COMMERCIAL BLOWER DOOR TESTING

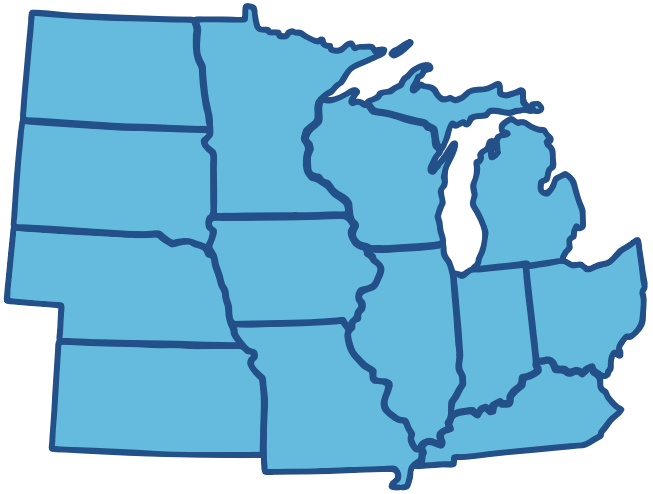
"GOING BEYOND SINGLE-FAMILY BLOWER DOOR TESTING"

Southface MEEA MIDWEST ENERGY EFFICIENCY ALLIANCE

Commercial Envelope Testing

MIDWEST ENERGY EFFICIENCY ALLIANCE

The Midwest Energy Efficiency Alliance (MEEA) is a collaborative network, promoting energy efficiency to optimize energy generation, reduce consumption, create jobs and decrease carbon emissions in all Midwest communities.



MEEA is a non-profit membership organization with 150+ members, including:

Energy service companies & contractors

State & local governments

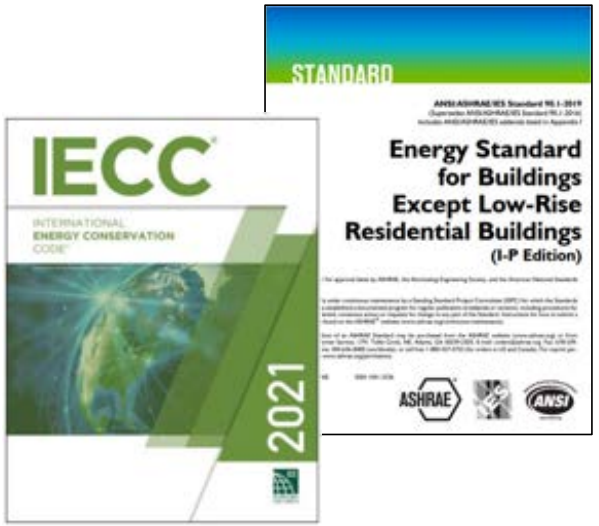
Academic & Research institutions

Electric & gas utilities

MEEA
MIDWEST ENERGY EFFICIENCY ALLIANCE

LOGISTICS

- Webinar is being recorded and will be shared with attendees
- Please remain muted – except for Questions!
- Questions? Use the Chat Feature or Raise Hand
- Questions any time!! Okay to Unmute and Ask



MEEA
MIDWEST ENERGY EFFICIENCY ALLIANCE

INTRODUCTIONS

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ABOUT SOUTHFACE

www.southface.org

Building Science & Energy Code

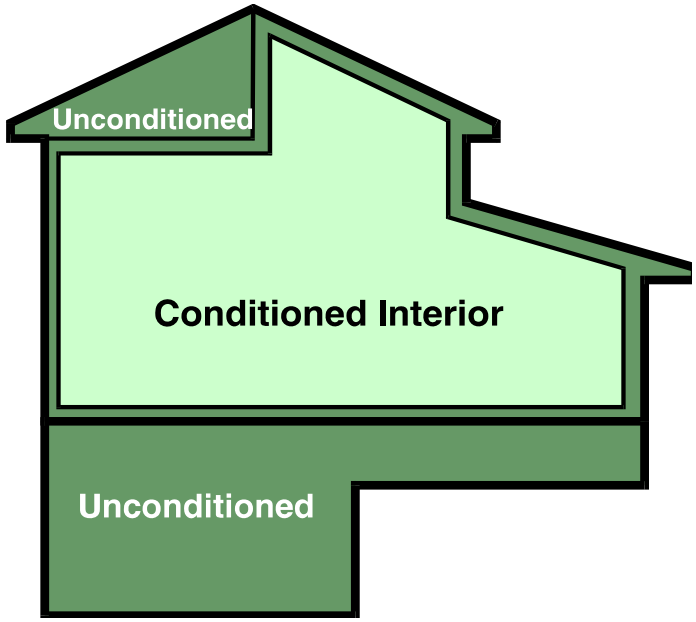
Photo: Jonathan Hillyer, 2009

BUILDING SCIENCE FUNDAMENTALS

Understand Building as a System

Control Flow of
- Heat
- Air
- Moisture

The **building thermal envelope** separates conditioned space from unconditioned (or outside) and consists of two elements: an air barrier and insulation that must be continuous and touching



BUILDINGS ARE SYSTEMS

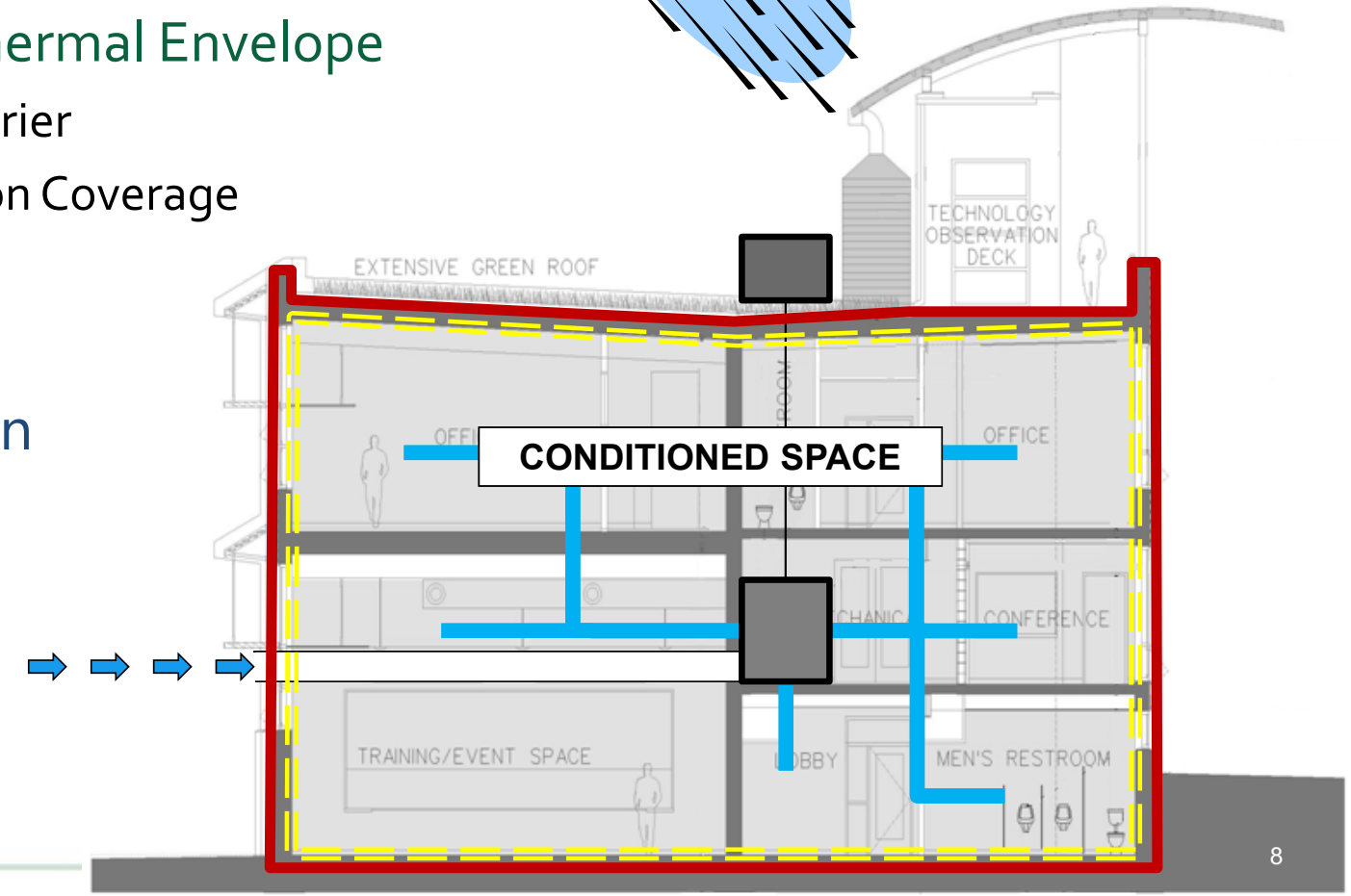
Complete Building Thermal Envelope

- Continuous Air Barrier
- Complete Insulation Coverage

Proper Heating & Cooling Systems

Controlled Ventilation

Deal with Moisture!



SCIENCE OF AIR MOVEMENT

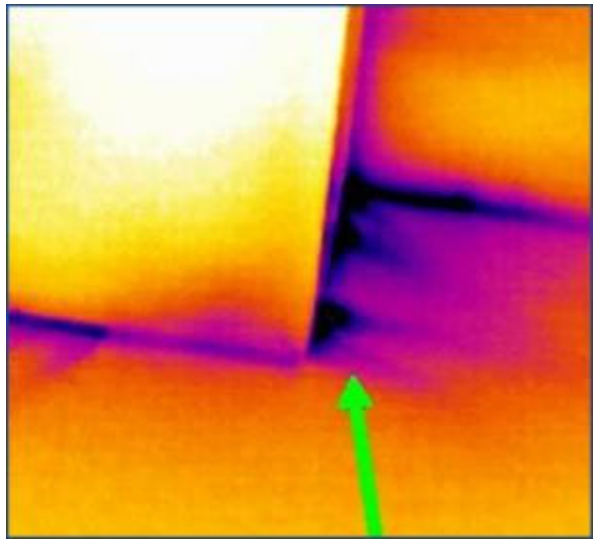
Basic Principle of Air Leakage

High or "+" Pressure → Low or "-" Pressure

Air will **always** move from an area of high pressure to an area of low pressure

When air moves out of a building, the same amount has to come in and vice-versa

CFMout = CFMin

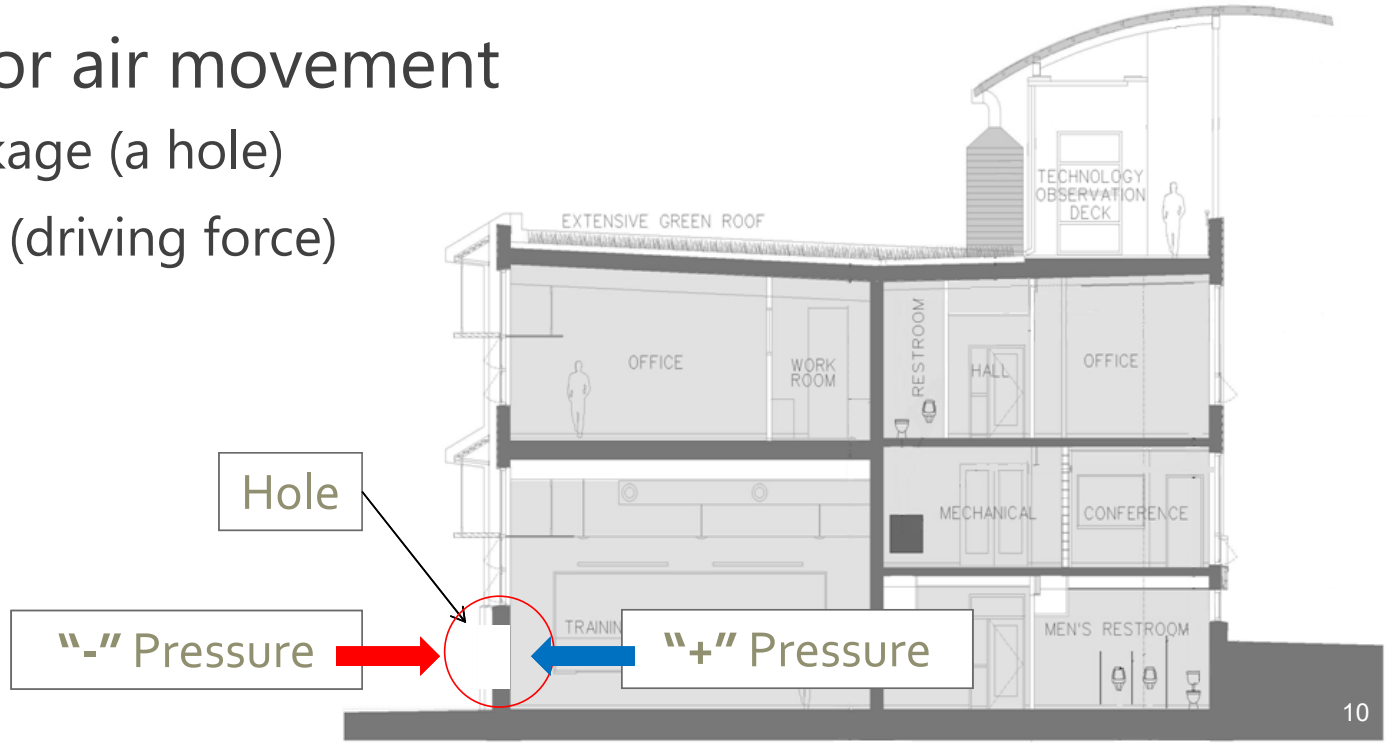


SCIENCE OF AIR FLOW (INFILTRATION)

Basic Principles of Air Infiltration

Two requirements for air movement

1. Pathway for air leakage (a hole)
2. Pressure difference (driving force)

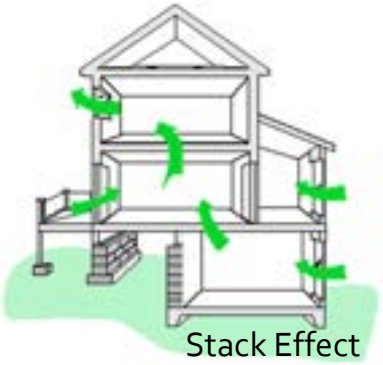


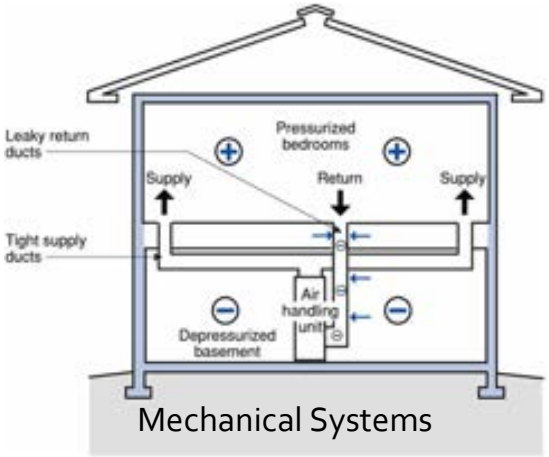
AIR LEAKAGE: DRIVING FORCES

Three forces create pressure differences in a building:

