Energy and Air Barriers- Navigating the New Codes

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Morrison Hershfield

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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.

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Building Envelope Commissioning Basics - BECx

Standards

- ASHRAE Guideline 0 “The Commissioning Process”
- NIBS Guideline 3 “Building Enclosure Commissioning Process BECx”
- ASTM E2813 “Standard Practice for Building Enclosure Commissioning”
- ASTM E2947 “Standard Guide for Building Enclosure Commissioning”

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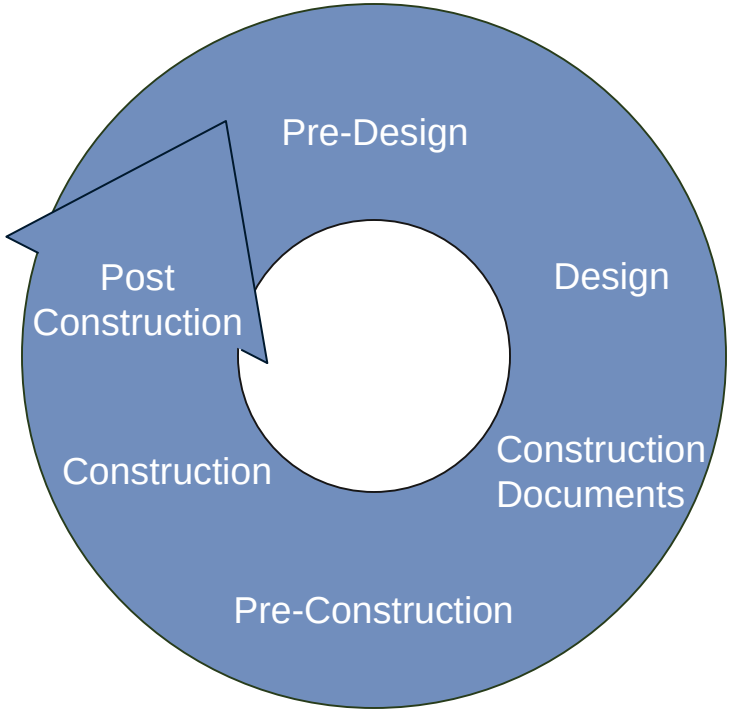
BECx Basics: Definitions

BECx

- Building Enclosure Commissioning
- A **quality-oriented process** for achieving, verifying and documenting that the design and constructed **performance** of building enclosure materials, components, assemblies and systems are **meet the OPR**.



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BECx: Integrated Approach

Pre-Design

- Kick-off meeting
- Review/develop OPR
- Review/develop BOD
- Develop initial BECx Plan

****Developed OPR prior to design team's Pre-Design activities such as: Architectural Programming*

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Integrating BECx

Design and Construction Documents

- Review/Update OPR & BOD
- Update BECx Plan
- Develop BECx Specification
- Design reviews
  - Continuity – air and thermal
  - Durability – life-cycle requirements
  - Constructability – sequencing; reglazing
  - Field Performance Testing – types and quantity
- Coordination Meetings (MEPx and Energy Modeler)
- Maintain Issues Log

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Integrating BECx

Pre-Construction

- Review OPR & BOD
- Update BECx Plan
- Review Submittals
- Review Shop Drawings
  - Continuity – air and thermal
  - Durability – life-cycle requirements
  - Constructability – sequencing; reglazing
  - Field Performance Testing – types and quantity
- Coordination Meetings
- Maintain Issues Log

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Integrating BECx

Construction

- Review OPR & BOD
- Update BECx Plan
- Mock Up / Constructability / Performance Testing
- Site Observations
- Field Performance Testing/Observation
- Progress/Coordination Meetings
- Maintain Issues Log
- Commissioning Report

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Integrating BECx

Mock-Ups

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Mock-Ups

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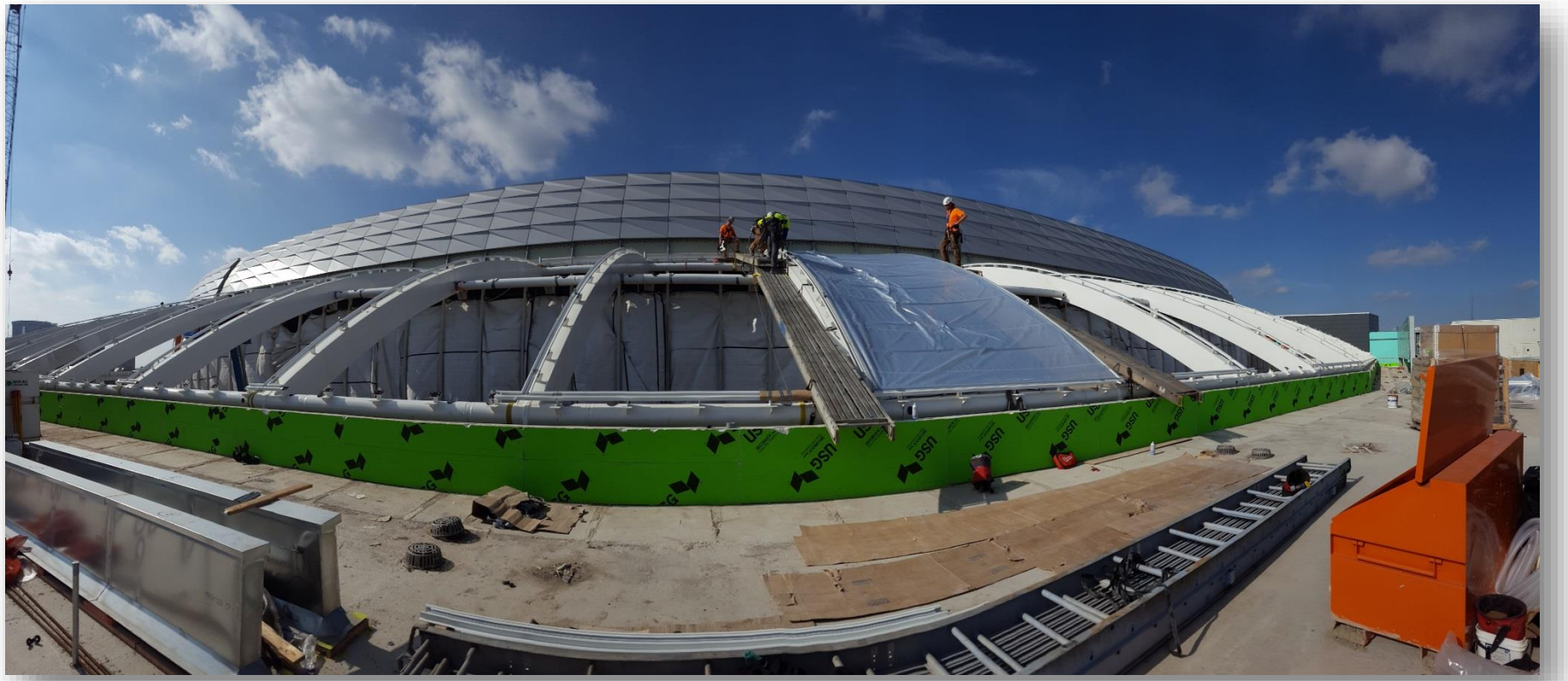
Construction Observation – Initial Installation



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Construction Observation/Testing

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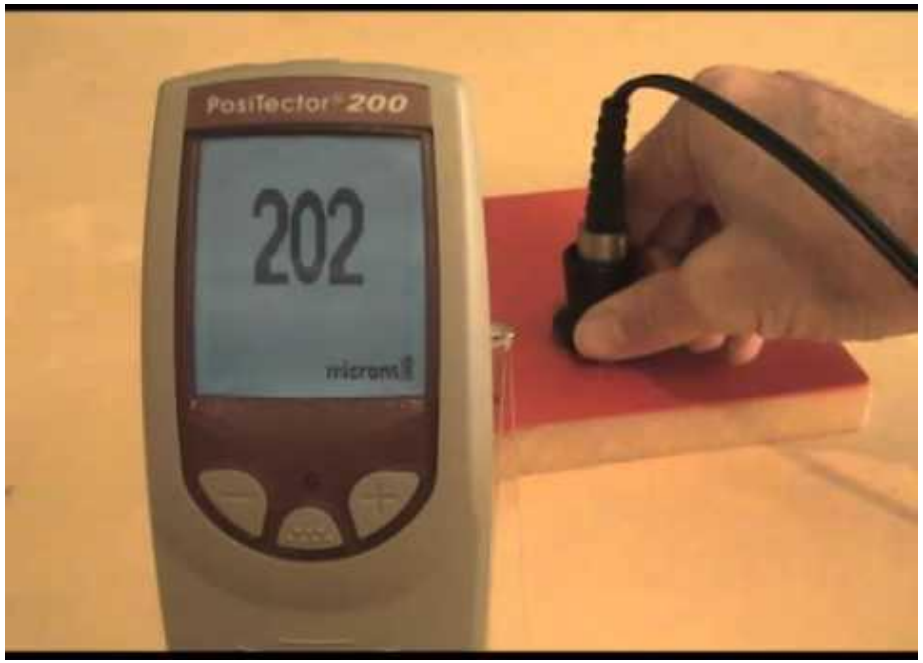
Construction Observation/Testing



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ASTM E1105 (Mockup and Building)

- “Standard Test Method for Field Determination of Water Penetration of Installed Exterior Windows, Skylights, Doors, and Curtain Walls, by Uniform or Cyclic Static Air Pressure Difference”

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ASTM E1105

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ASTM E783

- “Standard Test Method for Field Measurement of Air Leakage Through Installed Exterior Windows and Doors”

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ASTM D4541

- “Standard Test Method for Pull-Off Strength of Coatings Using Portable Adhesion Testers”

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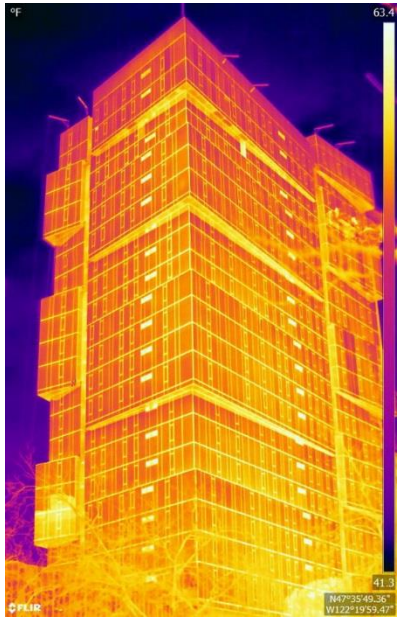
ASTM E1827/E779

- “Standard Test Method for Determining Airtightness of Buildings Using an Orifice Blower Door”
- “Standard Test Method for Determining Air Leakage Rate by Fan Pressurization”



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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

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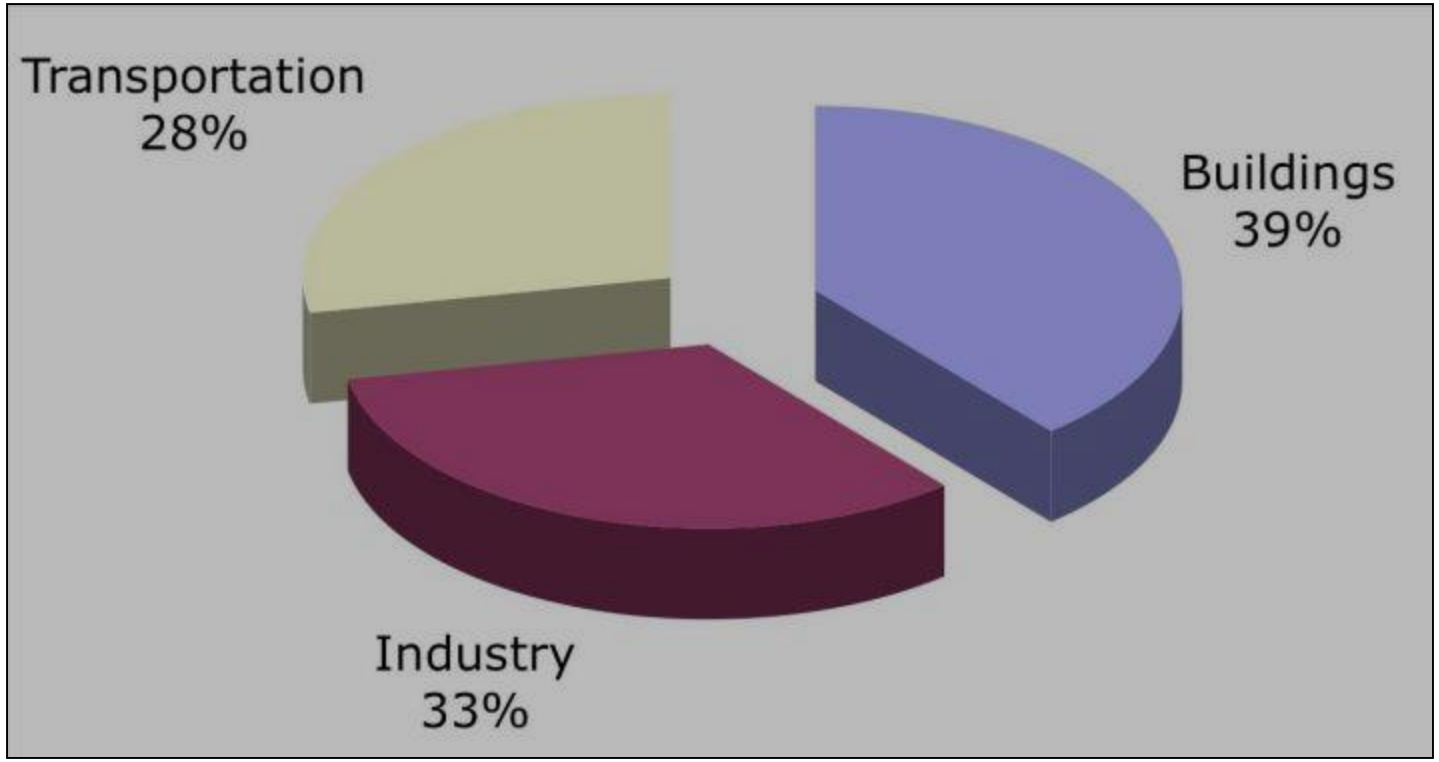
Where is Energy Used?



Source= USDOE

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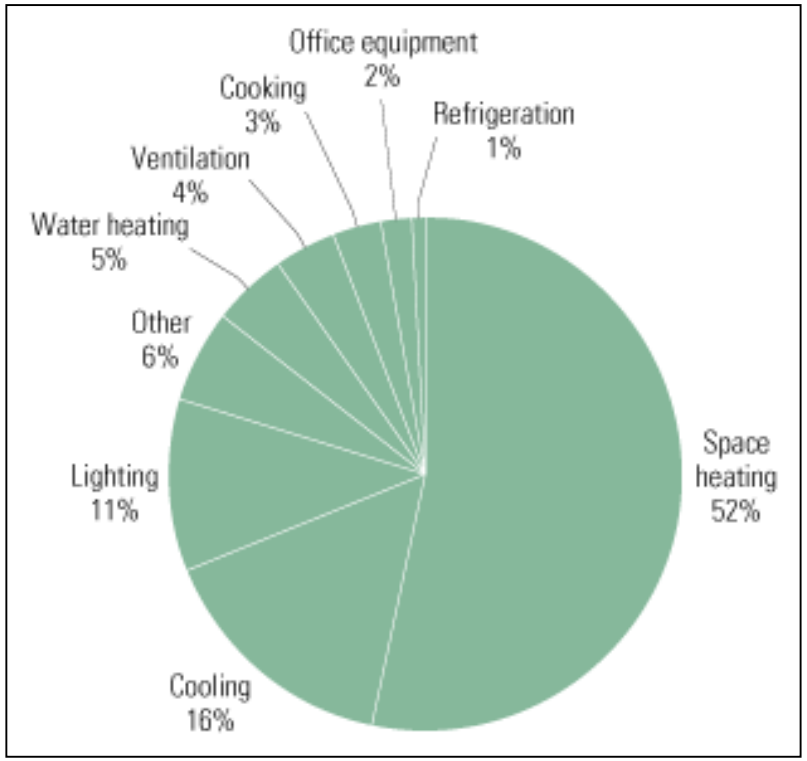
How Buildings Use Energy



- Building Envelope (walls, roof, windows, and floors)
- Lighting
- Heating, Ventilating, and Air Conditioning (HVAC)
- Internal and Process Loads (cooking, hot water, manufacturing, etc.)

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Energy

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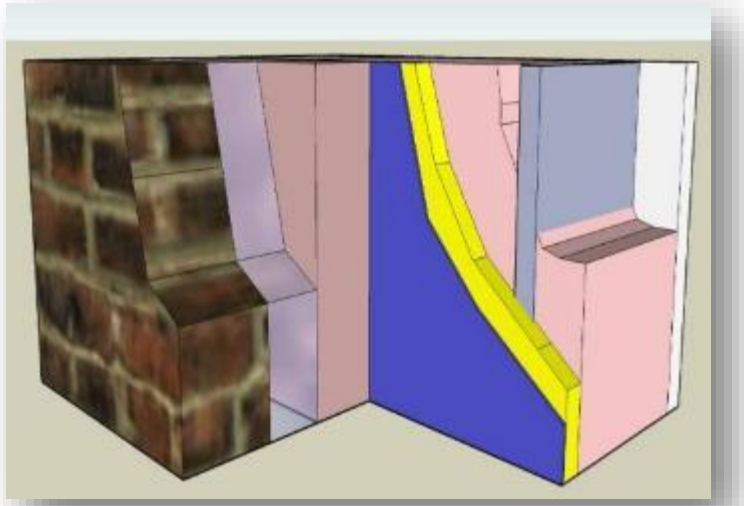
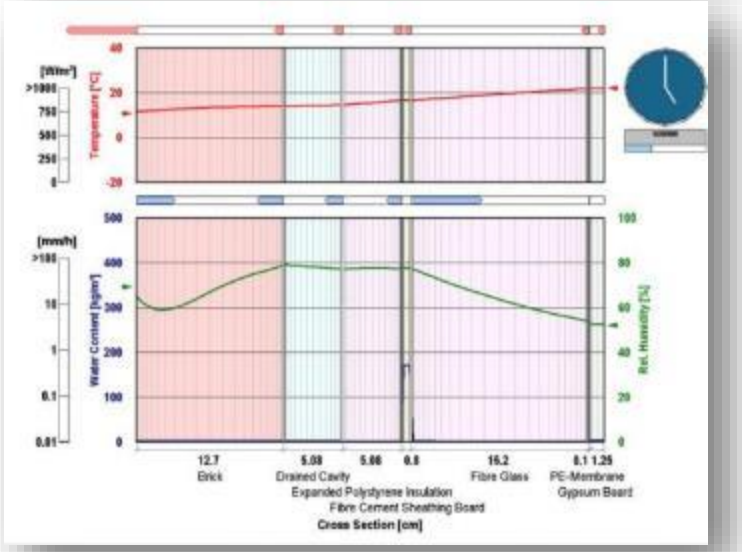
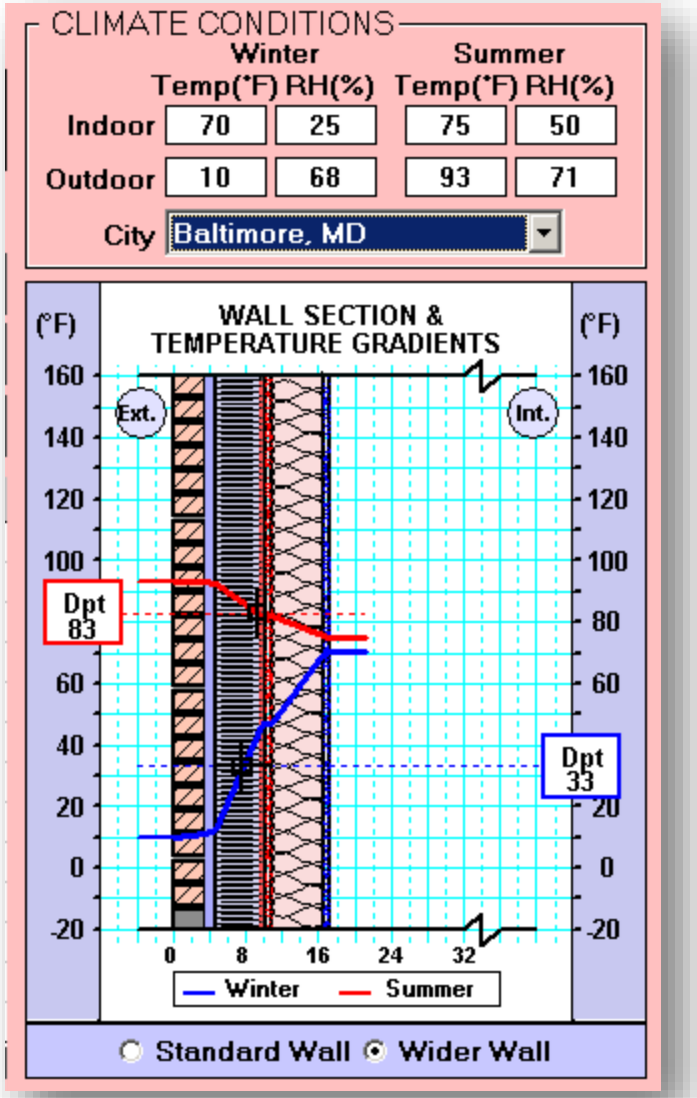
HAMM- Building Enclosure Design







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Durability

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Moisture Transport - Vapor Diffusion

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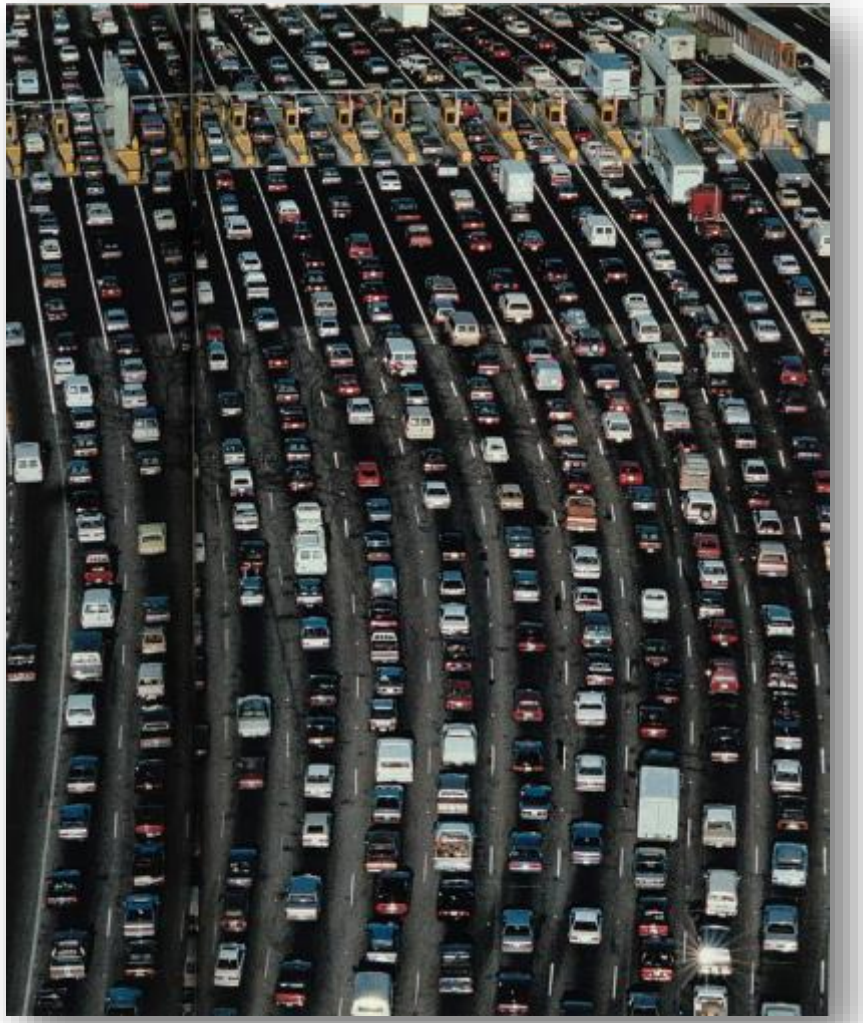
Moisture Transport – Air Leakage



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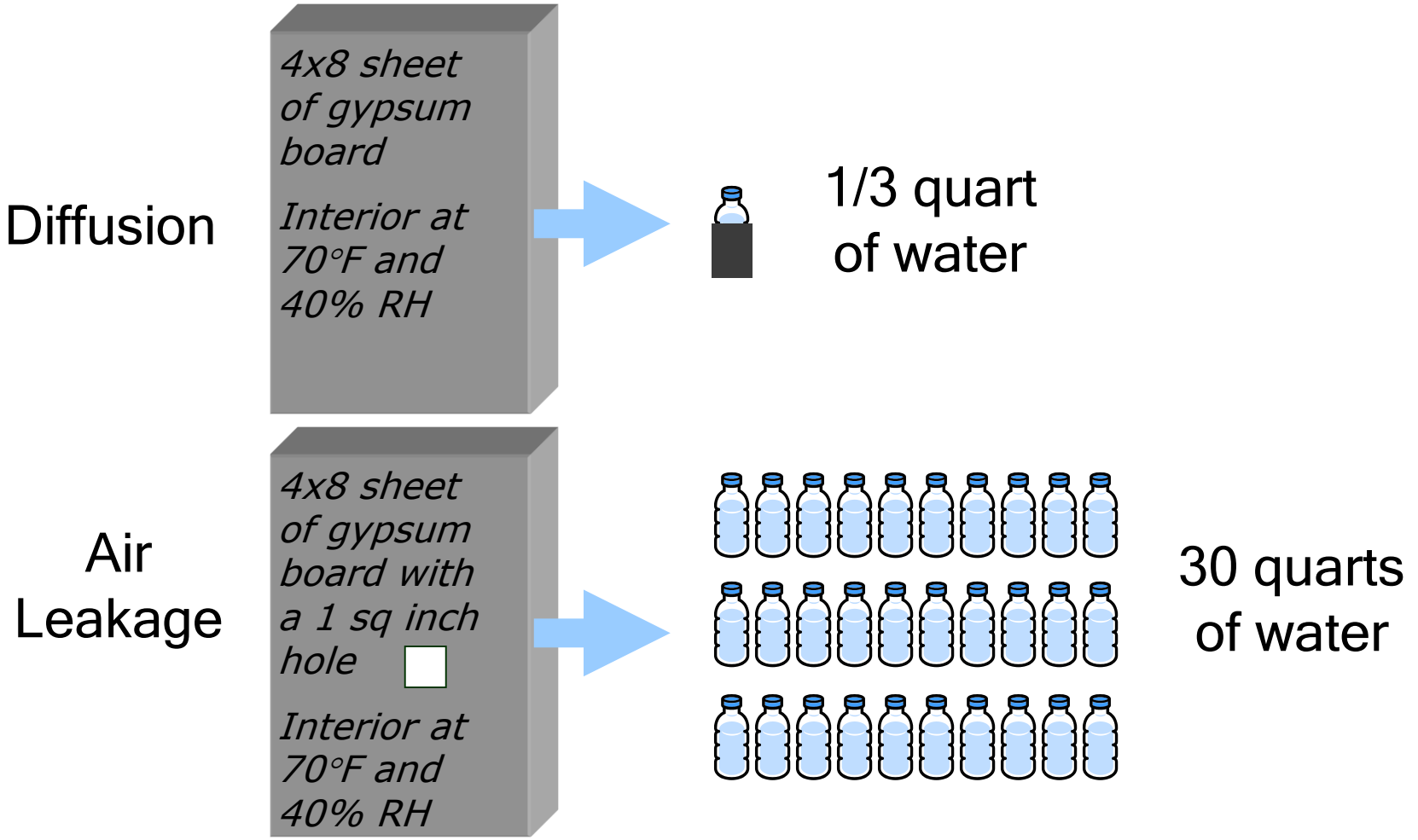
Airborne Moisture



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Vapor Diffusion or Vapor Laden Air?

