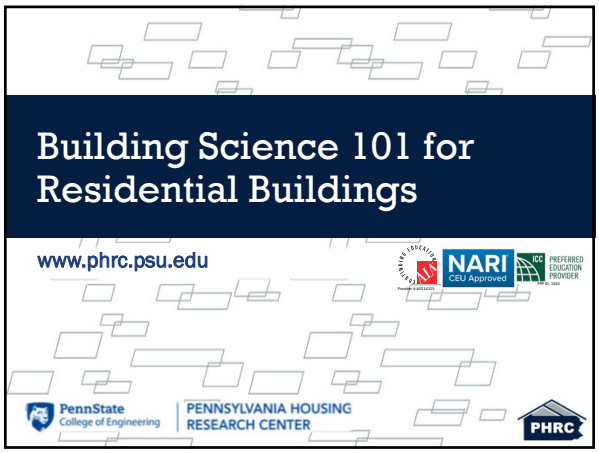
Building Science 101 for Residential Buildings
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PennState College of Engineering
PENNSYLVANIA HOUSING RESEARCH CENTER
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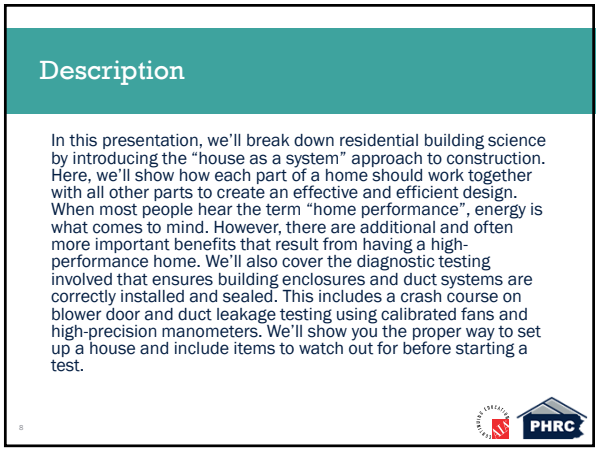
Description
In this presentation, we'll break down residential building science by introducing the "house as a system" approach to construction. Here, we'll show how each part of a home should work together with all other parts to create an effective and efficient design. When most people hear the term "home performance", energy is what comes to mind. However, there are additional and often more important benefits that result from having a high-performance home. We'll also cover the diagnostic testing involved that ensures building enclosures and duct systems are correctly installed and sealed. This includes a crash course on blower door and duct leakage testing using calibrated fans and high-precision manometers. We'll show you the proper way to set up a house and include items to watch out for before starting a test.
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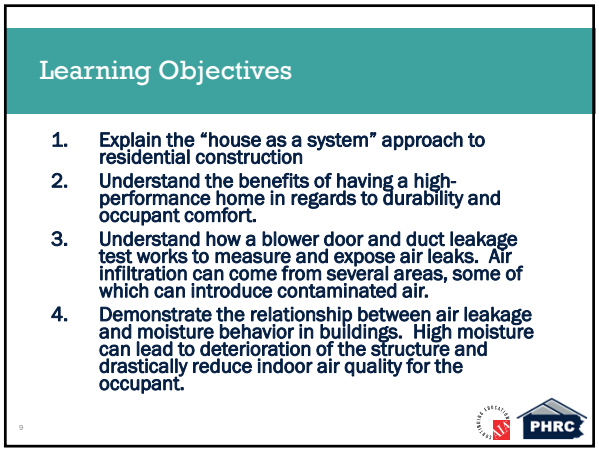
Learning Objectives
1. Explain the "house as a system" approach to residential construction
2. Understand the benefits of having a high-performance home in regards to durability and occupant comfort.
3. Understand how a blower door and duct leakage test works to measure and expose air leaks. Air infiltration can come from several areas, some of which can introduce contaminated air.
4. Demonstrate the relationship between air leakage and moisture behavior in buildings. High moisture can lead to deterioration of the structure and drastically reduce indoor air quality for the occupant.
9
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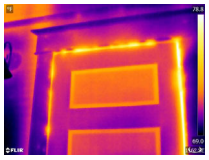
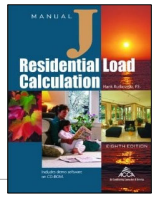
9

Building Science 101



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Sam Myers
sam@retrotec.com
www.retrotec.com

- RESNET Certified HERS rater
- Trainer at Retrotec
- Conducted hundreds of blower door and duct tests in the field
- Holds an MS degree in Sustainability concentrating on the built environment

Former:
- Building Science Specialist at Advanced Energy
- Researcher at East Carolina University

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General Categories

- Measurements
- Diagnostics - blower door & duct tests
- Testing Tips
- Equipment Care and Field Checks

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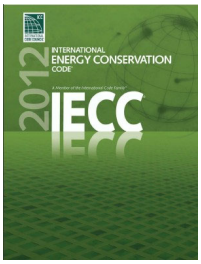
Why Test?



