The Cult of The Blower Door

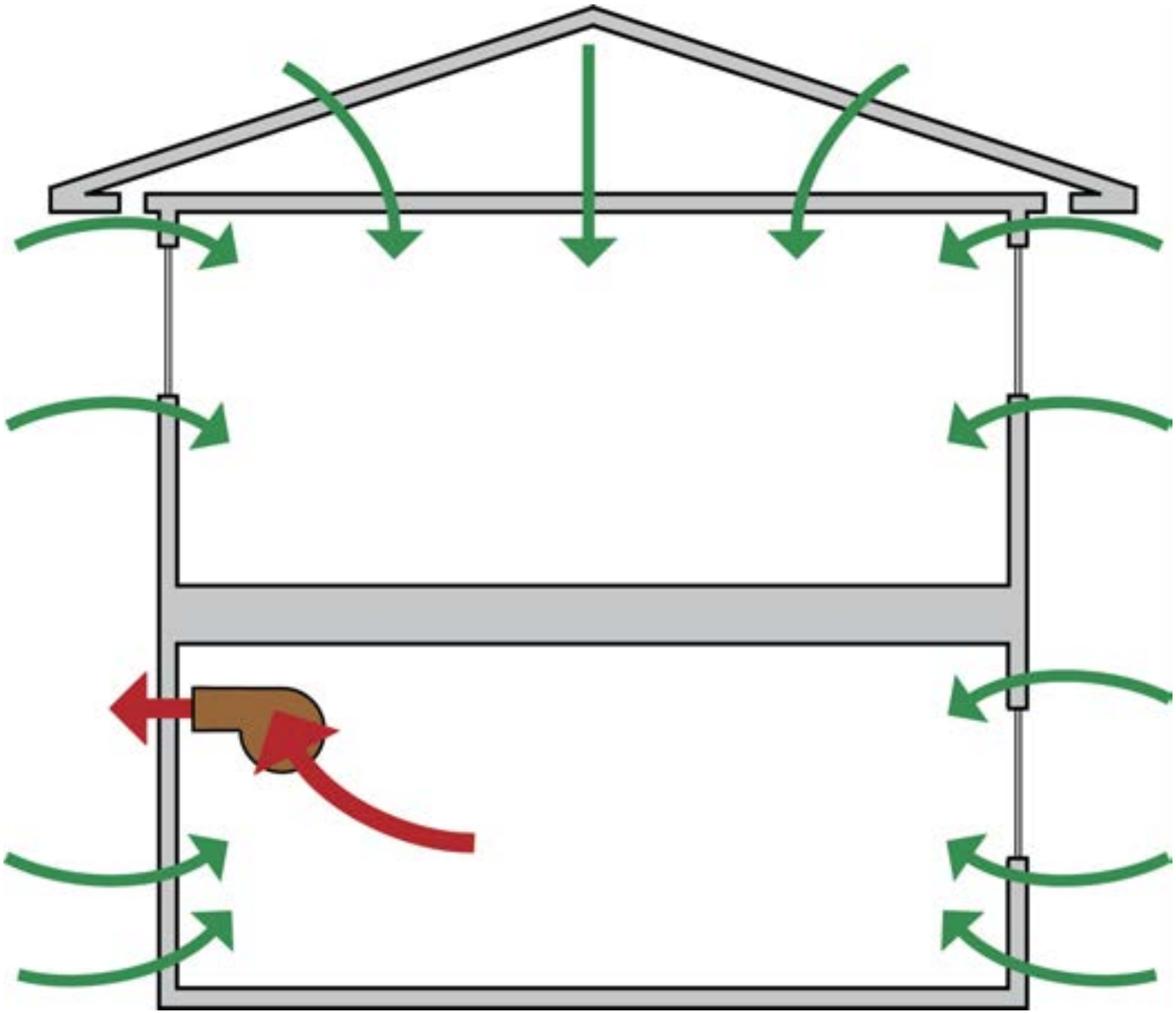
Blower Door Can't Get You The True ACH

On A Short Term Basis – Hour, Day, Week

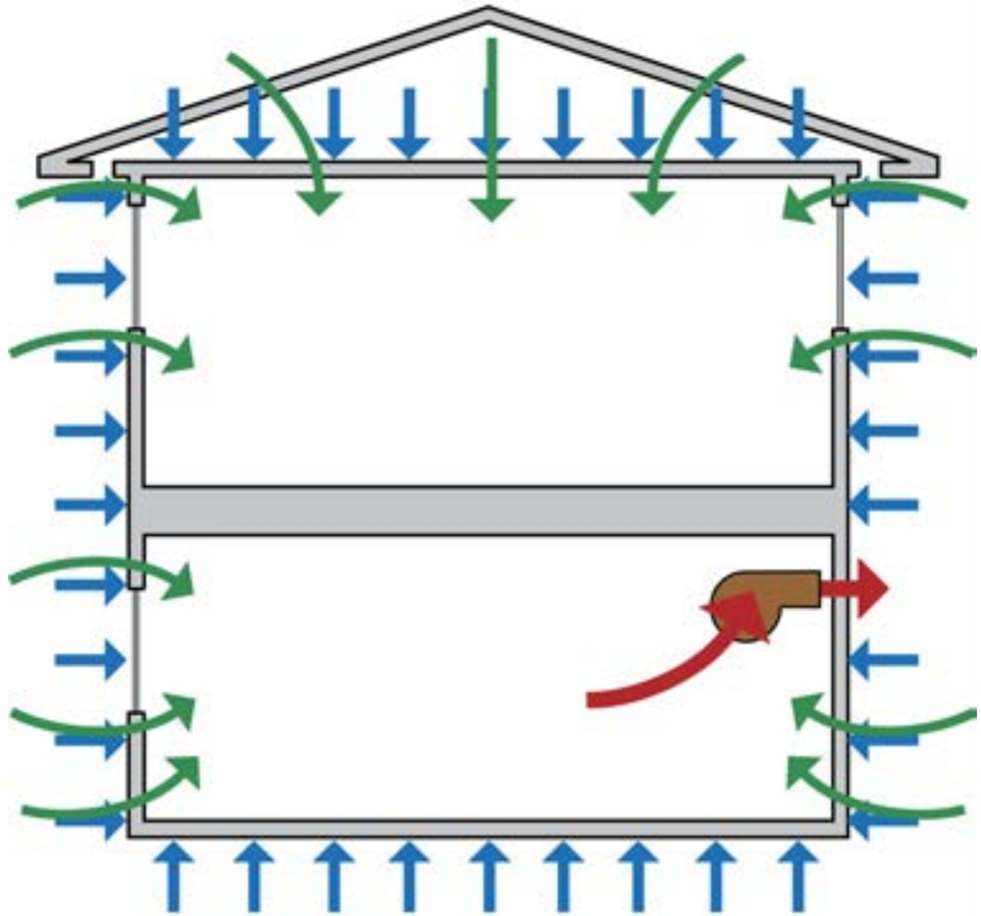
Don’t Know Where The Holes Are

Don’t Know The Type of Holes

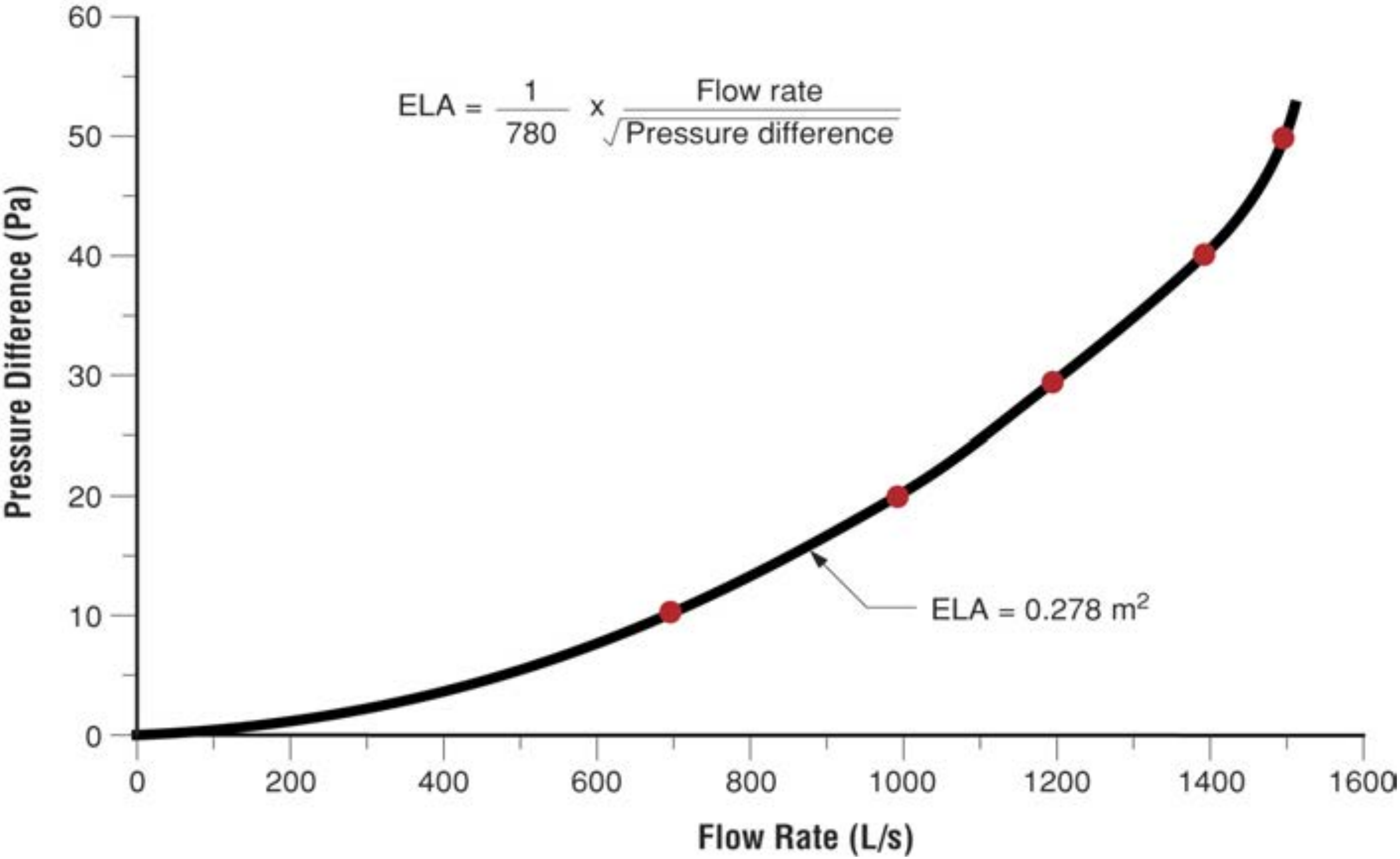
Don’t Know The Pressure Across The Holes



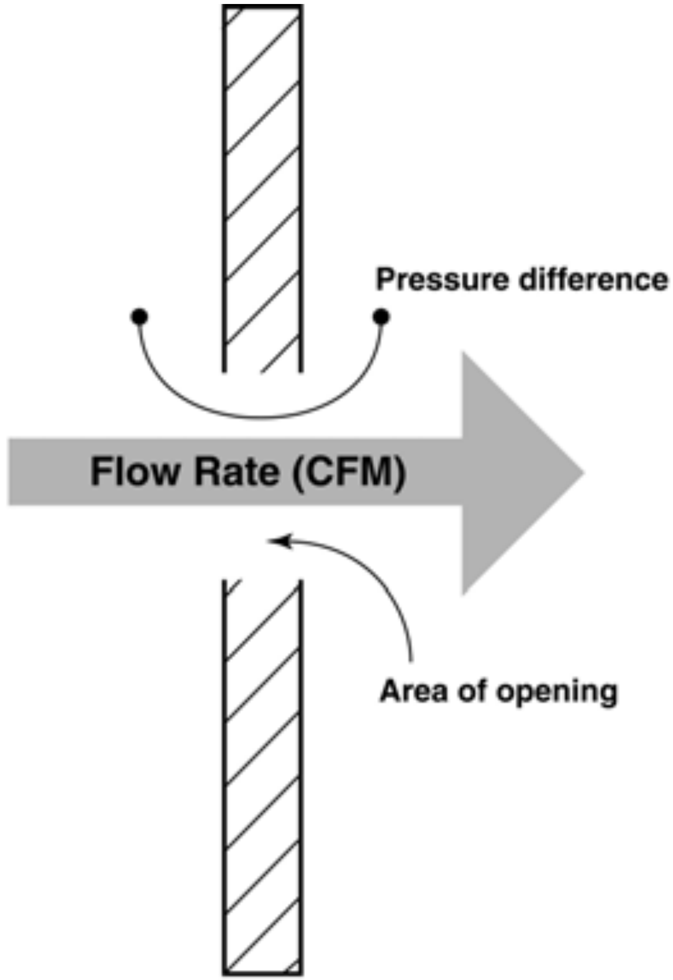
$$\text{ELA} \approx C \times \frac{\text{Rate of flow}}{\sqrt{\text{Pressure difference}}}$$

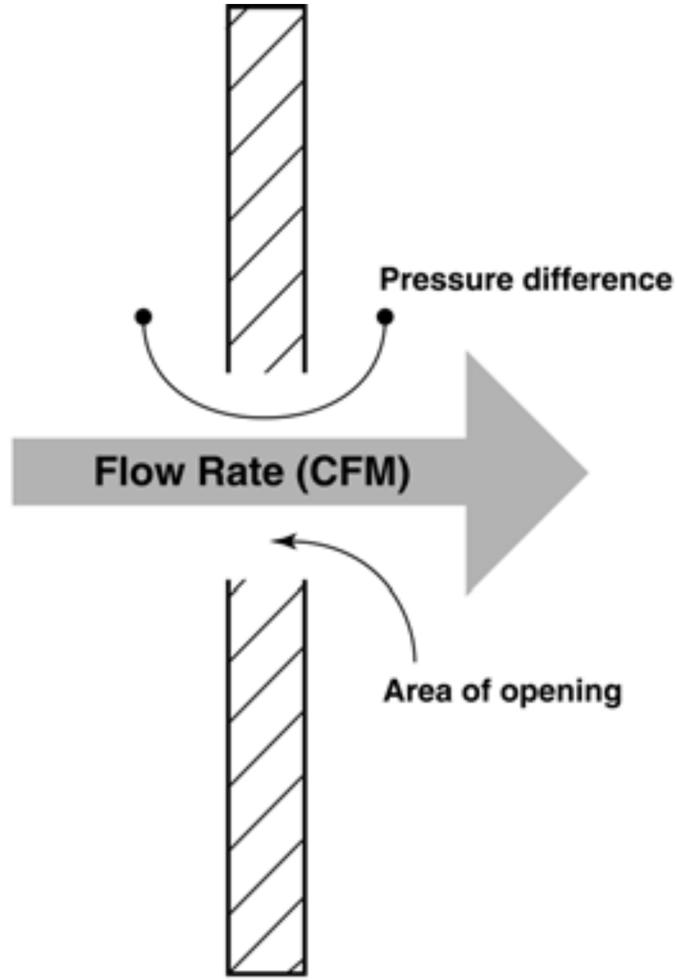


$$(\text{Meters})^2 \approx \frac{1}{780} \times \frac{\text{Litres per second}}{\sqrt{\text{Pascals}}}$$



$$\text{ELA} = \frac{1}{780} \times \frac{\text{Flow rate}}{\sqrt{\text{Pressure difference}}}$$
ELA = 0.278 m²
Pressure Difference (Pa)
Flow Rate (L/s)
0
10
20
30
40
50
60
0
200
400
600
800
1000
1200
1400
1600


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

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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"

