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HOUSTON 2023

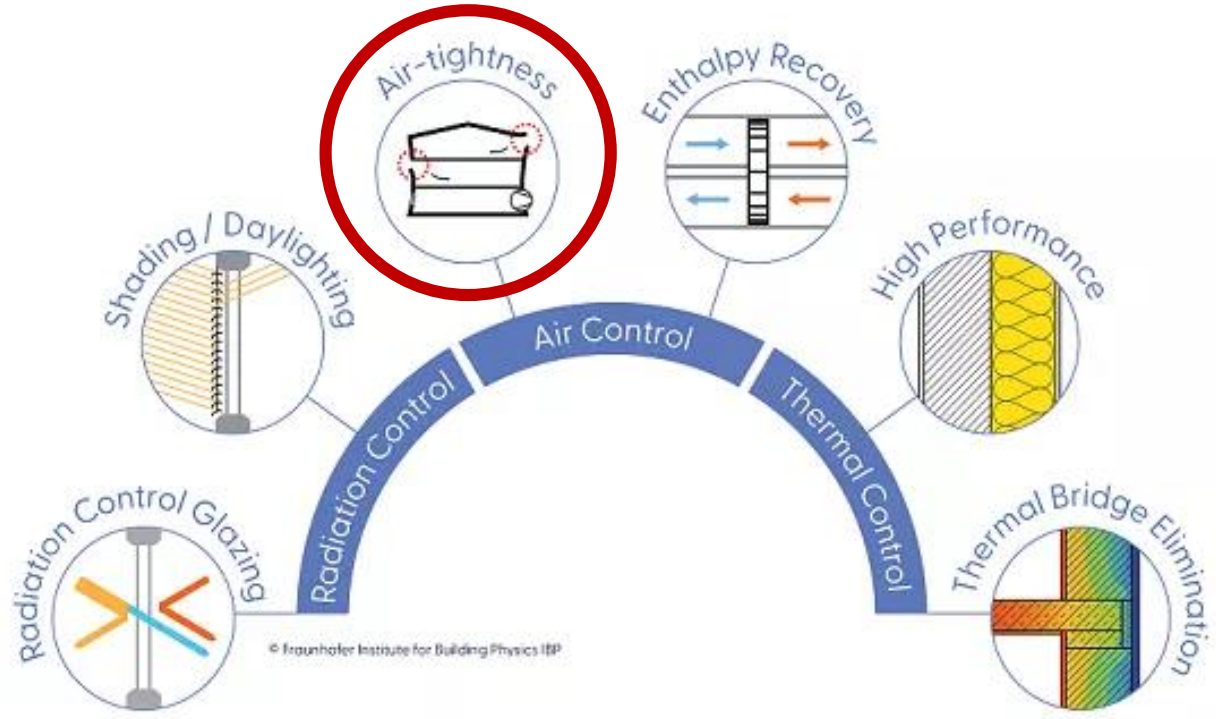
Whole Building Blower Door Testing

Collin Olson

- Senior Staff Physicist
- 25+ years experience in building science & performance
- Ph.D. from Univ. of Wisconsin, Madison

