


**Zone Pressure Diagnostics:  
The Hole Story  
(Basic)**  
Pre-Conference Session

National Weatherization Conference  
December 2009

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ZPD: The Hole Story (Basic)



Alden and the Minneapolis Blower Door, Model 3 from The Energy Conservatory

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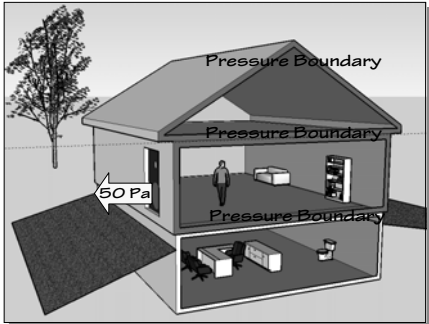
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# Introduction

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Series leakage or resistance

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## Leakage Pathways

Zone	Interior Surfaces	Exterior Surfaces
Attic	Floor/ceiling, bypass paths	Roof, gables, soffits
Crawl space	Crawl ceiling	Crawl walls
Basement	Basement ceiling	Basement walls
Garage	House/garage wall garage ceiling	Exterior garage walls
Knee walls	Knee wall, floor	Roof, soffits, end walls

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## Zone Pressure Diagnostics

- Objectives
  - Determine leakage area from building to zone.
  - Determine leakage area from zone to outdoors.
  - Determine total path CFM<sub>50</sub> from building to outdoors through a zone.
  - To help appraise IAQ issues, such as CO from attached garages and bad air from crawl spaces.


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### Zone Pressure Diagnostics - 1


- Allows analyst to determine if a space is connected by airflow (pressure) to the thermal envelope and/or the outdoors (secondary zones).
  - Pressure differences while blower door is running.
  - Be very cautious with this technique.
  - House/Zone + Zone/Outdoors = House/Outdoor  $\Delta P$ .

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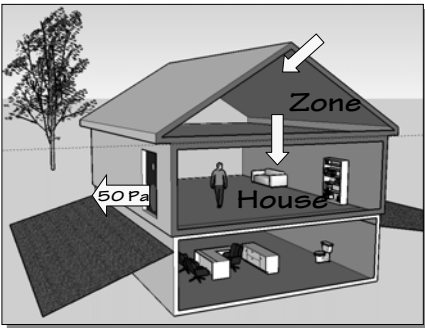
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### Zone Pressure Diagnostics - 2

- Allows analyst to determine the flow through two pressure boundaries in series (each individually and together) (primary zones).
  - Pressure differences while blower door is running.
  - Create a temporary opening in one pressure boundary.
  - Determine CFM<sub>50</sub> flow House/Zone, Zone/Outdoors, and Total Path.
  - Determine square inches of leakage through pressure boundaries.
  - Important for Quality Assurance because method gives pre- and post-weatherization results.

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### Examples of Secondary Zones (analyst is NOT able to open a hole)


- Joist cavities in Cape Cod style house.
- Crawl space with no access.
- Knee wall area with no access.
- Soffit above kitchen cabinets.
- Chimney cavities.
- Interior wall cavities.
- Attached porch roof/ceiling cavities.

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### Is Porch Roof Connected?




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### Examples of Primary Zones (analyst IS able to open a hole)

- Attics
- Knee wall areas
- Garages
- Basements
- Crawl spaces

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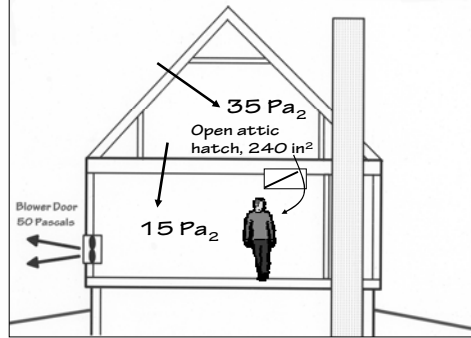
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A blower door is required for Zone Pressure Diagnostics, for both secondary and primary zone testing.