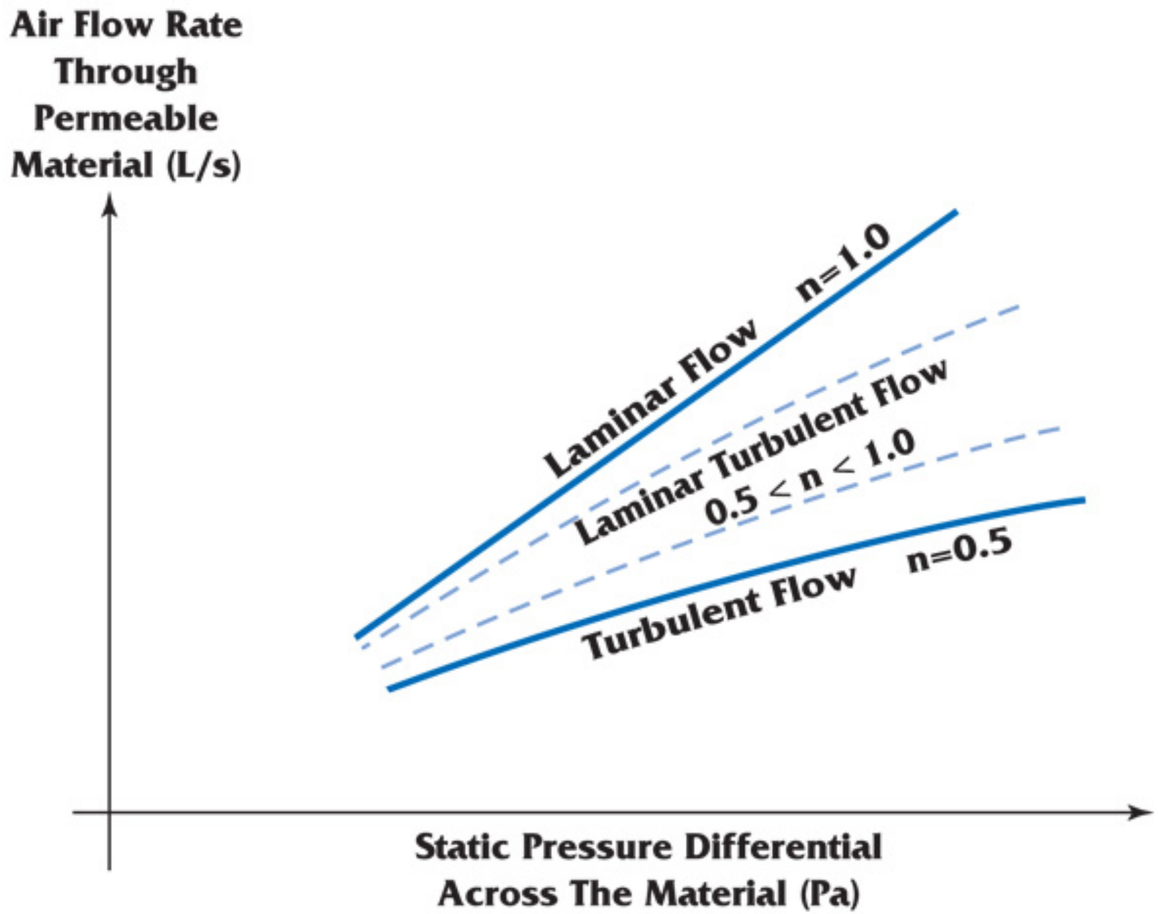
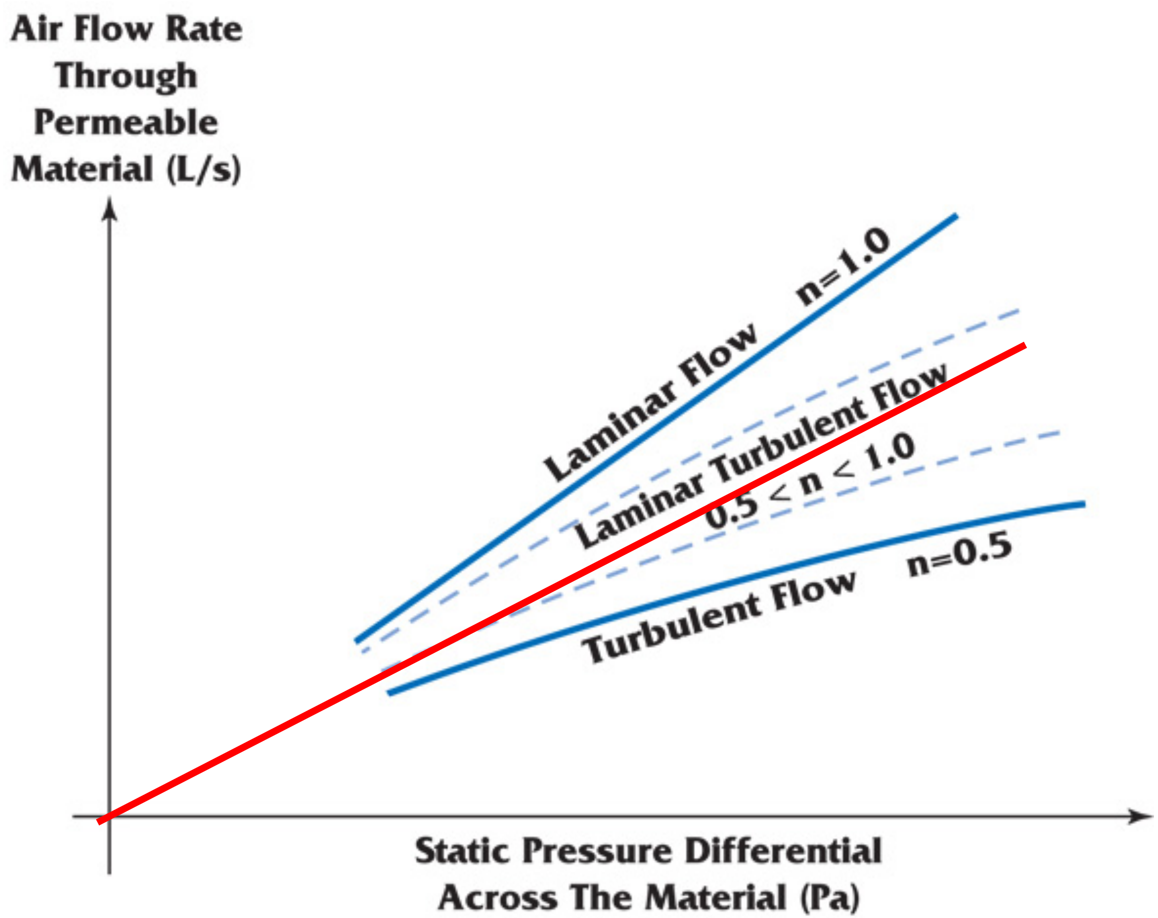


Figure 2.5
Modes of Air Flow
(from Bumbaru, Jutras and Patenaude, 1988)



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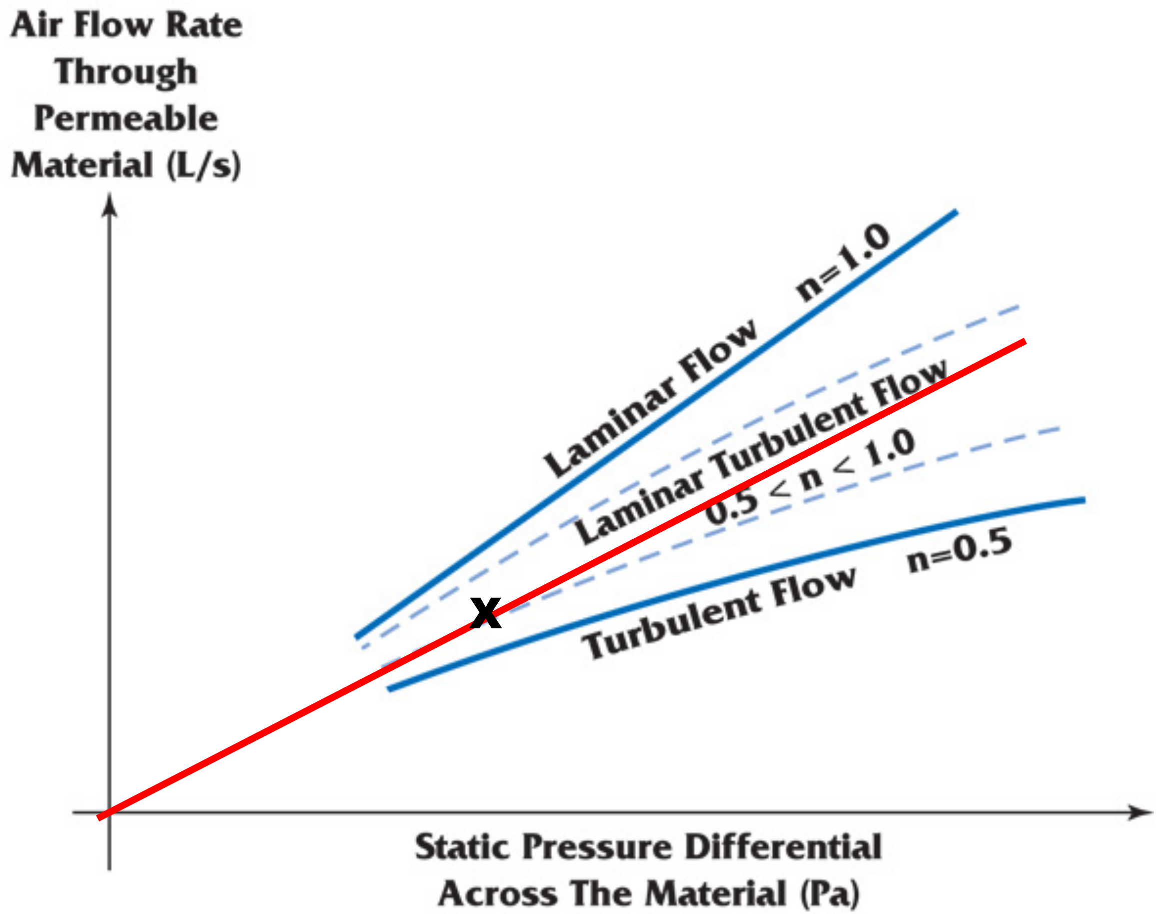

Figure 2.5
Modes of Air Flow
(from Bumbaru, Jutras and Patenaude, 1988)

Q = f (Dp) » k (Dp)^{b}

Q = air flow, volume/unit of time

D**p** = pressure difference

k = coefficient

b = exponent in approximate leakage function

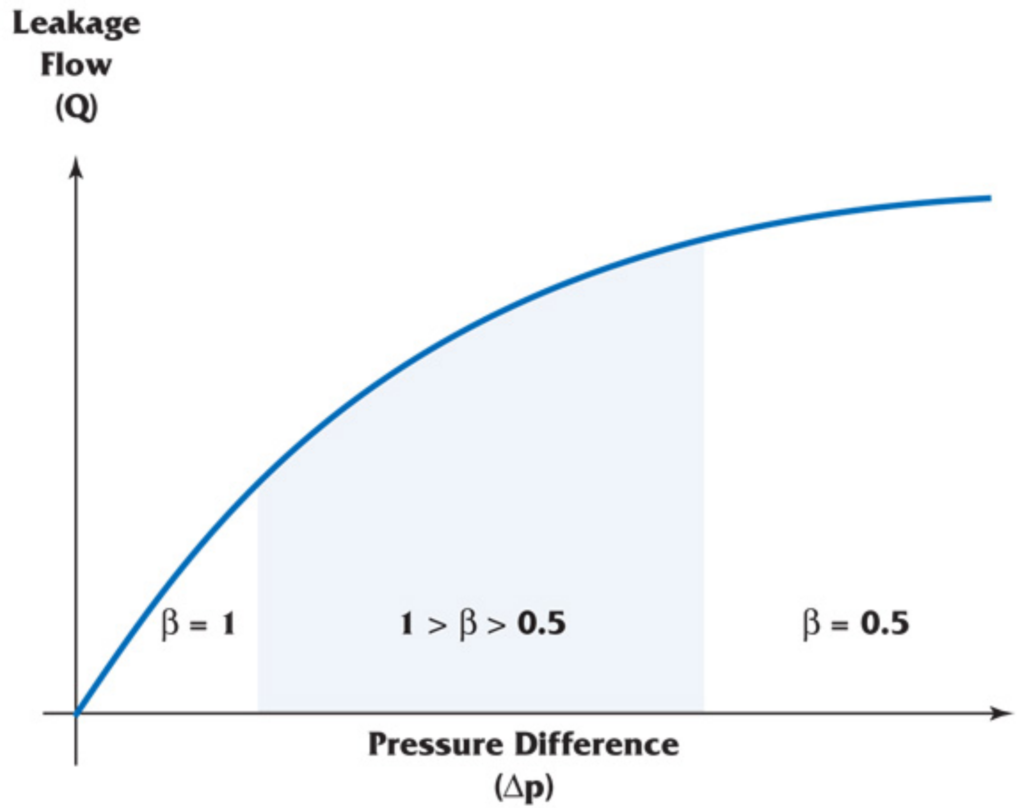

Figure 2.6

Characteristic Curve of Leakage Flow as a Function of Pressure Difference

(from Nylund, 1980)

Q = f (Dp) » k (Dp)^{b}

Q = air flow, volume/unit of time

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k = coefficient

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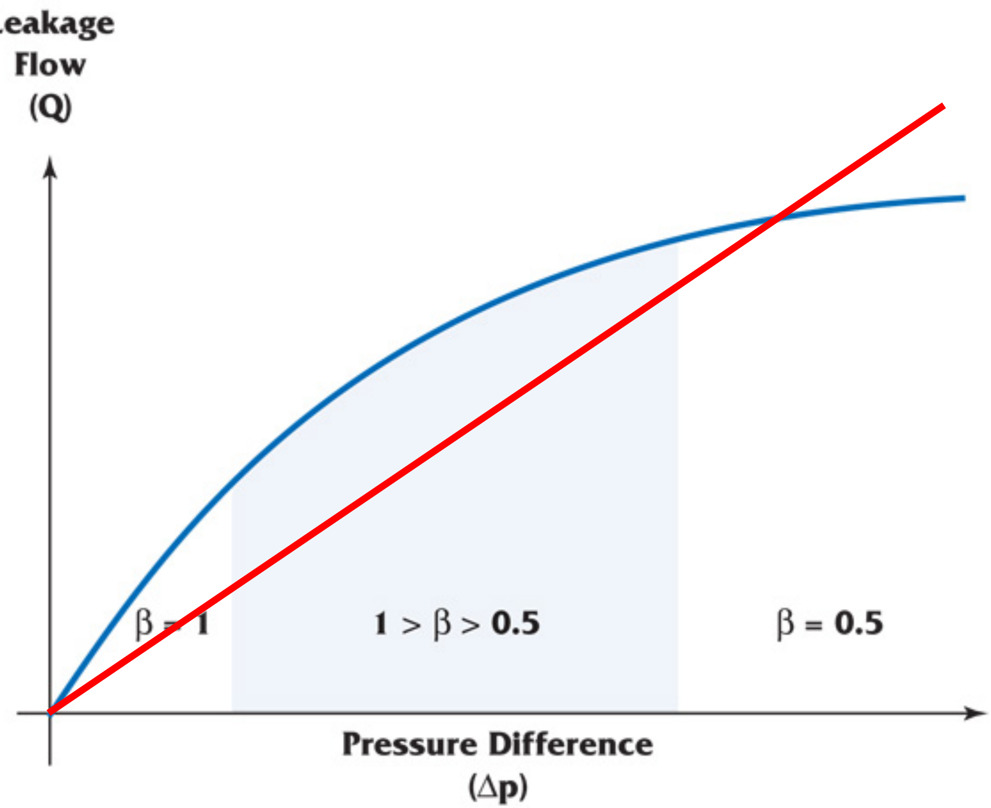

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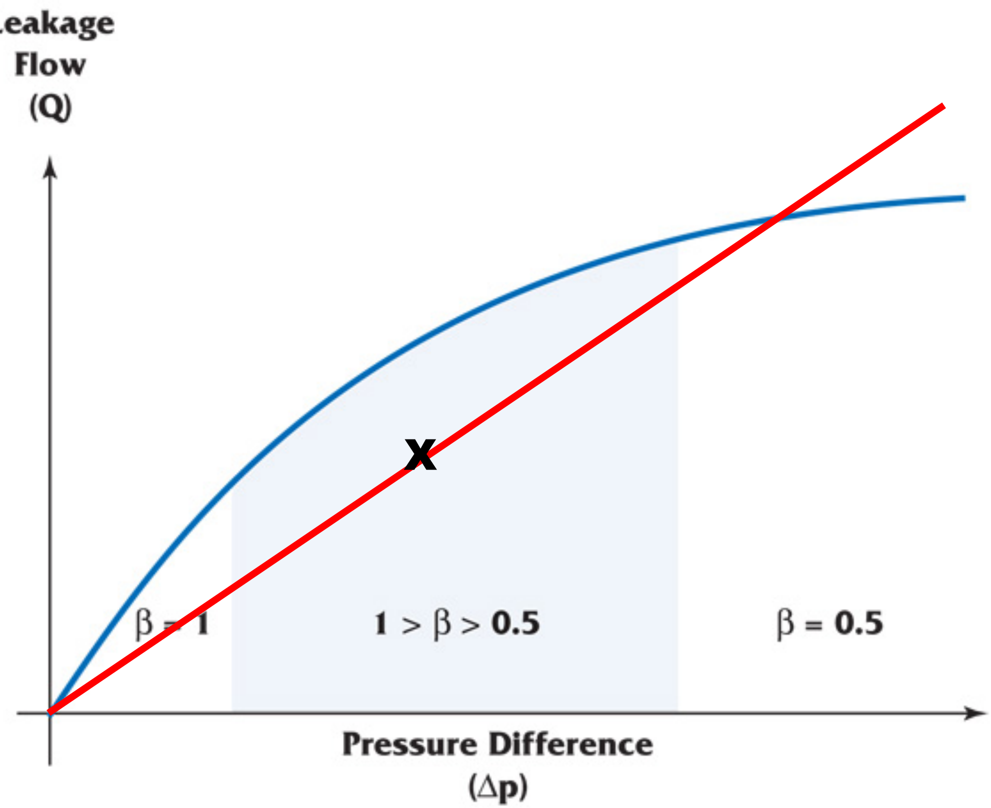

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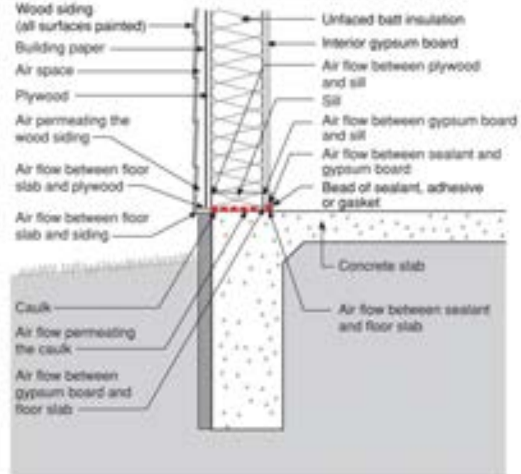
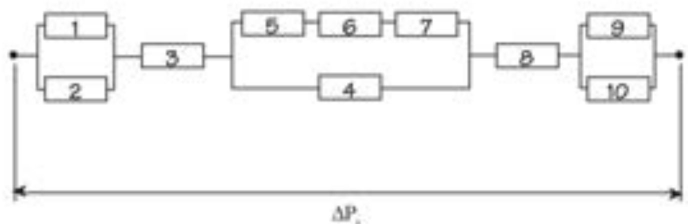
Characteristic Curve of Leakage Flow as a Function of Pressure Difference
(from Nylund, 1980)



