air barrier association of america

BUILDING ENCLOSURE CONFERENCE 2023

New Energy Code Impacts on Whole Building Air Leakage Testing

Lee Durston

Morrison Hershfield

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New Energy Code Impacts on Whole Building Air Leakage Testing

Over the past decade, energy codes have brought a number of changes with respect to improving the performance of the building envelope both in design and construction. Most notable is the increasing importance placed on air-leakage through the enclosure and how this often unknown value affects many of the energy efficiency metrics that define the performance of the building. In North America, there are currently 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 understood, common design and construction practices will experience shifts toward better performance, as was experienced in the early years of the USACE requirements on which the private sector codes are based. Through a review of multiple case studies of 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.

Lee Durston

Lee Durston is a Principal, Sr. Building Science Consultant with the Building Specialty Services division of Morrison Hershfield. Lee has over 19 years of building science experience over a variety of project types including military, mid-rise, high-rise, natatoriums, government, multi-family residential, and sporting venues. Lee performs holistic building envelope consulting and commissioning as well as forensic investigations using his skills in science and engineering to define, analyze, and remediate problems or failures in the building enclosure. Lee provides training for industry professionals, contractors, architects, developers, Navy Facilities Command (NAVFAC) and the US Army Corps of Engineers (USACE) on topics including Buildings Science, Infrared Thermography, and Air Barrier Design, Construction & Testing. He has served as a contributing editor for the USACE Air Leakage Testing Protocol.

abaa EDUCATION

Learning Objectives

1. Review the theory and historical progression of air tightness requirements and understand the metrics that provide the baseline for levels of air tightness.
2. Understand the basic phases of holistic enclosure consulting related to air barriers and performance verification of air barriers.
3. Familiarize participants with specific building envelope requirements related to air leakage testing in the most recent and upcoming energy codes and how those codes and standards are being enforced.
4. Understand validity, impact, and relevance of the wide range of air tightness codes and standards.

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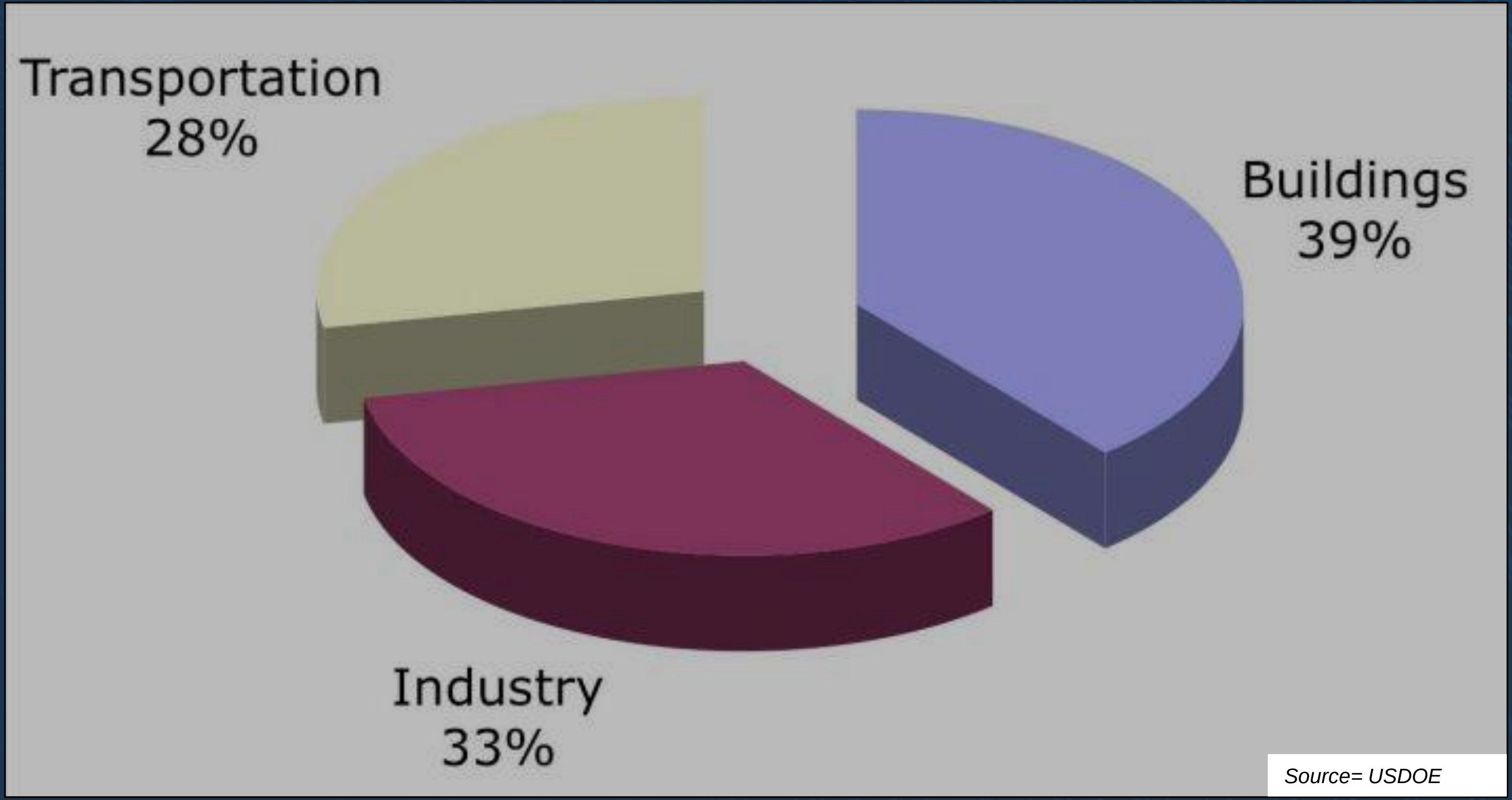
BE BUILDING ENCLOSURE

Why Air Barriers and Why Now?

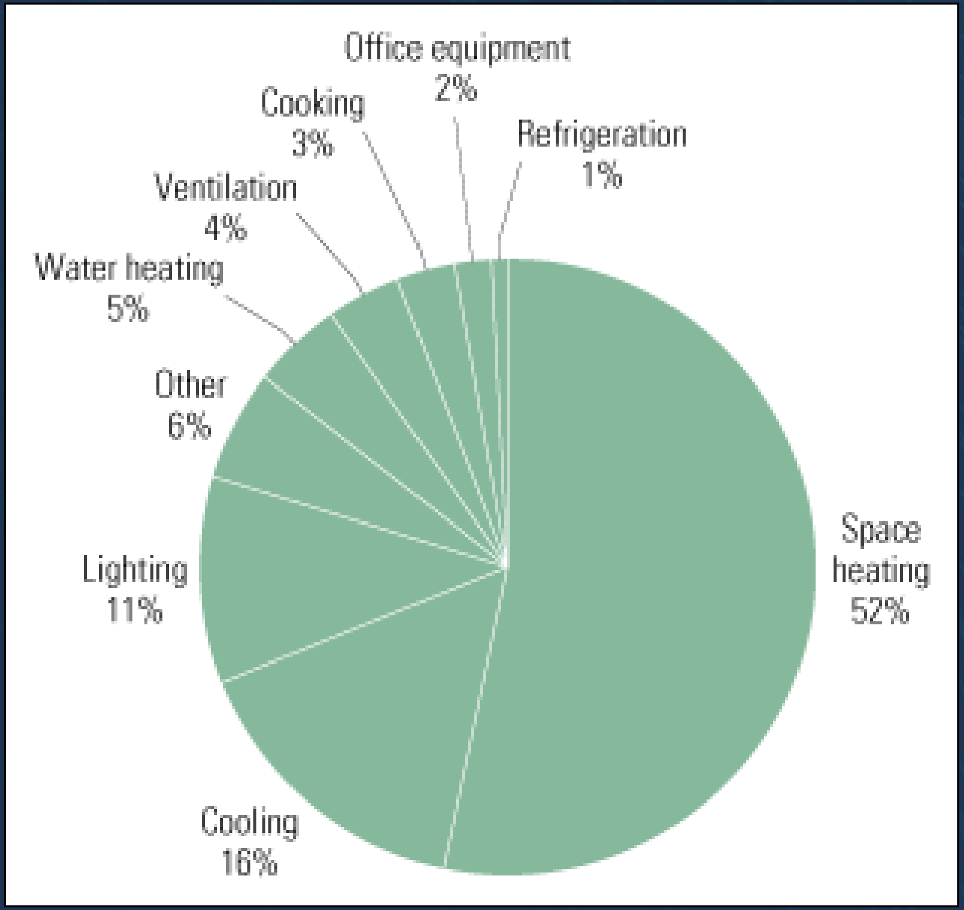
- Energy Conservation Measure
  - First Costs/Construction
  - Operational Costs

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

Where is Energy Used?



How Buildings Use Energy

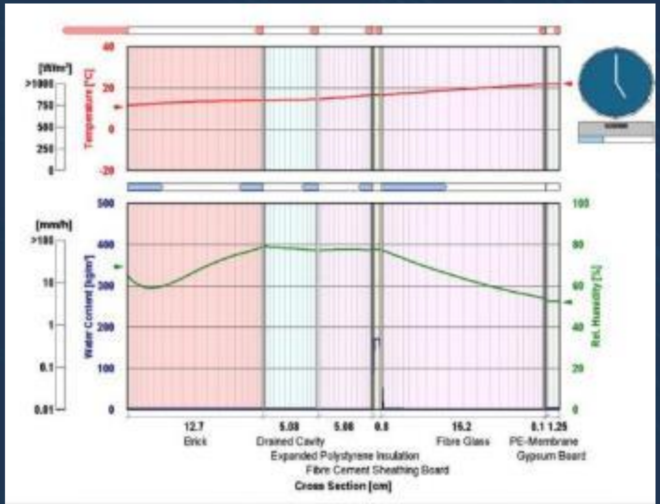


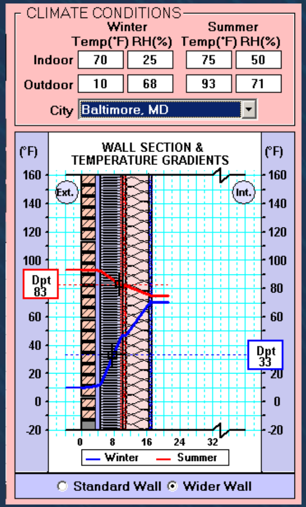
- Building Envelope (walls, roof, windows, and floors)
- Lighting
- Heating, Ventilating, and Air Conditioning (HVAC)
- Internal and Process Loads (cooking, hot water, manufacturing, etc.)