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35 Pa<sub>2</sub>  
Open attic hatch, 240 in<sup>2</sup>  
15 Pa<sub>2</sub>  
Blower Door 50 Pascals

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### Example House ZPD Details

- Sample Zone Pressure Diagnostics readings:
  - Attic as zone
    - Building/Zone = 2,295 CFM<sub>50</sub>
    - Zone/Outdoors = 11,226 CFM<sub>50</sub>
    - Total Path = 2,174 CFM<sub>50</sub>
  - Crawl space as zone
    - Building/Zone = 7,504 CFM<sub>50</sub>
    - Zone/Outdoors = 4,326 CFM<sub>50</sub>
    - Total Path = 3,431 CFM<sub>50</sub>

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### Basic Principle of Series Leakage

- The ratio of pressure differences across interior and exterior boundaries is related to the ratio of their leakage areas.

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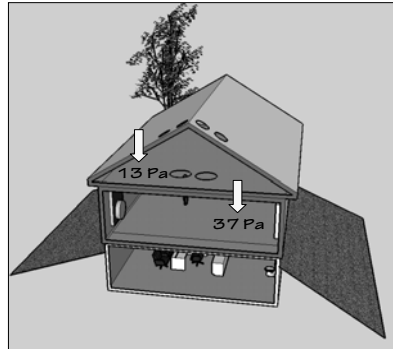
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### Pressures and Relative Leakage

Zone Pressures		Relative Size of Leaks	
House/Zone	Zone/Out	House/Zone	Zone/Out
12	38	2	1
25	25	1	1
37	13	1/2	1
41	9	1/3	1
45	5	1/4	1
48	2	1/8	1
49	1	1/13	1

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13 Pa<sub>2</sub>  
37 Pa<sub>2</sub>

The ratio of leakage areas here...

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... is the same as here.

What about flow and leakage areas?

Click 1

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### Zone Pressure Diagnostics

- Concepts - 1
  - Not every building needs Zone Pressure Diagnostics (ZPD) testing.
    - Very tight buildings usually don't need ZPD.
    - Sometimes very loose buildings don't need ZPD, at least not right away.
  - Every house does need safety checks.

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### Zone Pressure Diagnostics

- Concepts - 2
  - When leakage air must follow path through two or more air barriers, for example, attic floor and building roof, it is helpful to know the leakiness of each of the air barriers.
    - The relative resistance to airflow is expressed as a pressure difference. For example, 35 Pascals or 15 Pascals of pressure difference.
    - The absolute leakage is expressed as a flow. For example, 1200 CFM<sub>50</sub> or 950 CFM<sub>50</sub>, always with the building to outdoor pressure difference of 50 Pascals.

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### Zone Pressure Diagnostics

- Concepts - 3
  - Each pressure boundary imposes a resistance to airflow. The higher the pressure difference across the boundary, the greater its resistance to airflow.

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Blower Door 50 Pascals

18 Pa

32 Pa

Which air barrier has the greater resistance to airflow?

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### Secondary Zone Analysis

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### Examples of Secondary Zones

(analyst is NOT able to open a hole)

- Joist cavities in Cape Cod style house.
- Crawl space with no access.
- Knee wall area with no access.
- Soffit above kitchen cabinets.
- Chimney cavities.
- Interior wall cavities.
- Attached porch roof/ceiling cavities.

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Cape Cod House

2 Pa

Blower Door  
50 Pascals

Is there a connection here?

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Cape Cod House

48 Pa

Blower Door  
50 Pascals

Is there a connection here?

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### Is Porch Roof Connected?

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50 Pa

If your Program calls for H/Z  $\Delta P$  of less than 46 Pascals, how can you achieve this?

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### Your Examples?