Possible air flows around sill of a wood-framed house modelled as a resistance network

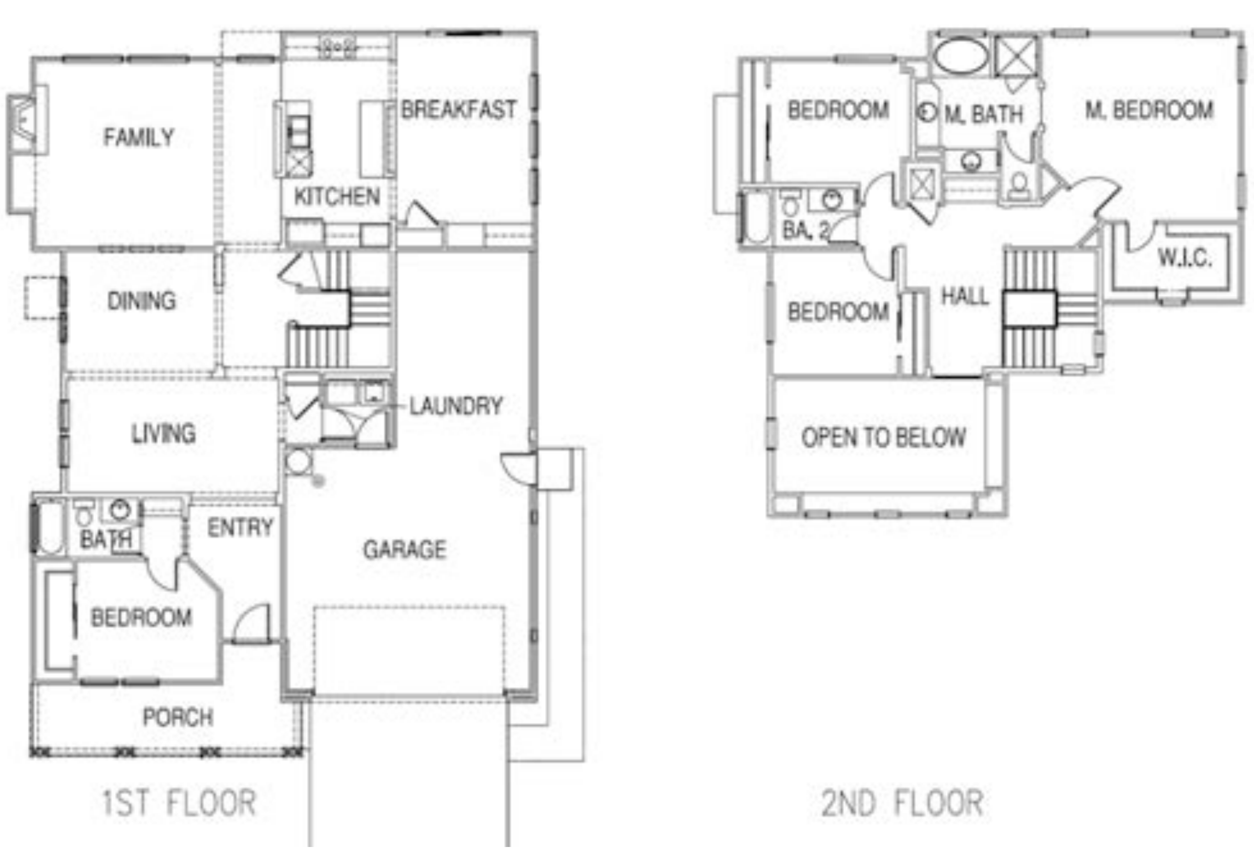


1. Air permeating the wood-panel cladding
2. Air flow between floor slab and panel
3. Air flow between floor slab and wind protection
4. Air permeating the caulking
5. Air flow between wind protection and sill
6. Air flow bewteen insulation material and sill
7. Air flow between inner lining and sill
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

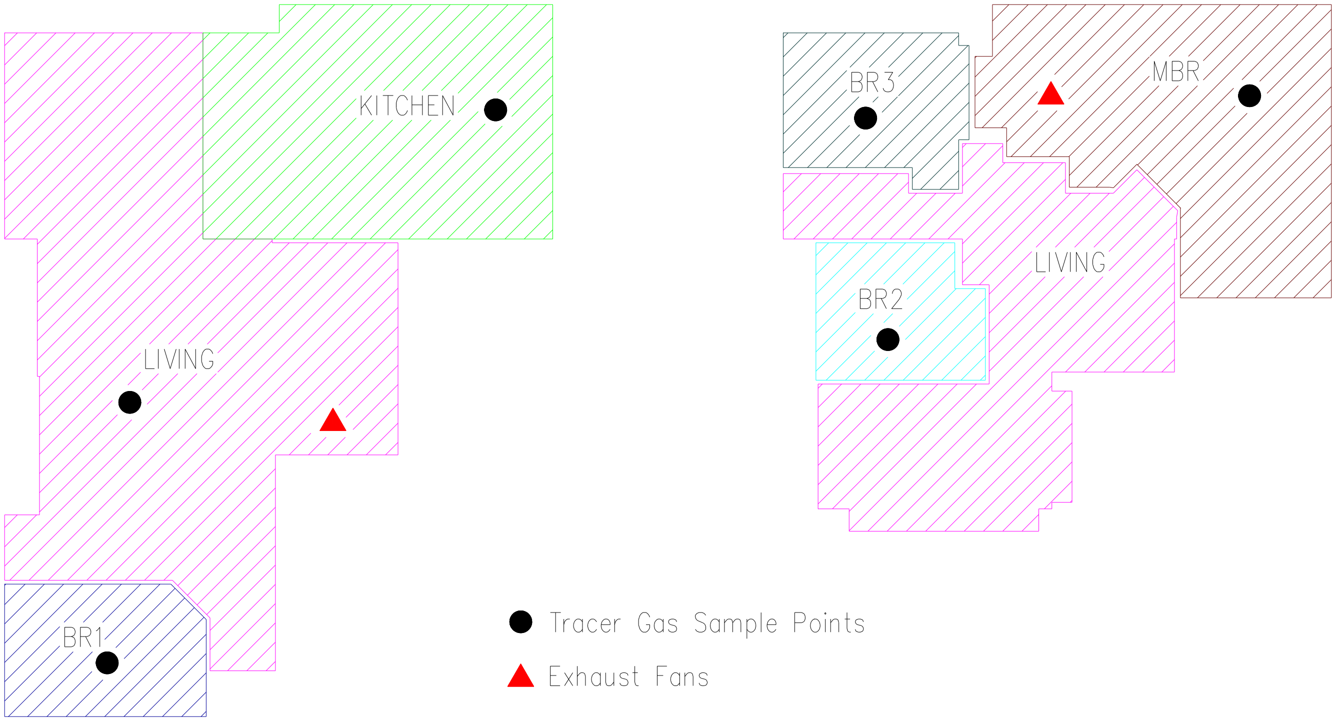
Figure 2.10
Resistance Network
(from Kronvall, 1980)

- 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

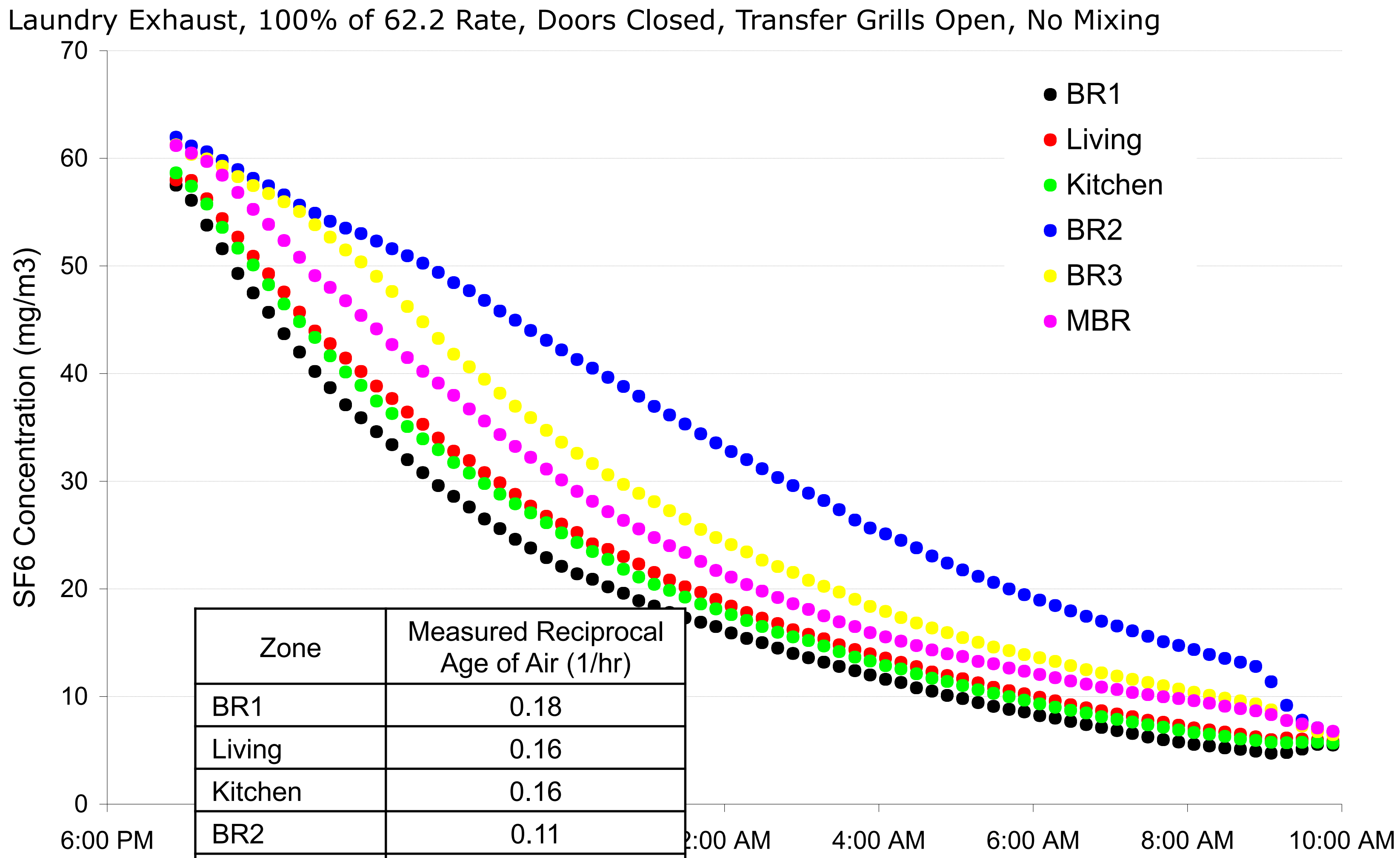


Zones – 2 Story House



- 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)

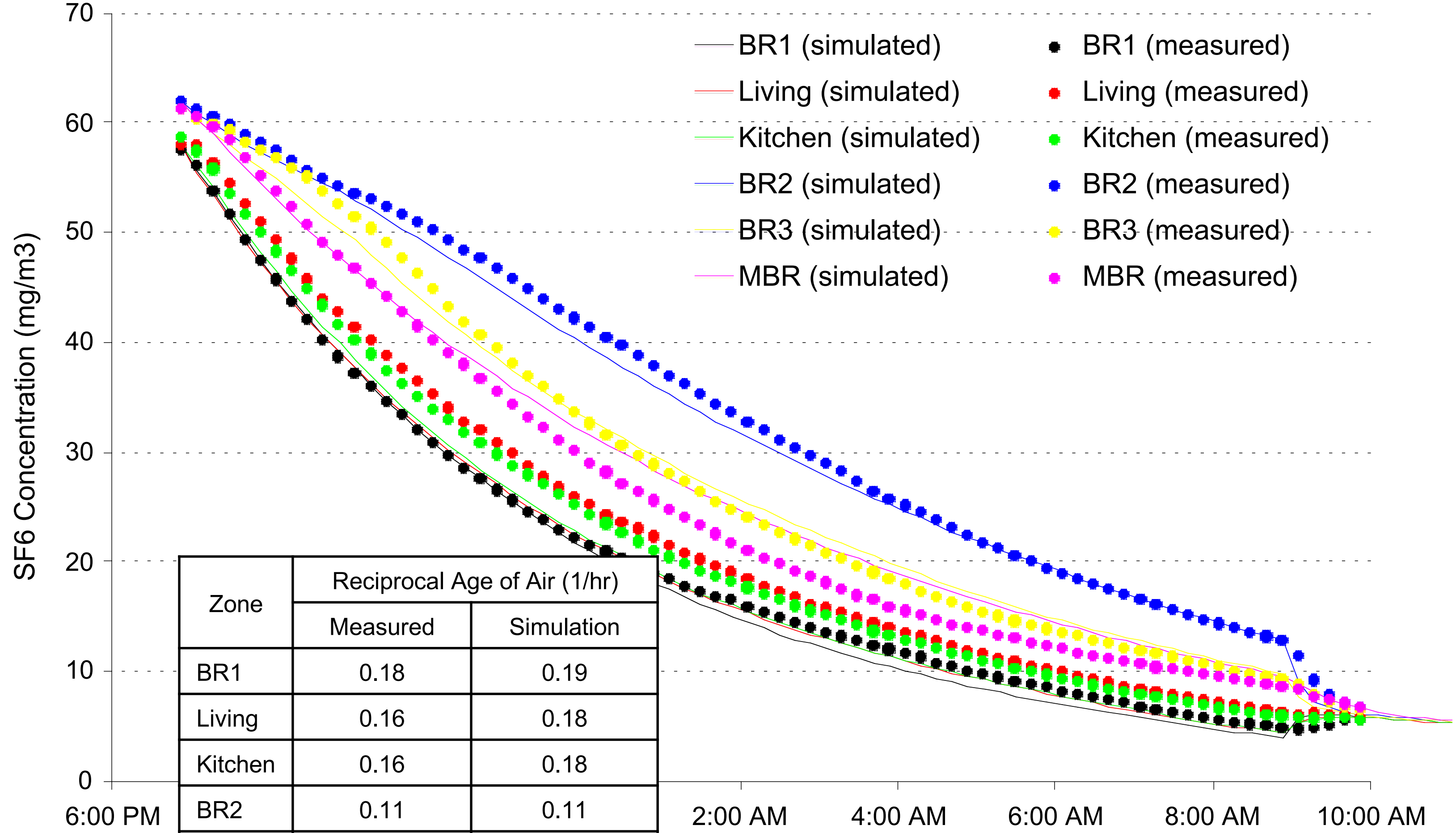
Example Results of Tracer Gas Testing



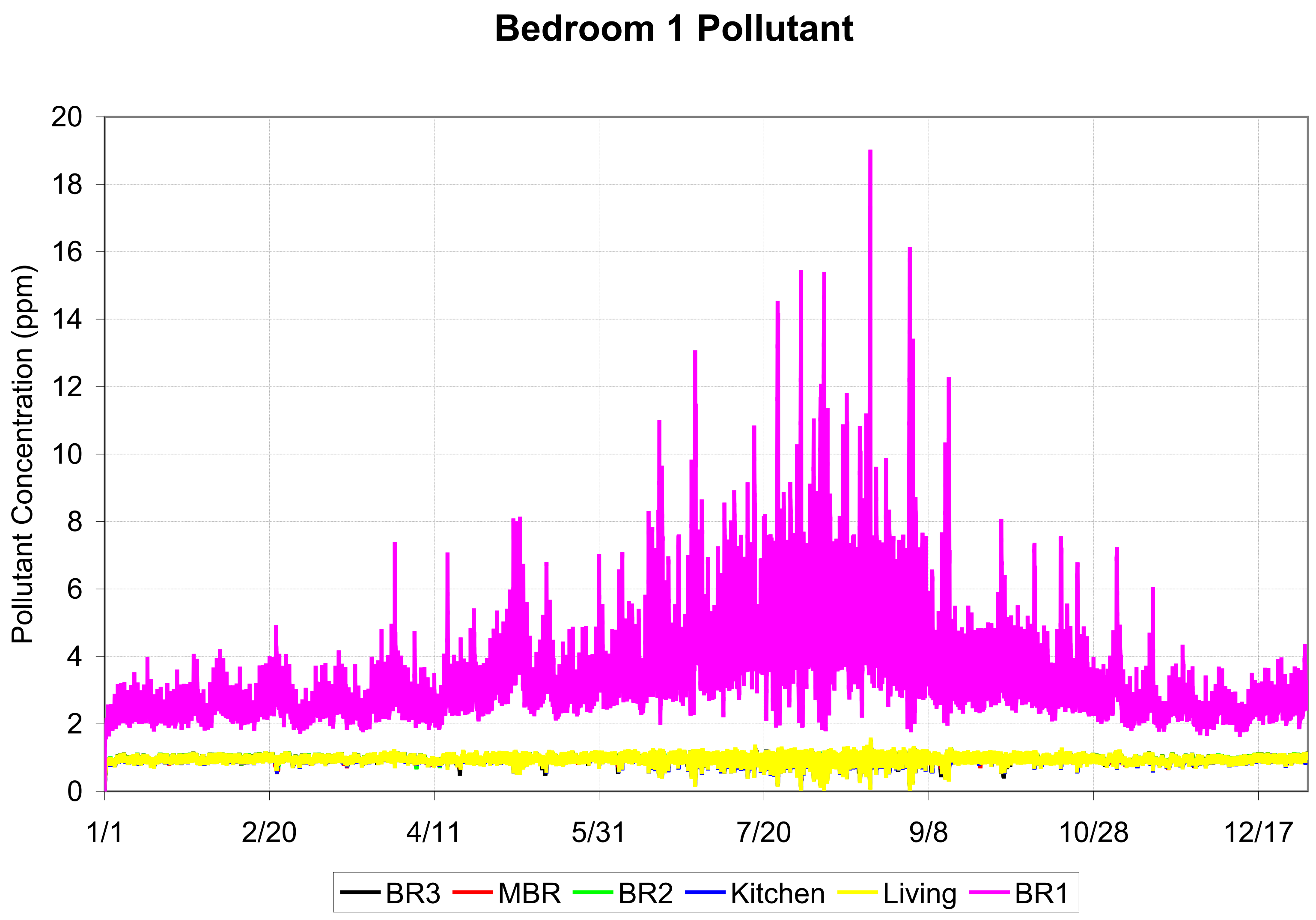
Zone	Measured Reciprocal Age of Air (1/hr)
BR1	0.18
Living	0.16
Kitchen	0.16
BR2	0.11
BR3	0.13
MBR	0.14

