

Joseph Lstiburek, Ph.D., P.Eng, ASHRAE Fellow

Building Science

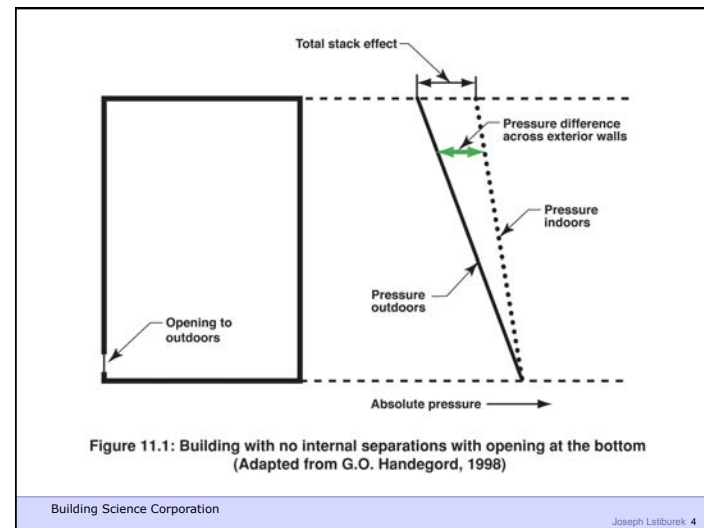
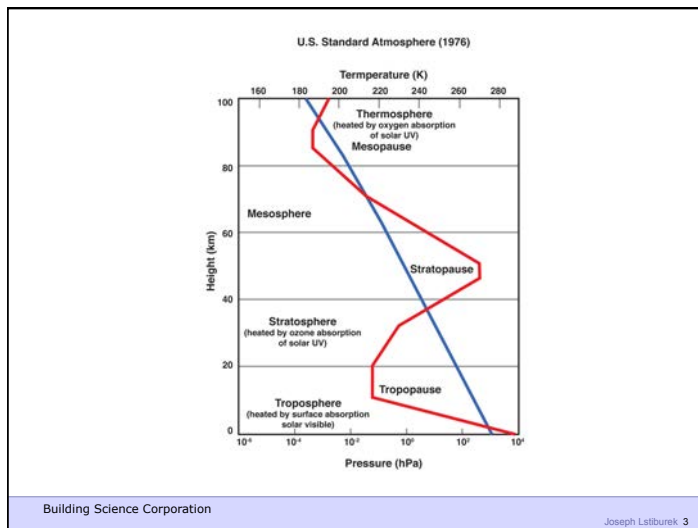
Ventilation

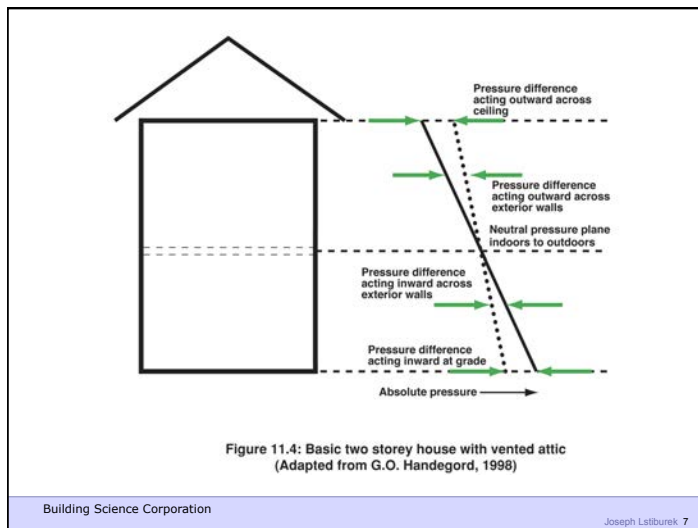
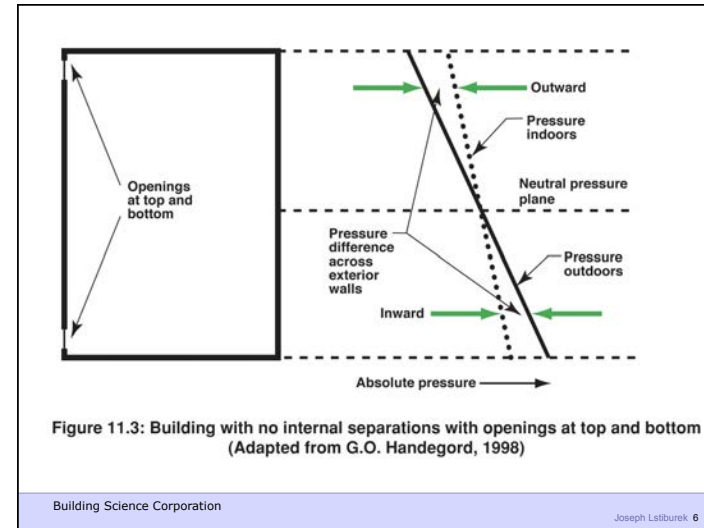
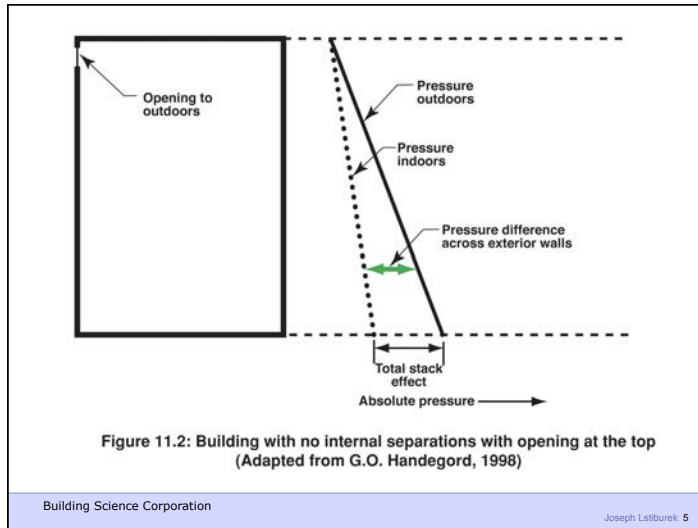
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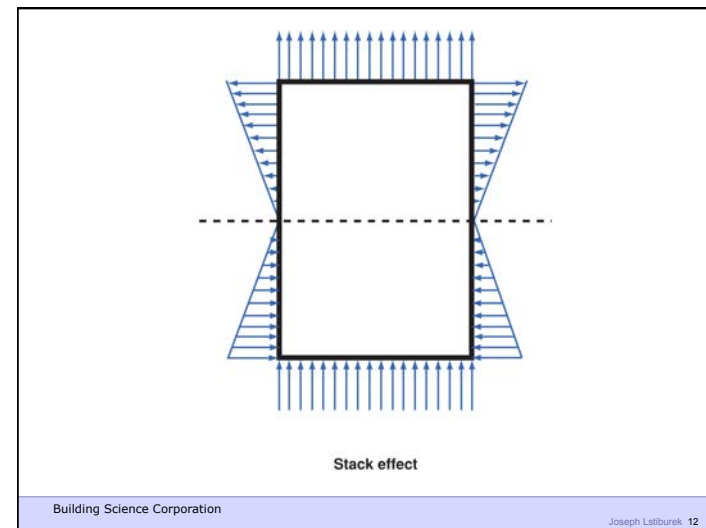
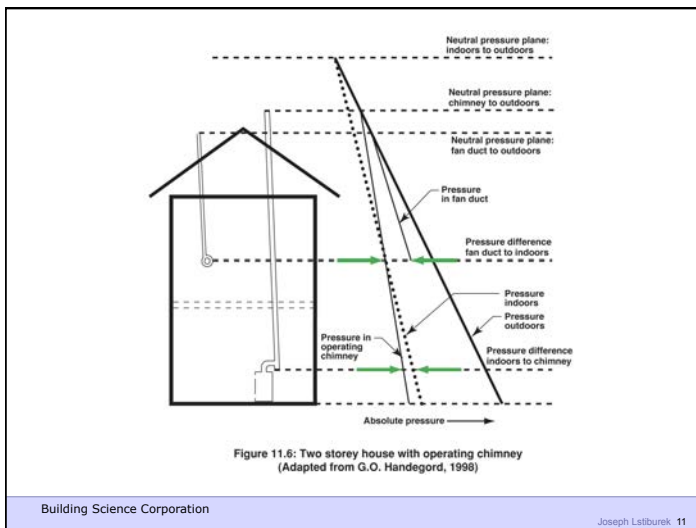
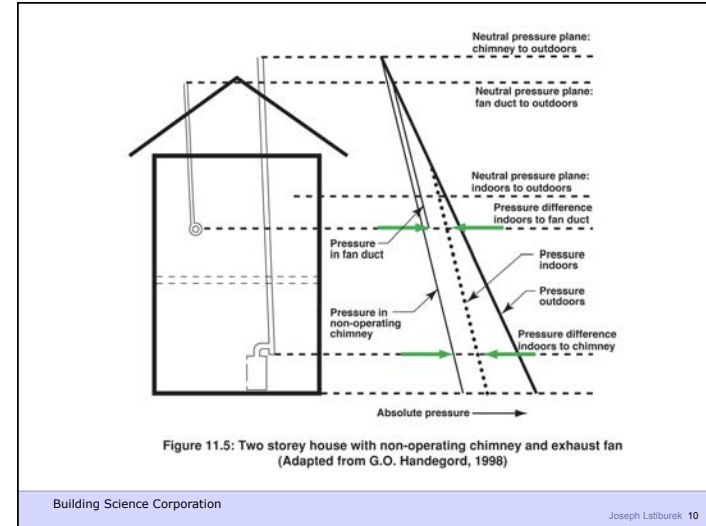
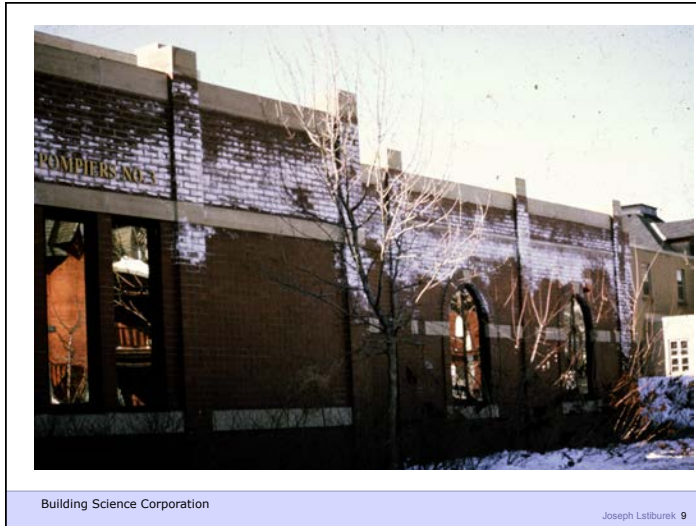
Lapse Rate

