The Cult of The Blower Door
Blower Door Can’t Get You The True ACH On A Short Term Basis – Hour, Day, Week
Don’t Know Where The Holes Are
Don’t Know The Type of Holes
Don’t Know The Pressure Across The Holes
ELA = C \times \frac{\text{Rate of flow}}{\sqrt{\text{Pressure difference}}}

(M\text{eters})^2 \approx \frac{1}{780} \times \frac{\text{Litres per second}}{\sqrt{\text{Pascals}}}

Building Science Corporation
ELA = \frac{1}{780} \times \frac{\text{Flow rate}}{\sqrt{\text{Pressure difference}}}

ELA = 0.278 \text{ m}^2
Pressure difference

Flow Rate (CFM)

Area of opening
“this is a lie”
Flow Through Orifices

Turbulent Flow - “inertial effects”

Flow Through Porous Media

Laminar Flow - “viscosity effects”
Flow Through Orifices

Turbulent Flow - “inertial effects”

Flow Through Porous Media

Laminar Flow - “viscosity effects”

“true but not useful”
\[ Q = A \cdot C_D \left[ \frac{2}{\rho} (\Delta P) \right]^\frac{1}{2} \]  
Bernoulli

\[ Q = C_K \frac{\rho}{\mu} (\Delta P) \]  
Darcy
\[ Q = A \cdot C_D \left[ \frac{2}{\rho} (\Delta P) \right]^\frac{1}{2} \] Bernoulli

\[ Q = C_K \frac{\rho}{\mu} (\Delta P) \] Darcy

\[ Q = A \cdot C (\Delta P)^\frac{1}{2} \]

\[ Q = C (\Delta P) \]
\[ Q = A \cdot C_D \left[ \frac{2}{\rho} (\Delta P) \right]^{\frac{1}{2}} \]  

Bernoulli

\[ Q = C_K \frac{\rho}{\mu} (\Delta P) \]  

Darcy

\[ Q = A \cdot C (\Delta P)^{\frac{1}{2}} \]  

\[ Q = C (\Delta P) \]  

\[ Q = A \cdot C (\Delta P)^n \]  

Kronval “an engineer”
Figure 2.5
**Modes of Air Flow**
(from Bumbaru, Jutras and Patenaude, 1988)
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**Modes of Air Flow**
(from Bumbaru, Jutras and Patenaude, 1988)
Figure 2.6

**Characteristic Curve of Leakage Flow as a Function of Pressure Difference**
(from Nylund, 1980)

\[ Q = f \left( Dp \right) \propto k \left( Dp \right)^b \]

- \( Q \): air flow, volume/unit of time
- \( Dp \): pressure difference
- \( k \): coefficient
- \( b \): exponent in approximate leakage function
\[ Q = f(Dp) \cdot k(Dp)^b \]

- **Q** = air flow, volume/unit of time
- **Dp** = pressure difference
- **k** = coefficient
- **b** = exponent in approximate leakage function

**Figure 2.6**

**Characteristic Curve of Leakage Flow as a Function of Pressure Difference**
(from Nylund, 1980)
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**Figure 2.6**

**Characteristic Curve of Leakage Flow as a Function of Pressure Difference**

(from Nylund, 1980)
Possible air flows around sill of a wood-framed house modelled as a resistance network.

Figure 2.10
Resistance Network
(from Kronvall, 1980)

1. Air permeating the wood-panel cladding
2. Air flow between floor slab and panel
3. Air flow between floor slab and wind protection
4. Air permeating the caulking
5. Air flow between wind protection and sill
6. Air flow between insulation material and sill
7. Air flow between inner lining and sill
8. Air flow between inner lining and floor slab
9. Air flow between fillet and inner lining
10. Air flow between fillet and floor slab
• Tracer gas test of a production Building America house in Sacramento
• 2-story, 4 bedrooms, ~2500 square feet
• Ventilation systems tested: supply and exhaust ventilation, with and without mixing via central air handler
Floor Plan - 2 Story House
Zones – 2 Story House

- Tracer gas decay tests—establish uniform concentration of tracer gas and then activate ventilation system to remove it
- Reciprocal age-of-air can be calculated from decay curves (if weather conditions are sufficiently constant)
Example Results of Tracer Gas Testing

Laundry Exhaust, 100% of 62.2 Rate, Doors Closed, Transfer Grills Open, No Mixing