Example Results of Tuned CONTAM Model

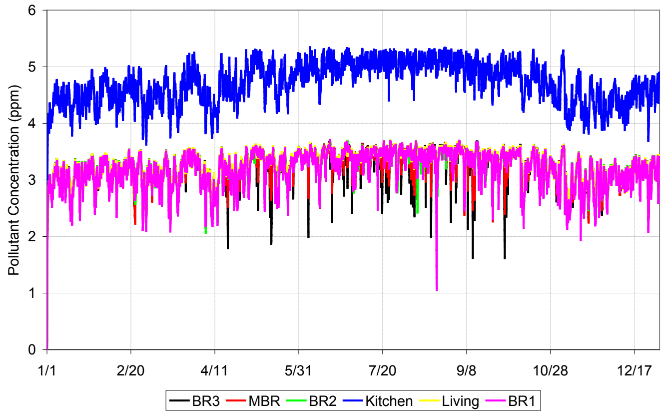
Laundry Exhaust, 100% of 62.2 Rate, Doors Closed, Transfer Grills Open, No Mixing



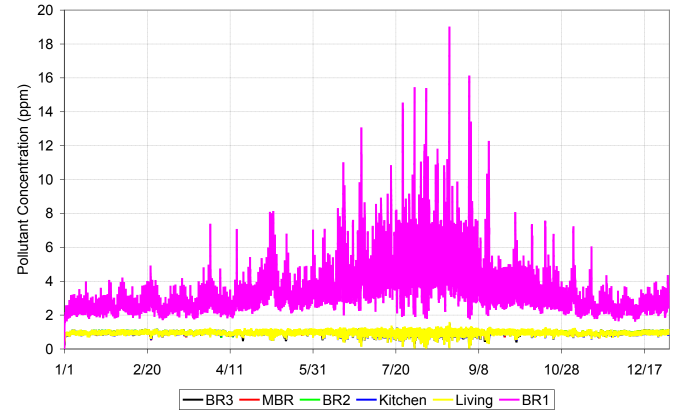
Zone	Reciprocal Age of Air (1/hr)	
	Measured	Simulation
BR1	0.18	0.19
Living	0.16	0.18
Kitchen	0.16	0.18
BR2	0.11	0.11
BR3	0.13	0.13
MBR	0.14	0.13


Bedroom 1 Pollutant
Pollutant Concentration (ppm)
20
18
16
14
12
10
8
6
4
2
0
1/1
2/20
4/11
5/31
7/20
9/8
10/28
12/17
BR3
MBR
BR2
Kitchen
Living
BR1

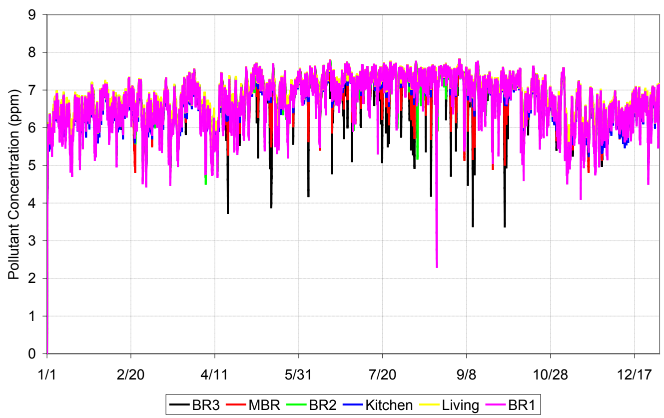
Kitchen Pollutant



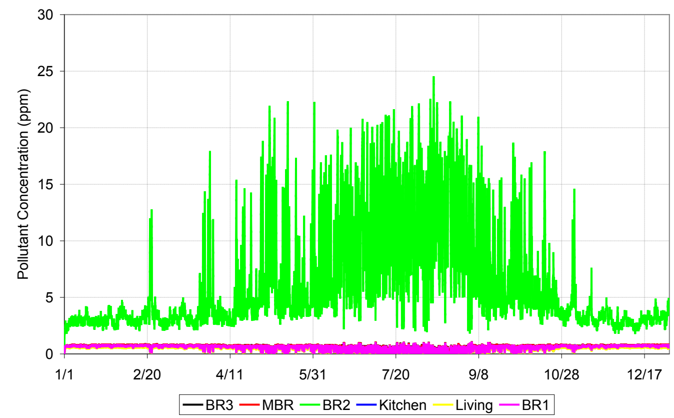
Bedroom 1 Pollutant



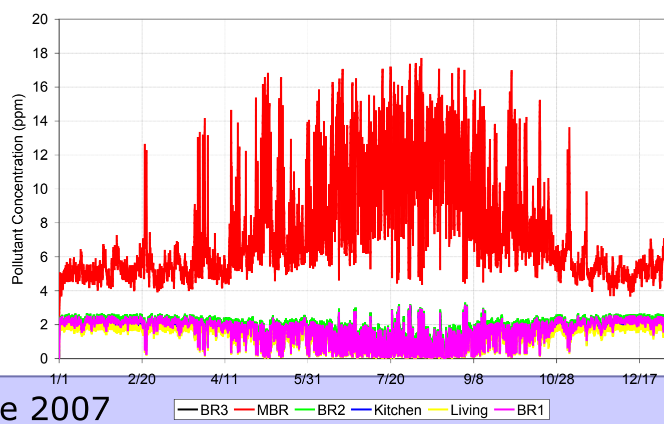
Living Room Pollutant



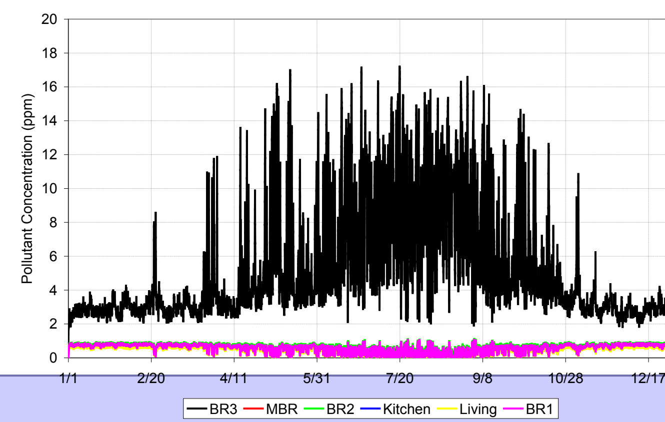
Bedroom 2 Pollutant

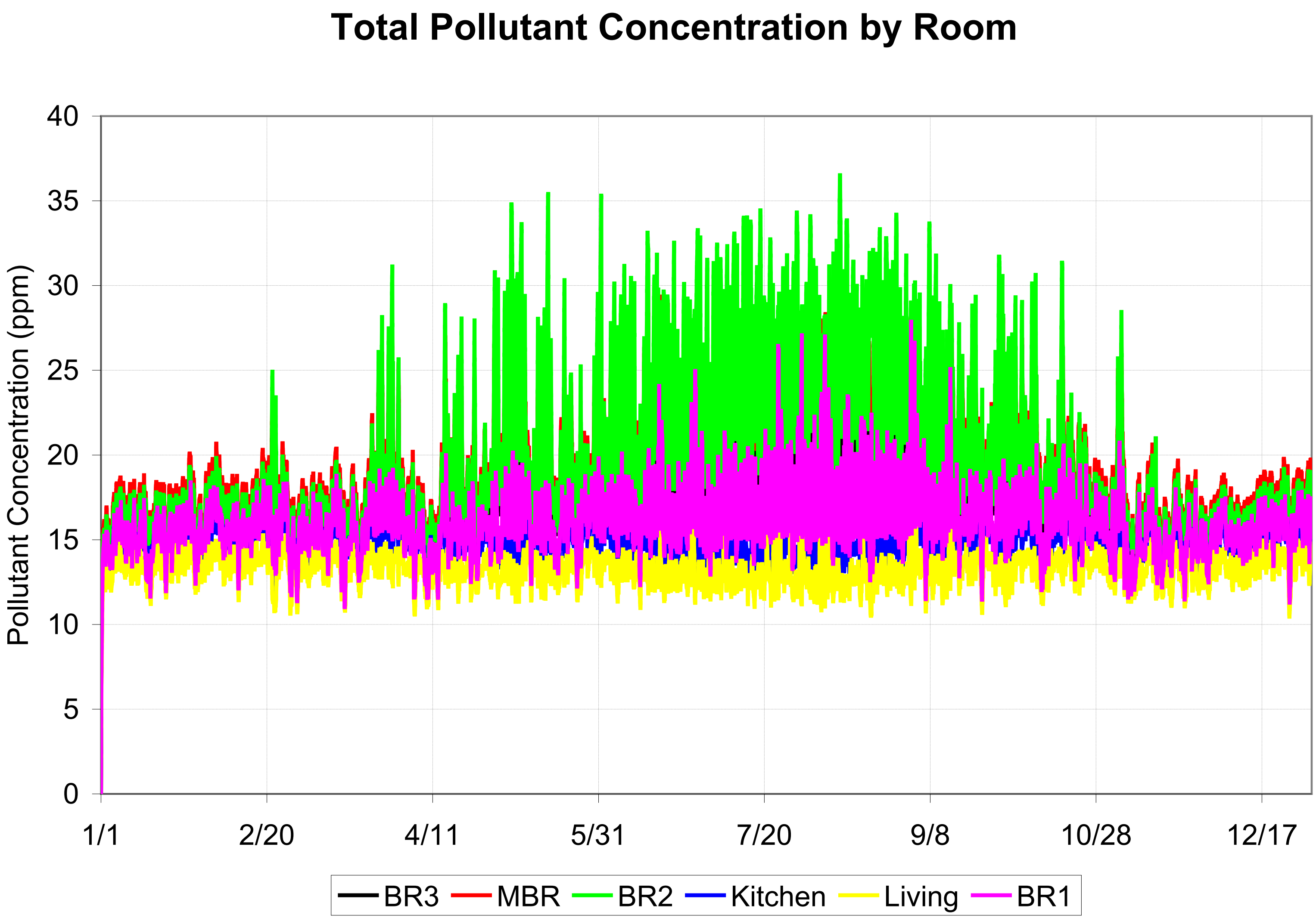


Master Bedroom Pollutant



Bedroom 3 Pollutant





Total Pollutant Concentration by Room
Pollutant Concentration (ppm)
40
35
30
25
20
15
10
5
0
1/1
2/20
4/11
5/31
7/20
9/8
10/28
12/17
BR3
MBR
BR2
Kitchen
Living
BR1