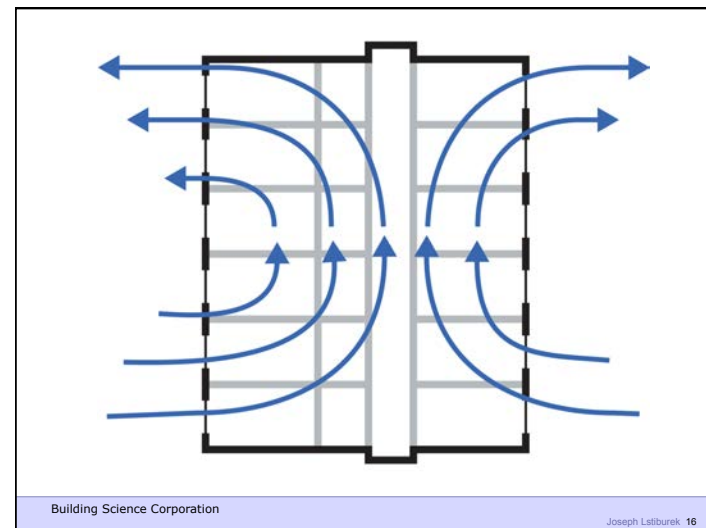
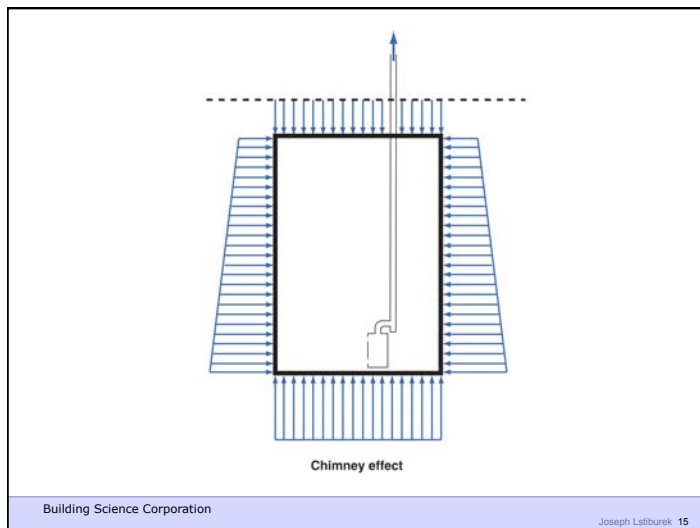
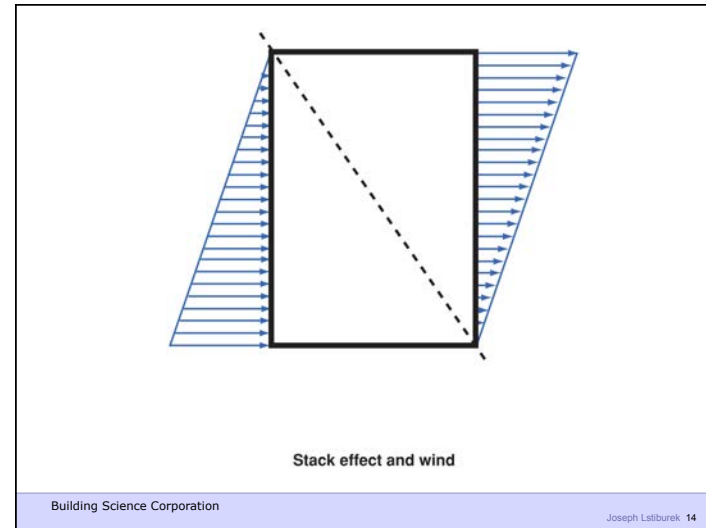
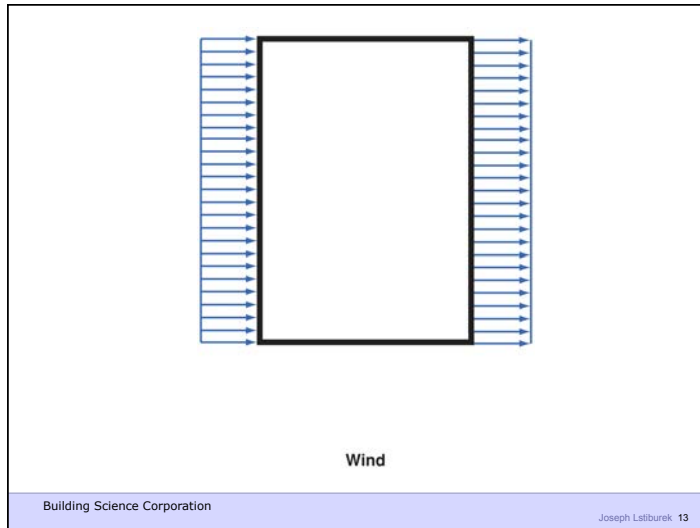
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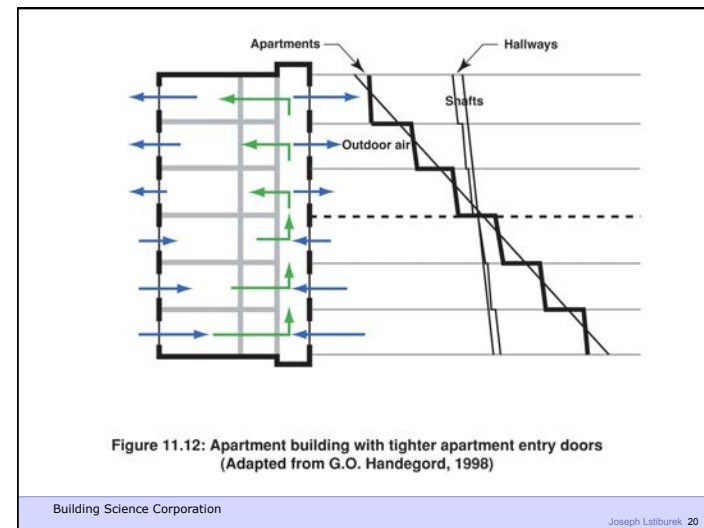
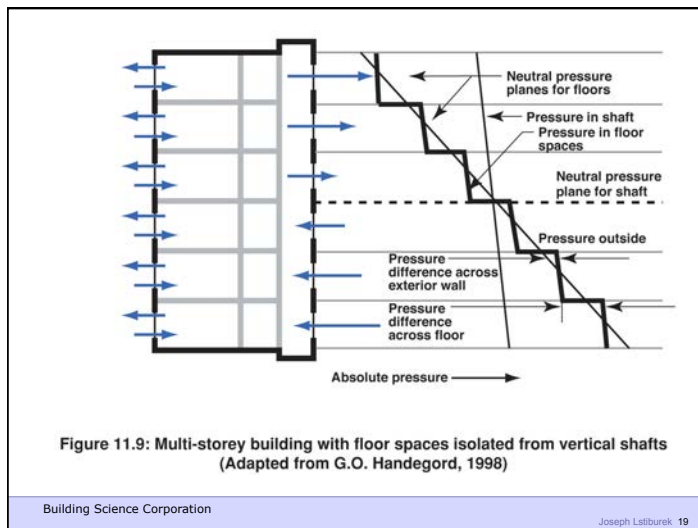
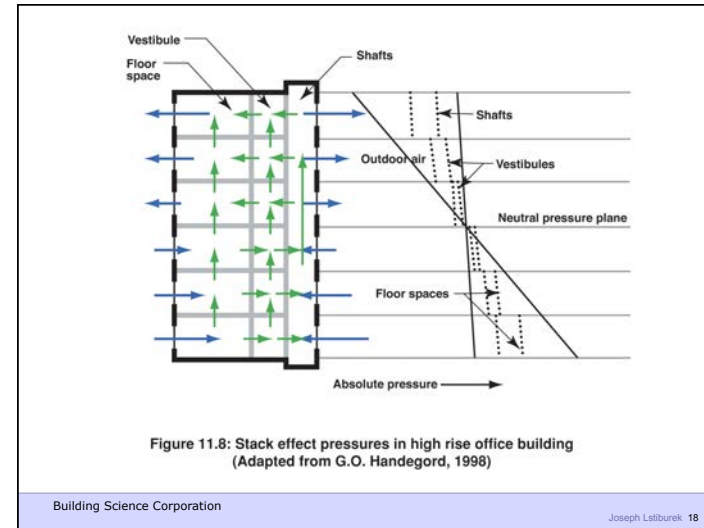
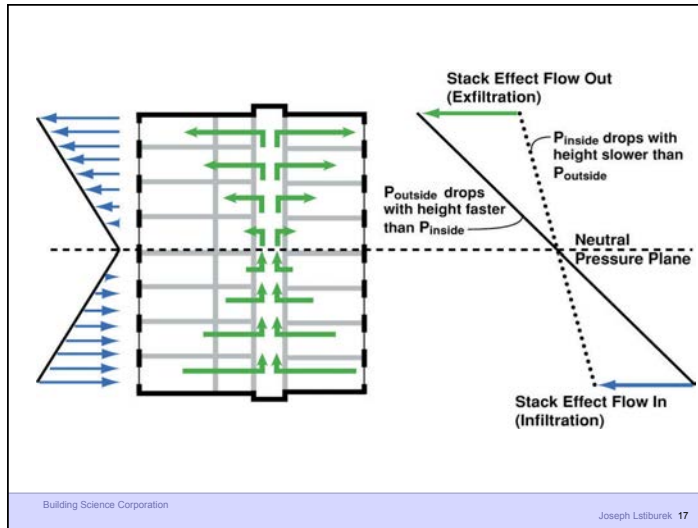
Joseph Lstiburek 2











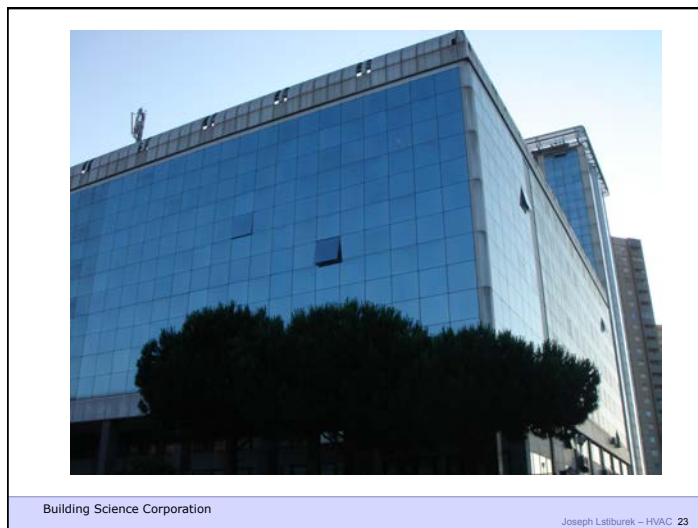
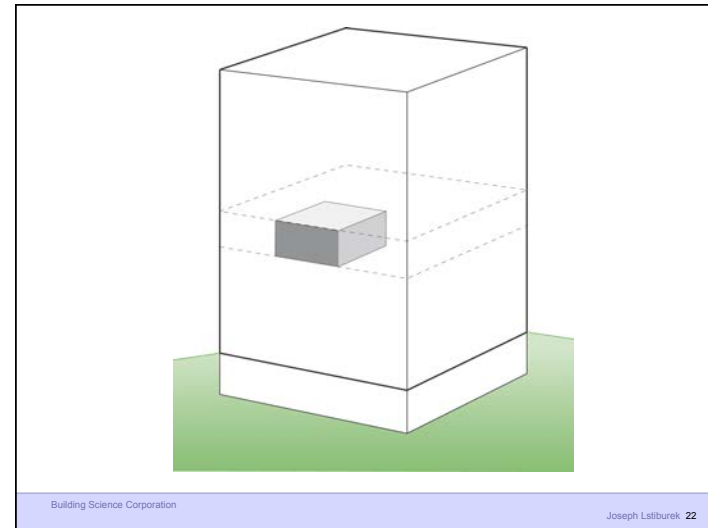
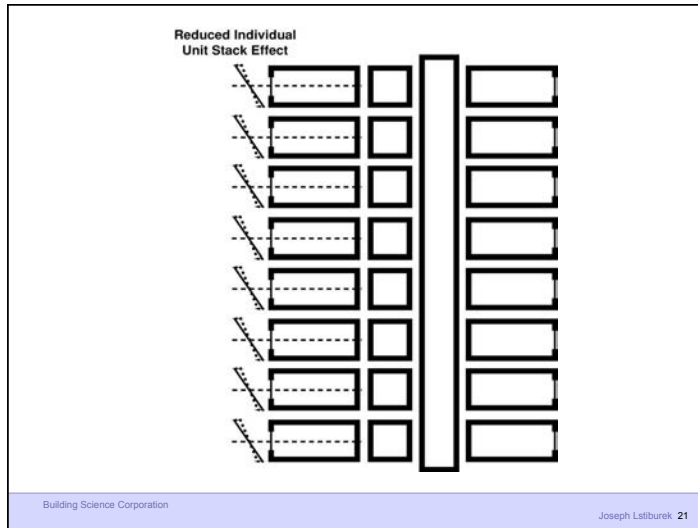
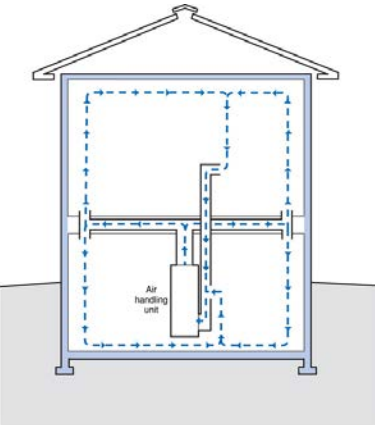


Figure 3.12
Ductwork and Air Handlers in Basements

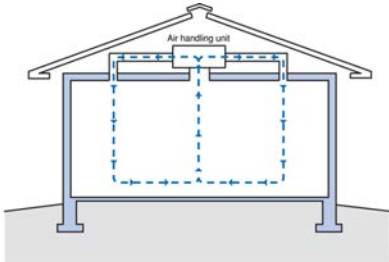
- No air pressure differences result in a house with an air handler and ductwork located in a basement if there are no leaks in the supply ducts, the return ducts or the air handler and if the amount of air delivered to each room equals the amount removed



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Figure 3.13
Ductwork and Air Handlers in Vented Attics

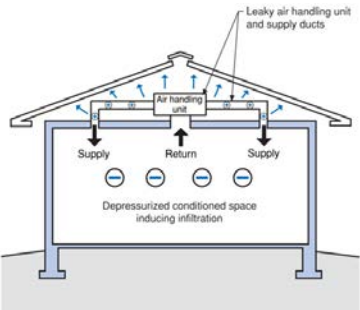
- No air pressure differences result in a house with an air handler and ductwork located in a vented attic if there are no leaks in the supply ducts, the return ducts or the air handler and if the amount of air delivered to each room equals the amount removed



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Figure 3.15
Leaky Ductwork and Air Handlers in Vented Attics

- Supply ductwork and air handler leakage is typically 20% or more of the flow through the system