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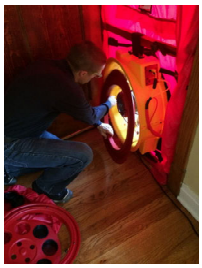

QC or Performance

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Why – because houses leak air.
Homes do not need to breathe?
We do! What are you breathing?

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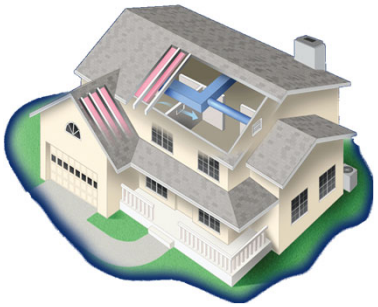
House as a System



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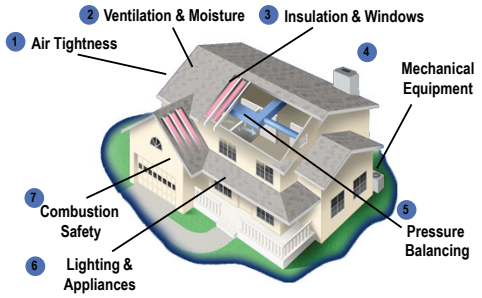
House as a System



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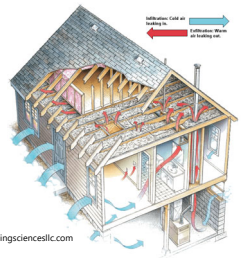
HVAC Contractors – Envelope conditions make up a large % of load



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3 ACH50
5 ACH50
7 ACH50

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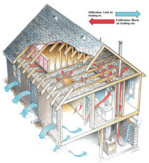
HVAC Contractors – Envelope conditions make up a large % of load



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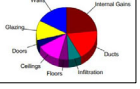
Heating

Component	Btuh/ft²	Btuh	% of load
Walls	3.8	4819	27.2
Glazing	15.5	1155	6.5
Doors	24.0	905	5.1
Ceilings	1.4	1959	11.1
Floors	1.7	1816	10.2
Infiltration	3.2	4451	25.1
Ducts		2611	14.7
Piping		0	0
Humidification		0	0
Ventilation		0	0
Adjustments		0	
Total		17716	100.0

Cooling

Component	Btuh/ft²	Btuh	% of load
Walls	1.9	2415	17.0
Glazing	23.3	1730	12.1
Doors	15.8	596	4.2
Ceilings	1.3	1801	12.6
Floors	0.7	712	5.0
Infiltration	0.7	973	6.8
Ducts		2695	18.9
Ventilation		0	0
Internal gains		3320	23.3
Blower		0	0
Adjustments		0	
Total		14242	100.0



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Manual J Calculations

IECC 2012/2015 $3ACH_{50}$ or $5ACH_{50}$

			Passive House 0.6
Tight	350 CFM_{50}	1 ACH_{50}	
Semi-tight	800 CFM_{50}	3 ACH_{50}	CZ 3 - 8
Average	1150 CFM_{50}	4 ACH_{50}	CZ 1 - 2
Semi-loose	1700 CFM_{50}	6 ACH_{50}	
Loose	2250 CFM_{50}	8 ACH_{50}	

***ACH_{50} is was calculated on a "base house" and adjusting the infiltration on the blower door input method to match the simplified calculated load. Individual results may vary.*

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Tight, Tighter, TOO TIGHT?

When is house TOO TIGHT?

When is does a house require mechanical ventilation? < 5 ACH_{50}

2012 IECC, Section R403.5 Mechanical ventilation (M)
2012 IRC, Section R303.4 Mechanical ventilation
Section N1102.4.1.2,
Section M1507.3.

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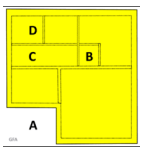
Tight, Tighter, TOO TIGHT?

BPI suggests homes need ventilation if they CFM50 result is lower than the conditioned sq. footage.

<



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Air Barriers

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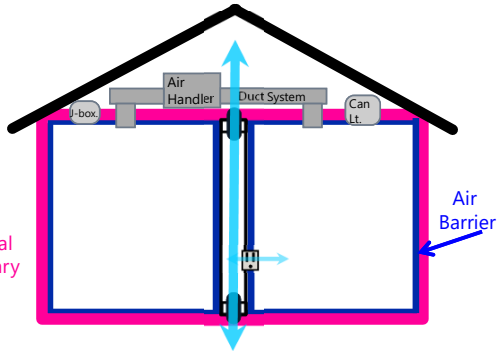
Location

Where is the Air Barrier?