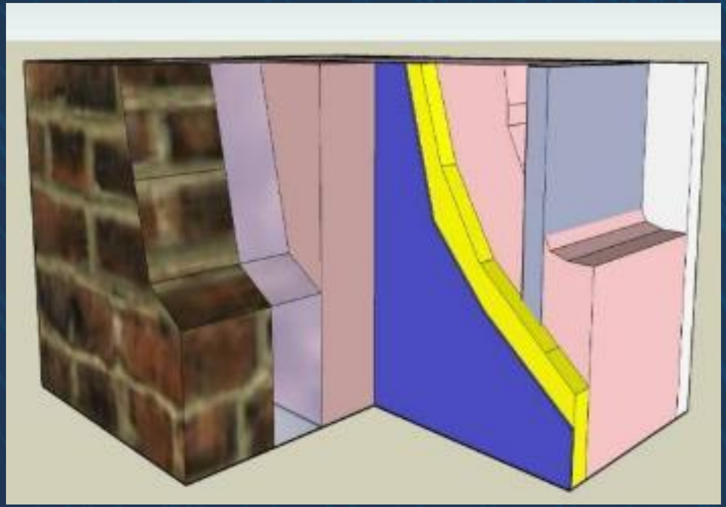
Energy

Durability

HAMM- Building Enclosure Design



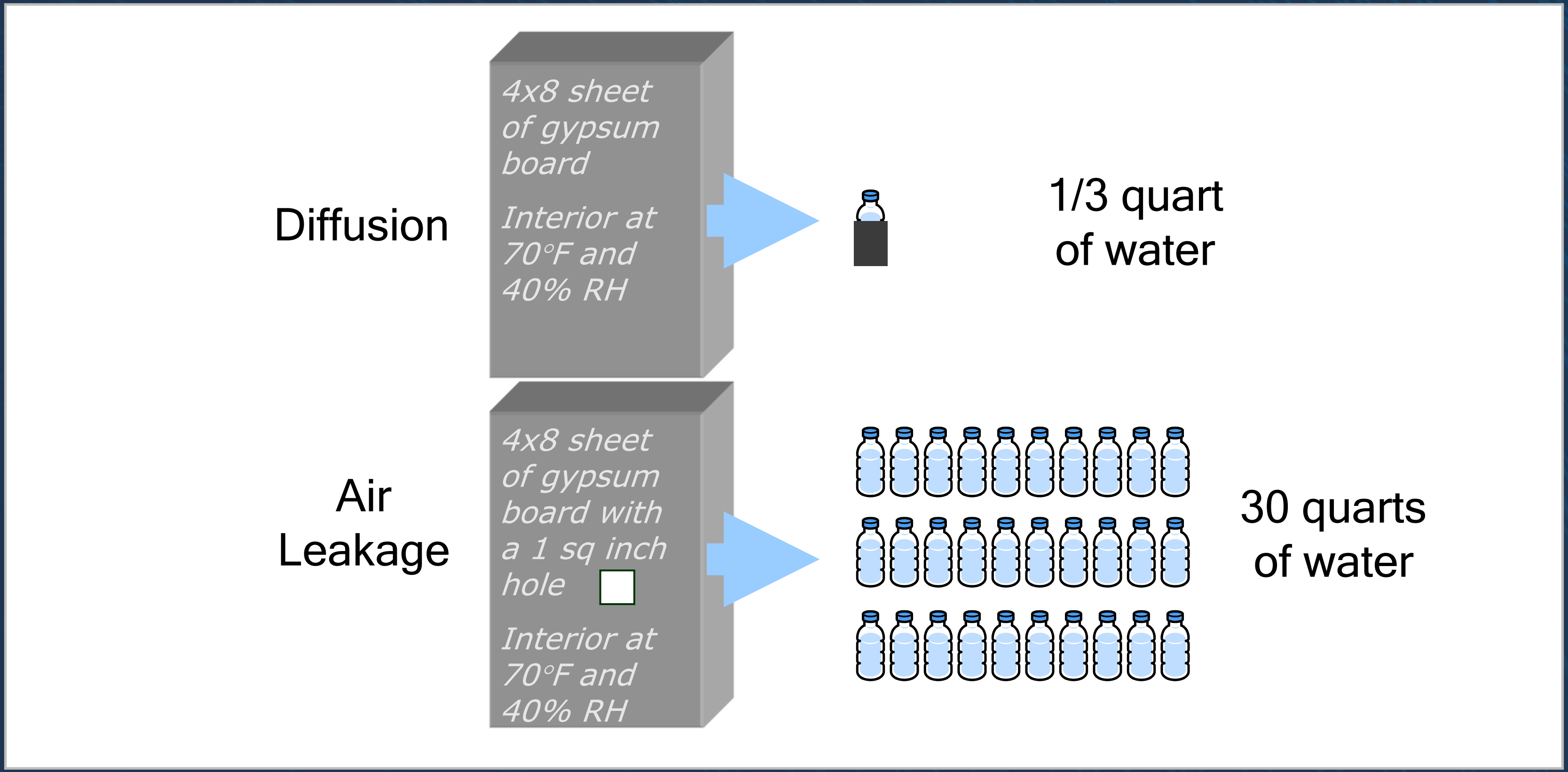




Moisture Transport - Vapor Diffusion

Moisture Transport – Air Leakage

Airborne Moisture



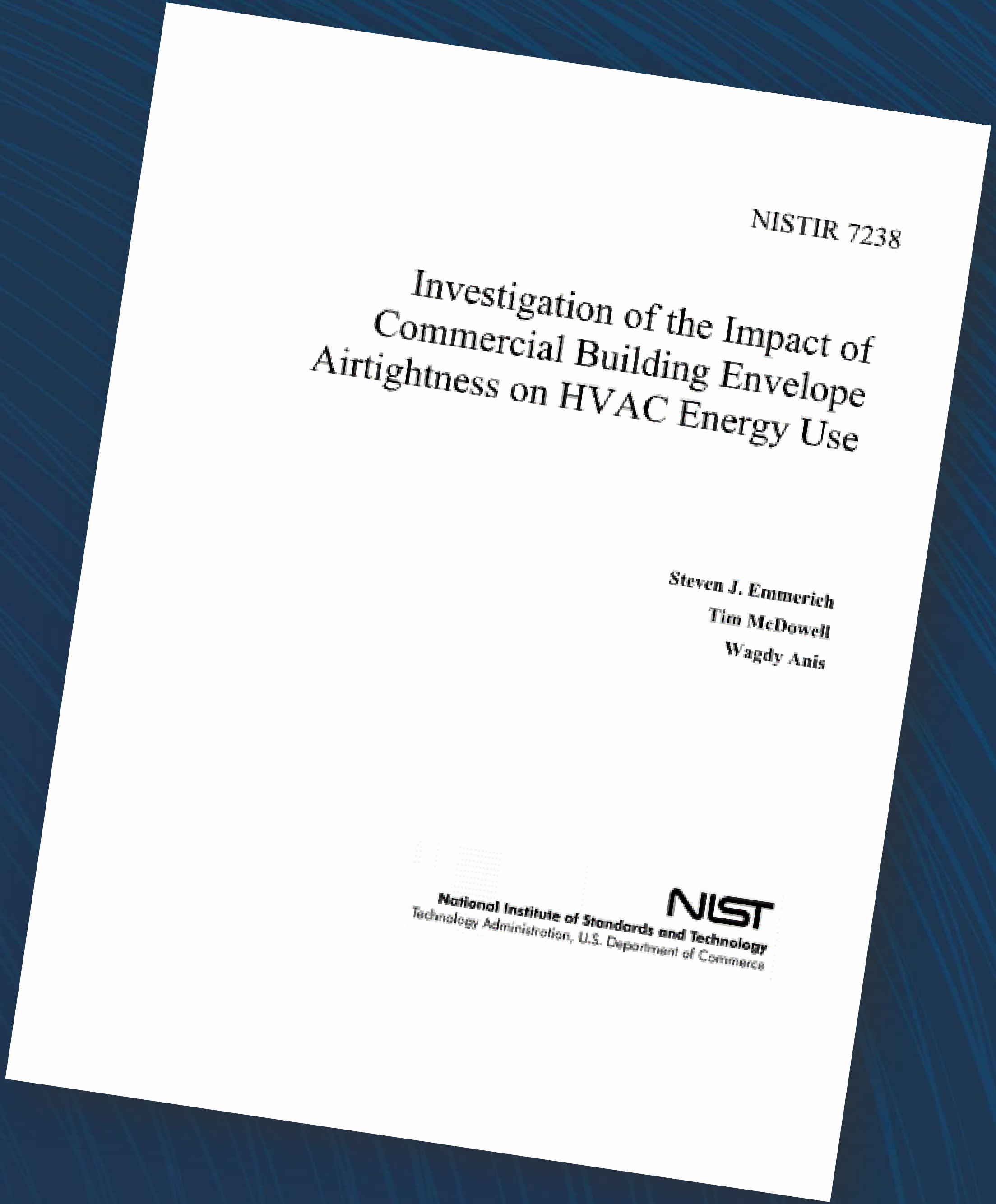
Vapor Diffusion or Vapor Laden Air?

Air Leakage Issues

Air Leakage Issues

It haunts me……

Is it all just Hot Air?



NISTIR 7238

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

Steven J. Emmerich
Tim McDowell
Wagdy Anis

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

green·wash

/ˈɡrēnwôSH,ˈɡrēnwäSH/

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

Stop the GREENWASH!

Stop the GREENWASH!

MailOnline

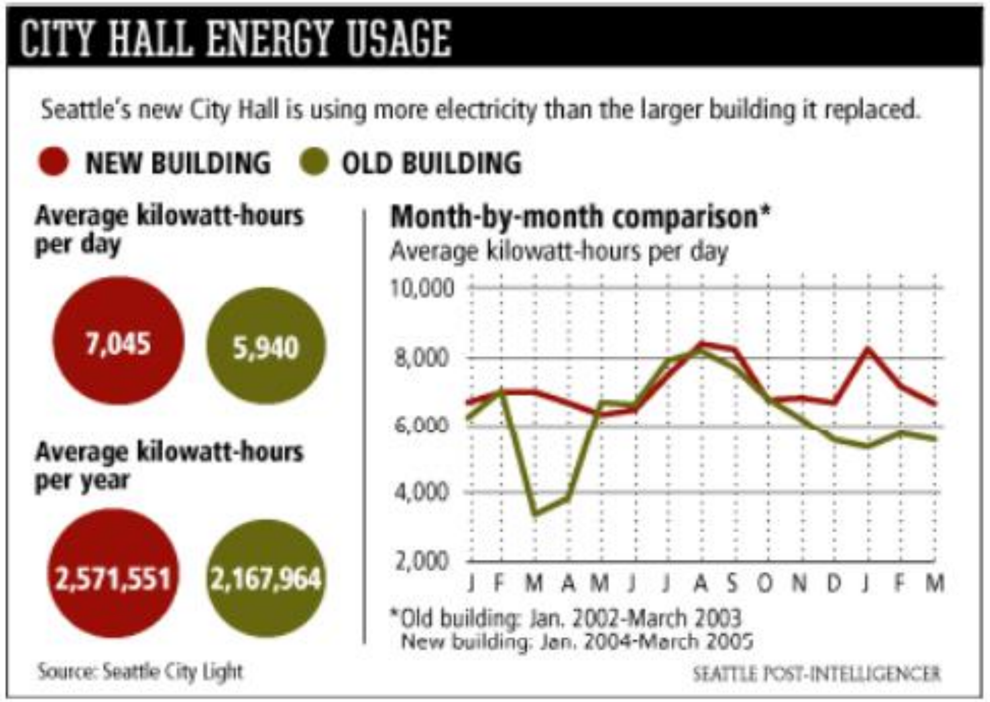
Airline asks passengers to use the toilet before boarding... so they will weigh less and help cut carbon emissions

- 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.

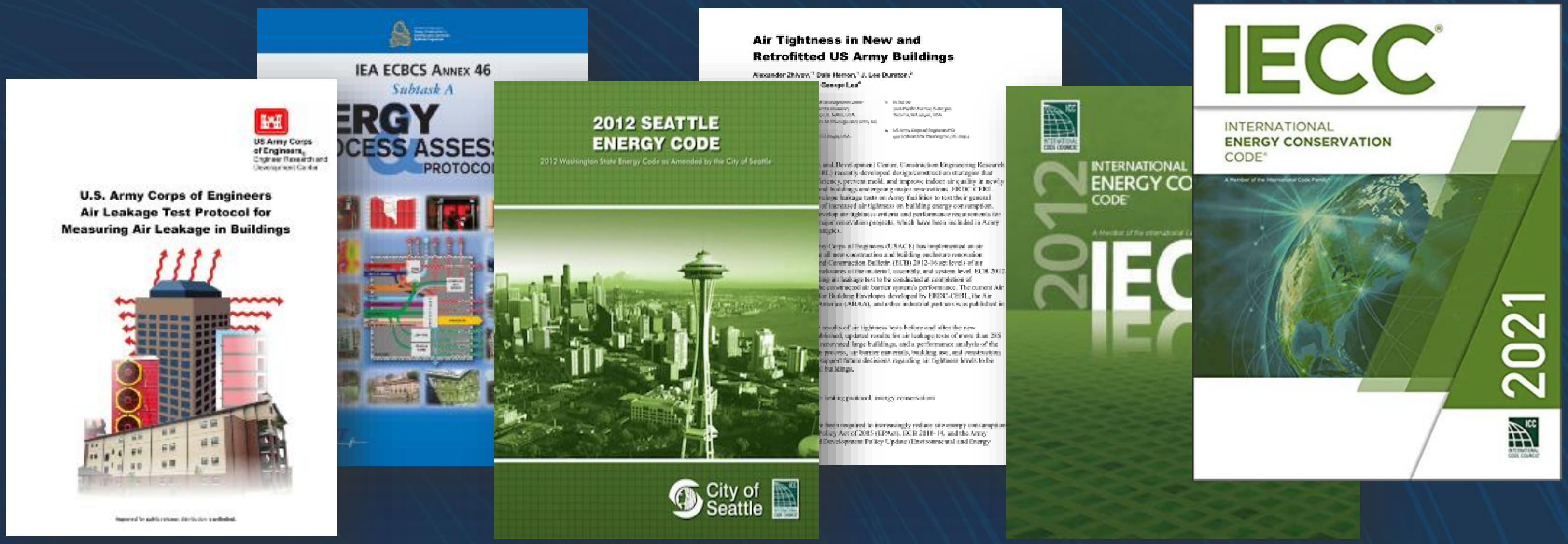
Stop the GREENWASH!

Stop the GREENWASH!

Stop the GREENWASH!



From Then to Now



A Look At Requirements Globally

			cfm/ ft²[L/s*m²]at 75Pa
US	ASHRAE / IECC	0.40 cfm/ft^2 at 75Pa	**0.40/2.02**
US	LEED	1.25 in^2 EfLA @ 4 Pa / 100 ft^2	**0.30/1.52**
US	ASHRAE Average handbook of fundamentals	0.30 cfm/ft^2 at 75Pa	**0.30/1.52**
	USACE / FEDERAL	**0.25 cfm/ ft^2 at 75Pa**	**0.25/1.27**
UK	TS-1Commercial Tight	2 m^3/h/m^2 at 50 Pa	**0.14/0.71**
CAN	R-2000	1 in^2 EqLA @10 Pa /100 ft^2	**0.13/0.66**
US	ASHRAE 90.1 Tight handbook of fundamentals	0.10 cfm/ft^2 at 75Pa	**0.10/0.51**

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

Leakier

Tighter

Passive House 0.06 cfm/ft^2 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 220,00

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)

Early Push Back to an Air Tightness Requirement

US Army Corps of Engineers®

- 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

Test 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

Lessons Learned

Poly Vapor Barrier = Air Barrier

Video credit BCRA Inc.