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Air Leakage Loads

Air leakage is driven by air pressure difference across the building envelope.

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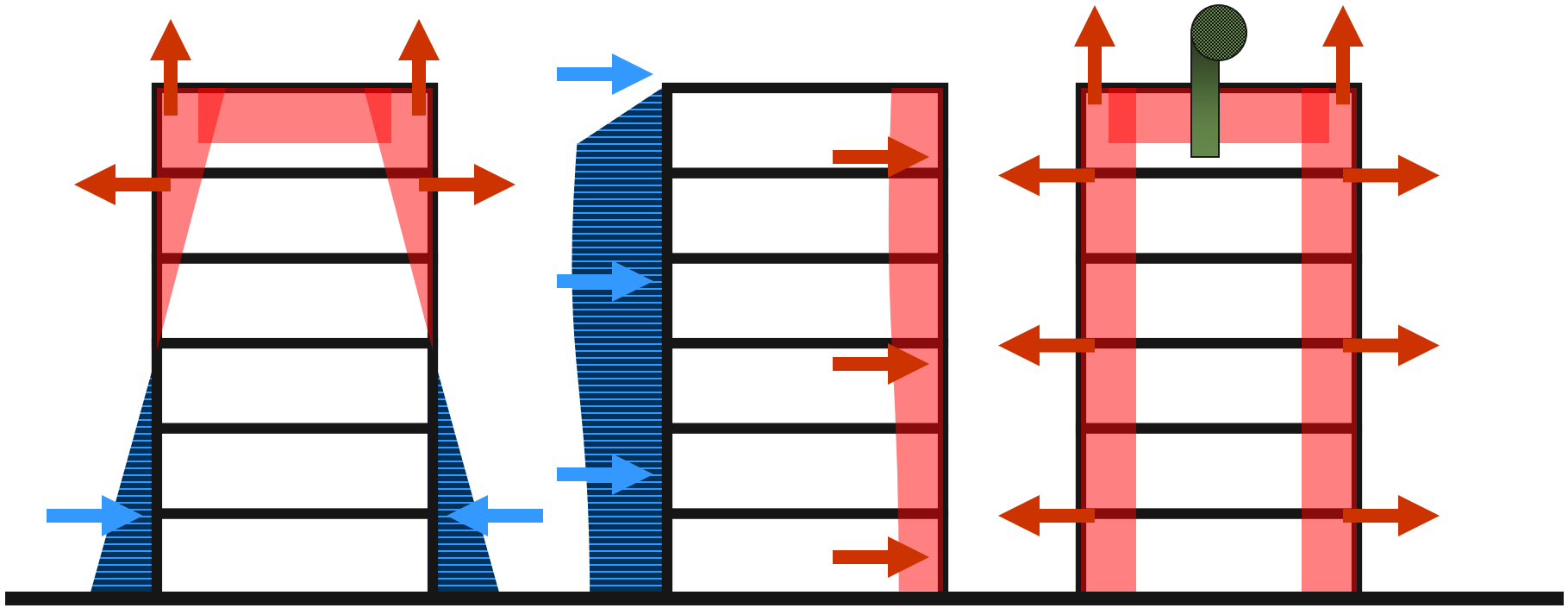
Air Pressure Difference



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Pressure Control Issues

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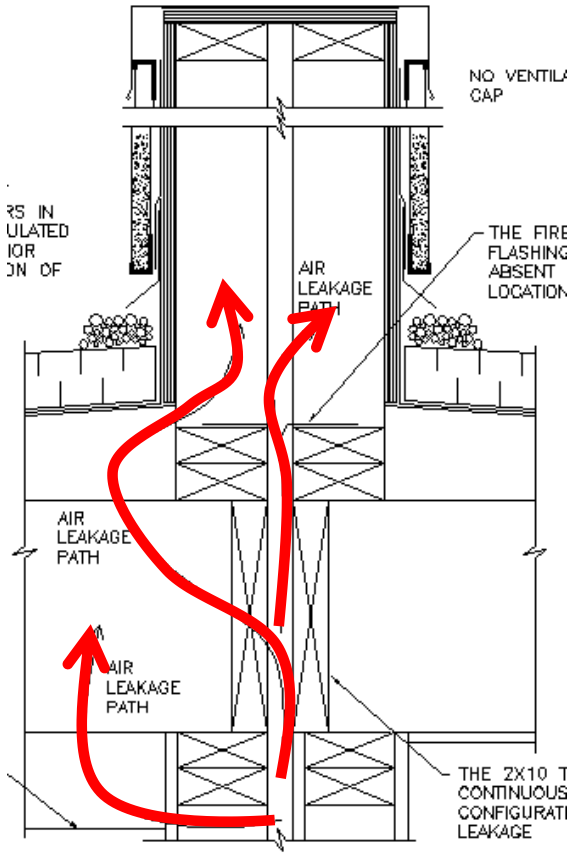
Unintended Air Leakage



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Air Leakage Issues

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Air Leakage Issues

Window Interface

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It haunts me……

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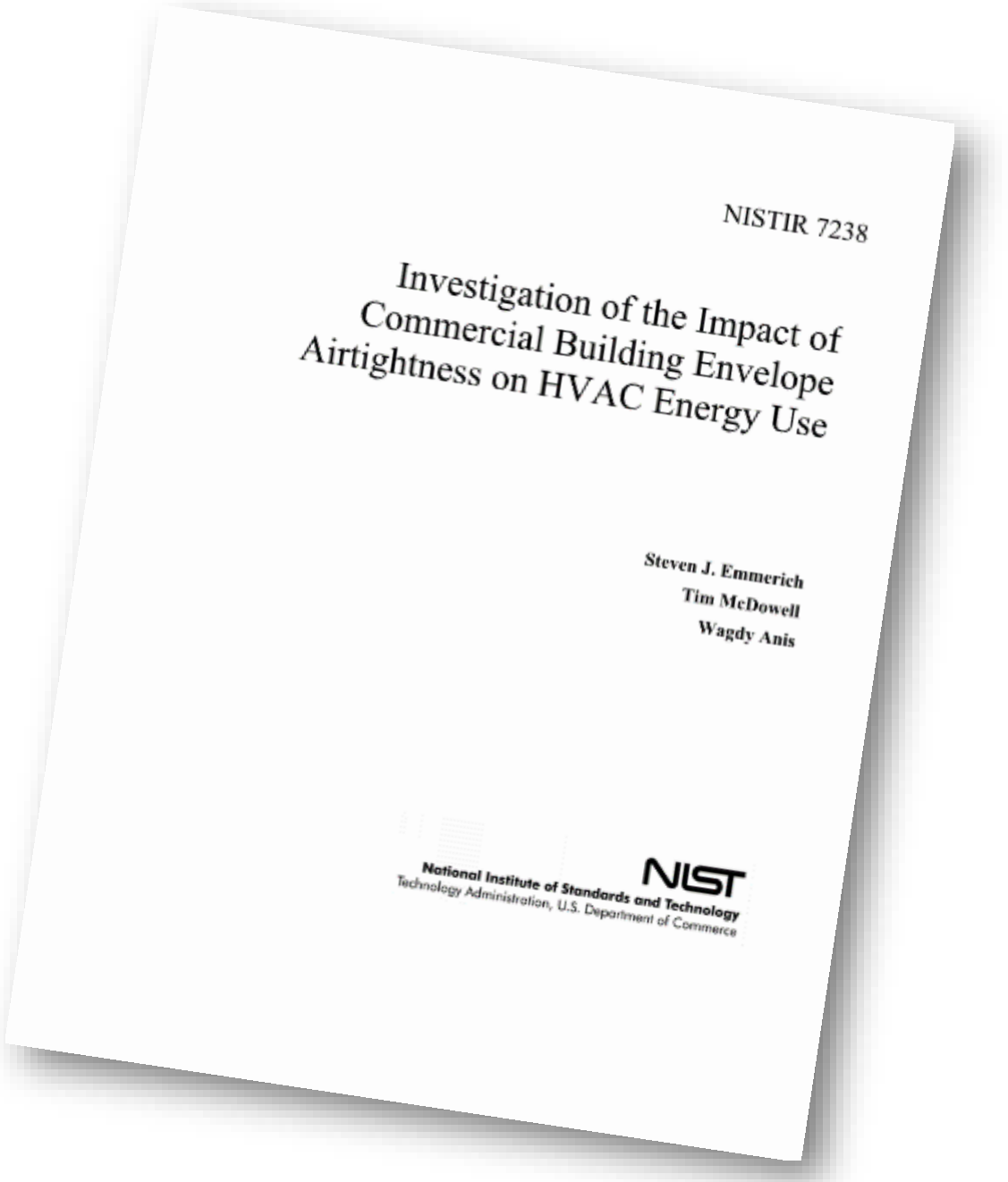
Is it all just Hot Air?



NISTIR 7238

Investigation of the Impact of Commercial Building Envelope Airtightness on HVAC Energy Use

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Wagdy Anis

National Institute of Standards and Technology
Technology Administration, U.S. Department of Commerce

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green·wash

/ˈgrēnwôSH,ˈgrēnwäSH/

noun

disinformation disseminated by an organization so as to present an environmentally responsible public image.
"the recycling bins in the cafeteria are just feeble examples of their corporate greenwash"

Translations, word origin, and more definitions

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Stop the GREENWASH!

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Stop the GREENWASH!

Mail Online

Airline asks passengers to use the toilet before boarding... so they will weigh less and help cut carbon emissions

- A Japanese airline has started asking passengers to go to the toilet before boarding in a bid to reduce carbon emissions.
- Nippon Airways (ANA) claims that empty bladders mean lighter passengers, a lighter aircraft and thus lower fuel use.
- ANA hopes the weight saved will lead to a five-tonne reduction in carbon emissions over the course of 30 days.

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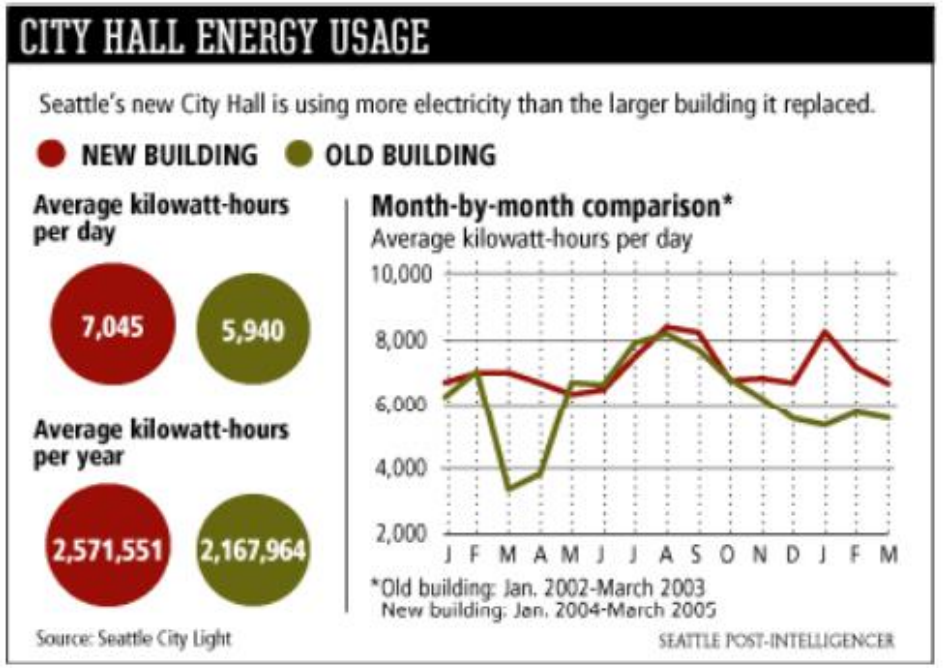
Stop the GREENWASH!



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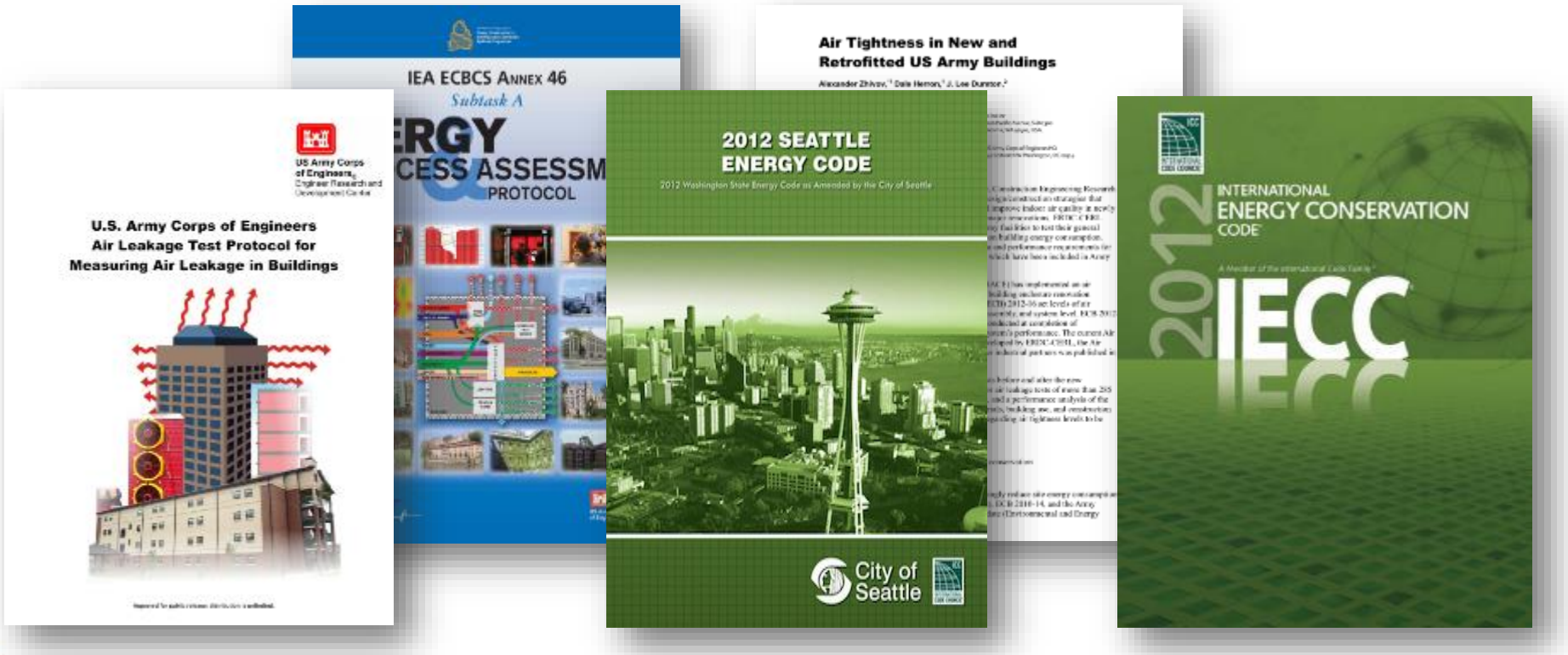
From Then to Now



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Energy Code Requirements

- Federal: Passing 0.25 cfm/ft^2 since 2009 (UFC)
  - Military Departments
  - Defense Agencies
  - DoD Field Activities

  - Federal Level Construction*

  - SOFA, HNFA, BIA, etc.

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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

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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.

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Energy Code Requirements

- Salt Lake City / State of Utah

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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**

Looser

Tighter

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

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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

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How Leaky Are Buildings…?

Example #2

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We Were Warned…..

- 0.25 cfm/sf is not achievable
- There are too many building types for one standard
- An air tightness standard will limit construction type
- An air tightness standard will limit material type
- This is space-age technology that requires new materials
- Needed is an education and training process that will take years to usher in

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Test Study

US Army Corps of Engineers

BCRA SCIENCE + ENGINEERING

pie CONSULTING & ENGINEERING

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- 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

Lessons Learned

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Poly Vapor Barrier = Air Barrier

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Video credit BCRA Inc.

Size Matters- Detroit Arsenal Building 270

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Detroit Arsenal Bldg. 270

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Detroit Arsenal Bldg. 270

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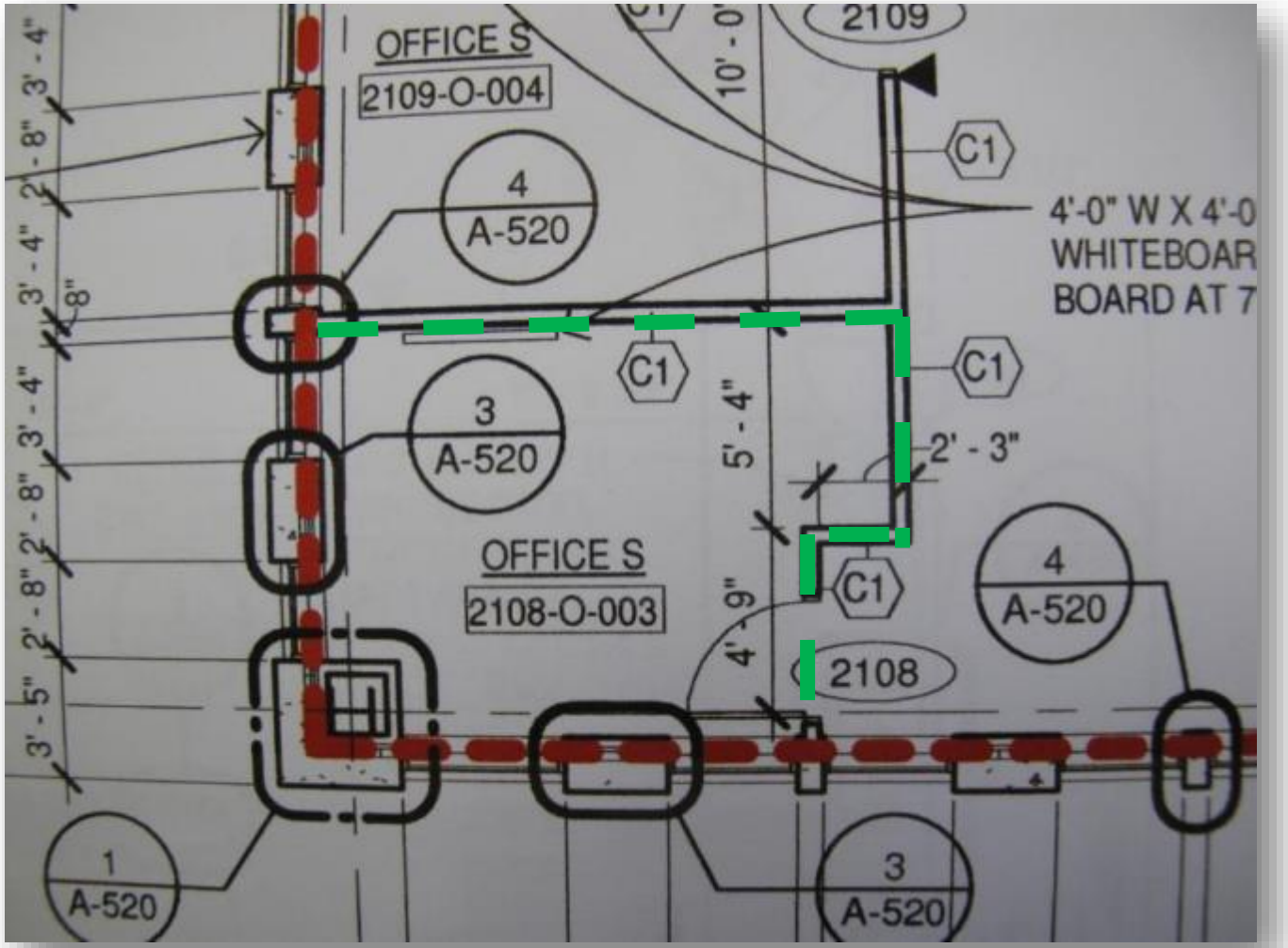
Confidence Test



~1300-sf of envelope

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WBALT

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Test Set-up

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Target Air Leakage

USACE	cfm/sf@75Pa
RFP Requirement	*.25cfm/sf @75PA*
Detroit Arsenal Bldg. 270	*Envelope SF: 144,622*
Allowable leakage rate	*36155.5 cfm*

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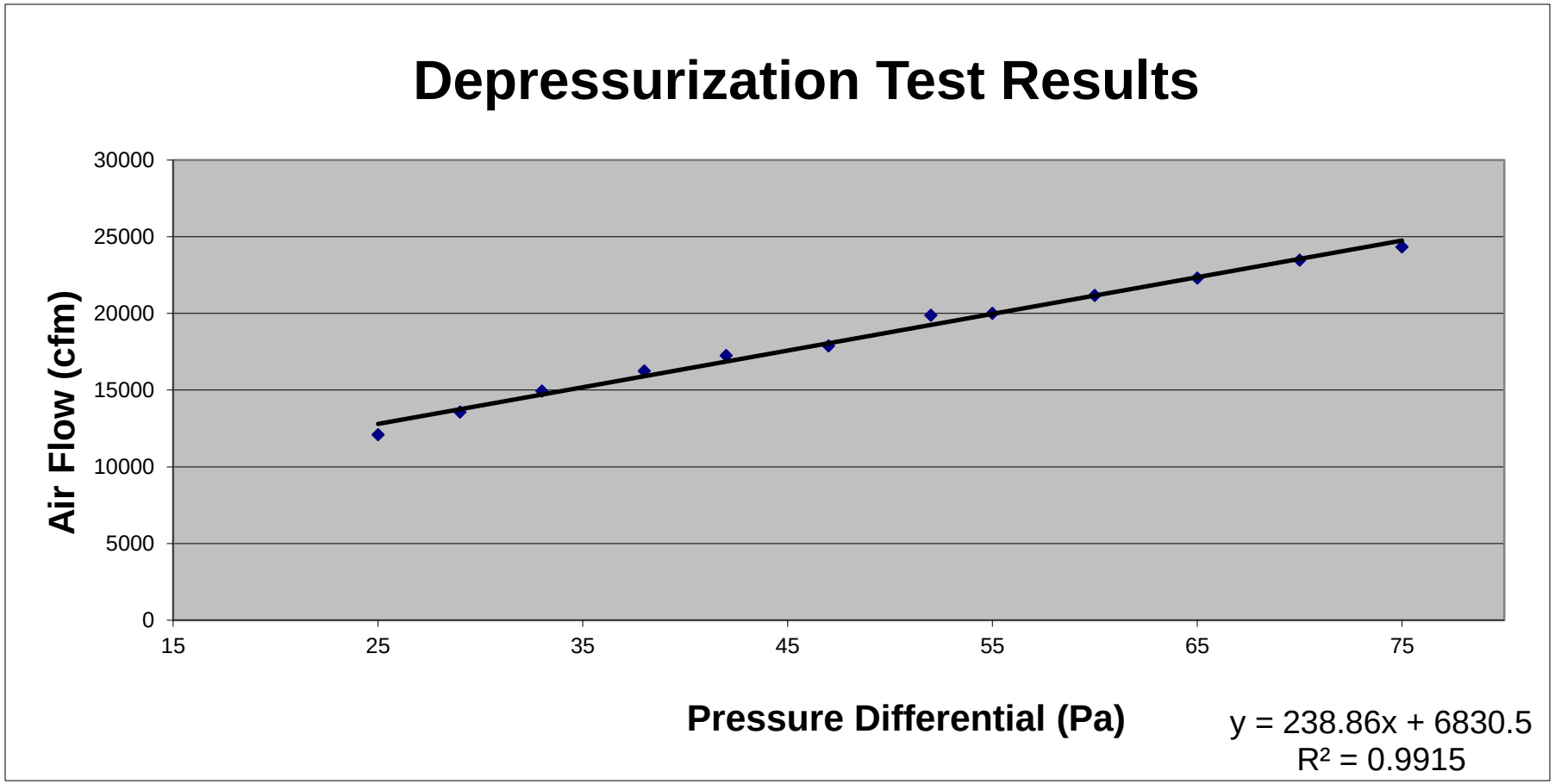
Data