- Joist cavities in Cape Cod style house.
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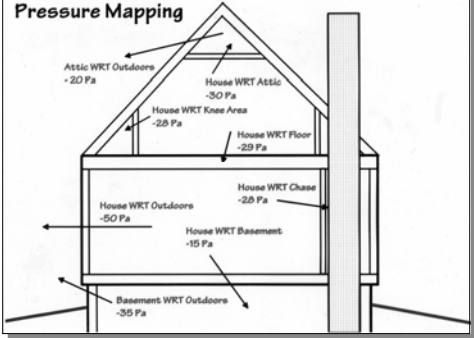
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# Pressure Mapping: A Secondary Zone Analysis


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## Pressure Mapping



Location	Pressure (Pa)
Attic WRT Outdoors	-20 Pa
House WRT Attic	-30 Pa
House WRT Knee Area	-28 Pa
House WRT Floor	-28 Pa
House WRT Chase	-28 Pa
House WRT Outdoors	-50 Pa
House WRT Basement	-15 Pa
Basement WRT Outdoors	-35 Pa

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**Zone Pressure Diagnostics:  
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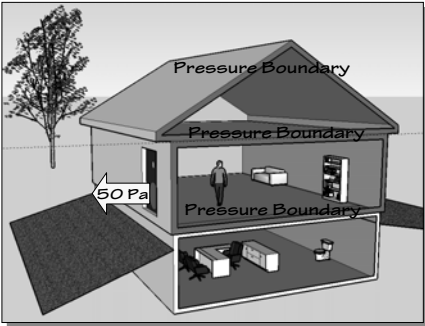
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**Quick Review of  
Basic ZPD Session**

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Series leakage or resistance 3 

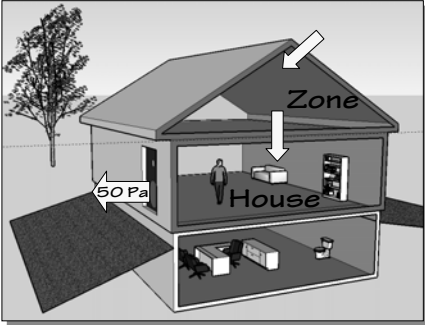
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**Zone Pressure Diagnostics**

- Objectives
  - Determine leakage area from building to zone.
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  - Determine total path CFM<sub>50</sub> from building to outdoors through a zone.
  - To help appraise IAQ issues, such as CO from attached garages and bad air from crawl spaces.

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**Examples of Secondary Zones  
(analyst is NOT able to open a hole)**

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- Soffit above kitchen cabinets
- Chimney cavities.
- Interior wall cavities.
- Attached porch roof/ceiling cavities.


*Covered in Basic ZPD*

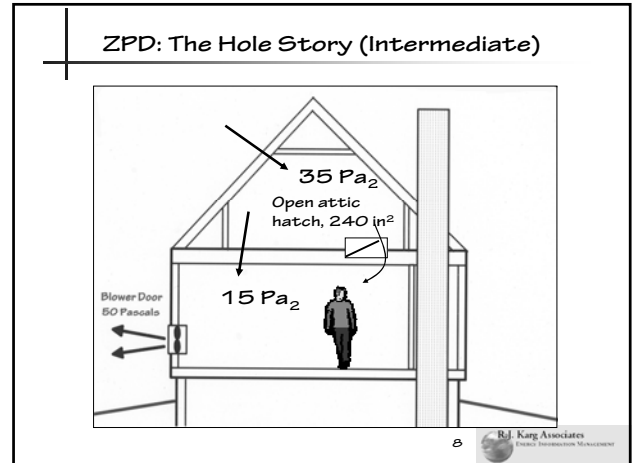
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### Examples of Primary Zones (analyst is able to open a hole)

- Attics
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- Garages
- Basements
- Crawl spaces


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### Example House ZPD Details

- Sample Zone Pressure Diagnostics readings:
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## Primary Zone Analysis

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### Examples of Primary Zones (analyst is able to open a hole)

- Attics
- Knee wall areas
- Garages
- Basements
- Crawl spaces

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## Add-a-Hole Method

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### Add-a-Hole, Low-Tech Version

- With house at 50 Pa, measure House/Zone.
- Open a hole (attic hatch) just big enough to cut the House/Zone pressure in half.
- Keep house at 50 Pa.
- The hole you added is roughly equal to the existing leakage.