Video credit BCRA Inc.

Size Matters- Detroit Arsenal Building 270

Detroit Arsenal Bldg. 270

Detroit Arsenal Bldg. 270

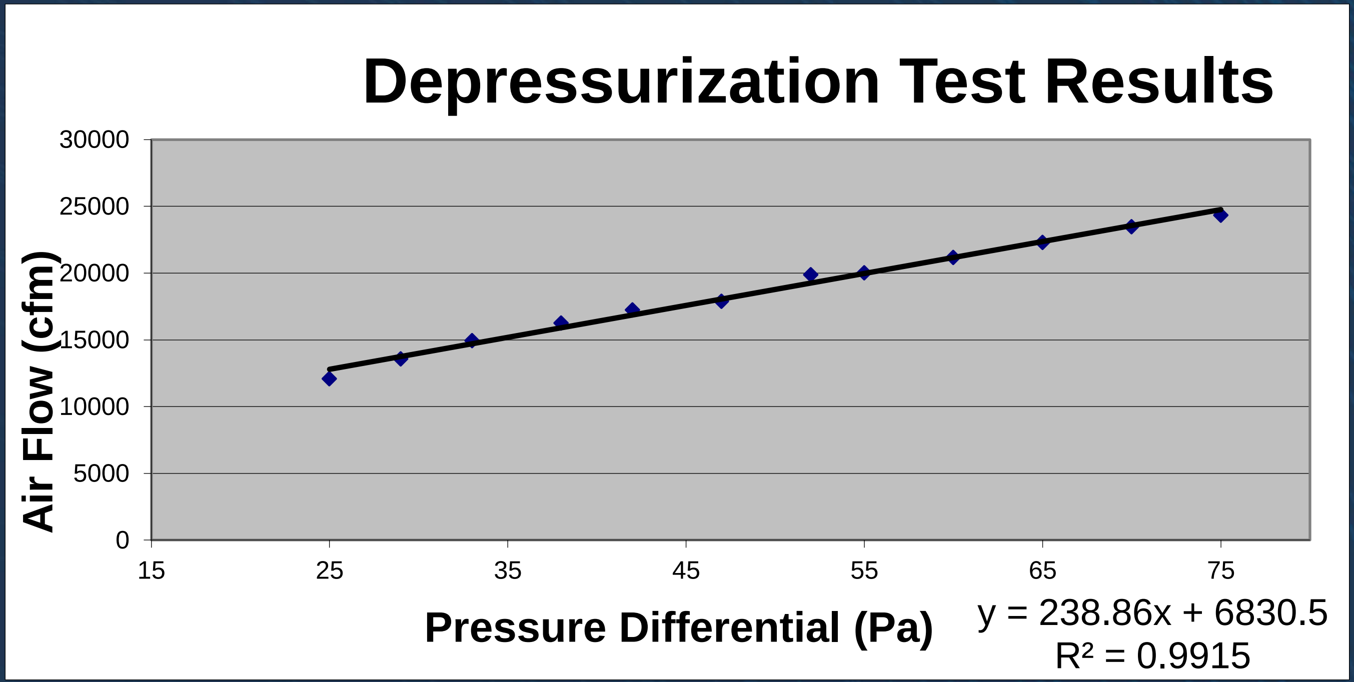
WBALT

Test Set-Up

Target Air Leakage

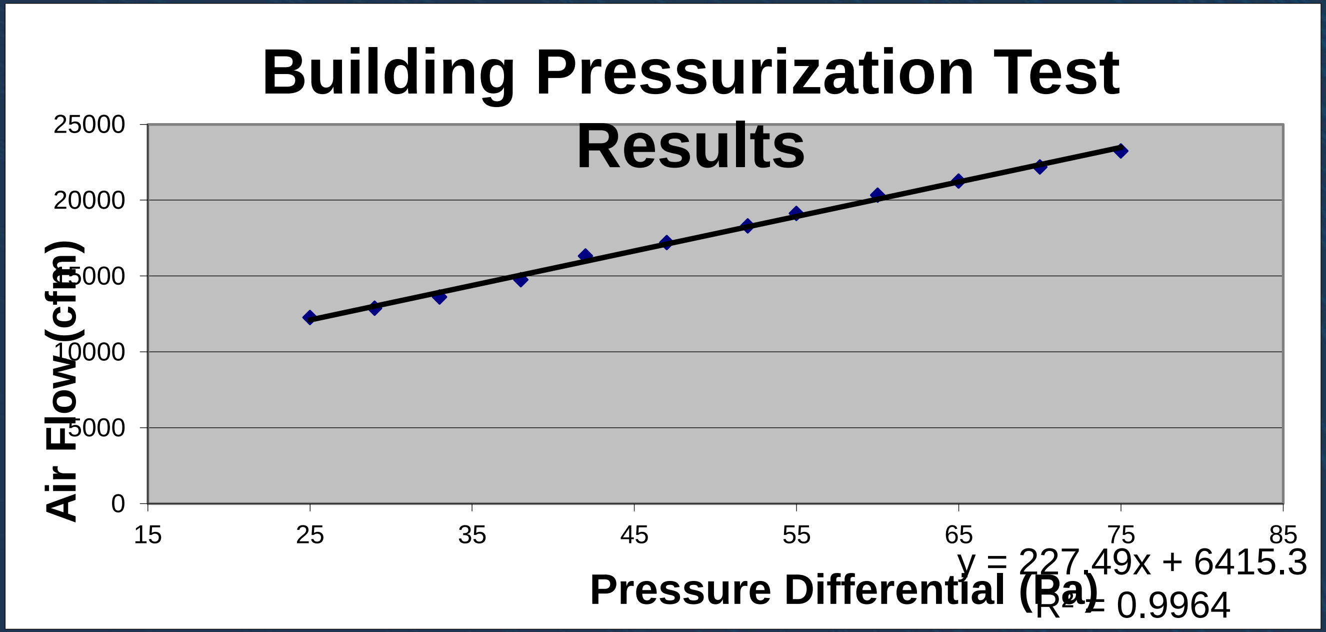
USACE	cfm/sf@75Pa
RFP Requirement	*.25cfm/sf @75PA*
Detroit Arsenal Bldg. 270 *Allowable leakage rate*	*Envelope SF: 144,622* *36155.5 cfm*

Data



Depressurization Test Results
30000
25000
20000
15000
10000
5000
0
Air Flow (cfm)
15
25
35
45
55
65
75
Pressure Differential (Pa)
y = 238.86x + 6830.5
R² = 0.9915

Data



Building Pressurization Test Results
25000
20000
15000
10000
5000
0
15
25
35
45
55
65
75
85
Air Flow (cfm)
Pressure Differential (Pa)
y = 227.49x + 6415.3
R² = 0.9964