Zone | Measured Reciprocal Age of Air (1/hr)
--- | ---
BR1 | 0.18
Living | 0.16
Kitchen | 0.16
BR2 | 0.11
BR3 | 0.13
MBR | 0.14
Example Results of Tuned CONTAM Model

Laundry Exhaust, 100% of 62.2 Rate, Doors Closed, Transfer Grills Open, No Mixing

<table>
<thead>
<tr>
<th>Zone</th>
<th>Reciprocal Age of Air (1/hr)</th>
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<tr>
<td></td>
<td>Measured</td>
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<tr>
<td>BR1</td>
<td>0.18</td>
</tr>
<tr>
<td>Living</td>
<td>0.16</td>
</tr>
<tr>
<td>Kitchen</td>
<td>0.16</td>
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<tr>
<td>BR3</td>
<td>0.13</td>
</tr>
<tr>
<td>MBR</td>
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</table>
Bedroom 1 Pollutant

Pollutant Concentration (ppm)

BR3  MBR  BR2  Kitchen  Living  BR1

1/1 2/20 4/11 5/31 7/20 9/8 10/28 12/17
Bedroom 1 Pollutant

Bedroom 2 Pollutant

Bedroom 3 Pollutant

Kitchen Pollutant

Living Room Pollutant

Master Bedroom Pollutant
Total Pollutant Concentration by Room

![Graph showing total pollutant concentration by room over time. The x-axis represents dates from 1/1 to 12/17, and the y-axis represents pollutant concentration in ppm. The graph is color-coded for different rooms: BR3 (black), MBR (red), BR2 (green), Kitchen (blue), Living (yellow), and BR1 (pink).]
Figure 5.13
Well-Defined Pressure Boundary
- Pressure boundary defines effective building envelope environmental separator
Figure 5.14

**Poorly-Defined Pressure Boundary**

- Pressure boundary poorly defined — ineffective at ceiling
- Pressure boundary not continuous at ceiling
Figure 5.15

**Tight Rim Closure**

- Floor assembly “inside” well-defined pressure boundary
- Pressure boundary continuous at rim closure
Figure 5.16

**Leaky Rim Closure**
- Floor assembly “outside” pressure boundary
- Pressure boundary not continuous at rim closure
Figure 5.17

**Pressure Boundary at Interior Floor**
- Pressure boundary not contiguous with building envelope thermal boundary

Floor cavity is effectively outside of the building due to poor rim closure.
Figure 5.18

**Wind Tunnel Effect**

“Wind tunnel” effect through open webbed floor trusses as a result of poor rim closure.
Figure 5.19

Supply Duct Leakage

- Leakage of supply ducts into floor space pressurizes floor space leading to exfiltration at rim closure
Figure 5.20

**Return Duct Leakage**

- Leakage of return ducts into floor space depressurizes floor space leading to infiltration at rim closure
Figure 5.21

**Combined Floor Paths and Pressure Drivers**

- Vertical and horizontal communication of open webbed floor trusses through fireplace and utility chaseways
- Pressure drivers are wind, the stack effect and the operation of the HVAC system
Duct Leakage Should Be Less Than 5% of Rated Flow As Tested by Pressurization To 25 Pascals
Duct Leakage Should Be Less Than 5% of Rated Flow As Tested by Pressurization To 25 Pascals

Where Did This Come From?
Note: Colored shading depicts the building's thermal barrier and pressure boundary. The thermal barrier and pressure boundary enclose the conditioned space.
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Figure 3.16

**Leaky Supply Ductwork in Vented Crawl Space**

- Air pressurization pattern with mechanical system ducts in the crawl space
Note: Colored shading depicts the building’s thermal barrier and pressure boundary. The thermal barrier and pressure boundary enclose the conditioned space.
All ductwork and air handling unit completely contained within the conditioned space.

Floor supply and ceiling return on upper floor.

Ceiling supply and floor return on lower floor.

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### Air Barrier Metrics

<table>
<thead>
<tr>
<th>Component</th>
<th>Airflow Rate ( l/(s-m^2) ) @ 75 Pa</th>
<th>Airflow Rate ( cfm/ft^2 ) @ 50 Pa</th>
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<td>-----------</td>
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<td>Getting German</td>
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</table>
Stack Effect Flow Out (Exfiltration)

\( P_{\text{inside}} \) drops with height slower than \( P_{\text{outside}} \)

\( P_{\text{outside}} \) drops with height faster than \( P_{\text{inside}} \)

Neutral Pressure Plane

Stack Effect Flow In (Infiltration)
Reduced Individual Unit Stack Effect