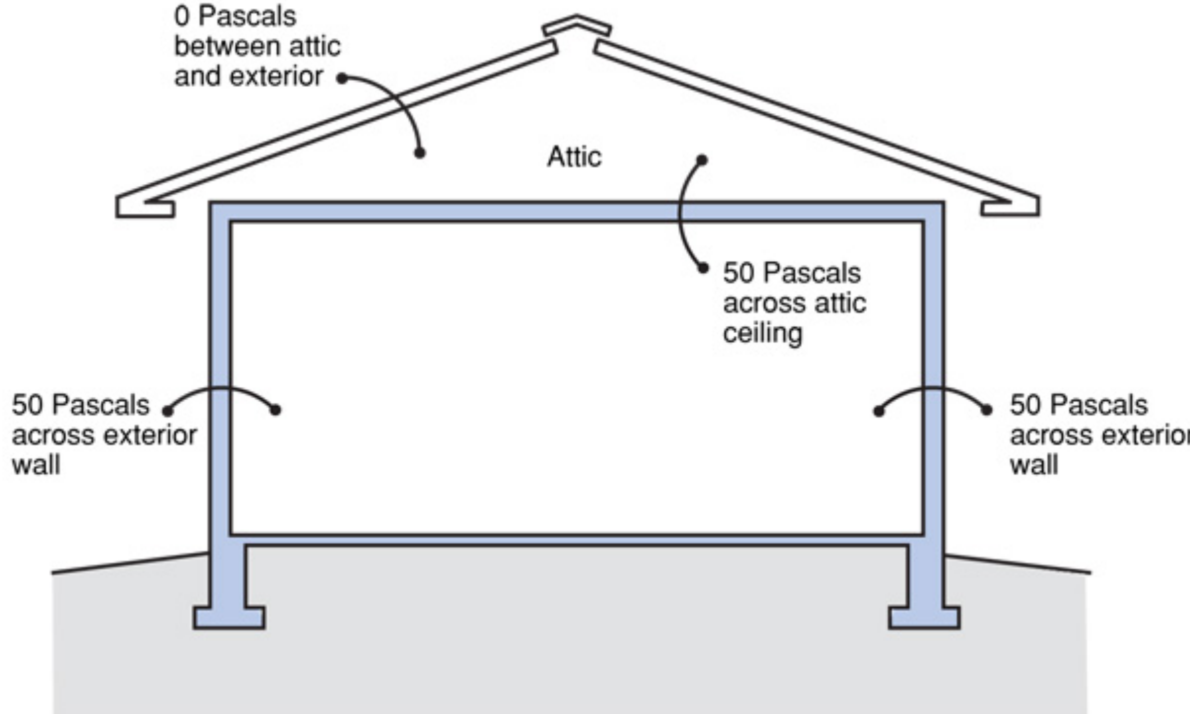


Figure 5.13

Well-Defined Pressure Boundary

- Pressure boundary defines effective building envelope environmental separator

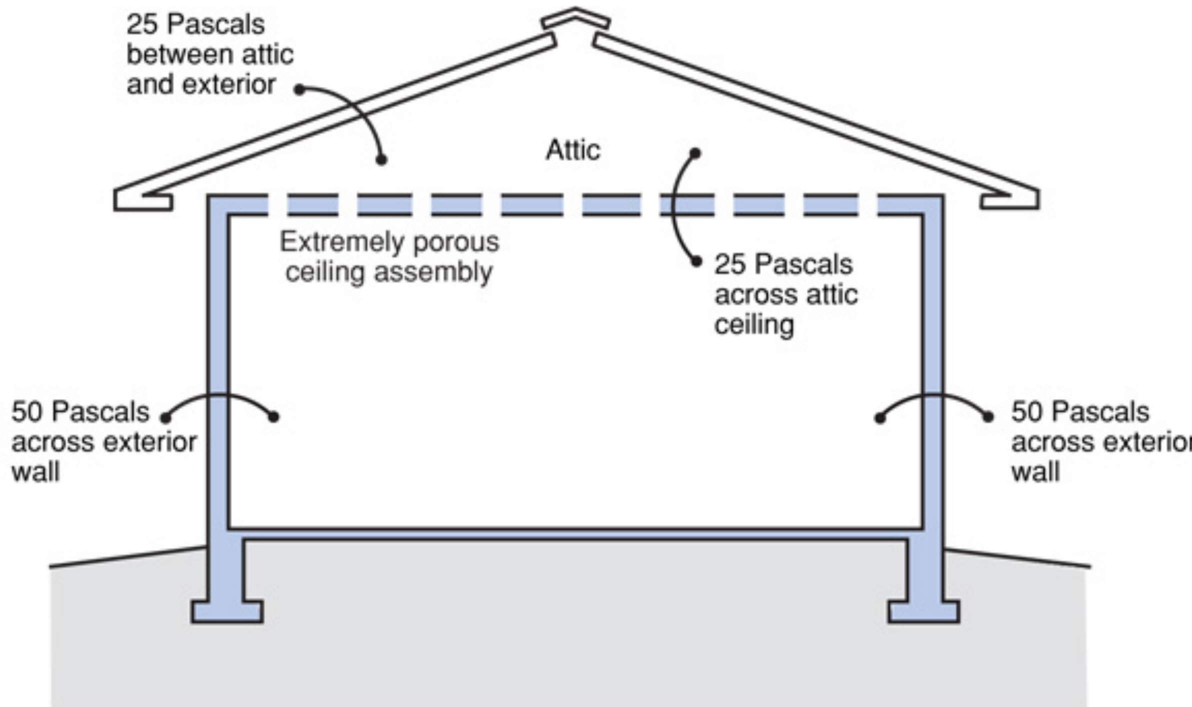


Figure 5.14

Poorly-Defined Pressure Boundary

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

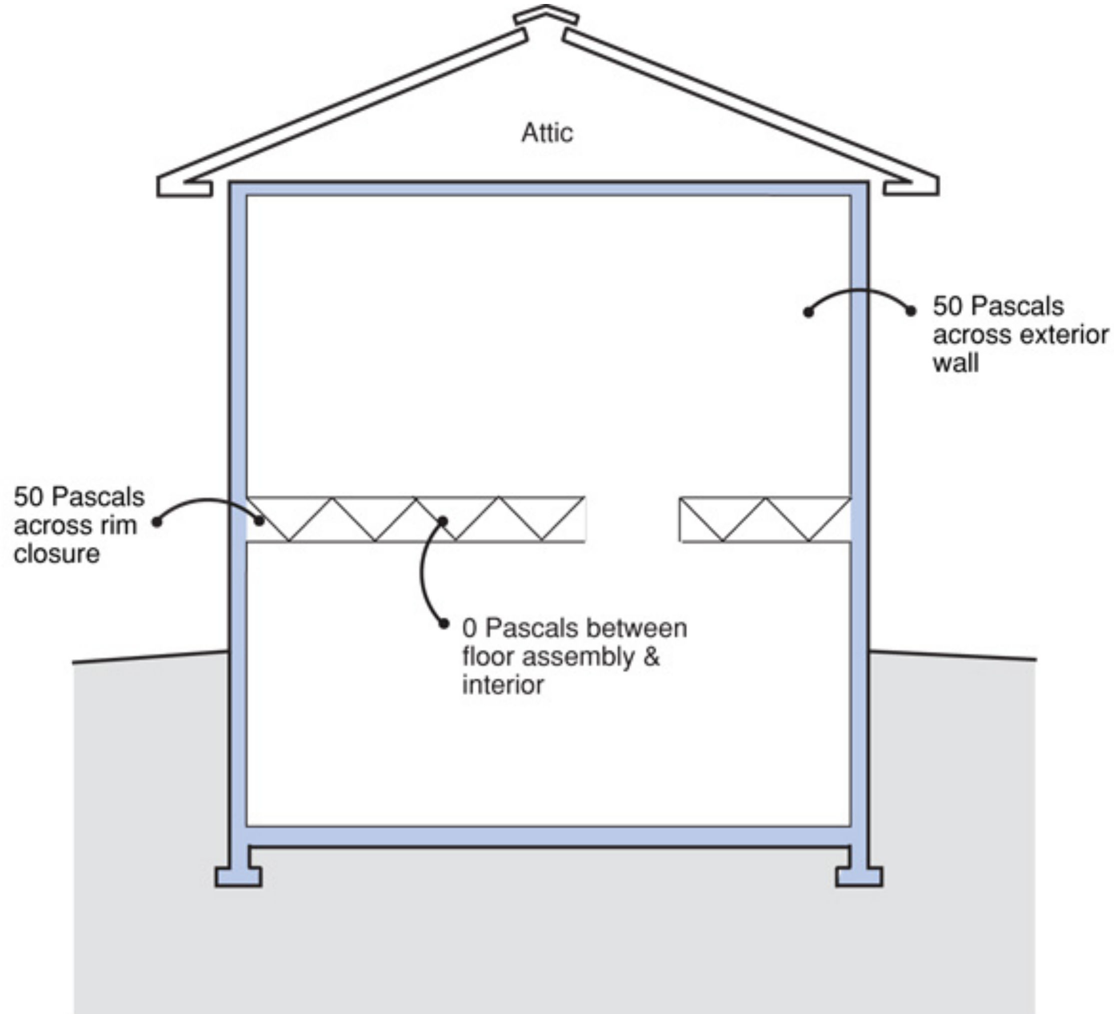


Figure 5.15

Tight Rim Closure

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

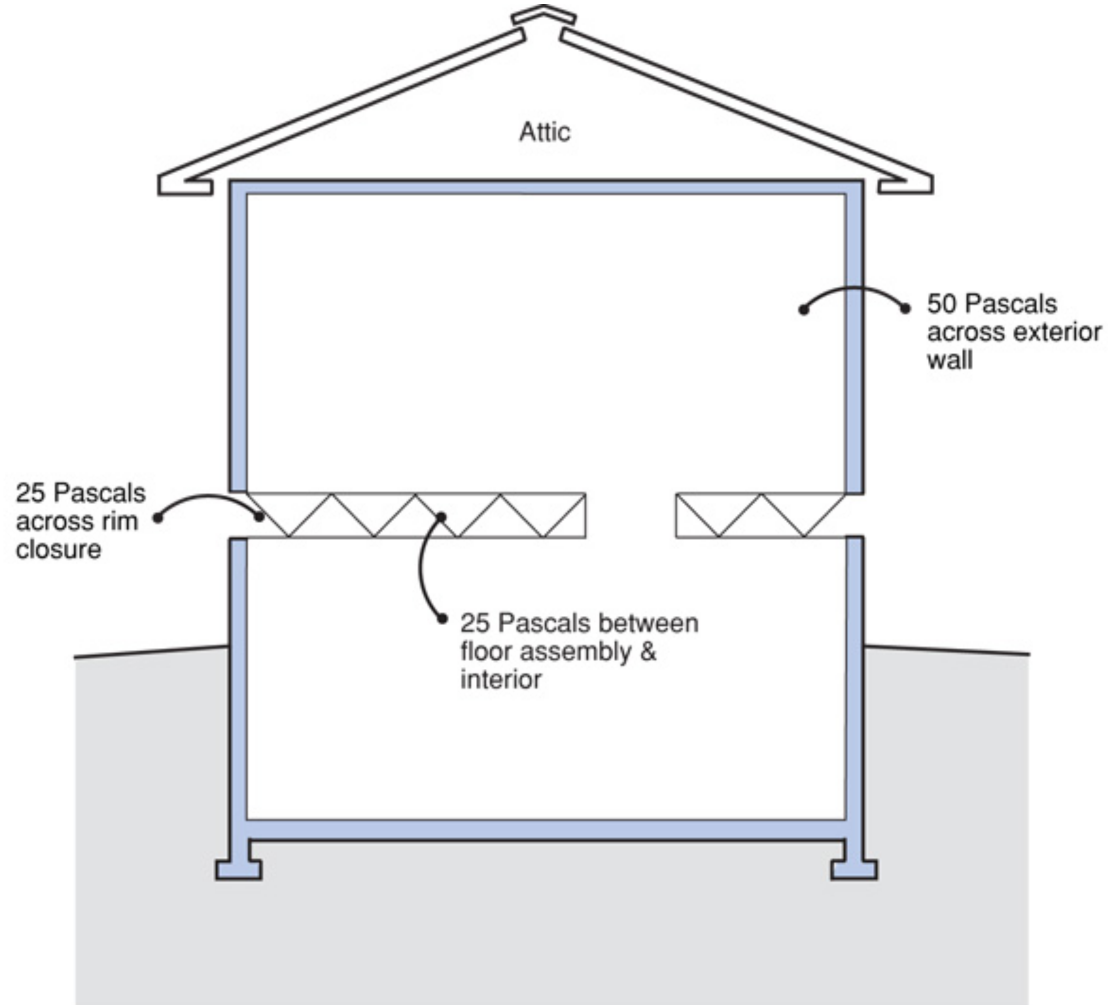


Figure 5.16

Leaky Rim Closure

- Floor assembly “outside” pressure boundary
- Pressure boundary not continuous at rim closure