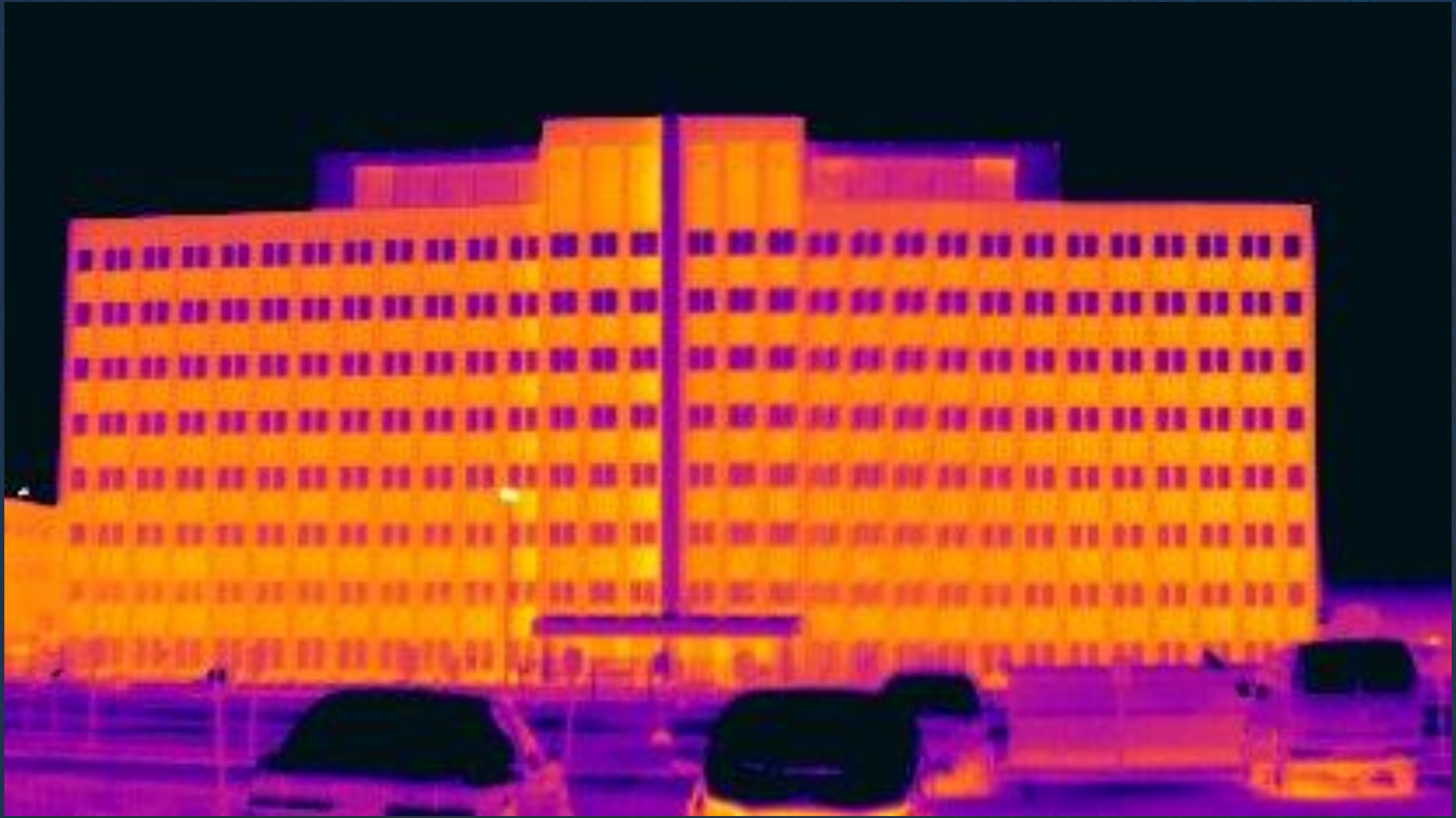
Results

Depressurize	Pressurize
0.168	0.161
24,330 cfm/75	23,235 cfm/75

Average = 0.16

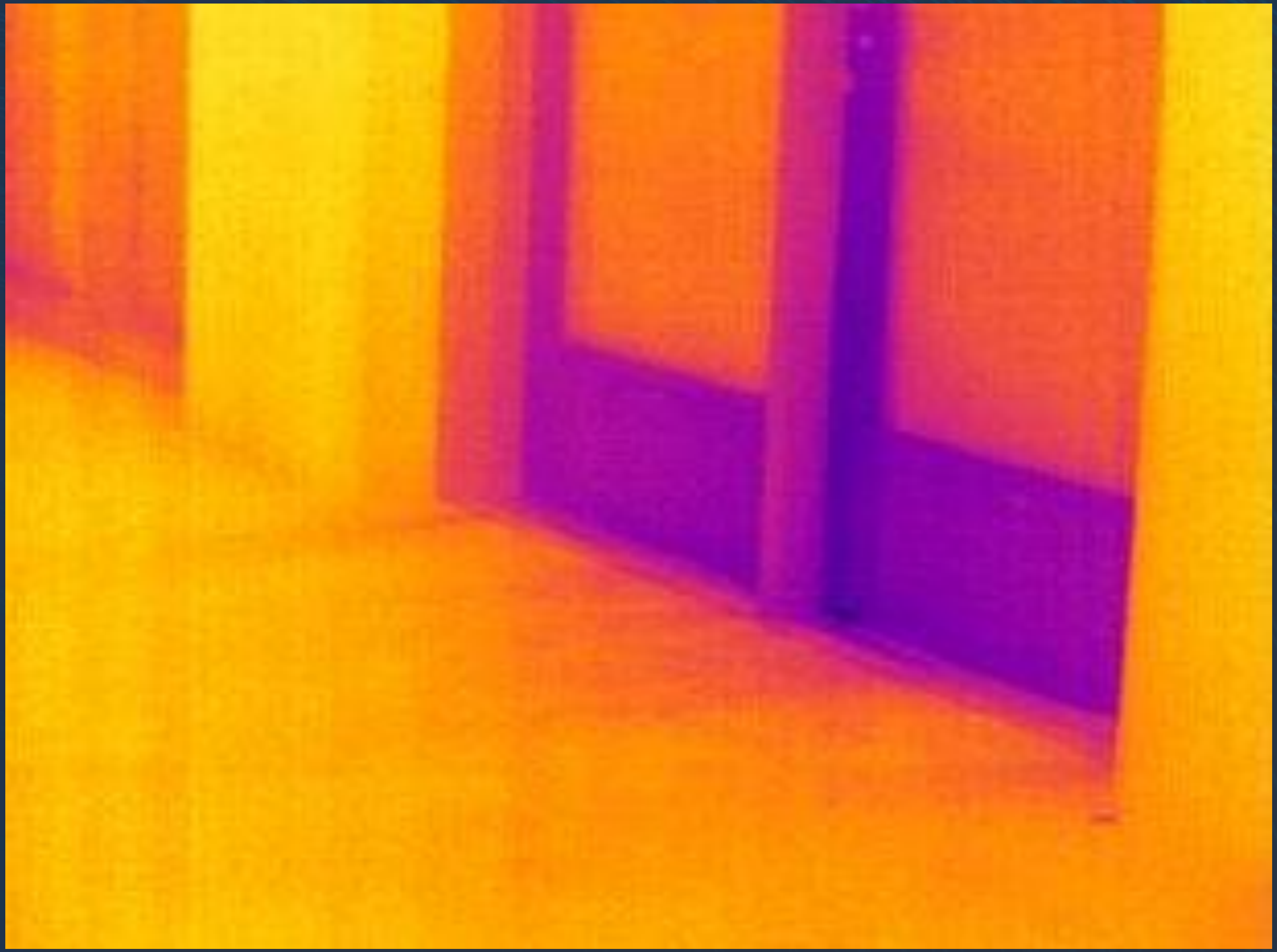
- Data correlation > 99%

Infrared Survey

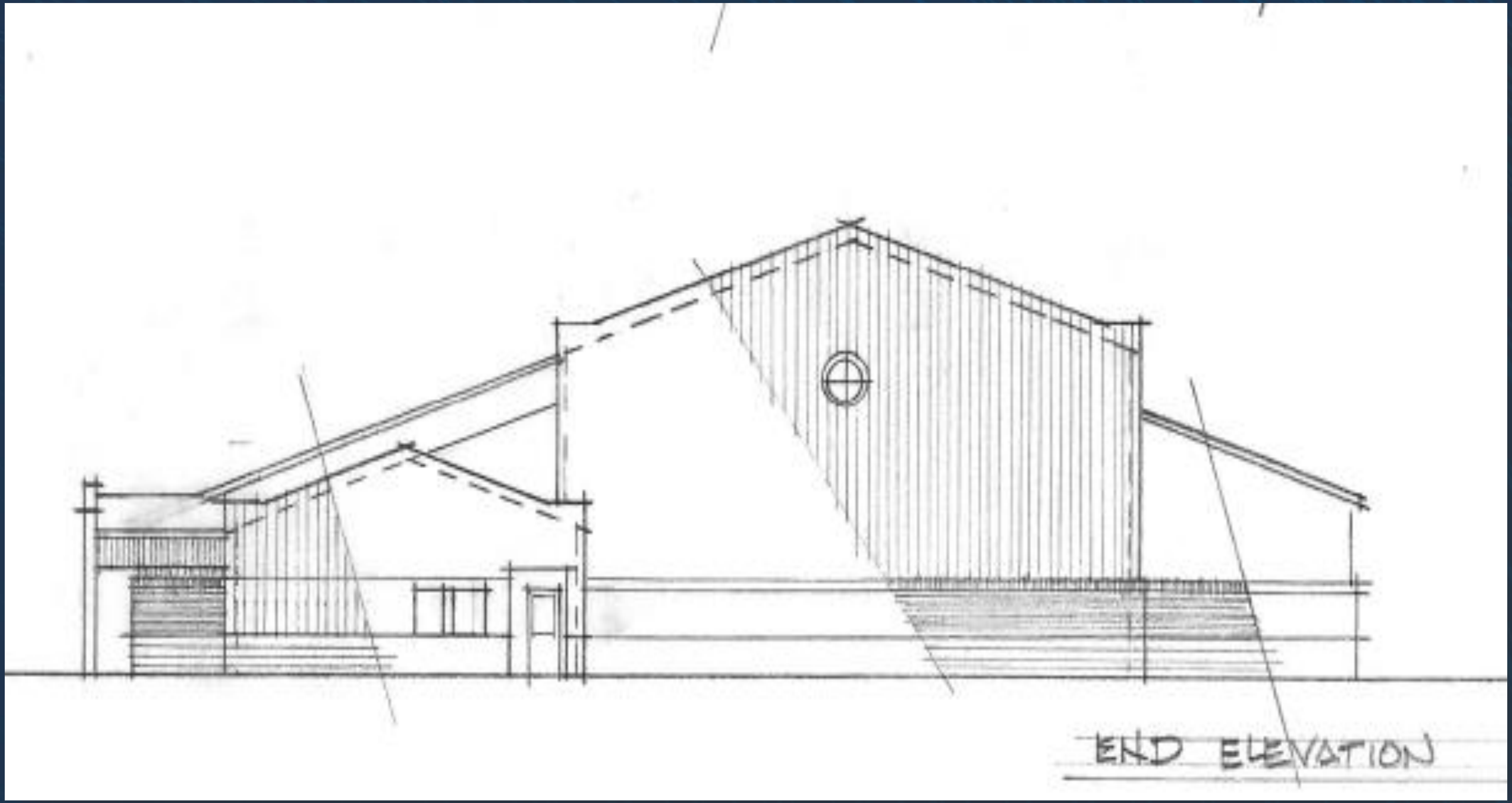


Infrared Survey

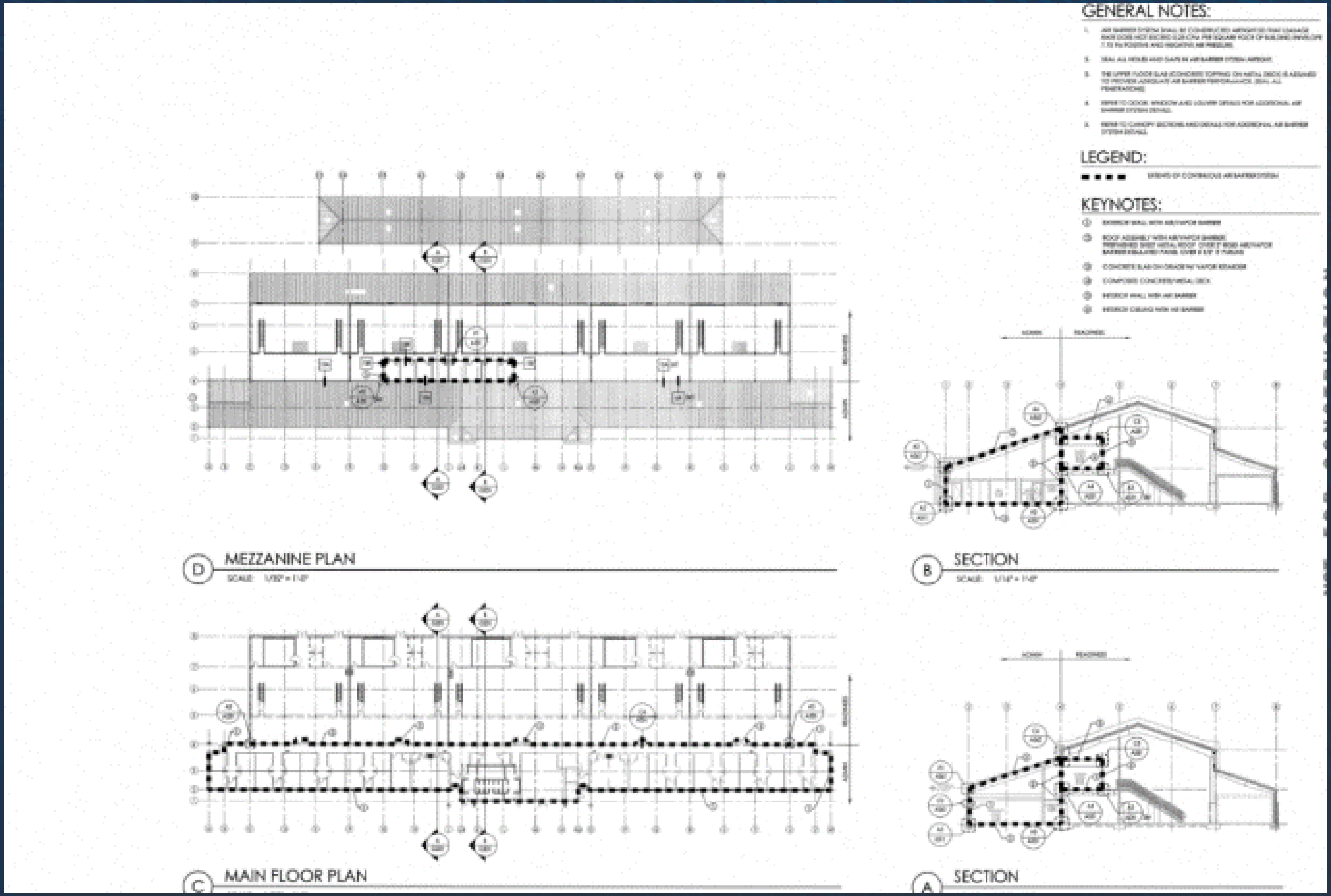
Infrared Survey



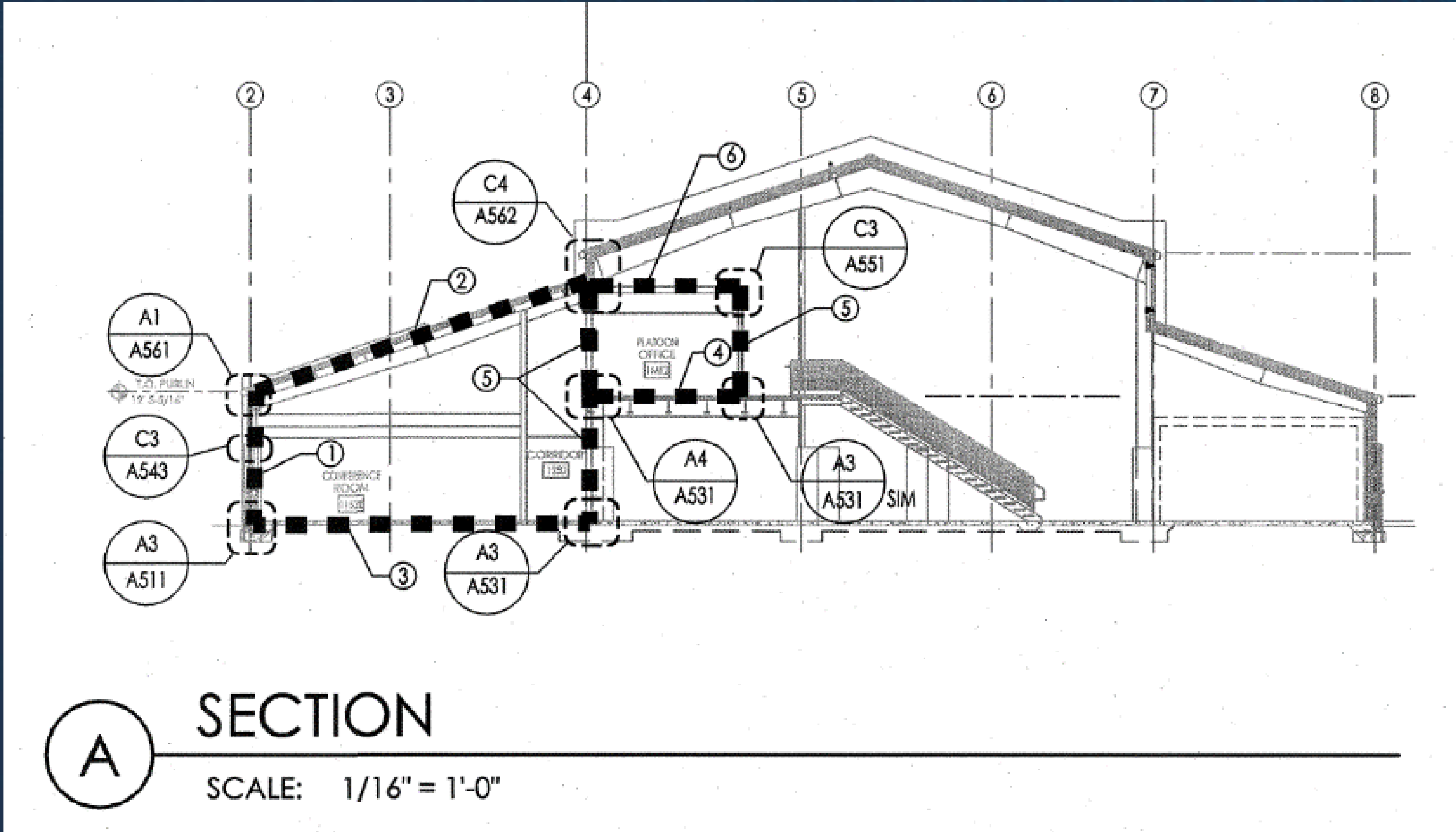
Size Does Matter- Case Study 5-5 ADA COF



