

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

Building Science

Airflow In Buildings I

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Stuff That Is Not Particularly Useful But Studied and Researched to Death

Stuff That Is Very Useful but Ignored by the Research Community

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Stuff That Is Not Particularly Useful But Studied and Researched to Death

“this is called Physics”

Stuff That Is Very Useful but Ignored by the Research Community

“this is called Engineering”

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“this is a lie”

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

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

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

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

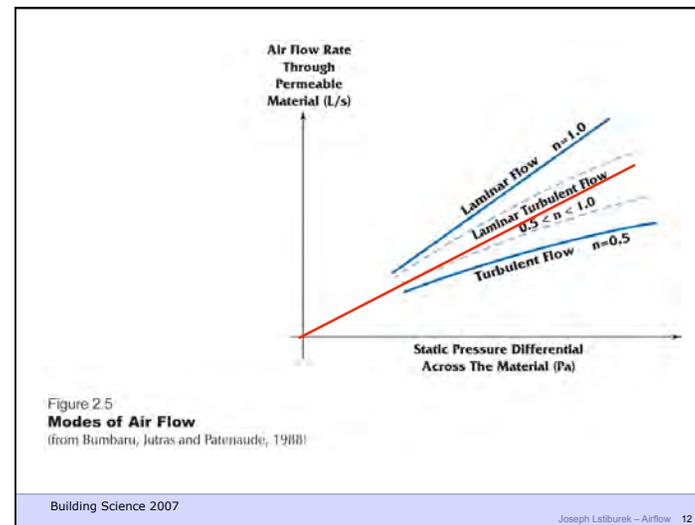
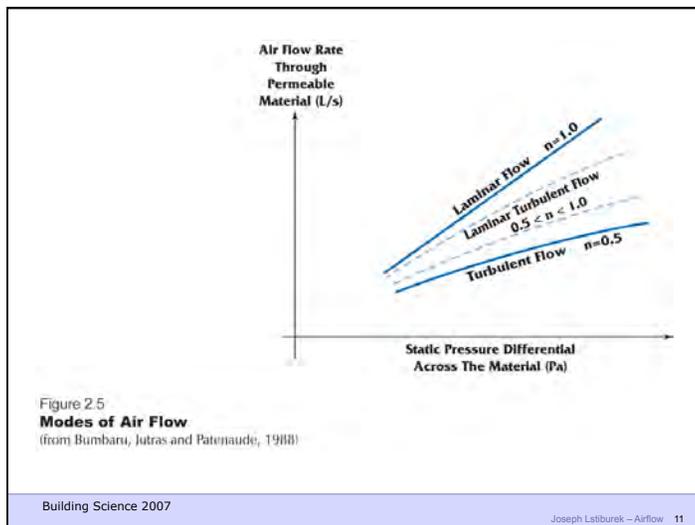
$$Q = C_K \frac{\rho}{\mu} (\Delta P) \quad \text{Darcy}$$

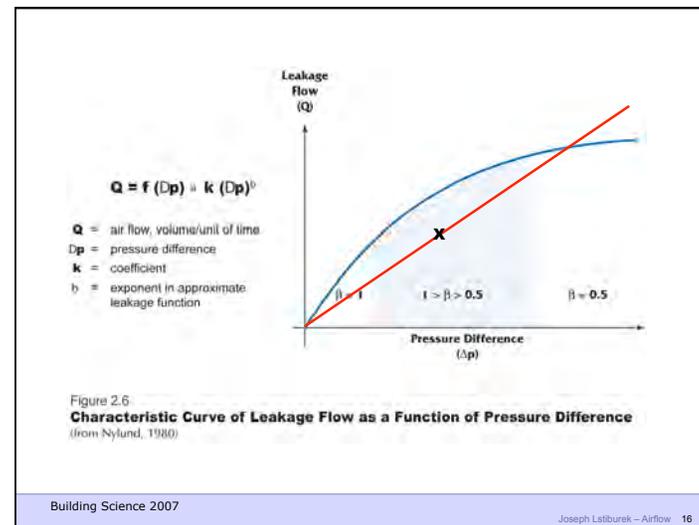
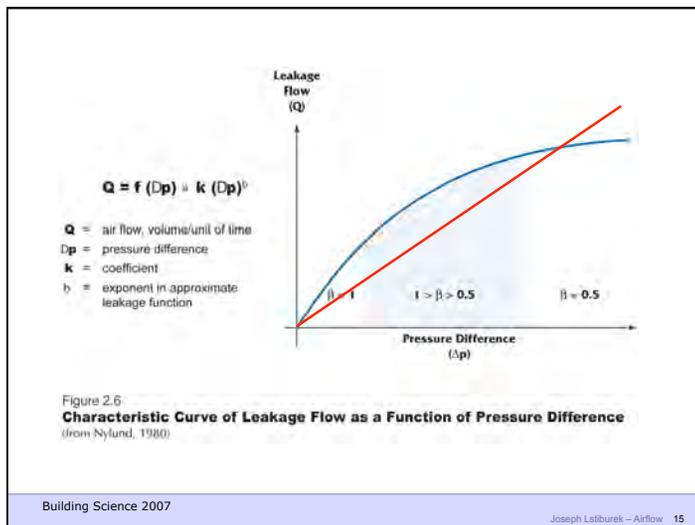
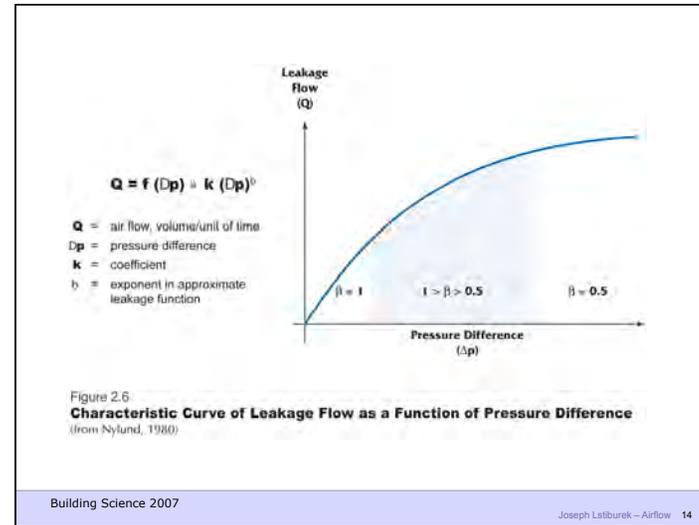
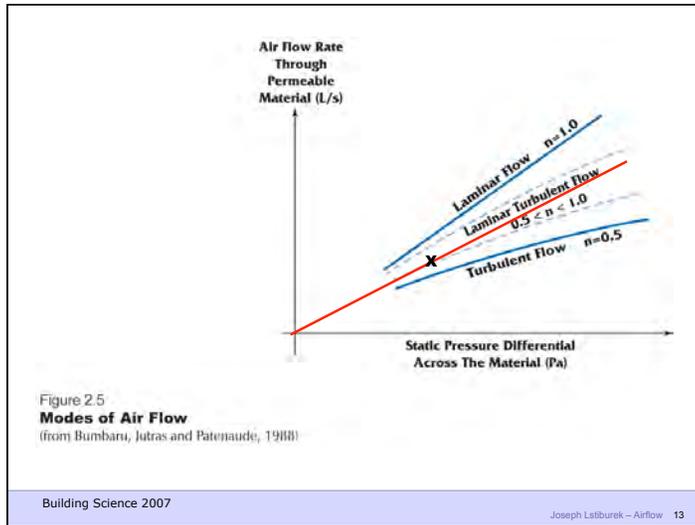
$$Q = A \cdot C (\Delta P)^{\frac{1}{2}}$$

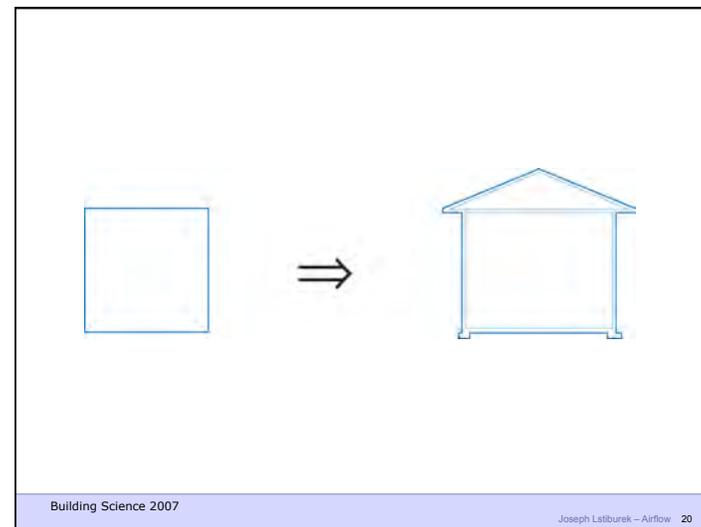
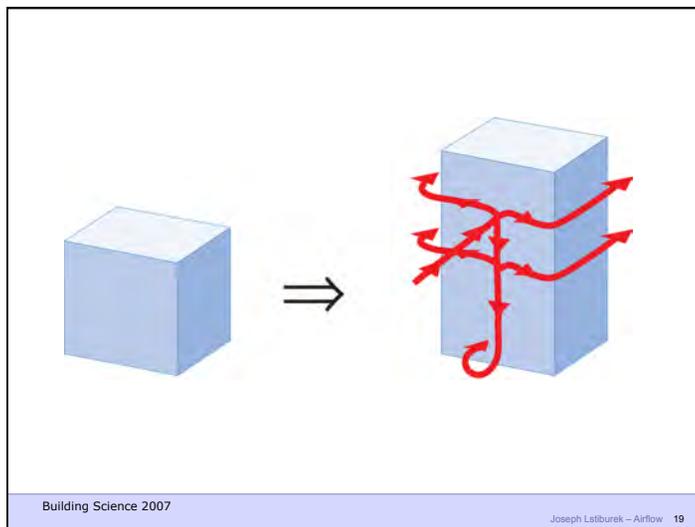
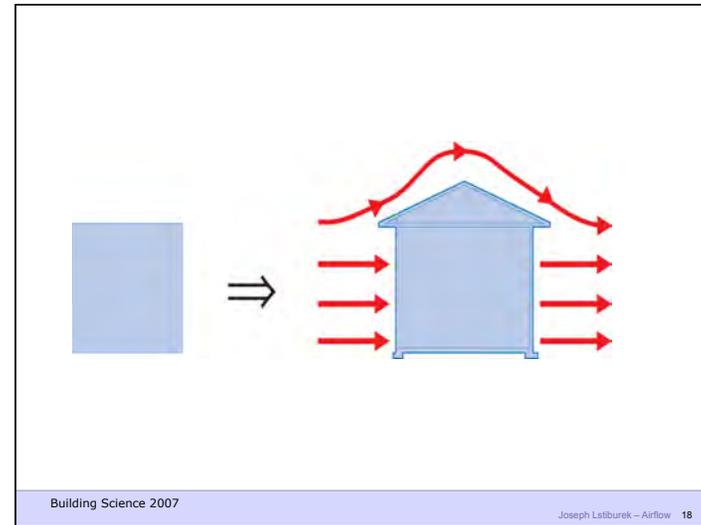
$$Q = C (\Delta P)$$