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TI-86 with ZipTest Pro<sup>2</sup>

Zone Pressure Diagnostics Screen

```

CFM50's
BLD/ZONE ----> 1419
ZONE/OUT ----> 2062
TOTAL PATH ---> 1062
ENTERED DATA:
32 18 1 240 15 35
HOLE METHOD
    
```

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Flow Method: Hole Added from House to Zone

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### Pressure Gauge

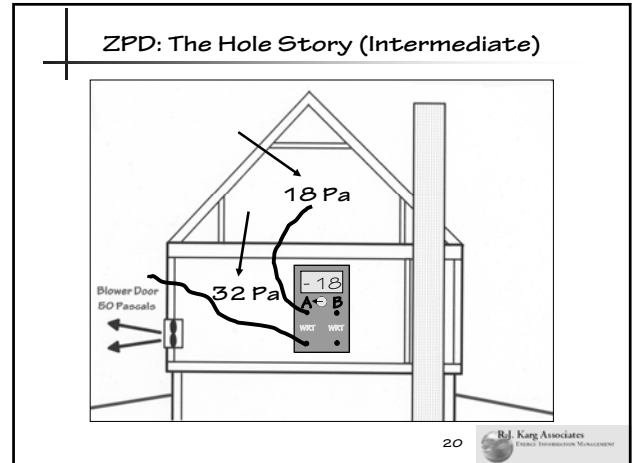
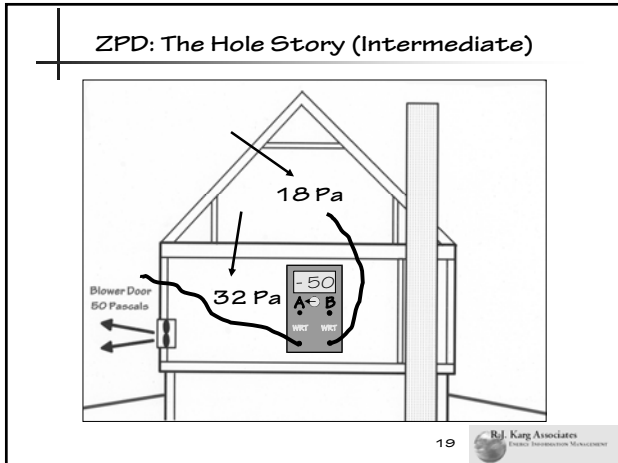
Hose to outdoors

Based on The Energy Conservatory DG-2 and DG-3, digital pressure gauges

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### Zone Pressure Diagnostics

- These pressure differences tell us which pressure boundary is most effective, but do not indicate the amount of leakage in either pressure boundary. Do not be misled by these pressure difference numbers; their usefulness is very limited.

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### Zone Pressure Diagnostics

- In order to determine the actual leakiness of a pressure boundary, we must determine the CFM<sub>50</sub> flow through each air barrier.
  - This must be done by opening a hole from House/Zone or Zone/Outdoors using a standard procedure and
    - A special chart.
    - ZipTest Pro<sup>3</sup>™ software.
    - Energy Conservatory Software.