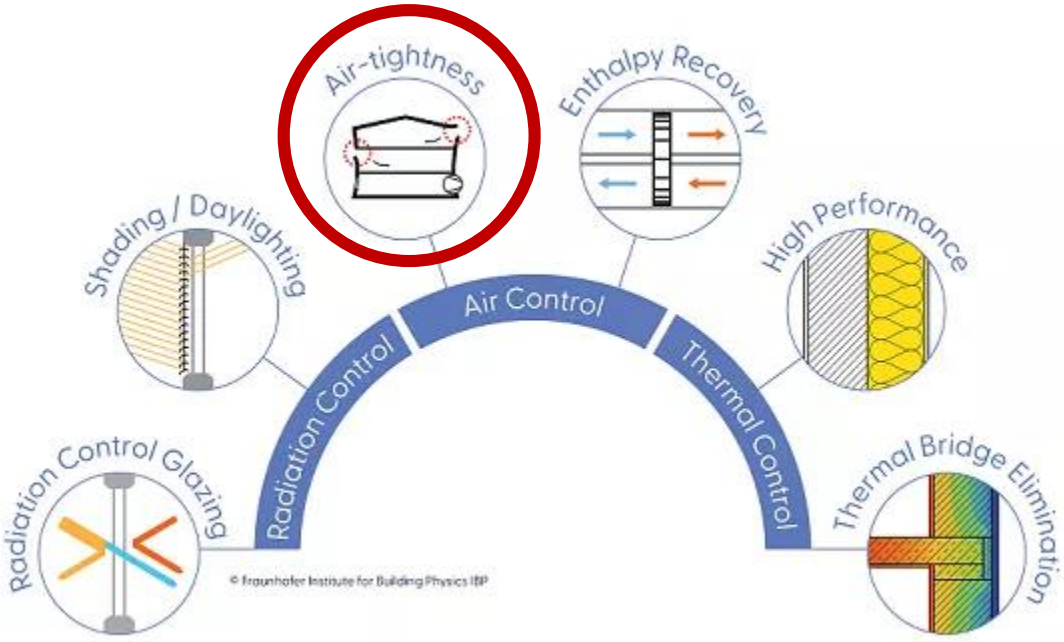
PHIUS Commercial Building Standards

PHIUS CORE COMM



https://www.phius.org/phius-core-comm-standard-specifications

- **Airtightness**
  Critical for building durability
- Phius sets a pass/fail certification requirement on airtightness. It is **per square foot of gross enclosure surface area** and has varying limits based on test pressure.
- Full building **pressurization and depressurization tests** are required to show compliance with this threshold.
- For most projects, the threshold is **0.060 CFM50 per square foot of enclosure**, but the exact requirements and protocol for each project can be found in the **Certification Guidebook.**



Airtightness is measured via a Blower Door Test

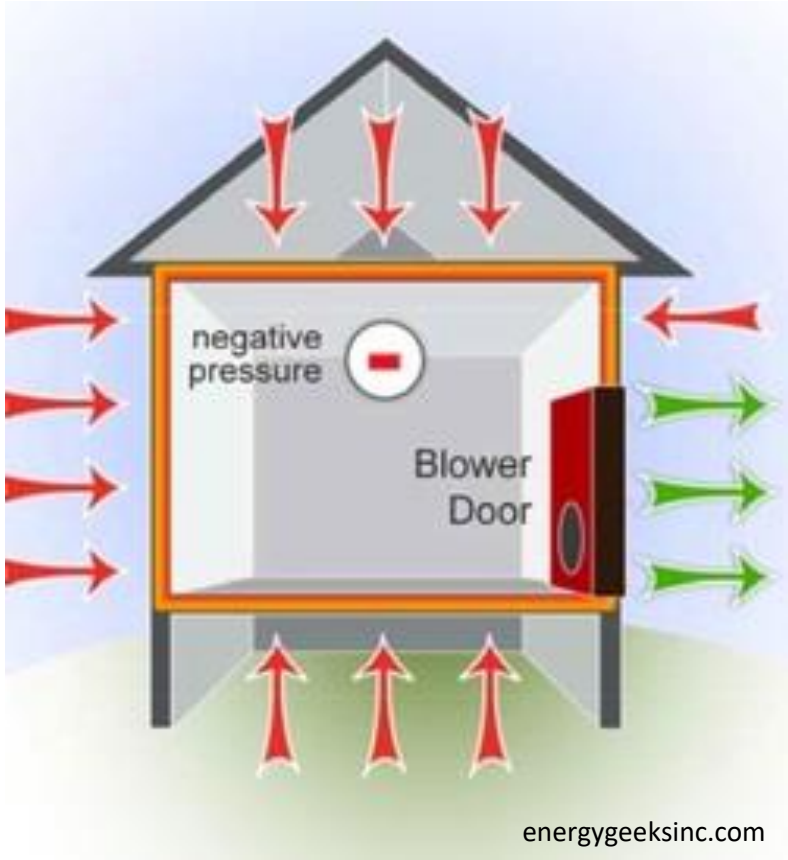
Agenda

- Building Performance and Air Tightness
- Planning a Blower Door Test
- Running a Blower Door Test
- Interpreting Results & Building a Report

What Happens During a Blower Door Test?

- A blower door test is typically done at an induced pressure difference of 50 (or 75) Pascals(Pa)*

- The fan is turned on and adjusted to change the pressure difference between inside and outside the building by 50 (or 75) Pa and the flow is measured.