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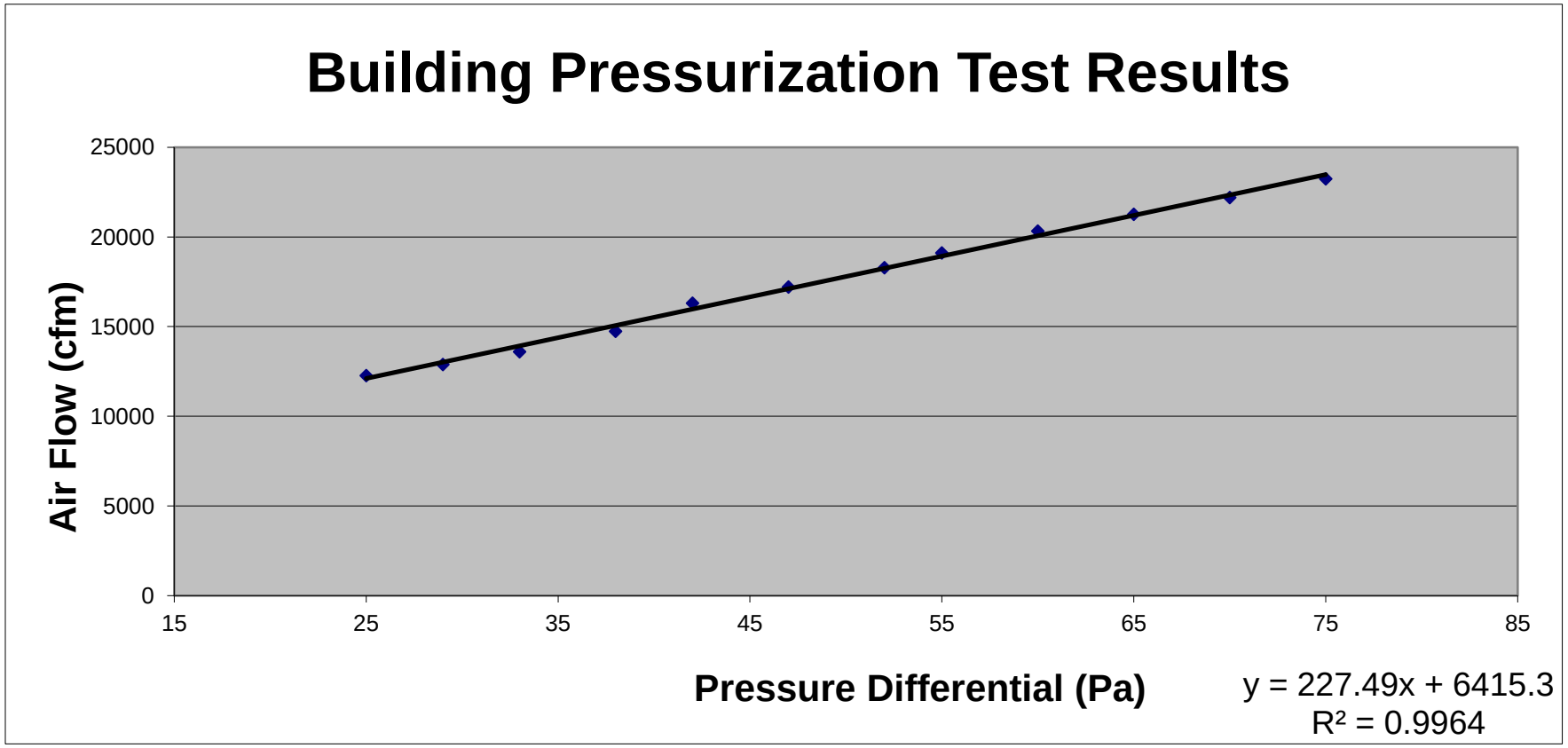
Data



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Results

Depressurize	Pressurize
0.168	0.161
24,330 cfm/75	23,235 cfm/75
Average = 0.16 - Data correlation > 99%	

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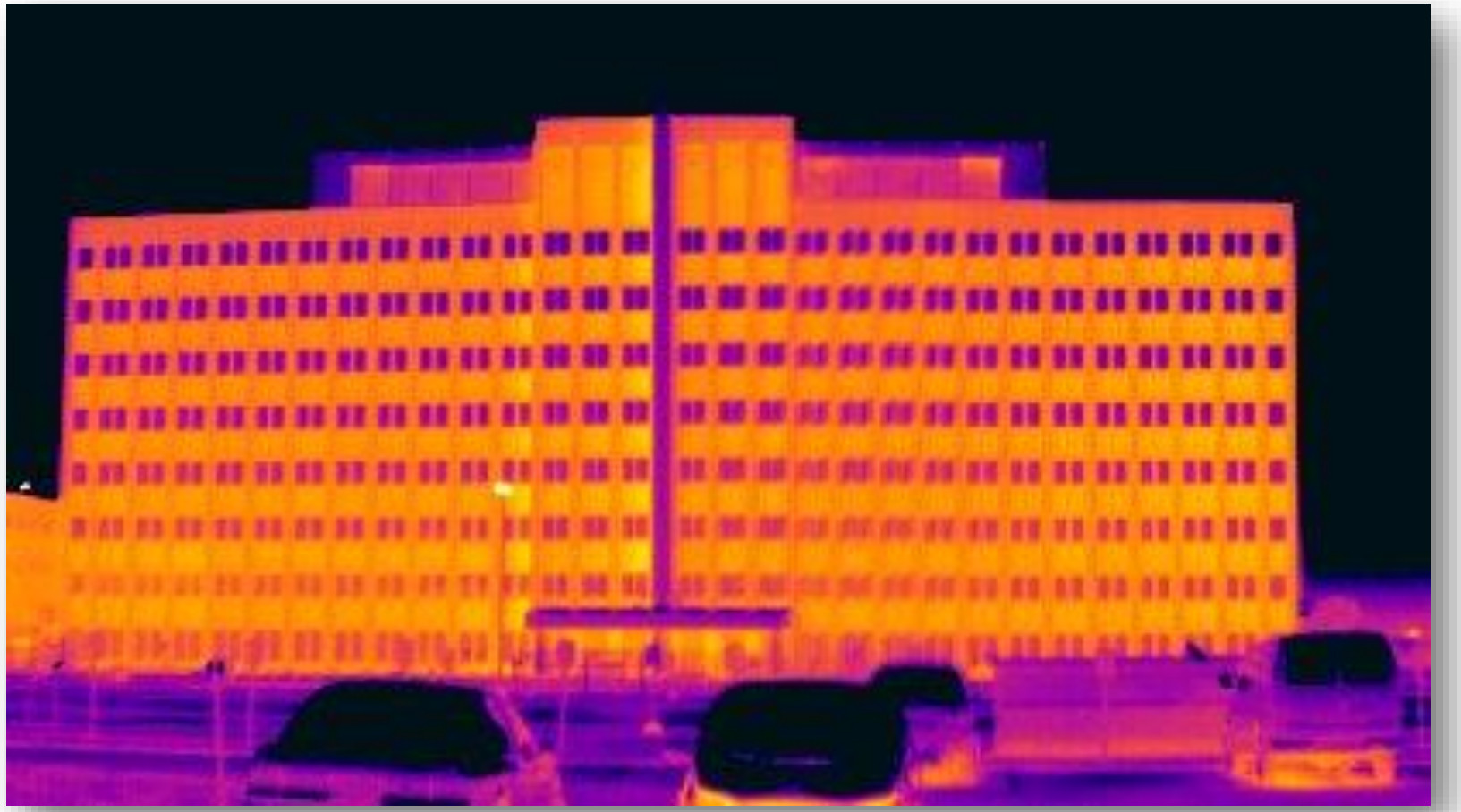
Infrared Survey



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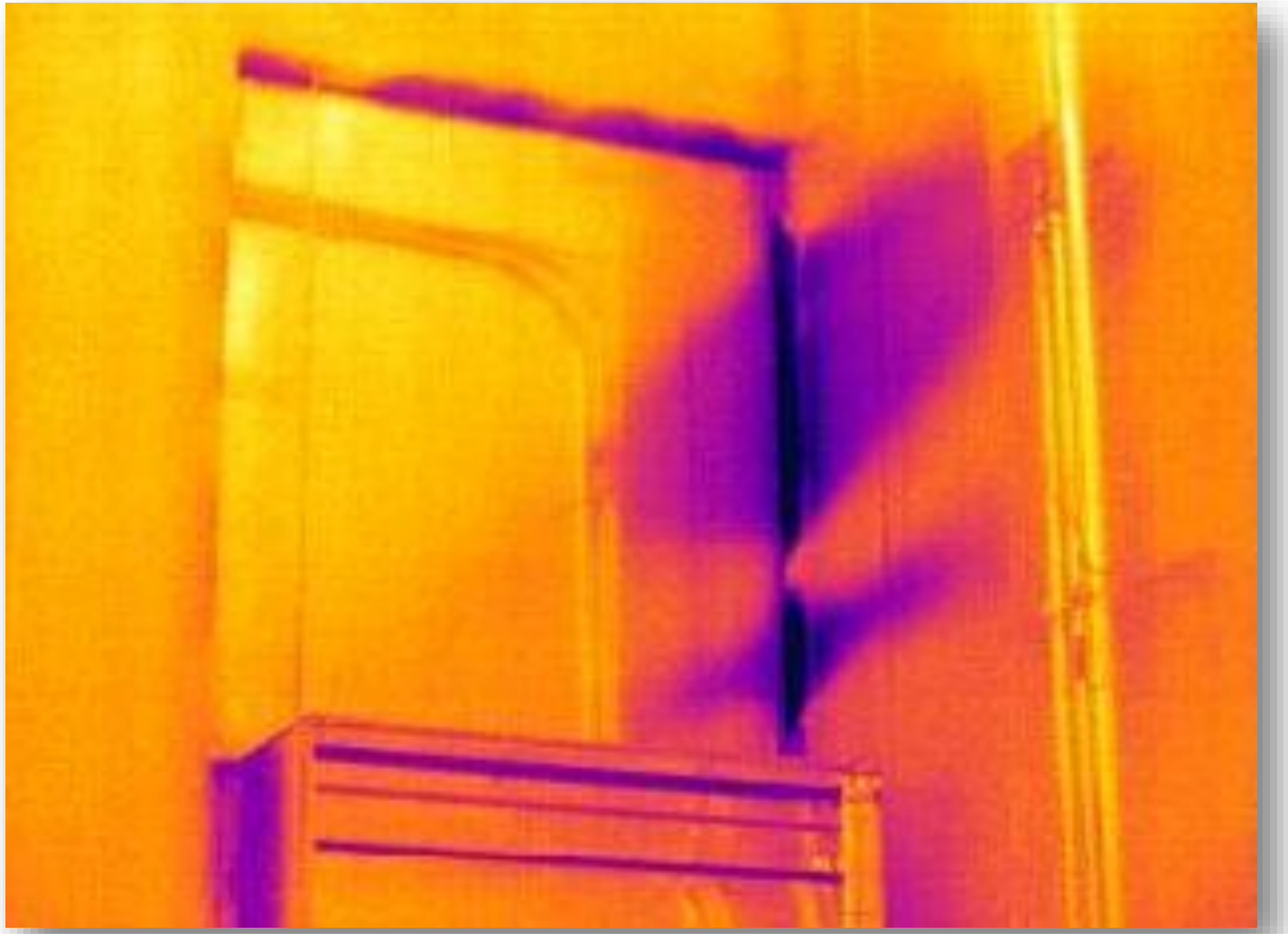
Infrared Survey



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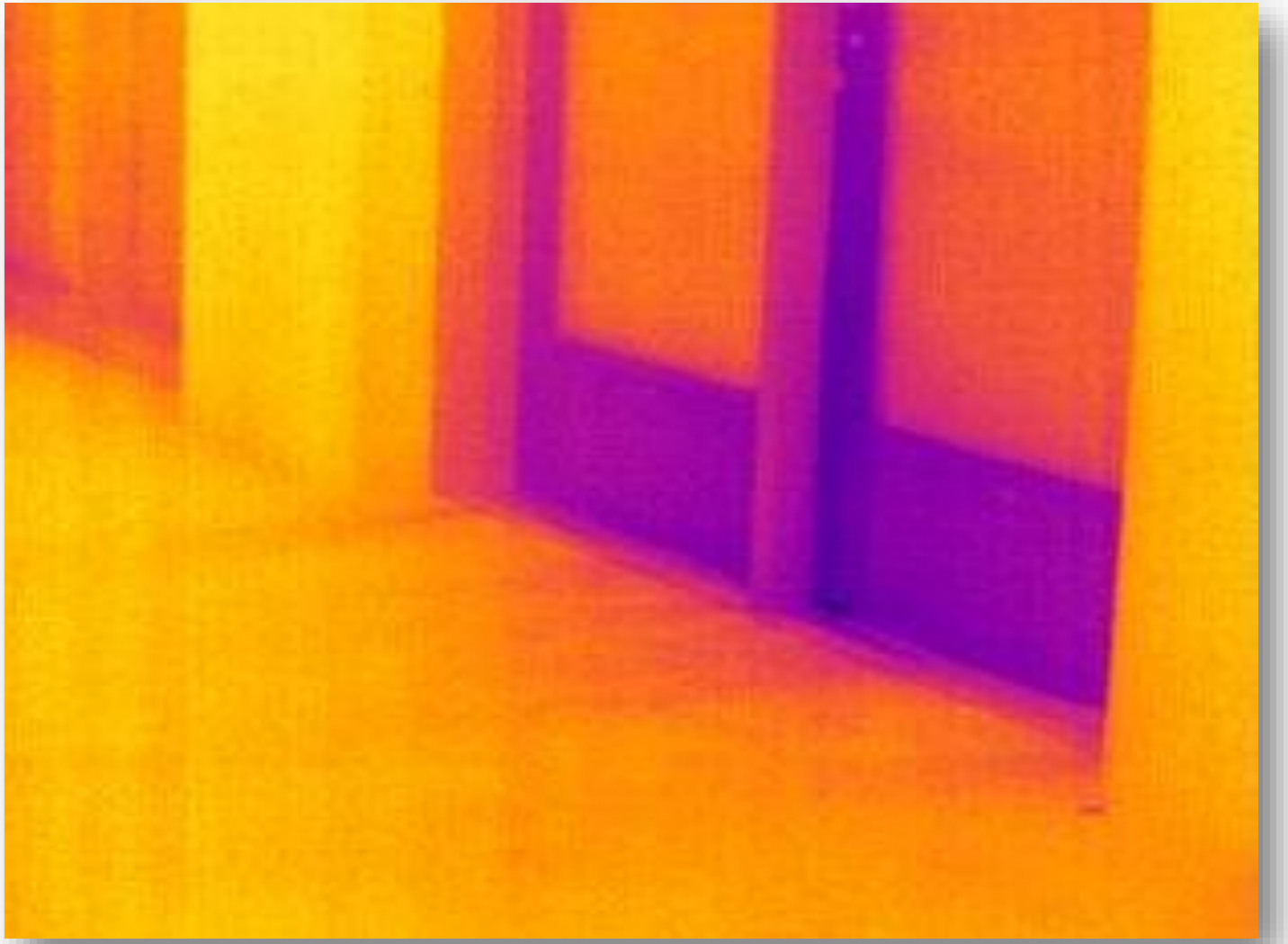
Infrared Survey



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Accommodating the Decision Makers

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Overhead Roll-up Doors

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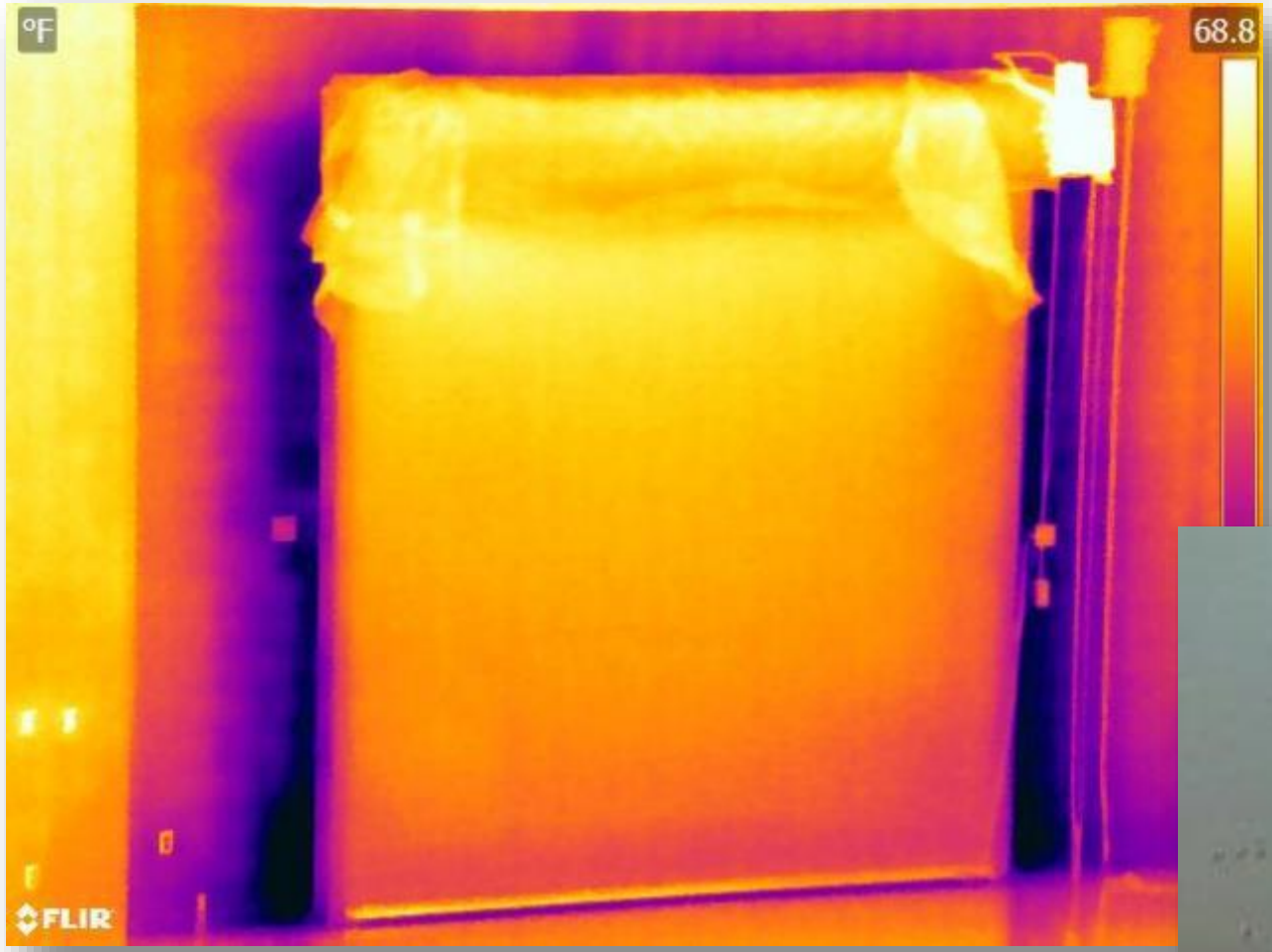

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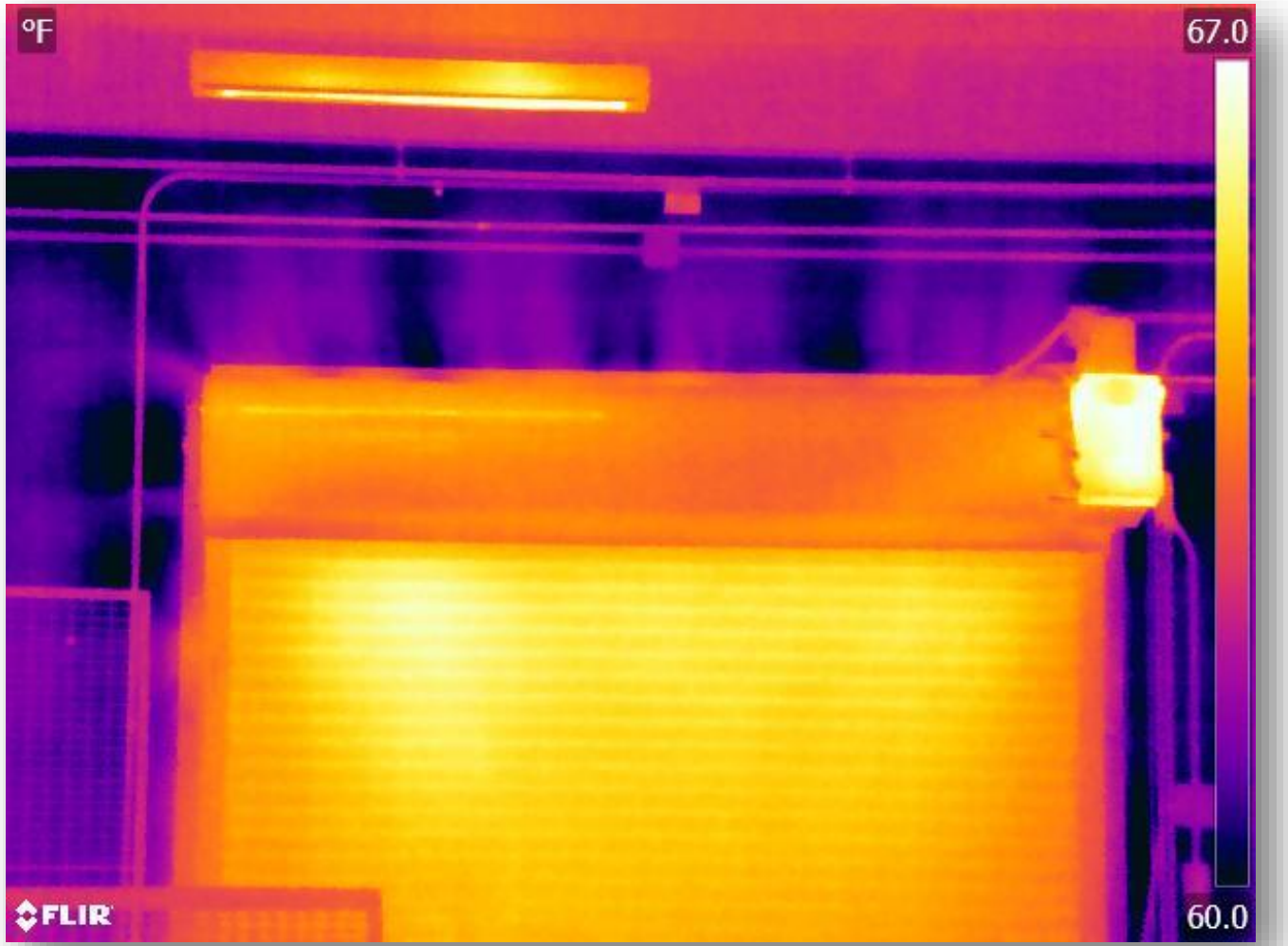