- Wind
- Stack Effect
- Mechanical Fans


Wind


Stack Effect



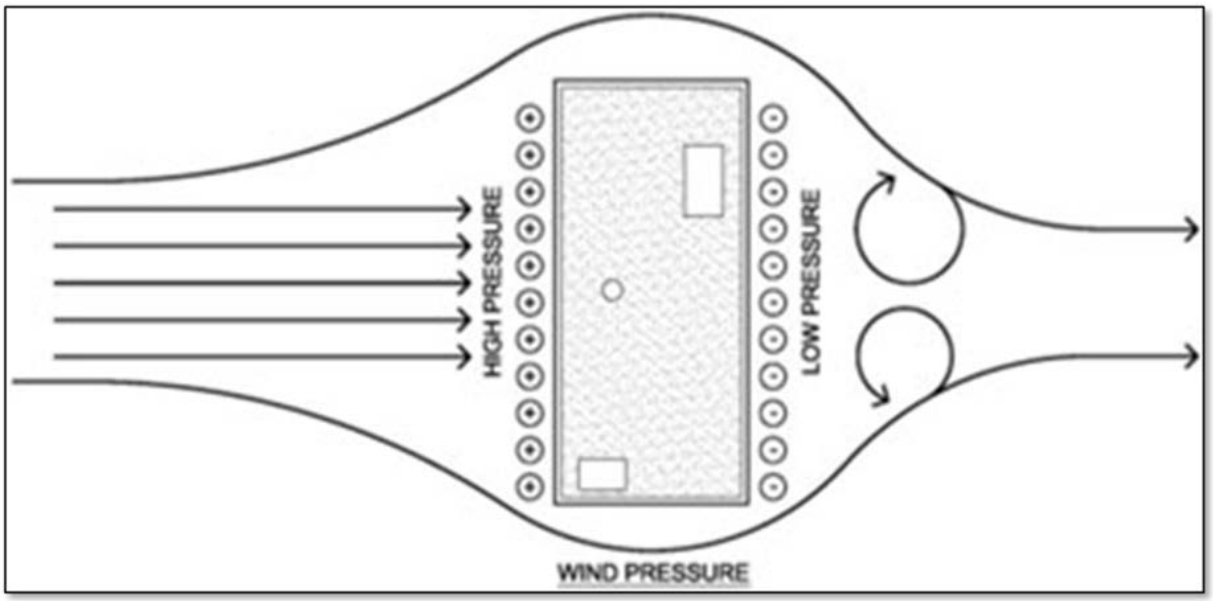
Mechanical Systems

PRESSURES / DRIVING FORCES

Wind

Air leaks across envelope assemblies driven by the pressure differential due to wind

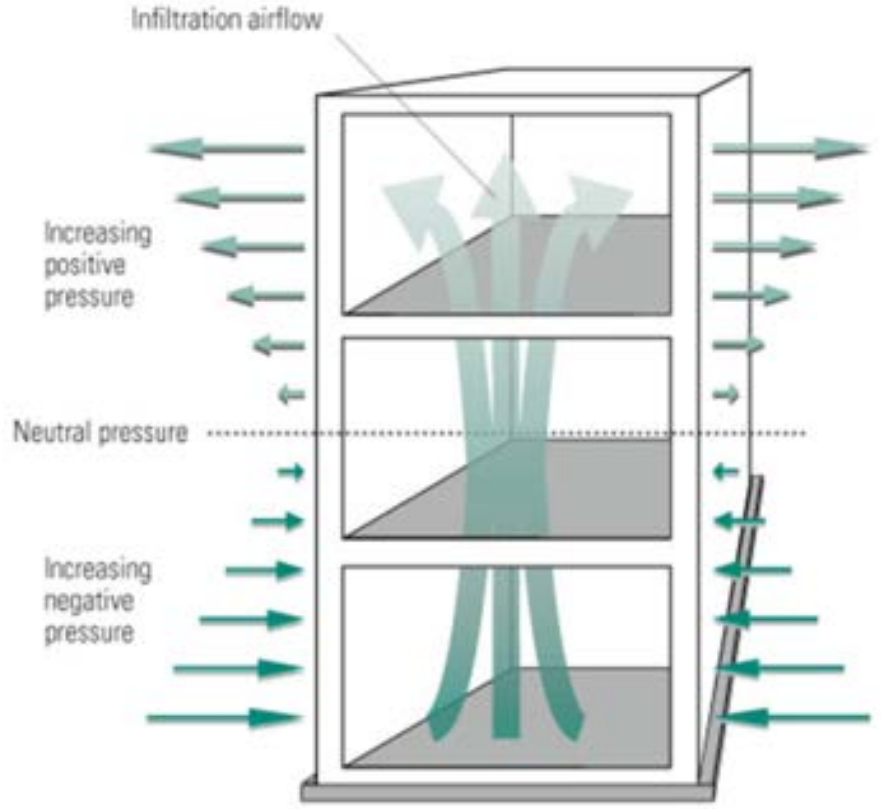
Air enters the building on the windward side (infiltration) and exits on the leeward side (exfiltration)



PRESSURES / DRIVING FORCES

Stack Effect

- The stack effect causes air movement due to the buoyancy of heated air
- The greater the thermal difference and the height of the structure, the greater the buoyancy force

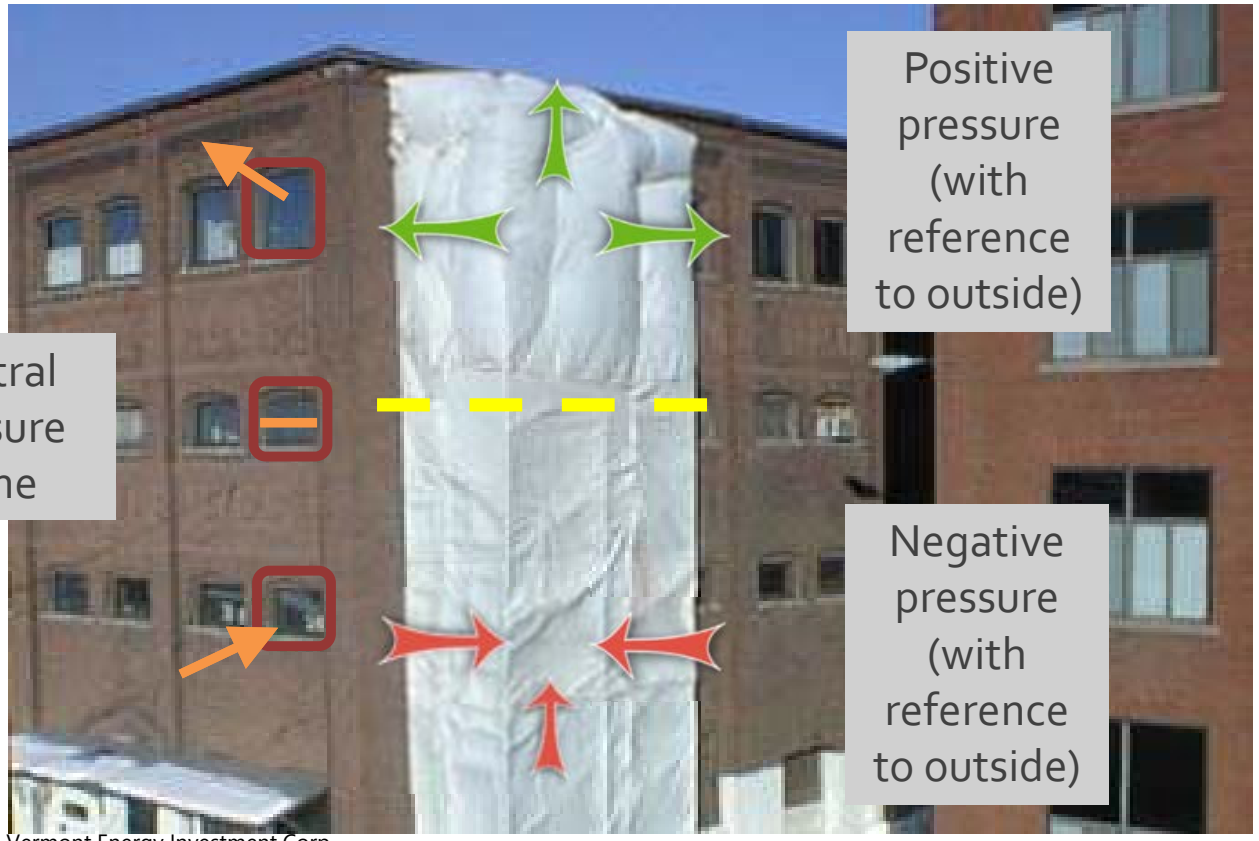


Source: E SOURCE

STACK EFFECT

Function of

- Building Height
- Temperature difference



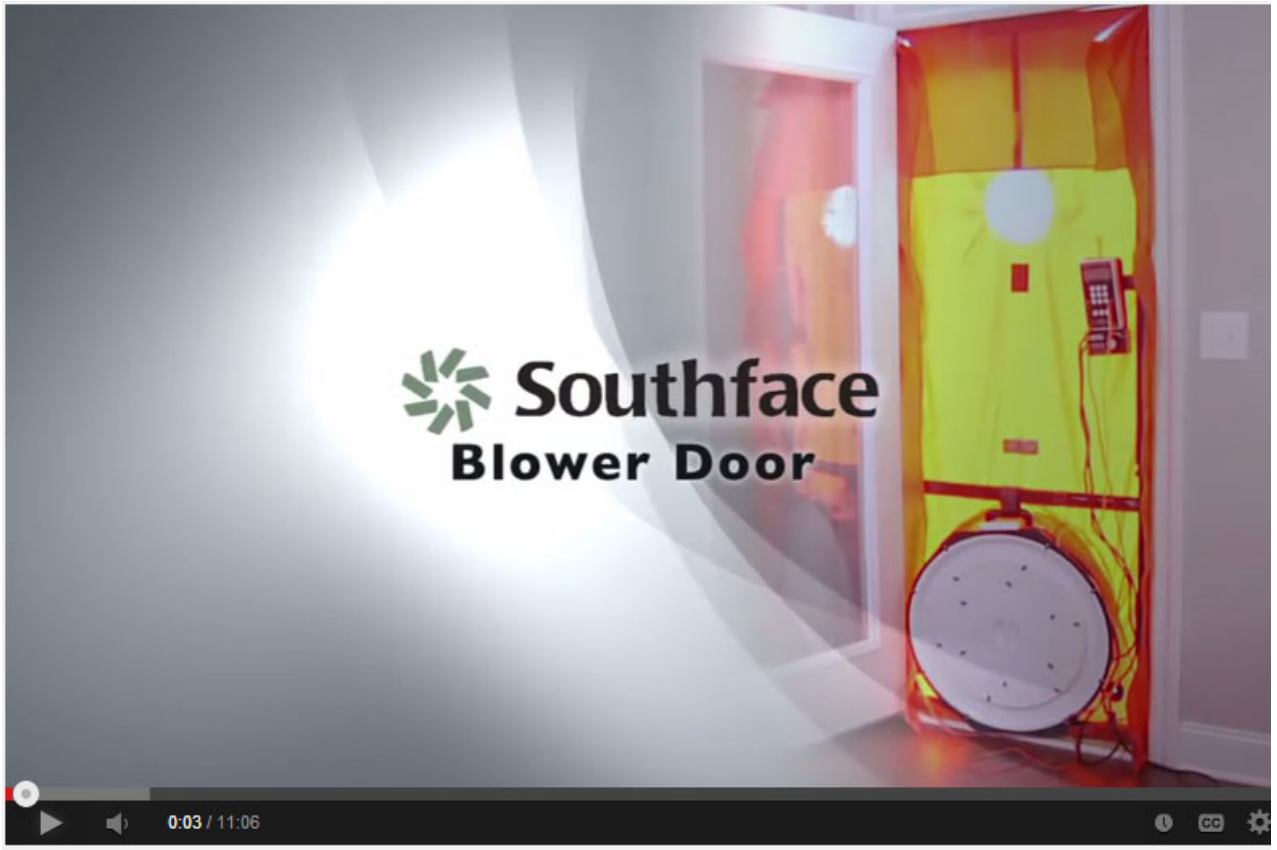
Vermont Energy Investment Corp.

Mechanical Fans

Mechanical fans in a building can create significant pressure differences which drive air exchanges.

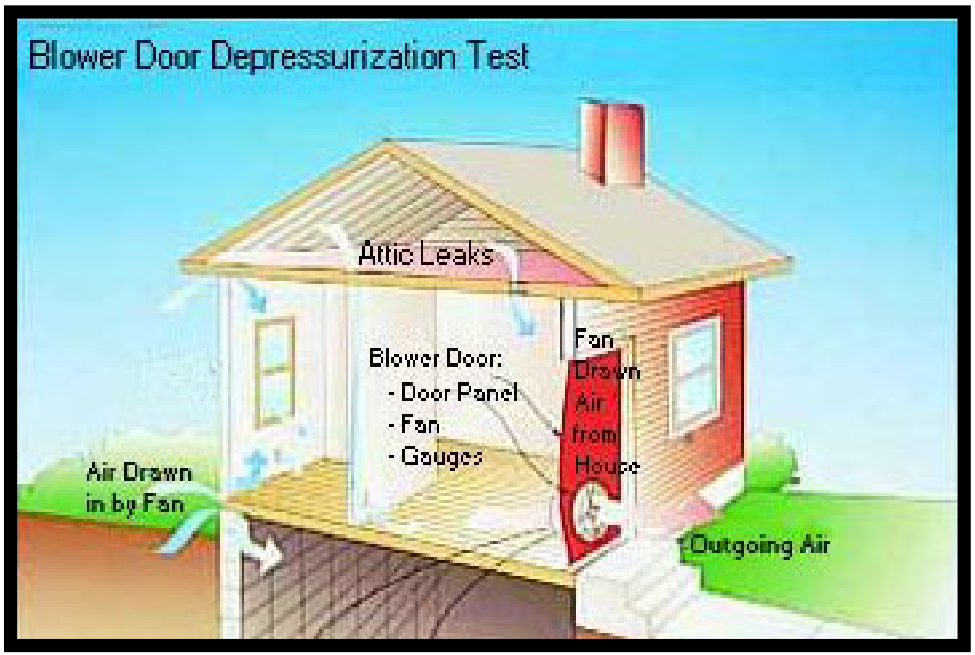
BLOWER DOOR TESTING

YouTube:
"Southface Blower"



TYPES OF BLOWER DOOR TESTING

- Single Point
- Multipoint
- Multi-Family
  - –Unguarded
  - –Guarded
- Multiple Fan



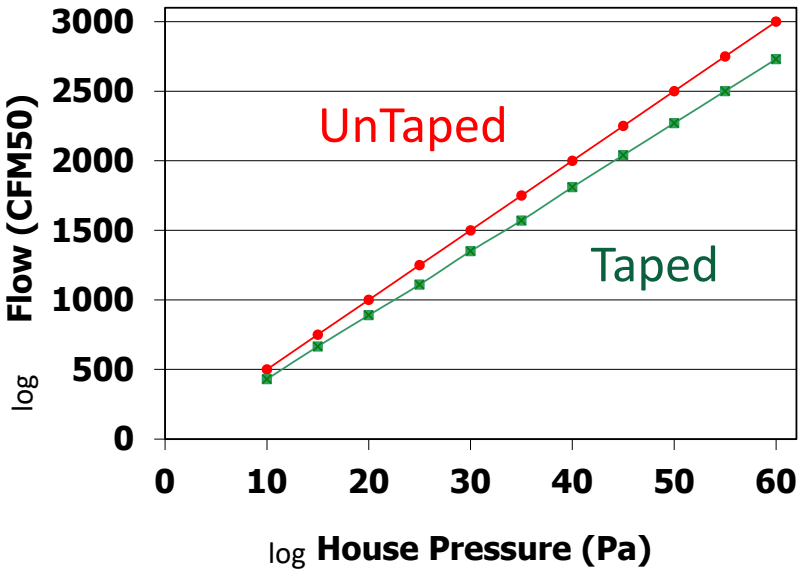
MULTIPOINT BLOWER DOOR TEST

An automated **Multipoint Blower Door (MBD)** Test may be performed using a laptop, software, and a BD fan controller

In a *MBD test*, the building's actual CFM_{XX} is determined at different pressures

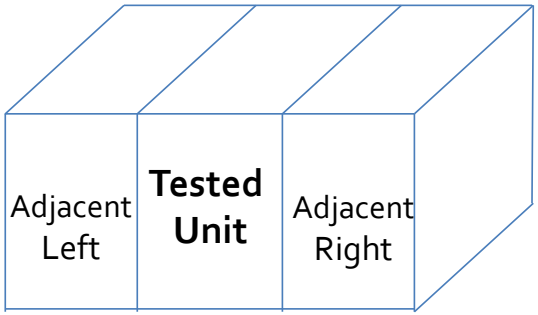
The results can be plotted to measure the infiltration at any given pressure – providing more accuracy than a single point test