Extents of Air Barrier



Extents of Air Barrier



Construction

Construction

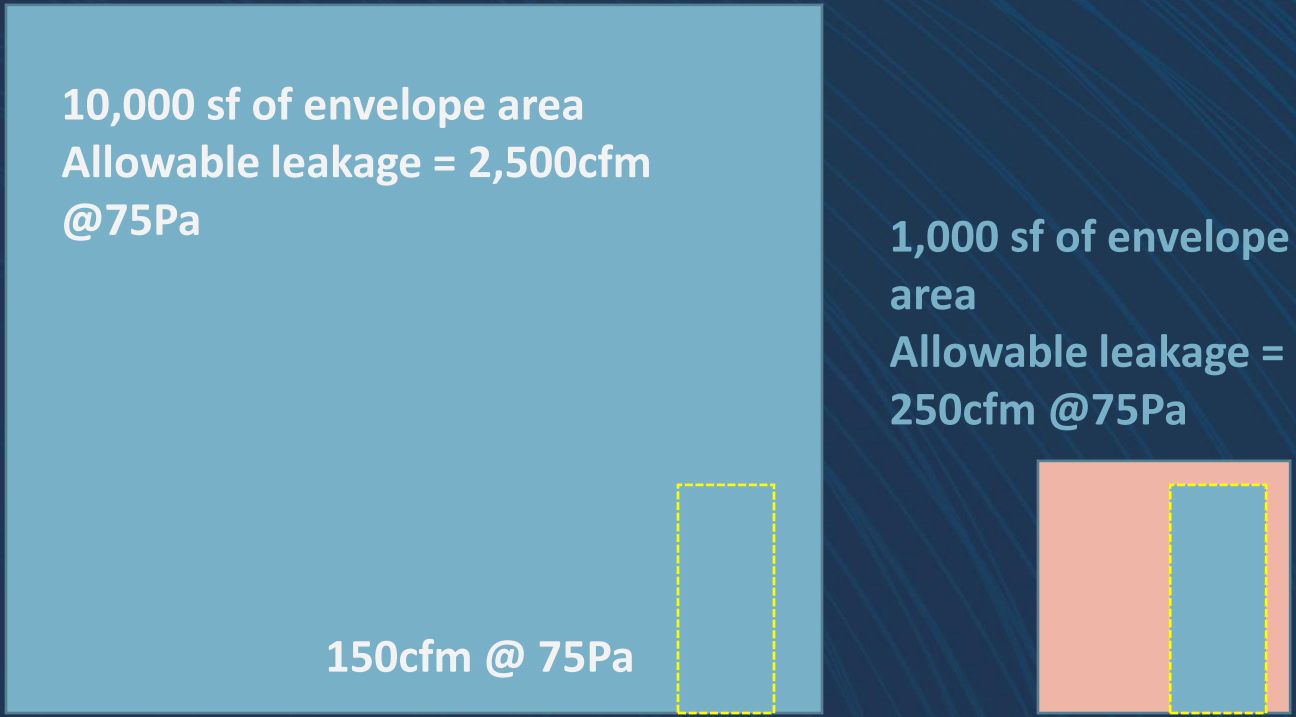
Target Air Leakage

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 Allowable leakage rate	Envelope SF 4,887 1,222 cfm

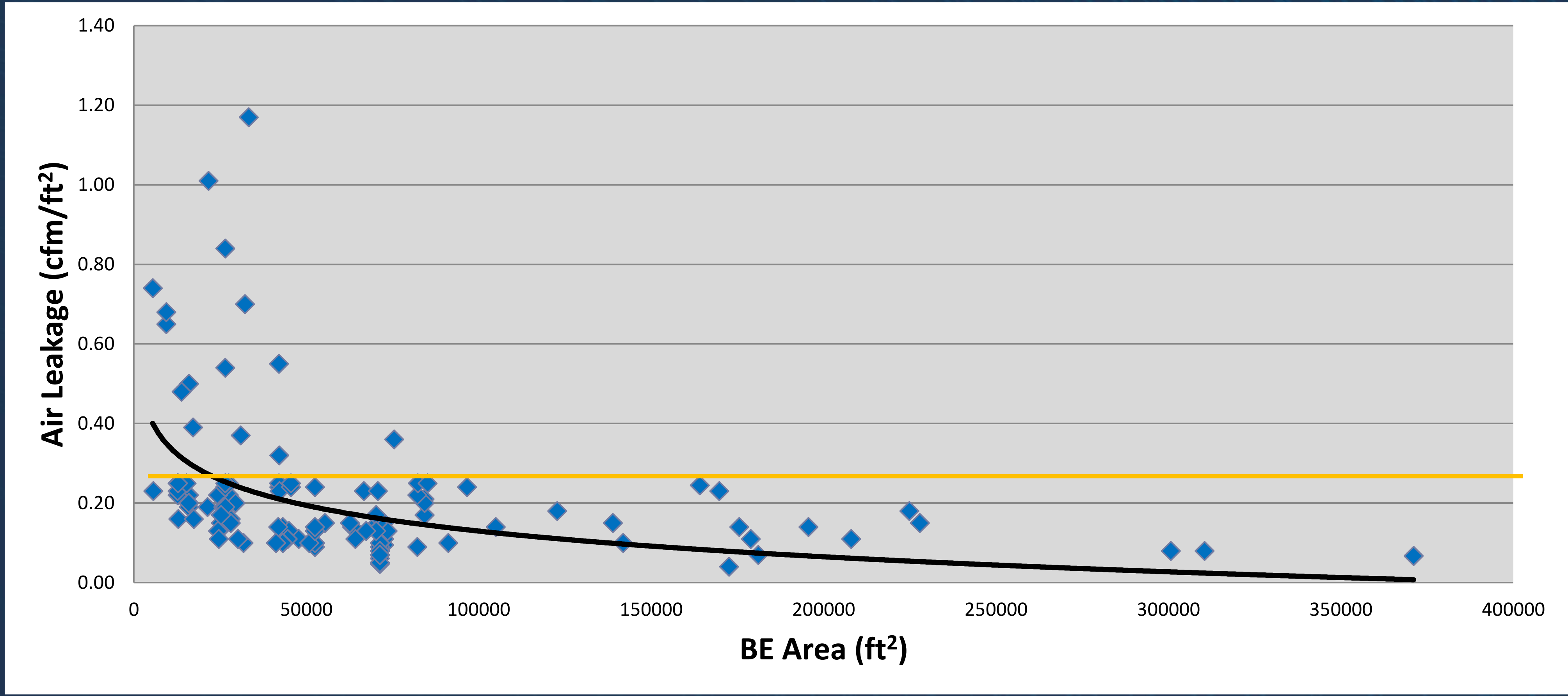
Results

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

Proportion of Operational Leaks



Leakage Rate vs. Building Size



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®

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.

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**
	USACE / FEDERAL	**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**

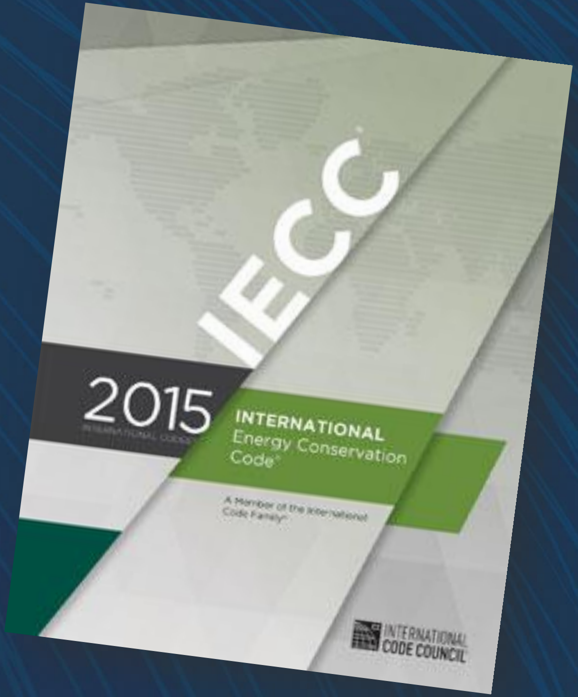
Leakier ↑ / Tighter ↓

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

Passive House 0.06 cfm/ft² at 75Pa

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



IECC – 2021 new developments

A modification to Section C402.5 (Air Leakage) of the 2021 International Energy Conservation Code (IECC) states that in Section C402.5, air leakage requirements are expanded to include requirements for residential and non-residential air leakage testing and for building envelope performance verification for buildings not tested.

Air leakage testing was introduced as a compliance alternative to meeting the material or assembly selection and installation provisions of the 2012 IECC, and the requirements remained largely unchanged until the expansion of requirements in the 2021 IECC. Three significant changes related to air leakage are made to the 2021 IECC:

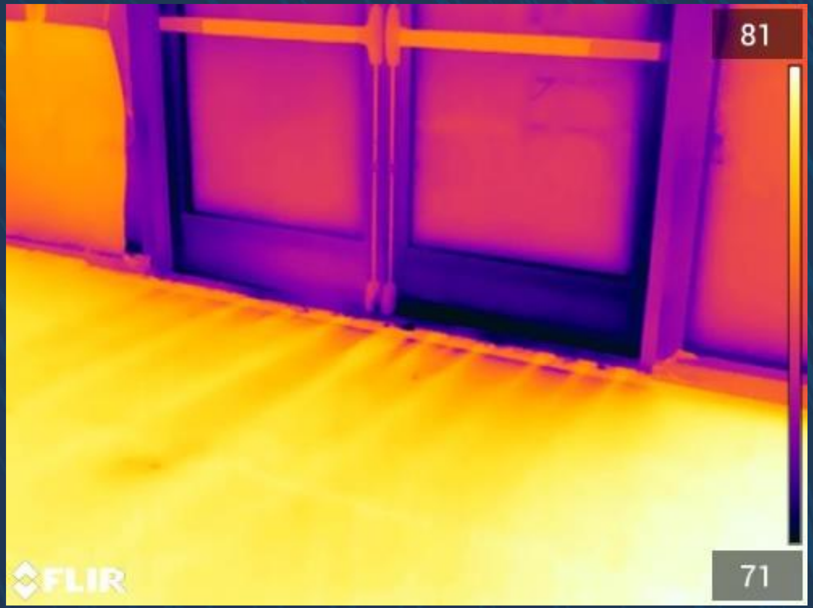
1. New requirements for dwelling unit air leakage testing for Group R and I occupancies
2. Revised and required air leakage requirements for occupancies other than Group R and I
3. New performance verification requirements

IECC – 2021 new developments

The updated air leakage testing requirements of Section C402.5 take into consideration occupancy type, climate zone and building size. Commercial buildings under 5,000 square feet can be tested using residential methods, technicians and equipment with the maximum leakage rate set at 0.30 cfm/ft2 (1.5 L/s 3 m2) at 0.2 in. w.g. (50 Pa). This testing pressure differential is common for residential testing and is equivalent to a leakage rate of 0.40 cfm/ft2 (1.5 L/s 3 m2) at 0.3 in. w.g. (75 Pa). Implementing the residential procedure can significantly reduce testing costs for these smaller buildings. Buildings that are not tested must meet the materials or assemblies requirements and the air barrier must be visually inspected. A final commissioning report is required for such inspections.

IECC – 2021 new developments

There are instances when the building is tested and it exceeds the maximum leakage rate. Section C402.5.3 provides reasonable options for mitigating air leakage when the rate is greater than allowed in the code but does not exceed 0.60 cfm/ft2, including the use of a smoke tracer or infrared imaging along with a visual inspection. Leaks must be sealed where it is possible to do so without destroying building components. Documentation showing all leaks that were found and mitigating measures must be submitted to the code official and building owner.



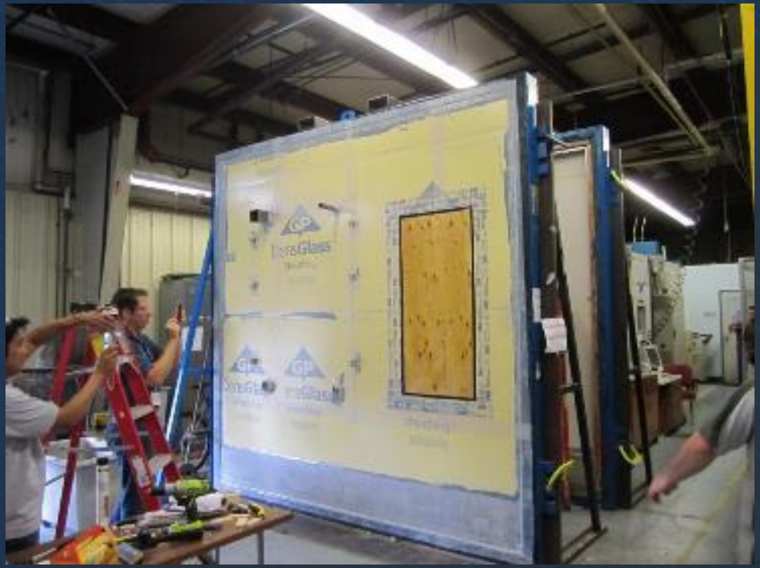
Specified Air Leakage Rates

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

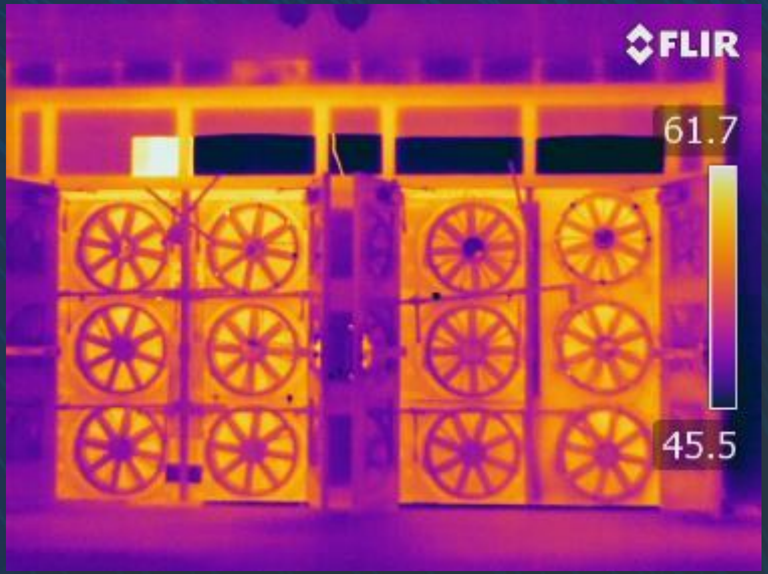
Past Construction Practices: 0.4 to 1.0 cfm/ft²