NEXT >

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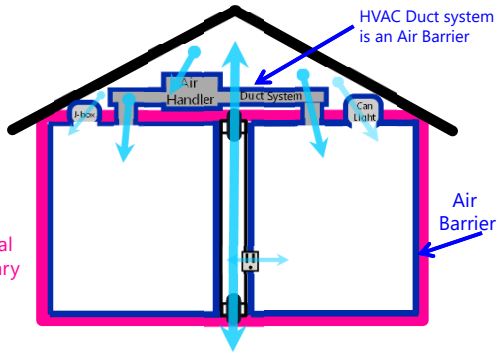
Location

Where is the Air Barrier?



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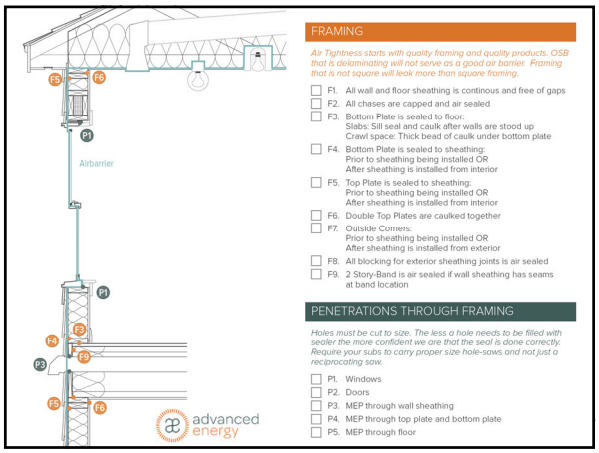


FRAMING

Air Tightness starts with quality framing and quality products. OSB that is delominating will not serve as a good air barrier. Framing that is not square will leak more than square framing.

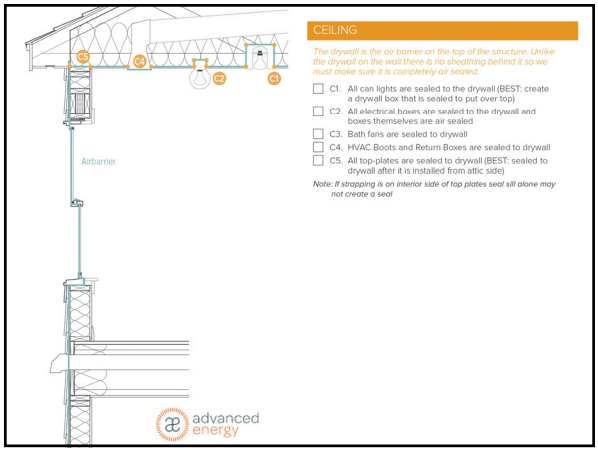
- ☐ F1. All wall and floor sheathing is continous and free of gaps
- ☐ F2. All chases are capped and air sealed
- ☐ F3. Bottom Plate is sealed to floor:
  Slabs: Sill seal and caulk after walls are stood up
  Crawl space: Thick bead of caulk under bottom plate
- ☐ F4. Bottom Plate is sealed to sheathing:
  Prior to sheathing being installed OR
  After sheathing is installed from interior
- ☐ F5. Top Plate is sealed to sheathing:
  Prior to sheathing being installed OR
  After sheathing is installed from interior
- ☐ F6. Double Top Plates are caulked together
- ☐ F7. Outside Corners:
  Prior to sheathing being installed OR
  After sheathing is installed from exterior
- ☐ F8. All blocking for exterior sheathing joints is air sealed
- ☐ F9. 2 Story-Band is air sealed if wall sheathing has seams at band location

PENETRATIONS THROUGH FRAMING

Holes must be cut to size. The less a hole needs to be filled with sealer the more confident we are that the seal is done correctly. Require your subs to carry proper size hole-saws and not just a reciprocating saw.

- ☐ P1. Windows
- ☐ P2. Doors
- ☐ P3. MEP through wall sheathing
- ☐ P4. MEP through top plate and bottom plate
- ☐ P5. MEP through floor

25



CEILING

The drywall is the air barrier on the top of the structure. Unlike the drywall on the wall there is no sheathing behind it so we must make sure it is completely air sealed.