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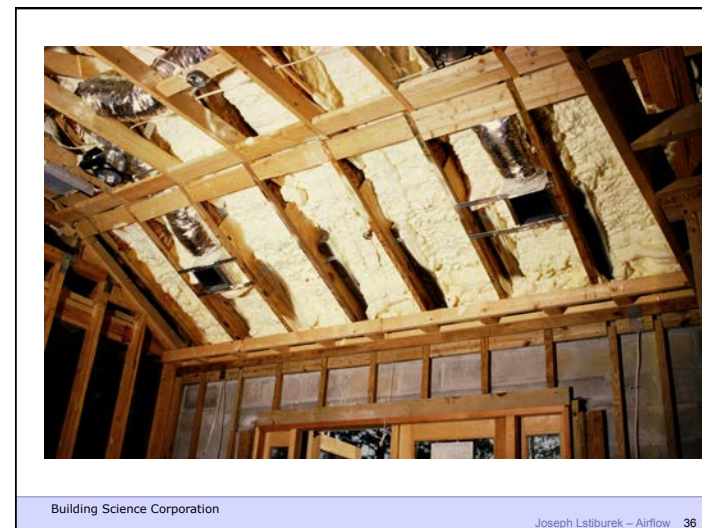
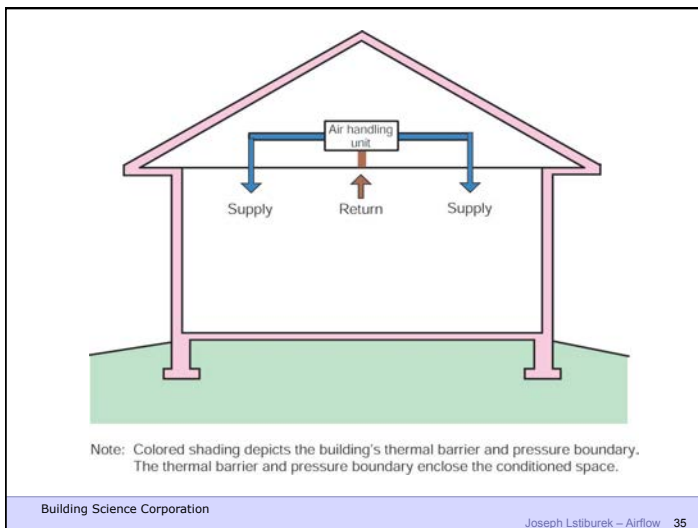
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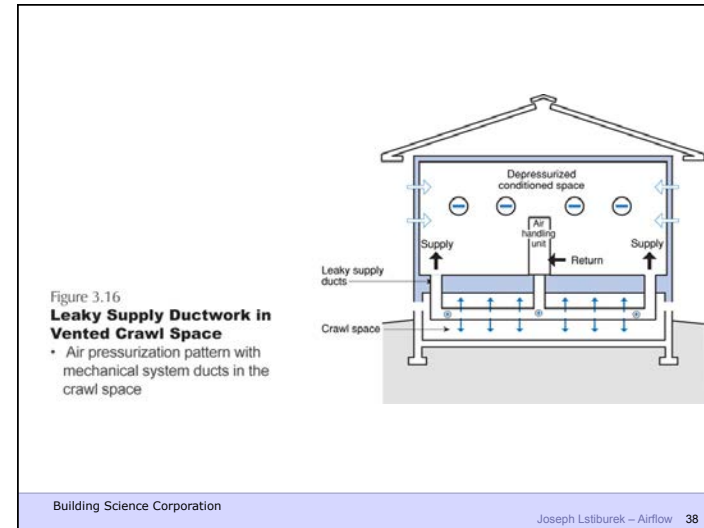
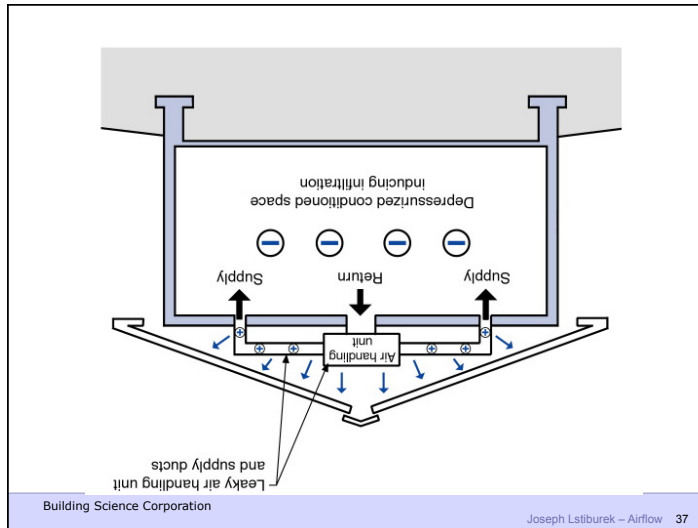
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Duct Leakage Should Be Less Than 5% of Rated Flow As Tested By Pressurization To 25 Pascals

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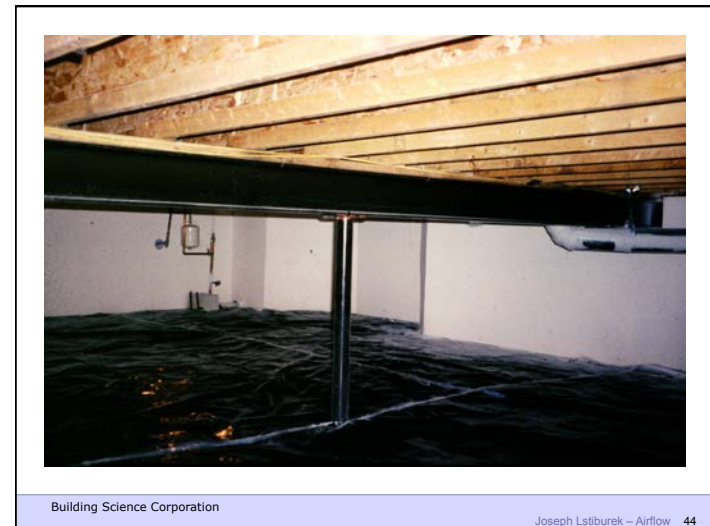
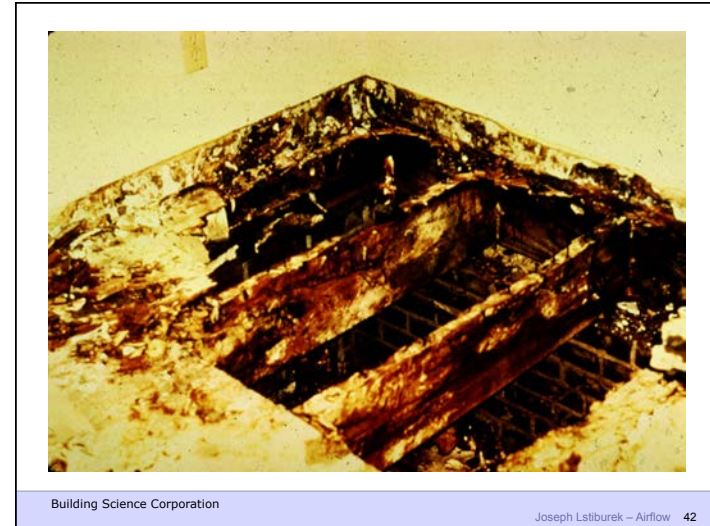
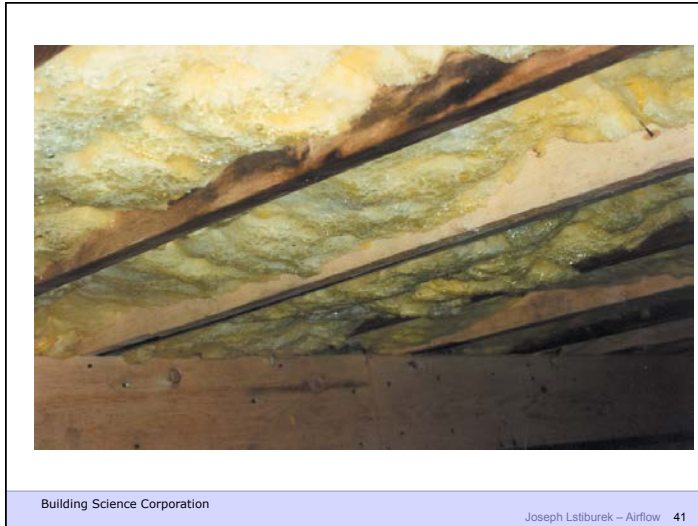


Figure 3.14
Leaky Ductwork and Air Handlers in Basements

- Air pressurization patterns in a house with leaky ductwork in the basement

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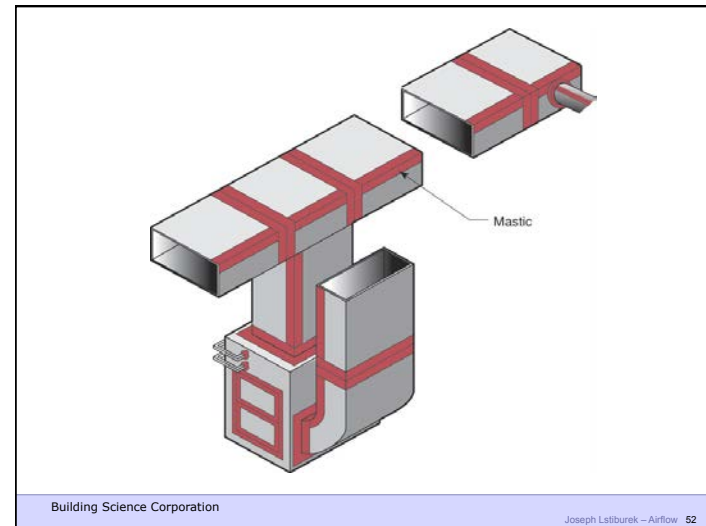
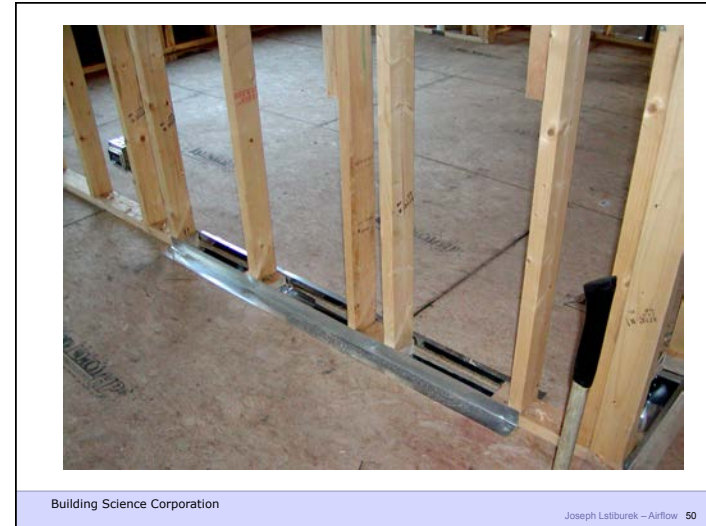


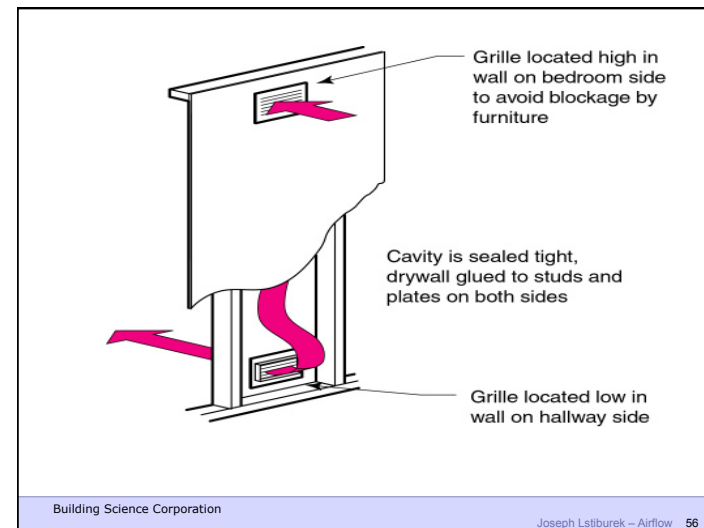


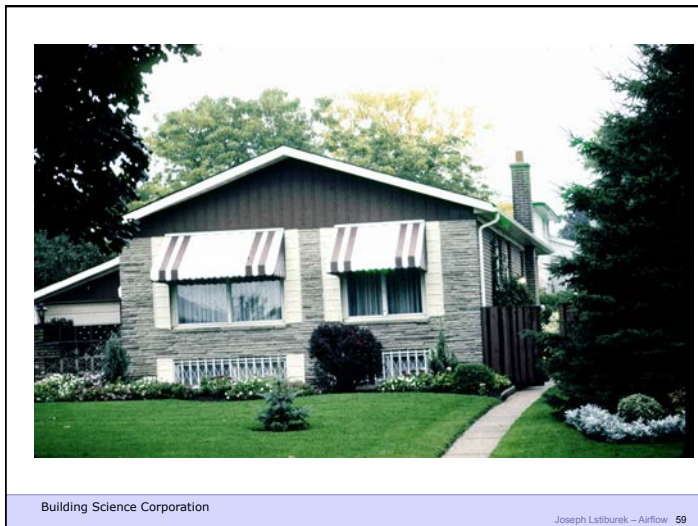
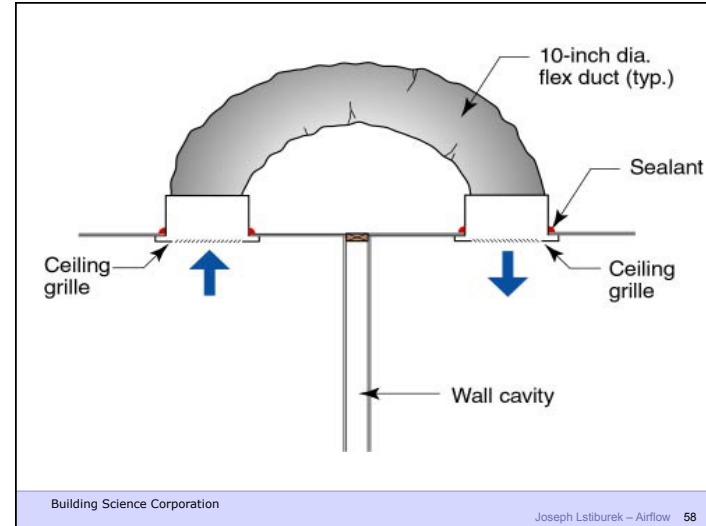
Figure 3.18
Insufficient Return Air Paths