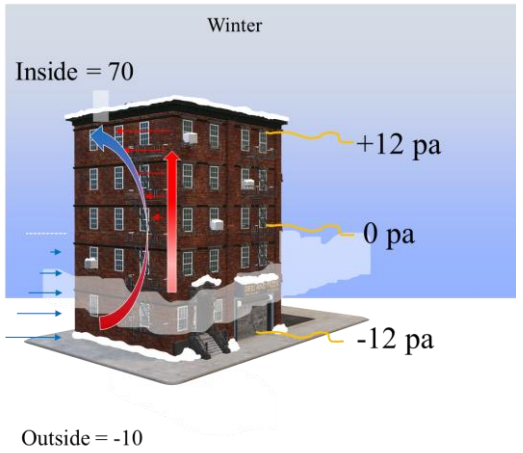
A Blower Door Test induces a pressure difference between inside and outside

* - Note: To simplify the explanation, we will talk about a single point blower door test at 50 PA. The same principles hold for multi-point tests using different pressures.

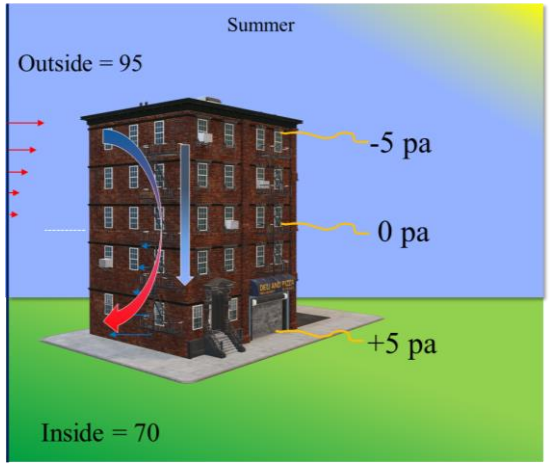
Considerations in Whole Building
(Beyond Residential)

- Baseline To address variation from Wind and Stack effect
  - Measure at 4 locations, lowest variability
- Monitor stack at top and bottom
  - Ensure target pressures for the test move all the leaks in one direction for all test pressures
  - TECLOG will complete this calculation for you when running E3158 test standard

Winter



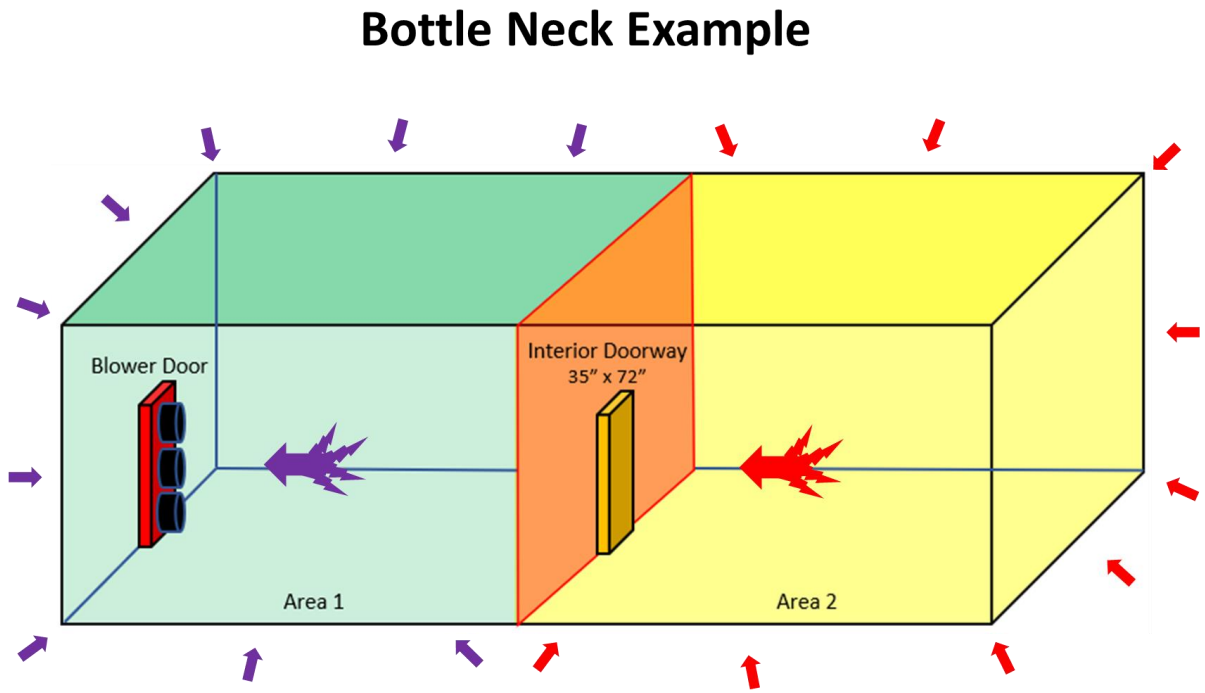
Summer



What Season?