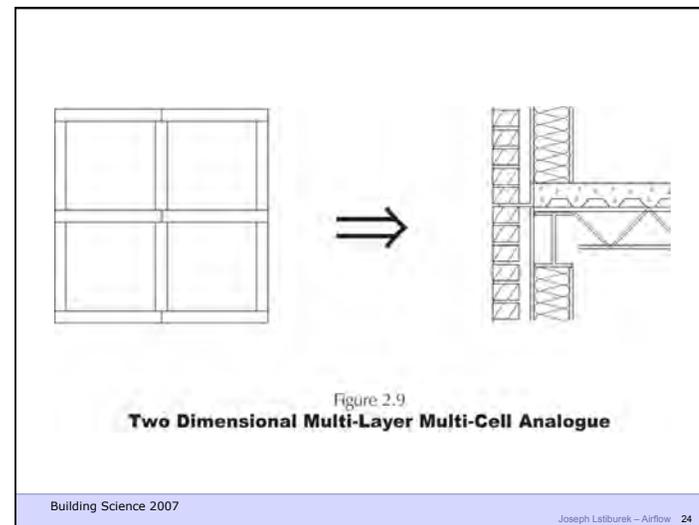
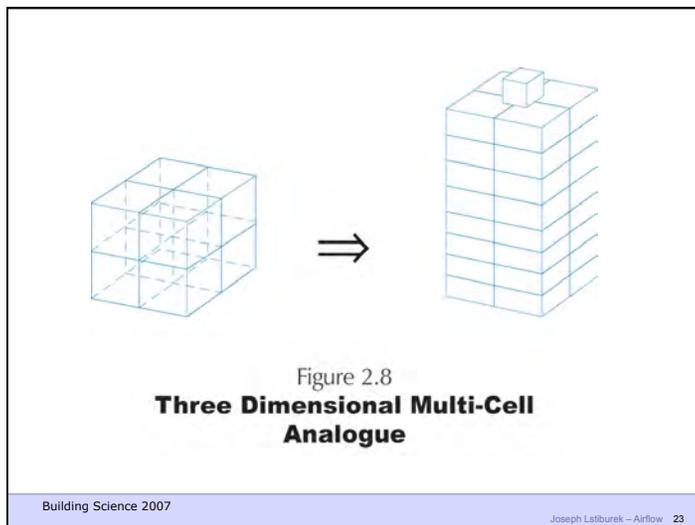
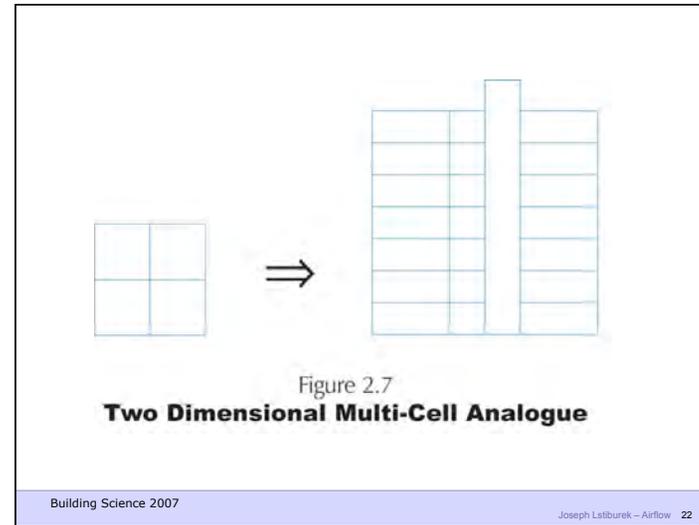
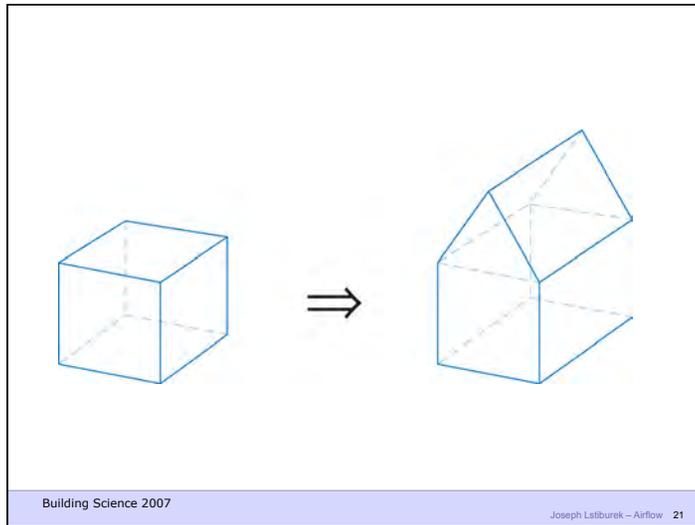
$$Q = A \cdot C (\Delta P)^n \quad \text{Kronval "an engineer"}$$

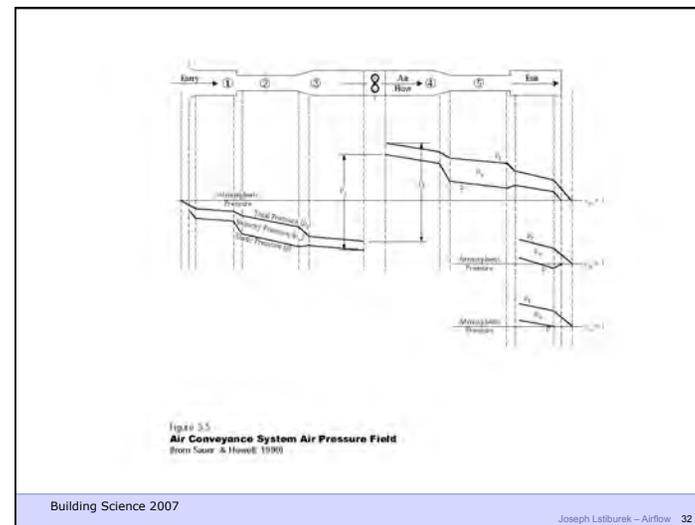
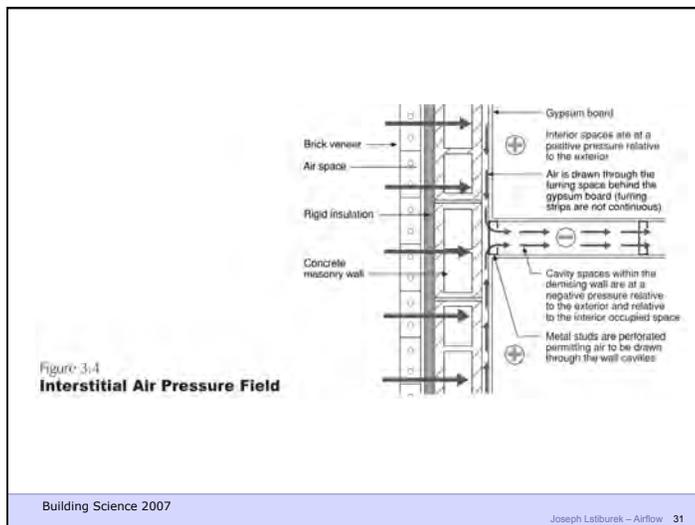
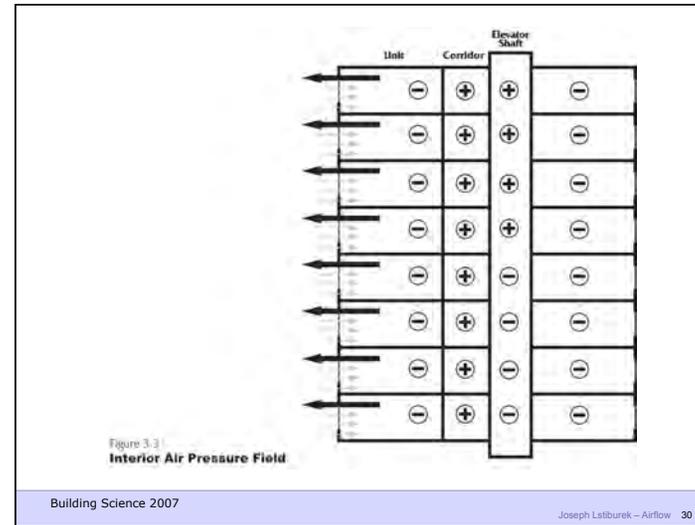
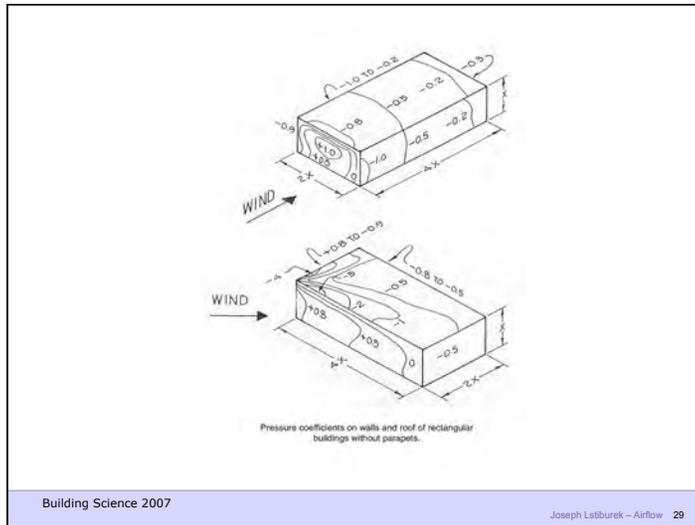
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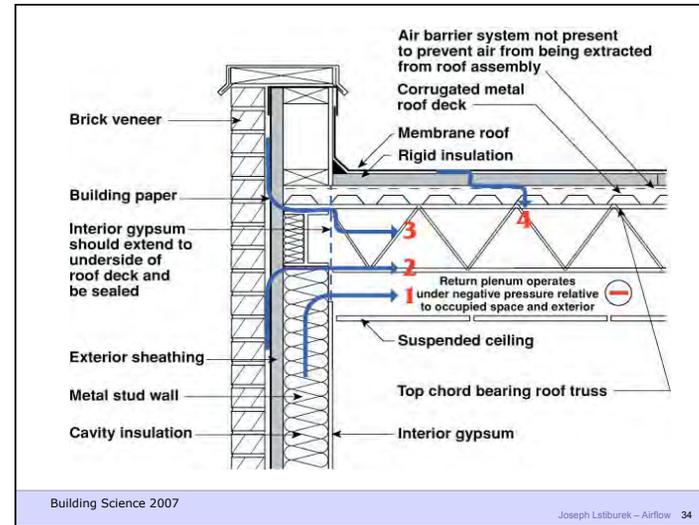
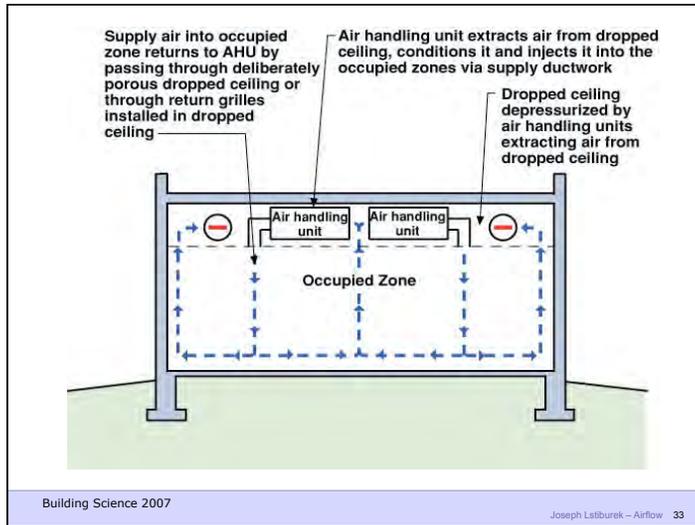