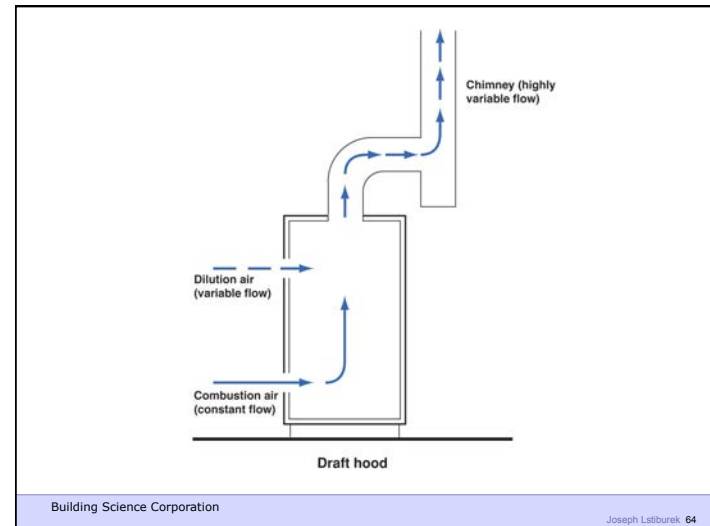
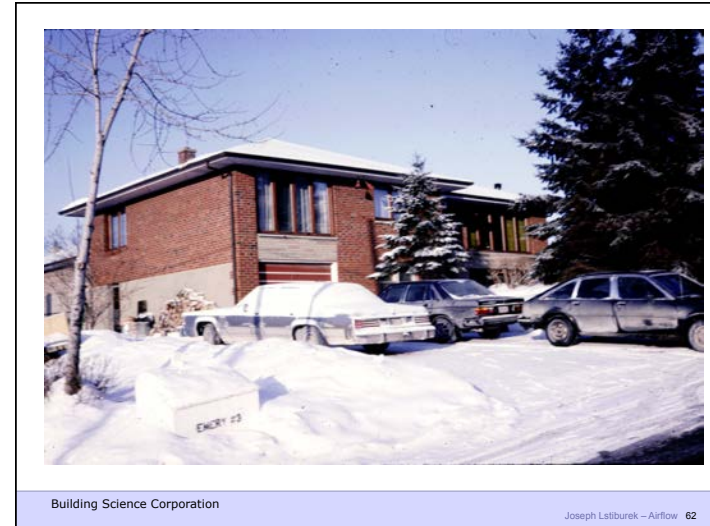
- Pressurization of bedrooms often occurs if insufficient return pathways are provided; undercutting bedroom doors is usually insufficient; transfer grilles, jump ducts or fully ducted returns may be necessary to prevent pressurization of bedrooms
- Master bedroom suites are often the most pressurized as they typically receive the most supply air
- When bedrooms pressurized, common areas depressurize; this can have serious consequences when fireplaces are located in common areas and subsequently backdraft

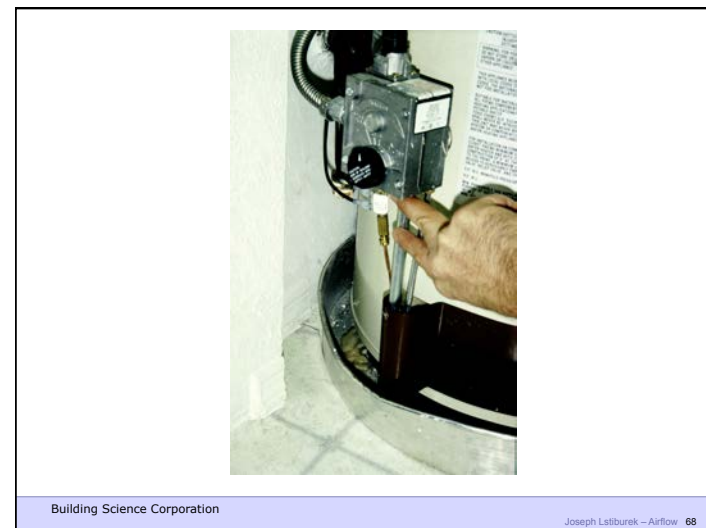
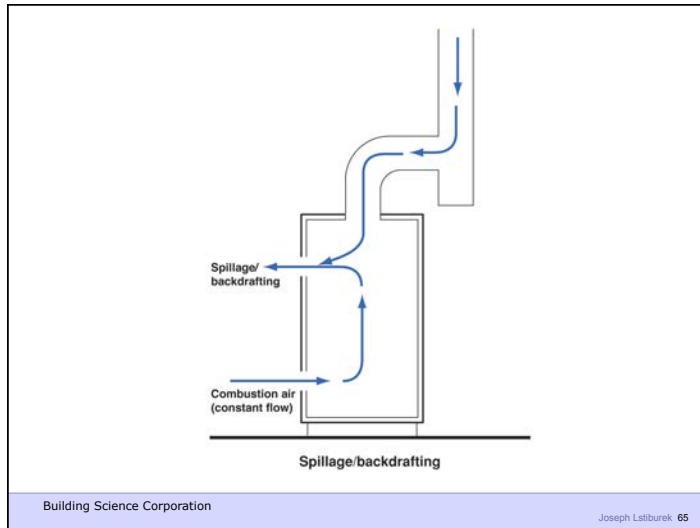
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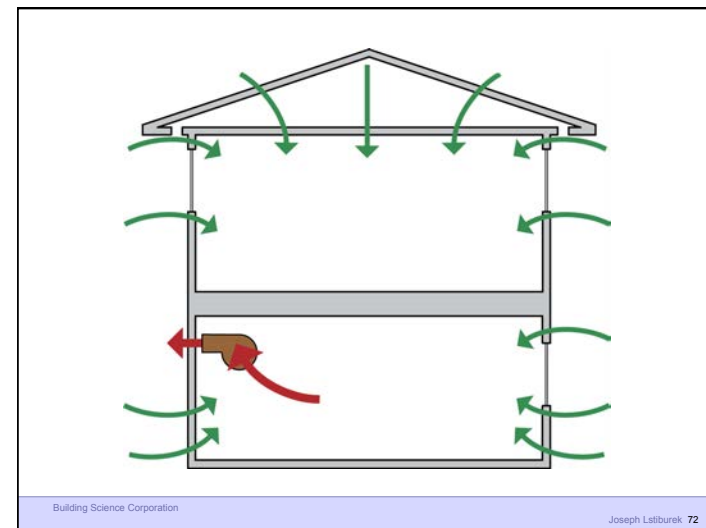
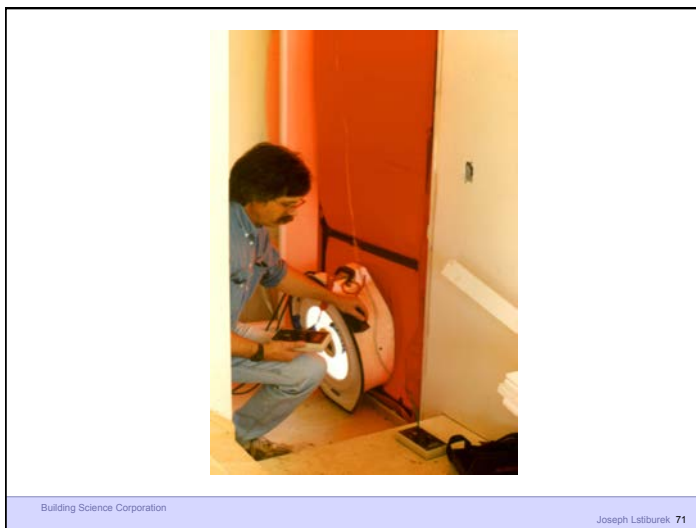


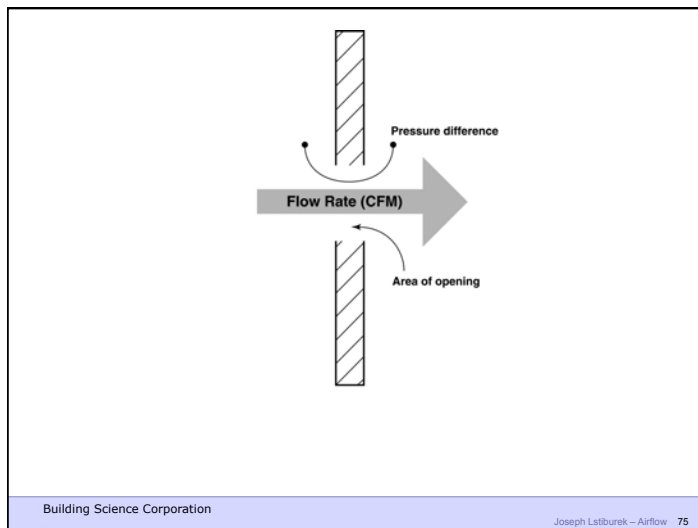
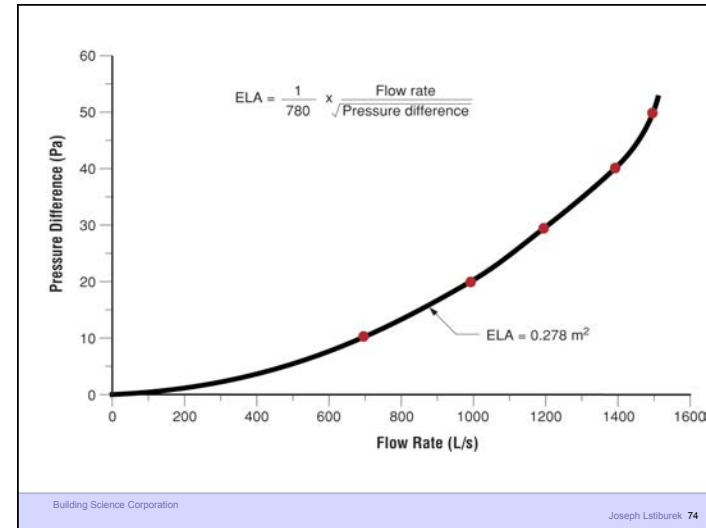
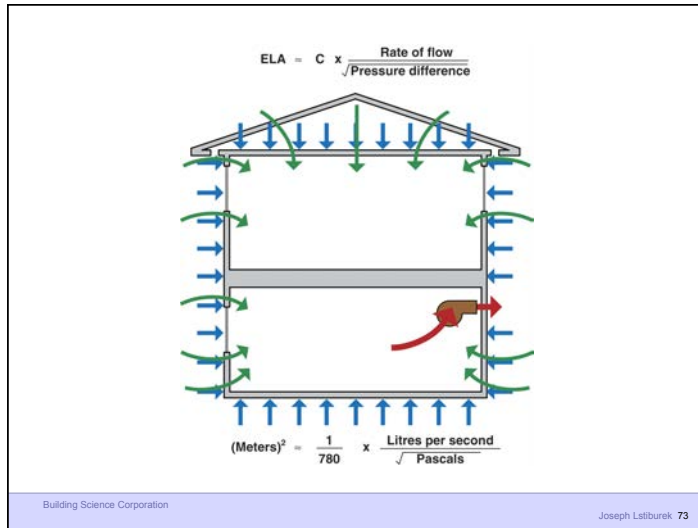
Air Barrier Metrics

Material	0.02 l/(s-m2)@75 Pa
Assembly	0.20 l/(s-m2)@75 Pa
Enclosure	2.00 l/(s-m2)@75 Pa

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Flow Through Orifices
Turbulent Flow - “inertial effects”

Flow Through Porous Media
Laminar Flow - “viscosity effects”