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Quantified

4,900cfm @75Pa

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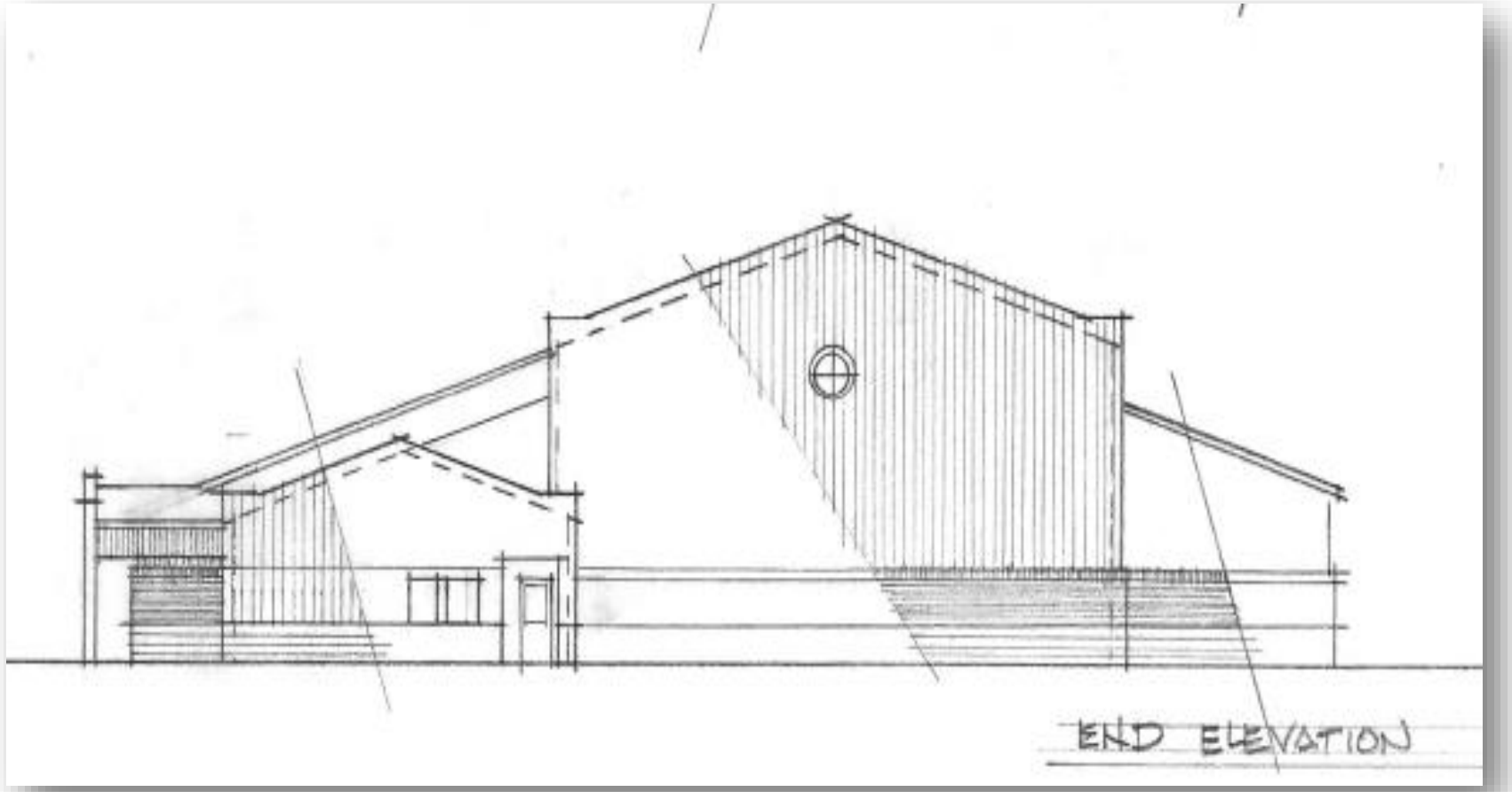
Size Does Matter



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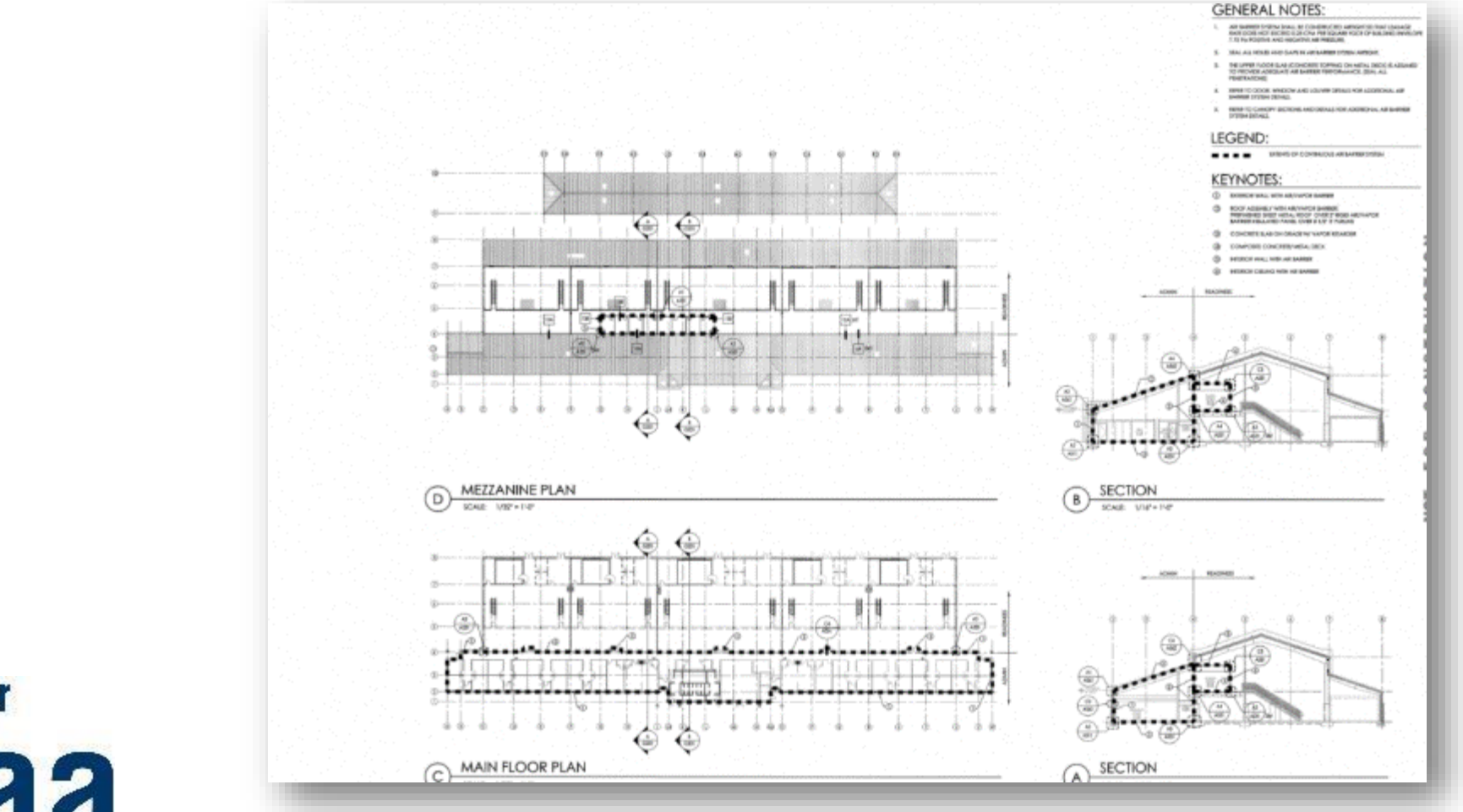
Extents of Air Barrier



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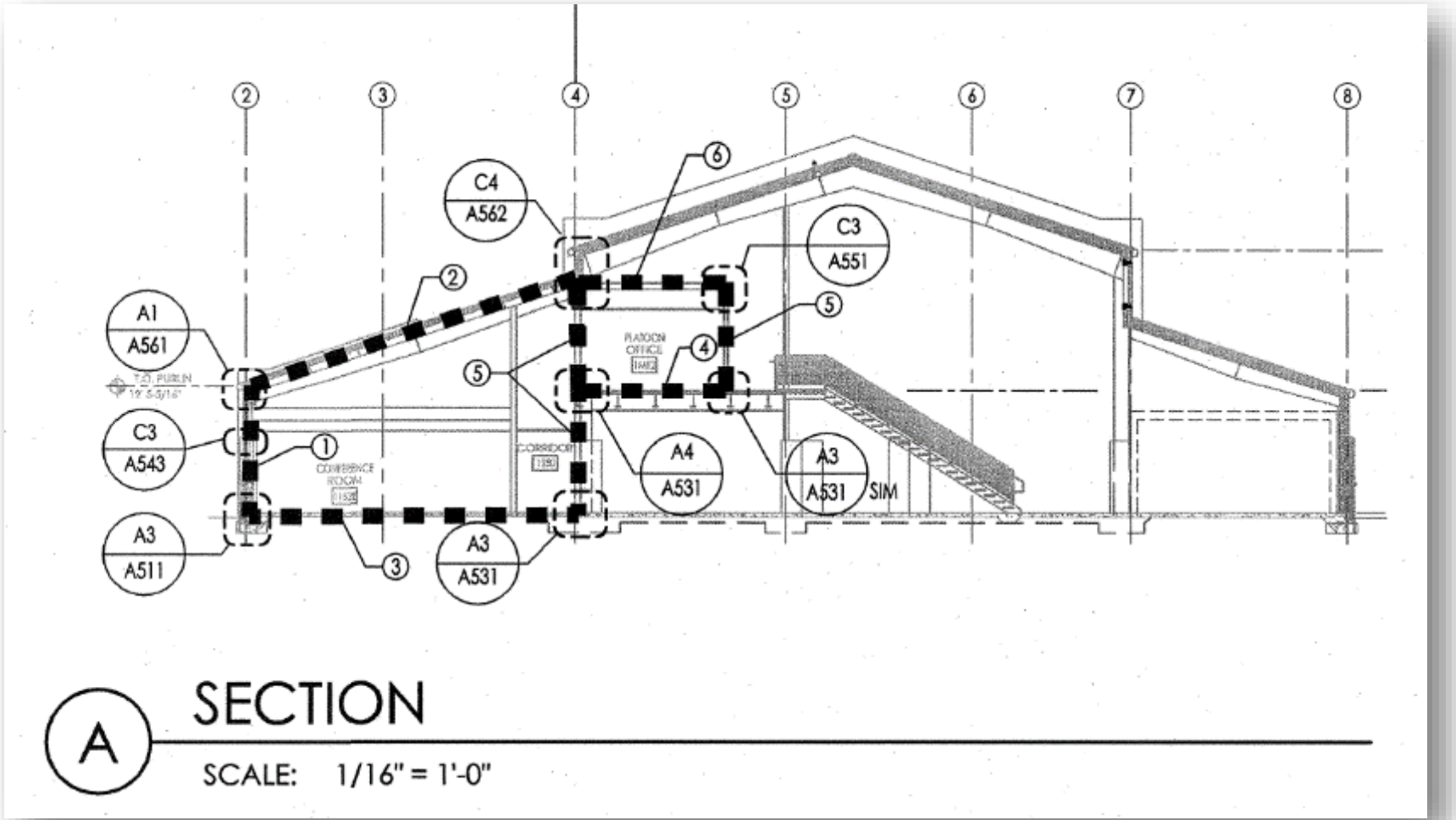
Extents of Air Barrier



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Construction

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Target Air Leakage

USACE	cfm/sf@75Pa
RFP Requirement	.25cfm/sf @75PA
5-5 COF Admin Office Area	Envelope SF 51,352
Allowable leakage rate	12,838 cfm
5-5 ADA COF Mezzanine Office	Envelope SF 4,887
Allowable leakage rate	1,222 cfm

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Results

Admin Area	Mezzanine Offices
0.063	0.209
3,260 cfm/75	1,020 cfm/75

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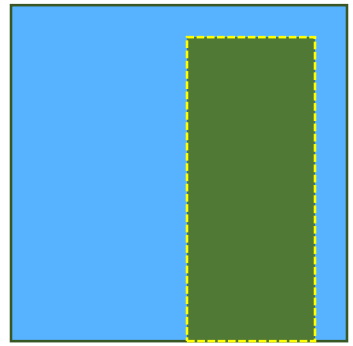
Proportion of Operational Leaks

1,000 sf of envelope area
Allowable leakage = 250cfm @75Pa



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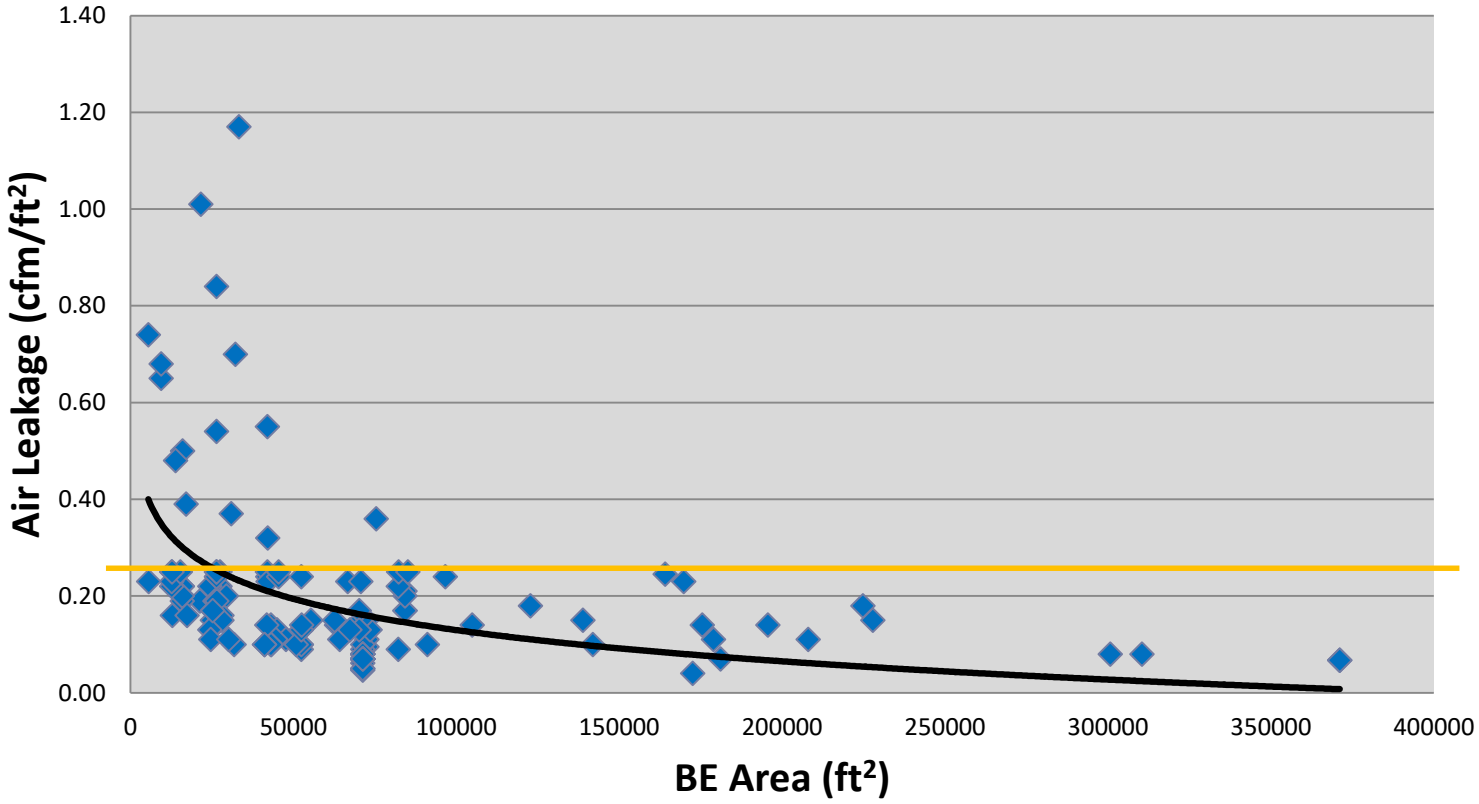
Leakage Rate vs. Building Size



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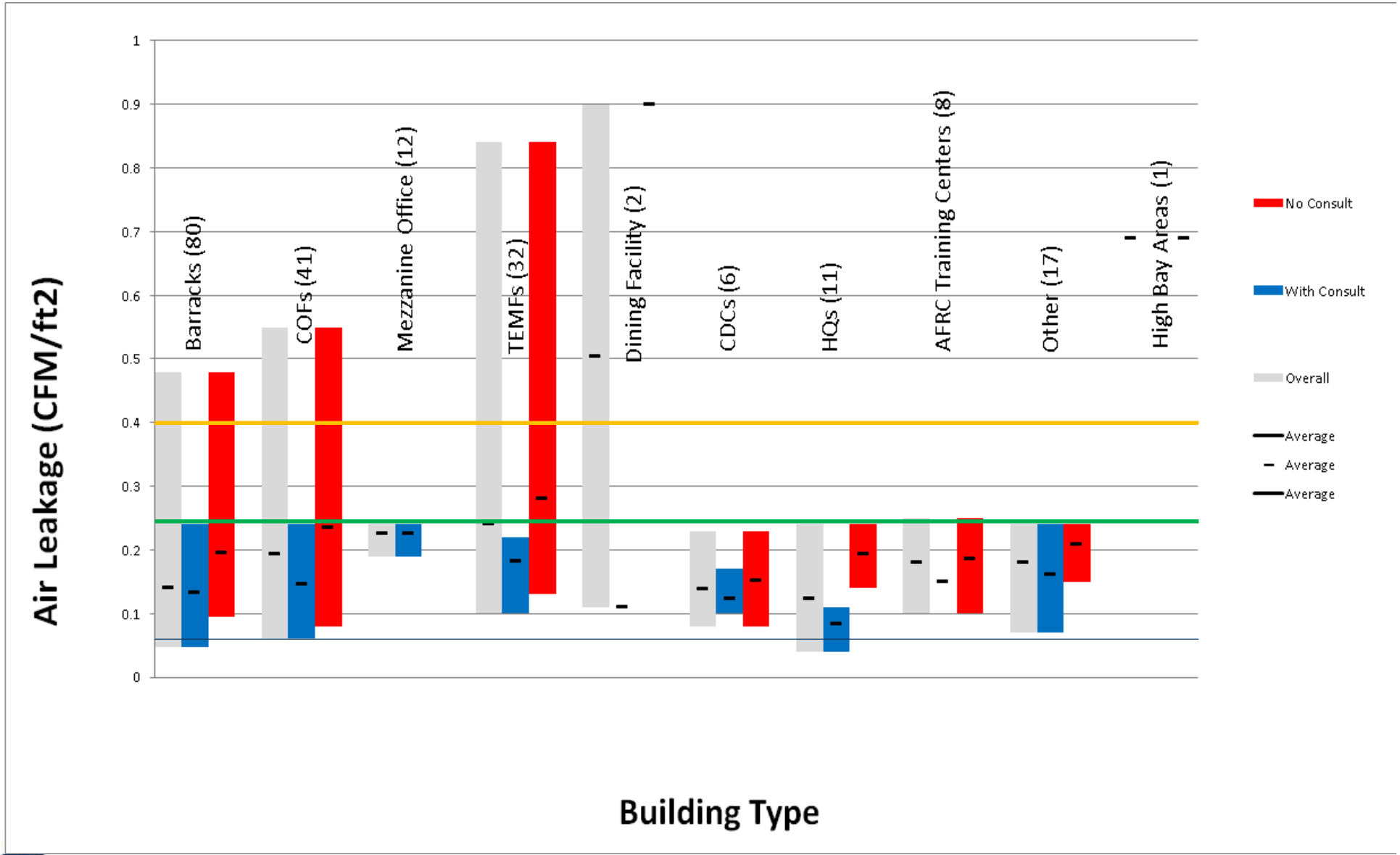

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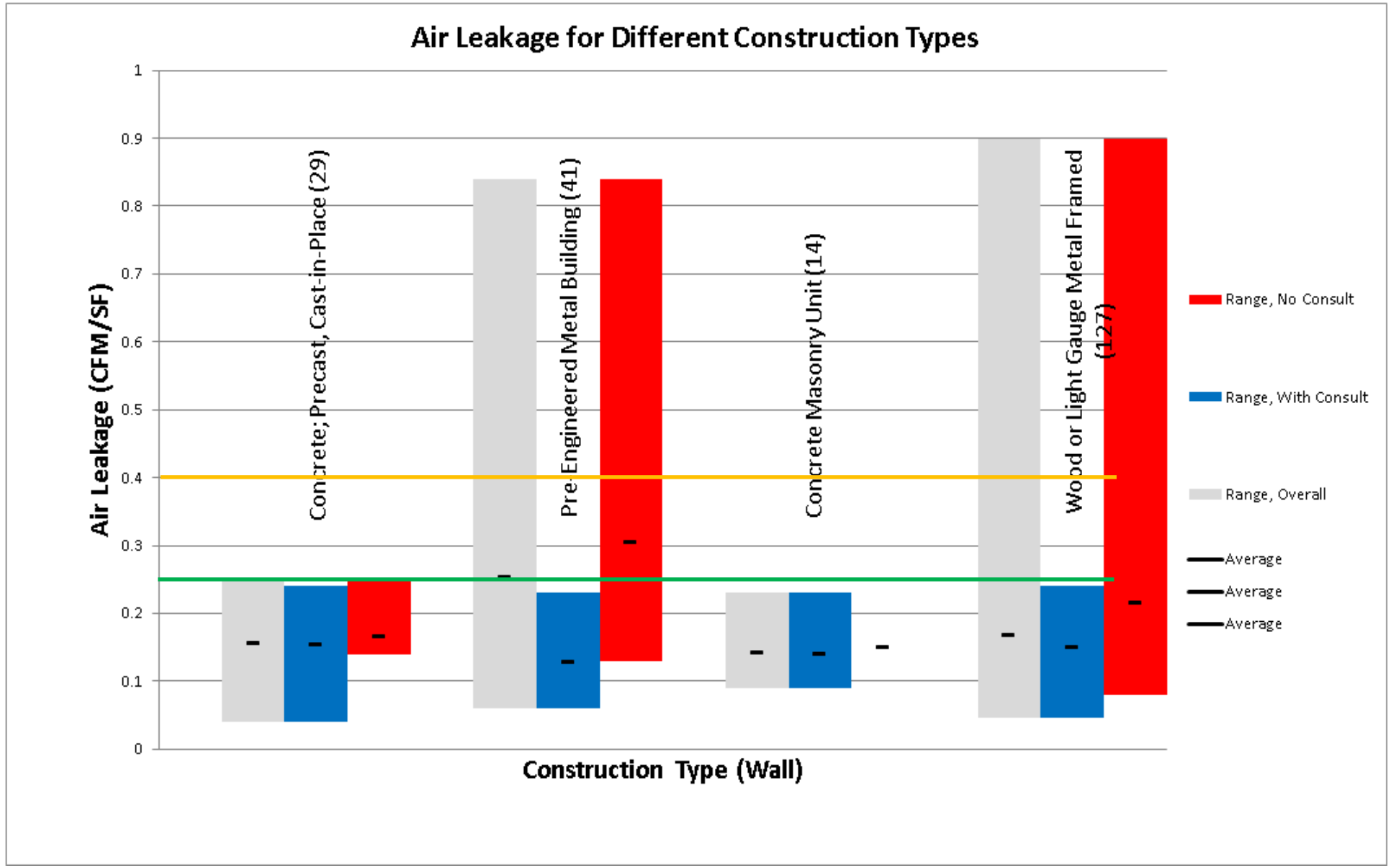