Considerations in Whole Building
(Beyond Residential)

- Single Zone Conditions
  - Partitions, floors and doors divide up spaces
  - Ensure that bottlenecked locations are within 10% of each other



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Planning a Blower Door Test

Process	Goals
Test Goals & Standards	Understand requirements of tests, metrics; Phius, **E779**, **E3158**, Envelope vs. Operational
Review blueprints	ID Test Boundaries, ID HVAC mechanicals
Determine # of Fans	Capacity to confirm compliance, etc.
HVAC Mechanical Prep	Sealing approach, equipment, etc.
AC Power	Ensure access to circuits needed
Plans with Building	Occupants, Safety, etc.


A1215
A1225
3 fans
2 DG700s
East Wall
3 fans
2 DG700s
1 spare channel
east tap
437' 7"
outside test
3 fans
2 DG700s
1 spare channel
A1258
A1245
Level 2 Tested air barrier shown in red
Mechanical Doors Open During Test
Doors Closed During Test
Outdoor Shell Pressure Taps

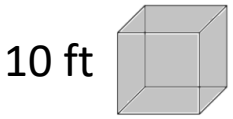

Level 3 Tested air barrier shown in red
Doors Closed During Test
Outdoor Shell Pressure Taps
outside test
outside test
outside test
south tap
578' 8"

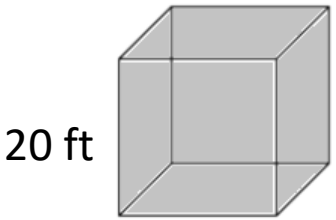

Level 4 Tested air barrier shown in red
Mechanical Doors Open During Test
Doors Closed During Test