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Flow Through Orifices
Turbulent Flow - “inertial effects”

Flow Through Porous Media
Laminar Flow - “viscosity effects”

“true but not useful”

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$$Q = A \cdot C_d \left[\frac{2}{\rho} (\Delta P) \right]^{\frac{1}{2}} \quad \text{Bernoulli}$$

$$Q = C_k \frac{\rho}{\mu} (\Delta P) \quad \text{Darcy}$$

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$$Q = A \cdot C_d \left[\frac{2}{\rho} (\Delta P) \right]^{\frac{1}{2}} \quad \text{Bernoulli}$$

$$Q = C_k \frac{\rho}{\mu} (\Delta P) \quad \text{Darcy}$$

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

$$Q = C (\Delta P)$$

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$$Q = A \cdot C_d \left[\frac{2}{\rho} (\Delta P) \right]^{\frac{1}{2}} \quad \text{Bernoulli}$$

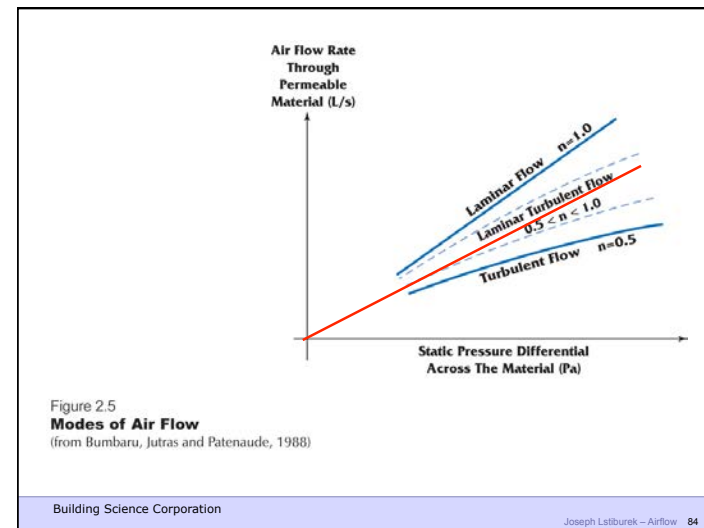
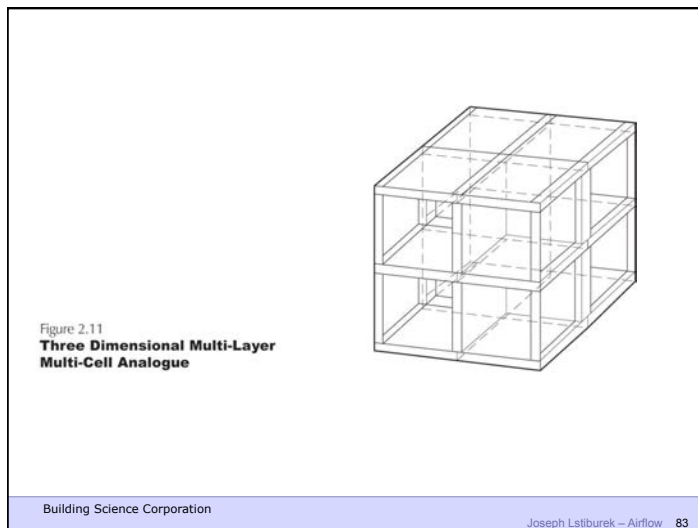
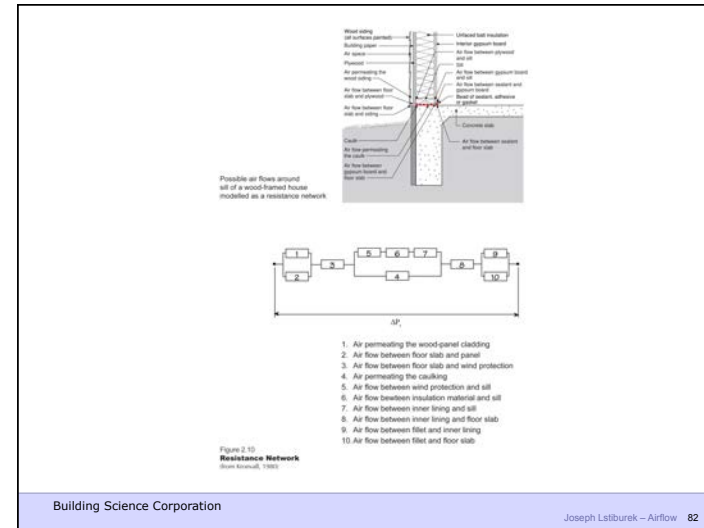
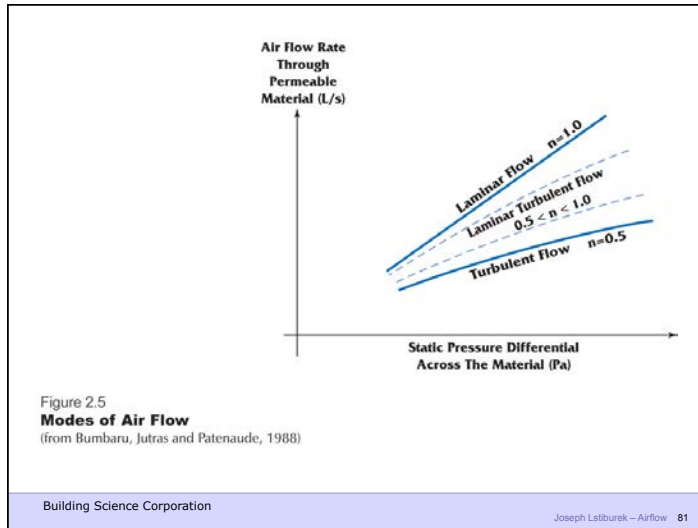
$$Q = C_k \frac{\rho}{\mu} (\Delta P) \quad \text{Darcy}$$

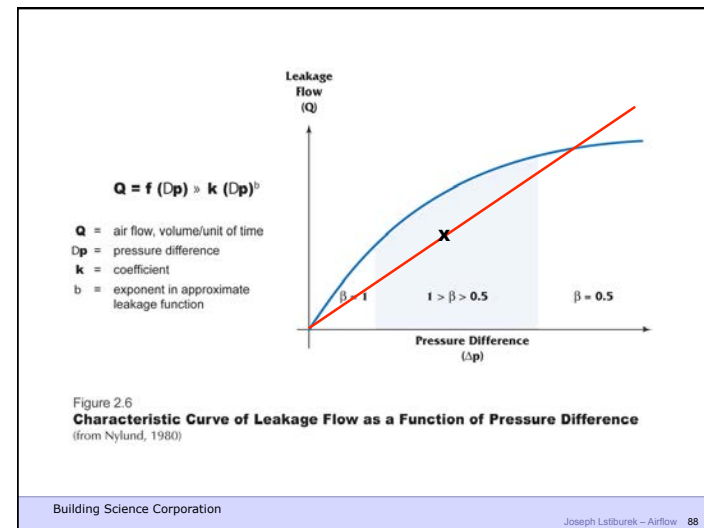
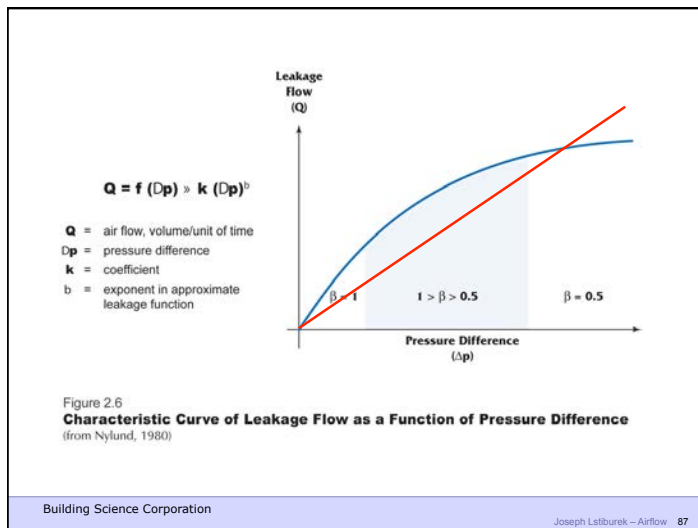
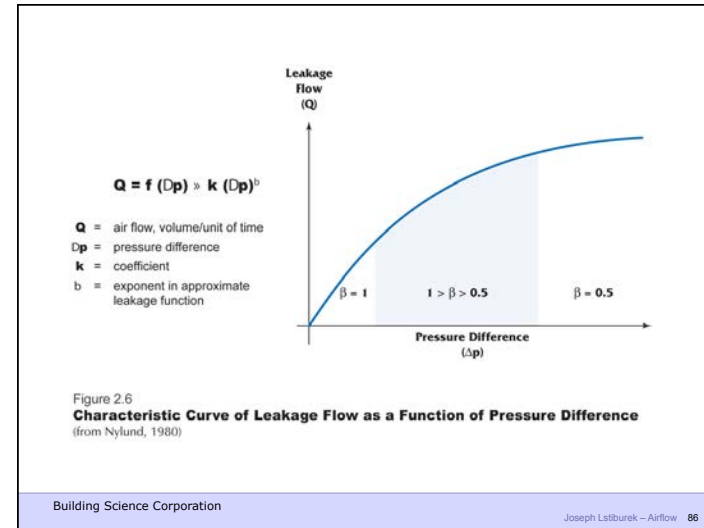
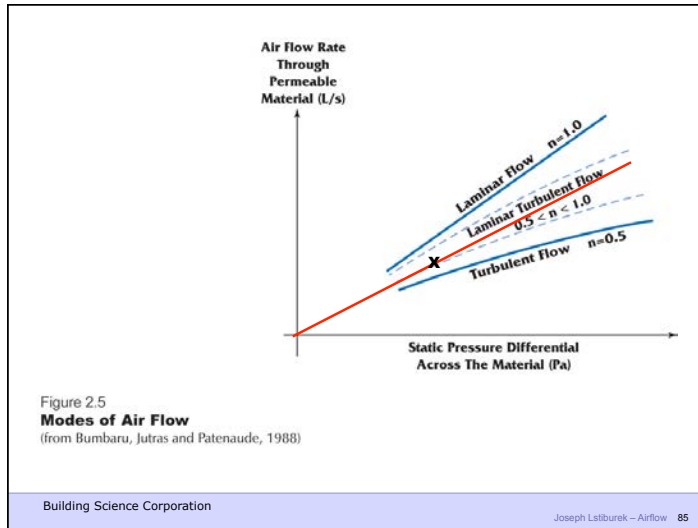
$$Q = A \cdot C (\Delta P)^{\frac{1}{2}}$$

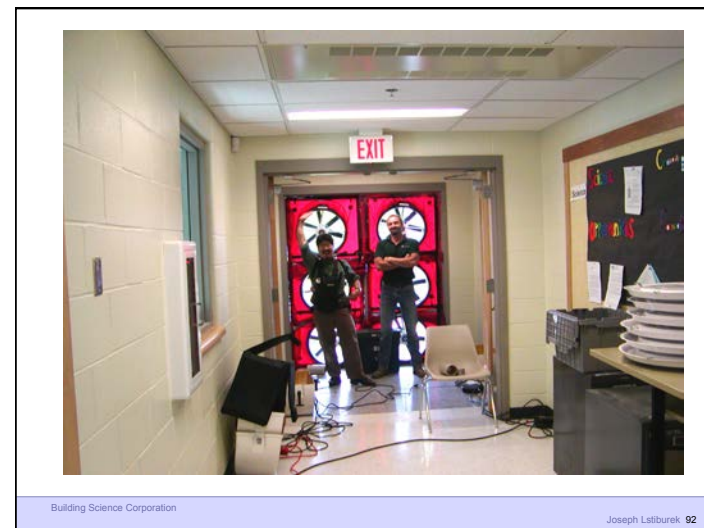
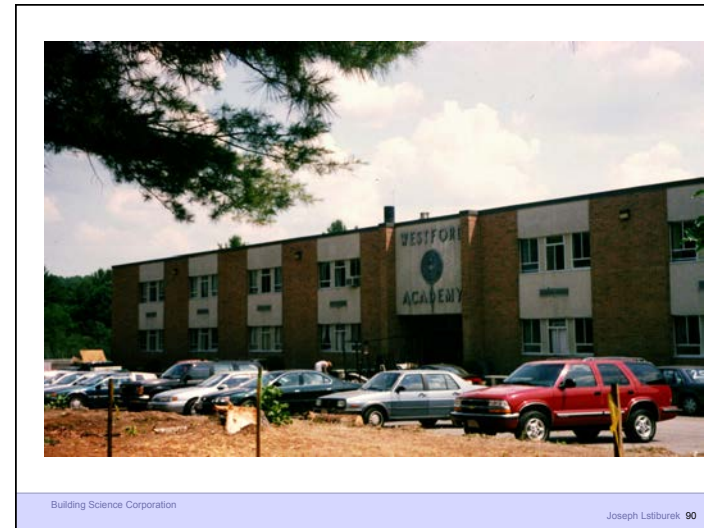
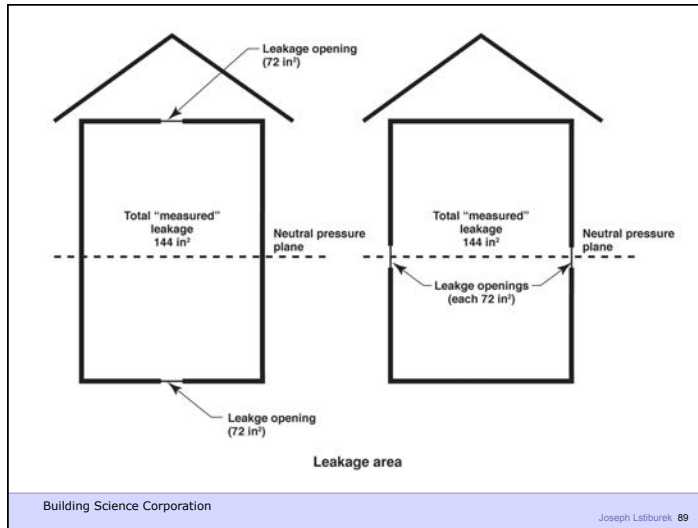
$$Q = C (\Delta P)$$