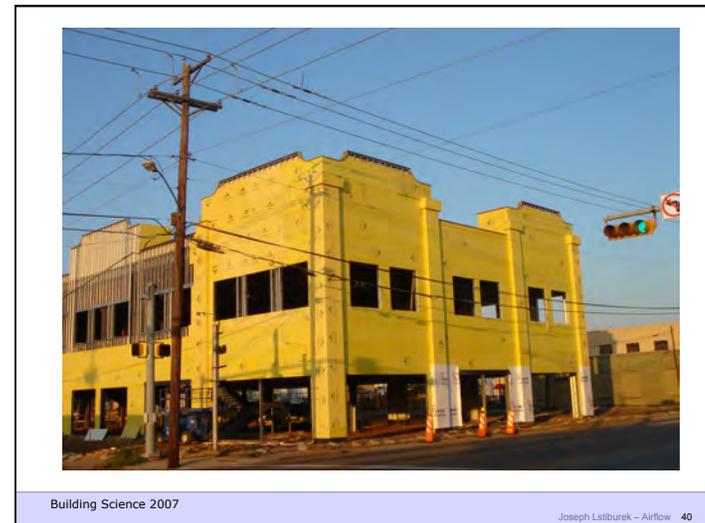
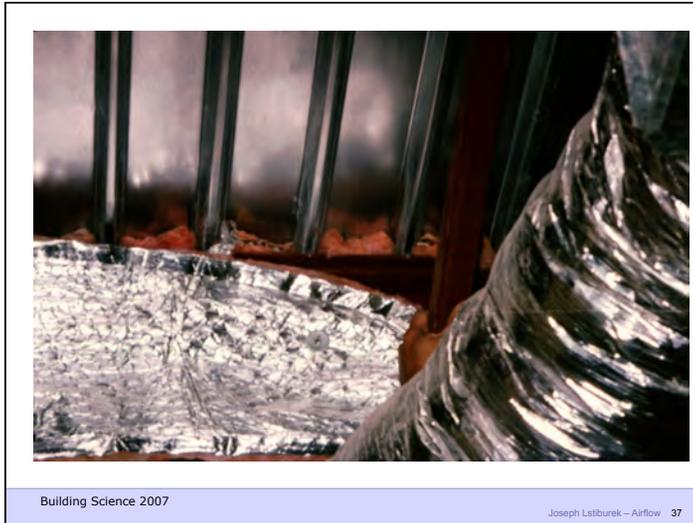


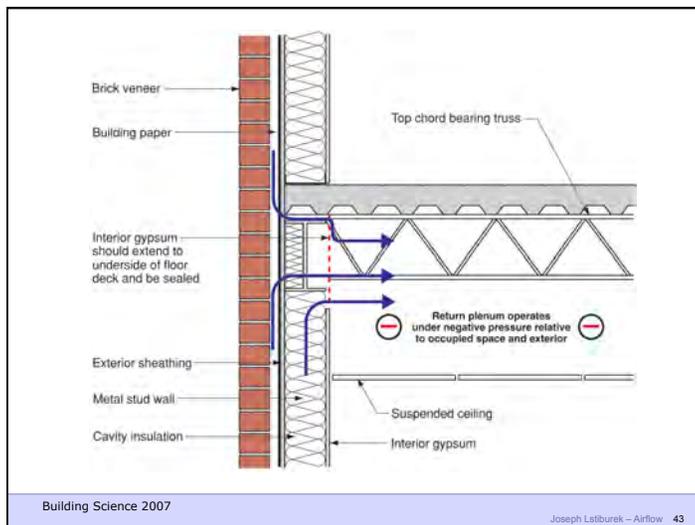
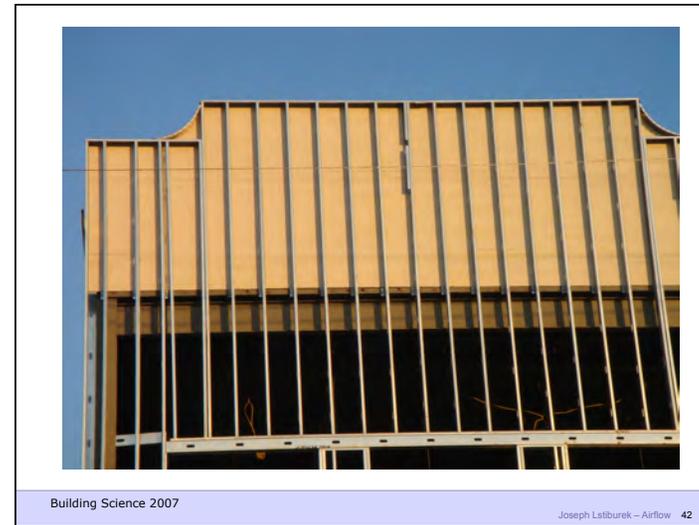
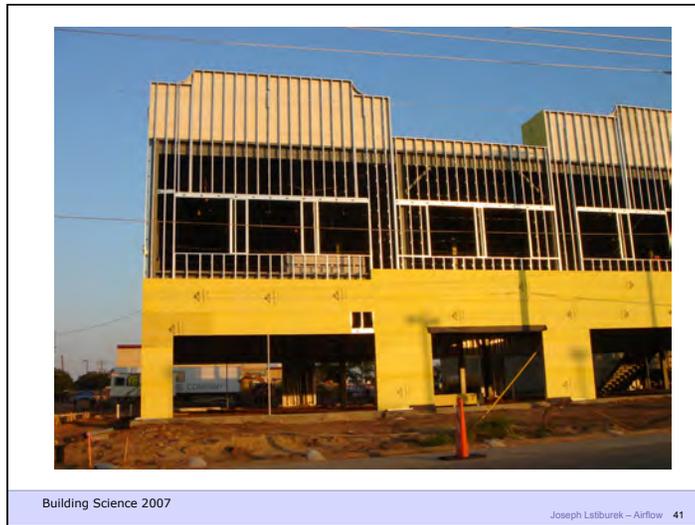


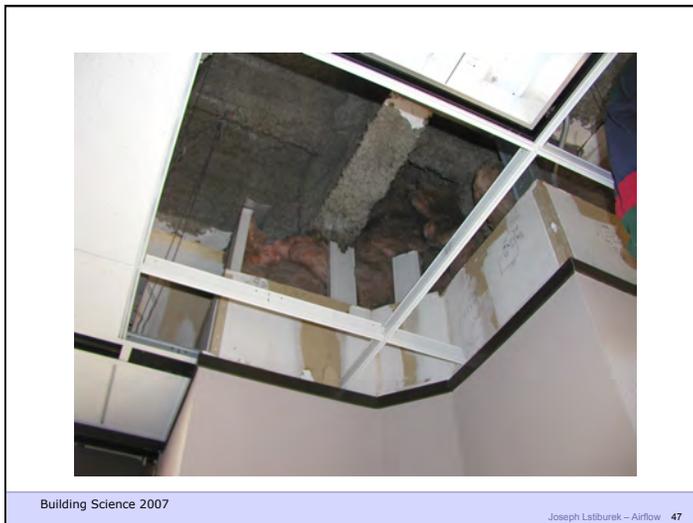
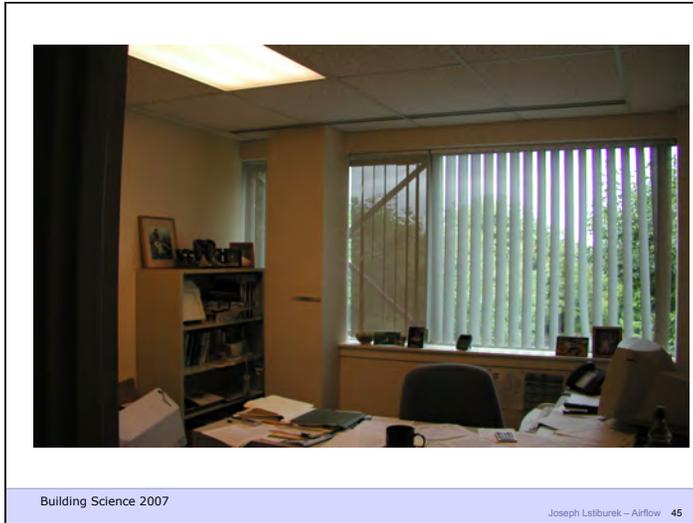