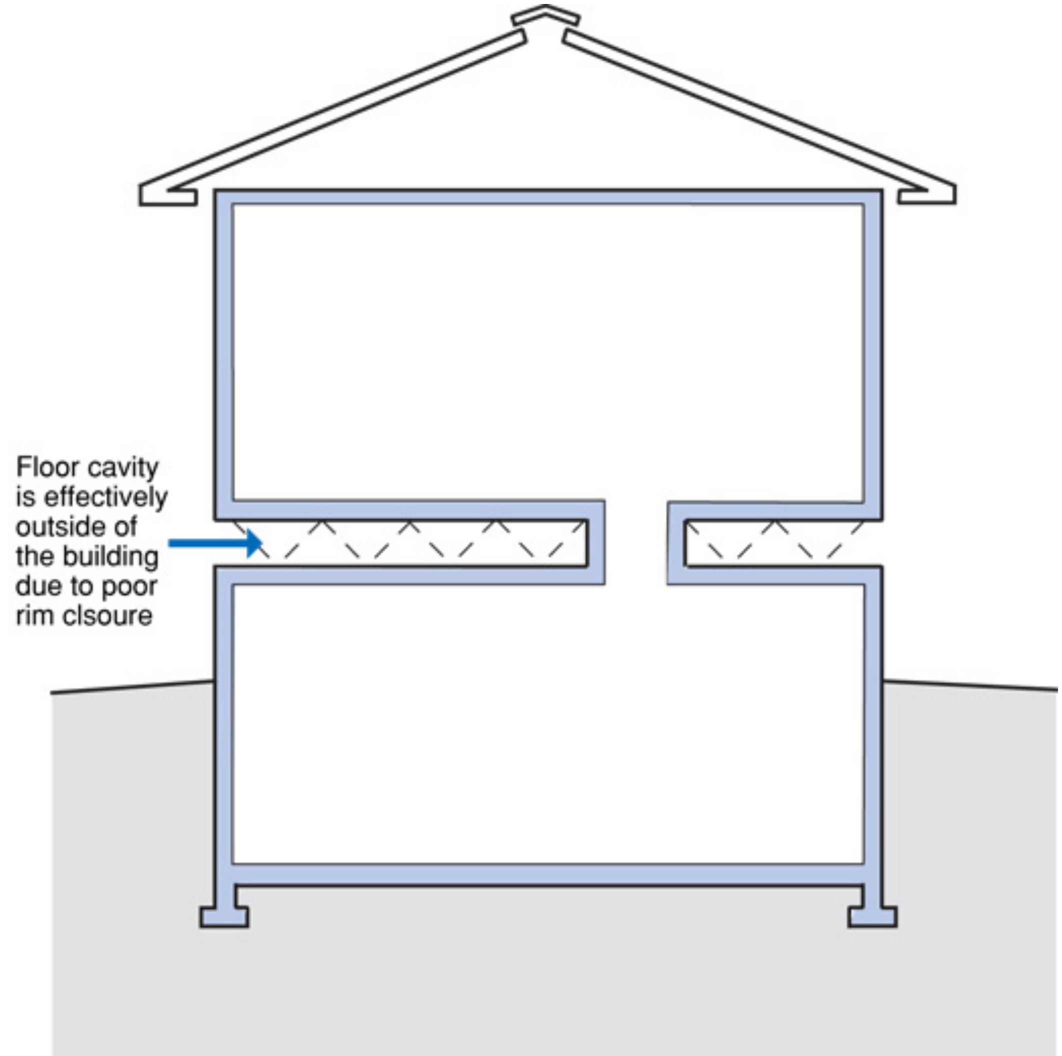


Figure 5.17

Pressure Boundary at Interior Floor

- Pressure boundary not contiguous with building envelope thermal boundary

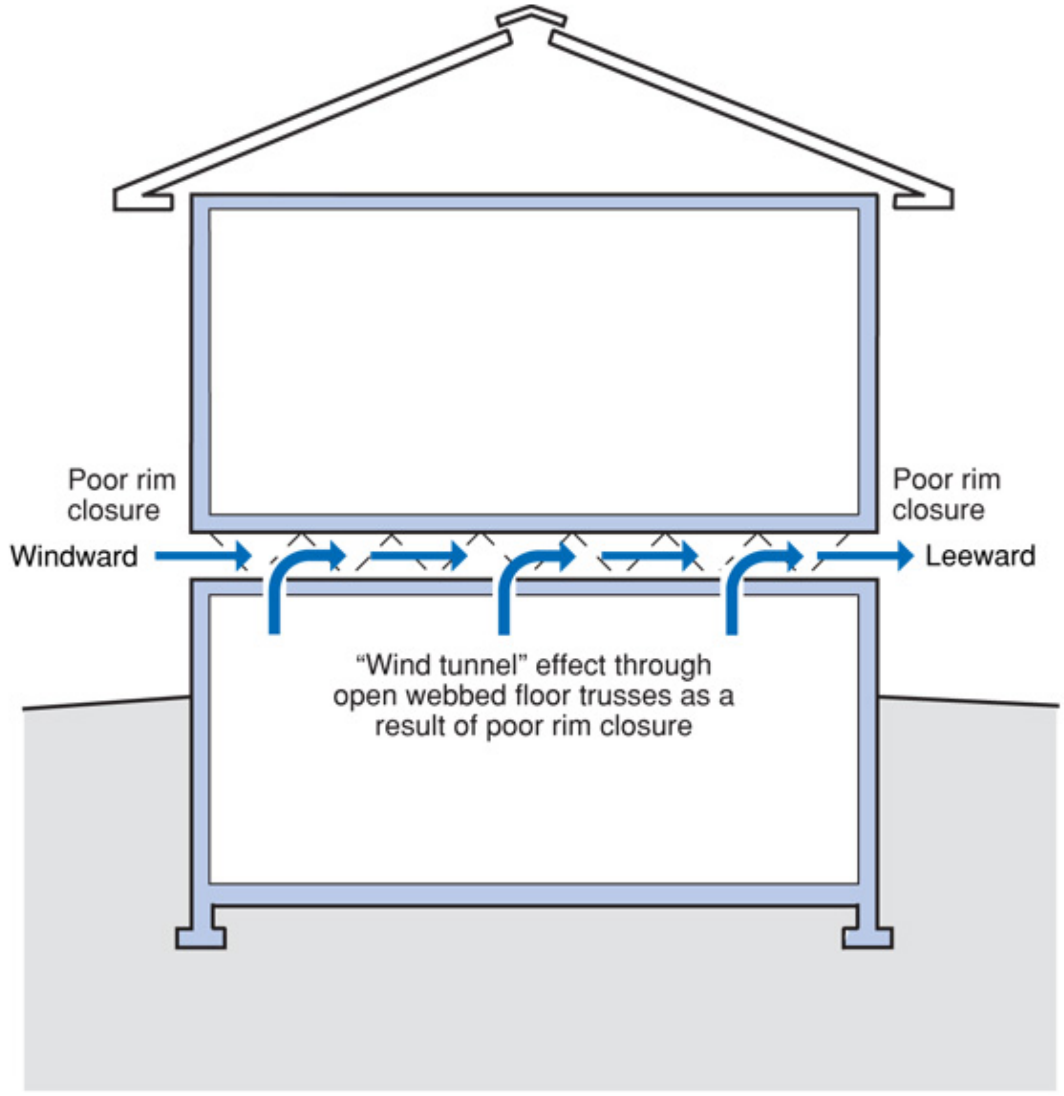


Figure 5.18
Wind Tunnel Effect

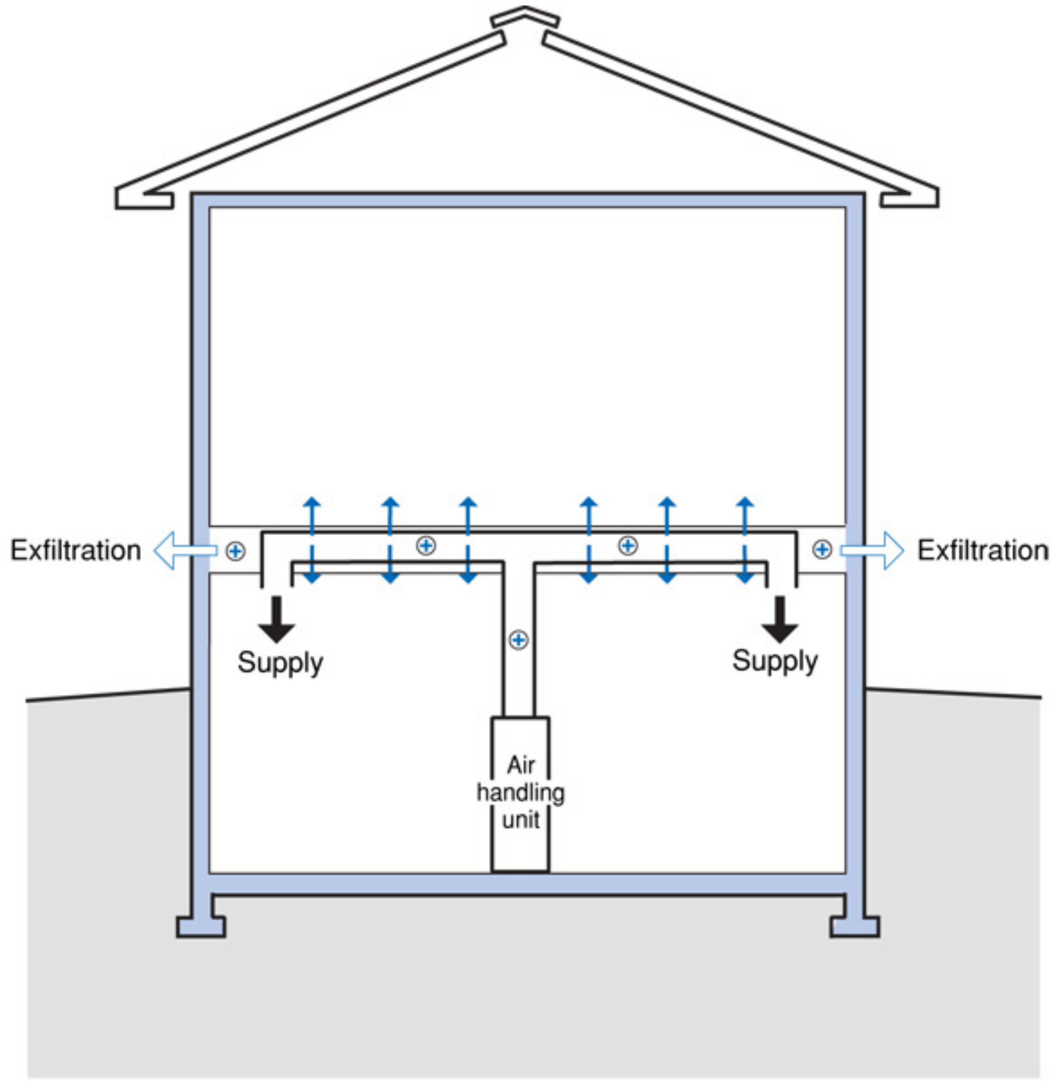


Figure 5.19

Supply Duct Leakage

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

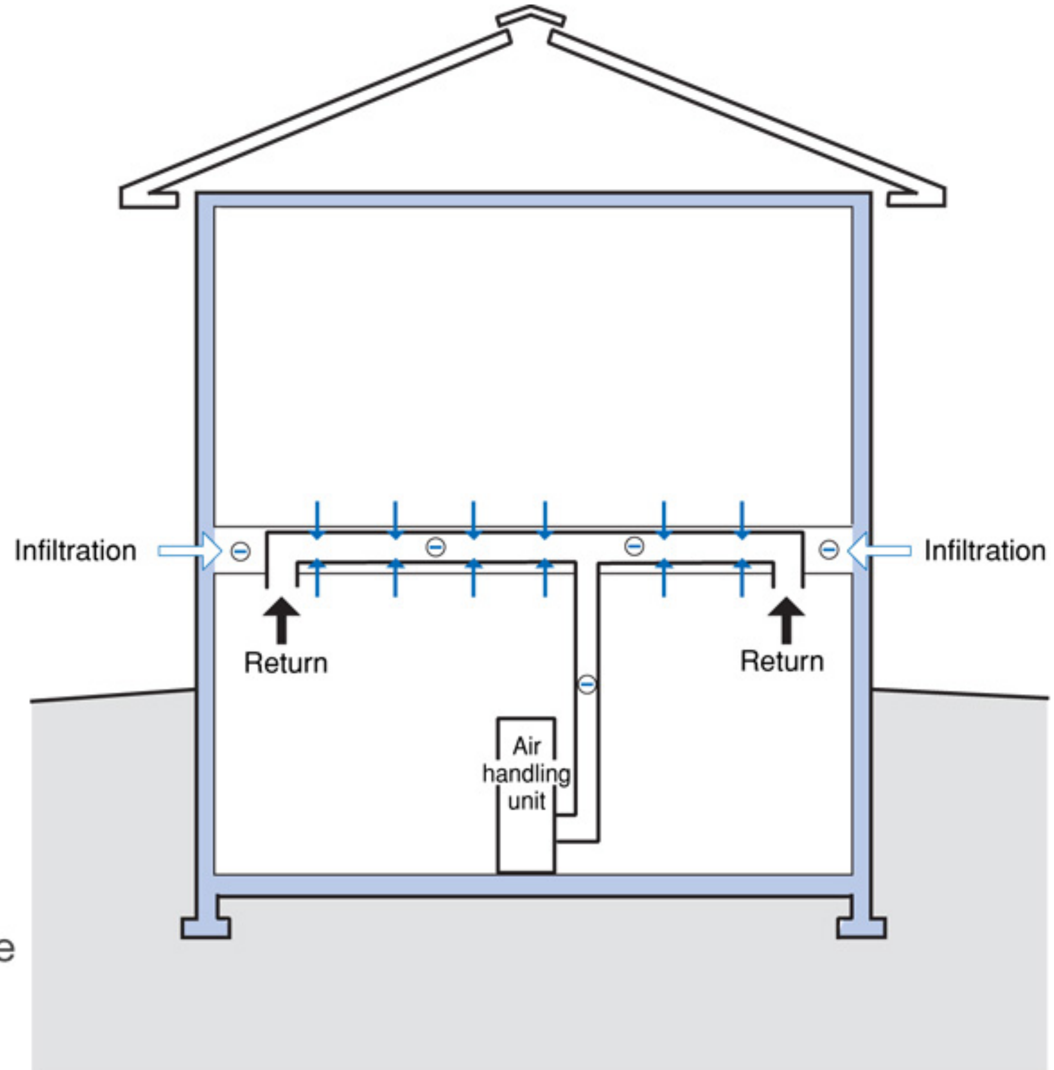


Figure 5.20

Return Duct Leakage

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

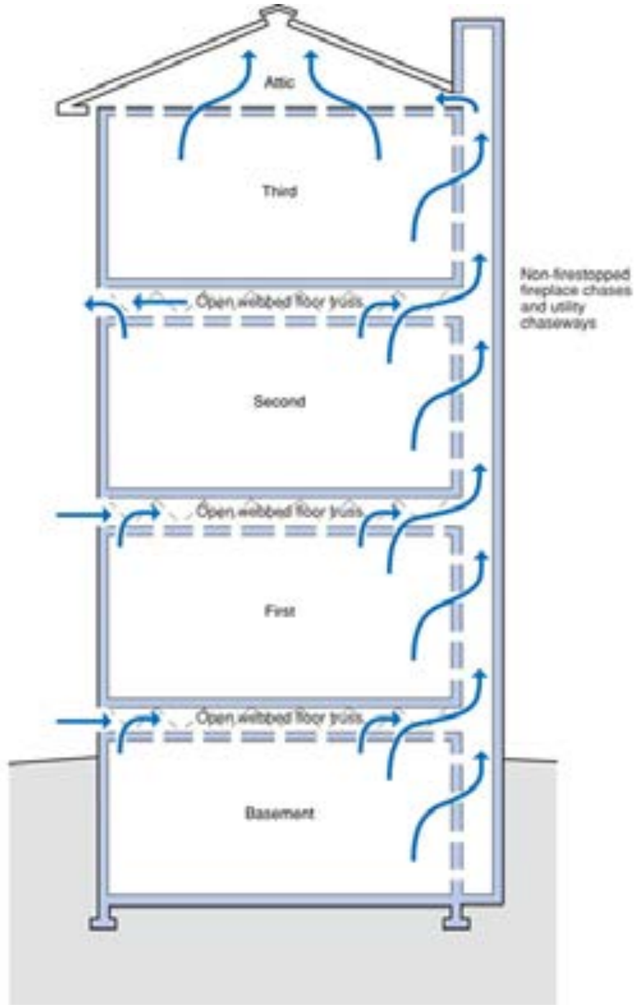


Figure 5.21

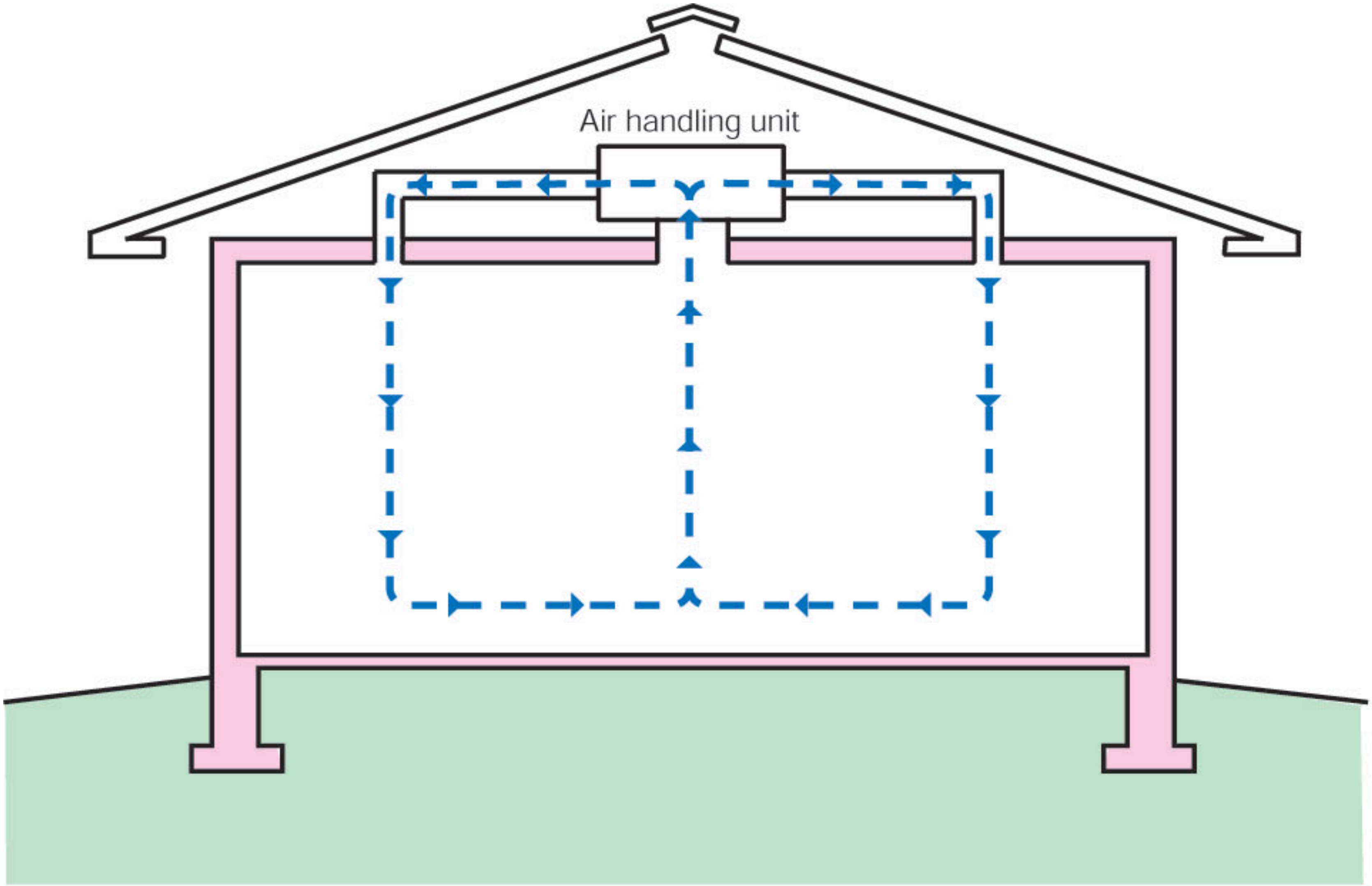
Combined Floor Paths and Pressure Drivers

- Vertical and horizontal communicationof open webbed floor trusses through fireplace and utility chaseways
- Pressure drivers are wind, the stack effect and the operation of the HVAC system

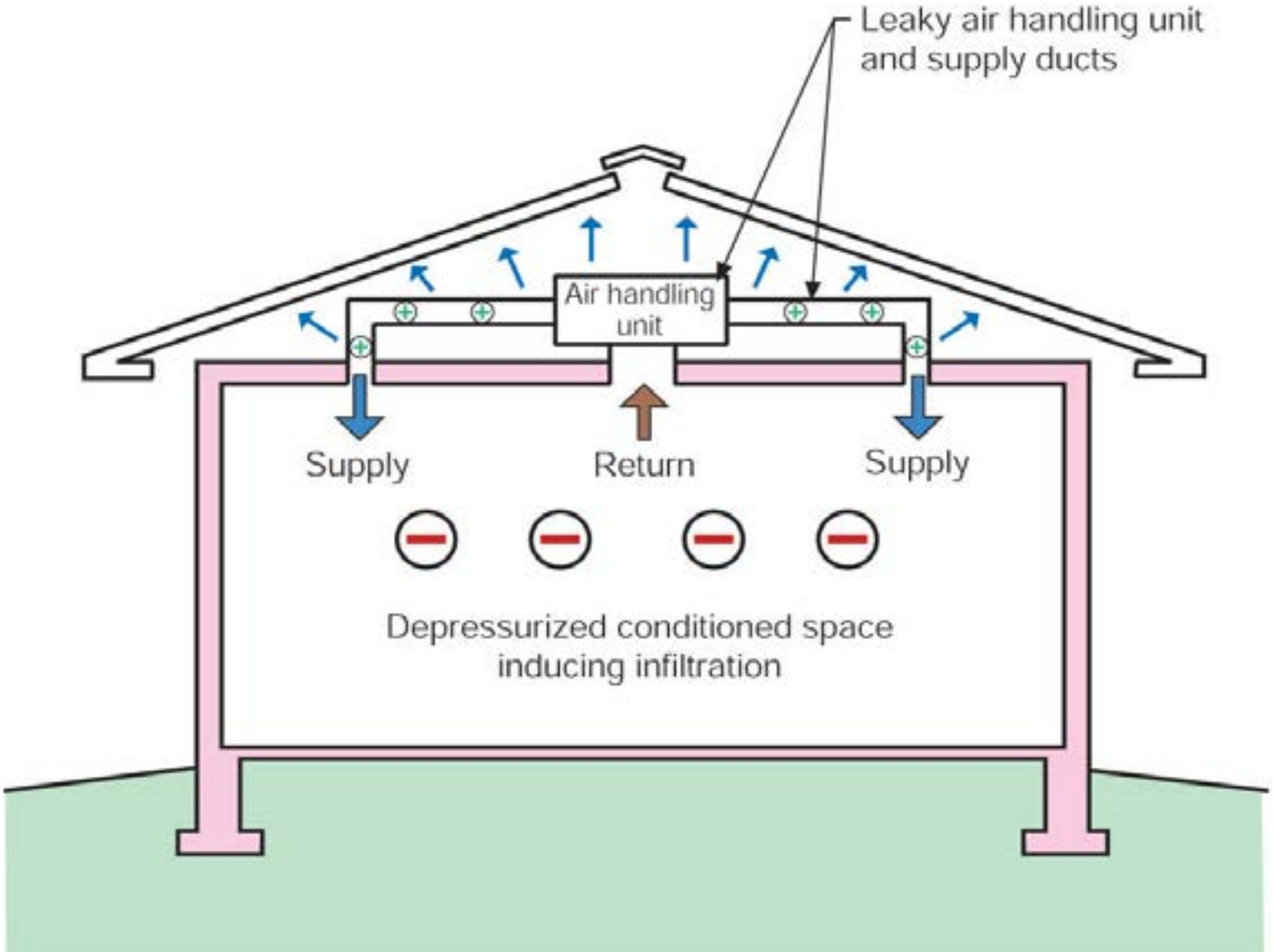
Duct Leakage Should Be Less Than 5% of Rated Flow As Tested by Pressurization To 25 Pascals

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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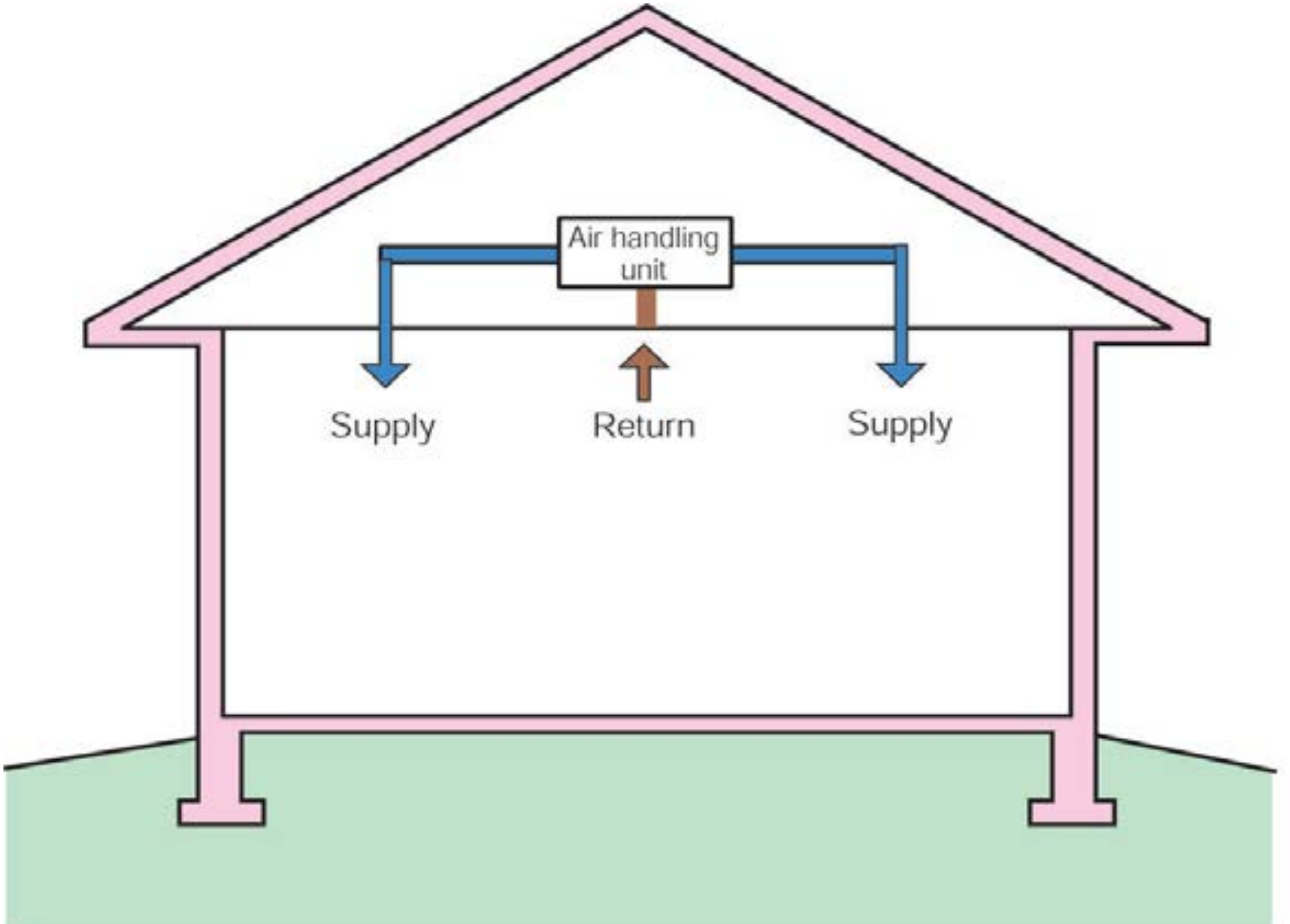

