Advanced Air Sealing

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Welcome!
Today we will...

• Explain the process of establishing a protocol for air sealing
• Explore advanced air sealing techniques
• Examine options for creating ventilation plans for the dwellings we treat
• Are there specific air sealing issue that you would like to discuss?
Air Sealing: Establishing a Protocol
On many projects, air sealing is one of the most important measures that we provide! It can also

- Be difficult to explain
- Be confusing to implement
- Be challenging to value
- Create conflicts with air quality concerns
A protocol: A step by step process to ensure that air sealing is approached in a careful, methodical manner

- Ensure thorough evaluation of opportunities
- Create an effective decision tree
- Turn guess work into targeting
- Increase efficiency of the work
Important tools: Brains

• Your Brain
• Your Co-workers’ Brains
• Your Customer’s Brains
An Advanced Air Sealing Protocol

1. Initial inspection
2. Health and Safety Evaluation
3. Initial Thermal Imaging
4. Initial Blower Door and Diagnostics
   - Blower Door Assisted IR Scan
   - Zonal Pressure Diagnostics
5. Define Priorities
6. Air Seal
7. Follow-up
Step 1: Initial inspection

Conduct an initial walk-through, both inside and out. This can be done while:

- calibrating for CO monitoring (outside)
- conducting gas leak testing
- readying the home for initial blower door testing.
“High Focus” Air Sealing Areas

• Attached garages
• Attic by-passes
• Dropped Ceilings
• Heat and cooling ducts outside of the thermal boundary
• Dropped soffits

• Band joists and rim joists
• Combustion Appliance vent chases
• Porches and attached roofs
• Electrical and Plumbing Penetrations
• Windows and doors
Step 2: Determine if air sealing is possible without adverse health effects to the occupants. Look for potential pollutants:

- Mold
- Mildew
- moisture:
- VOCs
- Formaldehyde
- Radon
- Wood smoke
- Asbestos
- Animal urine and feces
- Dust mites
- Poor hygiene
- Tobacco smoke
Health and safety checks should include combustion safety pretests as per BPI Standards

- Check for gas leaks if natural gas equipment or gas lines exist in the dwelling
- Check Ambient Carbon Monoxide (CO) readings
- Spillage and CO assessment for all combustion appliances
- Draft pressure checks of venting systems for space and water heaters
- Worst Case Depressurization
If unvented space heaters are in use in the living space

- DOE: requires removal prior to air sealing if primary heat. May remain as secondary heat only if it meets ANSI Z21.11.2
- Consider requiring removal of all (or at least disconnection and capping of gas line) prior to air sealing
- Provide client education on space heaters
If health and safety issues exist, either:

– Remediate;
– Drop air sealing from project; or
– Accommodate the concern through a ventilation plan.
Step 3: Initial Thermal Imaging

(Optional)

• Use thermal imaging to establish baseline reading of shell infiltration prior to running blower door.

• Tour as many accessible areas of the home with infrared imaging to discover unseen pathways of air infiltration or exfiltration.

• Both outdoor and indoor scans can be helpful
What my IR camera will do:

• It will detect thermal patterns
• It is passive investigation
• It will show warmer and colder areas
• It is only as good as the operator.
Step 4: Initial Blower Door Test and Diagnostics

- Define pressure boundary
- Initial blower door test*
- CAZ testing
- Diagnostics:
  - Visual inspection
  - Smoke
  - Infrared with blower door
  - Zonal Pressure Diagnostics

*Pressurize if there is a risk of drawing pollutants into living area
Blower doors are instrumental in locating leaks and determining how big the leaks are.
Initial blower door and CAZ testing

- Can be helpful in determining whether backdrafting is likely to occur from extensive air sealing.
- If the initial blower door test indicates a high degree of air leakage, and the CAZ test is borderline, it is likely that backdrafting will occur if air leakage is reduced significantly.
- For this reason, it is recommended that periodic CAZ testing be conducted during air sealing to reduce this risk.
The smoke knows.
Pressurize to move smoke away from you.
Blower Door Assisted Infrared Imaging
Northwest Corner of Attic Floor

Infrared Image
Air infiltration at drywall & molding
Blower Door and Zonal Numbers for the Attic and Basement

Series Leakage Calculation
Initial test

5200 CFM50

-50 Pa.
Initial test

5200 CFM50

-32 Pa.