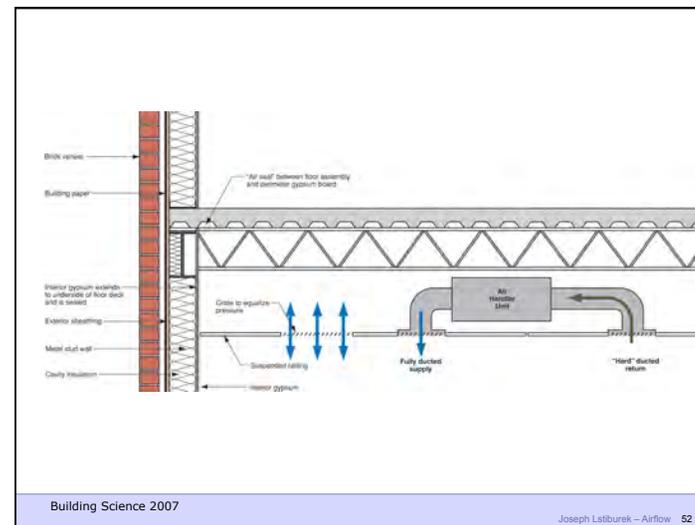
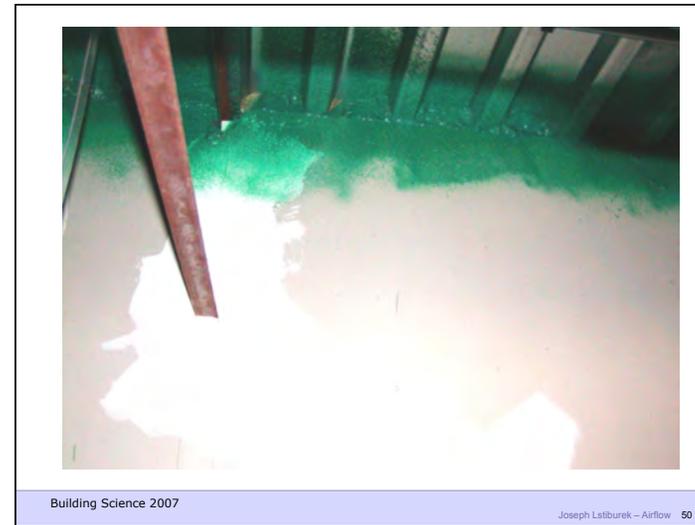


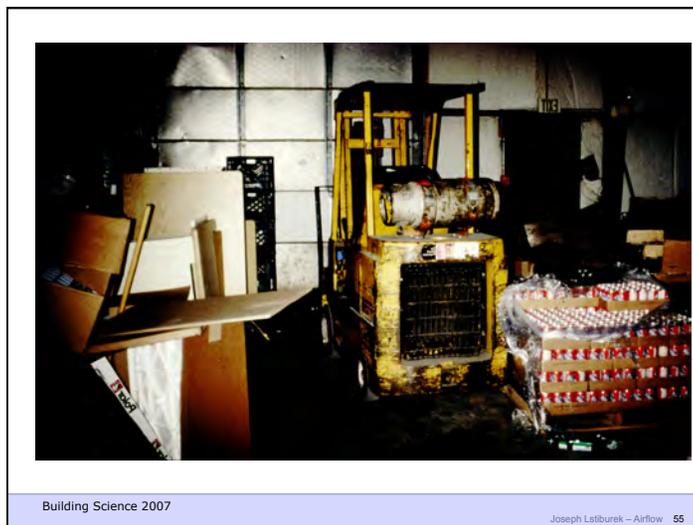
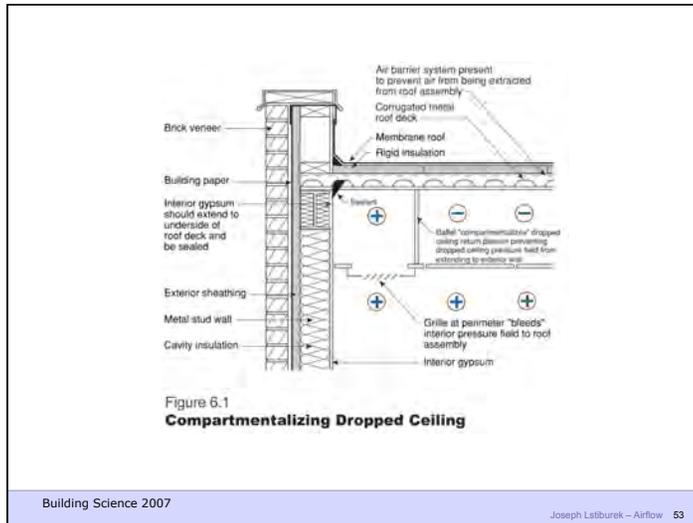


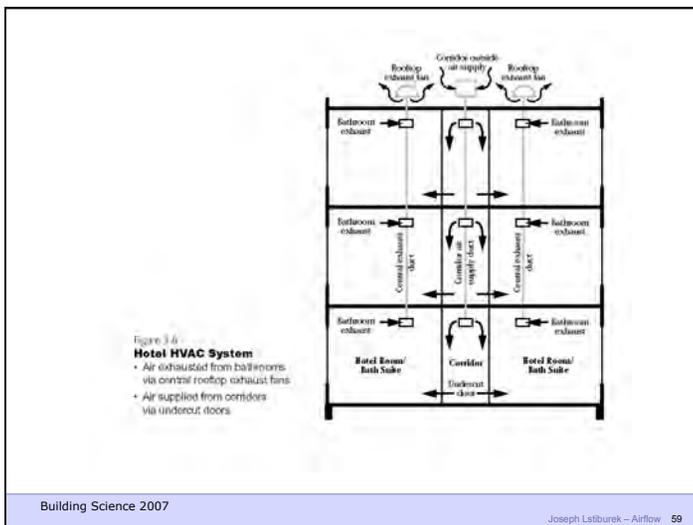
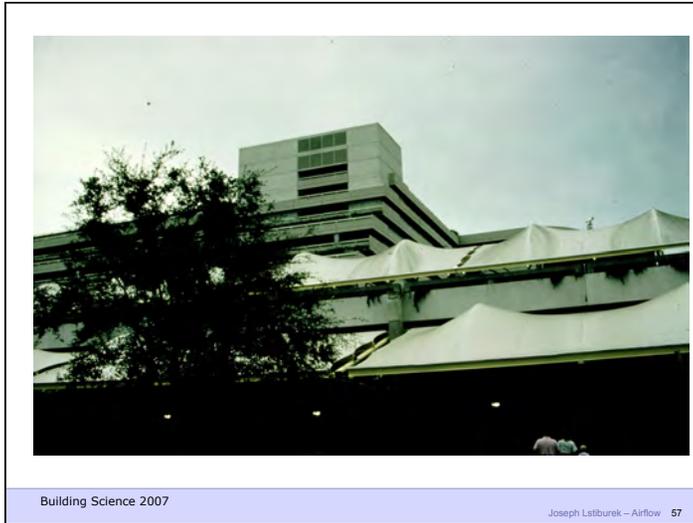