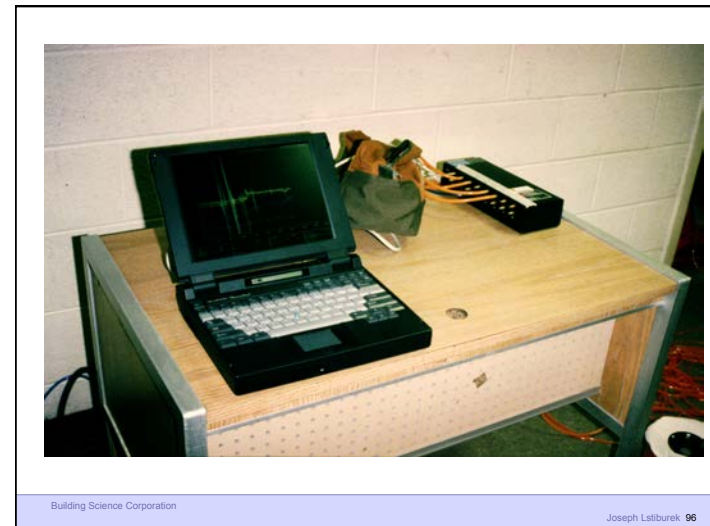
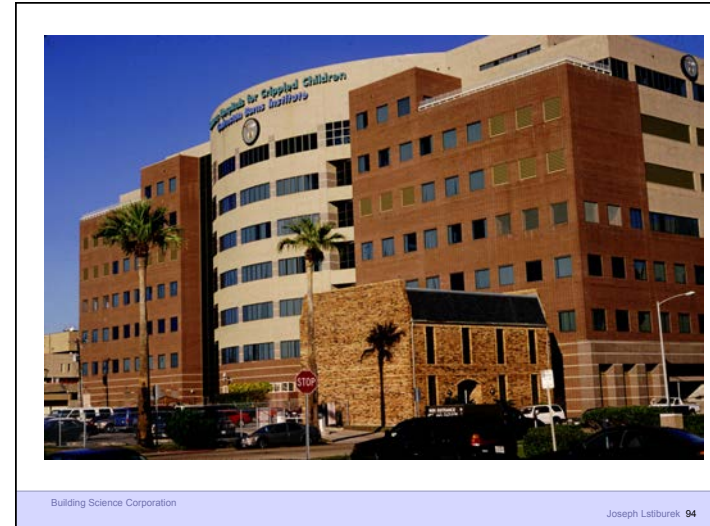
$$Q = A \cdot C (\Delta P)^n \quad \text{Kronval “an engineer”}$$

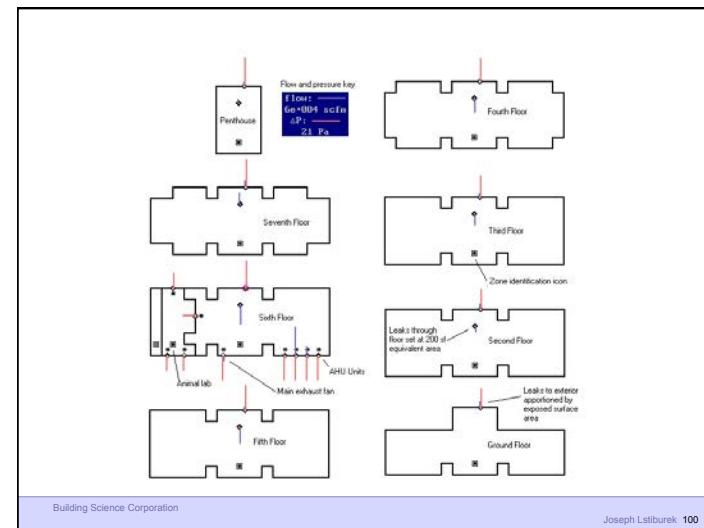
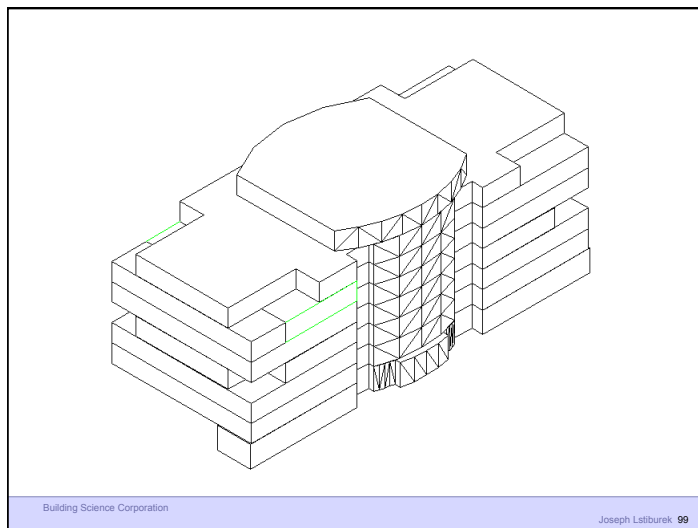
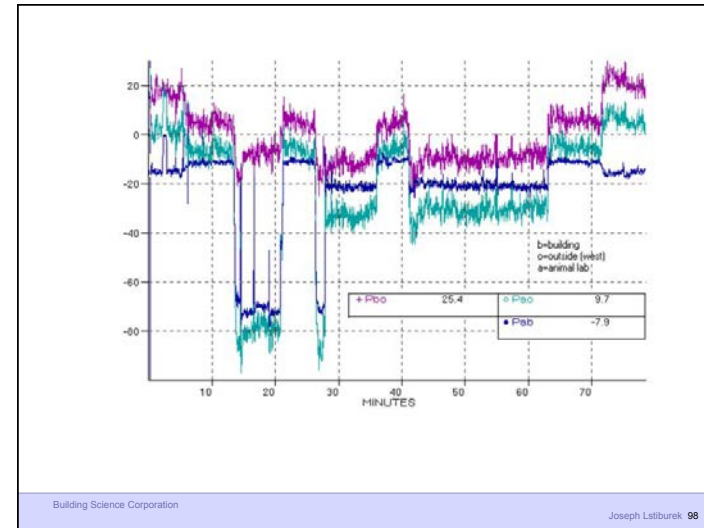
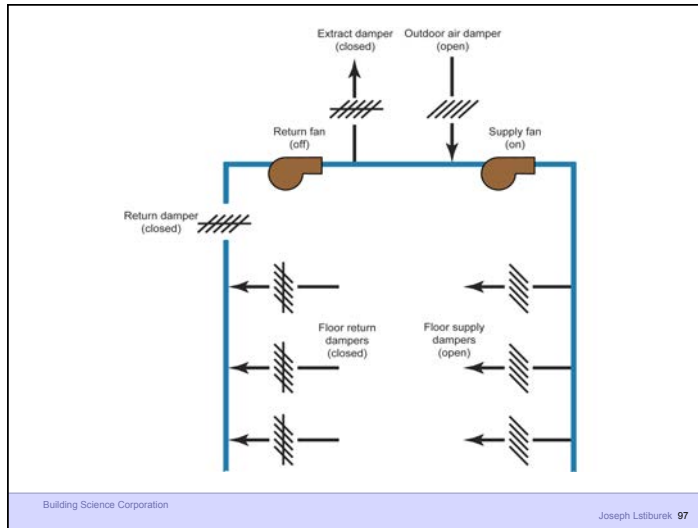
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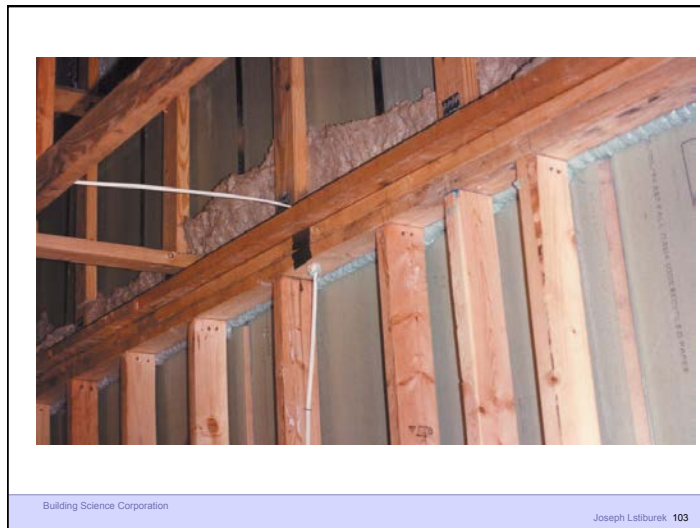
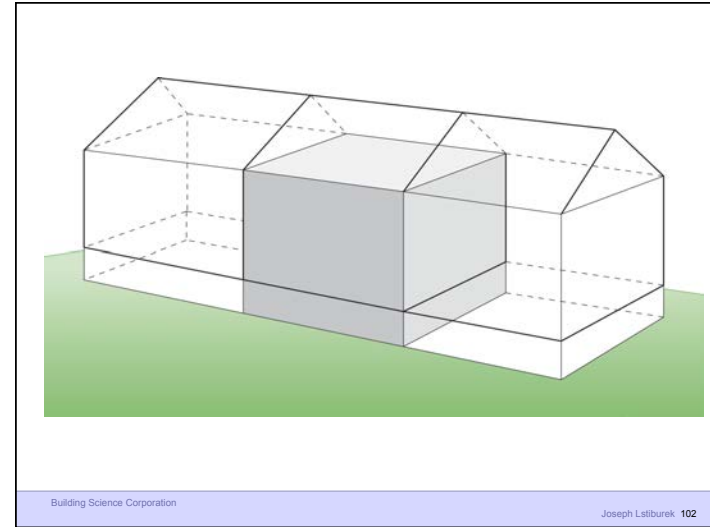
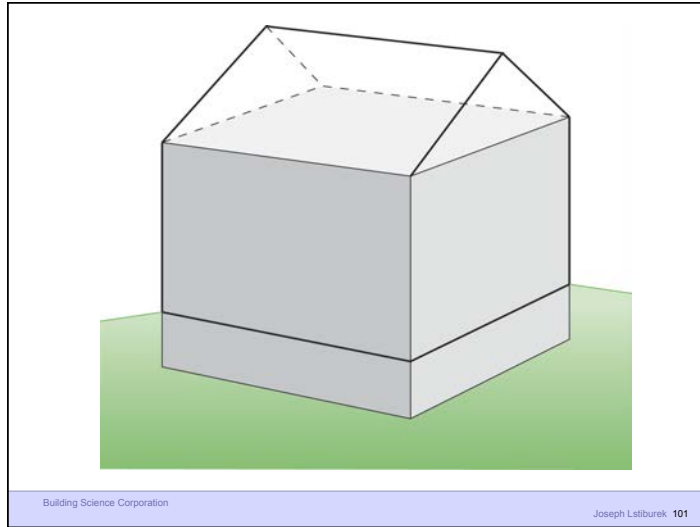