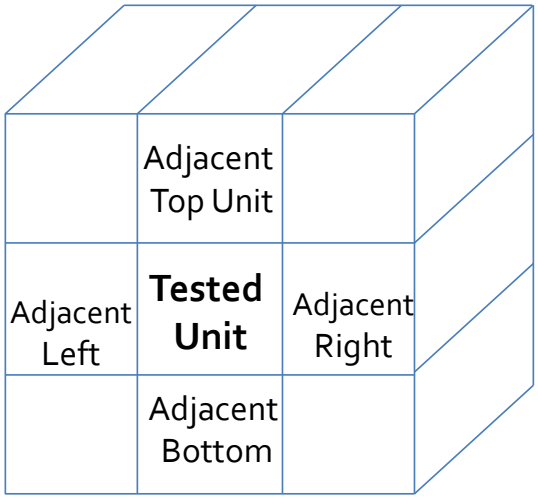
In theory, this approach reduces error and provides an acceptably accurate measurement of duct leakage via subtraction method



MULTIFAMILY BLOWER DOOR TESTING

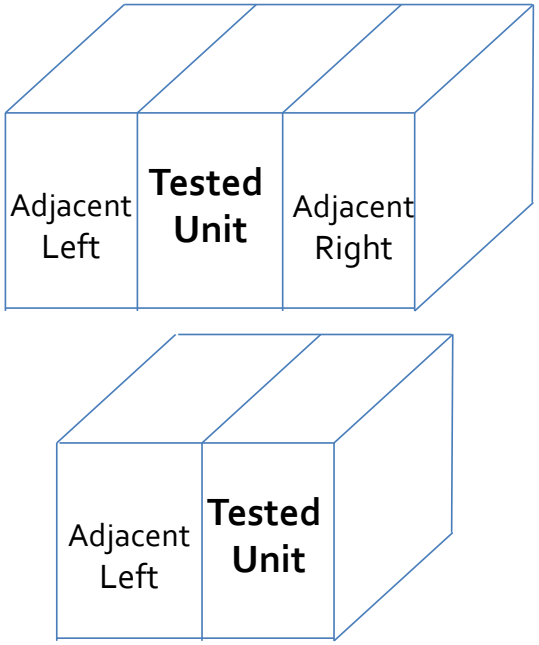
- Multi-Family
  - –Unguarded
  - –Guarded





MULTIFAMILY BLOWER DOOR TESTING

- Southface results for MF testing for five projects from 1998-2001
  - Unguarded to Guarded Reduction Range
  - Typical to find "a couple hundred cfm50" across units



Project	Units Tested	Reduction Range	Outliers
'98 Augusta	1	(30%)	
'99 Alexander City	10	(0-18%)	
'00 Sylacauga	9	(11-32%)	48%, 59%
'00 Tallahassee	16	(0-5%)	23%, 26%
'01 Ozark	8	(0-11%)	

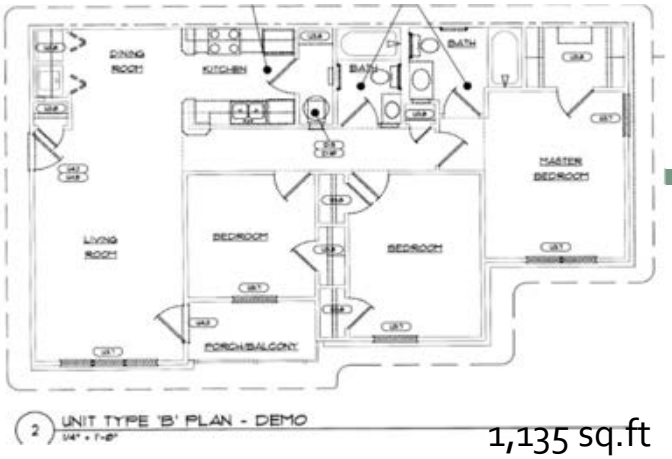
MAPLEWOOD PARK

Resarch to obtain real test data for ORNL's MULTEA numerical model

Three different unit types:

1,040 sq.ft

1,126 sq.ft



1,135 sq.ft

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GUARDED VS. UNGUARDED

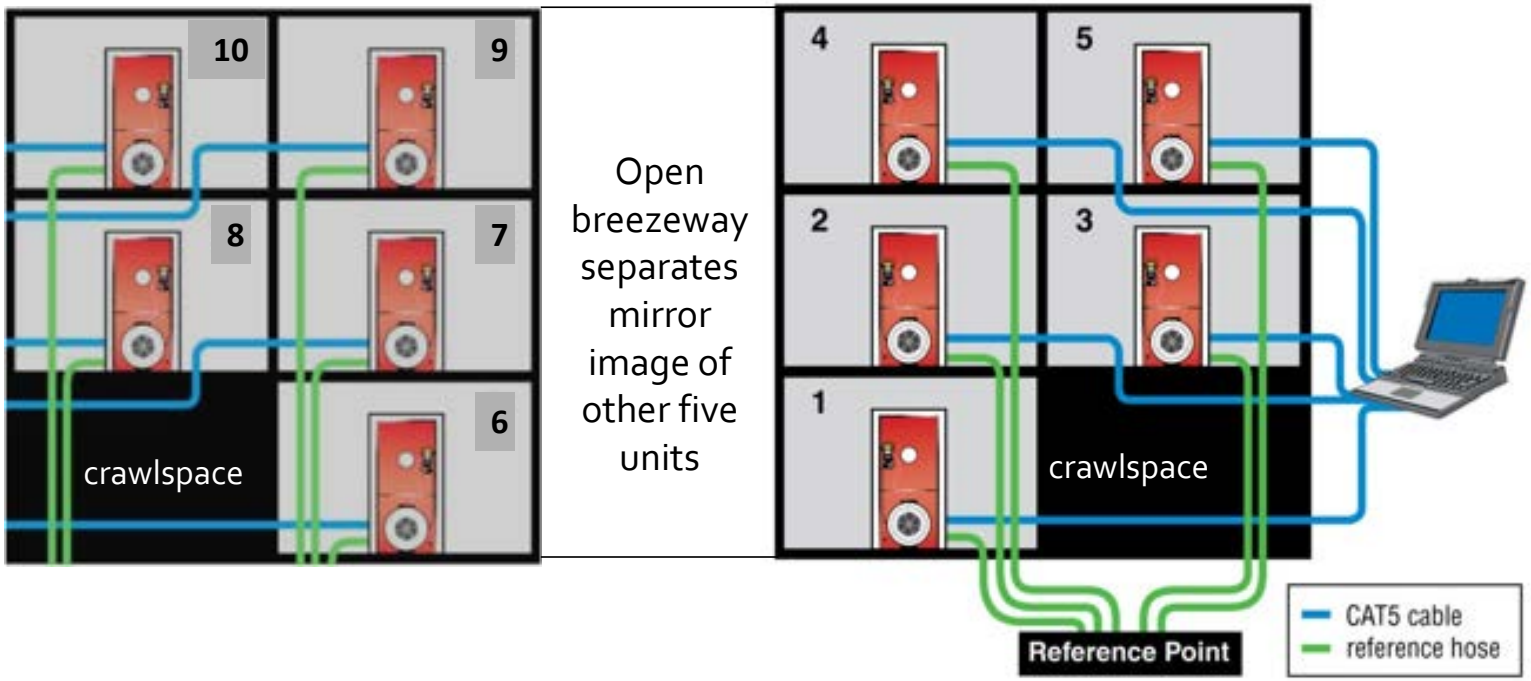
Vs.

TYPICALLY…

Unguarded – A single point infiltration test measures dwelling unit air leakage one time at single reference pressure (50 pa) using a single blower door fan.

HOWEVER…

Guarded – A guarded test measures dwelling unit air leakage at a reference pressure while inducing the same reference pressure to adjacent dwelling units through the use of multiple blower door fans



HOW DID WE DO THIS?

Breezeway

High tech bucket

2 of 5 Blower Doors

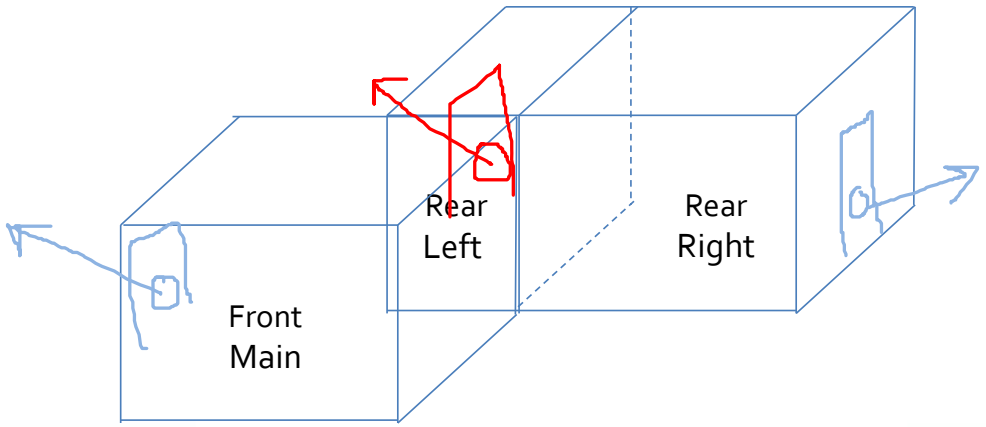
RESULTS: MAPLEWOOD PARK

Wing 1				Wing 2			
	CFM50				CFM50		
Unit	Unguarded	Guarded	Difference (%Unguarded)	Unit	Unguarded	Guarded	Difference (%Unguarded)
1	1628	1445	183 (11.2%)	**6**	1400	1304	96 (6.9%)
2	1435	1101	334 (23.3%)	**7**	1250	1015	235 (18.8%)
3	1718	1400	318 (18.5%)	**8**	1275	1027	248 (19.5%)
4	1104	1027	77 (7%)	**9**	1223	1132	91 (7.4%)
5	1544	1458	86 (5.6%)	**10**	1225	1149	76 (6.2%)
Total	7429	6431	998 (15.5%)	**Total**	6373	5627	746 (11.7%)

Top units were tightest!

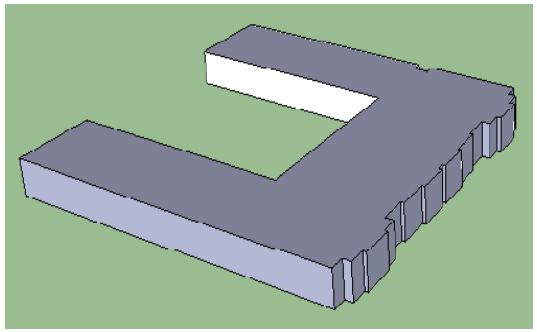
COMPARTMENTALIZATION

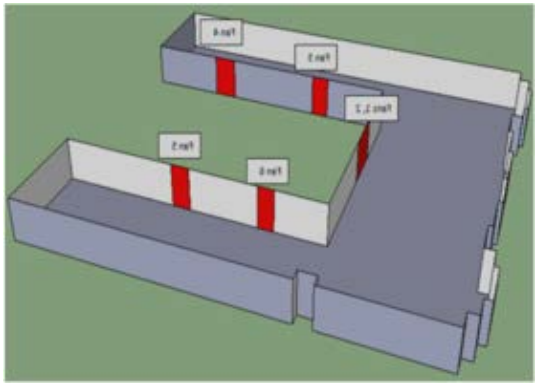
- Some commercial buildings do not openly connect / communicate throughout
  - Different compartments may have different leakage
  - Individually control each BD
  - Designate one BD zone as “master” and others as “subordinates” and control all BD’s to maintain consistent pressure between zones

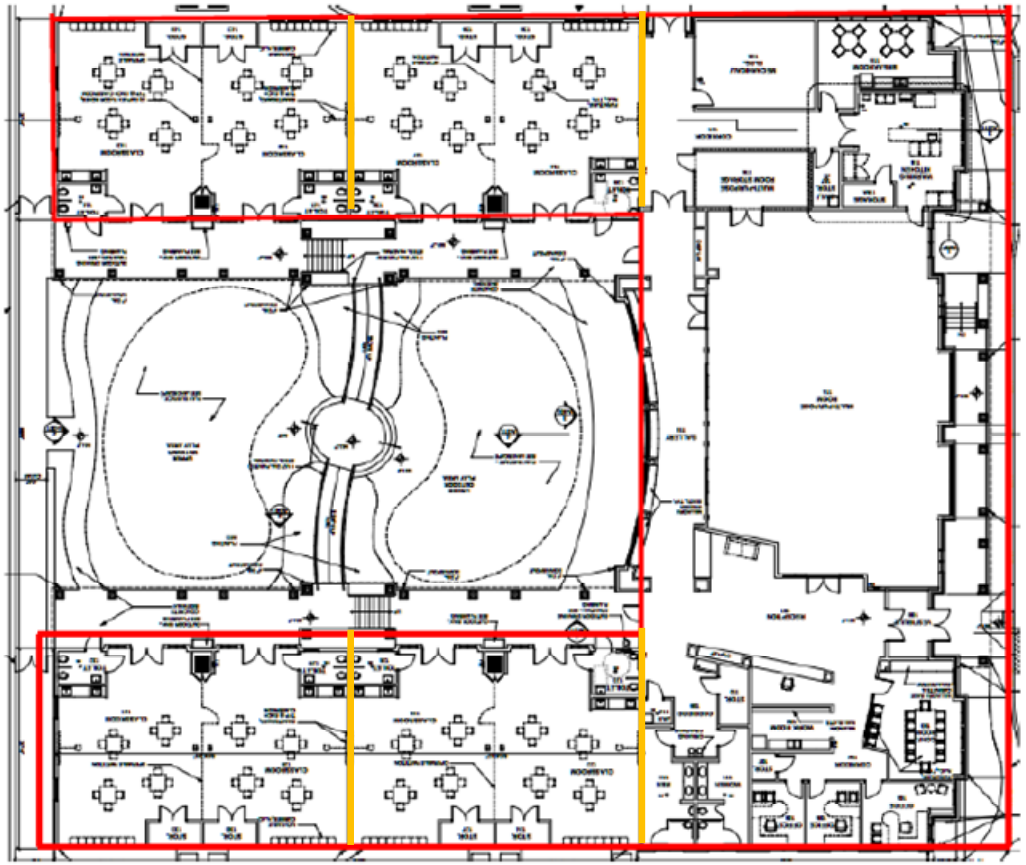


COMPARTMENTALIZATION - SCHOOL

- Five distinct compartments



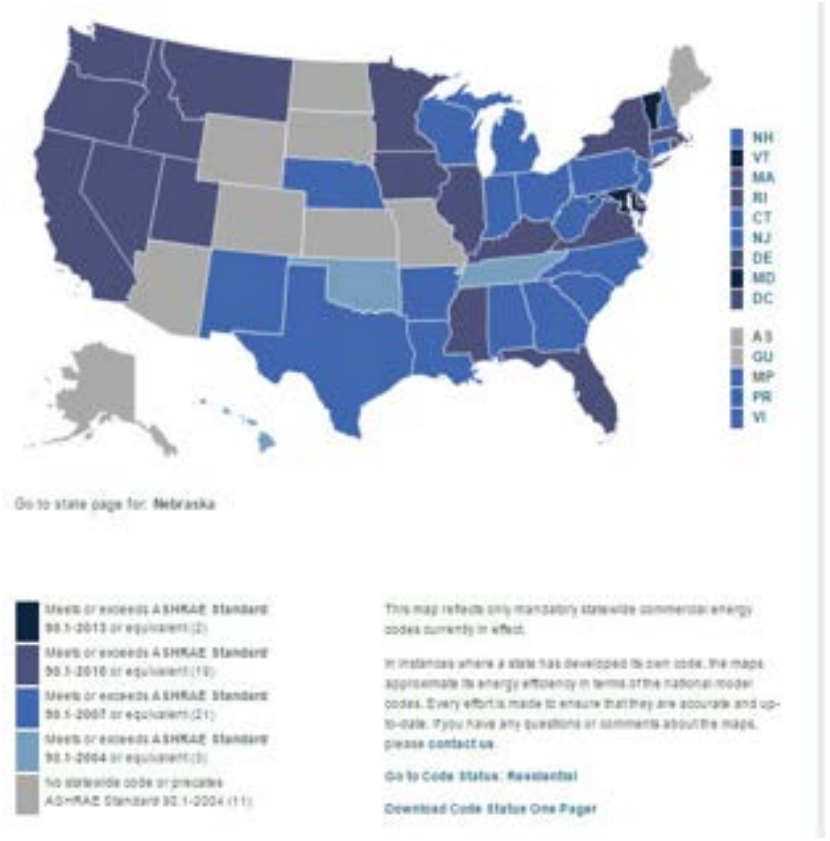




CODES AND PROGRAMS LEAKAGE REQUIREMENTS

Air Leakage Testing

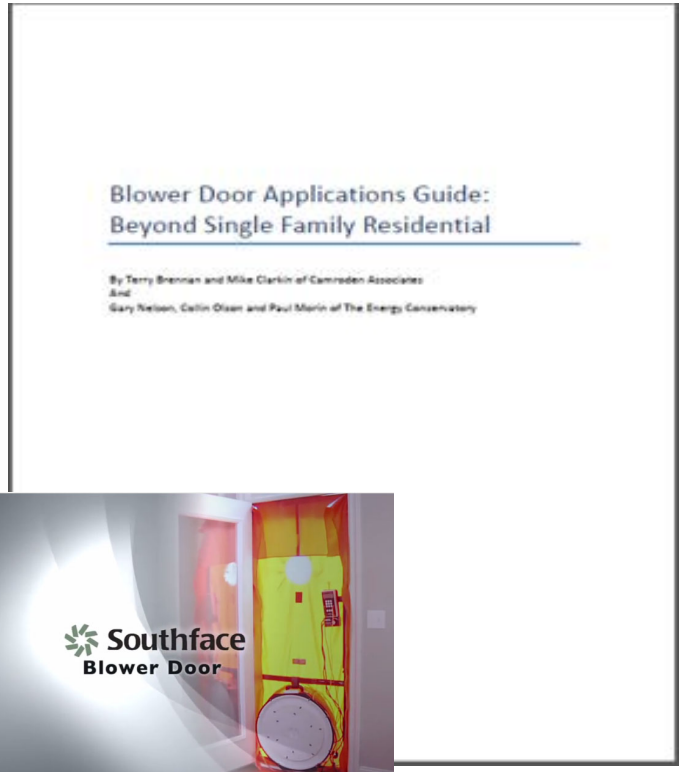
- GSA – new buildings
- Washington – >5 stories
- US Army Corps – new buildings and major renovations
- ASHRAE 189.1
- LEED BD+C
- EarthCraft Light Commercial
- IECC 2012 & beyond