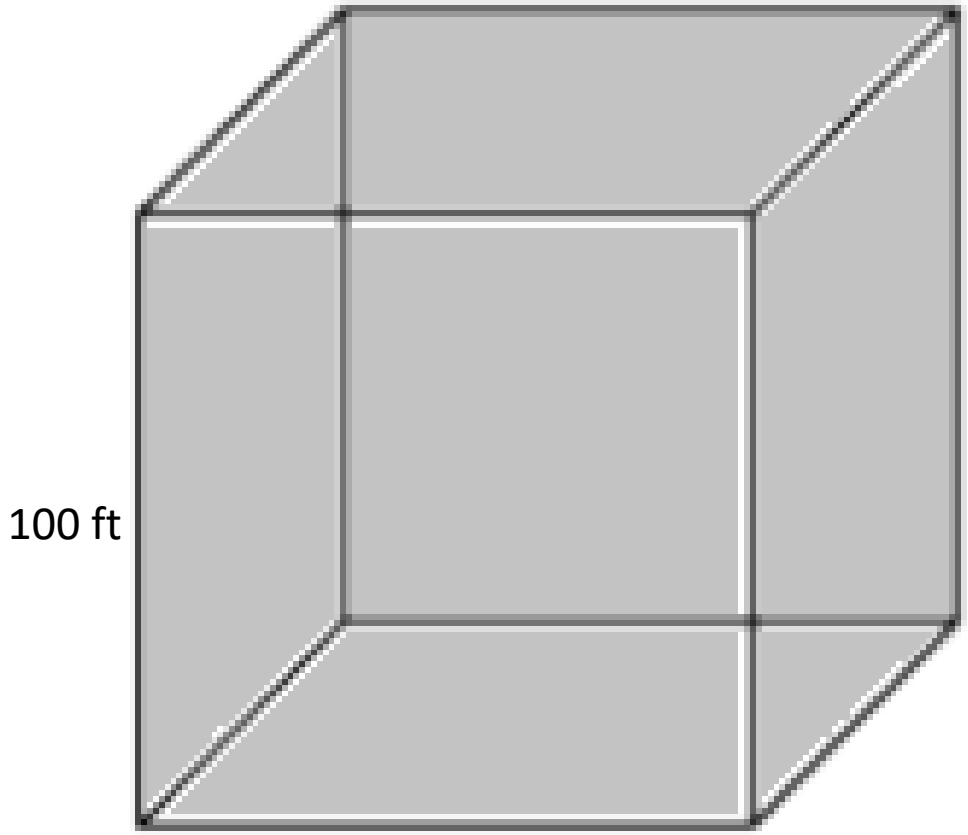
Airtightness Units / Metrics

- **Airflow at a test pressure:**
  - CFM at 50 pascals (CFM50)
  - CFM at 75 pascals (CFM75)
- **Normalized Metrics**
  - **CFM50 per sq ft enclosure = CFM at 50 Pa per square foot of enclosure (5 or 6 sides of the box)**
  - **CFM75 per sq ft enclosure = CFM at 75 Pa per square foot of enclosure (5 or 6 sides of the box)**
  - ACH50 = Air Changes per Hour at 50 Pascals = CFM50*60/Volume
  - SLA = ELA (4 Pa)/Conditioned Floor Area (both in same units)
- Equivalent Leakage Areas
  - ELA (4 pa) = the area of a theoretical hole (with rounded edges) in the building envelope that would leak as much as all of the building's actual holes at a pressure difference of 4 Pa. ELA (in square inches) approximately equals cfm50 divided by 18
  - EqLA (10 pa) = the area of a theoretical sharp-edged hole in the building envelope that would leak as much as all of the building's actual holes at a pressure difference of 10 Pa. EqLA (in square inches) approximately equals cfm50 divided by 10.

If all surfaces have same leakage per unit area $CFM_{50}/ft^2 = 0.20$







$CFM_{50}/ft^2 = 0.20$
ACH50 = 600*0.20/1000*60 = 7.2

$CFM_{50}/ft^2 = 0.20$
ACH50 = 2400*0.20/8000*60 = 3.6

$CFM_{50}/ft^2 = 0.20$
ACH50 = 60000*0.20/1000000*60 = 0.72

How much air do I need?

- Maximum leakage rate specified
  - Bring enough to induce the specified pressure difference with the specified flowrate
  - E.g. Area enclosure (ft2) x 0.25 cfm/ft2 at 75 pascals (ACE spec)
  - 0.6 ACH x enclosure volume (ft3) / 60 m/hr (passiv haus)
- Ordinary construction
  - 0.2 – 1.2 cfm/ft2 at 75 pascals ?

TEC has a Simple Excel Tool

Understanding Data Collection for ASTM E3158-18

Category	Subcategory	Requirement
Pressure Uniformity	Allowed pressure variation between spaces	≤ 10% of induced envelope pressure
	Min verification locations	Every 10 stories including top, bottom and middle floor
	Exceptions	If all rooms interconnected with 2 m^2 opening & total fan airflow at highest induced test pressure is < 6000 cfm, uniformity assumed
Baseline Pressure	Multi-point	Before & After (12 points min for 10 seconds each)
Range of Test Pressures	Multi-point	10 Pa ≤ Induced ΔP ≤ 100 Pa; min range = 25 Pa
# Test Points & Duration	Multi-point	≥ 10 points for at least 2x length of intervals used in baseline
Reporting Metric(s)	Multi-point	**C, n,** air leakage in units spec'd
Acceptable Ranges	Multi-point	0.45 ≤ n ≤ 1.05 r^2 ≥ 0.98 QP measured < reqmnt & 95% CI ≤ 8% reqmnt Largest pressure to be min 0.9 * (ΔP ref)
Accepted Test Direction		Depressurize, Pressurize, or Both
Other		Provides option for multi-zone / guarded testing

Prepare the Building

- If the whole building is one test zone
  - Close exterior doors and windows
  - Open interior doors (security exceptions)
- Close and mask HVAC penetrations IAW Specifications
- Default HVAC Penetrations
  - All exhausts and make-up air units off
  - Motorized O/A, make-up air, exhausts and relief air dampers in closed position
  - Gravity dampers left as found (option: block closed so they do not open during test)

Understanding Building Prep for ASTM E3158-18

Category	Envelope (Closed Up)	Operational (In Use)
Natural Ventilation openings	Sealed	Closed and latched
Active or passive smoke control systems	Sealed	As found
Waste or linen handling systems & equipment	Sealed at rooftop chute vent openings	• Rooftop vent = open • Chute intake doors = closed • Chute intake & discharge room doors = closed & latched • Fire dampers = as fnd
Interior doors, hatches, and operable windows inside the test envelope that are normally closed	Open	Closed and latched
Other interior doors	Open	Open
Mechanical ventilation or AC openings	Sealed; equipment with dampers are to have dampers closed and opening sealed	Sealed
Intermittently used mechanical ventilation or AC openings	Sealed	Sealed
Clothes dryer/vent	Sealed	As found; seal vent if dryer is not installed
Windows, doors and roof hatches	Closed & latched	Closed and latched
Solid fuel appliance (ie fireplace)	Dampers closed; chimney sealed	Dampers closed
Openings not intended for ventilation	Sealed; floor drains and plumbing traps filled	Floor drains and plumbing traps filled