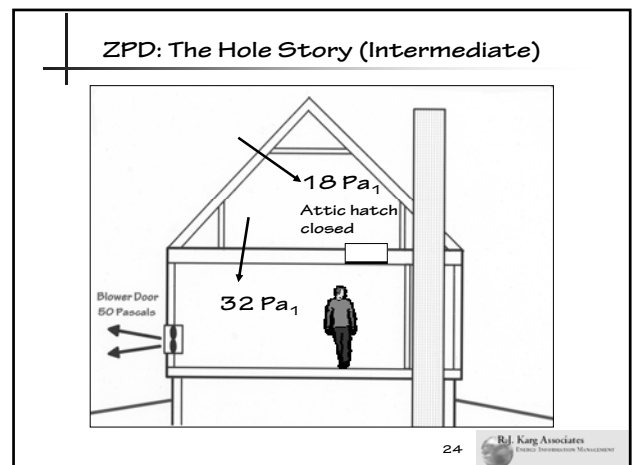
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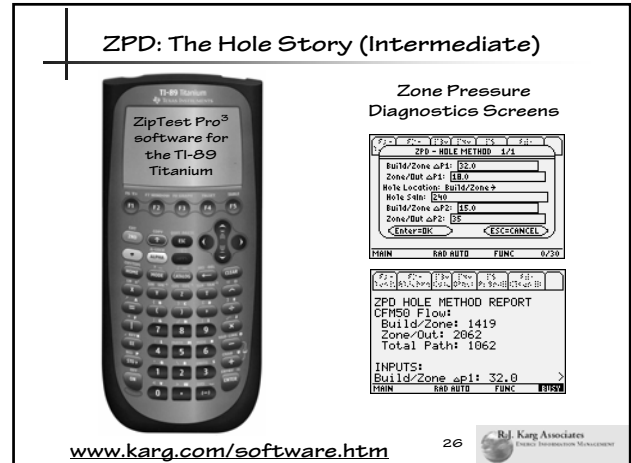
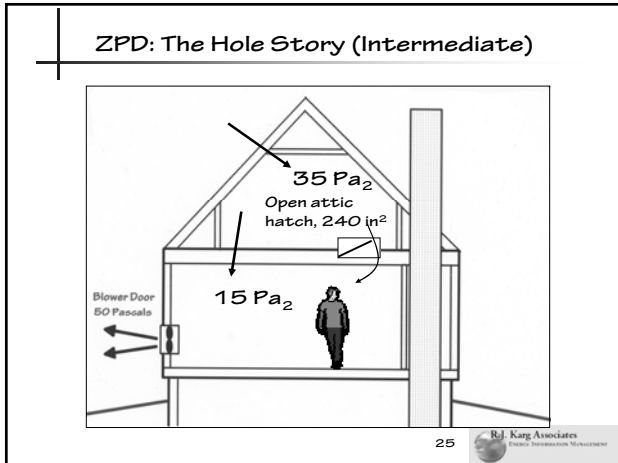
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### Zone Pressure Diagnostics

- Add-a-hole standard procedure:
  - Depressurize house to - 50 Pascals;
  - Measure H/Z and Z/O pressure differences;
  - Create a temporary hole in the best of the two air barriers, large enough to drop the pressure difference across the air barrier by about 15 Pascals;
  - Always keep house pressure at - 50 Pascals;
  - Measure size of open hole in square inches;
  - With hole open, measure H/Z and Z/O pressure differences;
  - Determine H/Z, Z/O, and total path CFM<sub>50</sub> (flow) values with ZipTest Pro<sup>3</sup>™ software;
  - Divide H/Z and Z/O CFM<sub>50</sub> values by 10 to determine approximate leakage area in square inches.

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What do the ZPD Numbers Mean?

- Building/Zone CFM<sub>50</sub> of 1491
  - This pressure boundary - the ceiling - would leak at a rate of 1491 CFM<sub>50</sub> if the other pressure boundary - the roof - were totally removed.
  - There are approximately 149 in<sup>2</sup> of leakage between the building or house and zone.

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What do the ZPD Numbers Mean?

- Zone/Outdoor CFM<sub>50</sub> of 2062
  - This pressure boundary - the roof - would leak at a rate of 2062 CFM<sub>50</sub> if the other pressure boundary - the ceiling - were totally removed.
  - There are approximately 206 in<sup>2</sup> of leakage between the building or house and zone.

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ZPD: The Hole Story (Intermediate)

What do the ZPD Numbers Mean?

- Total Path CFM<sub>50</sub> of 1062
  - This represents the combined leakage of the two pressure boundaries - the ceiling and the roof - acting together or in series, both imposing a resistance to airflow.
  - The total path CFM<sub>50</sub> is always less than either of the other two numbers (House/Zone or Zone/Outdoors).

(continued ...)

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What do the ZPD Numbers Mean?

- Total Path CFM<sub>50</sub> of 1062 (... continued)
  - This is a representation of the portion of the whole building CFM<sub>50</sub> leaking through the ceiling/roof.
    - For example, if the whole building CFM<sub>50</sub> is 3200, 1062 of this can be attributed to ceiling/roof leakage. This means that 3200 - 1062 = 2138 CFM<sub>50</sub> can be attributed to leakage in other parts of the envelope.

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# Door Method

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## ZPD Basic Door Methods - 1


- For this test, a door or other openable panel is closed for the first set of pressure readings and opened for the second set.
- The size of the opening does not have to be measured.