MULTI-FAN BLOWER DOOR TESTING - AN EXCELLENT RESOURCE

http://support.energyconservatory.com/hc/en-us/articles/202478994-Beyond-Residential

- Explains both theory and application
- Great websites, videos and training information from both:
  - Retrotec
  - Energy Conservatory

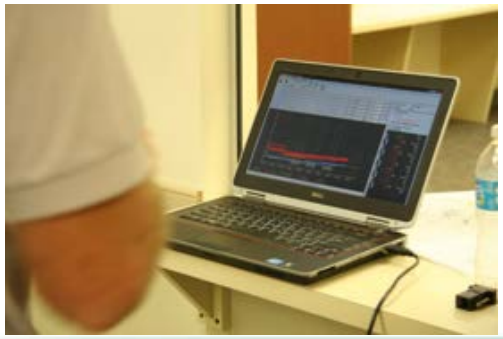


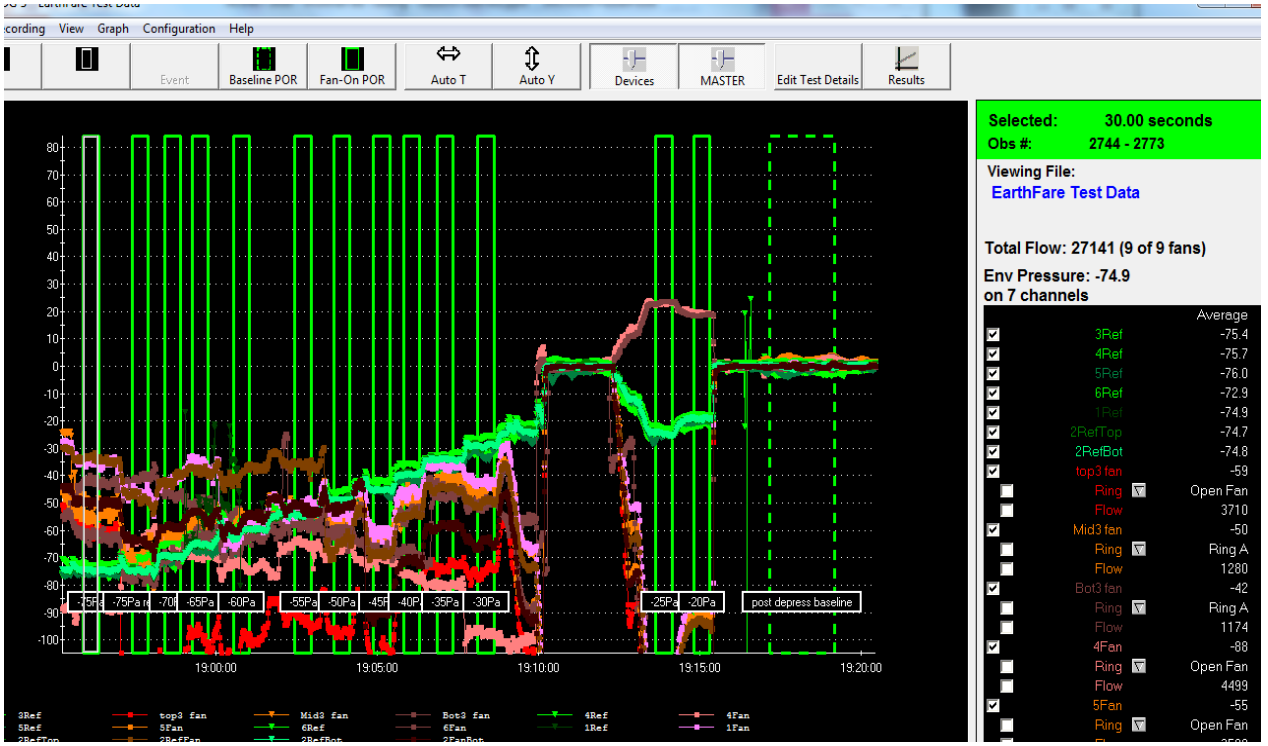
BIG PICTURE TEST PROCESS

- Follow a protocol
- Map equipment location
- Pre-test planning
  meeting of all participants – assign roles/stations
- Gather all equipment – confirm that it works
- Arrive, install equipment & prep building for testing
- Use software to perform testing
- Diagnose leaks and document results

BD TESTING COMMERCIAL BUILDINGS

- Address compartmentalization and guarded/unguarded issues
- Configure hardware and run software
- Prompts
  - for baseline(s)
  - for data recording periods
- Graphs results





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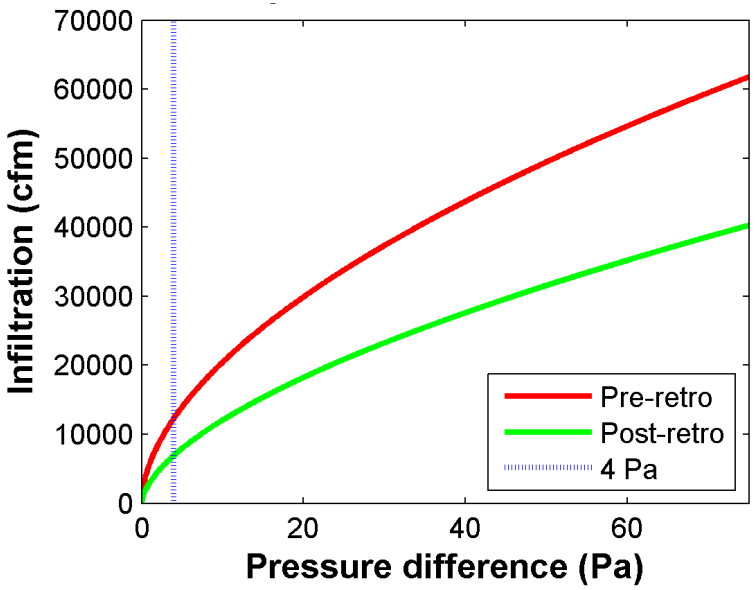
MULTI-POINT CURVE FIT – CONFUSING RESULTS

- ASTM Standard E779-03[3]: multi point test from ±20 Pa to ±75 Pa

Power Law equation: $Q = C * \Delta P^n$

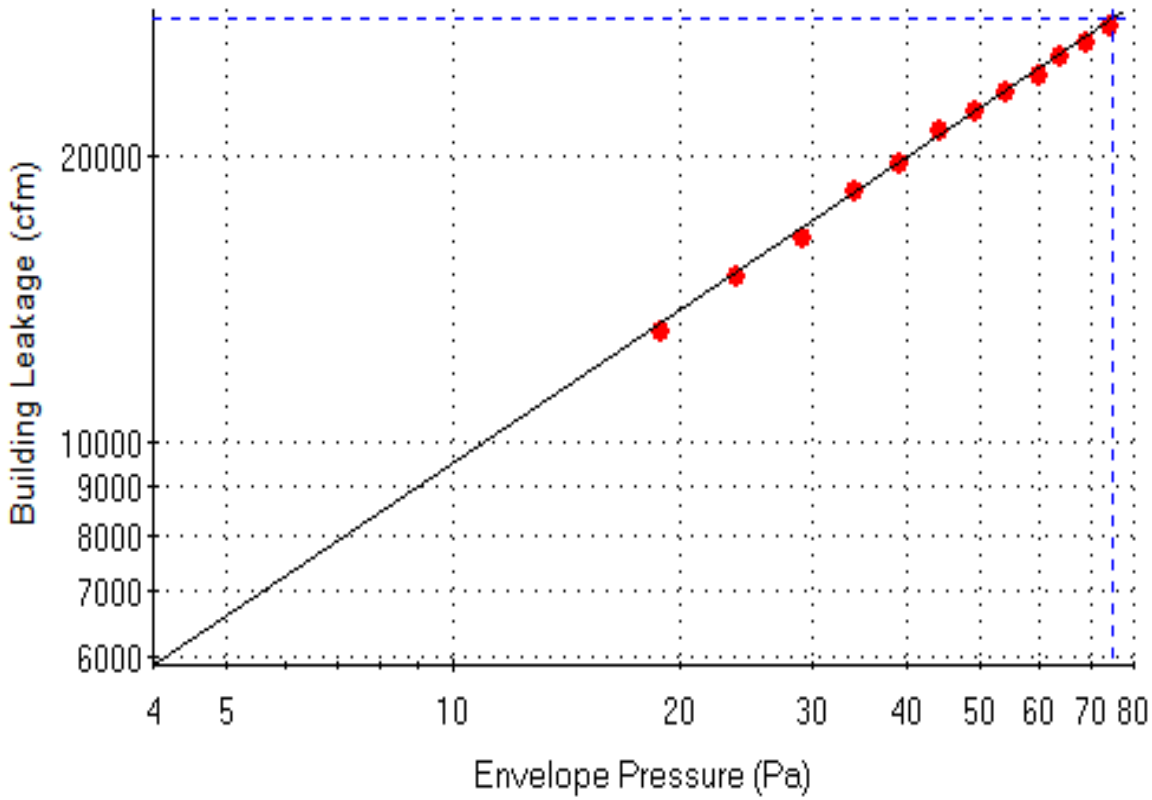
- Q – infiltration rate
- C – flow coefficient
- ΔP – pressure difference across envelope
- n – flow exponent

- *"n" is a value between 0.5 (perfectly round holes) and 1.0 (long slit)*
- *Typical default for* ***n = 0.65***



A BETTER WAY TO PLOT THE RESULTS

- Data becomes easier to read when plotted on logarithmic scale
- Curve allows leakage estimation at any pressure (e.g. 4 Pa)



AIR LEAKAGE WITH A BLOWER DOOR

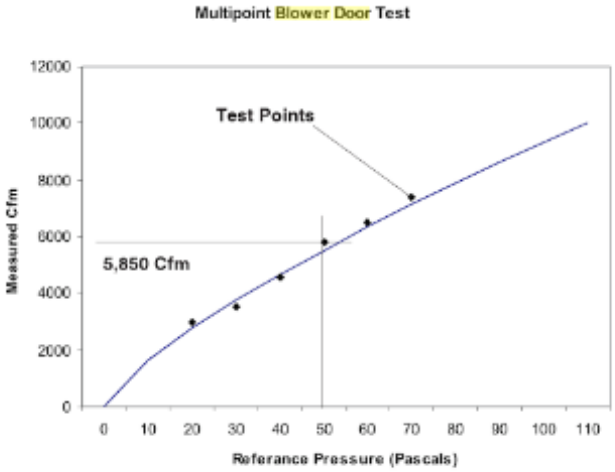


Figure 21-4

- Curve fitting allows you to determine coefficient "C" and exponent "n"

- $CFM_{Press} = C \times (\Delta Press)^n$

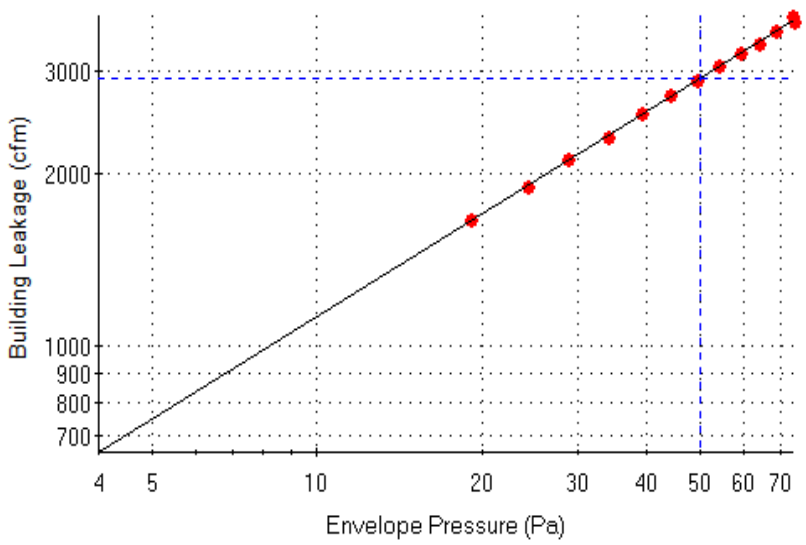
- $CFM_{50} = C \times (50)^n$

- "n" is a value between 0.5 (perfectly round holes) and 1.0 (long slit)
- Assume a default for **n = 0.65**

- $C = CFM_{50} / (50)^{0.65}$

"C" = CFM_{50} / 12.715

AIR LEAKAGE WITH A BLOWER DOOR



Reporting Pressure (Pa) 50

Test to View test 1

Test 1: Depressurization

Airflow at 50 Pascals

2929 cfm +/- 0.4 %
Range: 2916 to 2942
---- CFM @50/sq ft

Leakage Areas

EqLA (10 Pa) = 331.2 in2 +/- 1.6 %
ELA (4 Pa) = 185.7 in2 +/- 2.5 %

Building Leakage Curve

Coef. (C) = 287.5 cfm/Pa^n +/- 3.9 %
Exponent (n) = .593 +/- 0.010
Correlation Coef. (r) = .99967
Corr Coef Squared (r^2) = .99933

- A multipoint blower door test can determine the values for "C" and "n" which can then be entered into HVAC software

ENVELOPE LEAKAGE RATIO @ 75 PA "ELR75" – A BETTER METRIC

- Leakage occurs through shell of building (not through volume)
- Normalizing leakage at 75Pa (0.3 in w.c.) based on shell area is most common for commercial buildings

Building Thermal Envelope

The building thermal envelope is the portion of the building envelope that is comprised of the continuous air barrier and insulation and separates conditioned space from unconditioned space.

Example Calculation

A 7,600 square foot building (First floor: 3,600 square feet and second floor: 4,000 square feet) has a shell area of 13,920 square feet. The blower door test measures a flow of 3,340 CFM_{75}.

What is the Envelope Leakage Ratio at 75 Pa?