- ☐ C1. All can lights are sealed to the drywall (BEST: create a drywall box that is sealed to put over top)
- ☐ C2. All electrical boxes are sealed to the drywall and boxes themselves are air sealed
- ☐ C3. Bath fans are sealed to drywall
- ☐ C4. HVAC Boots and Return Boxes are sealed to drywall
- ☐ C5. All top-plates are sealed to drywall (BEST: sealed to drywall after it is installed from attic side)

Note: If strapping is on interior side of top plates seal sill alone may not create a seal

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Top plates from attic side

27

Top plates from attic side

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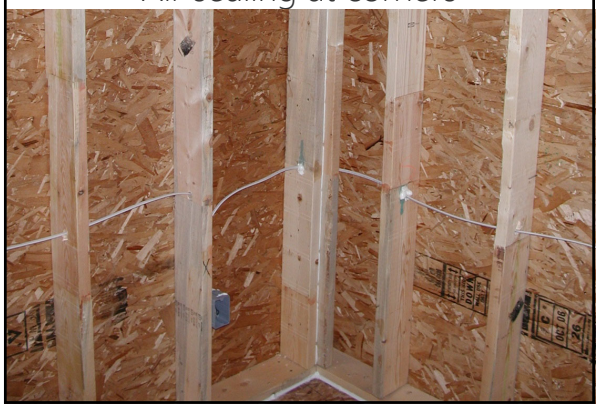
Uncapped Chase

29

Capped Chase

30

Air sealing at corners



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Main return in ceiling

33

Recessed lighting

34

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How a Blower Door Works

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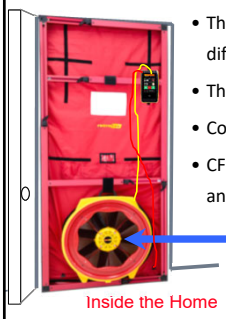
How a Blower Door Works



- Air flow across the sensor in center of the fan.
- The manometer measures the fan pressure difference of the interior reference to outdoors.
- The fan pressure calculated by the manometer.
- Converted to CFM (cubic feet per min.)
- CFM is used in the calculations for comparison and compliance.

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Fan Pressure to CFM Flow

- Pressure ports around the center of the fan.
- These ports connect to tubes that connect to the tubing port on the top of the fan.
- This connects to the gauge. The gauge converts the pressure to flow.

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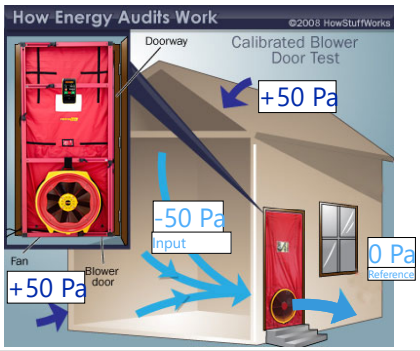
How a Blower Door Works



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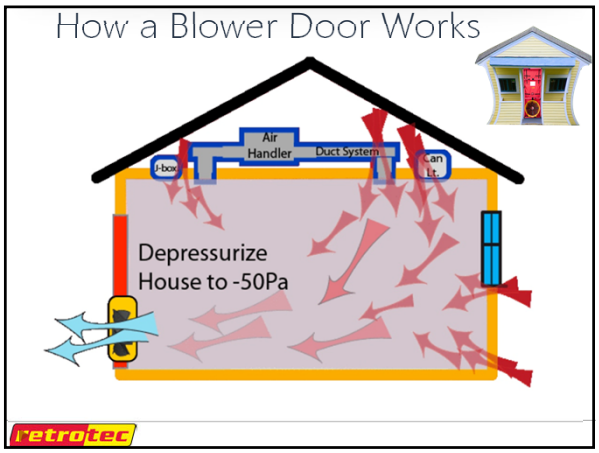
How a Blower Door Works
Air Handler
Duct System
J-box
Can Lt.
Depressurize House to -50Pa
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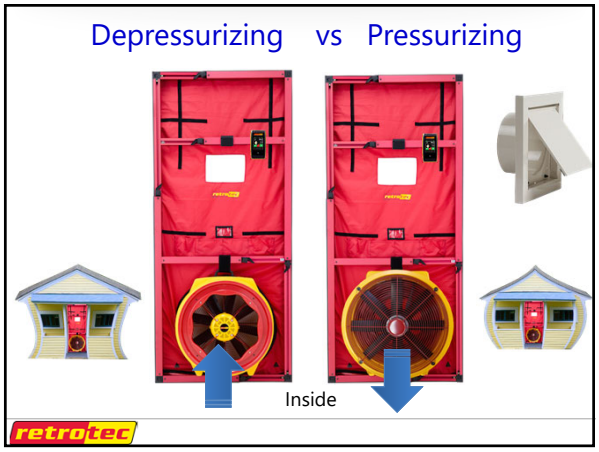
Depressurizing vs Pressurizing
Inside
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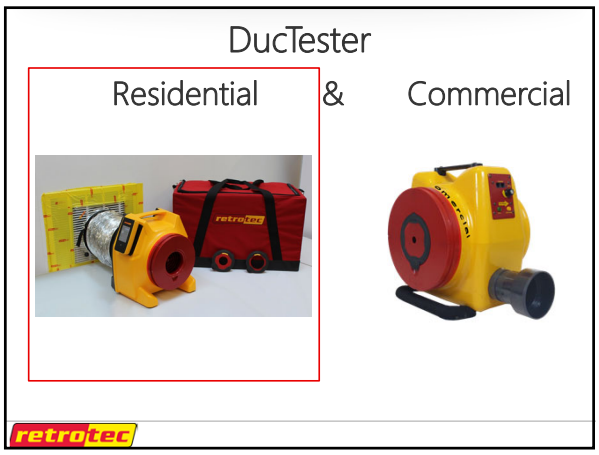
DucTester
Residential
&
Commercial
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NEW!