-50 Pa.
# Flow Method: Hole Added from House to Zone

| Start Press | 44 | 42 | 40 | 38 | 36 | 34 | 32 | 30 | 28 | 26 | 24 | 22 | 20 | 18 | 16 | 14 | 12 | 10 | 8   | 6   | 4   | 2   | 0   |
|-------------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| H/Z        |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Z/O        |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |

## Before Hole
- CFM50: 5200
- H/Z: 32

## After Hole
- CFM50: (Blank)
- H/Z: (Blank)

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**Answer**
- **CFM50 Diff**: (Blank)
- **Multiplier**: (Blank)
- **Maximum Reduction**: (Blank)
- **Total Path CFM50**: (Blank)

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*Anthony Cox and Collin Olson, 2006*
5200 CFM50 - 50 Pa.
-32 Pa.
-50 Pa.
5400 CFM50
### Flow Method: Hole Added from House to Zone

<table>
<thead>
<tr>
<th>Start Press</th>
<th>Ending Pressure After Making Hole to/from House to Zone</th>
<th>Uncertainty based on 1 CFM for Each 5 Press</th>
</tr>
</thead>
<tbody>
<tr>
<td>34 16</td>
<td>5.55  5.32  5.05  4.80  4.54  4.34  4.53  4.76</td>
<td>2.5%</td>
</tr>
<tr>
<td>33 16</td>
<td>5.10  4.87  4.65  4.41  4.19  4.01  4.20  4.44</td>
<td>2.5%</td>
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<tr>
<td>32 16</td>
<td>4.65  4.42  4.20  3.97  3.76  3.59  3.79  4.03</td>
<td>2.5%</td>
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<tr>
<td>31 16</td>
<td>4.20  4.07  3.86  3.64  3.44  3.27  3.49  3.73</td>
<td>2.5%</td>
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<td>30 16</td>
<td>3.75  3.63  3.42  3.21  3.01  2.85  3.08  3.32</td>
<td>2.5%</td>
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<tr>
<td>29 16</td>
<td>3.30  3.18  2.98  2.78  2.59  2.41  2.64  2.88</td>
<td>2.5%</td>
</tr>
<tr>
<td>28 16</td>
<td>2.85  2.75  2.56  2.37  2.19  2.02  2.26  2.50</td>
<td>2.5%</td>
</tr>
<tr>
<td>27 16</td>
<td>2.40  2.31  2.13  1.95  1.78  1.61  1.85  2.10</td>
<td>2.5%</td>
</tr>
<tr>
<td>26 16</td>
<td>1.95  1.87  1.69  1.52  1.36  1.20  1.44  1.69</td>
<td>2.5%</td>
</tr>
<tr>
<td>25 16</td>
<td>1.50  1.43  1.26  1.10  0.94  0.79  1.04  1.29</td>
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</tr>
<tr>
<td>24 16</td>
<td>1.05  0.99  0.83  0.67  0.52  0.37  0.63  0.89</td>
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<tr>
<td>23 16</td>
<td>0.60  0.55  0.39  0.24  0.09  0.04  0.30  0.56</td>
<td>2.5%</td>
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<tr>
<td>22 16</td>
<td>0.15  0.11  0.06  0.01  0.00  0.00  0.00  0.00</td>
<td>2.5%</td>
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<tr>
<td>21 16</td>
<td>0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00</td>
<td>2.5%</td>
</tr>
</tbody>
</table>

#### attic Example (Attic in Winter Mode)

- Attic Access Closed with Hose Running to Blower Door
- Measure House CFM 50 (example: 2400 CFM50)
- Measure House to Attic Pressure (Verify with Attic to Outside)
- 36 PA House to Attic

**Answer:**

CFM50 Diff: 1200

Multiplier: 2.0

Maximum Reduction: 6400

(otal path time CFM50)
## Flow Method: Hole Added from House to Zone

<table>
<thead>
<tr>
<th>Start Press</th>
<th>44</th>
<th>42</th>
<th>38</th>
<th>34</th>
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</tbody>
</table>

### Before Hole
- **CFM50:** 5200
- **H/Z:** 32
- **After Hole:**
  - **CFM50:** 6400
  - **H/Z:** 22

**ANSWER**
- **CFM50 Diff:** 1200
- **Multiplier:**
- **Max Reduction:**

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**NOTES**
- attic example: house in winter mode.
- attic access closed with hose running to blower door.
- measure house CFM50 (example: 2400 CFM50).
- measure house to attic pressure (verify with attic to outside: 36 PA House to attic).
- Make Opening from House to Attic (enough for at least 6 PA Change).
- Measure house CFM50 (example: 3000 CFM50).
- Measure house to attic pressure (verify with attic to outside: 36 PA House to attic).
- Take 2nd blower door reading (3000) - first blower reading (2400) = 600.
- look in row with 36 H/Z and move over to column with 29 H/Z to find multiplier = 1.56.
- take 900 X 1.56 = 936.
- This is maximum CFM50 reduction available by sealing all holes to attic.
- To determine uncertainty range multiply answer by percentage in uncertainty table.
- To determine approximate hole size divide answer by 10 (636 / 10 = 63.6 sq in).
**Flow Method: Hole Added from House to Zone**