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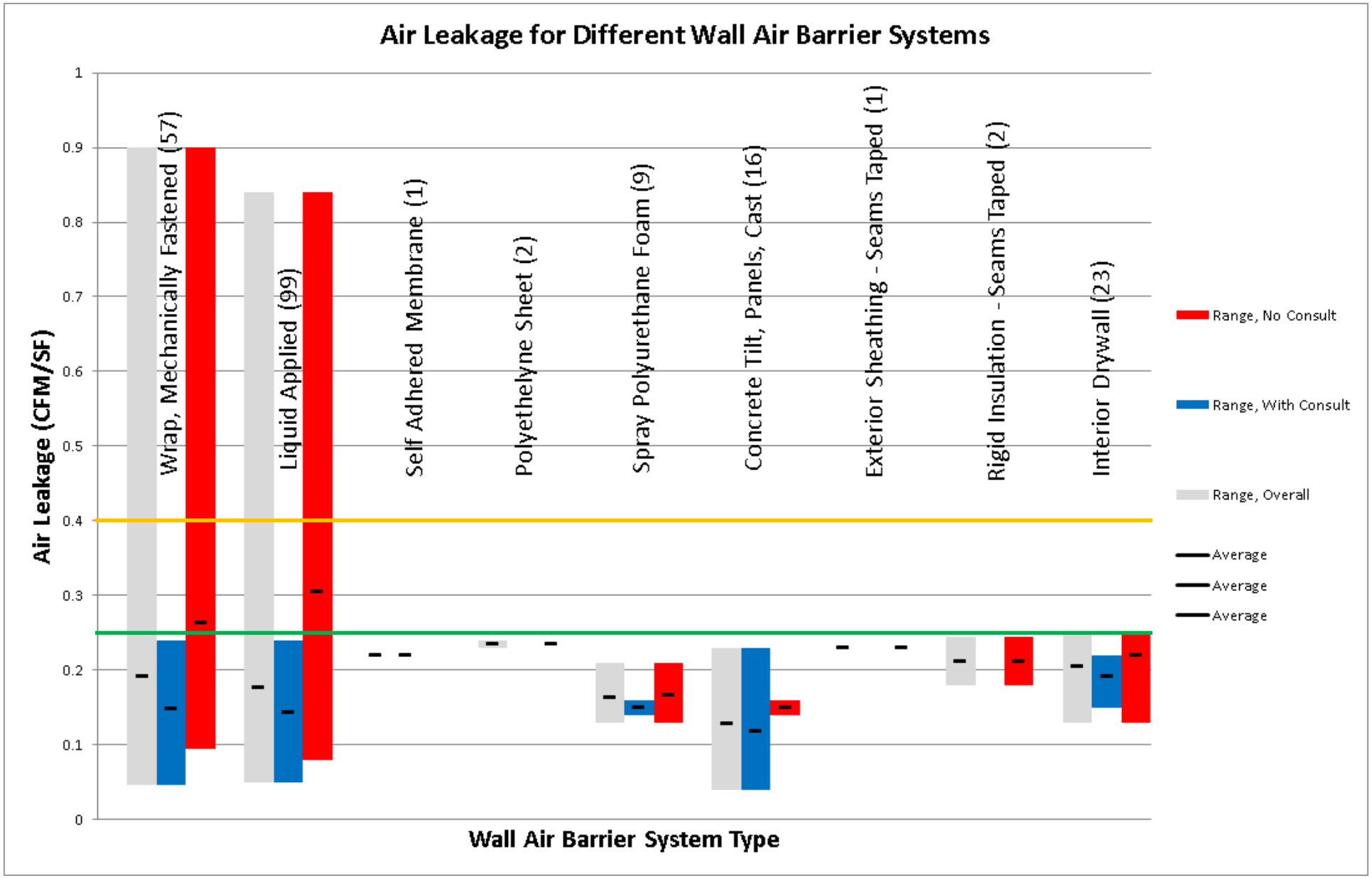

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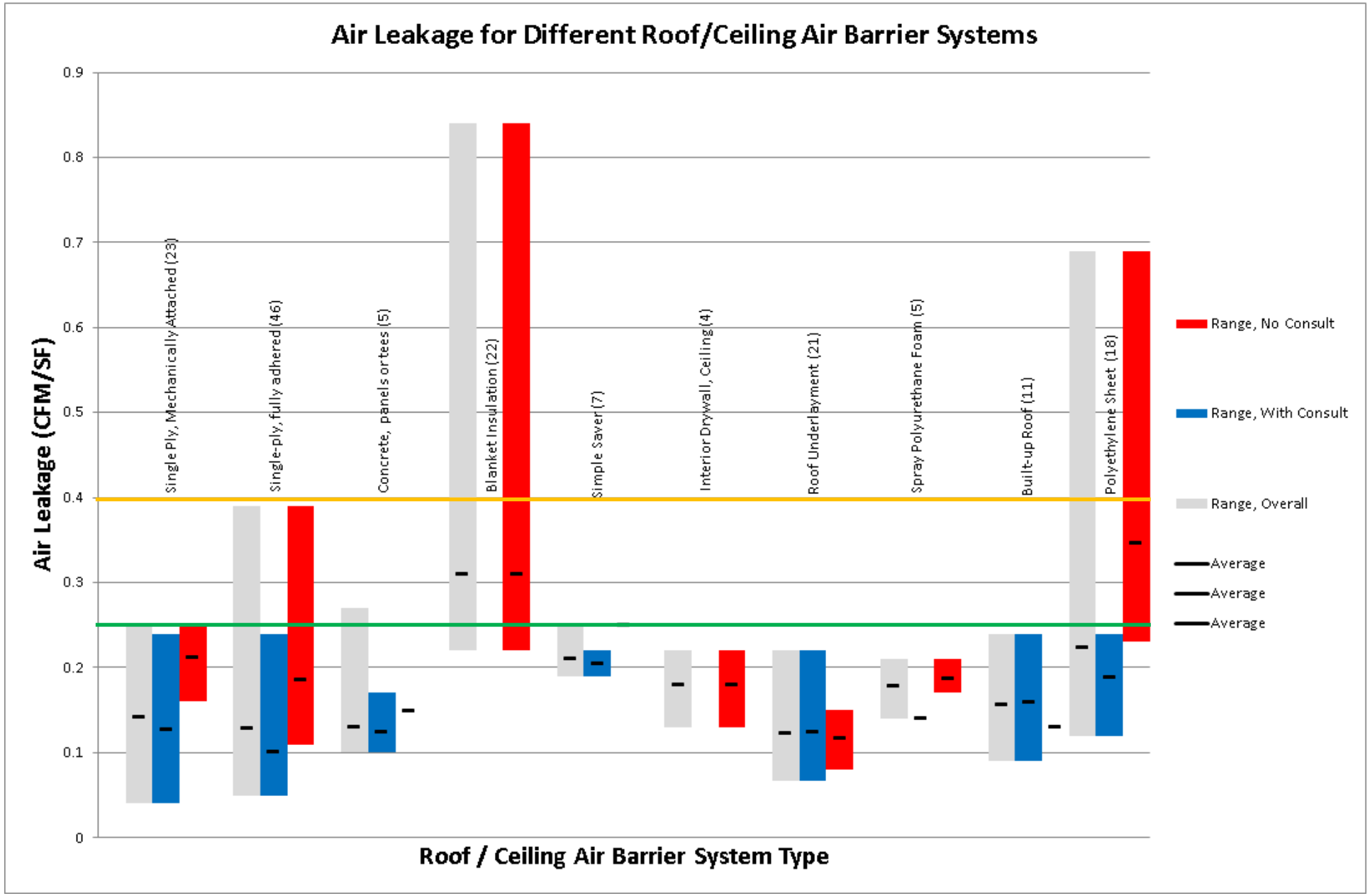

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Success of the Air Tightness Requirement

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

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Seattle –

- 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).

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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, this is good practice and it will be required by the Contractor and Testing Agency to prepare and conduct whole-building air leakage test.

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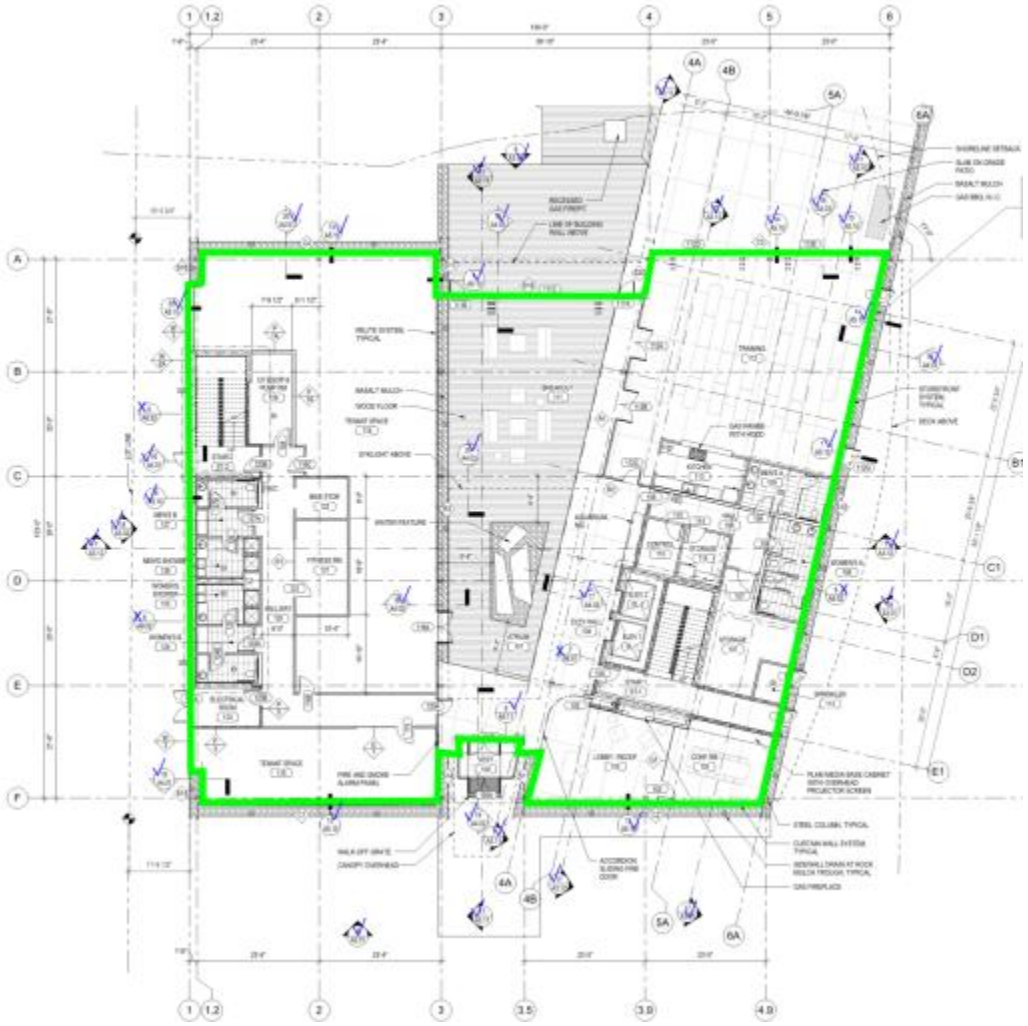
Building's Pressure Boundary



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

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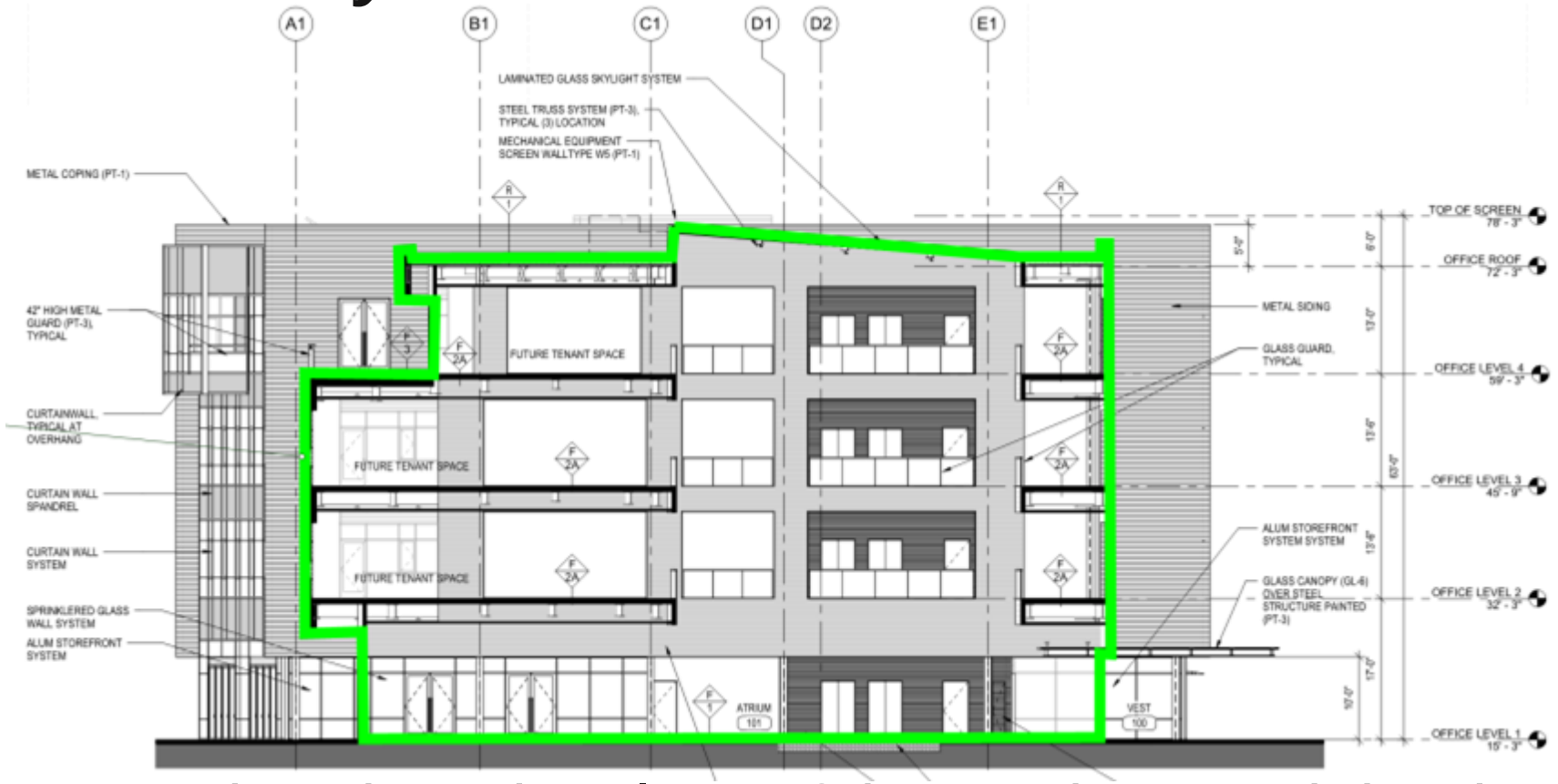
Building's Pressure Boundary



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

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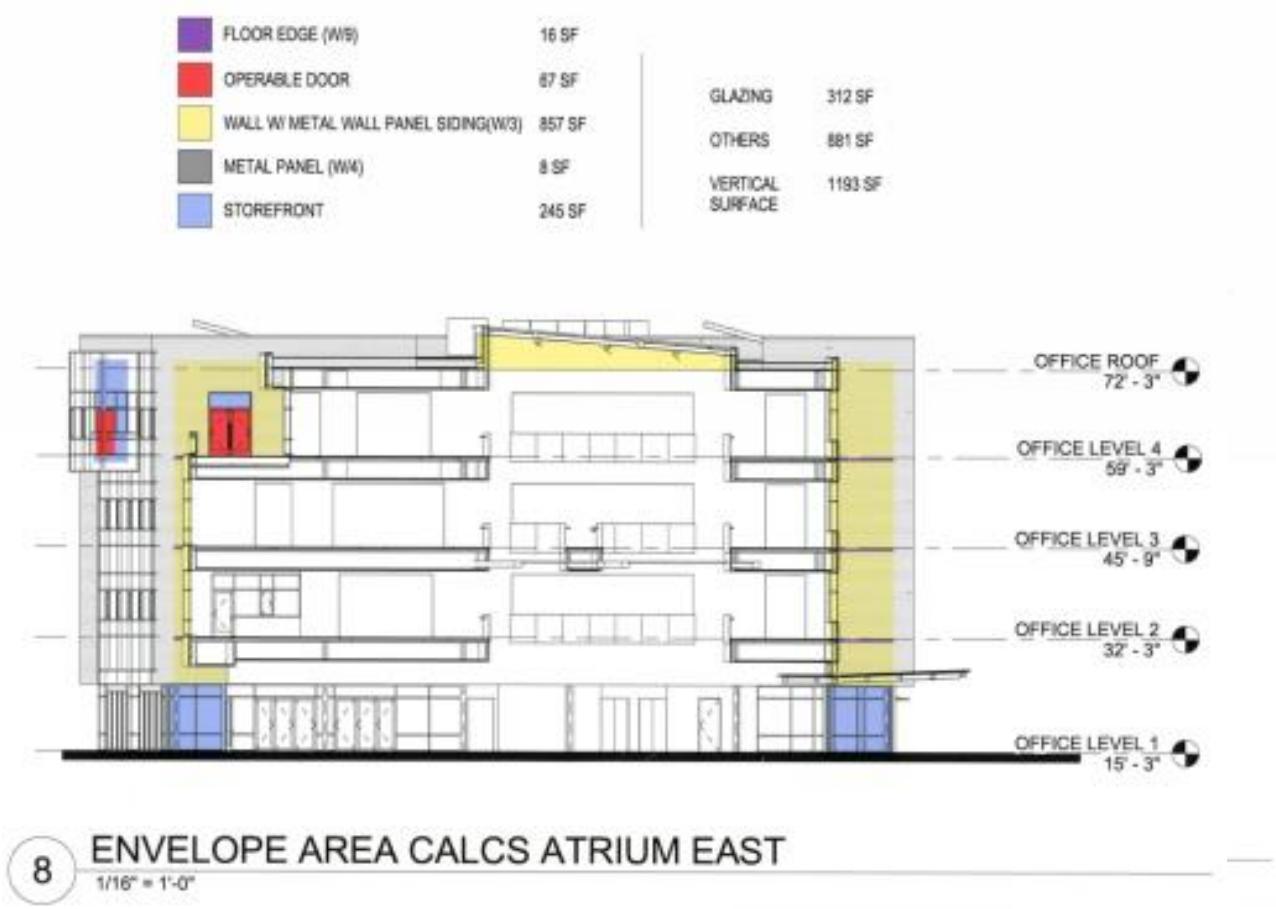

Pay special attention:

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

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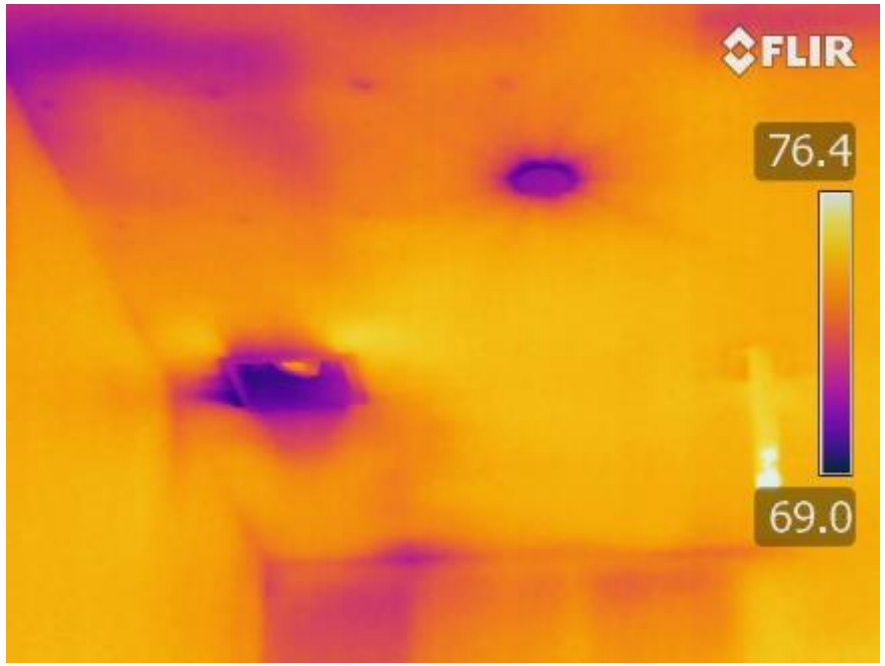
Envelope System Decisions

- Location of the Air Barrier
- Material selections

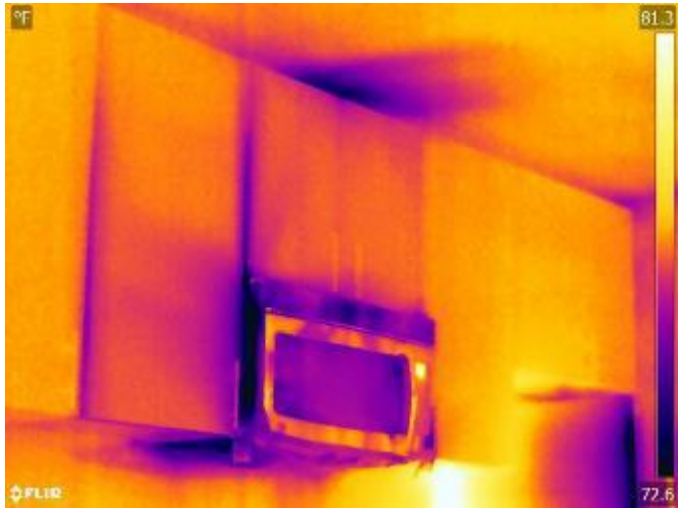
Envelope System Decisions

- Air barrier @ GWB ceiling

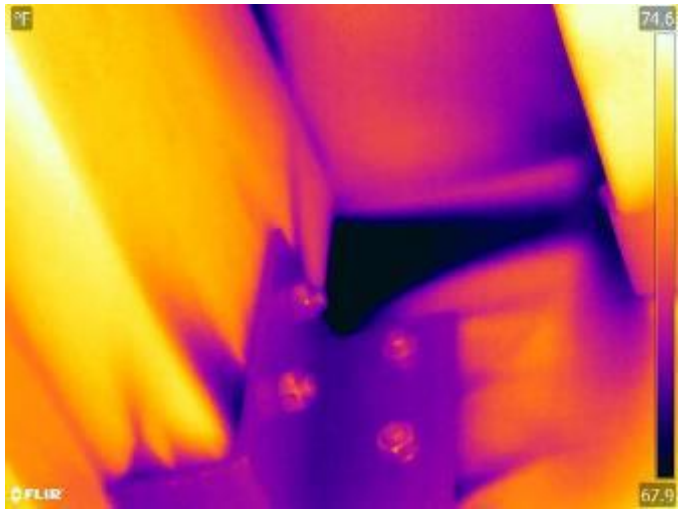


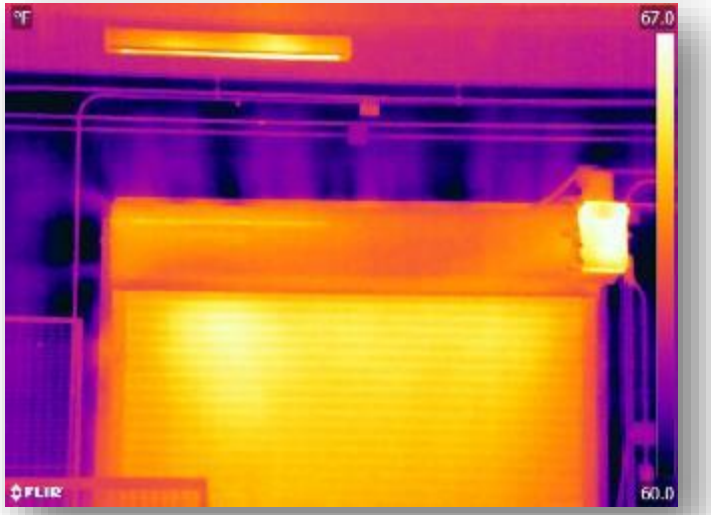
Envelope System Decisions

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



Envelope System Decisions





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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

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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
- 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

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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**
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**

Looser

Tighter

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

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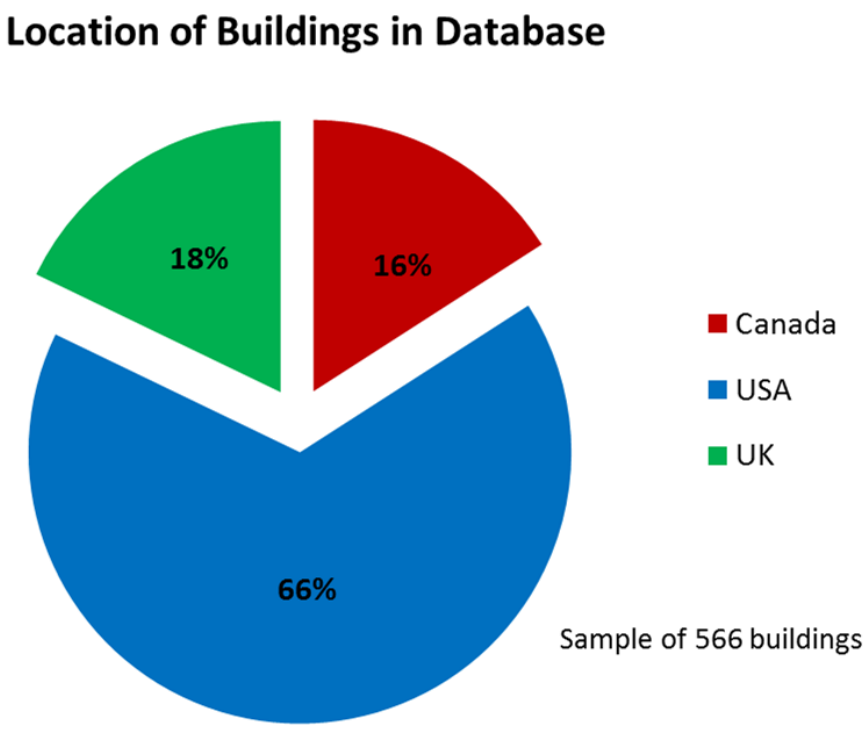
Passive House 0.06 cfm/ft² at 75Pa