- Block interior doors open
- In occupied buildings this may present an unacceptable security issue

Identify & Seal HVAC Related Enclosure Penetrations

- Outdoor air intakes
- Exhaust systems
- Passive relief
- Steam vents
- Dampers: Motorized, gravity, none
- Fan runs continuously?
- Elevator vents and kitchen range hoods – no dampers

Materials for Temporary Sealing

- Adhesive backed carpet protector tape
- Duct mask tape
- Garbage bags
- Light weight sheet goods and tape
- Tarps and straps
- Windex or rubbing alcohol to clean surfaces

Make sure traps have water in them


06/01/2012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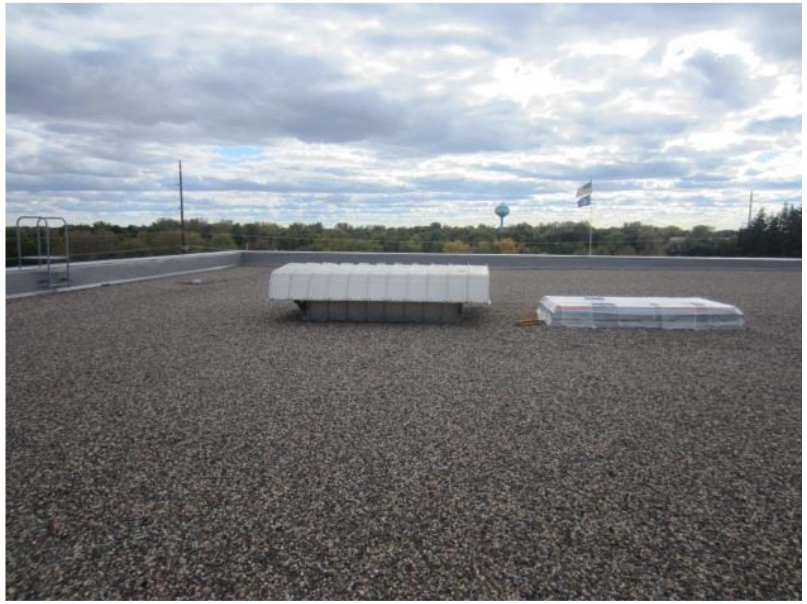


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Final Review of Planning

- New, unoccupied buildings/Occupied buildings
- Identify parties
- Select date
- Identify Test Enclosure Boundaries
- Identify HVAC equipment that must be turned off and penetrations that must be sealed
- Remember Health & Safety, OSHA guidelines
- Test plan must be submitted in advance and affected parties notified

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Running a Blower Door Test

Process
Similar to SF, software is different

- Envelope pressure measurements
- Interior pressure measurements
- Fan pressure / Flow measurements
- Distribute equipment, Central Command
- Install Fans
- Configurations
  - Tubing, Control, Communication/Network
- TECLOG

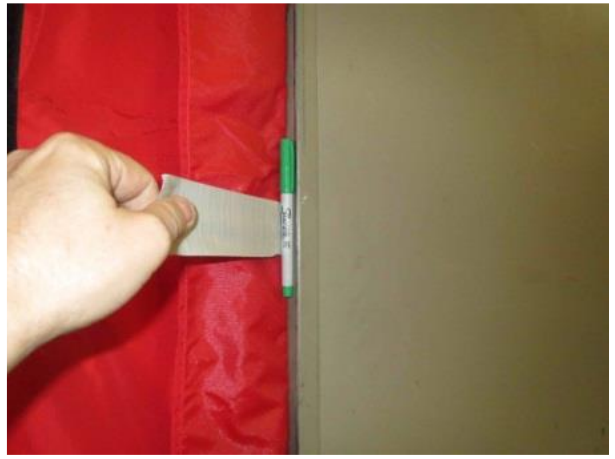
Equipment

- Blower Door Fans & Rings
- Frames & Panels
- Controllers
- Gauges
- Tubing
- Networking/communication
- Power
- Other: Door wedges, ladders, sealing materials, tapes, mask, carpet protectors, clenaers, garbage bags