Materials or Assemblies or WBALT

ASTM 2178



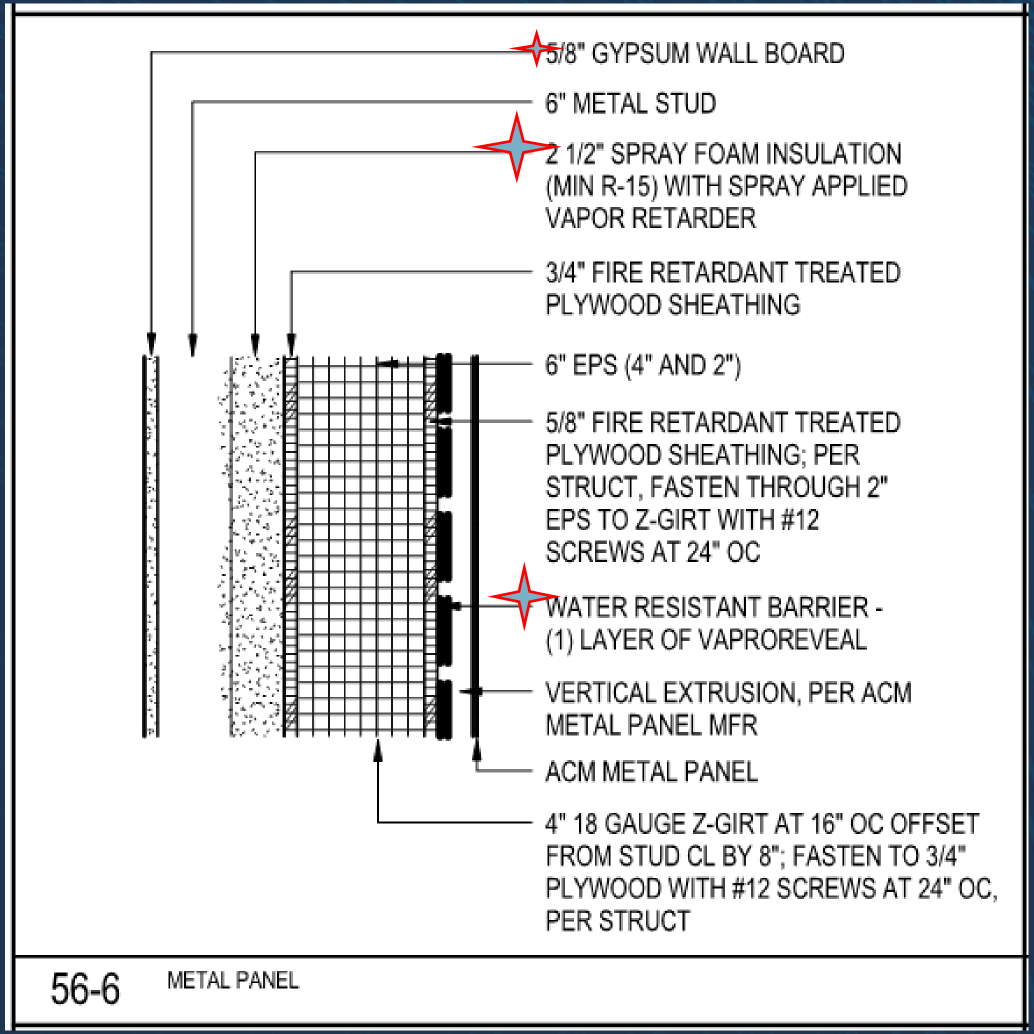
ASTM 2357



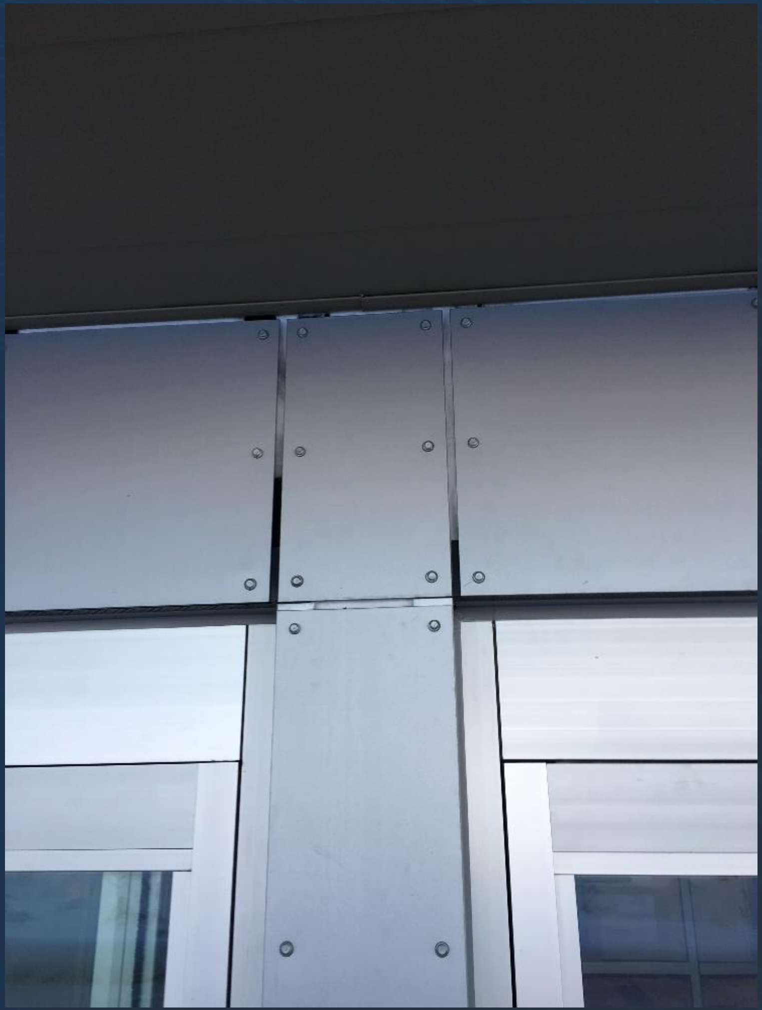
ASTM e779….

Shouldn’t it be and, and

Materials, Assemblies….all Good….right?



No Continuity



Ice Maker

The Truth

Pacific Northwest National Laboratory's technical brief, titled, "Envelope Air Tightness for Commercial Buildings" notes:

While it is important that the materials and assemblies have limited leakage, that alone does not guarantee a low leakage building. Recent research1 (Wiss 2014) shows that 40% of buildings constructed without an envelope consultant have air leakage exceeding the currently optional test standard requirements, while buildings with envelope consultants all had leakage below 0.25 cfm/ft2. Testing is the most reliable means of ensuring that the intent of this code section—limiting unintended energy waste in buildings due to air infiltration—will be achieved.

The Building is a Patchwork

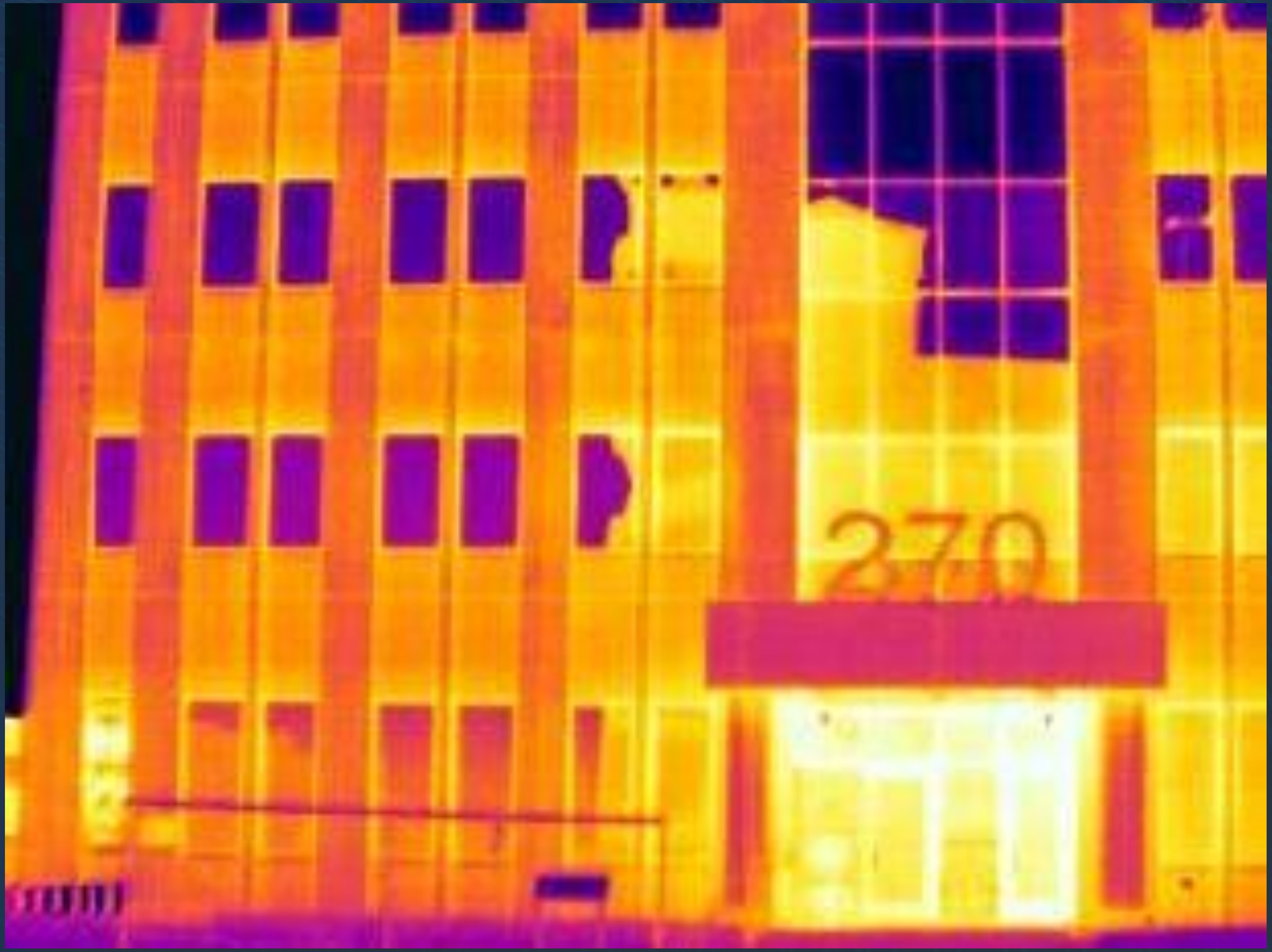
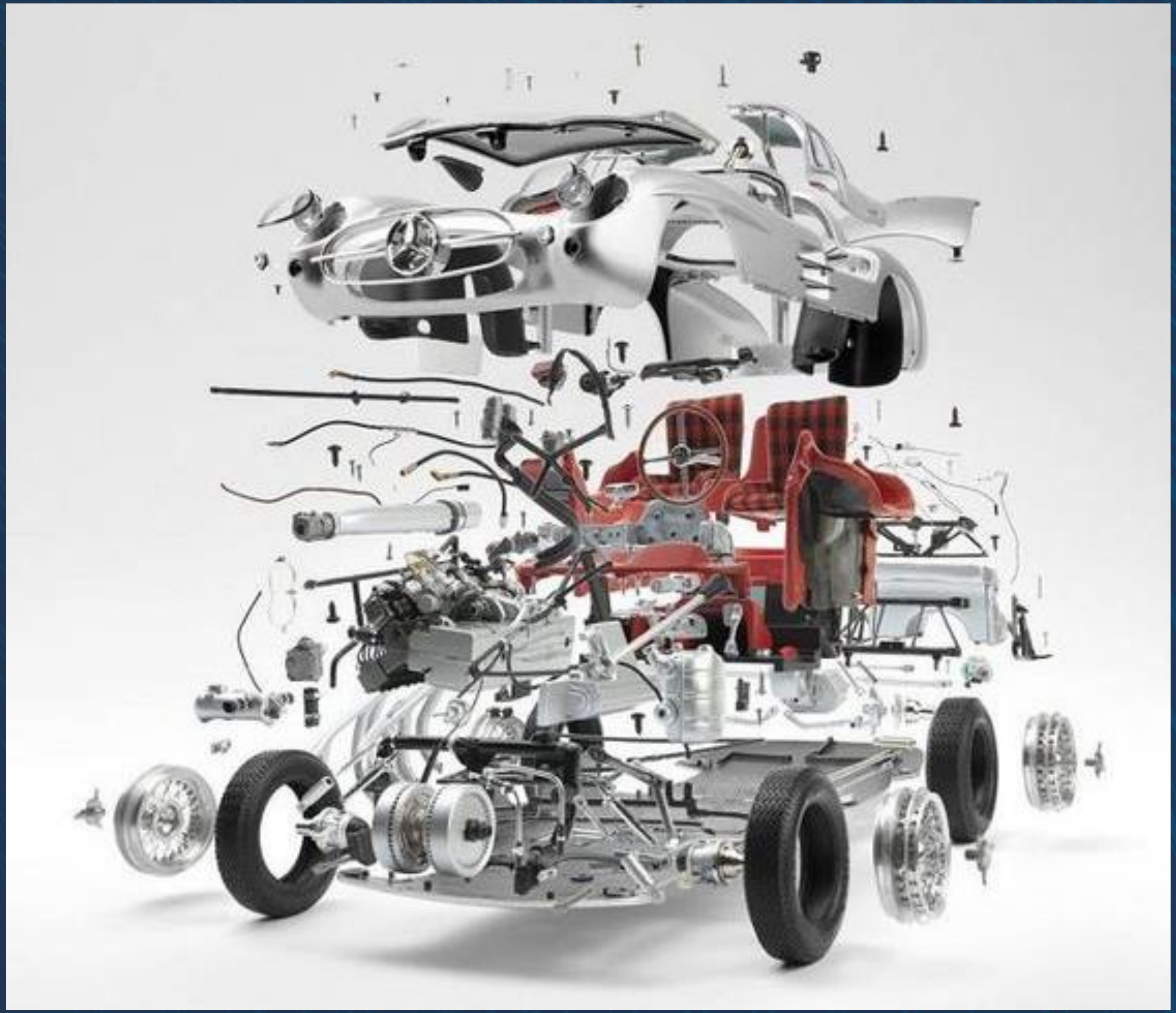