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## ZPD Basic Door Methods - 2


- So, let's assume the garage is the zone.
- With the door to the garage closed, measure the whole-house CFM<sub>50</sub>, say 2250.
- Now measure House/Zone ΔP, say 32 Pa.
- And measure Zone/Outdoor ΔP, say 18 Pa.

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## ZPD Basic Door Methods - 3

- Now open the door to the garage and again measure the whole-house CFM<sub>50</sub>, say 3000.
- The pressure now across the pressure boundary in which you opened the door (house to garage) should be less than 1 Pa.

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**Zone Pressure Diagnostics Screens**

MAIN RAD AUTO FUNC 0/20

Zone Pressure Diagnostics Screens

Basic ZPD - DOOR METHOD 1/4

Closed CFM50: 2250

Builds/Zone of: 125

Zone/Outdoors of: 18

Door Location: Build/Zone

Open CFM50: 3000

Enter/Cancel

---

ZPD DOOR METHOD REPORT

CFM50 Flow: 2250

Build/Zone: 125


Zone/Out: 18

Total Path: 796

INPUTS:

Door Closed CFM50: 2250

MAIN RAD AUTO FUNC 0/20

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### OPEN A DOOR (ZONE PRESSURE - SERIES LEAKAGE DIAGNOSTICS)

**FOR OPENING THE DOOR FROM GARAGE TO HOUSE**

CFM	ΔP	Zone	House	Outdoor
18	3.14	1.74	0.73	0.65
19	3.14	1.74	0.73	0.65
20	3.14	1.74	0.73	0.65
21	3.14	1.74	0.73	0.65
22	3.14	1.74	0.73	0.65
23	3.14	1.74	0.73	0.65
24	3.14	1.74	0.73	0.65
25	3.14	1.74	0.73	0.65
26	3.14	1.74	0.73	0.65
27	3.14	1.74	0.73	0.65
28	3.14	1.74	0.73	0.65
29	3.14	1.74	0.73	0.65
30	3.14	1.74	0.73	0.65
31	3.14	1.74	0.73	0.65
32	3.14	1.74	0.73	0.65
33	3.14	1.74	0.73	0.65
34	3.14	1.74	0.73	0.65
35	3.14	1.74	0.73	0.65
36	3.14	1.74	0.73	0.65
37	3.14	1.74	0.73	0.65
38	3.14	1.74	0.73	0.65
39	3.14	1.74	0.73	0.65
40	3.14	1.74	0.73	0.65
41	3.14	1.74	0.73	0.65
42	3.14	1.74	0.73	0.65
43	3.14	1.74	0.73	0.65
44	3.14	1.74	0.73	0.65
45	3.14	1.74	0.73	0.65
46	3.14	1.74	0.73	0.65
47	3.14	1.74	0.73	0.65
48	3.14	1.74	0.73	0.65
49	3.14	1.74	0.73	0.65
50	3.14	1.74	0.73	0.65

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# Advanced ZPD Methods

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## Advanced ZPD

- Study Completed by Center for Energy and Environment, Michael Blasnik & Assoc. and the Energy Conservatory, 2001.
- To test how accurate the current tests are and when to use them.
- Actually ended up creating a Hybrid method by combining Add-a-Hole and Door Method.


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### An Investigation Into Zone Pressure Diagnostic Protocols For Low Income Weatherization Crews

Phase I and Phase II Final Report Appendices  
December 2001

Prepared by  
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<http://www.ecw.org/productdetail.php?productid=383>

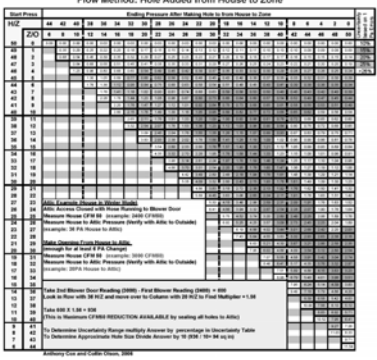


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Flow Method: Hole Added from House to Zone



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### OPEN A DOOR (ZONE PRESSURE - SERIES LEAKAGE DIAGNOSTICS)