300x DucTester

- Stable foundation
- High impact plastic shell
- Mount gauge to the fan

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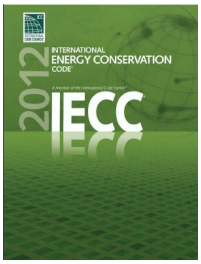
Why Test?



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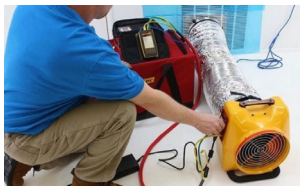

QC or Performance

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Duct Leaks

- Locations
  - Duct connections & seams

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Duct Leaks

- Locations
  - Duct connections & seams
  - Register & boot framing connections
    - floors, walls and ceilings

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Duct Leaks

Supply and Return Boot Sealed to Drywall

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Main return

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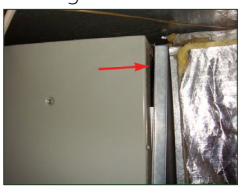
Duct Leaks

- Locations
  - Duct connections & seams
  - Register & boot framing connections
    - floors, walls and ceilings
  - Air Handler
  - Filter slots



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Duct Leaks

- Locations
  - Duct connections & seams
  - Register & boot framing connections
    - floors, walls and ceilings

  - Air Handler
  - Filter slots
  - Panned duct (ducts created from framing)
- If you can touch it, seal it!

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Best Duct Sealing Product

Bucket Mastic

- Apply as thick as a nickel
- Use all ALL connections including trunk to collar, splicing collars, all metal seams in boots and boxes, collar to flex, elbows

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Connecting Flex Ducts

Panduit Straps

- Duct tape should not be used to connect ducts
- Use Panduit wrench, hand tightening is not enough

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Total Duct Leakage

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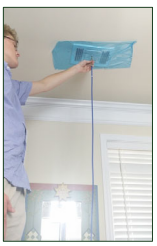
Duct Test Fundamentals – Seal Duct System

Seal supply registers and any other return grills



Insert Blue Tube in to supply duct Nearest the Air Handler

next >

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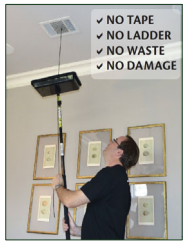
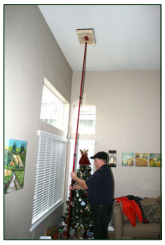
Duct Sealing Options





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Clear Flange

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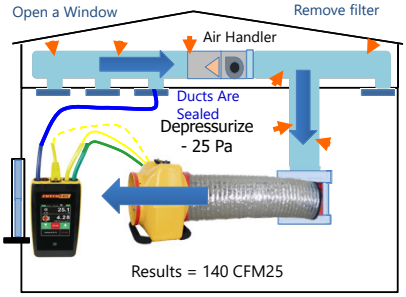
Total Leakage – Depressurization



140 CFM25 ÷ 2400 Area = 5.8 CFM per 100 sq ft

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Testing at Rough-in

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Rough In Test




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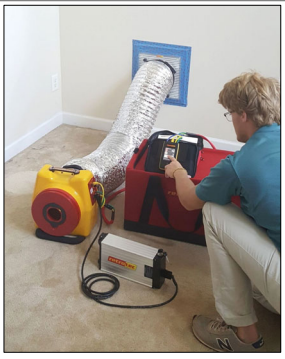
Rough In Test – battery pack option!

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Rough In Test – battery pack option!

LeafBike makes the battery, Retrotec makes the cable to connect with the DucTester

https://www.leafbike.com/products/lithium-battery/48v-li-battery/

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Rough In Test – crawl space tape!

