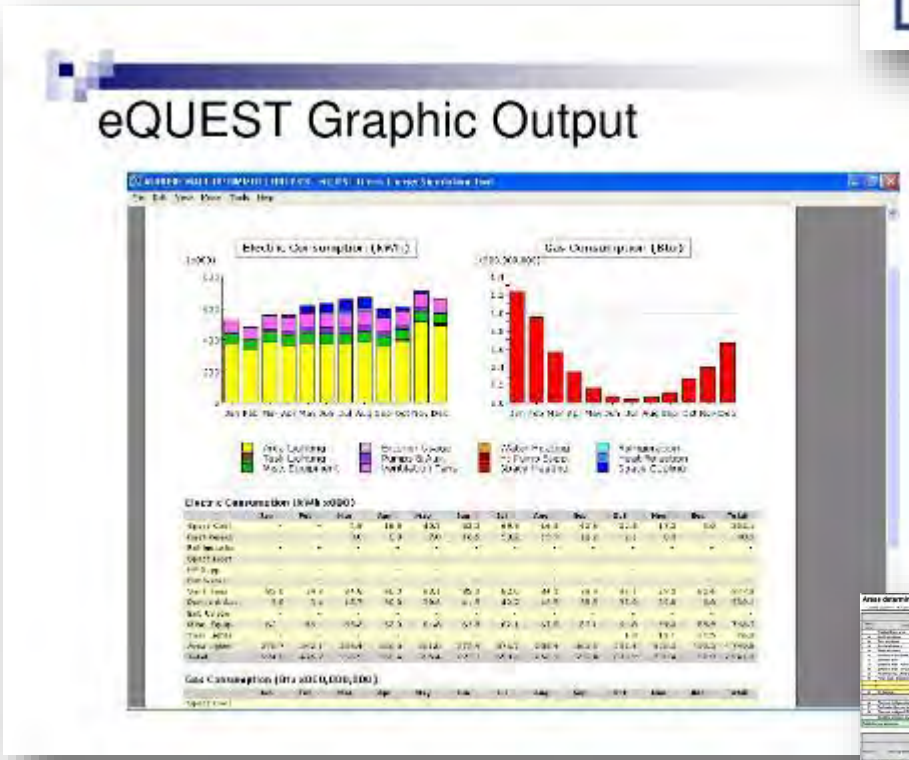
Looser

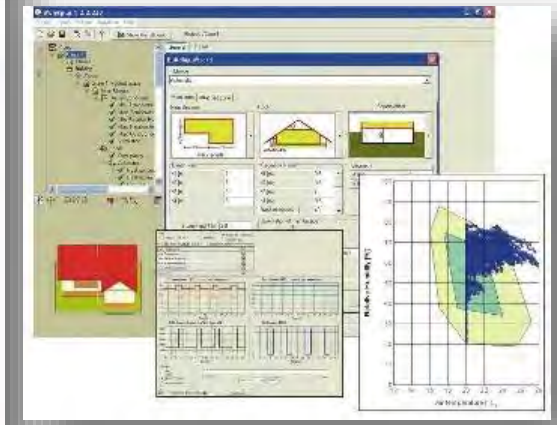
Tighter

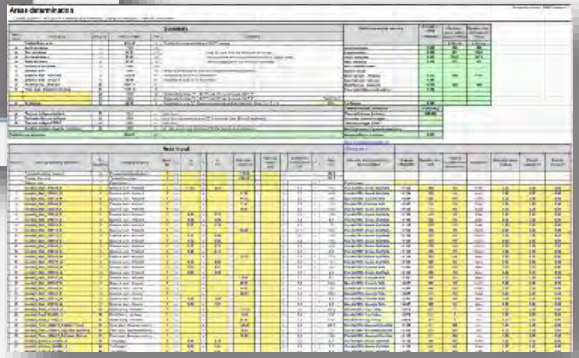
Passive House 0.06 cfm/ft² at 75Pa

What Does the Energy Model Say?

- What is your air leakage value assumed/input into the energy model?
- Is it a material value?
- Is it an assembly value?
- Is it a Whole Building value?
- Measured or Assumed?







Conclusions

- Understanding of Air Barrier Systems and Air Leakage Testing has come a long way in a short period of time.
- An Air Barrier System that performs is achievable with current construction and materials.
- Typically, the building can be made to be as tight as it is required to be.
- Overall, an air tightness requirement is easier to implement when the entity writing the requirement is also owning the delivery.
- To date the US DoD / Passive House models have performed the best.
- Its not all about energy….shouldn’t we also consider durability?
- If the energy model assumes an air leakage value it should be confirmed that that level of air tightness was achieved in the field.

Special Thanks to:

- *Retrotec Inc., U.S. Corps of Engineers Construction Engineering Research Laboratories, Professional Investigative Engineers (PIE), and BCRA Inc., for contributions to this presentation.*

Discussion

Morrison Hershfield