ELR75 is calculated by dividing the measured CFM75 by the total shell area of the envelope.

$$\textbf{Shell Area} = 4000ft^2 + 4000ft^2 + 5920ft^2 = \mathbf{13,920}ft^2$$

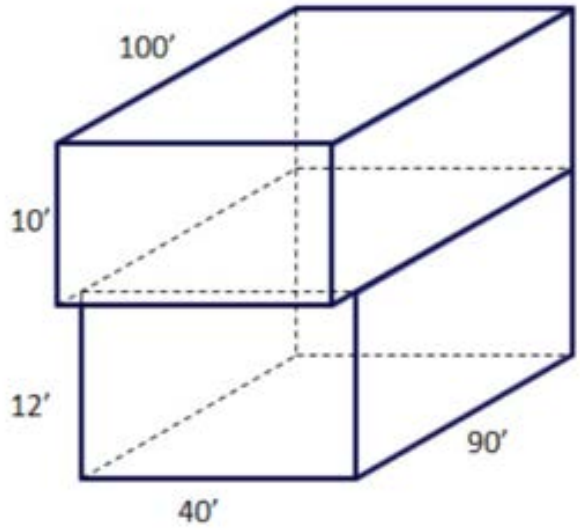
$$\textbf{BD Fan Flow Measurement} = \mathbf{3,340}\ CFM_{75}$$

$$ELR_{75} = \frac{CFM_{75}}{\textbf{Shell Area}}$$

$$ELR_{75} = \frac{3{,}340\ CFM_{75}}{13{,}920\ sf}$$

$$ELR_{75} = \mathbf{0.24}$$

Envelope passes program requirement and earns additional points



VERIFYING AN ENERGY EFFICIENT BUILDING ENVELOPE

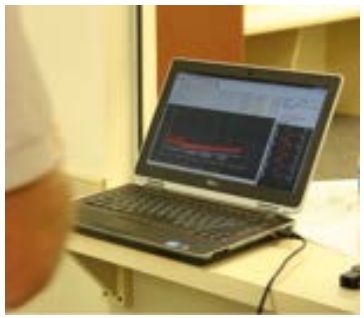
Blower Door Testing – Recognized by IECC

- Prove Air Sealing
- Envelope Integrity

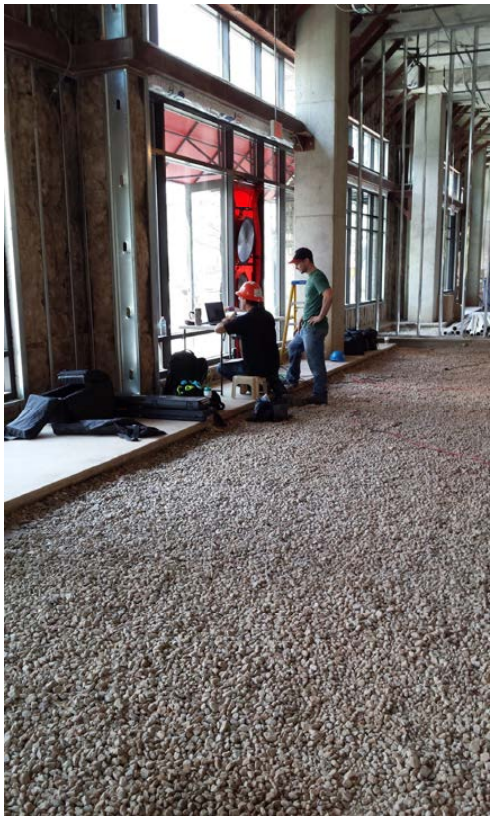
C402.5 Air leakage—thermal envelope (Mandatory). The *thermal envelope* of buildings shall comply with Sections C402.5.1 through C402.5.8, or the building *thermal envelope* shall be tested in accordance with ASTM E 779 at a pressure differential of 0.3 inch water gauge (75 Pa) or an equivalent method approved by the code official and deemed to comply with the provisions of this section when the tested air leakage rate of the building thermal envelope is not greater than 0.40 cfm/ft^2 (0.2 L/s · m^2). Where compliance is based on such testing, the building shall also comply with Sections C402.5.5, C402.5.6 and C402.5.7.

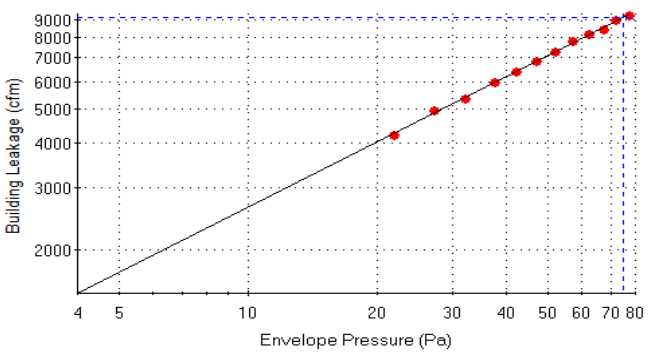
$$ELR_{75} = \frac{CFM_{75}}{\text{shell area}}$$

$$ELR_{75} \leq 0.40$$



MULTI-BLOWER DOOR – ENVELOPE LEAKAGE TEST





Label	Base?	start	end	nobs	Avg Pressu	Total Flow
pre depress	True	5571	5686	116	1.92	0
-75Pa	False	7414	7443	30	-75.06	9233.5
-70Pa	False	7469	7498	30	-69.94	8950.7
-60Pa	False	9106	9135	30	-59.98	8128.6
-65Pa2	False	9146	9175	30	-65.08	8381.5
-55Pa	False	9196	9225	30	-55.06	7795.6
-50Pa	False	9244	9271	28	-49.76	7255
-45Pa	False	9286	9313	28	-44.85	6837.3
-40Pa	False	9333	9362	30	-39.97	6360.2
-35Pa	False	9390	9419	30	-35.31	5945.9
-30Pa	False	9476	9503	28	-29.9	5341.5

Copy Data Table to Clipboard

Reporting Pressure (Pa) 75

Test to View test 1

Test 1: Depressurization

Airflow at 75 Pascals

9150 cfm +/- 1.0 %
Range: 9057 to 9243
0.160 CFM @75/sq ft (0.159 to 0.162)

Leakage Areas

EqLA (10 Pa) = 776.6 in2 +/- 2.6 %
ELA (4 Pa) = 426.5 in2 +/- 4.1 %

Building Leakage Curve

Coef. (C) = 639.5 cfm/Pa^n +/- 6.3 %
Exponent (n) = .616 +/- 0.016
Correlation Coef. (r) = .99929
Corr Coef Squared (r^2) = .99857

View / Edit Test Details

Export to Tectite Express...

USACE Report

OK

PREDICTING LEAKAGE?

Is there a Leakage Correlation based on:

- Age / Code in place? Size? Usage type? Construction Materials?

What is baseline & expected range for a standard building in the southeast?
Was there anything predictable?

- Corrugated metal roof connections
- Junctions of two different planes (e.g., roof to wall)
- Junctions of different materials (e.g., metal or wood to block or drywall)
- Hidden pathways (e.g., above the drop ceiling tiles)
- Enforcement of code fire blocking

- Utility Chases
- Metal Roof Decking
- Gabled Roof Junctions
- Mechanical RTU Penetrations
- Roof Membrane Connections

BD REVEALS COMMON LEAKAGE PATHWAYS

UTILITY CHASE

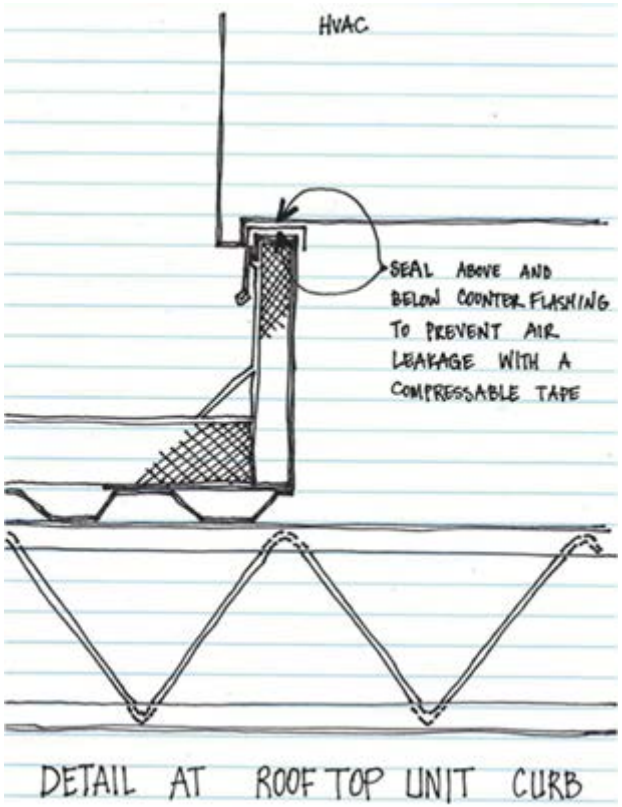
METAL BUILDING ROOF

Roof above shims

GABLED ROOF

RTU LEAKAGE

RTU ENVELOPE PENETRATIONS



Wall and roof penetration require sealing at curb and equipment

FLAT ROOFED STRIP RETAIL

PARAPET WALL LEAKS

HOW TO GET FOG IN THE RIGHT PLACE

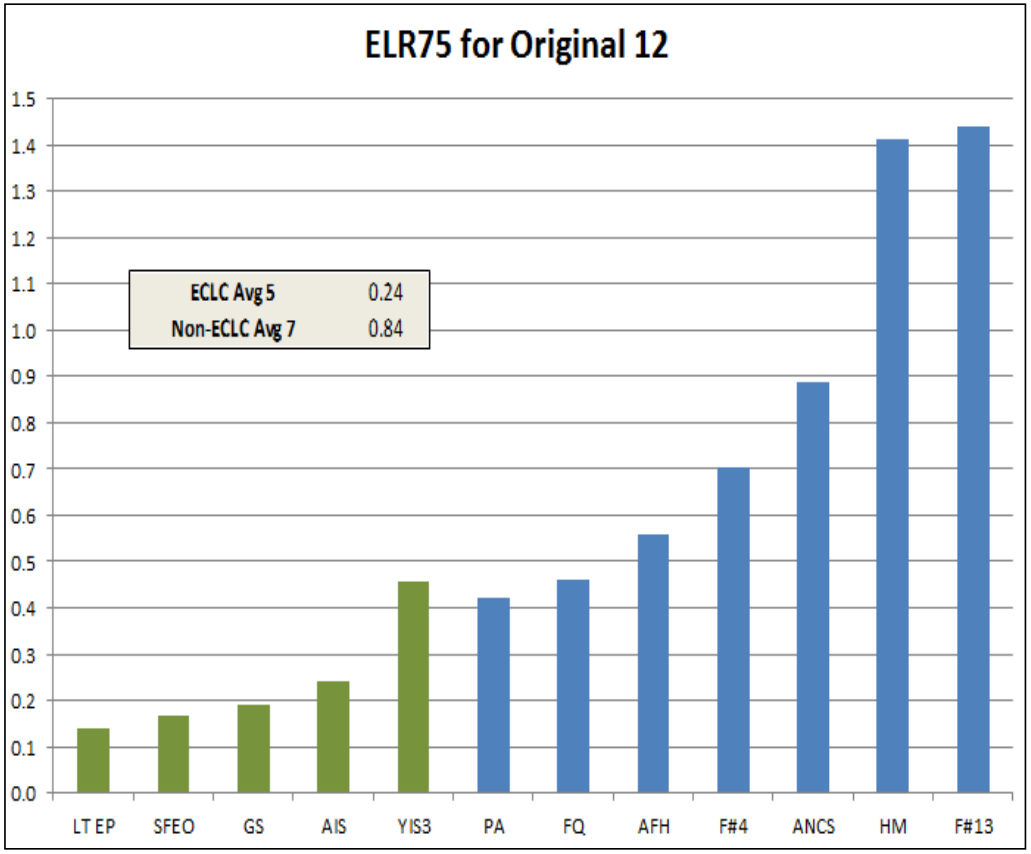
INFLATED TPO MEMBRANE

PENETRATION DETAILS

ACBI ORIGINAL 12 BUILDINGS

Test Buildings	Date of Test	Cond. Floor Area (s.f.)	SFBE	# of Stories	ELR75	Depressurization @-75Pa (masked)	Pressurization @+75Pa (masked)
	7/17/2014	17,283	48,330	1	**0.240**	11,602	12,355
	7/30/2014	2,318	9,775	1	**0.141**	1,378	1,366
	6/19/2014	3,533	12,437	2	**0.189**	2,353	2,674
	8/6/2014	5,946	11,637	3	**0.167**	1,938	2,331
	9/16/2014	12,864	36,845	1	**0.456**	16,794	20,319
	5/20/2014	11,117	29,008	3	**0.461**	13,365	14,234
	5/15/2014	17,176	41,635	1	**0.560**	23,322	23,539
	4/10/2014	5,910	15,422	1	**0.702**	10,823	9392**
	6/10/2014	34,200	69,600	2	**0.887**	61,751	74,721
	10/10/2014	34,200	69,600	2	**0.578**	40,212	44,683
	5/28/2014	3,035	8,804	1	**1.277**	11,245	12,154
	11/22/2014	3,035	8,804	1	**1.412**	12,428	12,422
	6/19/2014	7,912	20,956	1	**0.423**	8,854	9,234
	7/15/2014	5,020	15,402	2	**1.438**	22,151	22,308

ORIGINAL 12 BUILDINGS



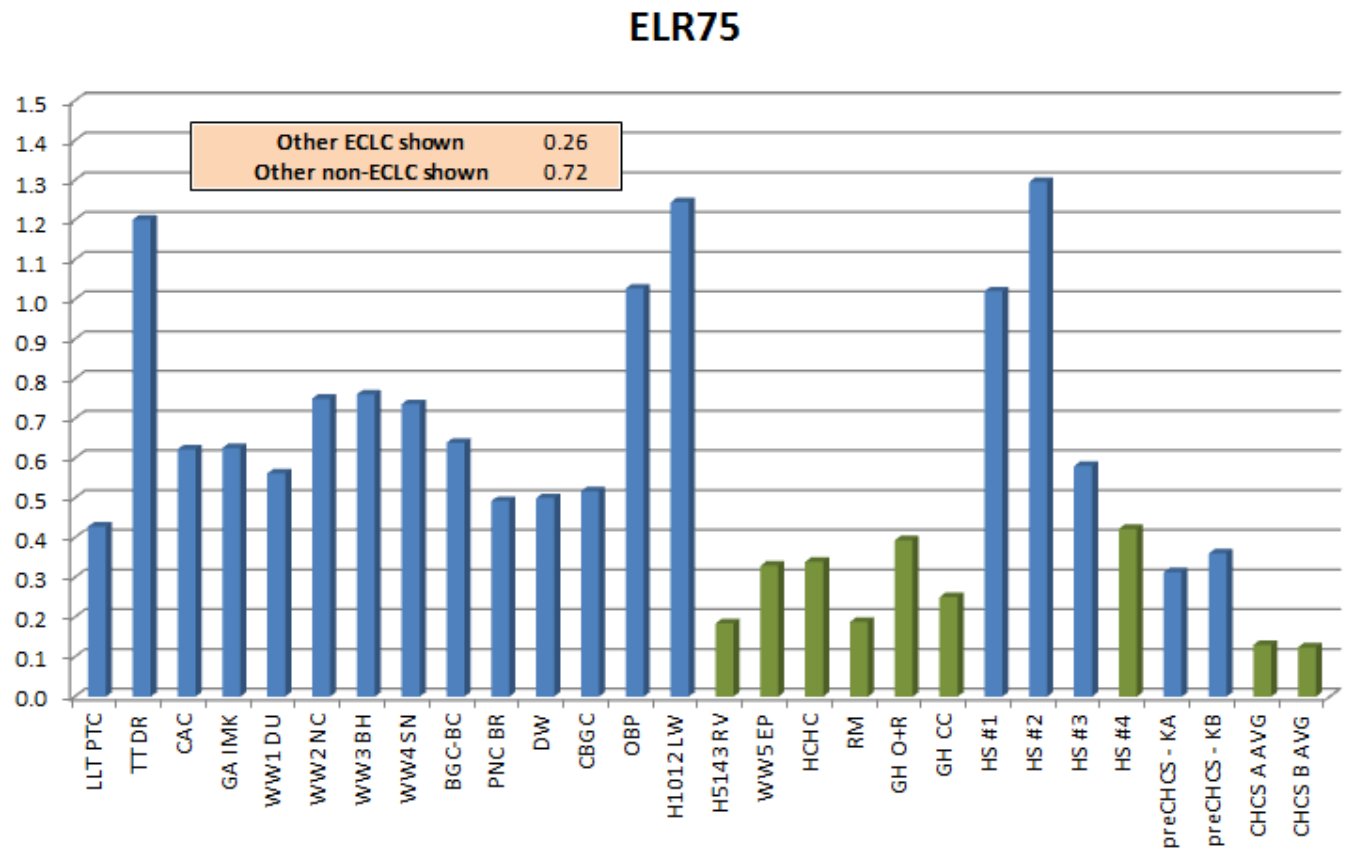
ANALYZING TESTING RESULTS

- **All buildings are created unequal** – no apparent correlation between age, type of construction, location, etc.
- **Air Sealing** – starts at design
- **Existing buildings** – can be retro sealed
- **Designed air barrier** – 0.25 ELR_{75} ; (average existing 0.84 – over 3 times leakier!)
- **Modeling tools** vary significantly in predicted savings from air sealing – approximately~10%