Database Population Characteristics



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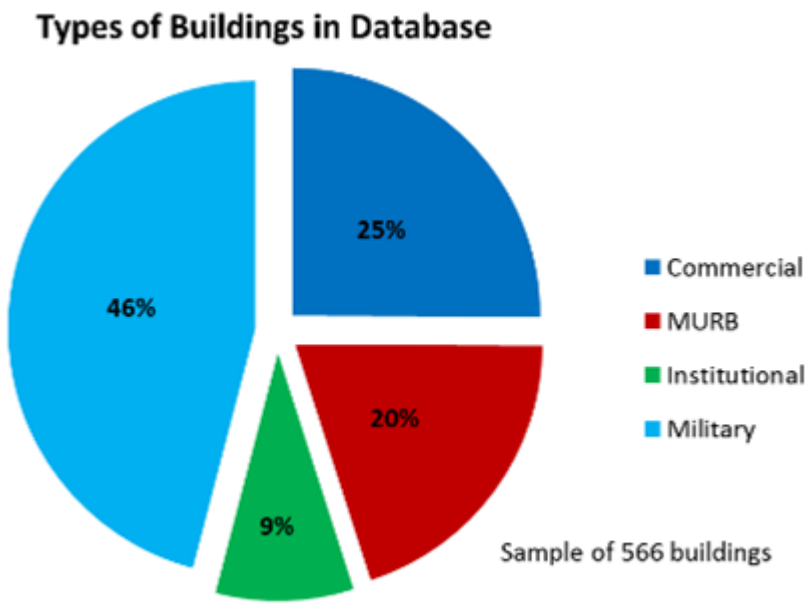
Database Population Characteristics



- Lots of USACE buildings

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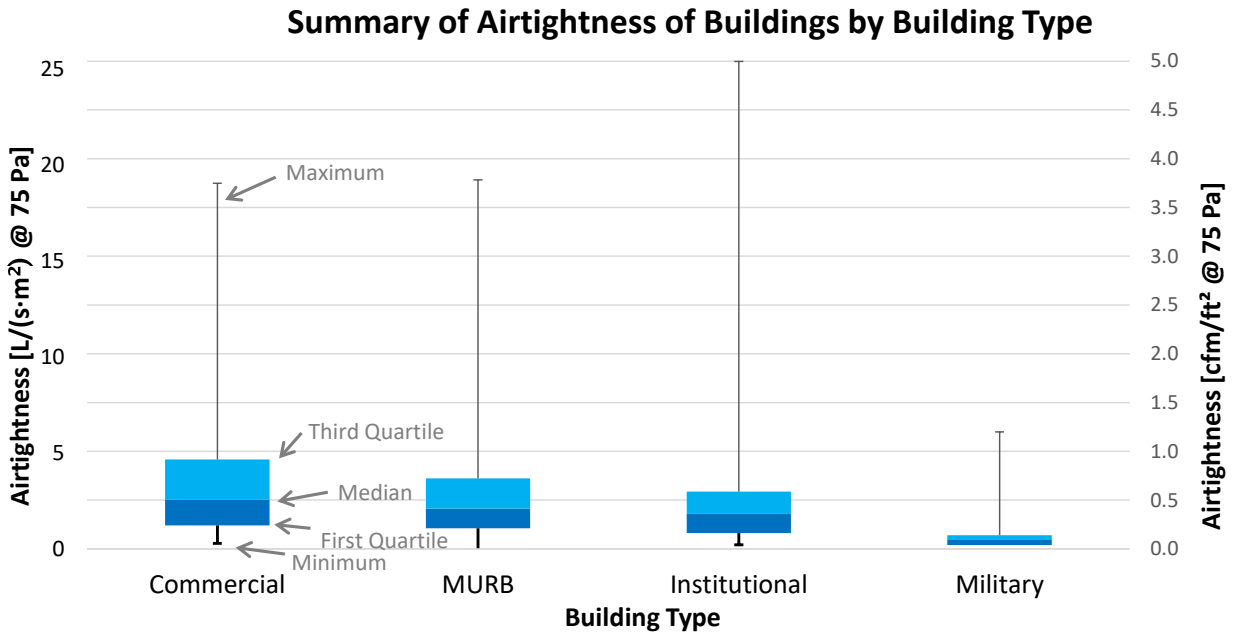
Airtightness versus Building Type



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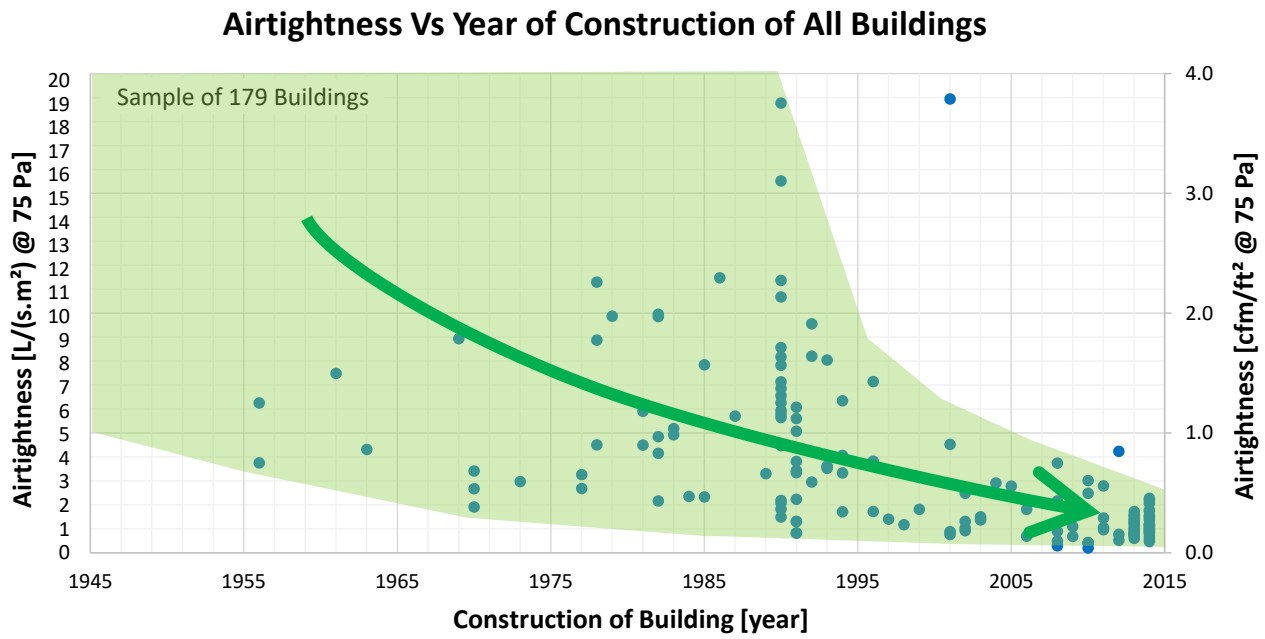
Building Age vs Airtightness



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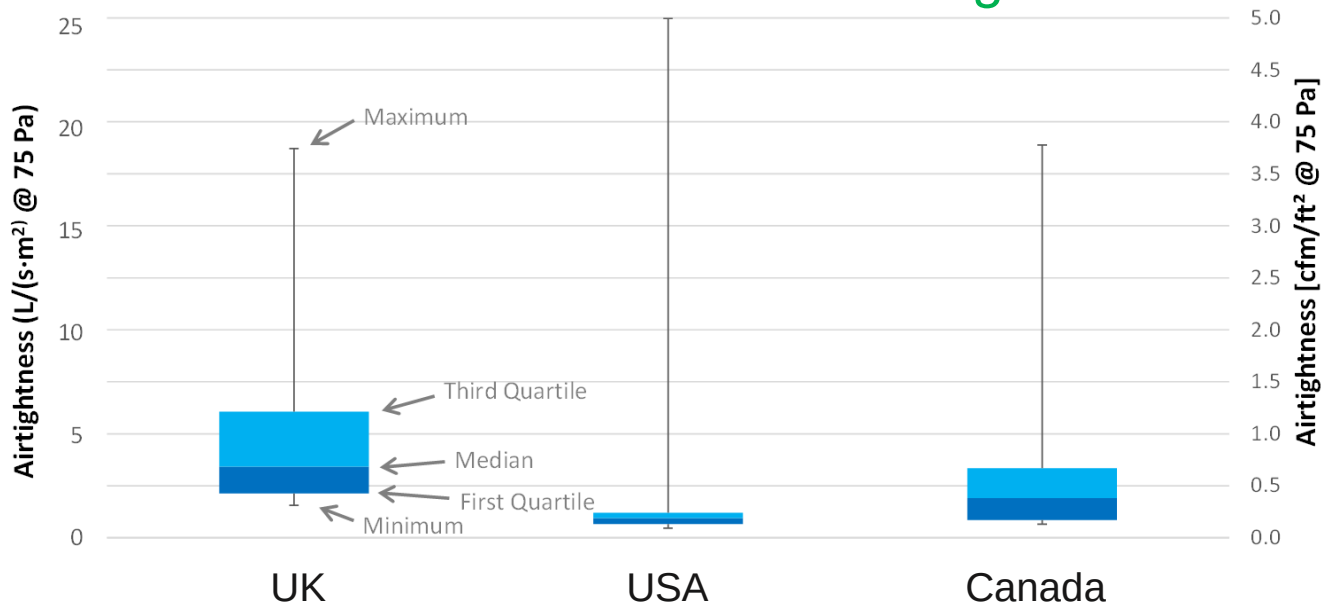
Airtightness of Buildings by Building Location

Looks like the USA is winning…



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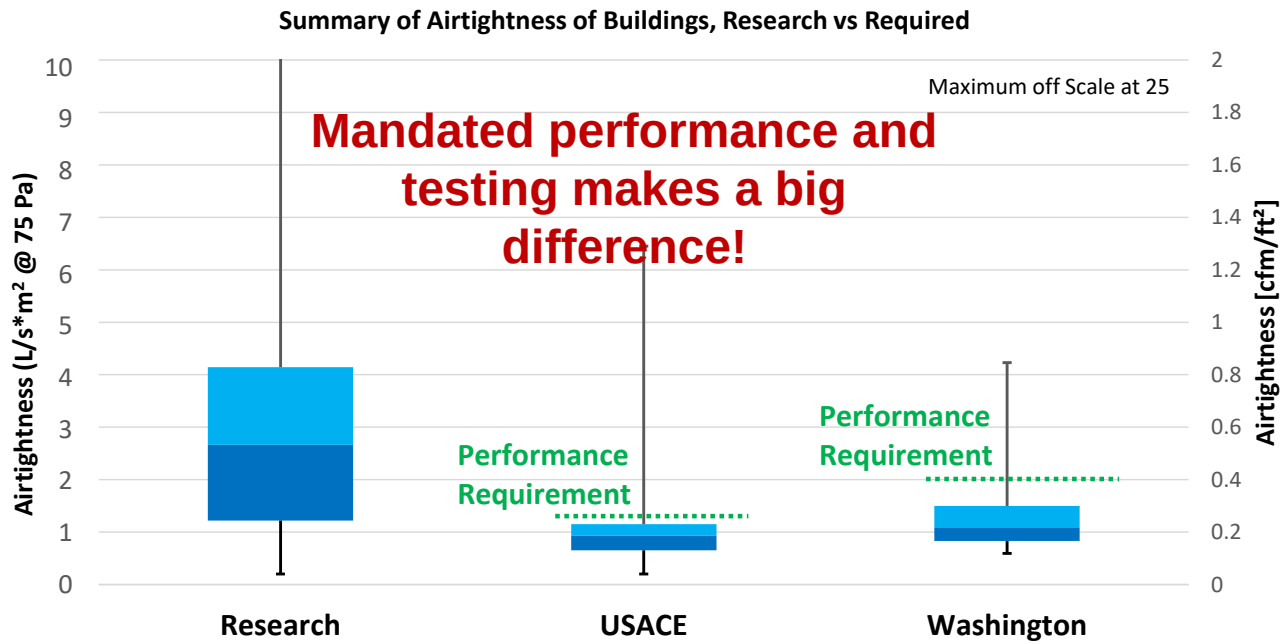
Airtightness of Buildings by Building Location



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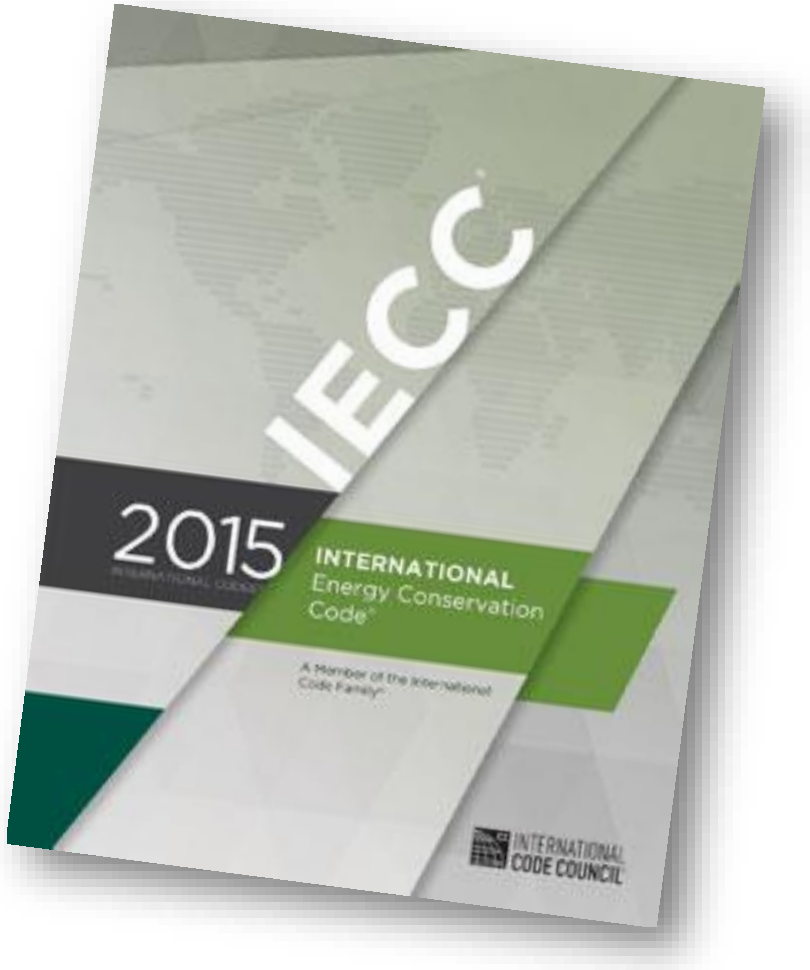
IECC – 2012, 2015

- 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



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Definitions: Specified Air Leakage Rates

	ASHRAE 90.1 Append. Z (cfm/ft² @ .3" w.c.)	US Army Corps Engineers	Canada NBC (L/(s*m² @75Pa)
Material	0.004		0.02
Assembly	0.04		0.2
Building	0.4	0.25	2.0

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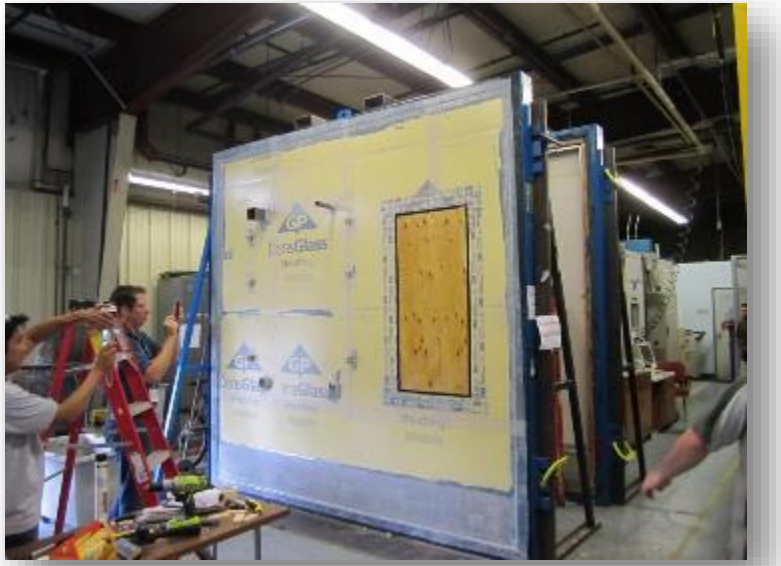
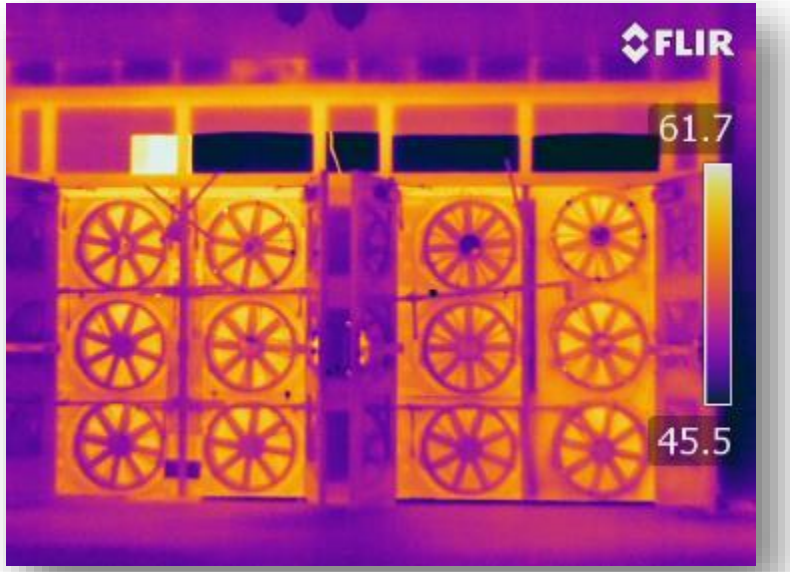
Past Construction Practices: 0.6 to 1.6 cfm/ft²

Materials or Assemblies or WBALT

ASTM 2178



ASTM 2357



ASTM e779….

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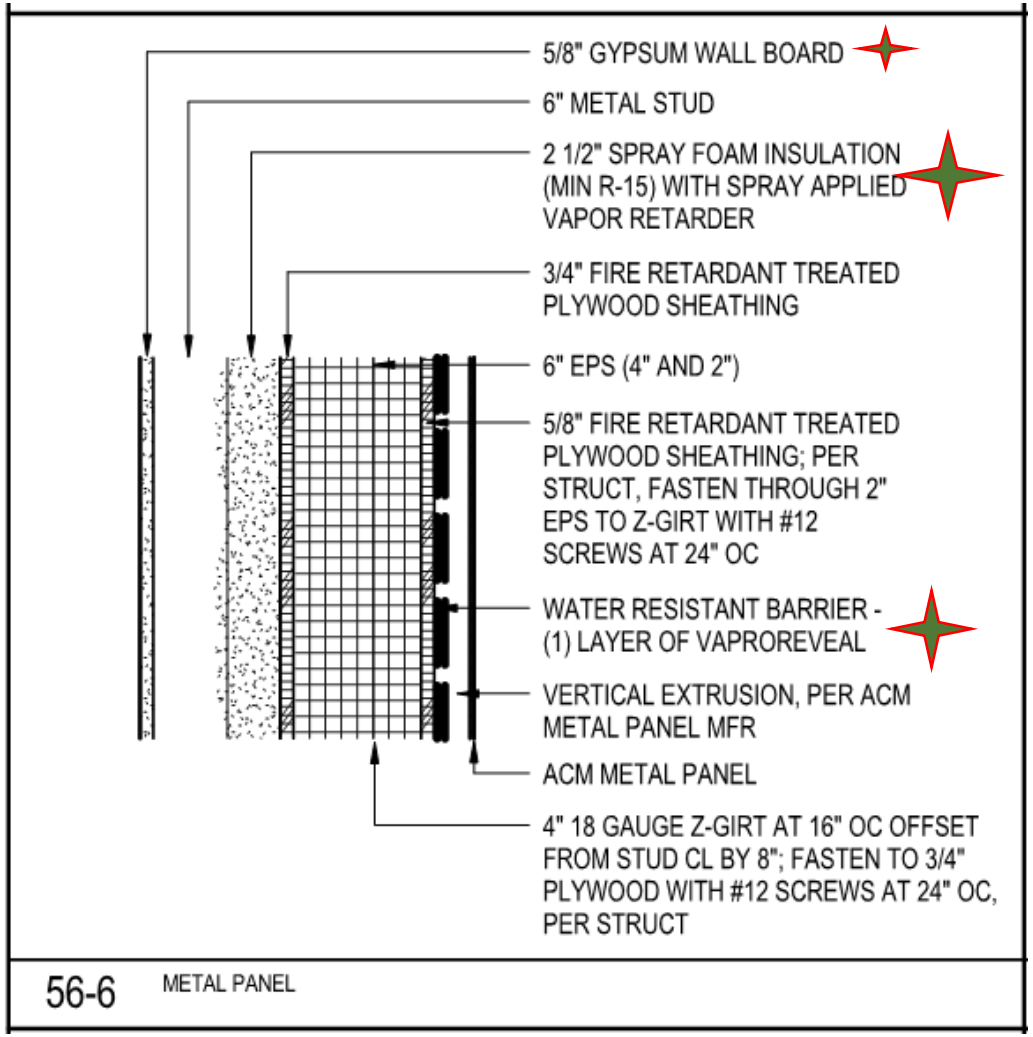
Shouldn't it be and, and

Materials, Assemblies….all Good….right?



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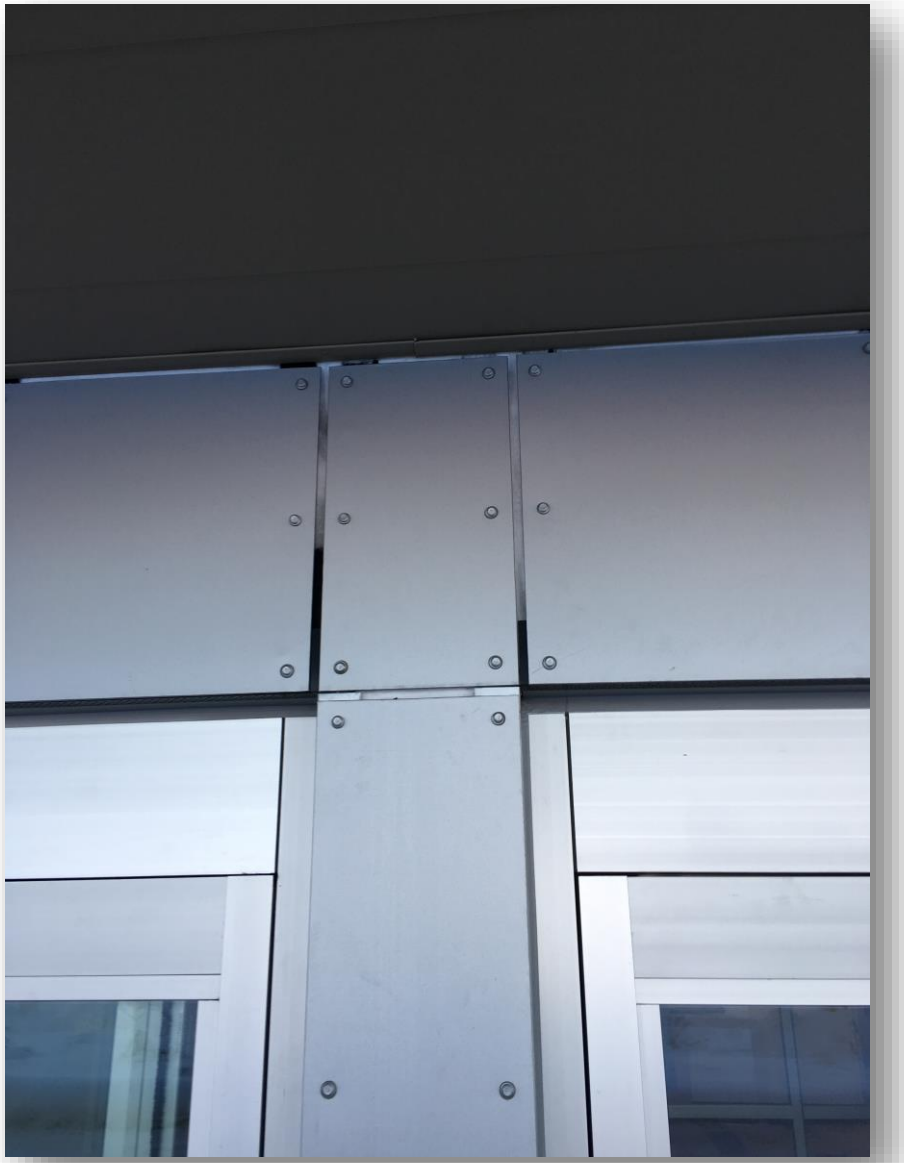
No Continuity



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Ice Maker

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The Building is a Patchwork

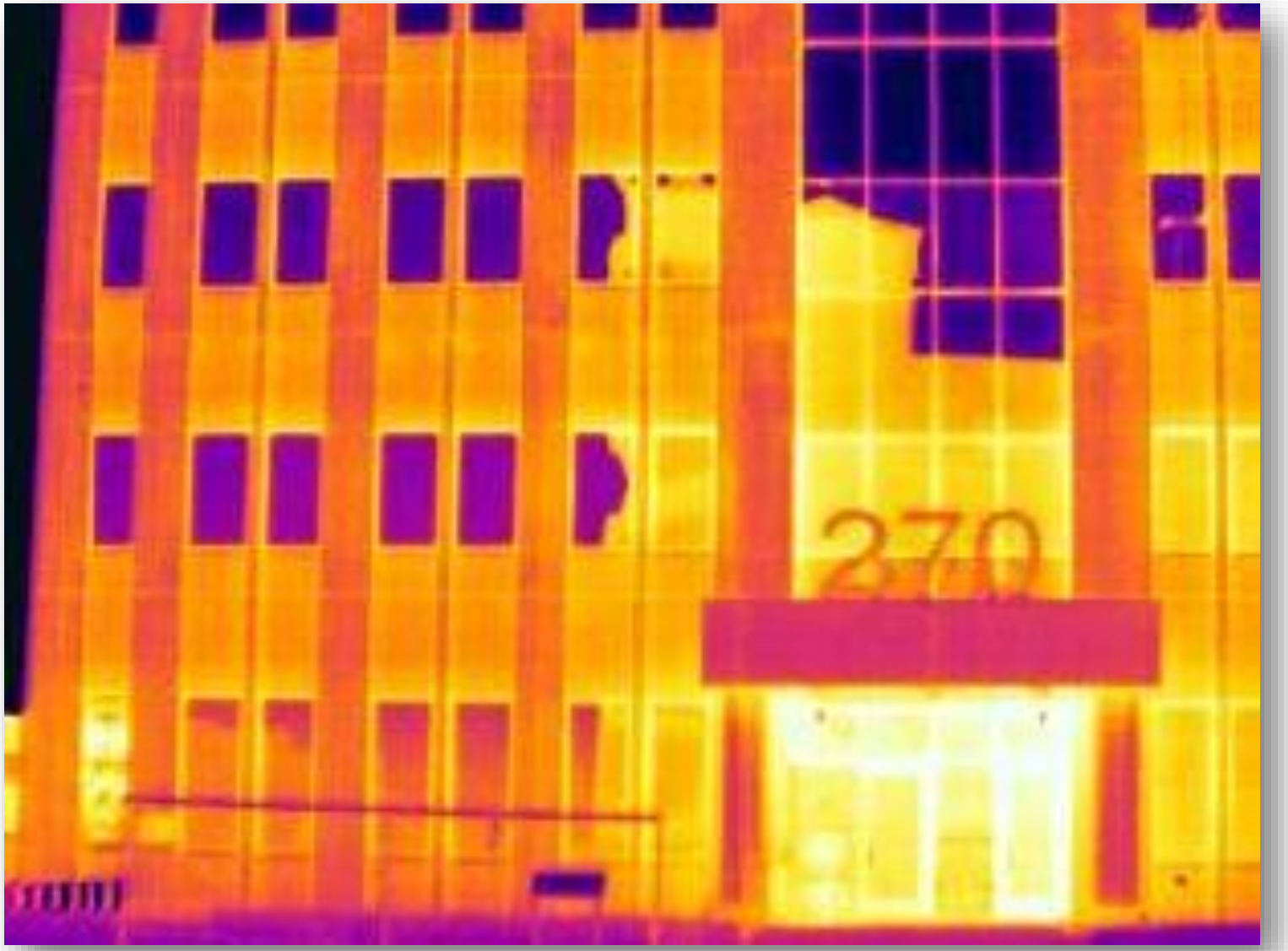

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Photo credit BCRA Inc.