Distribute the Equipment

Setting up Frame and Panel

- Set up frame so it will not pop out
- Secure frame in both directions



Setting up the Equipment

- Confirm door sizes
- Door closers / security alarms

- Prop doors open

Install the Fans

- Pressurize or depressurize first
- Rings or caps

Two Gauges and Three Fans

Gauge 1
CH A: Envelope Press
CH B: Bottom Fan

3-way Fan Control Splitter
Connected to 3 Controllers

Gauge 2
CH A: Middle Fan
CH B: Top Fan

No open taps on gauges

Tubes vs Cables

- Stepping on tubes results in pressure spikes
- Tubes of longer than 100’ will cause measurement errors.
- Tubing of a smaller diameter will cause larger measurement errors.
- Sun shining on long lengths of tubing will cause errors, as will anything that causes tubing to change temperature.
- Tubing running vertically through a space at a different temperature than the rest of the building causes errors due to stack effect.

Short tubes and long cables are best

Fan Speed Control: Auto Versus Manual

- Manual Control Advantages
  - Better flow precision
  - Lower current draw
  - Eliminates fan speed control cables
- Auto Control Advantages
  - Easier to hit precise targets
  - Can bring all fans up to speed together
  - Interruptions easier to deal with
  - Makes balancing pressures possible
- Hybrid Approach is also Possible

Each fan on its own circuit

- Plug in lower fan
- Run an extension cord for the 2nd fan
- Plug volt meter into this cord
- Turn up 1st fan quickly
- If volts drops by about 2-3 volts, they are on the same circuit
- Repeat with other fans
- You can get by with 2 fans on the same circuit but make sure you have access to breaker box.
- Fans will also have less capacity – 4200 CFM75 instead of 4800 CFM75

TECLOG & DG-1000 Networking Options

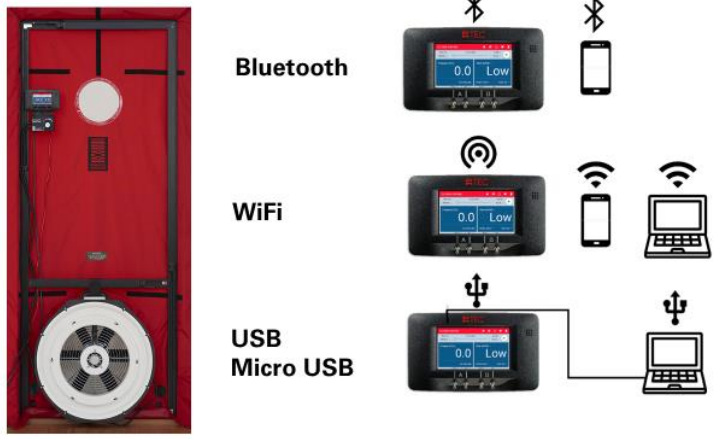
Networking Options for DG 1000 in Single Fan and Multi-Fan Systems