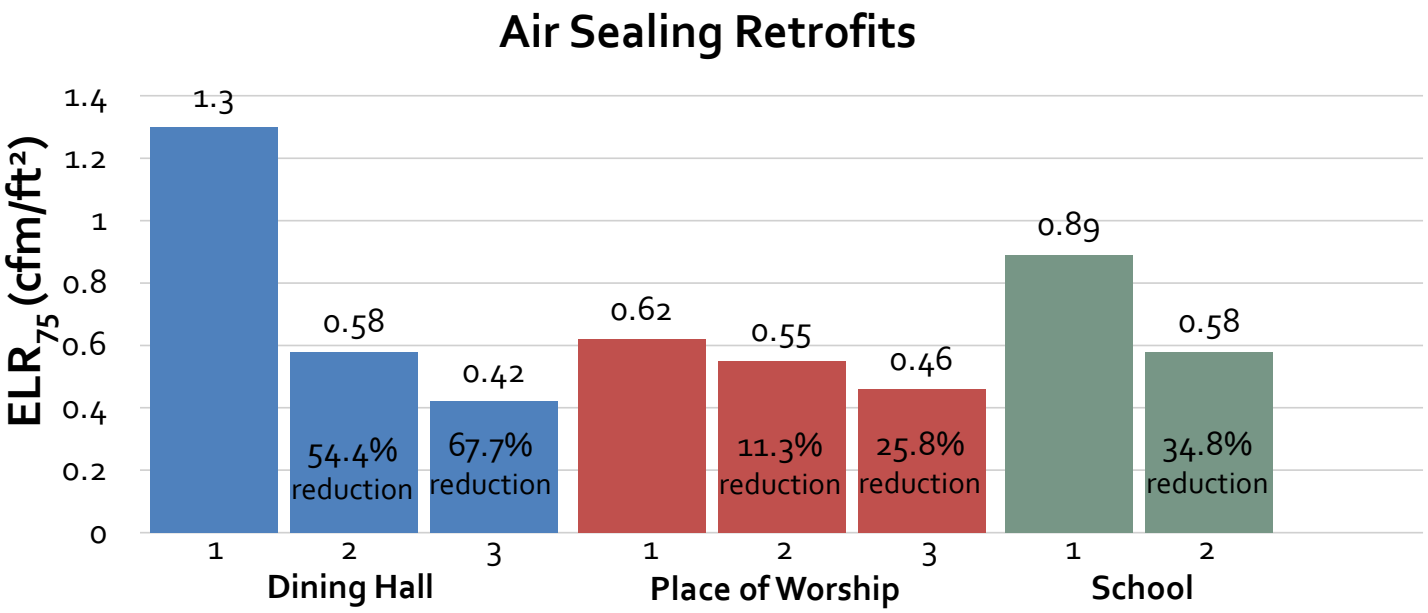
ADDITIONAL BUILDINGS – SIMILAR RESULTS

Test Buildings	Date of Test	Cond. Floor Area (s.f.)	SFBE	# of Stories	ELR75	Depressurization @-75Pa (masked)	Pressurization @+75Pa (masked)
	11/11/2014	4,261	13,219	1	0.429	5,666	5,518
	11/17/2014	6,692	16,829	2	1.201	20,214	19,589
	12/4/2014	2,128	5,760	1	0.623	3,587	3,628
	12/10/2014	1,081	3,562	1	0.626	2,230	2,269
	12/15/2014	1,480	5,480	1	0.562	3,081	3,501
	12/16/2014	2,207	8,878	1	0.750	6,662	6,745
	12/17/2014	1,586	6,743	1	0.761	5,134	5,134
	12/18/2014	1,895	7,907	1	0.737	5,825	5,662
	12/19/2014	1,561	6,674	1	0.330	2,200	2,181
	1/14/2015	12,142	32,873	1	0.639	21,020	22,286
	2/4/2015	3,416	9,336	1	0.493	4,601	4,672
	2/9/2015	4,236	10,390	1	0.500	5,195	5,194
	11/12/2015	11,417	20,297	3	0.184	3,740	4,738
	1/11/2016	3,020	8,123	1	0.517	4,200	4,553
	1/12/2016	4,315	14,359	1	1.028	14,758	16,428
	1/13/2016	3,900	12,000	1	1.244	14,933	15,513
	8/22/2012	21,628	44,259	2	0.339	15,019	n/a
	5/22/2014	11,202	37,370	1	0.188	7,030	n/a
	6/11/2014	1,634	4,847	2	0.394	1,910	2,352
	6/11/2014	500	2,545	1	0.251	638	791
	7/10/2014	6,082	13,937	1	1.021	14,224	
	7/29/2014	4,615	11,165	1	1.296	14,467	15,824
	8/4/2014	4,615	14,668	1	0.581	8,515	
	8/18/2014	4,615	14,668	1	0.422	6,192	6,402
	8/26/2014	1,135	3,949	1	0.313	1,238	
	8/26/2014	1,680	6,409	1	0.360	2,310	
	10/2/2014	1,135	3,949	1	0.13	514	
	10/2/2014	1,680	6,409	1	0.12	798	

ADDITIONAL BUILDINGS – SIMILAR RESULTS



AIR SEALING RETROFITS



Air leakage of existing buildings can be substantially reduced with spray foam

ENERGY MODELING CHALLENGES

- Commercial building air leakage testing is in its infancy (relatively few buildings in largest known database); modeling default values are unsubstantiated
- Input for modeling software varies: ACH_{nat} , ACH_{50}, cfm/ft^2 of floor area, cfm_4/ft^2 of envelope area @ 4 Pa (ELR_4)
- Testing is conducted at accelerated pressures to minimize other driving forces – must extrapolate from multipoint regression analysis

TESTING PROCEDURE LESSONS LEARNED

- Get floor plans or at least get fire evacuation plan
- Consider a SketchUp model for more cut-up assemblies and to assist in take-off calculations
- Pre meeting – assign tasks and zone responsibilities
- Written test procedure
- Site communication – local contact
    - Signage around building
    - Walkie-talkies
    - Pre-condition of thermostat settings

TESTING PROCEDURE LESSONS LEARNED, CONT.

- Reinforce masking
- Foam insulation tubes / pool noodles at doors with auto closers; door shims
- 1 fan per circuit
- Extension cords, power indicators, long tubing
- Theatrical fog machine, fan, flex duct and pole
- Duplicate fans (if possible, face in alternate directions)

- Ladders, extension cords, batteries, extra kits if available

HOW TO ESTIMATE NUMBER OF FANS

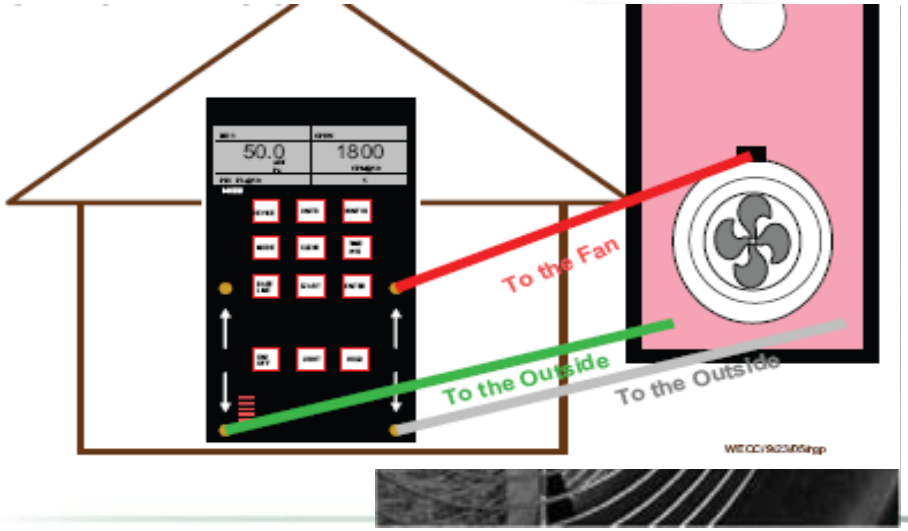
- Minimum one per "compartment"
- Estimate an ELR75
  - Determine shell area
  - Back out CFM75
- Assume ~5,000 cfm per fan plus one extra fan

- Example: 40' x 60' x 25' building
  - Shell Area: 9800 s.f. (Ceiling: 2400 s.f., Floor 2400 s.f., Walls: 5000 s.f.)
  - Assume leaky ELR75 = 1.5 = CFM75 / 9800 so CFM75 = 14,700
  - 14,700 / 5000 = 2.9 which rounds to 3 and then add 1 for **4 BD's total**

PRESSURIZATION - FANS NEED REF TUBE

The blower door fan pressure is always measured at the flow sensor WRT the **fan inlet side:**

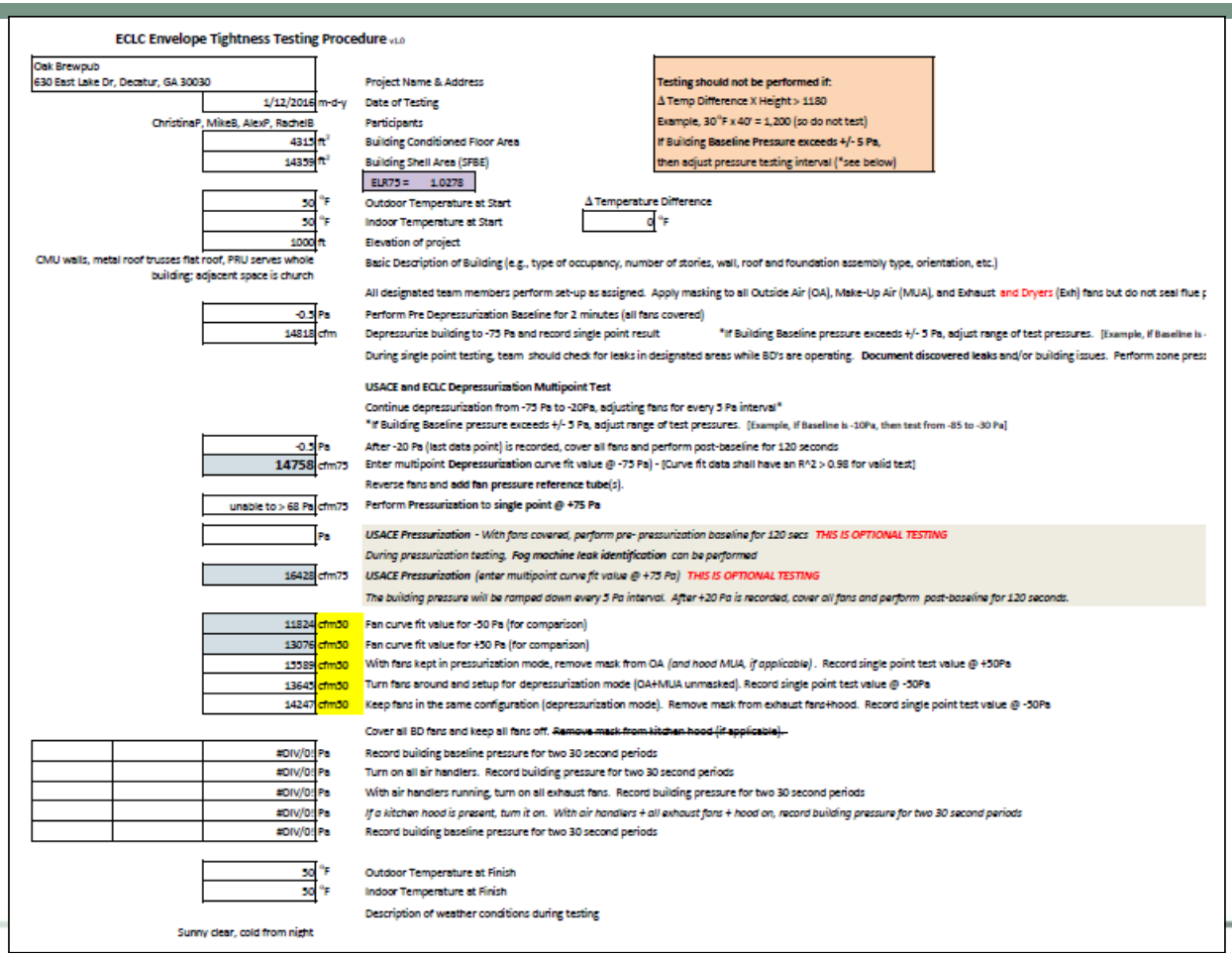
- *the building when depressurizing*
- *the outside when pressurizing – use reference tube*



SOUTHFACE RESOURCES – ONE PAGE TEST SHEET

Multi-fan multi-point testing

- Test protocol
- Paper copy is great for results tracking while performing testing
- Spreadsheet version can perform calculations



ECLC Envelope Tightness Testing Procedure v1.0

Oak Brewpub 630 East Lake Dr, Decatur, GA 30030		Project Name & Address
1/12/2016	m-d-y	Date of Testing
ChristineP, MikeB, AlexP, RachelB		Participants
4315	ft²	Building Conditioned Floor Area
14359	ft²	Building Shell Area (SFBE)
ELR75 = 1.0278		
50	°F	Outdoor Temperature at Start
50	°F	Indoor Temperature at Start
1000	ft	Elevation of project
CMU walls, metal roof trusses flat roof, PRU serves whole building; adjacent space is church		Basic Description of Building (e.g., type of occupancy, number of stories, wall, roof and foundation assembly type, orientation, etc.)
-0.5	Pa	Perform Pre Depressurization Baseline for 2 minutes (all fans covered)
14818	cfm	Depressurize building to -75 Pa and record single point result
-0.5	Pa	After -20 Pa (last data point) is recorded, cover all fans and perform post-baseline for 120 seconds
14758	cfm75	Enter multipoint **Depressurization** curve fit value @ -75 Pa) - [Curve fit data shall have an R^2 > 0.98 for valid test]
unable to > 68 Pa	cfm75	Perform **Pressurization** to **single point @ +75 Pa**
	Pa	
16428	cfm75	
11824	cfm50	Fan curve fit value for -50 Pa (for comparison)
13076	cfm50	Fan curve fit value for +50 Pa (for comparison)
13589	cfm50	With fans kept in pressurization mode, remove mask from OA *(and hood MUA, if applicable)*. Record single point test value @ +50Pa
13645	cfm50	Turn fans around and setup for depressurization mode (OA+MUA unmasked). Record single point test value @ -50Pa
14247	cfm50	Keep fans in the same configuration (depressurization mode). Remove mask from exhaust fans+hood. Record single point test value @ -50Pa
#DIV/0!	Pa	Record building baseline pressure for two 30 second periods
#DIV/0!	Pa	Turn on all air handlers. Record building pressure for two 30 second periods
#DIV/0!	Pa	With air handlers running, turn on all exhaust fans. Record building pressure for two 30 second periods
#DIV/0!	Pa	*If a kitchen hood is present, turn it on. With air handlers + all exhaust fans + hood on, record building pressure for two 30 second periods*
#DIV/0!	Pa	Record building baseline pressure for two 30 second periods
50	°F	Outdoor Temperature at Finish
50	°F	Indoor Temperature at Finish
Sunny clear, cold from night		Description of weather conditions during testing

Testing should not be performed if:
Δ Temp Difference X Height > 1180
Example, 30°F x 40' = 1,200 (so do not test)
If Building Baseline Pressure exceeds +/- 5 Pa,
then adjust pressure testing interval (*see below)

Δ Temperature Difference: 0 °F

All designated team members perform set-up as assigned. Apply masking to all Outside Air (OA), Make-Up Air (MUA), and Exhaust and Dryers (Exh) fans but do not seal flue p

*If Building Baseline pressure exceeds +/- 5 Pa, adjust range of test pressures. [Example, if Baseline is -

During single point testing, team should check for leaks in designated areas while BD's are operating. **Document discovered leaks** and/or building issues. Perform zone press

USACE and ECLC Depressurization Multipoint Test

Continue depressurization from -75 Pa to -20Pa, adjusting fans for every 5 Pa interval*
*If Building Baseline pressure exceeds +/- 5 Pa, adjust range of test pressures. [Example, if Baseline is -10Pa, then test from -85 to -30 Pa]

USACE Pressurization - With fans covered, perform pre- pressurization baseline for 120 secs THIS IS OPTIONAL TESTING

During pressurization testing, Fog machine leak identification can be performed

USACE Pressurization (enter multipoint curve fit value @ +75 Pa) THIS IS OPTIONAL TESTING

The building pressure will be ramped down every 5 Pa interval. After +20 Pa is recorded, cover all fans and perform post-baseline for 120 seconds.