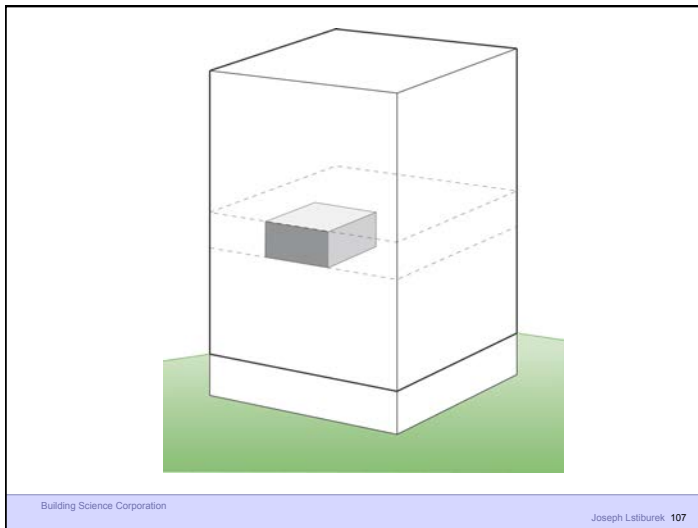
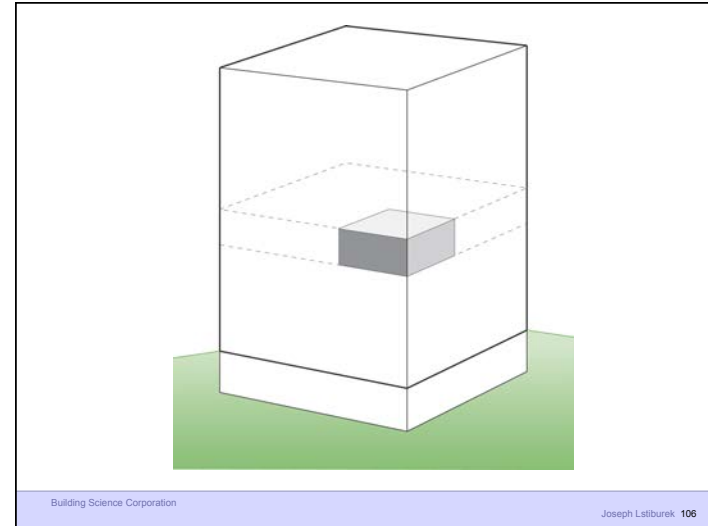
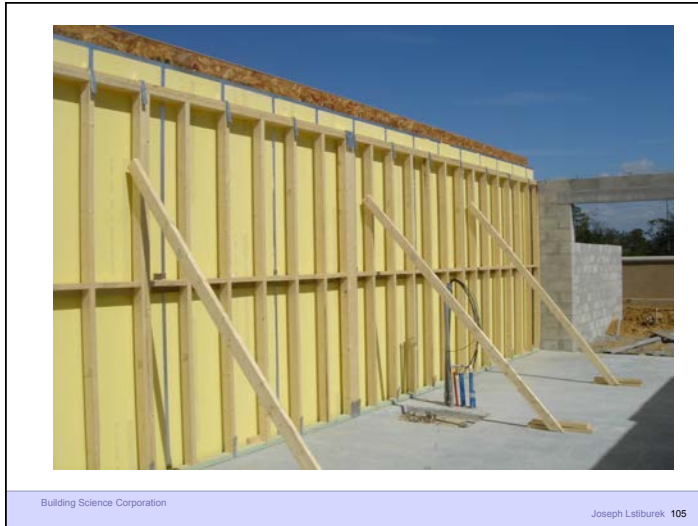












Build Tight - Ventilate Right

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Build Tight - Ventilate Right
How Tight?
What's Right?

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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

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

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Best

As Tight as Possible - with -
 Balanced Ventilation
 Energy Recovery
 Distribution
 Source Control - Spot exhaust ventilation
 Filtration
 Material selection

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Worst

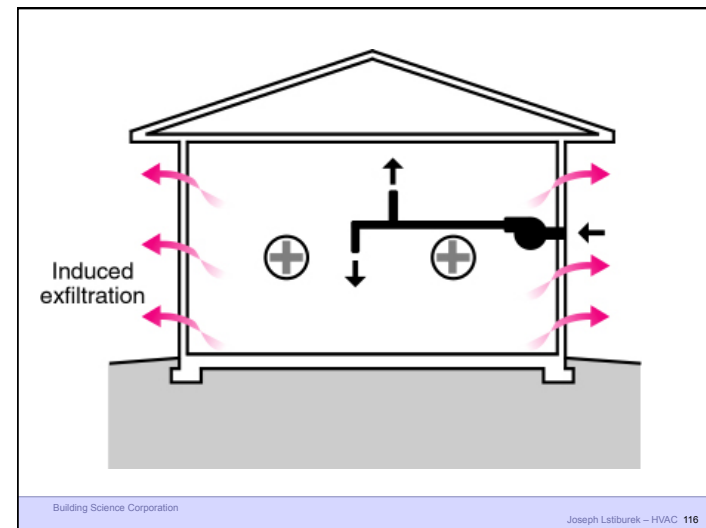
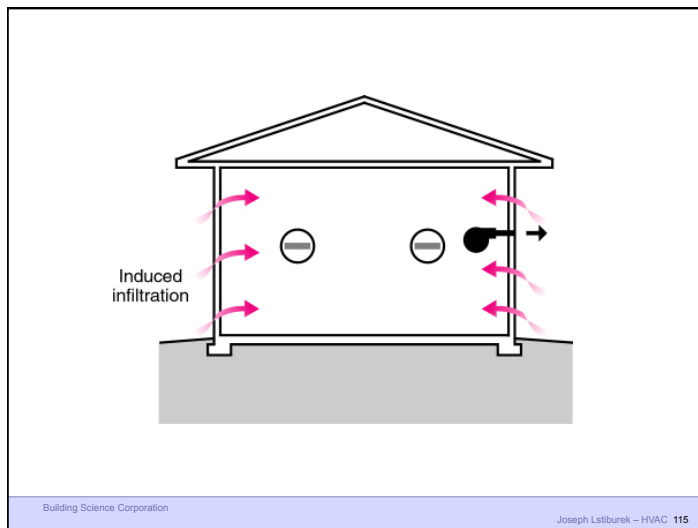
Leaky - with – Nothing
 Spot Ventilation in Bathroom/Kitchen
 Exhaust Ventilation – with – No Distribution

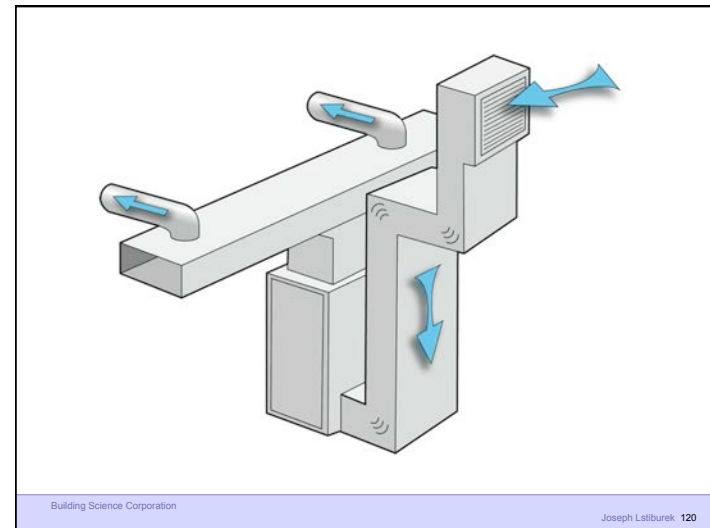
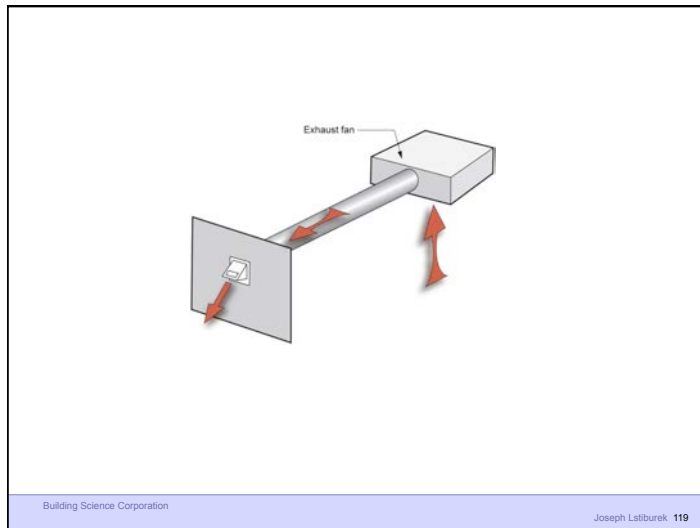
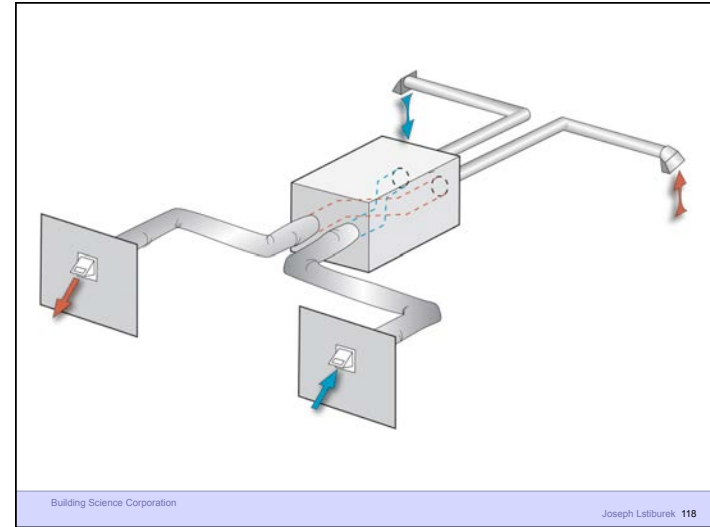
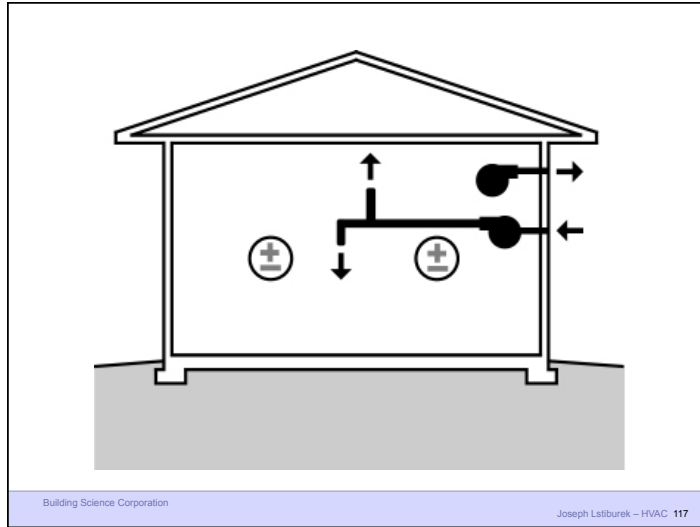
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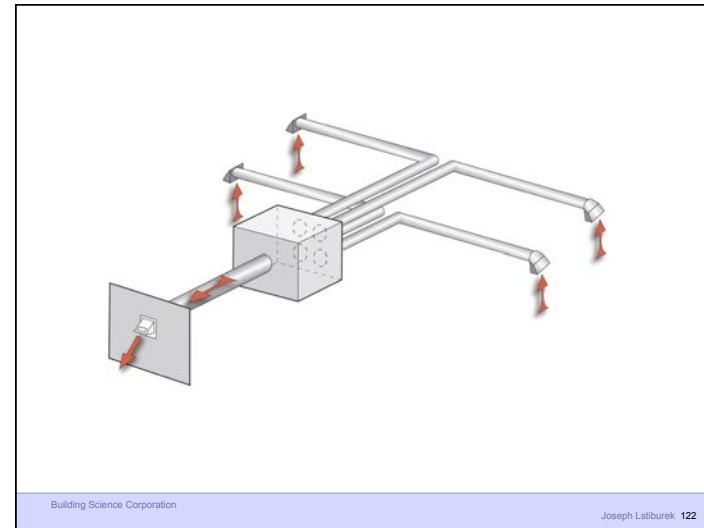
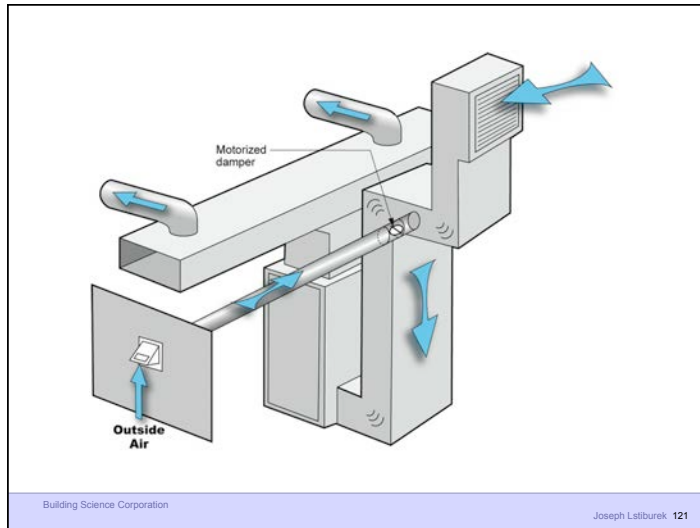
Three Types of Controlled Ventilation Systems

Exhaust Ventilation
 Supply Ventilation
 Balanced Ventilation

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Cost	Exhaust	\$150
	Exhaust + Dist	\$200
	Supply + Dist	\$200
	Spot + Ex/Sup + Dist	\$500
	Balanced/HRV	\$1,250

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The Cult of The Blower Door

Building Science Corporation Joseph Lstiburek 124



Building Science Corporation

Joseph Lstiburek 125

Blower Door Can't Get You The True ACH
On A Short Term Basis – Hour, Day, Week

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Joseph Lstiburek 126

Don't Know Where The Holes Are
Don't Know The Type of Holes
Don't Know The Pressure Across The Holes