| Start Press | Ending Pressure After Making Hole to/from House to Zone | Uncertainty based on 1 CFM 50 | Before Hole | CFM50
<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>Z/O</td>
<td>6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50</td>
<td></td>
<td>CFM50</td>
<td>5200</td>
</tr>
<tr>
<td>59</td>
<td>0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00</td>
<td>0.00%</td>
<td>0.00</td>
<td>0.00</td>
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<tr>
<td>58</td>
<td>0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00</td>
<td>0.00%</td>
<td>0.00</td>
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</tr>
<tr>
<td>57</td>
<td>0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00</td>
<td>0.00%</td>
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<tr>
<td>56</td>
<td>0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00</td>
<td>0.00%</td>
<td>0.00</td>
<td>0.00</td>
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<td>55</td>
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<td>0.00%</td>
<td>0.00</td>
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<tr>
<td>54</td>
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<tr>
<td>53</td>
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<td>0.00%</td>
<td>0.00</td>
<td>0.00</td>
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<tr>
<td>52</td>
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<td>0.00%</td>
<td>0.00</td>
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</tr>
<tr>
<td>51</td>
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<td>0.00%</td>
<td>0.00</td>
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<tr>
<td>50</td>
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<td>0.00%</td>
<td>0.00</td>
<td>0.00</td>
</tr>
</tbody>
</table>

**Answer**

- **CFM50 Diff:** 1200
- **Multiplier:** 3.01
- **Maximum Reduction:** 3612 (total path CFM50)

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Anthony Cox and Collin Olson, 2006

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NYSDWA

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Weatherization

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NYSERDA
Initial test

5200 CFM50

3612 CFM path

-32 Pa.

-50 Pa.
Blower Door and Zonal number’s for the Basement

Series Leakage Calculation

Pre Blower Door: 5,200 @cfm50
Initial test

5200 CFM50

-50 Pa.

-25 Pa.
The image contains a table and a diagram related to flow methods in weatherization, specifically focusing on 'Hole Added from House to Zone'. The table provides values for different conditions and pressures. The diagram shows the process flow with values and steps.

### Flow Method: Hole Added from House to Zone

<table>
<thead>
<tr>
<th>H/Z</th>
<th>Z/O</th>
<th>Start Press</th>
<th>Ending Pressure After Making Hole to from House to Zone</th>
<th>Uncertainty based on 1% of Total Flow (CFM50)</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>60</td>
<td>44 40 38 36 34 32 30 28 26 24 22 20 18 16 14 12 10 8 6 4 2 0</td>
<td>5200</td>
<td>25</td>
</tr>
</tbody>
</table>

#### Before Hole
- CFM50: 5200
- H/Z: 25

#### After Hole
- CFM50
- H/Z

### Attic Example: House in Winter Mode
- Attic Access Closed with Hose Running to Blower Door
- Measure House CFM50 (example: 2400 CFM50)
- Measure House Pressure to Attic Pressure (Verify with Attic to Outside)
- Measure PA House to Attic

### Make Opening From House to Attic
- Enough for at least 6 PA Change

### Measure House CFM50
- Example: 3000 CFM50

### Measure House to Attic Pressure (Verify with Attic to Outside)
- Example: 30 PA House to Attic

### Take 2nd Blower Door Reading (3000) - First Blower Reading (2400) = 600
- Look in Row with 36 H/Z and move over to Column with 29 H/Z to Find Multiplier = 1.56

### Take 900 X 1.56 = 936
- (This is Maximum CFM50 REDUCTION AVAILABLE by sealing all holes to Attic)

### To Determine Uncertainty Range multiply Answer by percentage in Uncertainty Table
- 22% 24%

### To Determine Approximate Hole Size Divide Answer by 10 (636 / 10 = 63.6 sq in)
- 63.6

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*Anthony Cox and Collin Olson, 2006*
Initial test

5200 CFM50

-50 Pa.

-25 Pa.
Initial test

5800 CFM50

-50 Pa.