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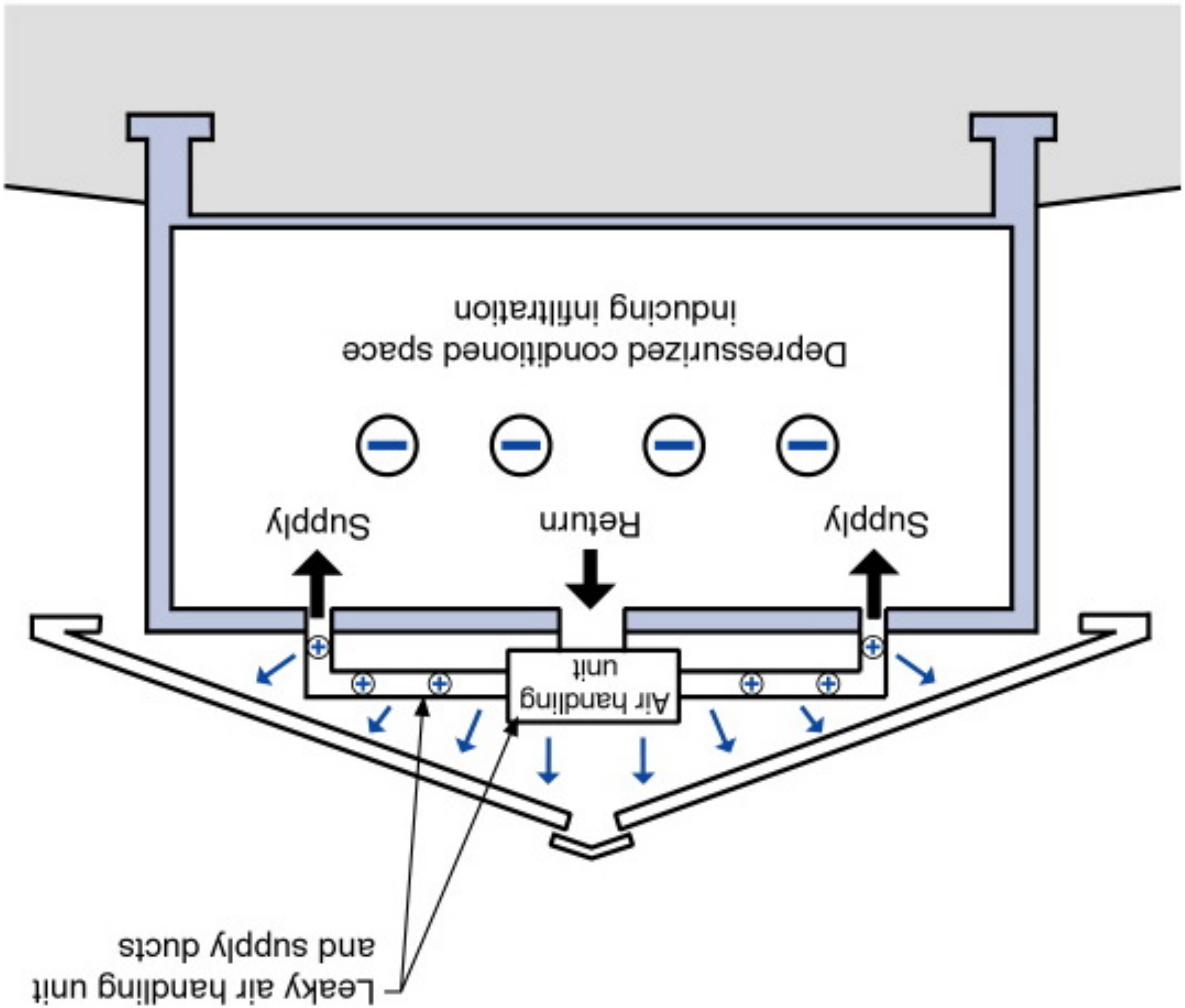

Depressurized conditioned space
inducing infiltration
Supply
Return
Supply
Air handling
unit
Leaky air handling unit
and supply ducts

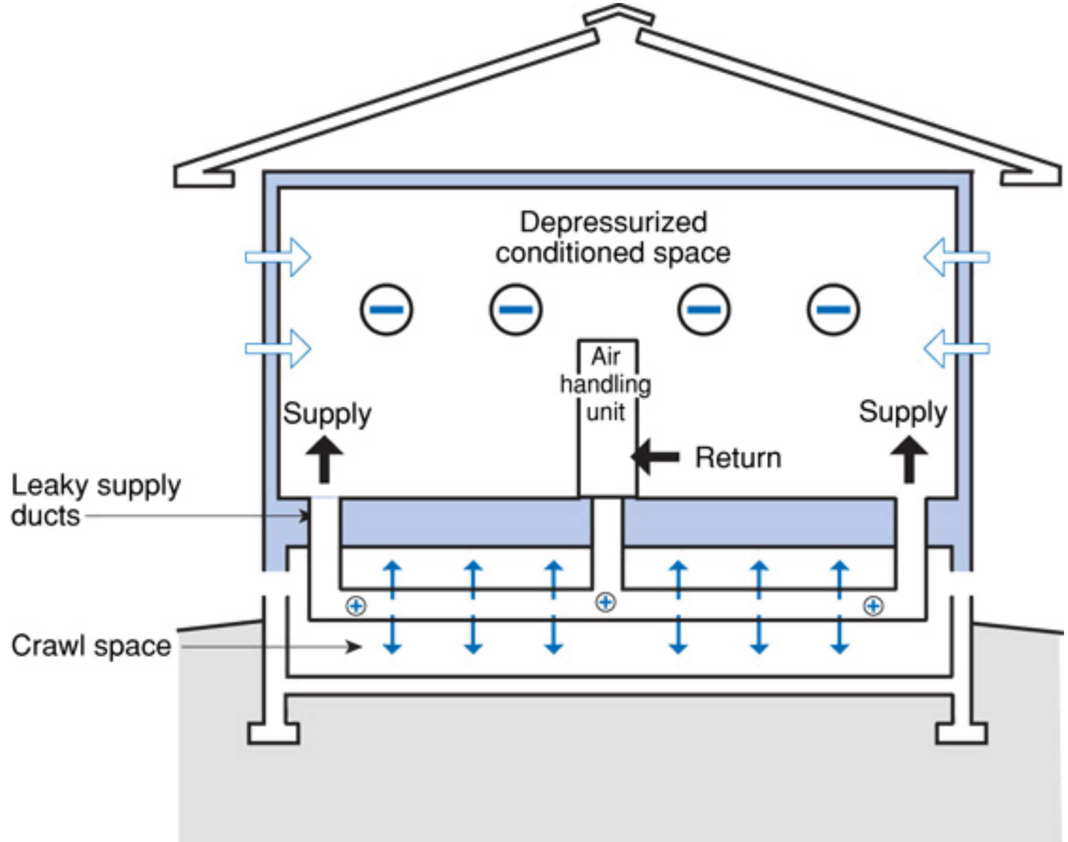
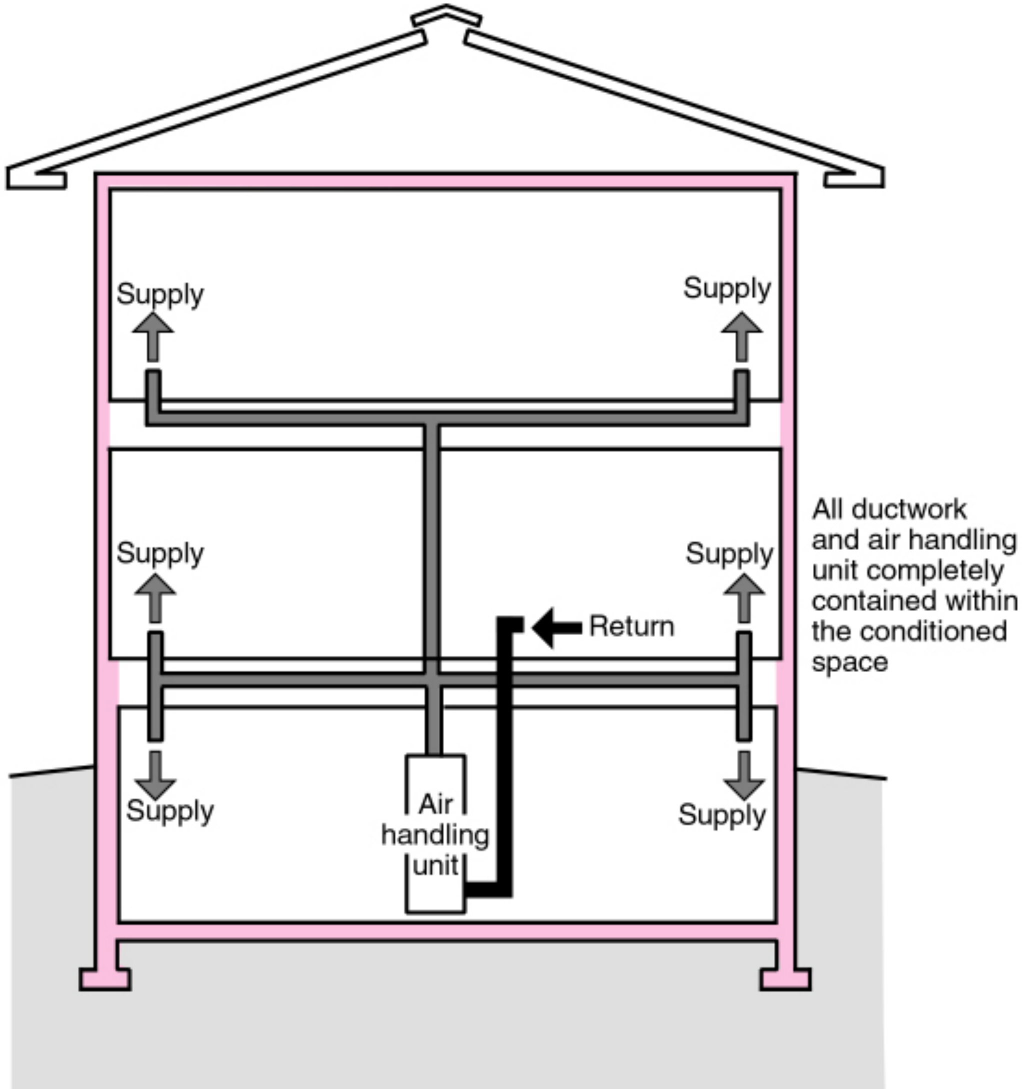


Figure 3.16

Leaky Supply Ductwork in Vented Crawl Space

- Air pressurization pattern with mechanical system ducts in the crawl space



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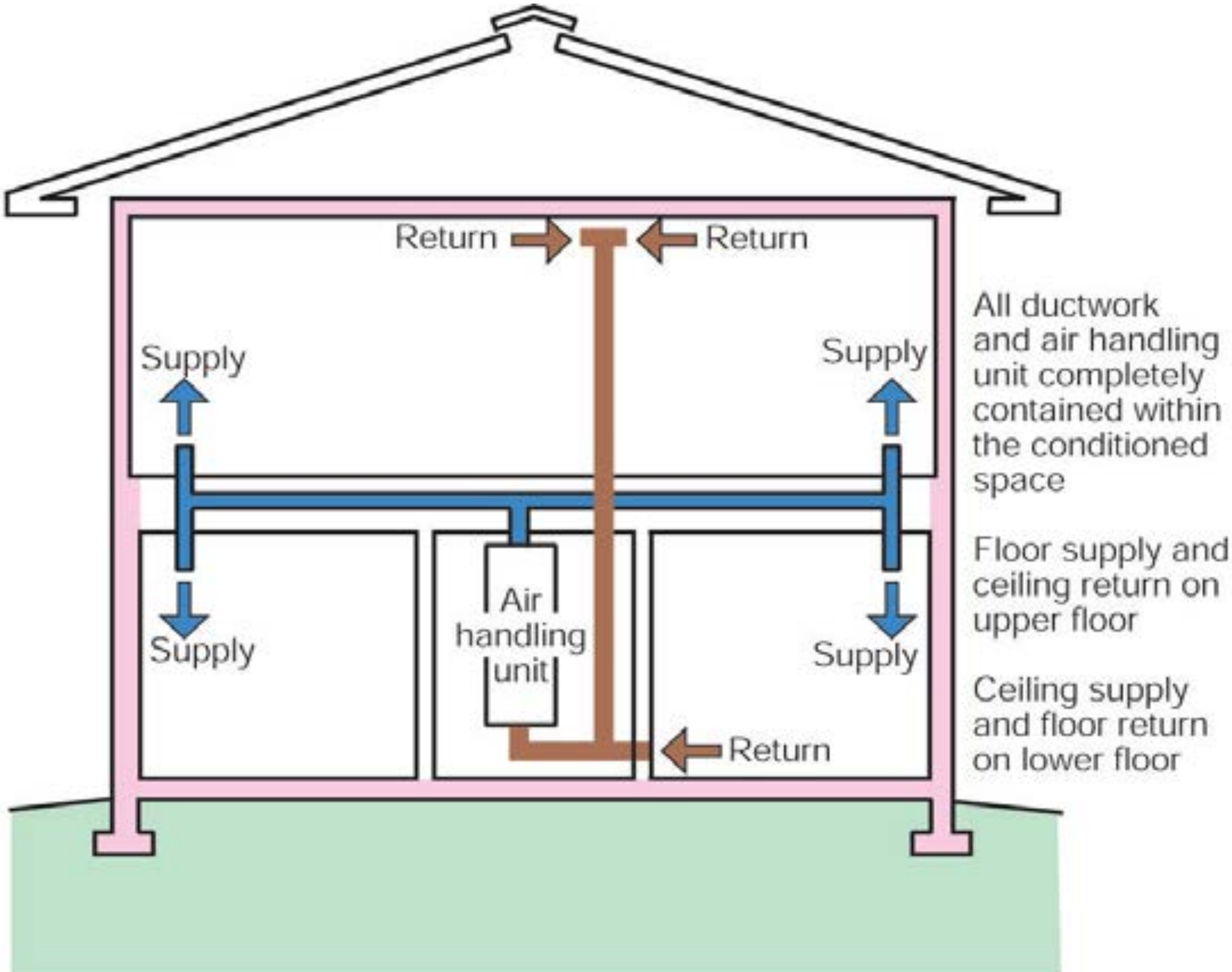

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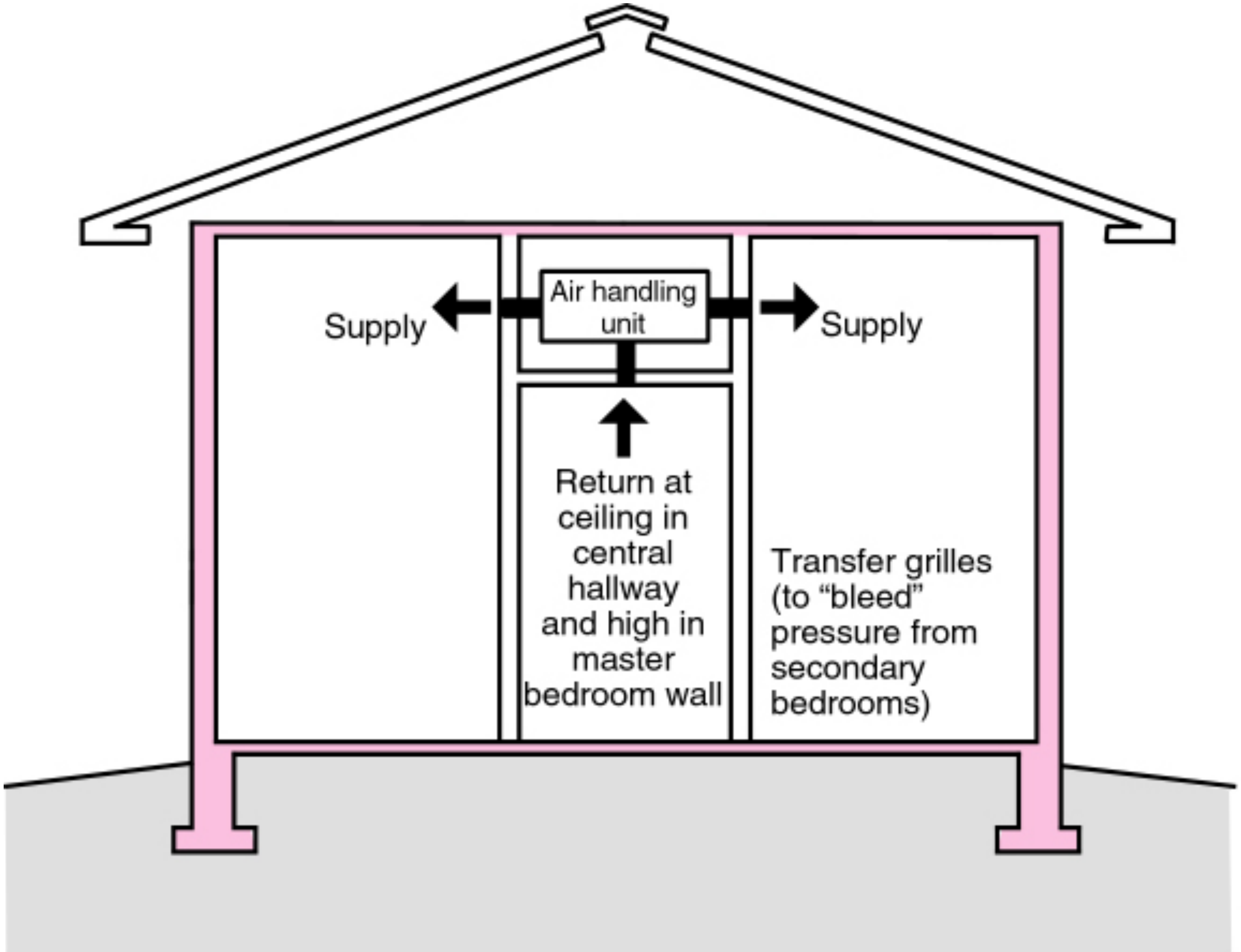