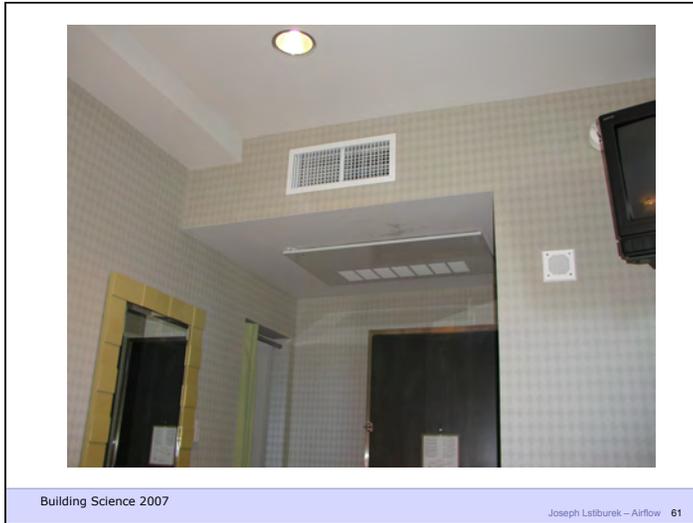






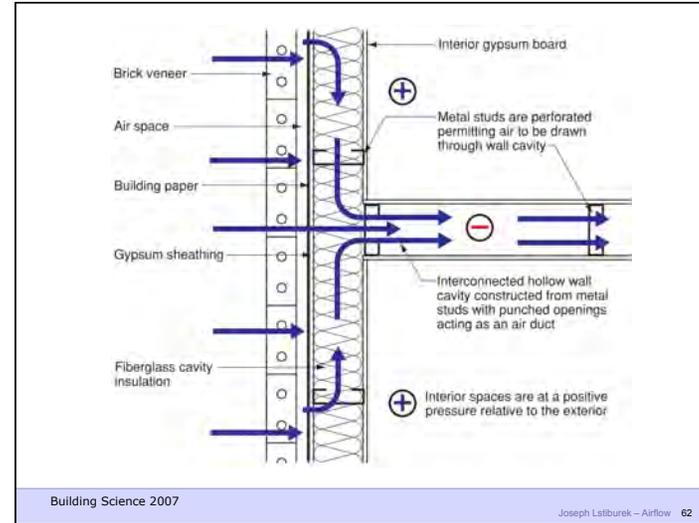






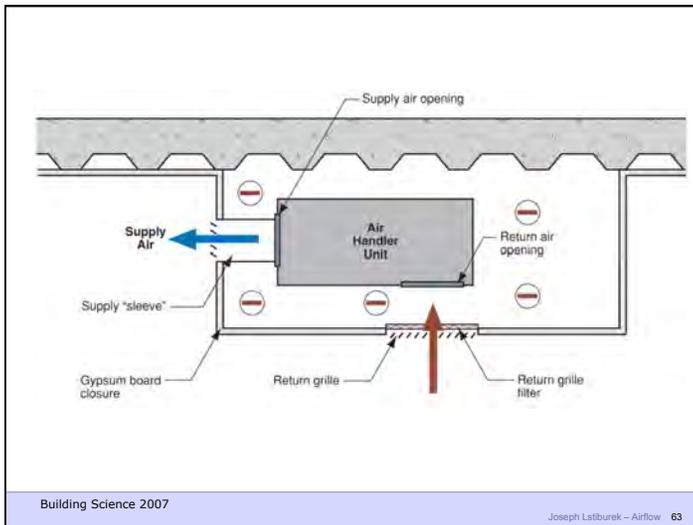
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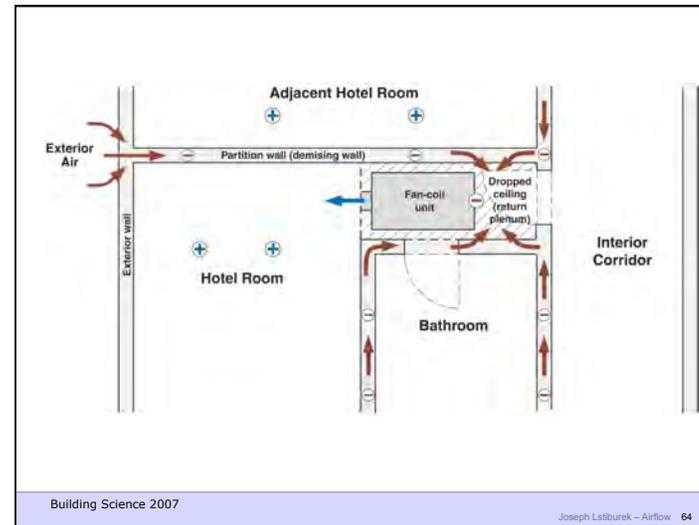
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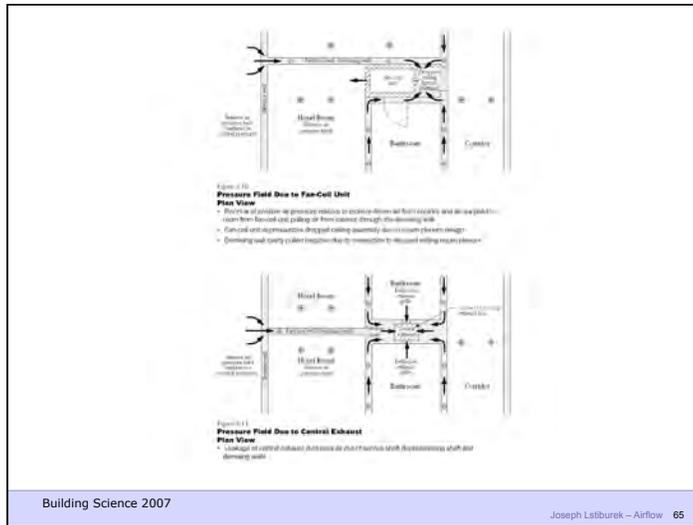
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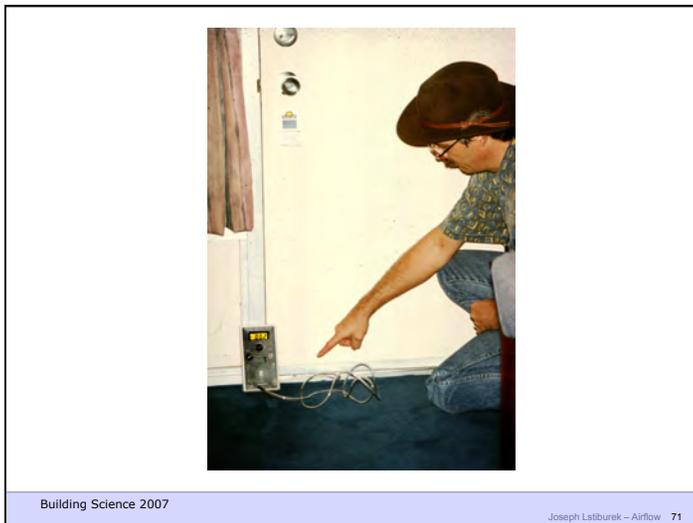
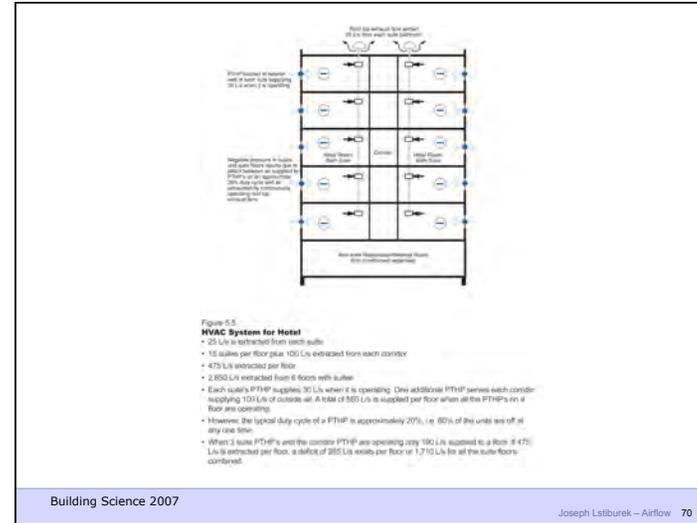
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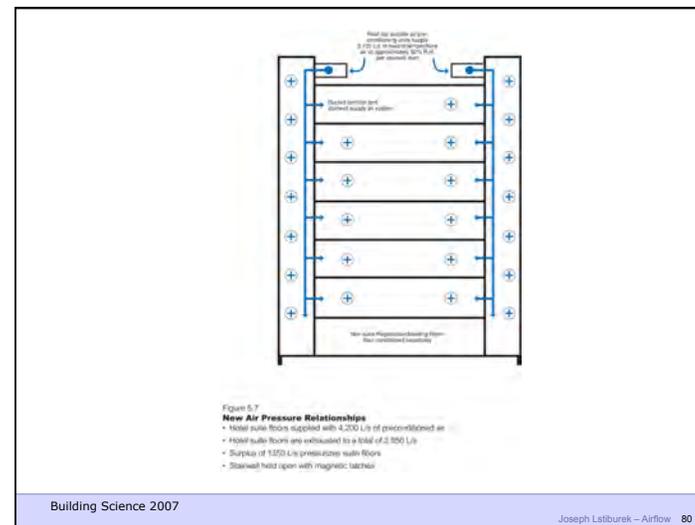
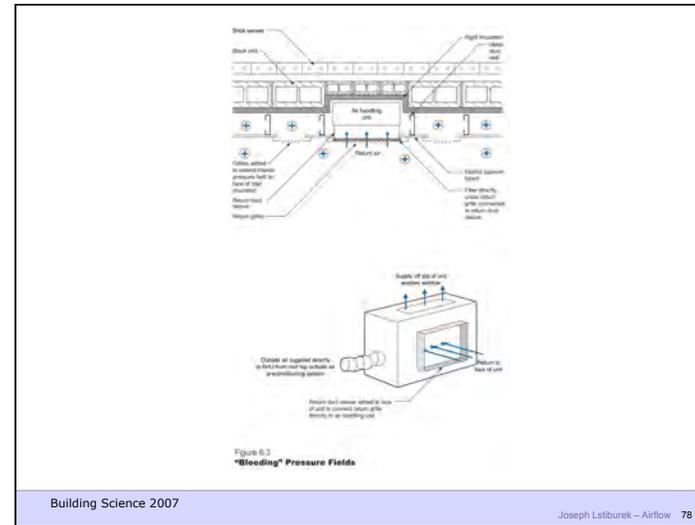
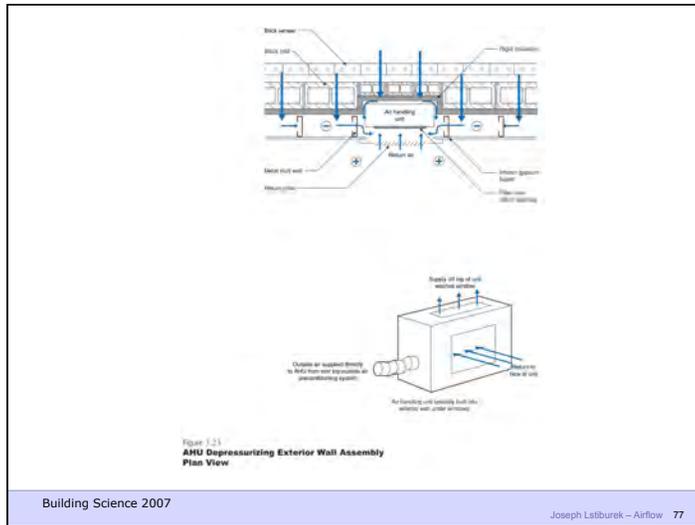
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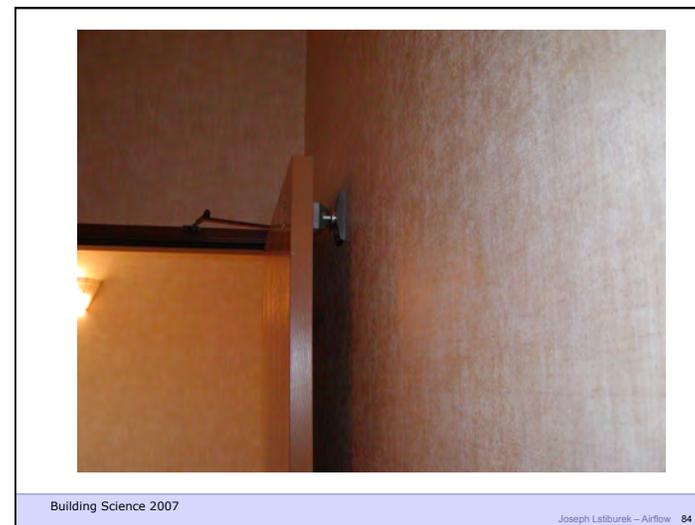
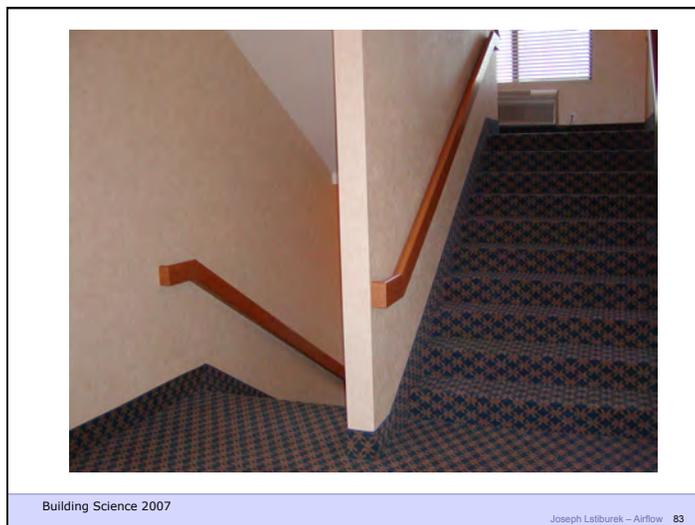
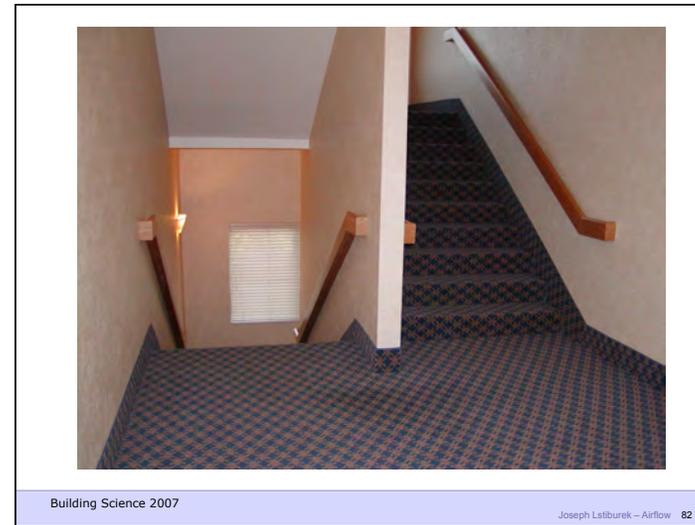
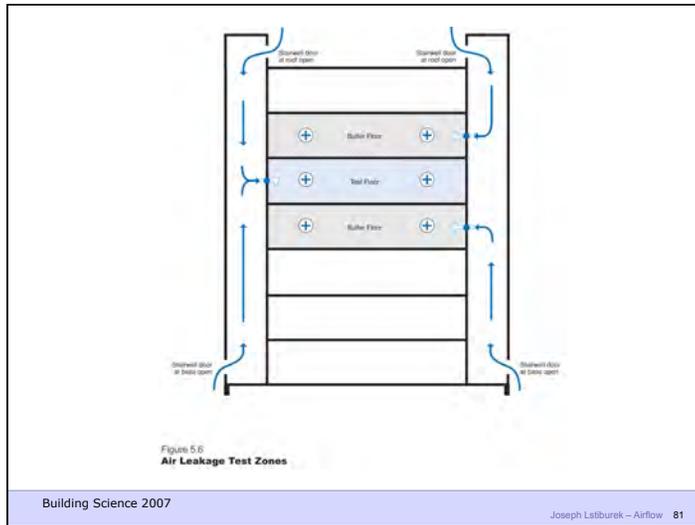
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Smoke Extraction System
Smoke Infiltration System