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Joseph Lstiburek 127

Good For Long Term Average If No Big
Pressures

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Joseph Lstiburek 128

Good For Long Term Average If No Big Pressures
Good For Average Annual Energy Prediction

Building Science Corporation Joseph Lstiburek 129

Good For Long Term Average If No Big Pressures
Good For Average Annual Energy Prediction
Not Good For IAQ Unless You Accept Average Annual Exposure As A Metric

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Cost of Addressing the Problems Are Less Than The Cost of Testing To See If You Have Problems

Building Science Corporation Joseph Lstiburek 131

Combustion Safety
Indoor Contaminants
Comfort
Energy

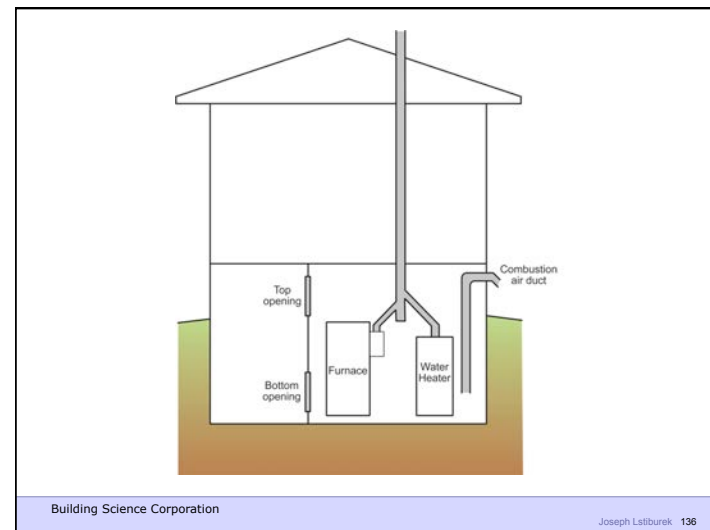
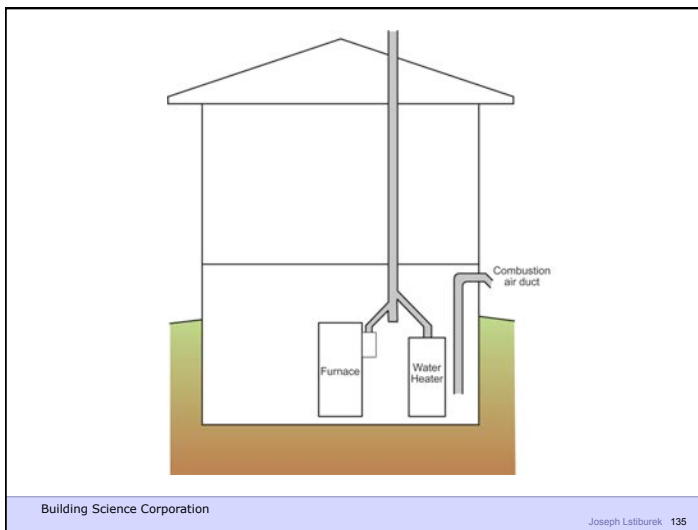
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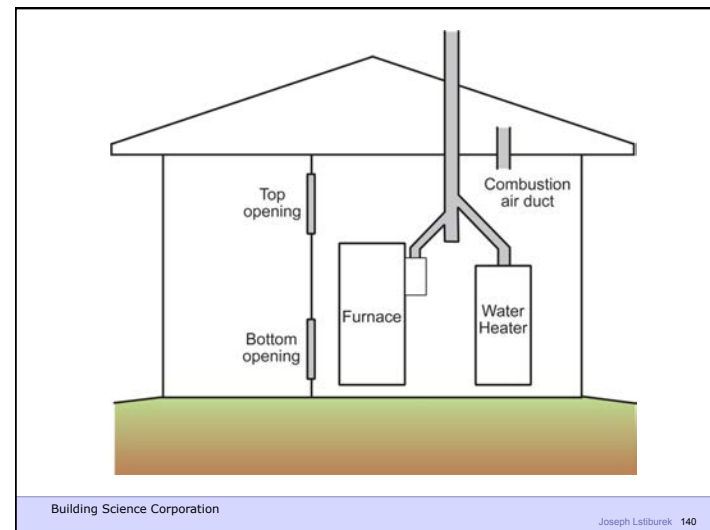
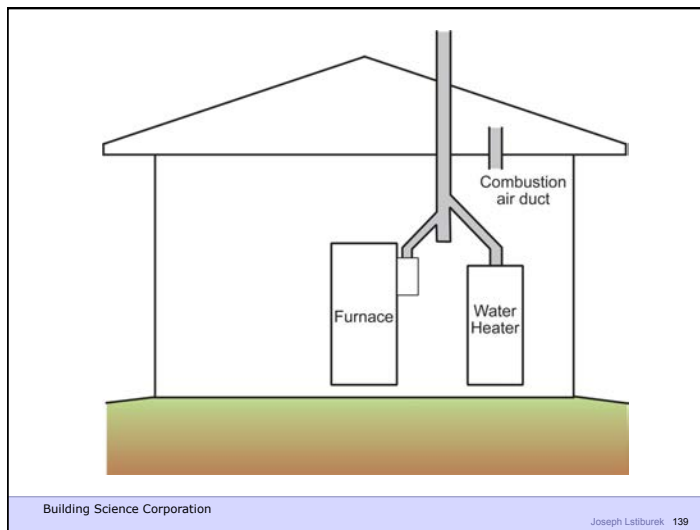
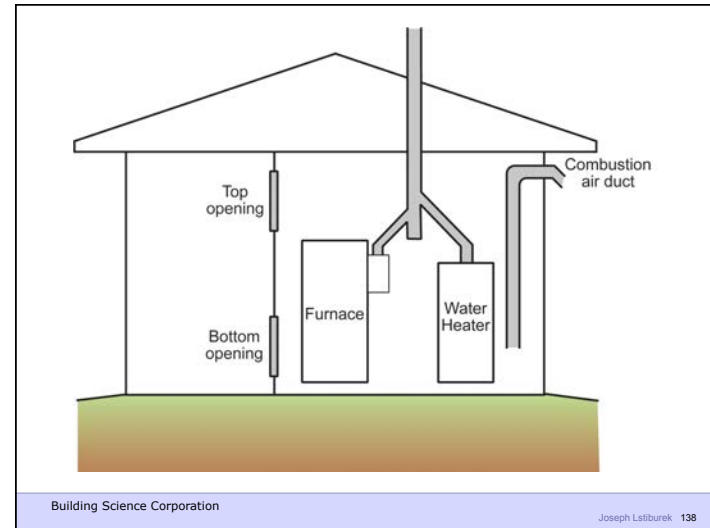
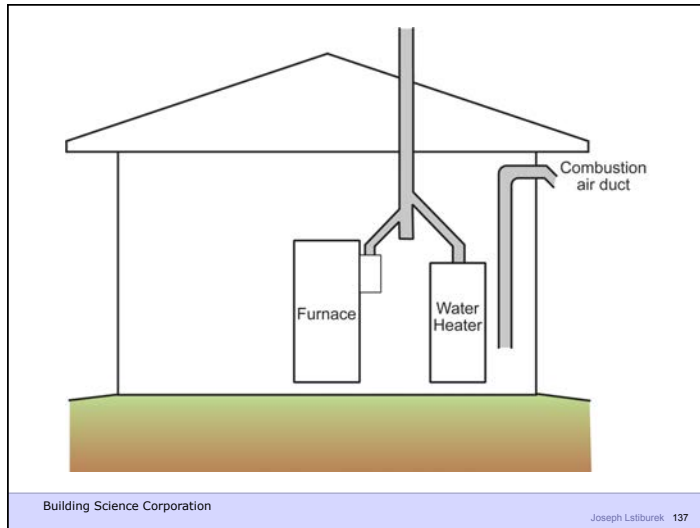
Bring Combustion Appliances Up To Code
Control Pressures
Install Controlled Ventilation
Get Rid of Big Holes
Insulate

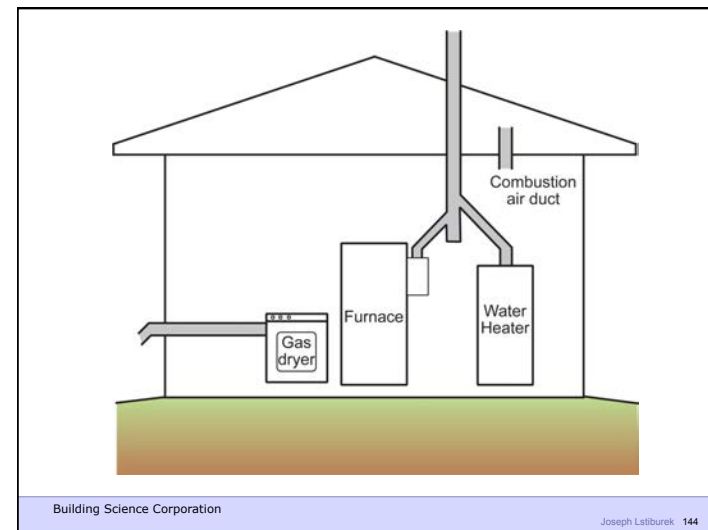
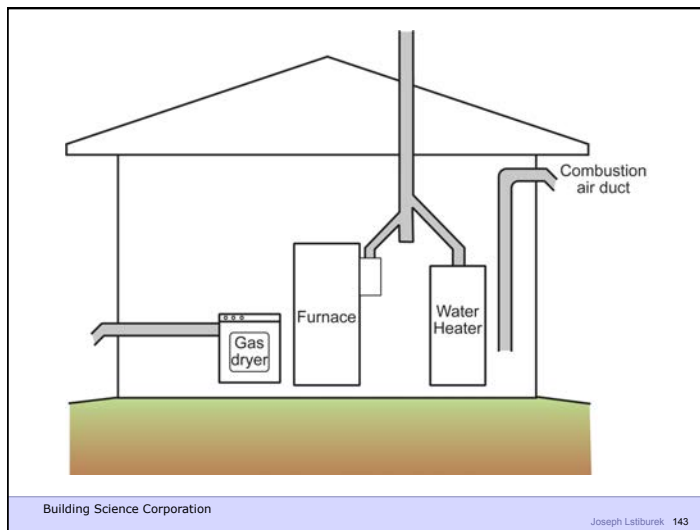
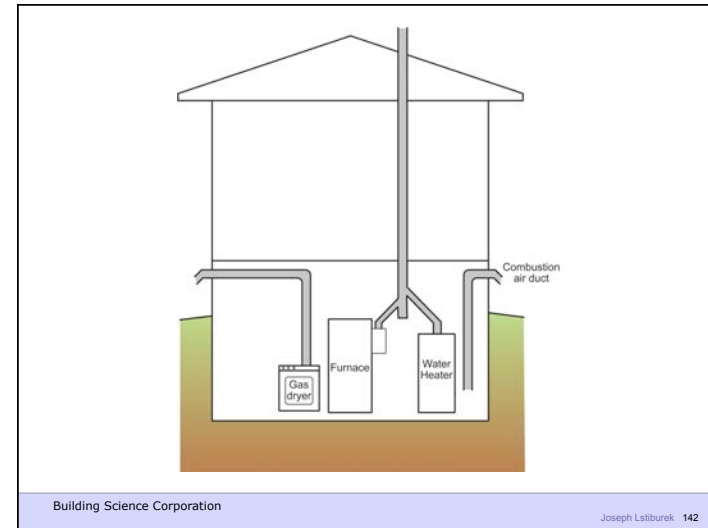
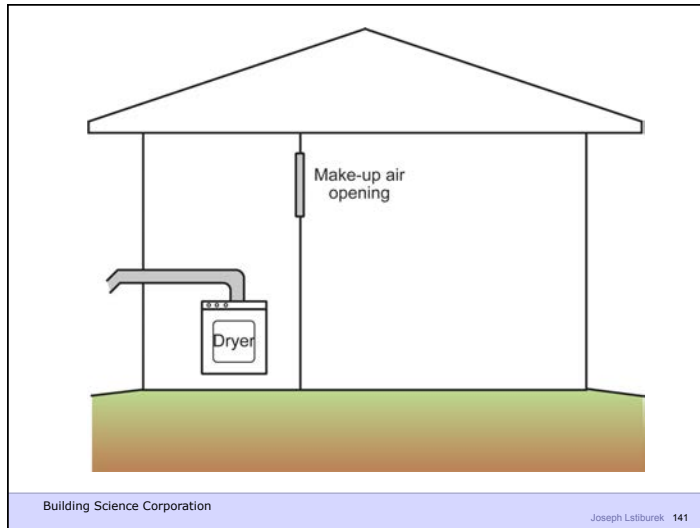
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Code Compliant Combustion Air

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Sealed Combustion Appliances

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Joseph Lstiburek 146



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Joseph Lstiburek 147

Control Pressures

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Joseph Lstiburek 148