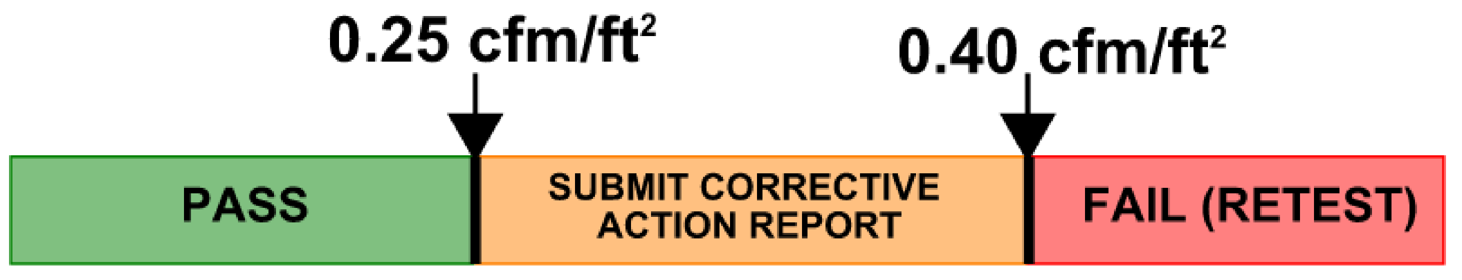
Photo credit BCRA Inc.

Materials, Assemblies….all Good….right?



Washington State & Seattle Energy Codes

- All applicable buildings must be tested per ASTM E779 or equivalent and must pass at a rate of 0.25 cfm/ft^2 (1.27 L/s m^2).
- If air leakage rate between 0.25 cfm/ft^2 and 0.40 cfm/ft^2 , contractor must provide report outlining locations of excessive air leakage and provide repairs within reason.
- If air leakage rate exceeds 0.40 cfm/ft^2, then air leakage must be addressed, and building must be re-tested until less than 0.40 cfm/ft^2.

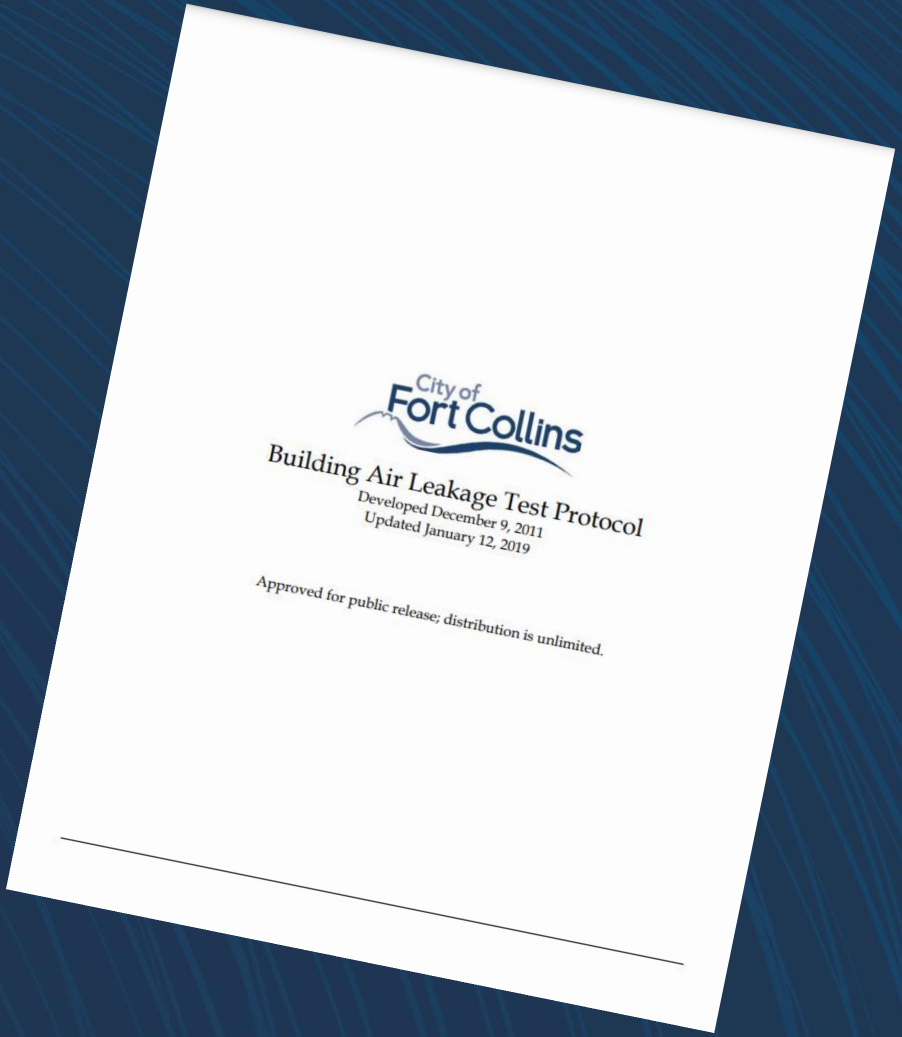


C406 Compliance (Performance Options)

- Reduced air leakage can be selected as one of the eleven (11) C406 options (C406.11).
- Selecting reduced air leakage as a C406 option can potentially save time and cost associated with achieving higher building energy performance.
- **Commercial building** envelope air leakage rate < 0.17 cfm/ft^2 (0.86 L/s m^2) @ 0.3” H2O (75 Pa)
- Can be achievable with additional planning, design, execution, and inspection.

City of Fort Collins, CO

- All new construction, including commercial buildings, are required to pass a building air tightness test.
- Mirrors the USACE Protocol
- 0.25cfm/sf @ 75Pa



City of Fort Collins

Building Air Leakage Test Protocol

Developed December 9, 2011

Updated January 12, 2019

Approved for public release; distribution is unlimited.

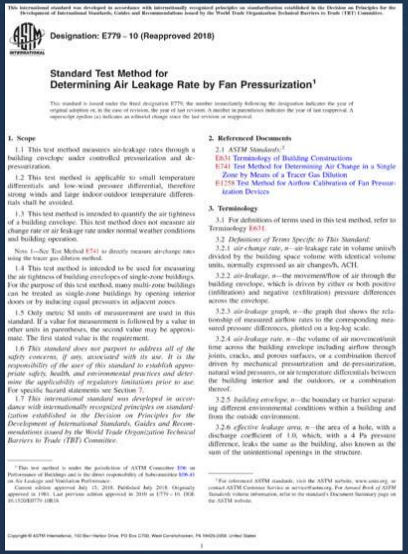
City of Denver, CO

Section C402.5.1.2 (p. 542) of the Denver 2019 Amendments requires buildings other than Group I to meet the requirements of Section C402.5.1.2.3 Building Thermal Envelope Performance Verification. Section C402.5.1.2.3 requires:

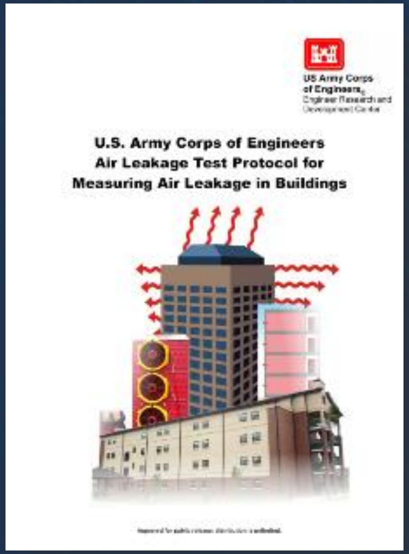
1. Review of Documents (Materials, Assemblies)
2. Inspection of the air barrier components and assemblies during construction. 100% inspection is required unless testing is performed.
3. Or…. Whole Building Air Leakage Test
4. Report

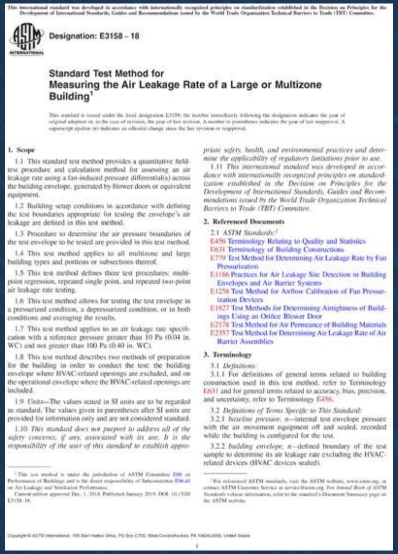
Next… How to Test

- ASTM E779 or equivalent….
- USACE Protocol
- ASTM e3158
- ABAA T0001-2016

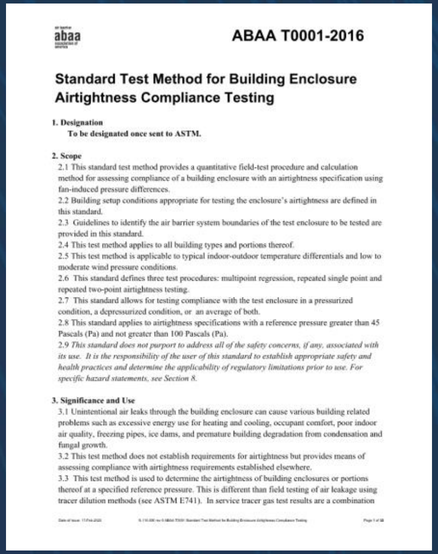

Designation: E779 – 10 (Reapproved 2018)

Standard Test Method for
Determining Air Leakage Rate by Fan Pressurization[1]


U.S. Army Corps of Engineers
Air Leakage Test Protocol for
Measuring Air Leakage in Buildings