Performance Testing Tools
612.827.1117 | www.energyconservatory.com

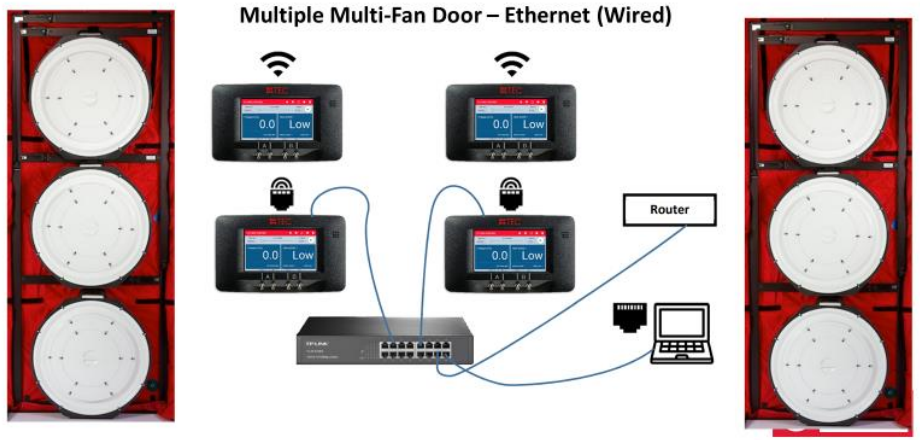
TEC
The Energy Conservatory

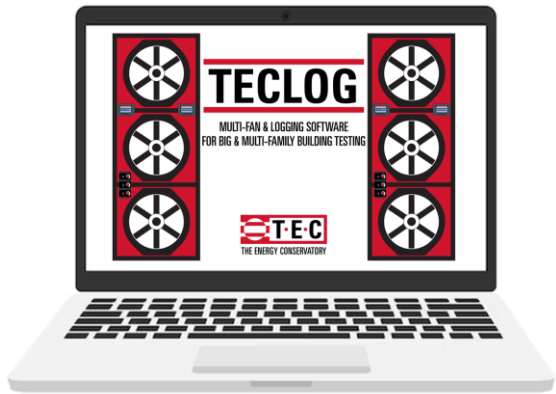
Available from TEC Website

Single Fan Testing Connection Options



Multi-Family, Large Building Connection Options





Interior Pressures

- Measure to check for pressure uniformity
  - Identify Suspected Pressure Drops
  - Measure or Monitor Interior pressure differences
  - USACE and ASTM E779 require no two spaces differ by more than 10% of test pressure (wording not clear)

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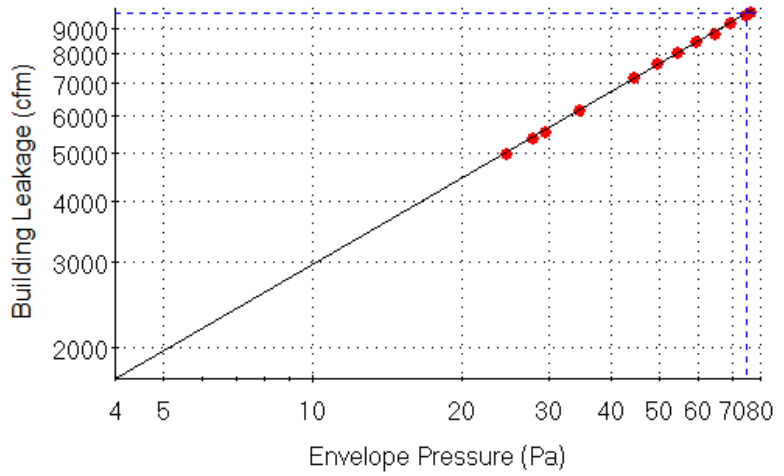
Interpreting the Flow vs Pressure Graph

- Flow is on the Y-axis (Vertical)
- Envelope Pressure is on the X-axis (Horizontal)
- Plotted as Log-Log
  - Square relationship between pressure and flow means it should be a straight line on log-log plot
- Review the correlation coef. ® and correlation coefficient square (r^2)
  - Higher is better. 1.0 means all the data points fall perfectly on a straight line
  - Most standards will require values greater than 0.98
- When correlation coefficients are low, it means there are some data points off the line – review graph.



Label	Base?	start	end	nobs	Avg Pressu	Total Flow
	True	83	106	24	-0.74	0
	False	160	171	12	-25.13	4988.9
	False	180	191	12	-28.45	5402.6
	False	243	254	12	-30.05	5568.9
	False	289	300	12	-35.02	6160
	False	342	353	12	-45.02	7167.6
	False	391	402	12	-50.01	7668.5
	False	431	442	12	-54.96	8056.3
	False	454	464	11	-59.96	8470.7
	False	486	497	12	-64.99	8848.4
	False	508	519	12	-70.04	9306.6

Reporting Pressure (Pa) 75

Test to View test 1

Test 1: Depressurization

Airflow at 75 Pascals

9736 cfm +/- 0.5 %

Range: 9684 to 9788

Leakage Areas

EqLA (10 Pa) = 870.6 in2 +/- 1.4 %

ELA (4 Pa) = 489.6 in2 +/- 2.2 %

Building Leakage Curve

Coef. (C) = 761.0 cfm/Pa^n +/- 3.4 %

Exponent (n) = .590 +/- 0.009

Correlation Coef. (r) = .99977

Corr Coef Squared (r^2) = .99955

View / Edit Test Conditions

Export to Tectite Express...

OK

How accurate does the test have to be?

- It depends:
  - Just finding holes
  - Just getting a rough idea
  - Testing to a specific leakage rate

Sources of Uncertainty in Airtightness Testing

- Error in pressure difference across the shell
- Error in flow measurements
- Error in normalizing to volume or enclosure area
- Error in setting up building

A Word of Advice

- Always check your data before you tear down

Make Sure It Isn’t Your Fault

- Check your data
- Compare envelope pressures
- Correct ring selection
- Correct reporting pressure
- Correct temperatures and elevation

Compare Envelope Pressures

- On calm days the pressures should be within a couple of Pascals of each other
- On windy days there may be 20 or more Pascals difference

- Check for tubing and connection problems

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Whole Building Blower Door Testing

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Thank you