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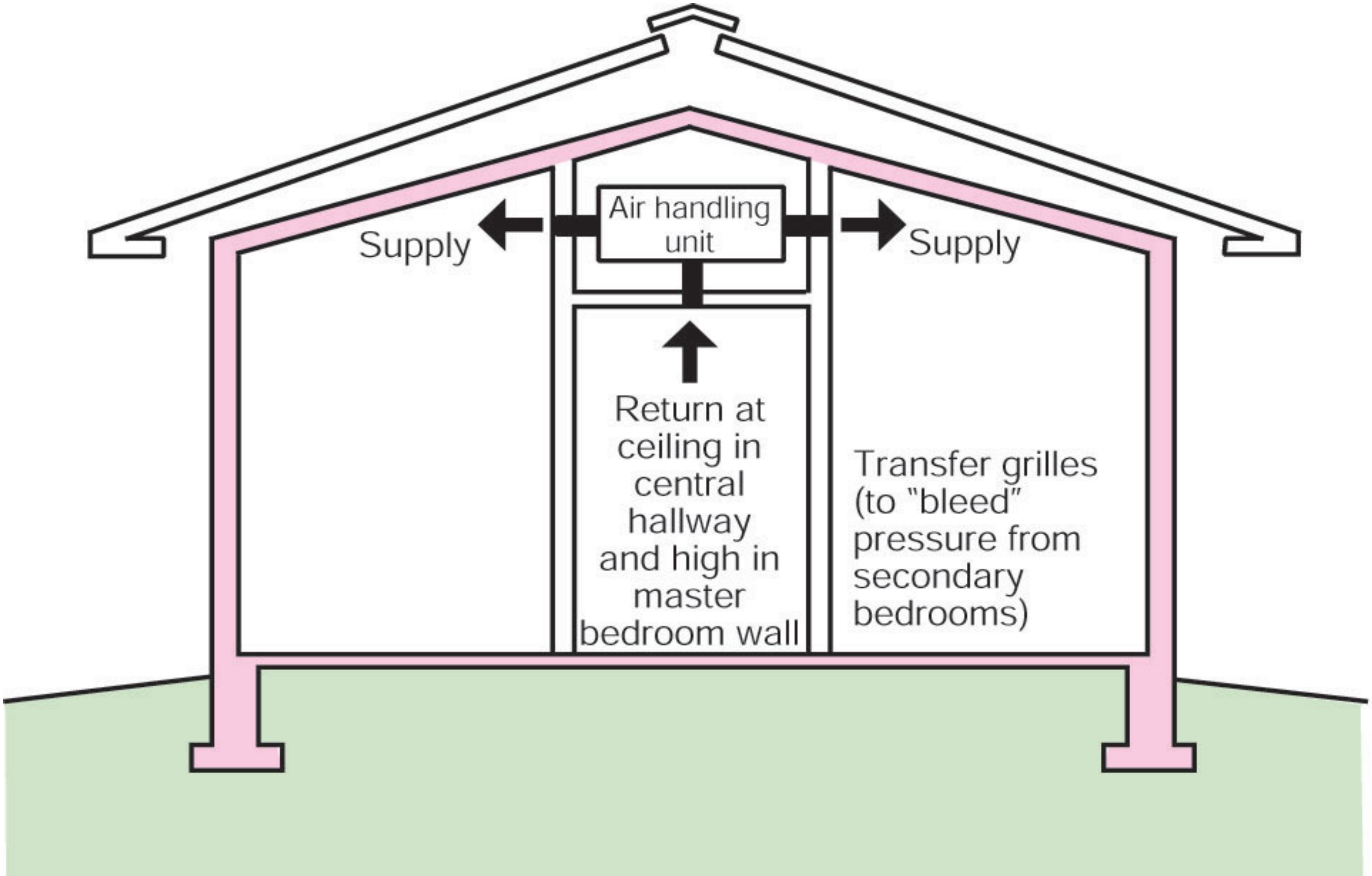

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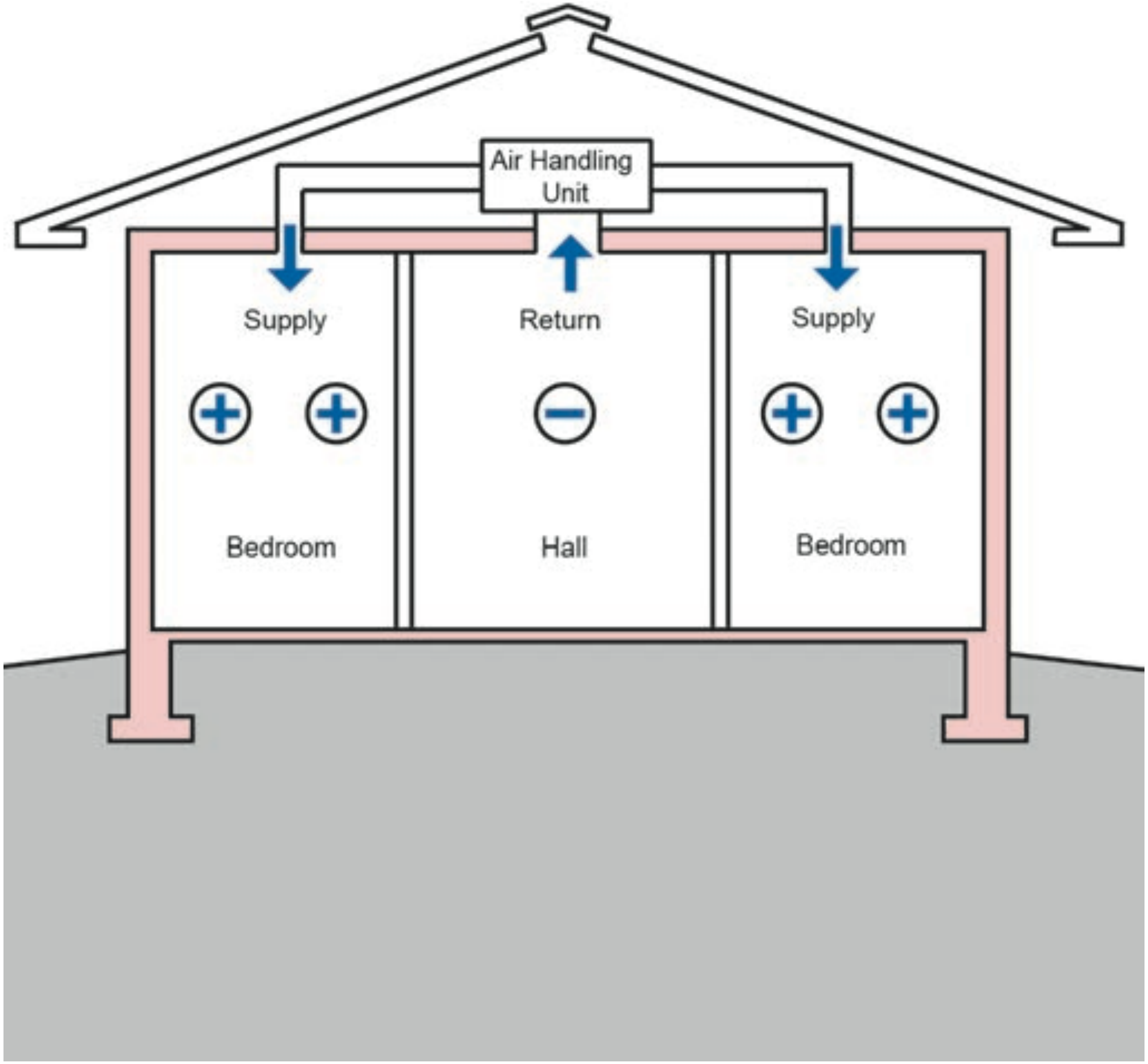
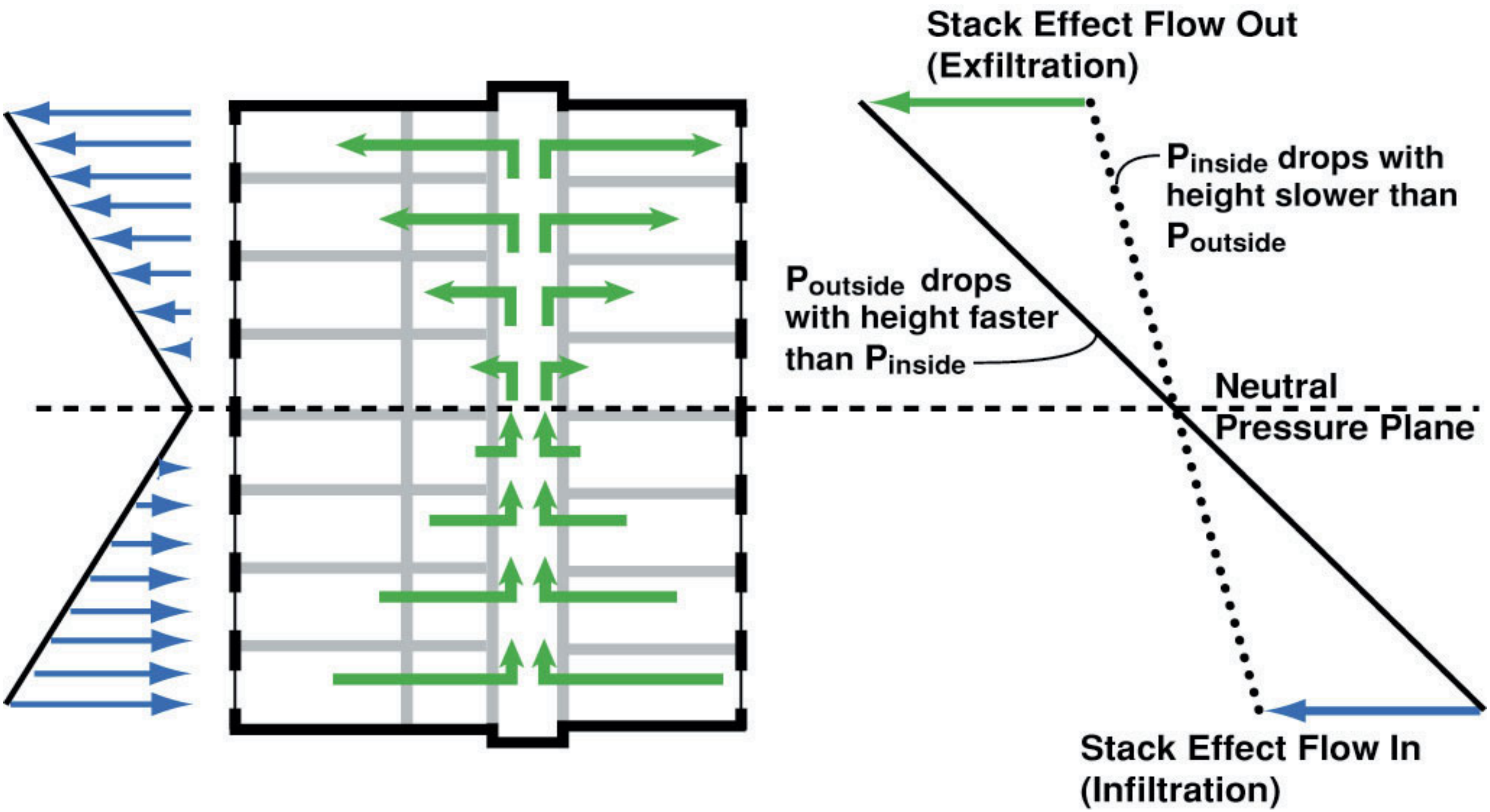

Air Handling Unit
Supply
Return
Supply
Bedroom
Hall
Bedroom

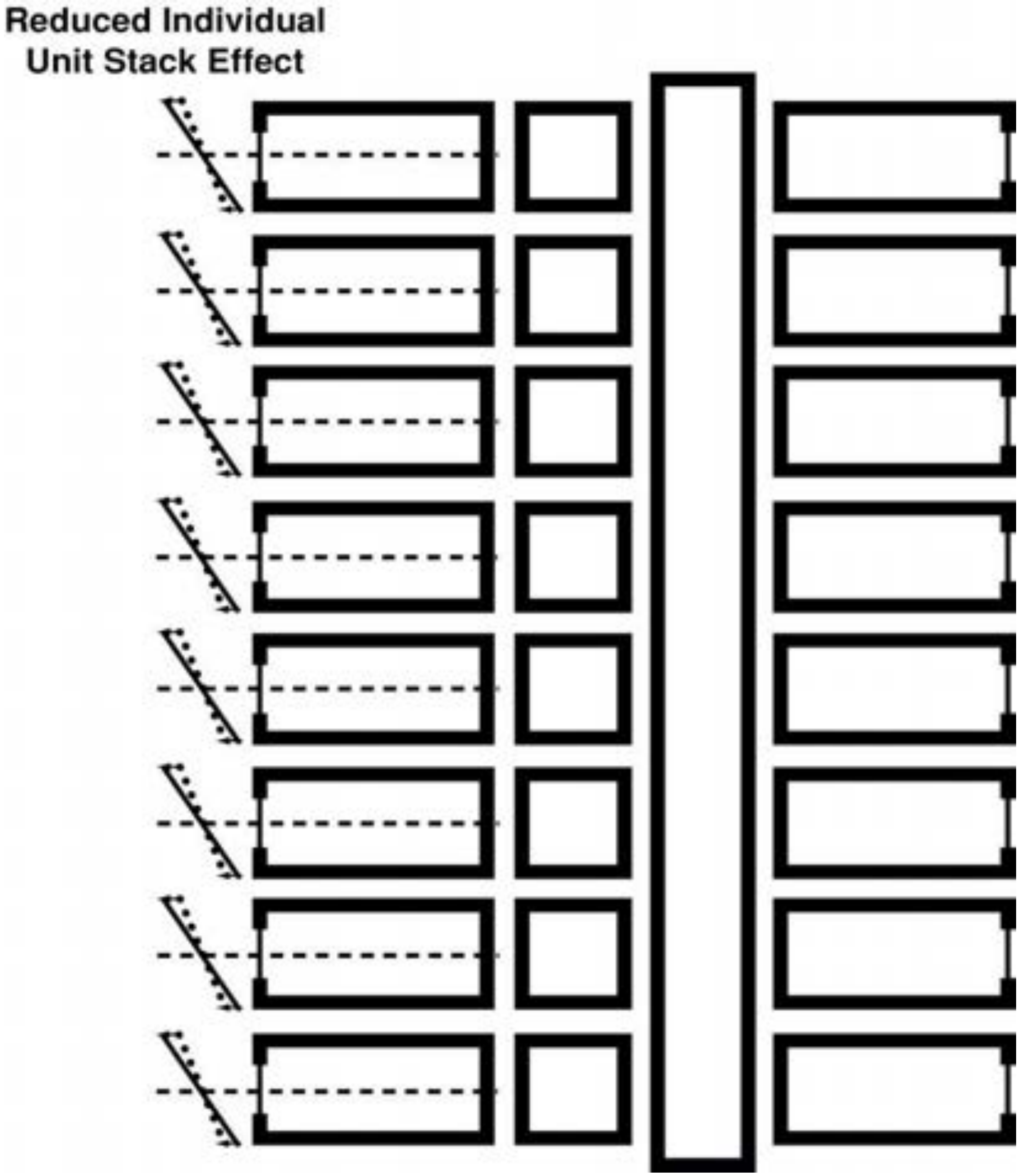

Richly
Scented Candle
EMPIRE

Air Barrier Metrics

Material	0.02 l/(s-m2) @ 75 Pa	
Assembly	0.20 l/(s-m2) @ 75 Pa	
Enclosure	2.00 l/(s-m2) @ 75 Pa	
		0.35 cfm/ft2 @ 50 Pa
		0.25 cfm/ft2 @ 50 Pa
		0.15 cfm/ft2 @ 50 Pa

Getting rid of big holes	3 ach@50
Getting rid of smaller holes	1.5 ach@50
Getting German	0.6 ach@50


Stack Effect Flow Out
(Exfiltration)
P_{inside} drops with height slower than $P_{outside}$
$P_{outside}$ drops with height faster than P_{inside}
Neutral Pressure Plane
Stack Effect Flow In
(Infiltration)



Reduced Individual
Unit Stack Effect