Figure 6.9
Smoke Extraction System

- If hotel is pressurized 25 Pa and smoke flow/flows are depressurized 25 Pa, net exhaust smoke control pressure differential is greater than the design specified 25 Pa.
- Approximately 1,000 L/s per floor is required to pressurize each floor 25 Pa relative to the exterior or approximately 6,000 L/s to pressurize the 6 hotel floors with suites when the roof top exhaust systems are not operating.

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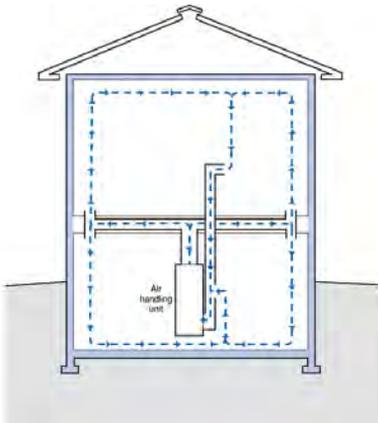
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Figure 3.12
Ductwork and Air Handlers in Basements

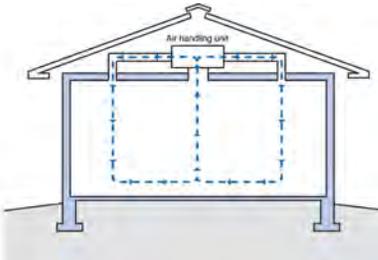
- No air pressure differences result in a house with an air handler and ductwork located in a basement if there are no leaks in the supply ducts, the return ducts or the air handler and if the amount of air delivered to each room equals the amount removed



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Figure 3.13
Ductwork and Air Handlers in Vented Attics

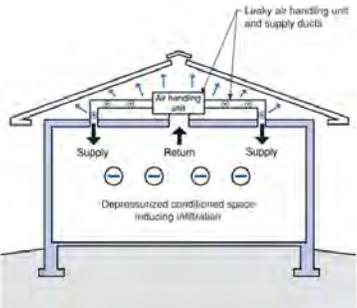
- No air pressure differences result in a house with an air handler and ductwork located in a vented attic if there are no leaks in the supply ducts, the return ducts or the air handler and if the amount of air delivered to each room equals the amount removed



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Figure 3.15
Leaky Ductwork and Air Handlers in Vented Attics

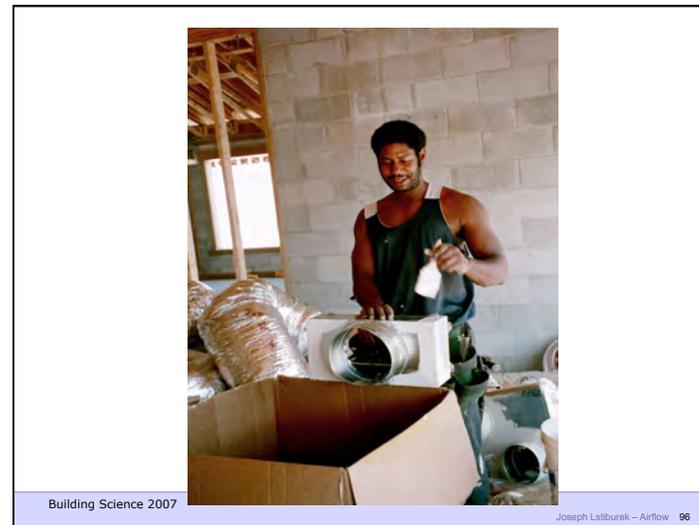
- Supply ductwork and air handler leakage is typically 20% or more of the flow through the system



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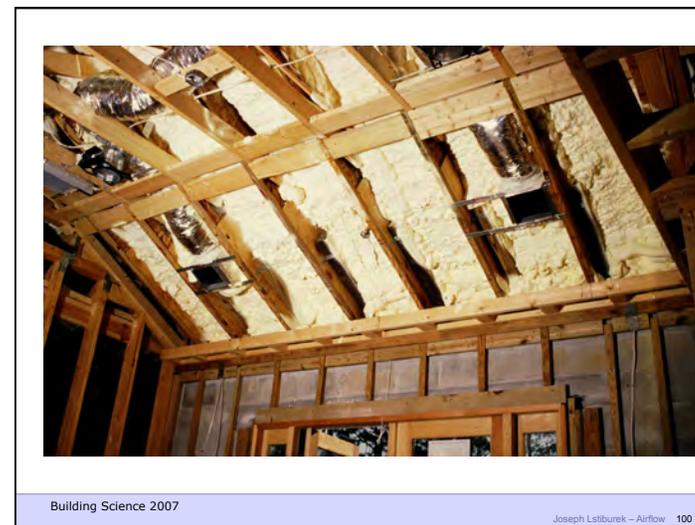
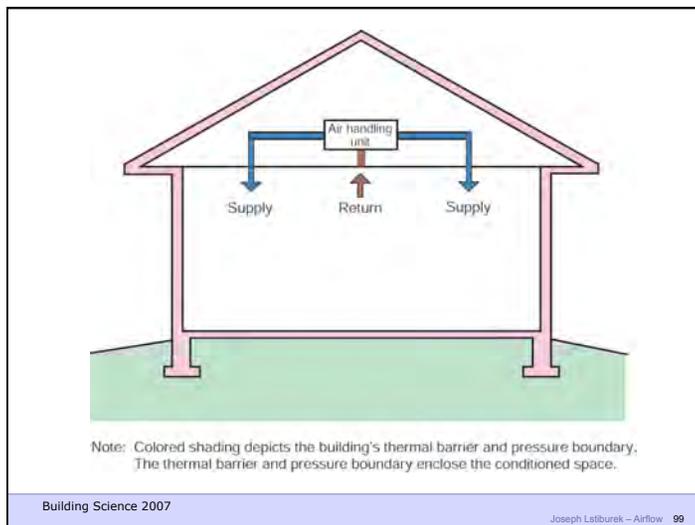
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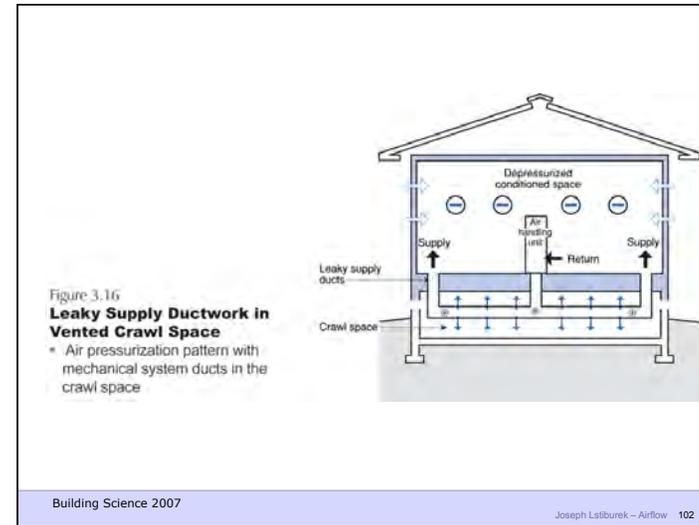
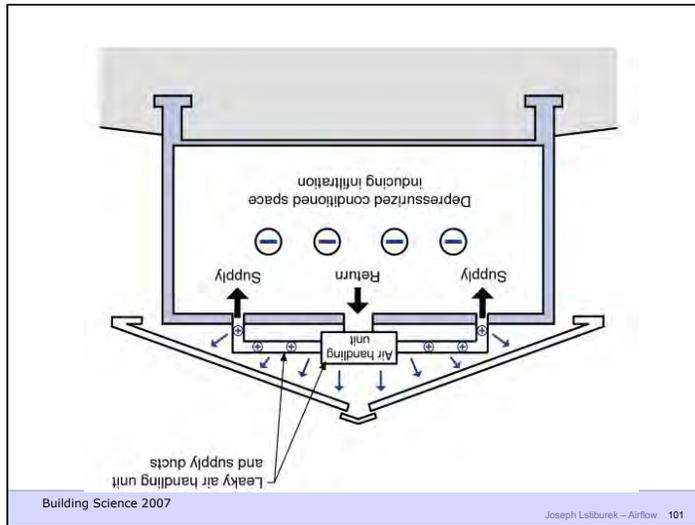