Cover all BD fans and keep all fans off. ~~Remove mask from kitchen hood (if applicable).~~

SOUTHFACE RESOURCES

- Assessment toolkit
  - Process
  - Data collection
  - Analysis
  - Report template
  - Implementation checklist
- Quick guides
  - Fire stations
  - Rec centers
  - Small commercial on campus
- Multiple Fan multi-point testing
  - Test protocol
  - Report template

Visit www.sourthface.org for a link to these resources

Commercial Energy Codes

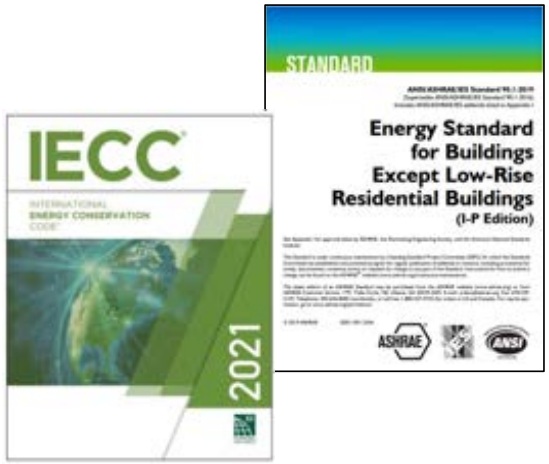
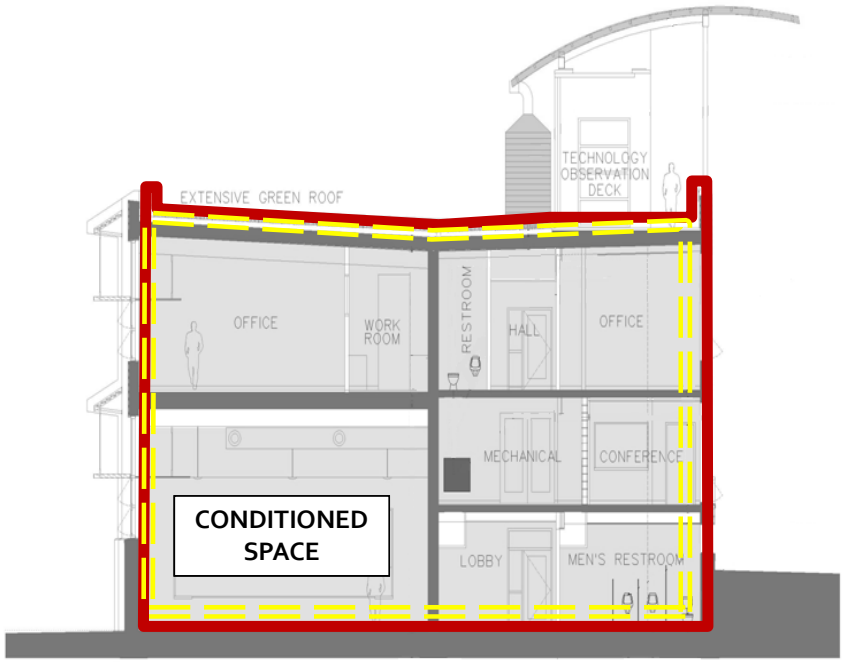


Photo: Jonathan Hillyer, 2009

WHAT IS THE BUILDING THERMAL ENVELOPE?

These assemblies can comprise the building thermal envelope if they **separate conditioned from unconditioned space or outside air**

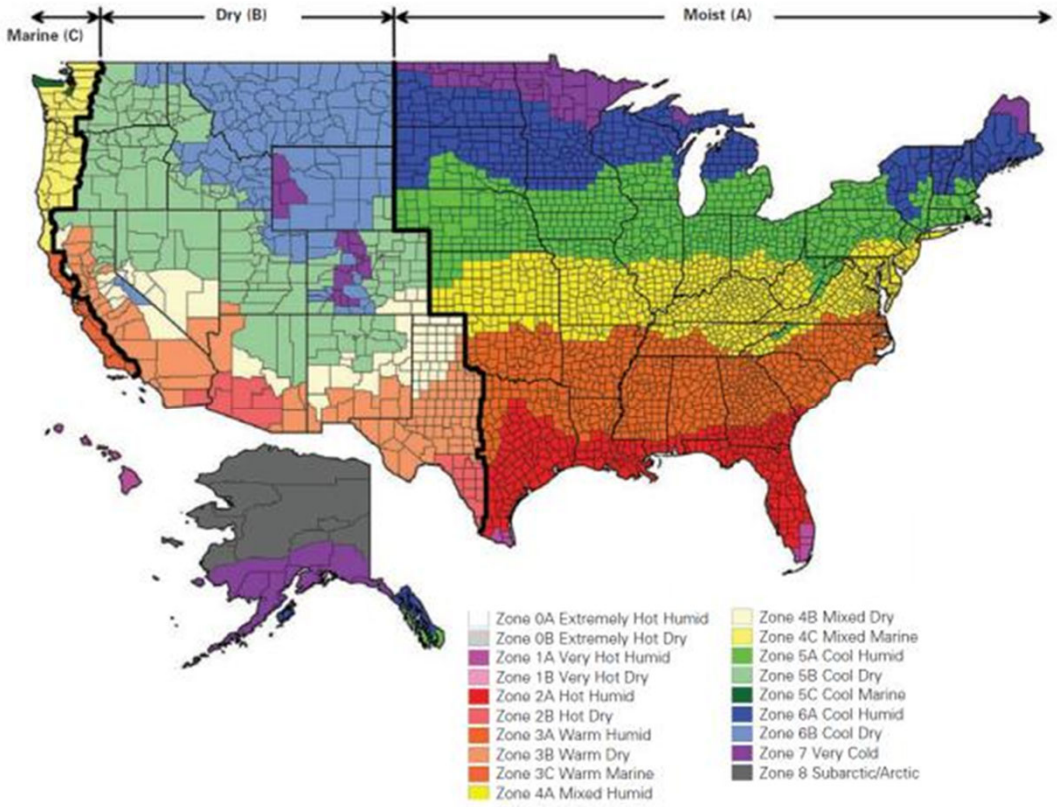
- Roof/Ceiling Assembly
- Wall Assembly
- Vertical Fenestration and Skylights
- Floor Assembly
- Slab Edge
- Below-Grade Wall Assembly



COMPLIANCE OPTIONS - PRESCRIPTIVE

Building must comply with

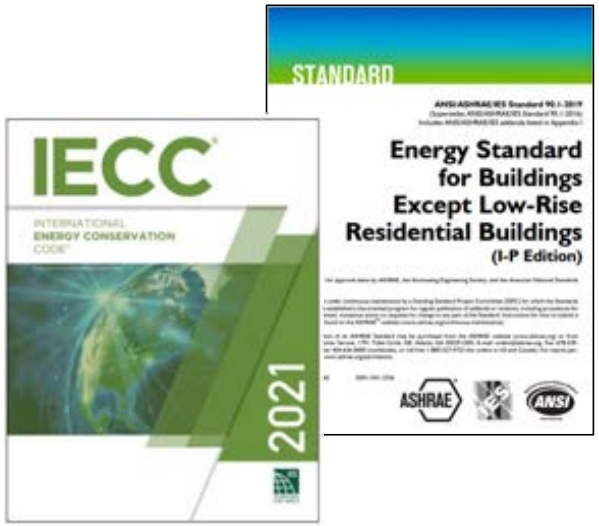
- C402 Envelope
- C403 Mech
- C404 SWH
- C405 Lighting
- Plus pick one additional efficiency package



ADDITIONAL EFFICIENCY PACKAGE OPTIONS

One additional efficiency feature must be selected to comply with the IECC

- C406.2 More efficient **HVAC** performance, OR
- C406.3 Reduced **lighting** power density system, OR
- C406.4 Enhanced lighting **controls**, OR
- C406.5 On-site supply of **renewable** energy
- C406.6 Dedicated outdoor air system (**DOAS**), OR
- C406.7 More efficient SWH (**hot water**) OR
- C406.8 Enhanced **envelope** performance OR
- C406.9 Reduced air **infiltration**


IECC
INTERNATIONAL
ENERGY CONSERVATION
CODE
2021
STANDARD
Energy Standard
for Buildings
Except Low-Rise
Residential Buildings
(I-P Edition)
ASHRAE
ANSI

AIR BARRIER

CONTINUOUS AIR BARRIER

Continuous air barrier required except in:

- Semiheated spaces in climate zones 0-6
- Single wythe concrete masonry buildings in climate zone 2B

The air barrier shall be designed and noted

- Air barrier components identified or noted in construction documents
- Joints, intersections, and penetrations of air barrier components (incl. lighting fixtures) detailed
- Air barrier must extend over all surfaces of building envelope at lowest floor, exterior walls, and ceiling or roof
- Designed to resist positive and negative pressures from wind, stack effect, and mechanical ventilation

AIR BARRIER MATERIALS

Materials that have an air permeance not exceeding 0.004 cfm/ft^2 under a pressure differential of 0.3 in. of water (1.57 psf) when tested in accordance with ASTM E2178. The following materials meet these requirements:

Material	Thickness (minimum)
Plywood	3/8 in.
Oriented strand board	3/8 in.
Extruded polystyrene insulation board	½ in.
Foil-faced urethane insulation board	½ in.
Exterior gypsum sheathing or interior gypsum board	½ in.
Cement board	½ in.
Built up roofing membrane	
Modified bituminous roof membrane	
Single-ply roof membrane	
A Portland cement/sand parge, stucco, or gypsum plaster	½ in.
Cast-in-place and precast concrete	
Sheet metal	
Closed cell 2 lb/ft^3 nominal density spray polyurethane foam	1 in.

AIR BARRIER INSTALLATION

The following areas are to be wrapped, sealed, caulked, gasketed, or taped:

- Joints around fenestration and door frames (both manufactured and site-built)
- Junctions between walls
  - And foundations
  - At building corners
  - And roofs or ceilings
- Penetrations for roofs, walls, and floors
- Building assemblies used as ducts or plenums
- Joints, seams, connections between planes, and other changes in continuous air barrier materials

RECESSED LIGHTING

All recessed luminaires installed in the building thermal envelope must be IC rated and have the following:

- Sealed with gasket or caulk between housing and interior wall or ceiling covering
- Labeled in accordance with ASTM E 283 to allow ≤2.0 cfm of air movement between conditioned and unconditioned spaces

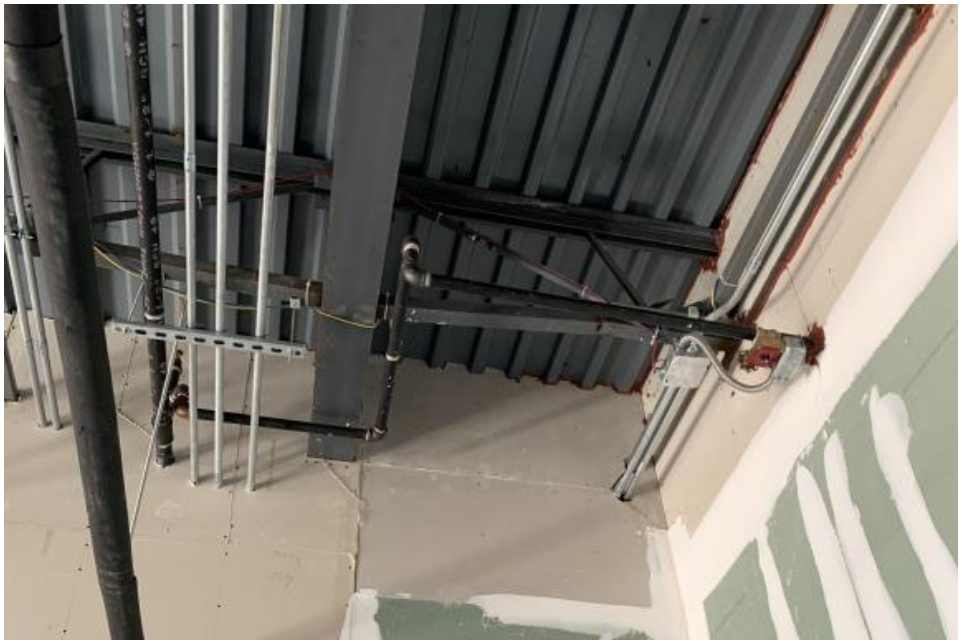
MAJOR AIR LEAKAGE LOCATIONS

- Cavities above suspended ceilings
- Plenum return spaces (Highly depressurized)
- Ventilated walls
- Equipment tunnels and chases
- Mechanical rooms and mezzanines
- Unconditioned adjacent space (storage, plant, warehouse, etc.)

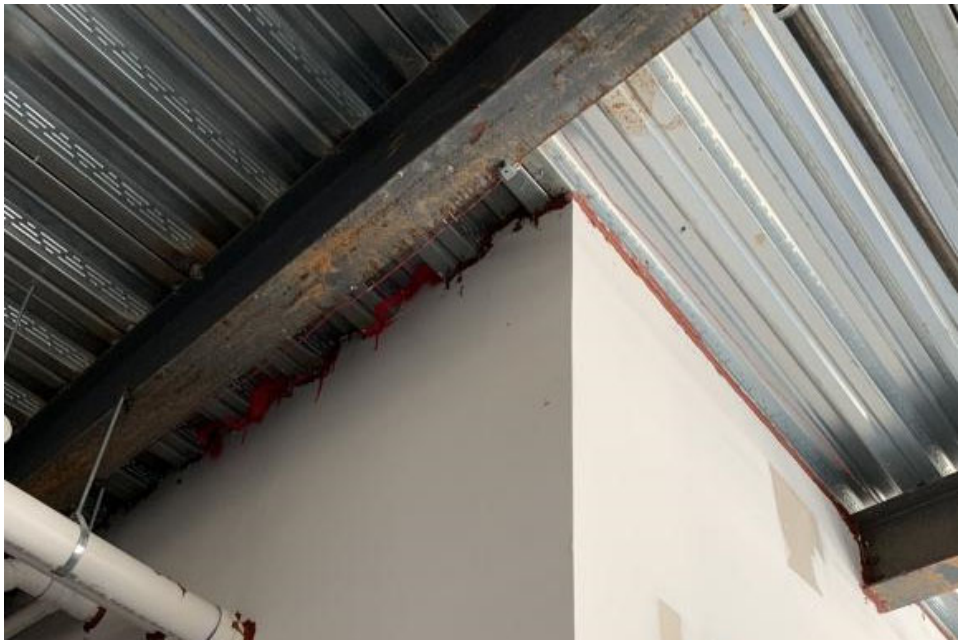
AIR SEALING IS MANDATORY

Roof leak or something else?

NO OR POOR QUALITY AIR SEALING



GETTING BETTER



HOW TO ASSESS AIR SEALING

Look up!
Sometimes behind
a drop ceiling.