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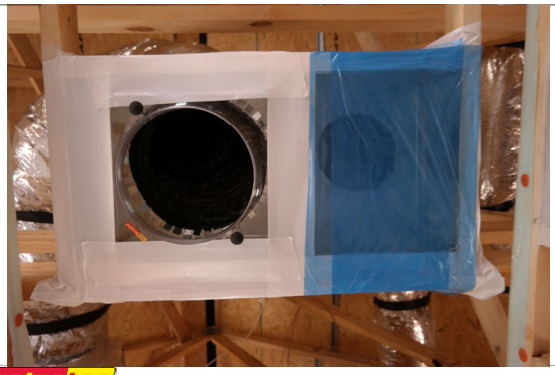
Rough In Test – crawl space tape!

64

Rough In Test – crawl space tape!



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Rough In Test – crawl space tape!

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Leakage to Outside

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Leakage to Outdoors

DucTester and blower door running at the same time

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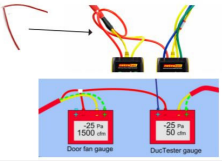
Leakage to Outdoors

Method #1:

Both gauges at -25 Pa **

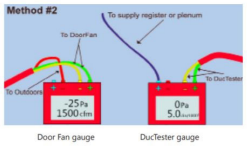
- ☐ Connect the red T-connected tubes to red ports and all other tubes per diagram.
- ☐ Tap **[Set Pressure] [25] [Enter]** on DucTester gauge then on Door Fan gauge.
- ☐ Tap **[@ Pressure]** on DucTester gauge to display the results "@25Pa".
- ☐ When "-25 Pa" +/– 1 is achieved on both gauges, record duct leakage to outdoors from the DucTester gauge.



Method #2:

DucTester at 0 Pa, Door Fan at -25 Pa **

- ☐ Connect tubes to gauges per diagram.
- ☐ With DucTester off,
- ☐ Set the Door Fan gauge to -25 Pa by tapping **[Set Pressure] [25] [Enter]**.
- ☐ Set the DucTester to "0 Pa" by tapping **[Set Pressure] [0] [Enter]**.
- ☐ When "0 Pa" +/– 1 is achieved, record duct leakage to outdoors from DucTester gauge.



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Locating Leaks

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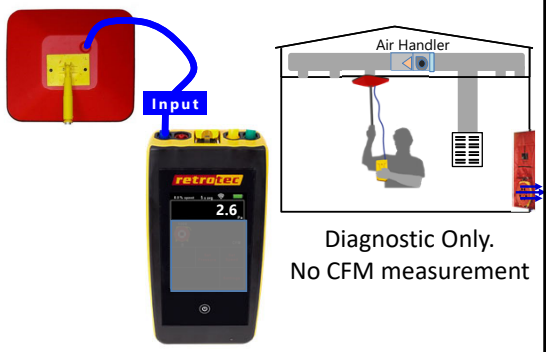
Pressure Pan Test - BD locates leaky duct run(s)



Diagnostic Only.
No CFM measurement

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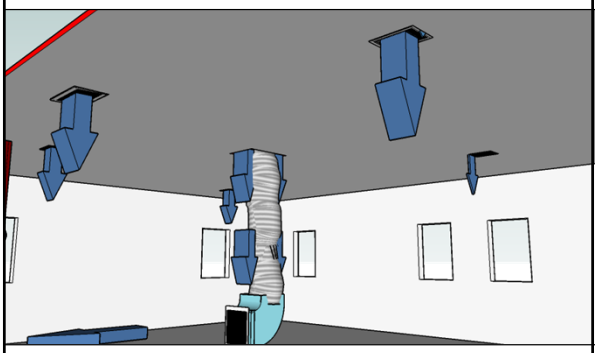
Pressure Pan Test - BD locates leaky duct run(s)



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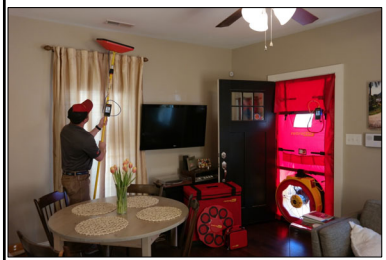
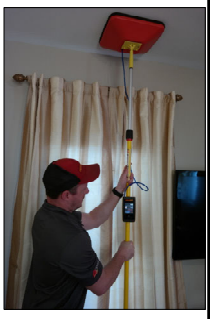
Pressure Pan Test - BD locates leaky duct run(s)





- Depressurize house to -50Pa
- Attached pressure pan to blue port on DM-32
- Cover supply/return with pressure pan
- Determine if there is a significant pressure difference

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73

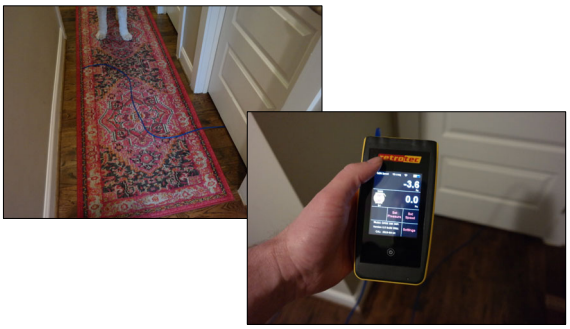
Tiny S – Smoke Generator

74

What can house pressure tell you?