-25 Pa.
### Flow Method: Hole Added from House to Zone

<table>
<thead>
<tr>
<th>Start Pressure</th>
<th>Ending Pressure After Making Hole from House to Zone</th>
<th>Uncertainty based on 5% for Each H/Z</th>
</tr>
</thead>
<tbody>
<tr>
<td>H/Z</td>
<td>44</td>
<td>42</td>
</tr>
<tr>
<td>60</td>
<td>0</td>
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<tr>
<td>54</td>
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</tr>
</tbody>
</table>

**Attic Example (House in Winter Mode)**

- **H/L: 25**
- **CFM50: 5200**
- **CFM60 Diff: 600**
- **Multiplier: 25**
- **Maximum Reduction: 5800**

**ANSWER:**

- **Total path CFM50: 600**
- **CFM63 Diff: 600**
- **Multiplier: 25**
- **Maximum Reduction: 5800**

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*Anthony Cox and Collin Olson, 2006*
## Flow Method: Hole Added from House to Zone

### Table: Ending Pressure After Making Hole to/from House to Zone

| Start Press | 44   | 42   | 40   | 38   | 36   | 34   | 32   | 30   | 28   | 26   | 24   | 22   | 20   | 18   | 16   | 14   | 12   | 10   | 8    | 6    | 4    | 2    | 0    |
|-------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| H/Z         | 50   | 52   | 54   | 56   | 58   | 60   | 62   | 64   | 66   | 68   | 70   | 72   | 74   | 76   | 78   | 80   | 82   | 84   | 86   | 88   | 90   | 92   | 94   | 96   |
| Z/O         | 6    | 8    | 10   | 12   | 14   | 16   | 18   | 20   | 22   | 24   | 26   | 28   | 30   | 32   | 34   | 36   | 38   | 40   | 42   | 44   | 46   | 48   | 50   | 52   |
|             | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

### Notes:
- 

### Diagram:
- attic access closed with hose running to blower door
- measure house CFM 50 (example: 2400 CFM50)
- measure house to attic pressure (verify with attic to outside)
- take 2nd blower door reading (3000) - first blower reading (2400) = 600
- look in row with 36 H/Z and move over to column with 29 H/Z to find multiplier = 1.58
- take 900 X 1.58 = 1426
- this is maximum CFM50 reduction available by sealing all holes to attic
- to determine uncertainty range multiply answer by percentage in uncertainty table
- to determine approximate hole size divide answer by 10 (600/10= 60 sq in)

### Answer:
- H/Z: 25
- CFM50: 5200
- After Hole: 25
- Multiplier: 600
- Maximum Reduction: 1426

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*Anthony Cox and Collin Olson, 2006*
### Flow Method: Hole Added from House to Zone

<table>
<thead>
<tr>
<th>Start Press</th>
<th>Ending Pressure After Making Hole to from House to Zone</th>
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<tbody>
<tr>
<td>H/Z</td>
<td>44 42 40 38 36 34 32 30 28 26 24 22 20 18 16 14 12 10 8 6 4 2 0</td>
</tr>
<tr>
<td>H/Z</td>
<td>59 58 57 56 55 54 53 52 51 50 49 48 47 46 45 44 43 42 41 40 39 38 37 36 35 34 33 32 31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1</td>
</tr>
</tbody>
</table>

#### Before Hole

<table>
<thead>
<tr>
<th>CFM50</th>
<th>5200</th>
</tr>
</thead>
<tbody>
<tr>
<td>H/Z</td>
<td>25</td>
</tr>
</tbody>
</table>

#### After Hole

<table>
<thead>
<tr>
<th>CFM50</th>
<th>5800</th>
</tr>
</thead>
<tbody>
<tr>
<td>H/Z</td>
<td>15</td>
</tr>
</tbody>
</table>

**ATTIC EXAMPLE**

1. **Atten Example (House in Winter Mode)**
2. Measure House to Attic Pressure (Verify with Attic to Outside)
3. Take 2nd Blower Door Reading (3000) - First Blower Reading (2400) = 600
4. Look in Row with 36 H/Z and move over to Column with 29 H/Z to Find Multiplier = 1.58
5. Take 600 X 1.58 = 936
6. (This is Maximum CFM50 REDUCTION AVAILABLE by sealing all holes to Attic)
7. To Determine Uncertainty Range multiply Answer by percentage in Uncertainty Table
8. To Determine Approximate Hole Size Divide Answer by 10 (636 / 10 = 63.6 sq in)

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Anthony Cox and Collin Olson, 2006
Initial test

- 3612 CFM path
- 32 Pa.

- 2478 CFM path
- 50 Pa.

5200 CFM

- 50 Pa.

- 25 Pa.