BONUS - REDUCED AIR INFILTRATION

Air infiltration verified by whole-building pressurization test

- Per ASTM E779 or ASTM E1827
- By an independent third party

Measured air-leakage rate not to exceed 0.25 cfm/ft^2 under pressure differential of 0.3 inches w.c. (75 Pa), with calculated surface area the sum of above- and below-grade building envelope

Submit report to code official and building owner, including: tested surface area, floor area, air by volume, stories above grade, and leakage rates

Exception: Buildings over 250,000 ft^2 of conditioned floor area don't need testing on whole building, can test representative above-grade sections. Tested areas to total not less than 25% of conditioned floor area and tested per C406.9

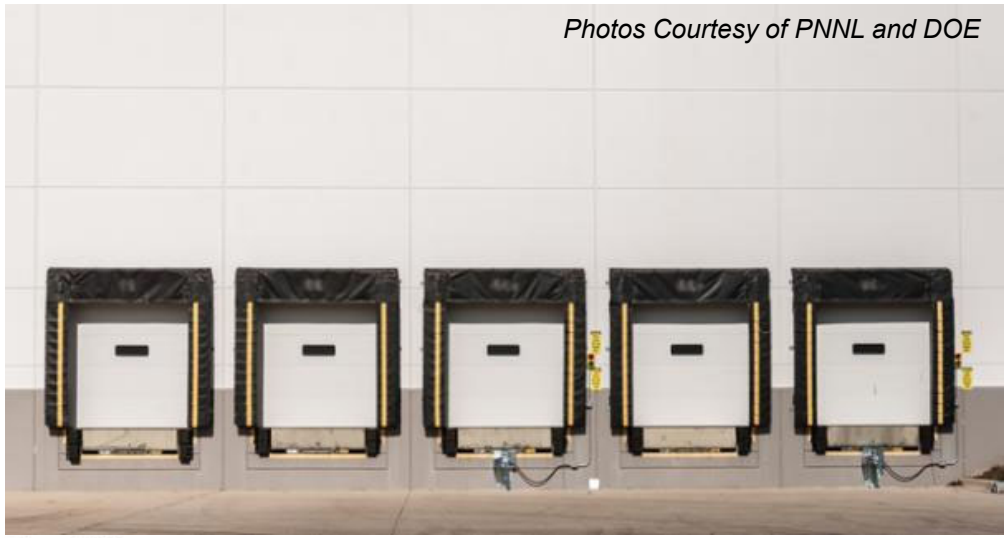
BUILDING ENVELOPE

Findings of Case Study

- House of Worship
  - Designate materials that will act as air barrier
  - Create material transition location details to link one air barrier material to the next

LOADING DOCK WEATHERSEALS

Cargo and loading door openings must be equipped with weatherseals to restrict infiltration and provide direct contact with vehicles along top and sides



Photos Courtesy of PNNL and DOE

LOADING DOCK WEATHERSEALS

ASHRAE 90.1 2019

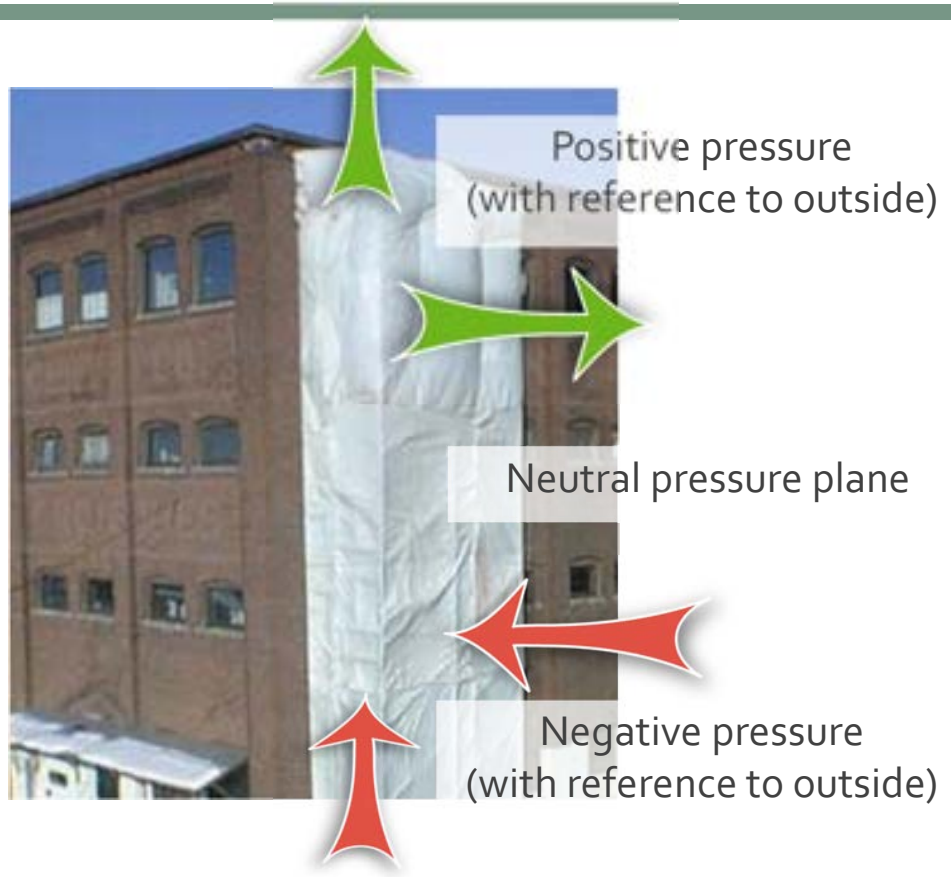
Exception – Climate zones 1-3

IECC 2021

No exceptions for warmer climate zones

VESTIBULES

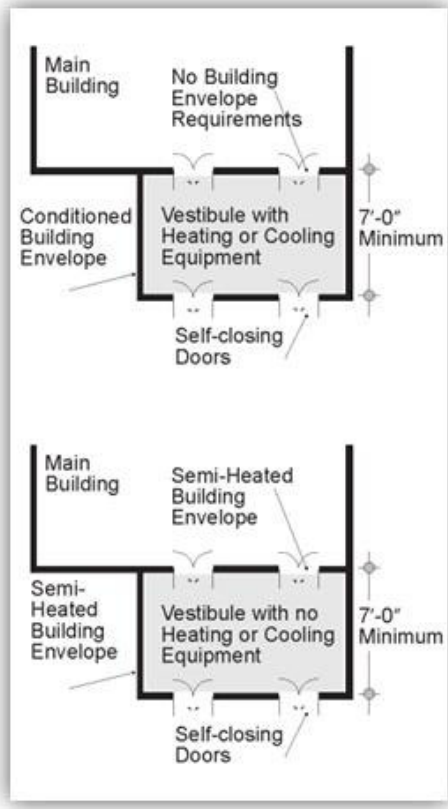
- Required for both codes with many exceptions
- The taller the building, the greater the need for vestibules
- Both codes vary greatly on requirements based on zones and other inputs



VESTIBULES

Vestibules must have

- Self-closing doors
- Interior and exterior doors not open at the same time
- Distance between interior and exterior doors not < 7 ft when in closed position
- *Floor* area of each vestibule to not exceed the greater of 50 ft^2 or 2% of the gross *conditioned floor area* for that level of the *building*
- Exterior envelope of conditioned vestibule comply with *conditioned space* requirements
- Interior/exterior envelope of unconditioned vestibule comply with *semiheated space* requirements



90.1 - VESTIBULES EXCEPTIONS

- Non-entrance *doors* or *doors* opening from *dwelling unit*
- *Building entrances* with revolving *doors*
- All *building entrances* in climate zones 1 and 2 **OR**
  in *buildings* in climate zone 3 < 4 stories and < 10,000 ft^2 in gross conditioned floor area **OR**
  in buildings < 1000 ft^2 in *gross conditioned floor area* in climate zones 0 and 4-8
- All *doors* that open from *spaces* < 3000 ft^2 and separate from *building entrance*
- *Semiheated spaces*
- Enclosed elevator lobbies for *building entrances* directly from parking garages

90.1 VESTIBULES FOR LARGE SPACES

Vestibules opening into large *conditioned spaces* (large retail)

- *spaces* having a *gross conditioned floor area* for that level of the *building* of 40,000 ft^2 and greater,
- and when the *doors* opening into and out of the vestibule are equipped with automatic, electrically driven, self-closing devices, the interior and exterior *doors* shall have a minimum distance between them of not less than 16 ft.

VESTIBULES DETAILS

Building entrances shall be protected with an enclosed vestibule, with all doors opening into and out of the vestibule equipped with self-closing devices. Vestibules shall be designed so that in passing through the vestibule it is not necessary for the interior and exterior doors to open at the same time. The installation of one or more revolving doors in the building entrance shall not eliminate the requirement that a vestibule be provided on any doors adjacent to revolving doors.

VESTIBULES EXCEPTIONS

1. Buildings in Climate Zones 1 and 2.
2. Doors not intended to be used by the public, such as doors to mechanical or electrical equipment rooms, or intended solely for employee use.
3. Doors opening directly from a sleeping unit or dwelling unit.
4. Doors that open directly from a space less than 3,000 square feet (298 m^2) in area.
5. Revolving doors.
6. Doors used primarily to facilitate vehicular movement or material handling and adjacent personnel doors.
7. Doors that have an **air curtain** with a velocity of not less than 6.56 feet per second (2 m/s) at the floor that have been tested in accordance with ANSI/AMCA 220 and installed in accordance with the manufacturer's instructions. Manual or automatic controls shall be provided that will operate the air curtain with the opening and closing of the door. Air curtains and their controls shall comply with Section C408.2.3.

2022 MISSOURI ENERGY CODE ENVELOPE QUIZ

A 3 story 25,000 ft^2 office building is located in CZ4. The primary public entrance doors open into the main lobby which is 4000 ft^2 and has a centrally located security desk; each hallway off this lobby has double swinging doors.

Is this building required to have a vestibule?

SECTION 6 – 6.4.3.9
HEATING AND COOLING IN VESTIBULES

Include automatic controls to shut off heating system when

- OA temps are > 45°F
- Also controlled by a thermostat in the vestibule with setpoint limited to maximum of 60°F

Note: a single heating thermostat in the vestibule limited to 45°F would meet the requirements

Shut off vestibule cooling system when

- Controlled by a thermostat in the vestibule with setpoint limited to minimum of 85°F

Exceptions, vestibules:

- heated or cooled by site-recovered energy
- tempered with transfer air that would otherwise be exhausted

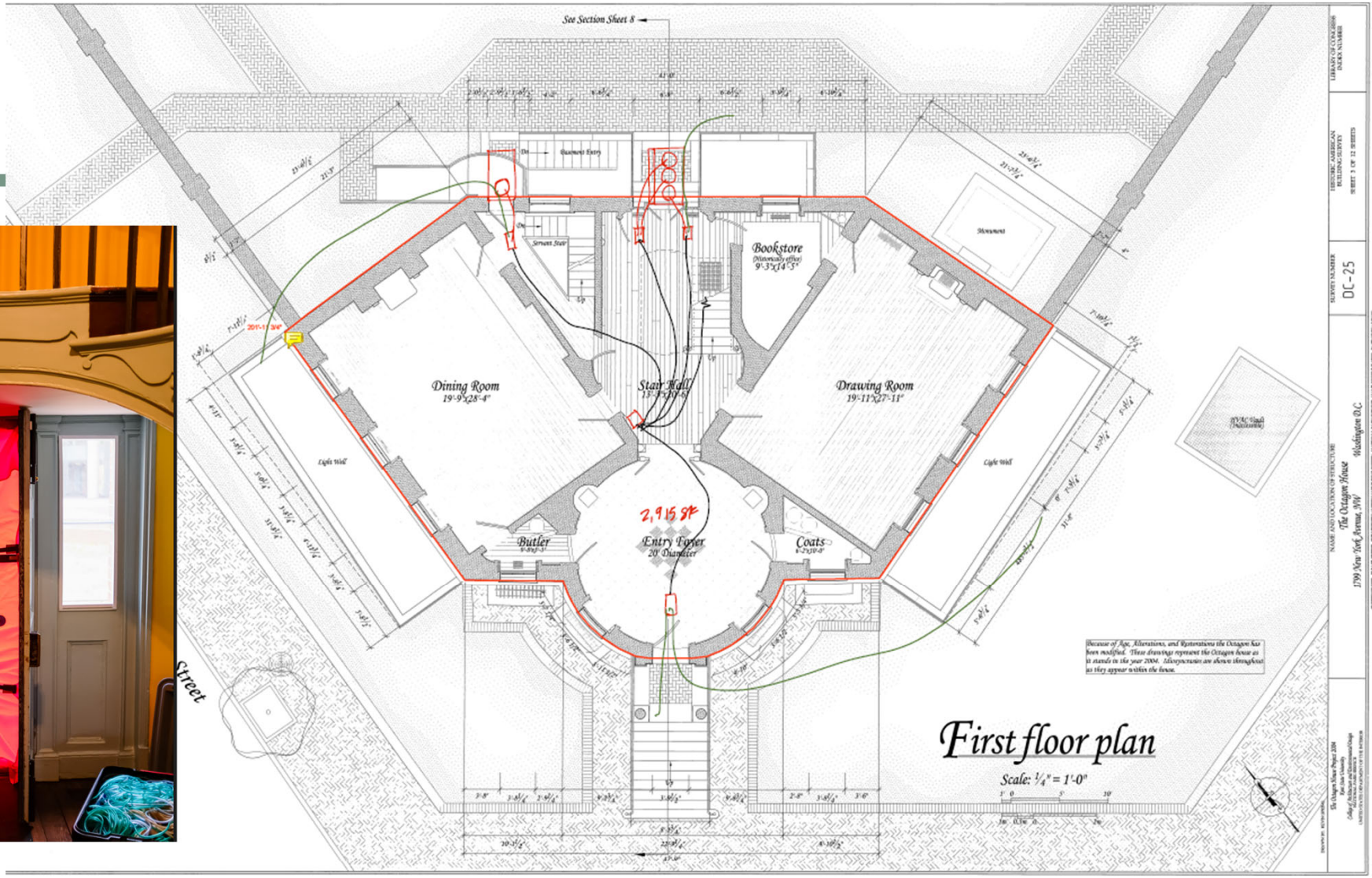
CONDITIONED VESTIBULES?

CASE STUDY – GHOST KITCHEN

Videos

CASE STUDY - HISTORIC OCTAGON MUSEUM

HISTORIC OCTAGON



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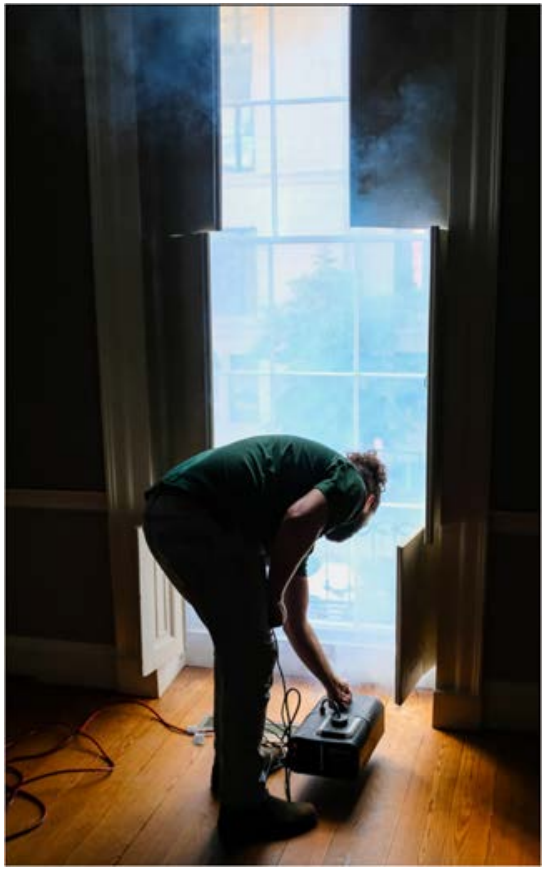
HISTORIC OCTAGON MUSEUM



RESEARCH HAS NO SHORT CUTS

Questions & Answers

Next webinar:
Aug 17 –
COMCheck &
RESCheck

https://vimeo.com/169382048/c973625071

https://www.surveymonkey.com/r/PYBTJZH

COMMERCIAL BLOWER DOOR TESTING

"GOING BEYOND SINGLE-FAMILY BLOWER DOOR TESTING"

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