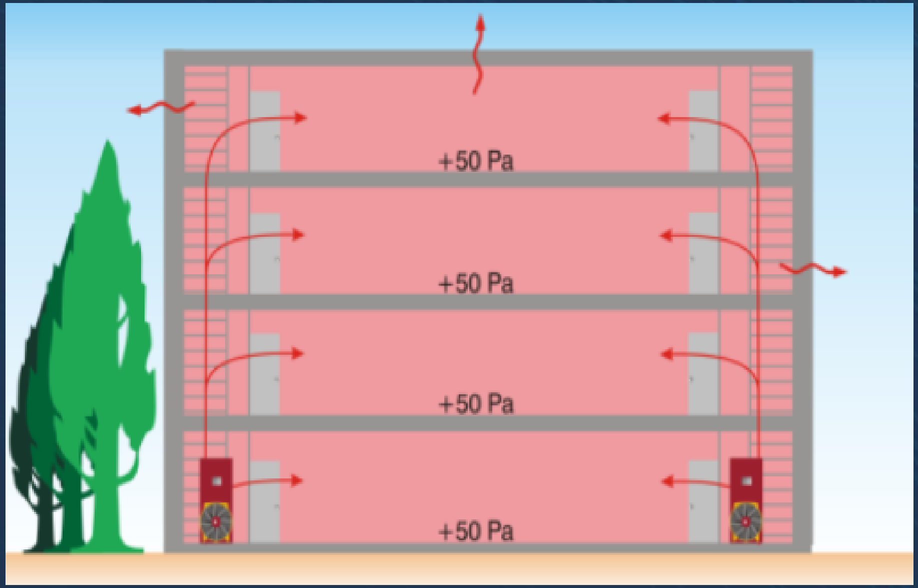

Designation: E3158 – 18

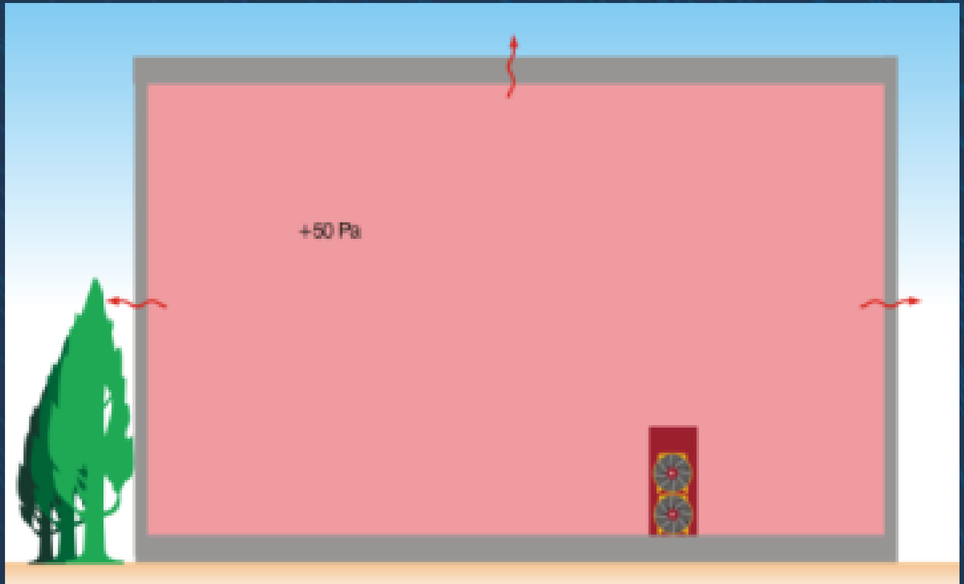
Standard Test Method for
Measuring the Air Leakage Rate of a Large or Multizone Building[1]


ABAA T0001-2016

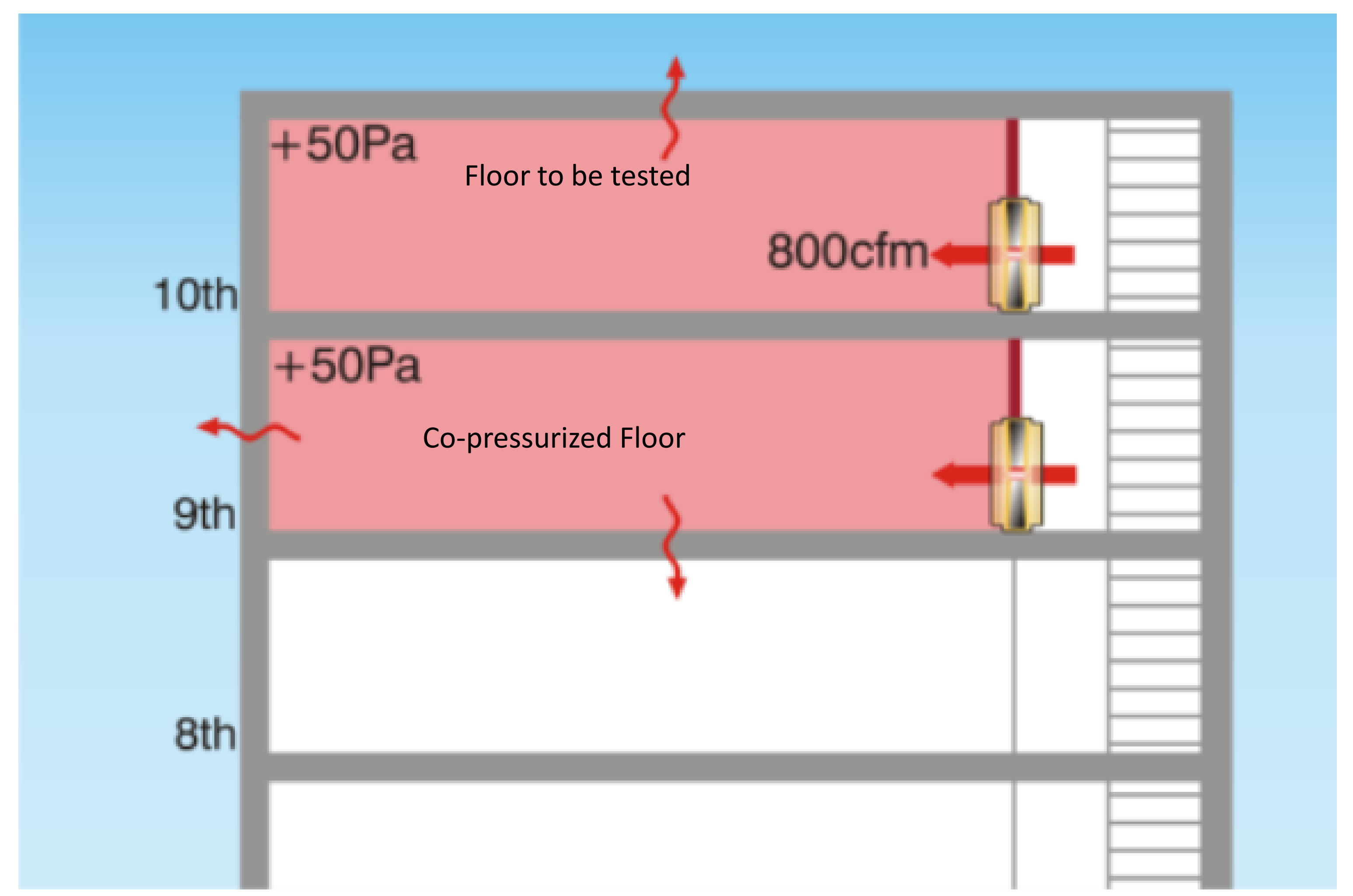
Standard Test Method for Building Enclosure
Airtightness Compliance Testing

Single Zone Test



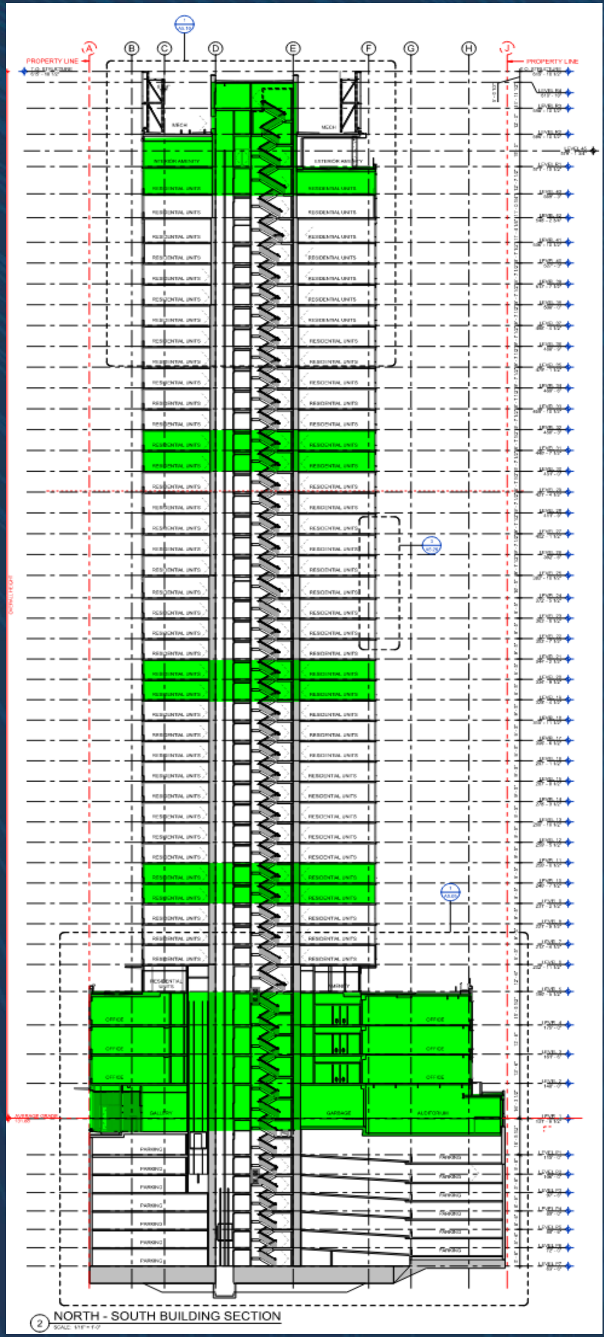


Multi-Zone Test (Sectional Method)



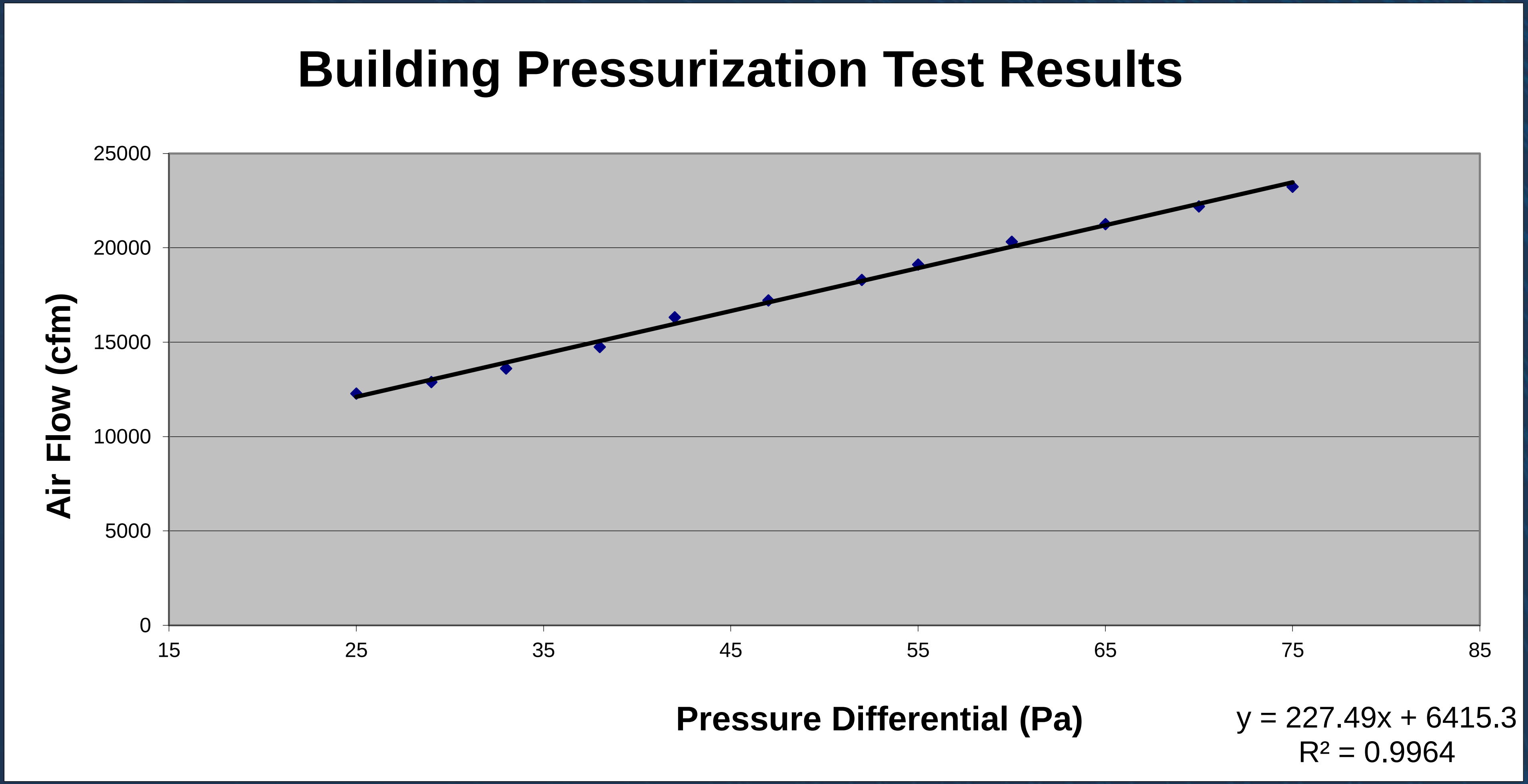
Sectional Method- Sampling

- A solution to reduce the impacts to the construction schedule and cost associated with preparation work.
- Larger buildings can be divided and tested in isolated sections.
- Will require the approval from the code official.
- Can reduce the amount of preparation work but will increase the cost of testing due to multiple mobilizations.
- May impact the accuracy of the test results
- Certain building designs and envelope types may not permit this method of testing



How to Test…What to Test

How to Test…Statistically Accurate



Conclusions/Summary

- 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 in a way that reduces energy use and improves durability of the enclosure 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?

Major Take-Away

With multiple jurisdictions defining air leakage requirements and how to confirm compliance we need to make sure what is being required isn't just greenwash and actually results in improved performance (energy and durability) of the building.

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