3612 CFM
2478 CFM
6090 CFM

2478 CFM path

5200 CFM
Zonal Pressure And Air Sealing
Step 5: Define priorities

1. Attic areas to conditioned spaces
2. Garage to conditioned space
3. Ductwork outside of conditioned space
4. Options that reduce or eliminate the impact of pollutants
5. Options that enhance your ventilation plan
6. Other cost-effective opportunities
Step 6: Targeted air sealing

- Follow worker safety protocols
- IMPORTANT: Conduct worse-case CAZ testing at the end of each day’s work
- Use materials appropriate for surfaces, and with a long life of measure
Use materials that meet the following standards:

✓ Products rated to a minimum 20-life.
✓ Air impermeable foams.
✓ Hydrophobic sealants
✓ Backer rod or other support for caulk when filling a gap wider than 3/8”
✓ Materials compatible with their intended surfaces
✓ Materials designed to retain effectiveness and appearance when used on the exterior of the home or in the path of direct sunlight.
✓ Approved non-combustible materials when in contact with chimneys, flues or vents; materials that meet ignition barrier specifications where applicable.
The attic as a zone:  
A Lesson in the Regression Curve
Balancing Progress and Process
Typical Attic Bypasses
Attic Simulation
What would a graph of attic air sealing look like?
House Pressure Constant @ 50pa

CFM Leakage vs. Area

Air leakage rate - CFMs vs. Total leakage area - sq. in.
Progressive Air Sealing Regression - (house pressure constant @ 50pa)

Air leakage rate, CFM<sub>50</sub> vs. Total leakage area, sq. in.
Attic Prop Controlled Air Sealing with Reduction Rates

<table>
<thead>
<tr>
<th>Description</th>
<th>CFM</th>
<th>total in² leakage</th>
<th>CFM/sq.in. reduction rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>all open with chimney flashed</td>
<td>2620</td>
<td>740.8</td>
<td>0.35</td>
</tr>
<tr>
<td>sealed first 1/2 of exterior balloon frame</td>
<td>2600</td>
<td>735.8</td>
<td>0.39</td>
</tr>
<tr>
<td>sealed second 1/2 of exterior balloon frame</td>
<td>2220</td>
<td>448.6</td>
<td>0.70</td>
</tr>
<tr>
<td>sealed interior balloon frame</td>
<td>1190</td>
<td>154.2</td>
<td>2.92</td>
</tr>
<tr>
<td>sealed around duct cavities</td>
<td>415</td>
<td>25.6</td>
<td>6.08</td>
</tr>
<tr>
<td>Sealed around stack vent</td>
<td>165</td>
<td>3.1</td>
<td>7.31</td>
</tr>
</tbody>
</table>
Cardinal Rules:

• Align the thermal and pressure boundary if appropriate!
• Start with the high priority items!
• Plug the big holes first!
• Don’t let the lack of immediate results discourage you!
• If the blower door stops showing results, perform series leakage testing!
Zonal Test Out
3100 CFM50

Final test

46 Pa.

900 CFM path

2784 CFM Original
900 CFM Final
1884 CFM Reduced

1554 CFM Original
1300 CFM Final
254 CFM Reduced

-50 Pa.

1300 CFM path

17 Pa.
Step 7: Follow up

– Final CAZ testing
– Zonal pressure testing
  • Can ensure that goals are met
  • Help determine final ventilation paths
– Review: what worked, what didn’t
Developing a Ventilation Plan
A key goal in air sealing is to determine the most effective air flow patterns for the dwelling based on

- Any existing pollutants
- The configuration of home
- Use of mechanical and passive ventilation
- Air Sealing opportunities
Examples of Ventilation Plans
No pollutants, passive venting
Basement pollutants, mechanical venting
Basement pollutants, mechanical venting

The fan must overcome the chimney effect

The risk of backdrafting must be monitored
If pollutants exist in the basement

- Consider air sealing the ceiling of the basement, not the perimeter
- Consider installing mechanical ventilation in the basement rather than upstairs
- If a warm air furnace is in the basement, ensure that the furnace filter slot has a covering
- Seal leaks in the duct work, especially returns
- **Always CAZ test**, especially if atmospheric combustion appliances exist
Pollution in conditioned space, mechanical venting
Woodstove in conditioned space, passive venting
If pollutants exist in the living space

- Consider strategies that draw pollutants directly from the point source of pollution to exhaust, rather than drawing the pollutant through the house.
- Ensure that air movement occurs in areas away from the pollution: avoid pockets of stale air.
- Educate household on behaviors that reduce or eliminate the effect of pollution.
Remember:

• Every dwelling is different!
• Every project requires your careful evaluation
• Proper application of air sealing techniques, with a final goal of an appropriate ventilation path, is a powerful tool for energy savings in a health home.
Have all of your questions been answered?
Thanks!

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