FOR OPENING THE DOOR FROM GARAGE TO HOUSE

All Doors to Garage Closed (House in airtight mode)  
Get Blower Door to ISPA WRT Outside

A Measure House CFM 90 Door Closed  
B Measure Closed Door Zonal Pressure House WRT Garage  
C CFM 90 Door Open - CFM 90 Door Closed

Look up Closed Door Zonal Pressure for House WRT Garage on Table

Enter Multiplier into labeled Multiplier Boxes Below  
Multiply CFM 90 Difference (D) x Multiplier in each row for results

Divide CFM 90 by 10 in each row To Determine Approx. Square Inches of Leakage

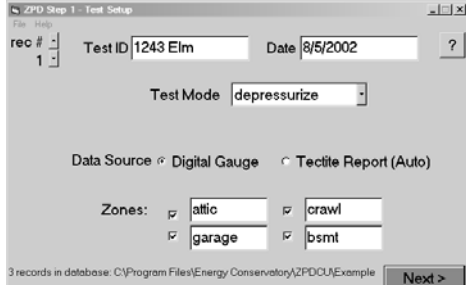
CFM 90 Difference	CFM 90	CFM 90	CFM 90
10	1.75	1.75	1.75
20	3.50	3.50	3.50
30	5.25	5.25	5.25
40	7.00	7.00	7.00
50	8.75	8.75	8.75
60	10.50	10.50	10.50
70	12.25	12.25	12.25
80	14.00	14.00	14.00
90	15.75	15.75	15.75
100	17.50	17.50	17.50
110	19.25	19.25	19.25
120	21.00	21.00	21.00
130	22.75	22.75	22.75
140	24.50	24.50	24.50
150	26.25	26.25	26.25
160	28.00	28.00	28.00
170	29.75	29.75	29.75
180	31.50	31.50	31.50
190	33.25	33.25	33.25
200	35.00	35.00	35.00
210	36.75	36.75	36.75
220	38.50	38.50	38.50
230	40.25	40.25	40.25
240	42.00	42.00	42.00
250	43.75	43.75	43.75
260	45.50	45.50	45.50
270	47.25	47.25	47.25
280	49.00	49.00	49.00
290	50.75	50.75	50.75
300	52.50	52.50	52.50
310	54.25	54.25	54.25
320	56.00	56.00	56.00
330	57.75	57.75	57.75
340	59.50	59.50	59.50
350	61.25	61.25	61.25
360	63.00	63.00	63.00
370	64.75	64.75	64.75
380	66.50	66.50	66.50
390	68.25	68.25	68.25
400	70.00	70.00	70.00
410	71.75	71.75	71.75
420	73.50	73.50	73.50
430	75.25	75.25	75.25
440	77.00	77.00	77.00
450	78.75	78.75	78.75
460	80.50	80.50	80.50
470	82.25	82.25	82.25
480	84.00	84.00	84.00
490	85.75	85.75	85.75
500	87.50	87.50	87.50
510	89.25	89.25	89.25
520	91.00	91.00	91.00
530	92.75	92.75	92.75
540	94.50	94.50	94.50
550	96.25	96.25	96.25
560	98.00	98.00	98.00
570	99.75	99.75	99.75
580	101.50	101.50	101.50
590	103.25	103.25	103.25
600	105.00	105.00	105.00
610	106.75	106.75	106.75
620	108.50	108.50	108.50
630	110.25	110.25	110.25
640	112.00	112.00	112.00
650	113.75	113.75	113.75
660	115.50	115.50	115.50
670	117.25	117.25	117.25
680	119.00	119.00	119.00
690	120.75	120.75	120.75
700	122.50	122.50	122.50
710	124.25	124.25	124.25
720	126.00	126.00	126.00
730	127.75	127.75	127.75
740	129.50	129.50	129.50
750	131.25	131.25	131.25
760	133.00	133.00	133.00
770	134.75	134.75	134.75
780	136.50	136.50	136.50
790	138.25	138.25	138.25
800	140.00	140.00	140.00
810	141.75	141.75	141.75
820	143.50	143.50	143.50
830	145.25	145.25	145.25
840	147.00	147.00	147.00
850	148.75	148.75	148.75
860	150.50	150.50	150.50
870	152.25	152.25	152.25
880	154.00	154.00	154.00
890	155.75	155.75	155.75
900	157.50	157.50	157.50
910	159.25	159.25	159.25
920	161.00	161.00	161.00
930	162.75	162.75	162.75
940	164.50	164.50	164.50
950	166.25	166.25	166.25
960	168.00	168.00	168.00
970	169.75	169.75	169.75
980	171.50	171.50	171.50
990	173.25	173.25	173.25
1000	175.00	175.00	175.00