Hand in Hand with HVAC

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But no one measures the room…

State of Utah

STATE OF UTAH - DEPARTMENT OF ADMINISTRATIVE SERVICES

Division of Facilities Construction and Management

DFCM

DESIGN REQUIREMENTS

5.0 HIGH PERFORMANCE BUILDING SYSTEM

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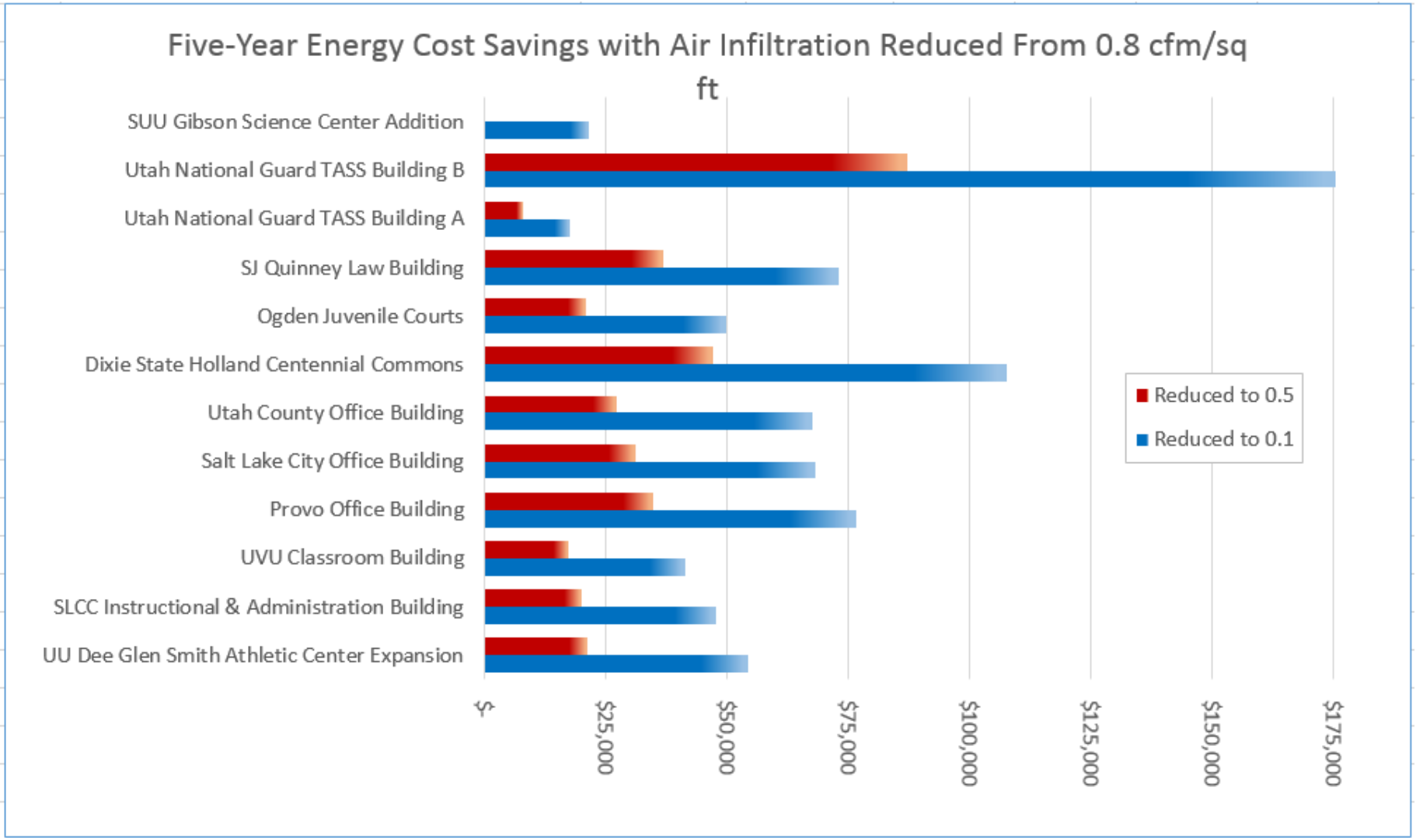
State of Utah – Modeling Air Leakage

Energy modeling by Colvin Engineers



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State of Utah

Requirements per the High Performance Building Standard:

- BECxA hired during programming phase
- Owner's Project Requirements clearly defined before design
- Design review, construction reviews, and testing program
- Mock-up testing
- Field and whole building air leakage testing

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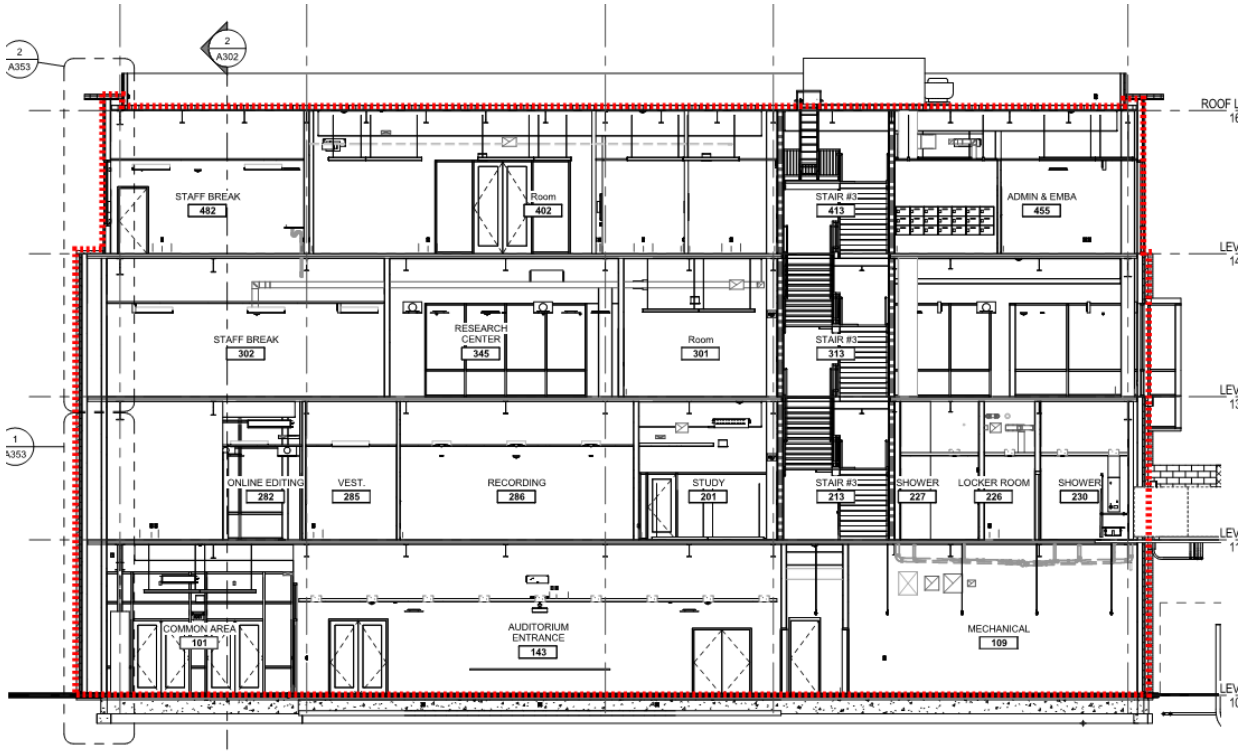
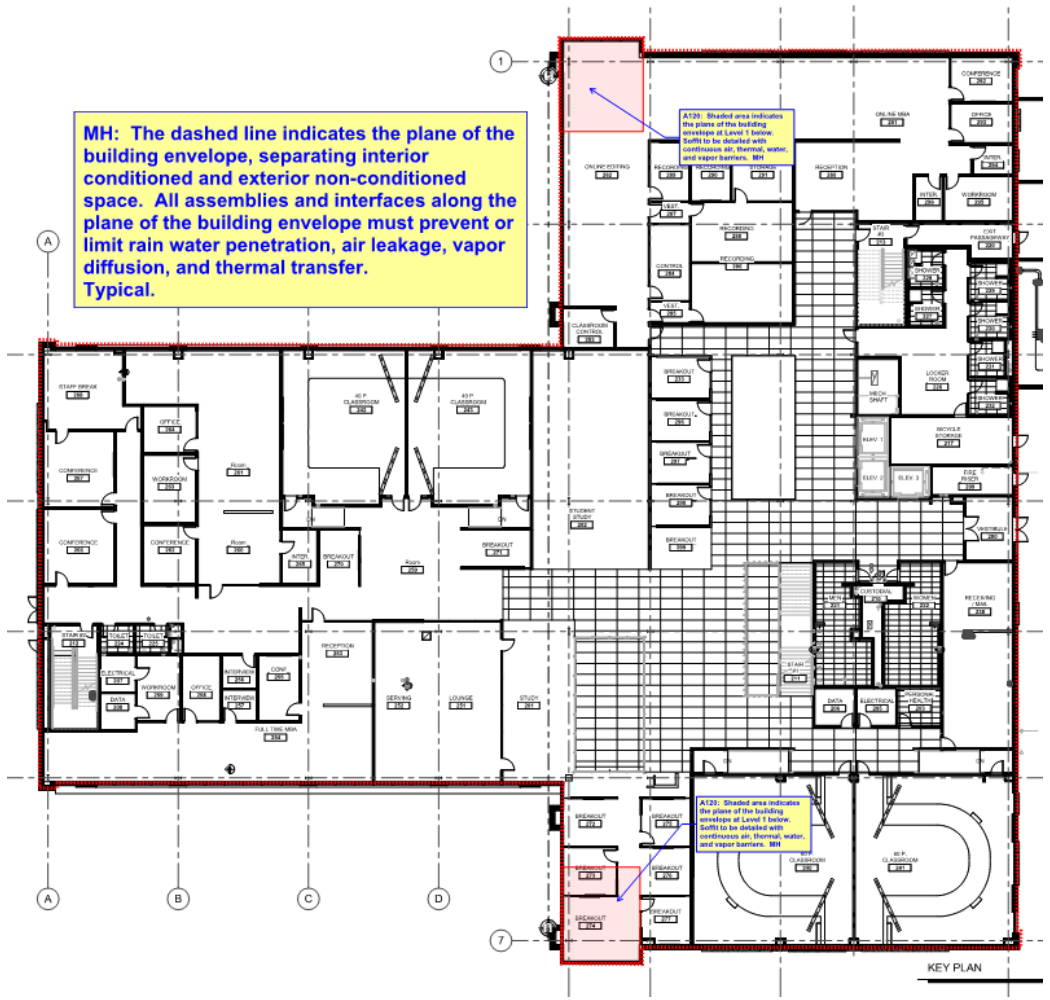
Design





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Mock-up Evaluation

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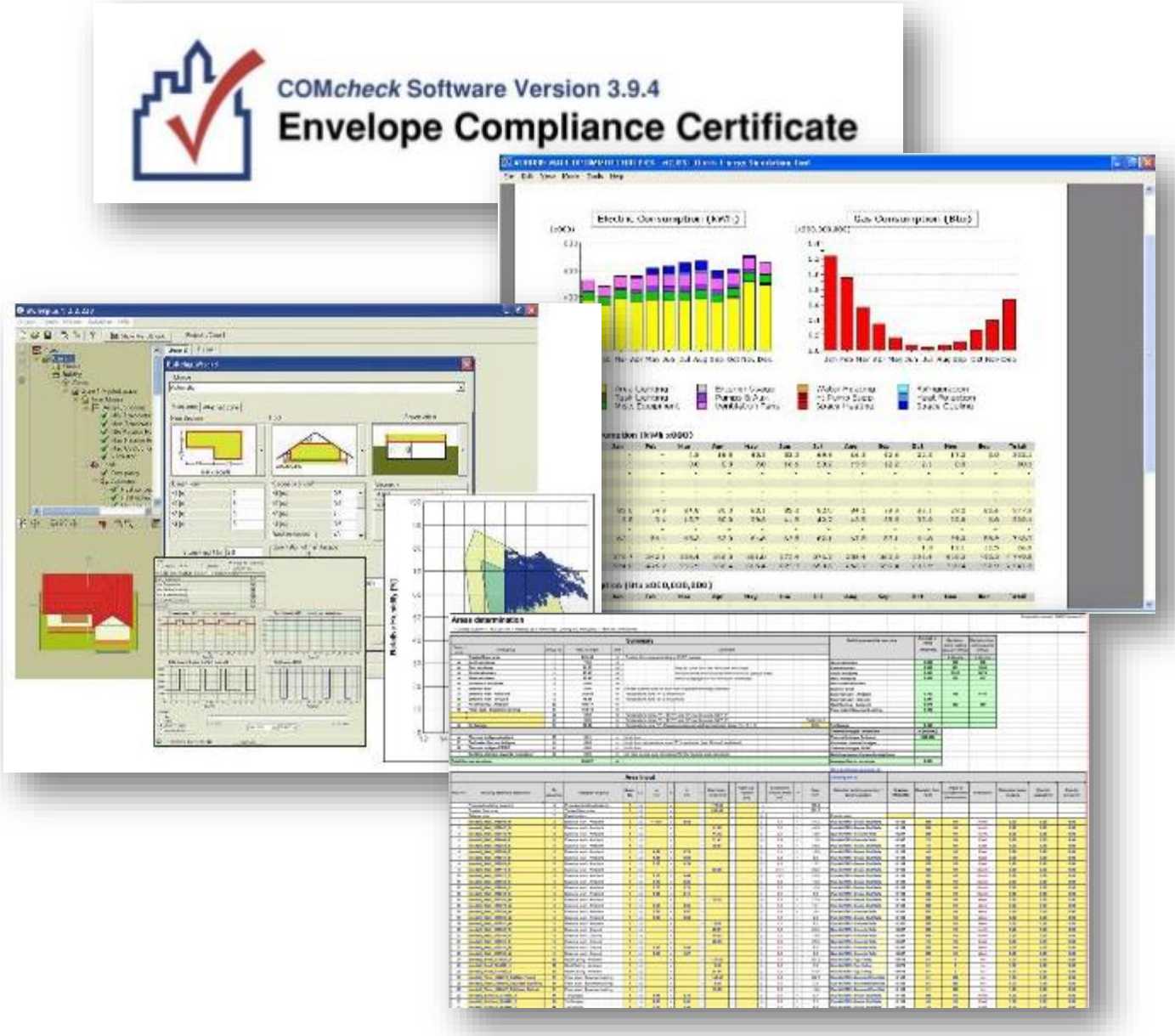
What Does the Energy Model Say?

- 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?



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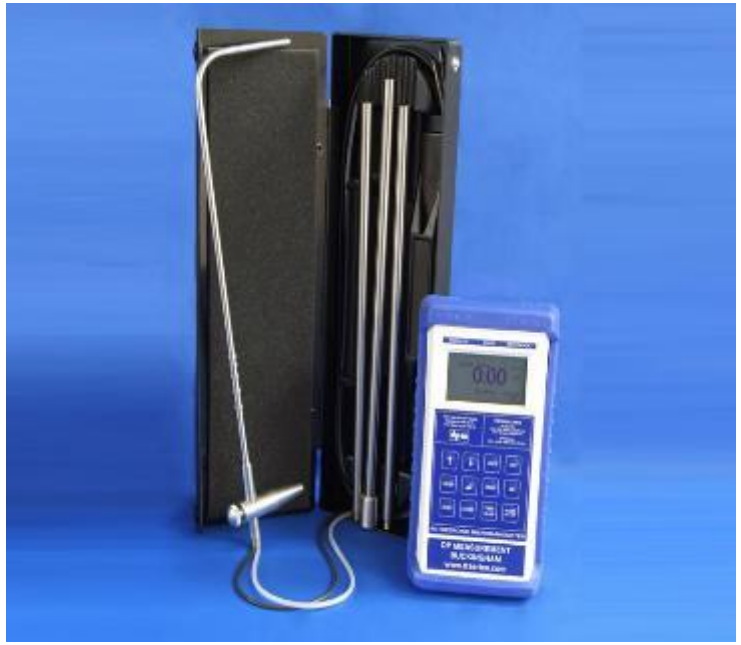
Using the Building's HVAC System



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Depressurization, Pressurization, or Both?

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Appropriateness of ALL Buildings

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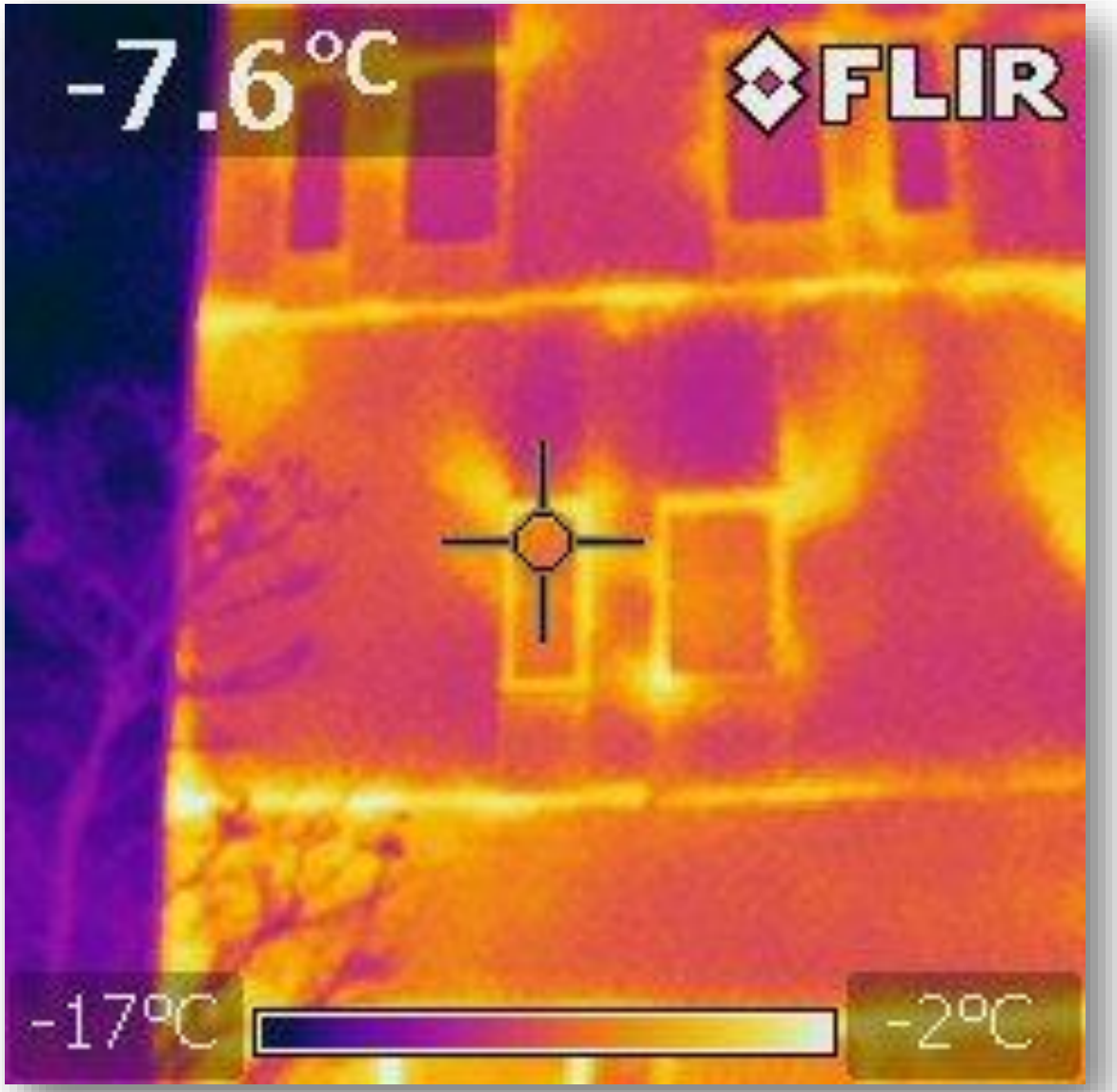
What Happens When It Fails?