75

Balancing with Room Pressures



76

Apps & Web-based Tools

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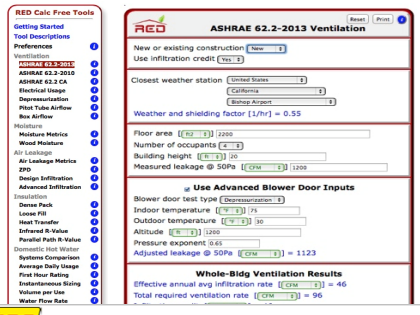
RED Residential Energy Dynamics

www.residentialenergydynamics.com



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RED Residential Energy Dynamics

www.residentialenergydynamics.com

Free Building Science Calculation Tools for Energy Professionals

Ventilation
- ASHRAE 62.2- 2010, 2013, 2016
- ASHRAE 62.2 CA
- Electrical Usage
- Depressurization
- Pitot Tube Airflow
- Box Airflow

Moisture
- Moisture Metrics
- Wood Moisture
- Air Leakage
- Air Leakage Metrics
- ZPD
- Design Infiltration
- Advanced Infiltration

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CI Construction Instruction

www.constructioninstruction.com

Mobile construction app has home construction videos, animated building details, building science articles, and building product & materials installation info, technical data, and other 'Best-Practices' information.

Construction Instruction®
Building Science for Everyone, Everywhere

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CI Construction Instruction

www.constructioninstruction.com

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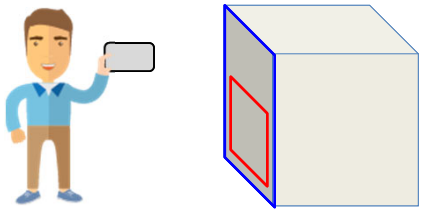
Photo Measurement apps



Known size reference

Calculated reference

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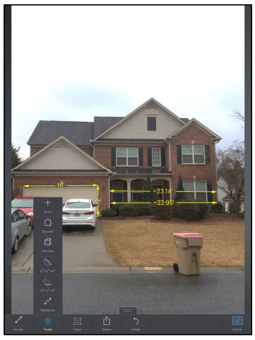
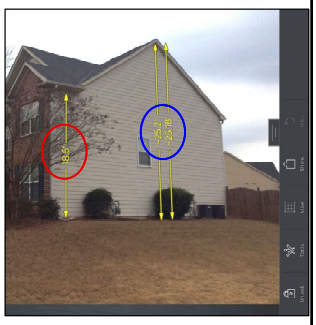
My Measures PRO

$7.99





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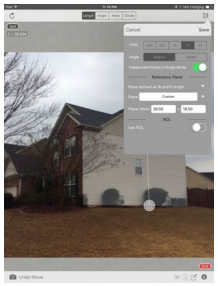
Partometer3D - camera measure



$2.99

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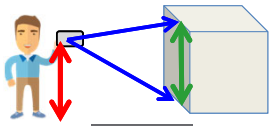
Many alternatives



EasyMeasure

STANLEY Smart Measure Pro

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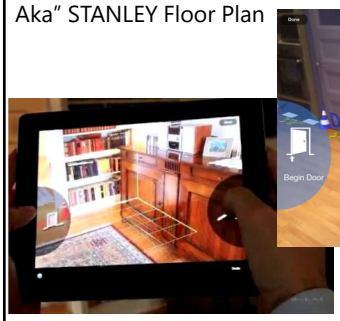
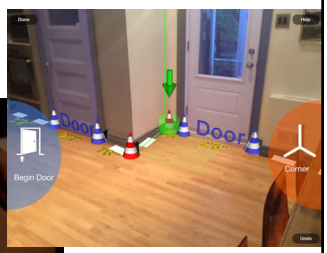
MagicPlan