Duct Leakage Should Be Less Than 5% of Rated Flow As Tested By Pressurization To 25 Pascals

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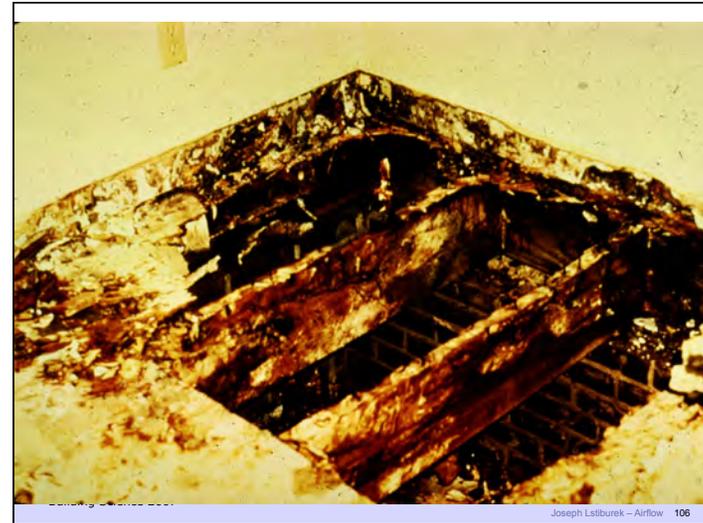


Figure 3.14
Leaky Ductwork and Air Handlers in Basements
 • Air pressurization patterns in a house with leaky ductwork in the basement

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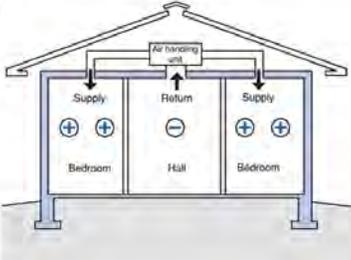
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 Joseph Lstiburek – Airflow 111

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 Joseph Lstiburek – Airflow 112

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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Grille located high in wall on bedroom side to avoid blockage by furniture

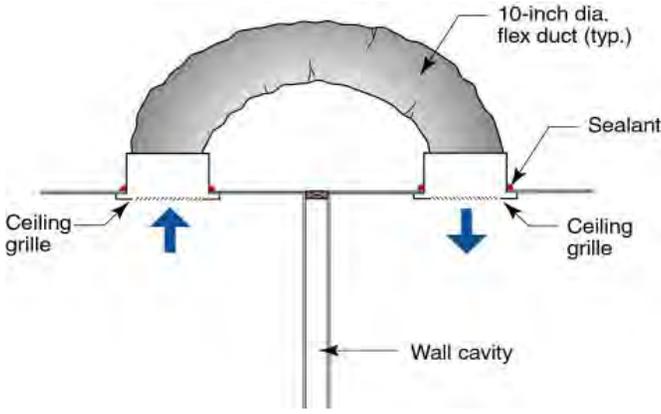
Cavity is sealed tight, drywall glued to studs and plates on both sides

Grille located low in wall on hallway side

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10-inch dia. flex duct (typ.)

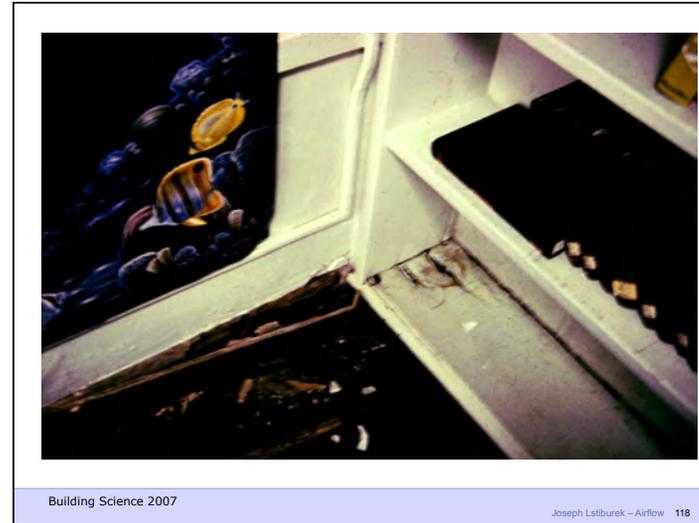
Sealant

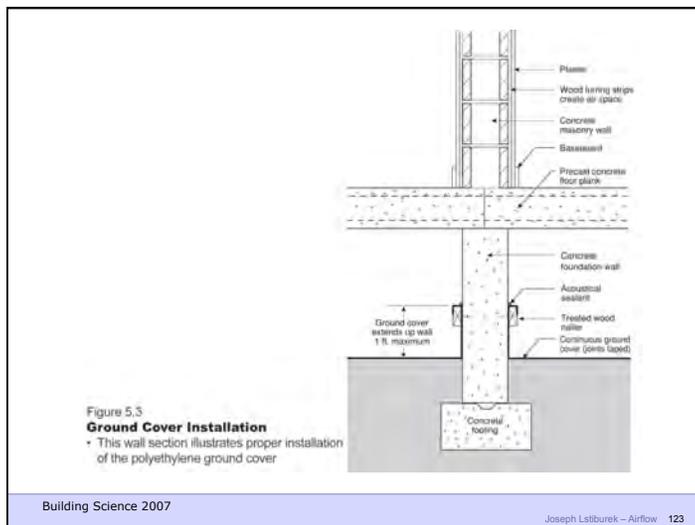
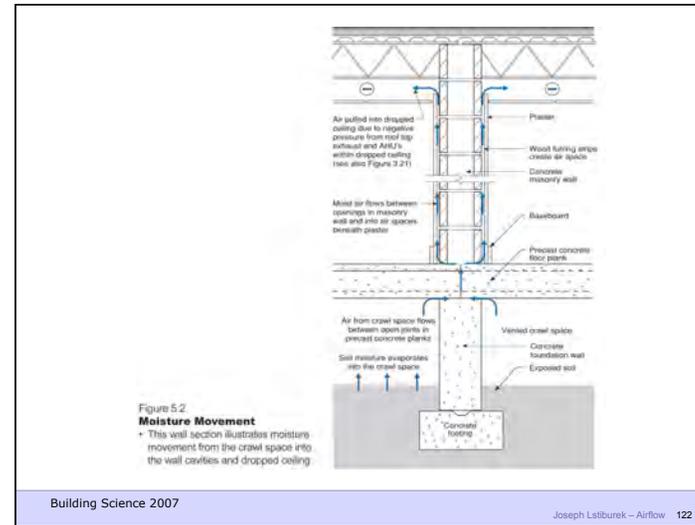
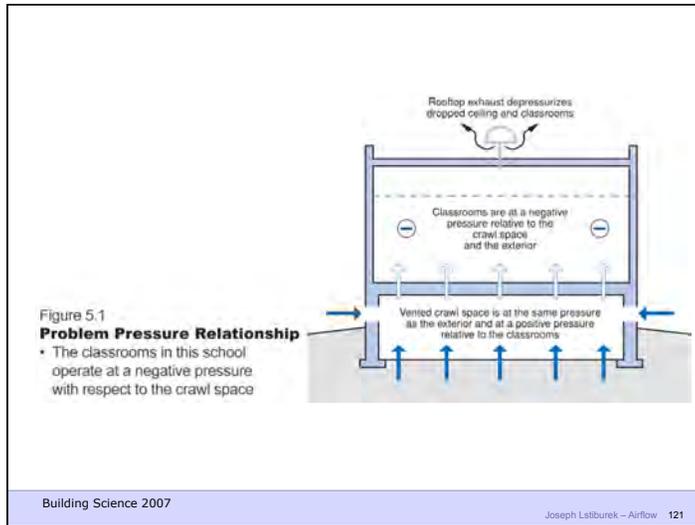
Ceiling grille