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Representative Sample Testing

- Projects with multiple floors of redundancy
- Projects with phased occupancy
- MURB
- Cost

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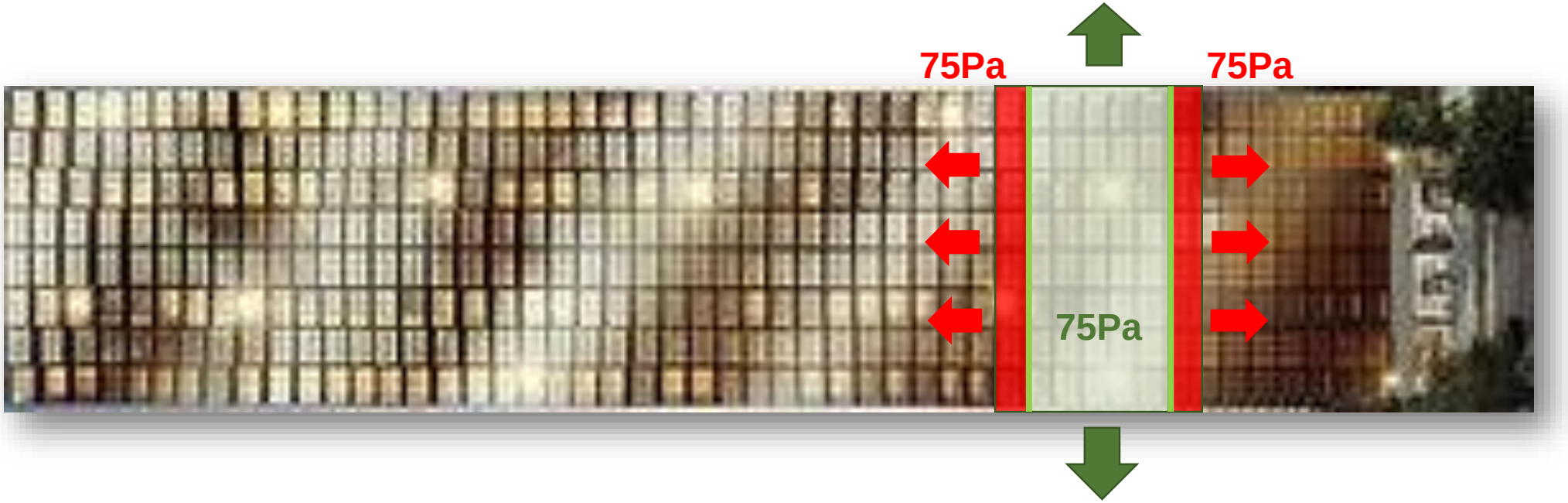
Isolating the Sample in High Rise



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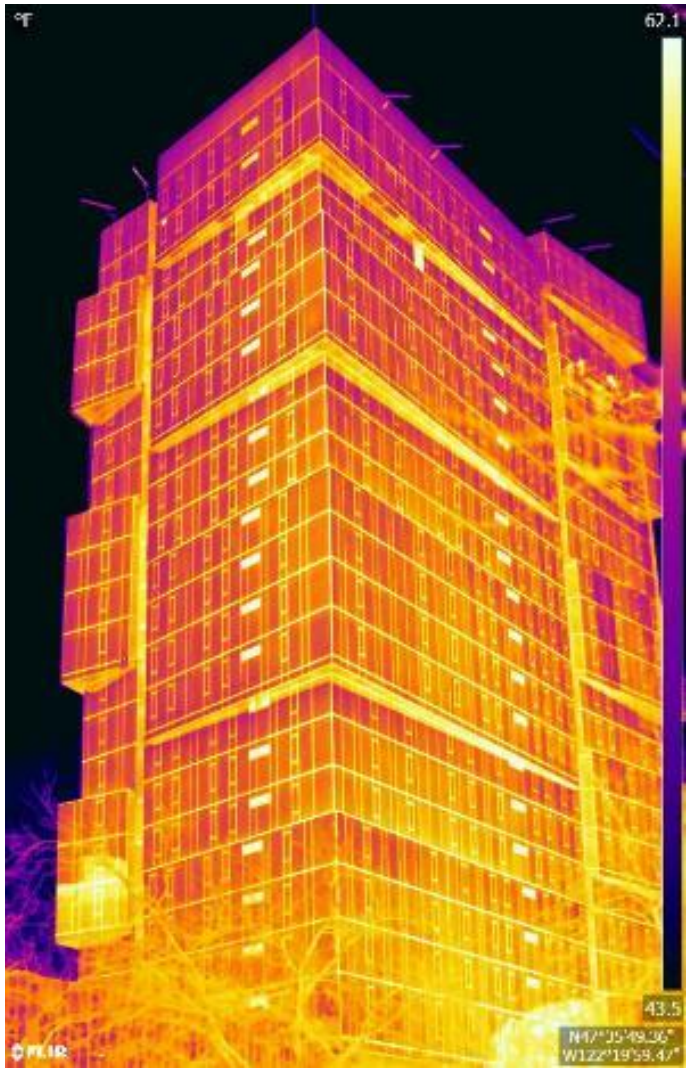
Unique Floor Plates / Wall Profiles



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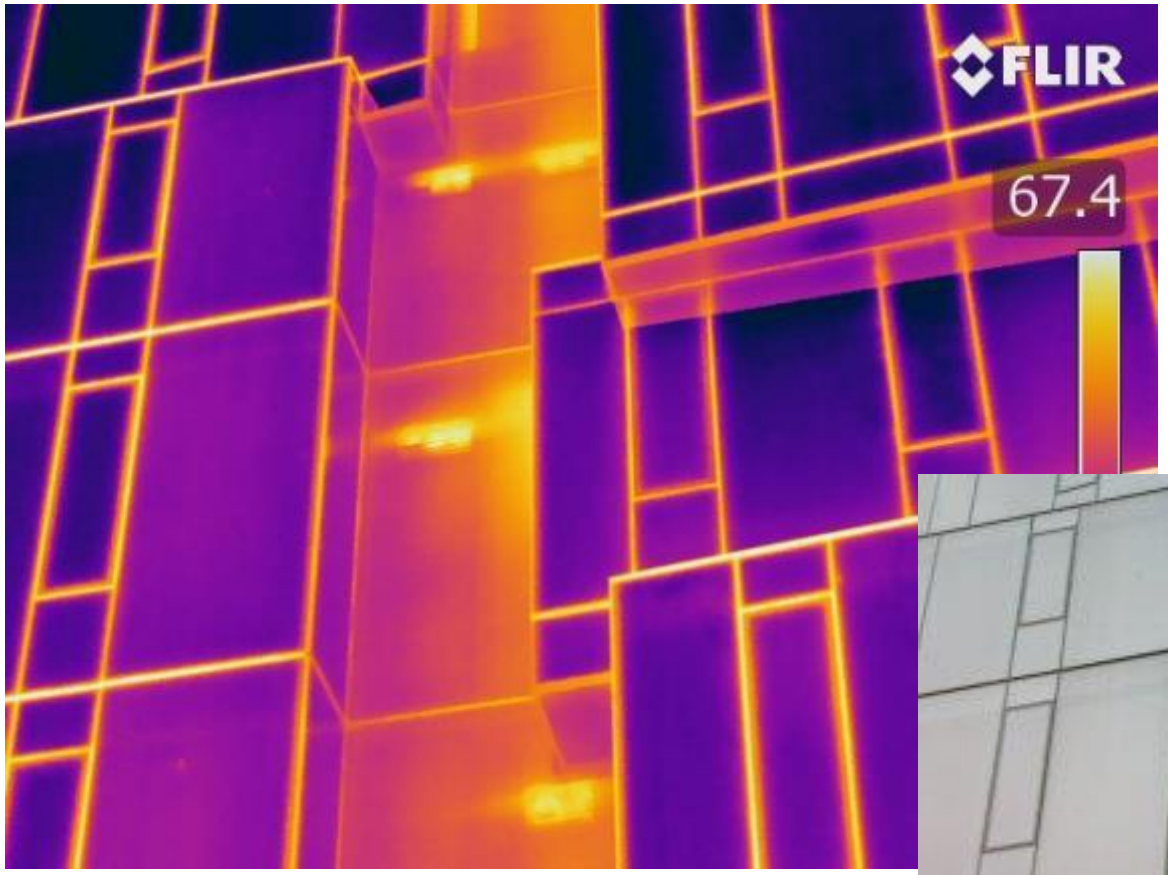
Unique Floor Plates / Wall Profiles



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Unique Floor Plates / Wall Profiles

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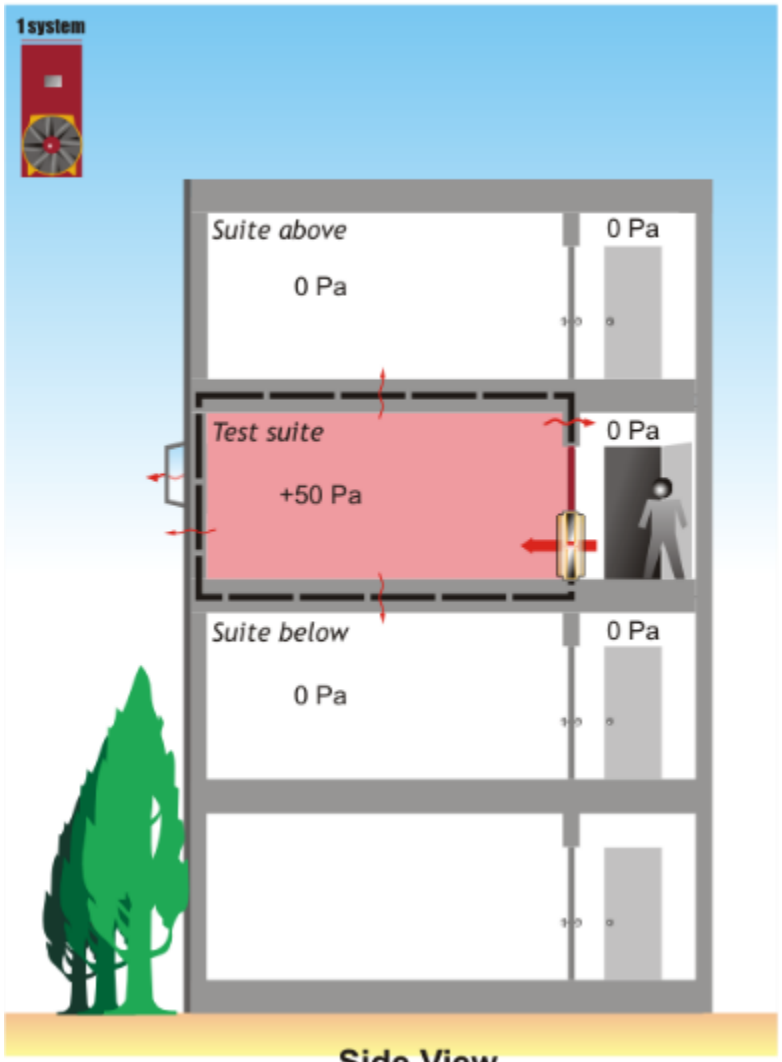
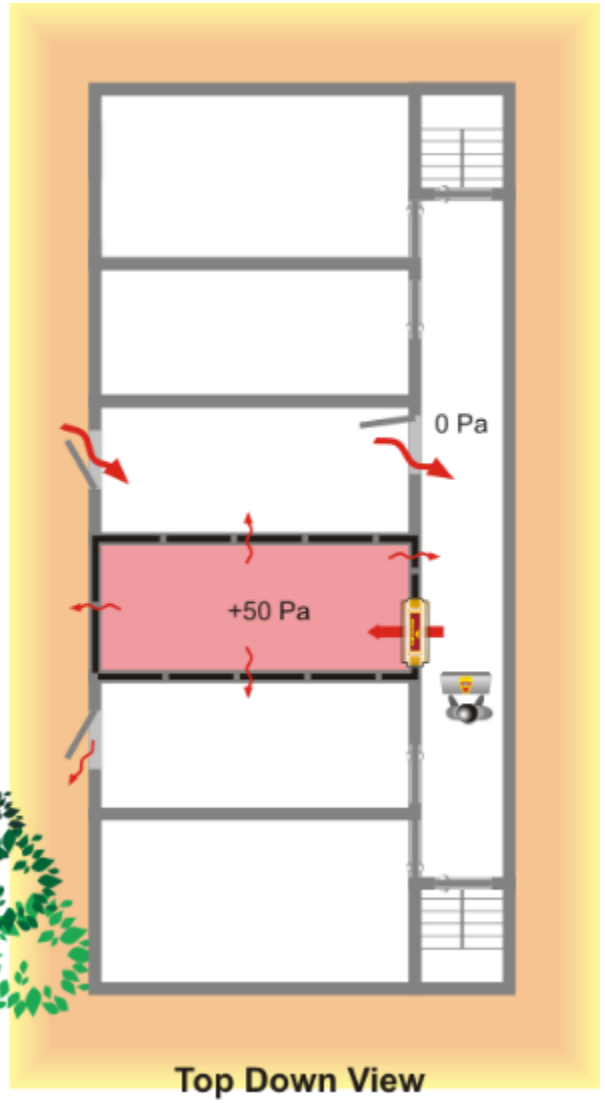
Isolating the Sample in MURBs



Side View



Top Down View

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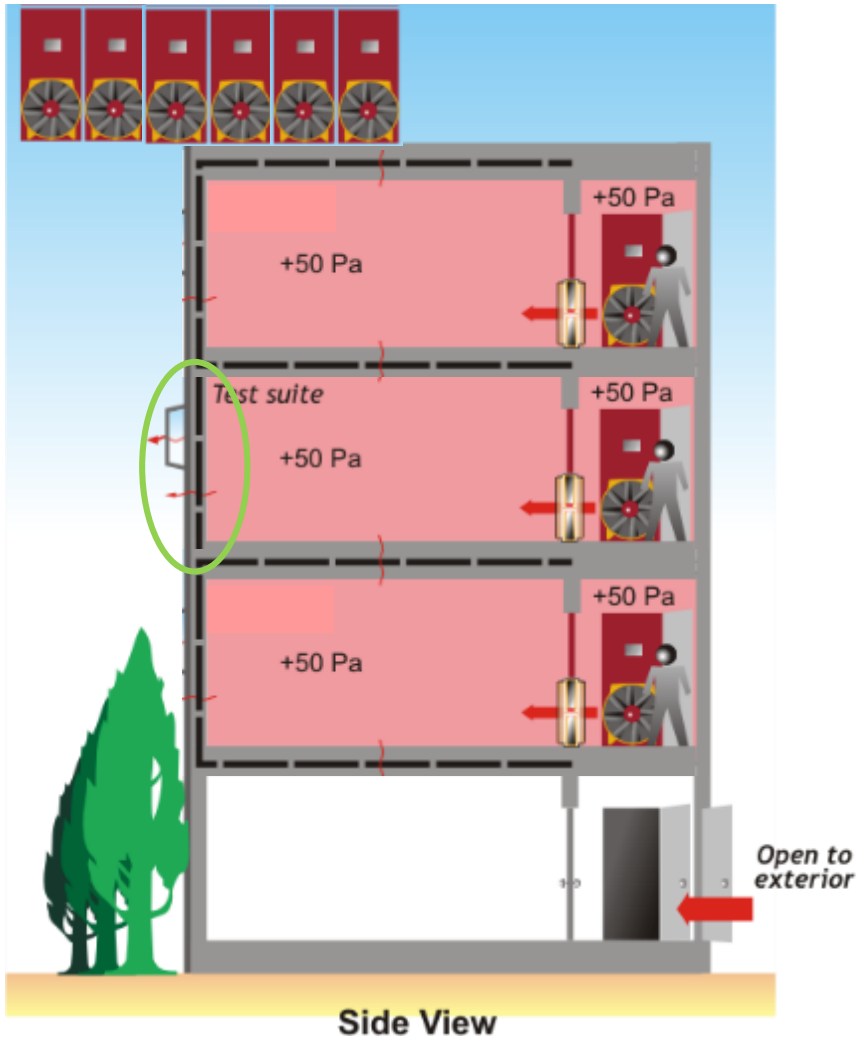
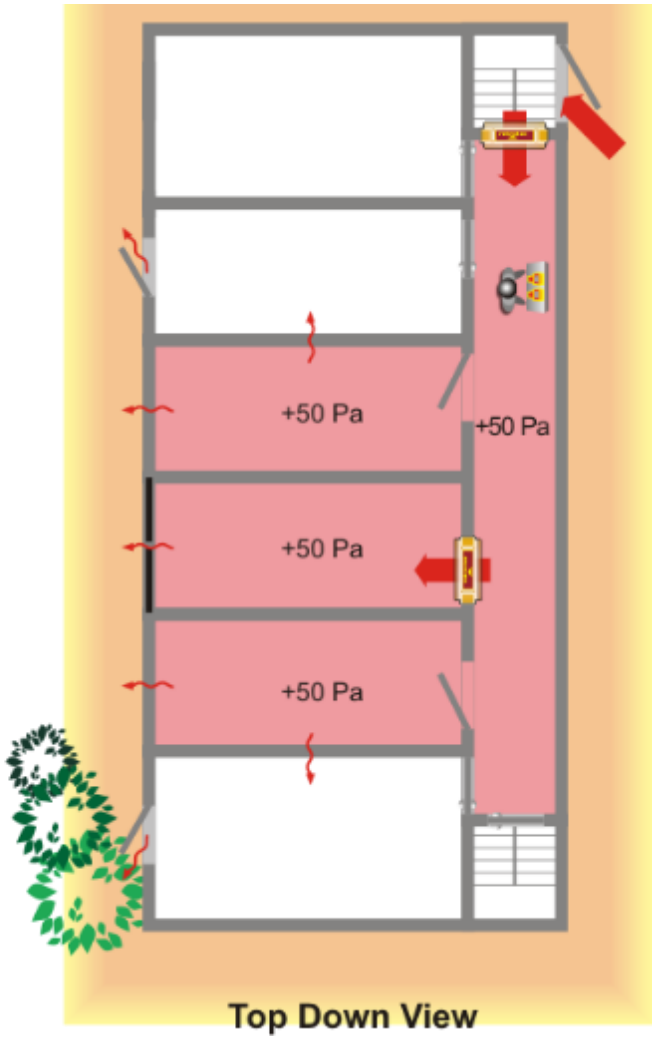
Isolating the Sample in MURBs





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Building Configuration and Size

- Compartmentalization
  - Trend in urban, mixed-use buildings is to include numerous, distinct spaces
  - Necessitates multiple test zones
    - Separate or concurrent tests
    - Coordination with the Contractor
    - Additional Time (money)

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Compartmentalization

- Separate tests vs. Combined tests
- Pressure equalization
- Vertical separation
- Shafts/ Penetrations
- Construction Sequencing

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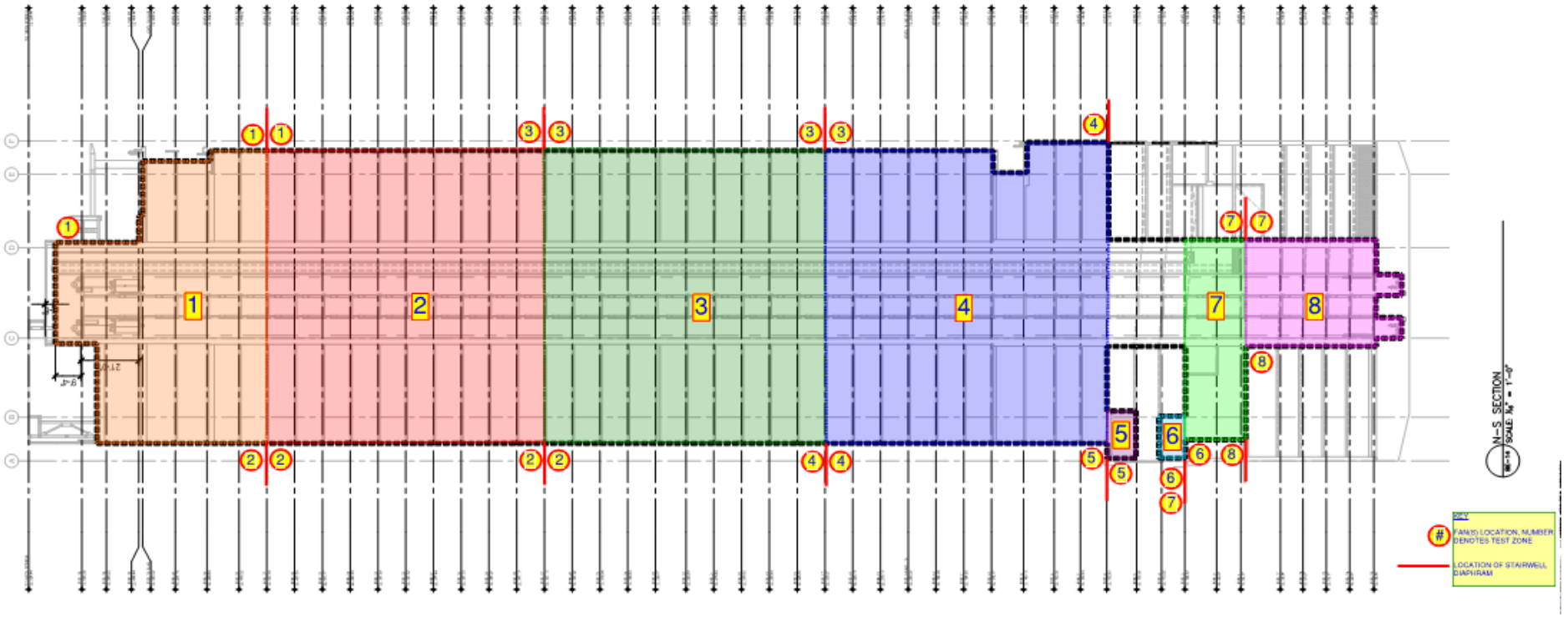
Compartmentalize or Whole Building?

- Tall tower broken up for phased move-in
  - Extensive preparation and testing effort
  - Diaphragms in Stairwells
  - Pressure-equalize above and below test zones



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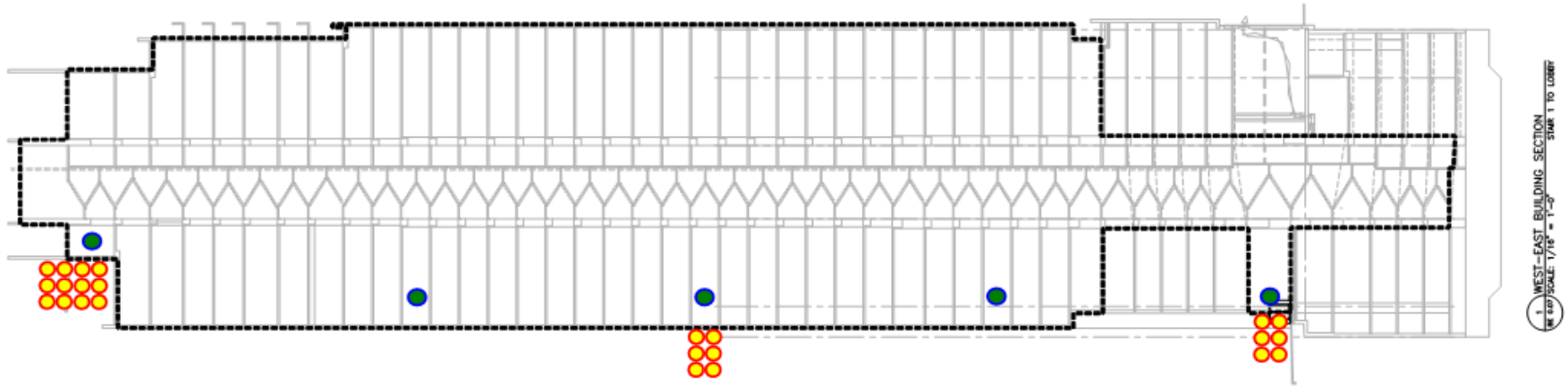
Compartmentalize or Whole Building?

- Tall tower tested as one zone
  - Preparation is simpler
  - Distributed Equipment



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?

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Conclusions

- Air is just the “A” in HAMM
  - H- Heat Barrier
  - A- Air Barrier
  - M_L- Moisture Liquid
  - M_V- Moisture Vapor

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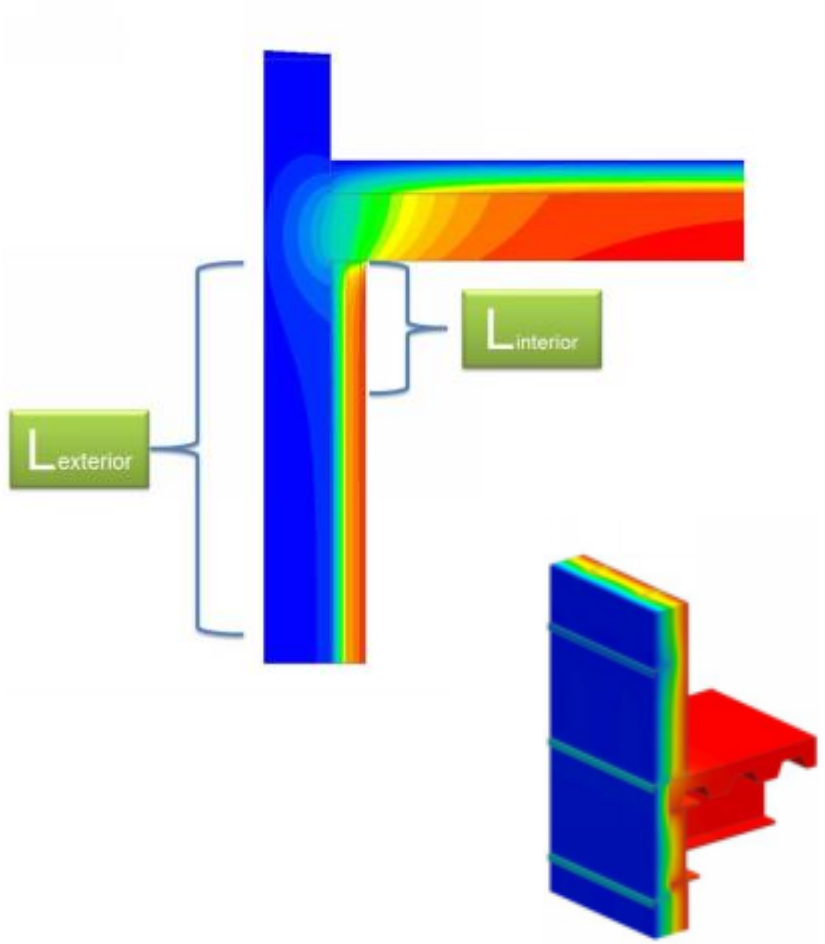
Heat Cx

- The truth about insulation
- The truth about continuous insulation
- Defining, measuring, 2D and 3D heatflow pathways
- Ushering in code/regulation control of thermal bridging



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All Together Now

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Photo credit BCRA Inc.

Special Thanks to:

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Thank you for your time