www.karg.com/papers.htm

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ZPD: The Hole Story (Intermediate)

### ZPD Utility by Energy Conservatory



3 records in database: C:\Program Files\Energy Conservatory\ZPD\Example

www.energyconservatory.com

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ZPD Step 2 - Baseline House Pressure - No Openings

Test ID: 1243 Elm

Inside Temp (F) 73    Outside Temp (F) 24

Enter three consecutive baseline house pressure readings (5 second averages of house with reference to outside)

-3.5    0.4    -1.4

Average Baseline (Pa) -1.5

Estimated Baseline Fluctuation 2.5

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ZPD Step 3 - Test Readings - No Openings

Test ID: 1243 Elm

Pressures wrt outside (Pa)

	Baseline	BD on	Change
House	-1.5	-51.5	-50
attic	2.1	-15.3	-17.4
garage	2.4	-13.5	-15.9
crawl	-1.3	-2.1	-0.8
bsmt	-2.1	-46	-43.9

BD Flow (CFM) 2235    Ring A

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ZPD Step 4 - Zone Guidelines

Test ID: 1243 Elm

House CFM50 = 2130

Minimum shift in zone pressure needed = 10 Pa

Zone	Ratio *	Suggested Opening Location	
		house/zone	zone/out
attic	0.35	BEST	OK
garage	0.32	BEST	OK
crawl	0.02	BEST	NO
bsmt	0.88	NO	BEST

\*Ratio is from 0 to 1 where 0 = out and 1 = in

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ZPD Step 5 - Test Readings - Opening Added

Test ID: 1243 Elm

Opening from attic to house orifice 225 Sq. In.

	Baseline	BD on	Change
House	-0.6	-50.6	-50
attic	1.5	-33.7	-35.2
garage	1.4	-18.5	-19.9
crawl	-1.2	-3.1	-1.9
bsmt	-1.8	-47.2	-45.4

BD Flow (CFM) 3075    Ring open

All Pressures wrt Outside

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ZPD Step 6 - Zone Leakage Results

Test ID: 1243 Elm

Zone Tested = attic

\* Zone Shifted by -17.8 Pa, From -17.4 to -35.2

	Leakage Range	
	min	max
house to attic leakage (sq. in.)	81	177
attic to outside leakage (sq. in.)	137	251
leakage through zone (CFM50)	610	1254

\* Adjusted to a house pressure of 50

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ZPD Step 7 - Additional Zones

Test ID: 1243 Elm

Zone Tested = attic

Zone	No Openings	Opening Added	Shift	detected connection to zone tested?
garage	-15.9	-19.9	4	yes
crawl	-8	-1.9	1.1	no
bsmt	-43.9	-45.4	1.5	no


Pressures adjusted to house pressure of 50

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## Some ZPD Standards


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## Attached Garage Hazard

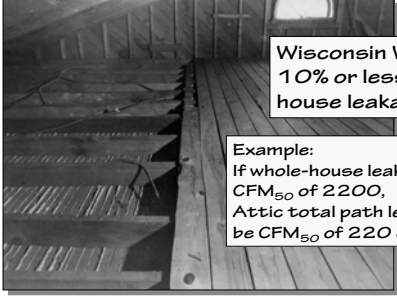


CFM<sub>50</sub> = 200  
flow between house  
and garage is OK?

50 

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## Leakage to Attic



Wisconsin Wx target:  
10% or less of whole-  
house leakage to attic!

Example:  
If whole-house leakage is  
CFM<sub>50</sub> of 2200,  
Attic total path leakage should  
be CFM<sub>50</sub> of 220 or less.

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