$Free

Aka" STANLEY Floor Plan





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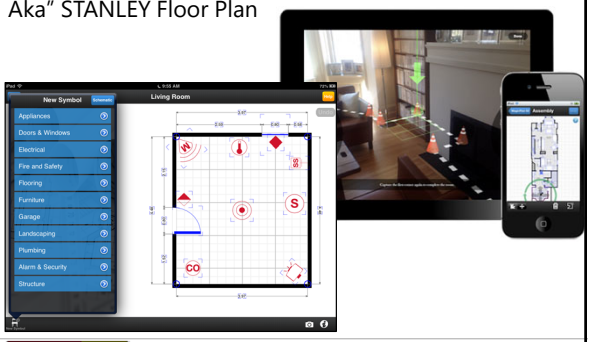
MagicPlan

$Free

Aka" STANLEY Floor Plan



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Laser Measurements

BOSCH
Invented for life

www.bosch-professional.com/static/specials/glm100c/gb/en/

Bosch GLM 100 Laser Tape Measure

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Laser Measurements

Bluetooth

Bosch GLM 50 C Bluetooth Enabled Laser Distance Measurer with Color Backlit Display

Emails

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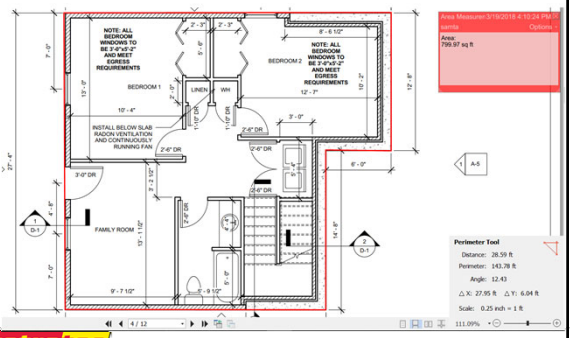
Take-offs from plans

$Free

PDF Foxit



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Tools, Gadgets, Etc.

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Smoke – Power Tiny S (smoke generator)

NEW PRODUCT

- Triethylene Glycol
  Monopropylene Glycol
  Dipropylene Glycol
  Demineralized Water
- Not - Neutral buoyancy smoke
- Controlled powered smoke
- Battery powered

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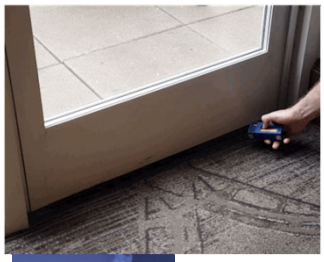
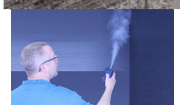
Power Tiny S – Smoke Generator





New Product

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Infrared Camera

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Infrared Camera

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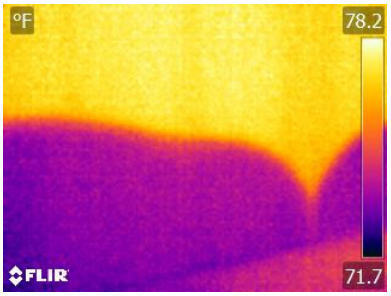
Building Moisture

Incidental



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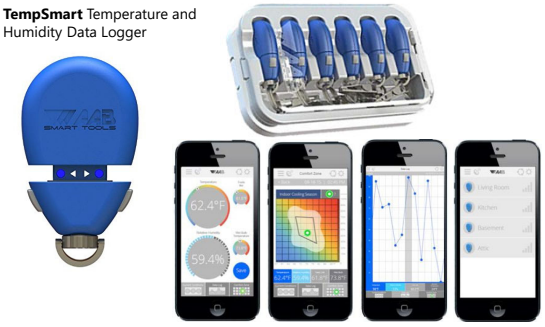
AAB Smart Tools TS-100 $60

TempSmart Temperature and Humidity Data Logger



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Testing Exhaust Fans

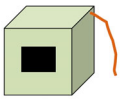
The Energy Conservatory Exhaust Fan Flow Meter

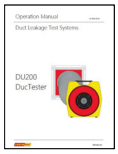
DM32

100

Device - Hole Flow

Cardboard box.





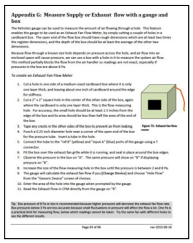


Figure 73: Exhaust fan flow meter

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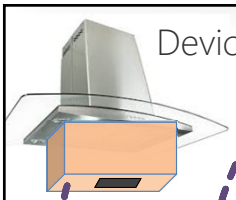
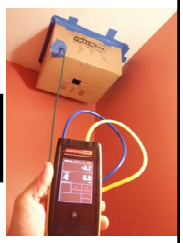
Device - Hole Flow





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Device - Hole Flow

$$Flow = Hole\ Area * \sqrt{PrB} * 1.0755$$

- Flow is in units of CFM
- Hole Area is in units of in^2
- PrB is the Channel B pressure, is in units of Pa

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919-922-3987
www.retrotec.com

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