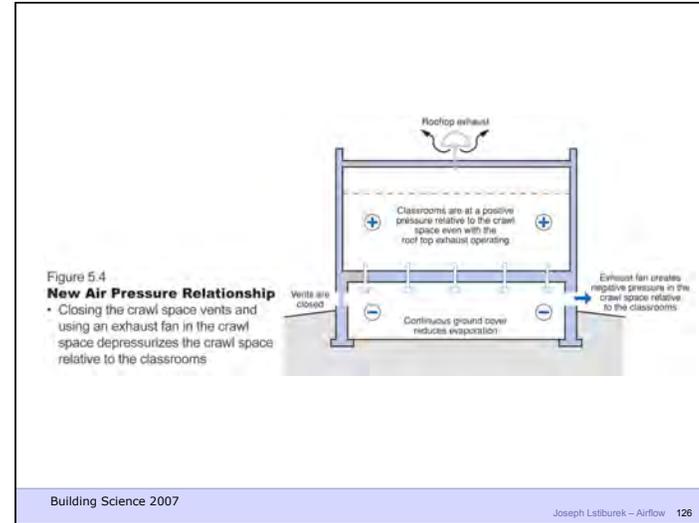
Ceiling grille

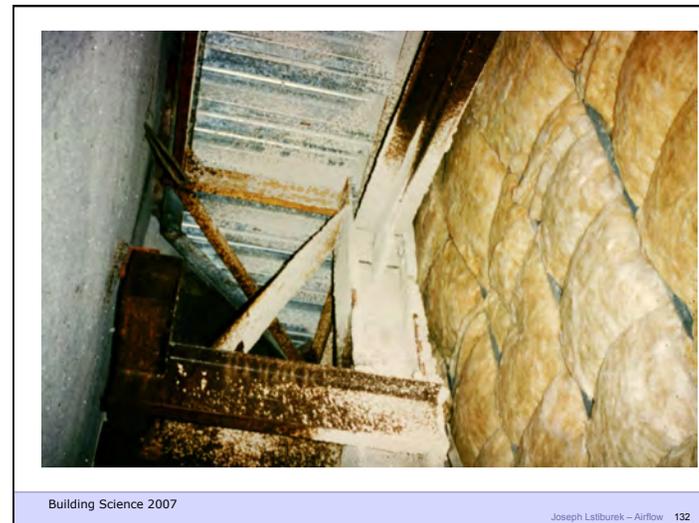
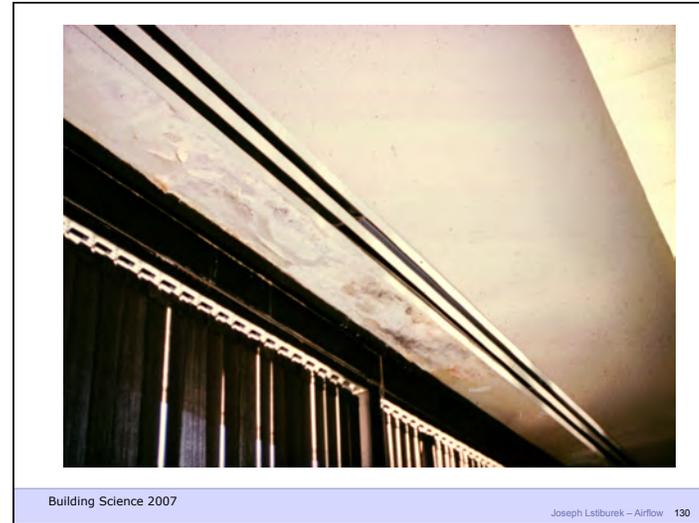
Wall cavity

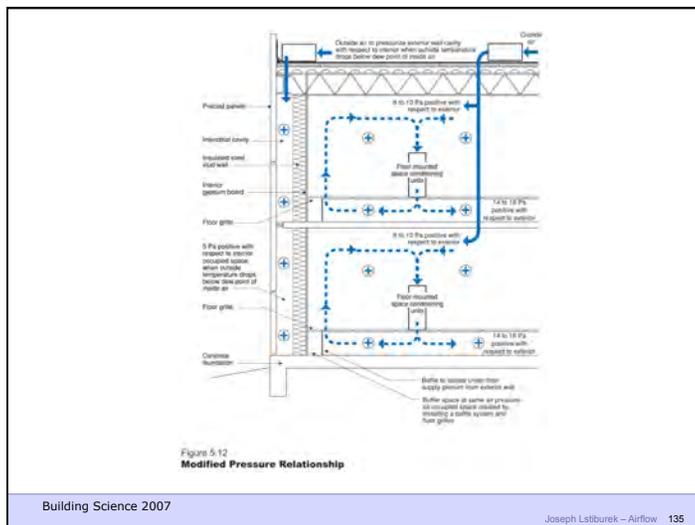
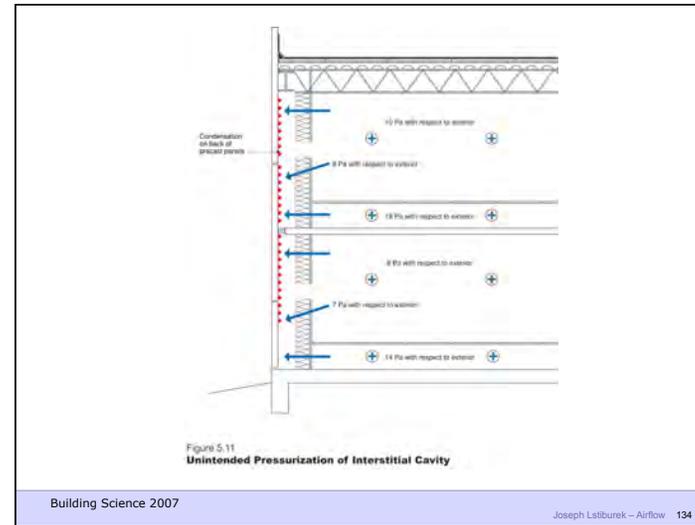
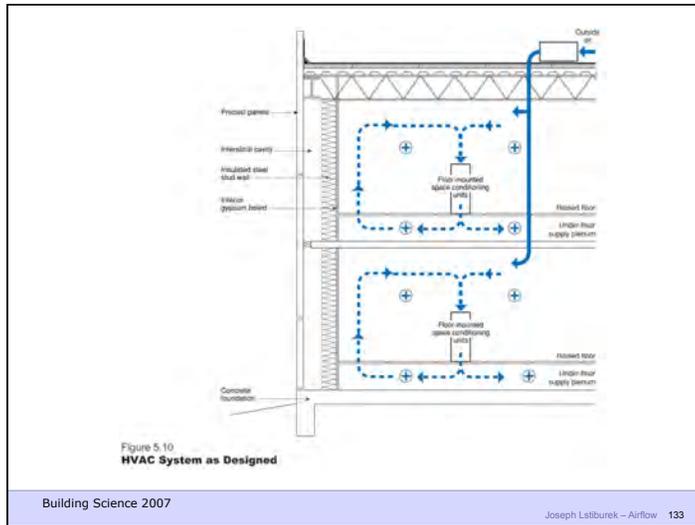
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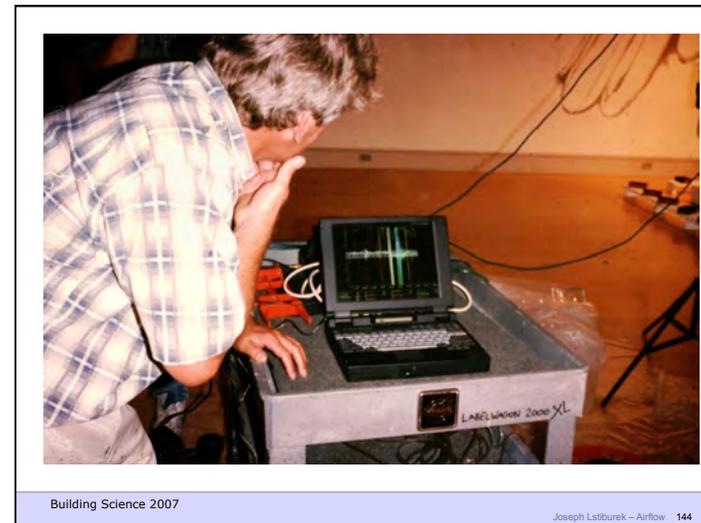
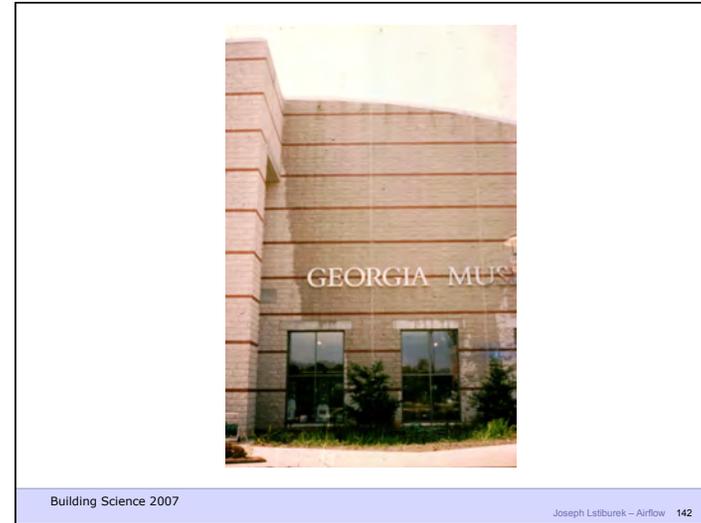


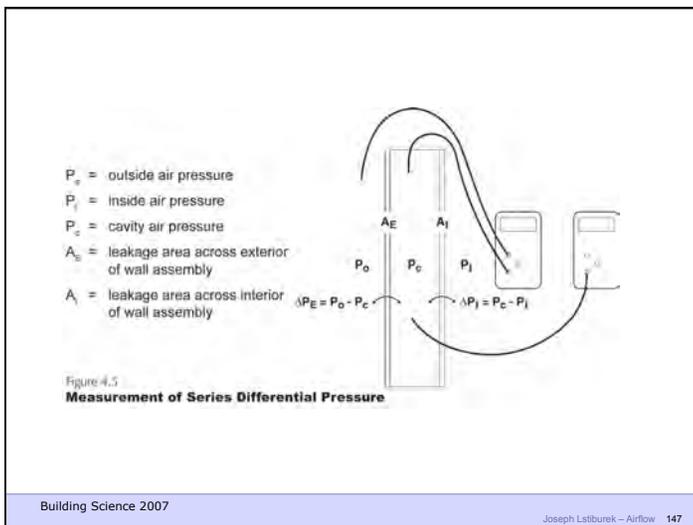
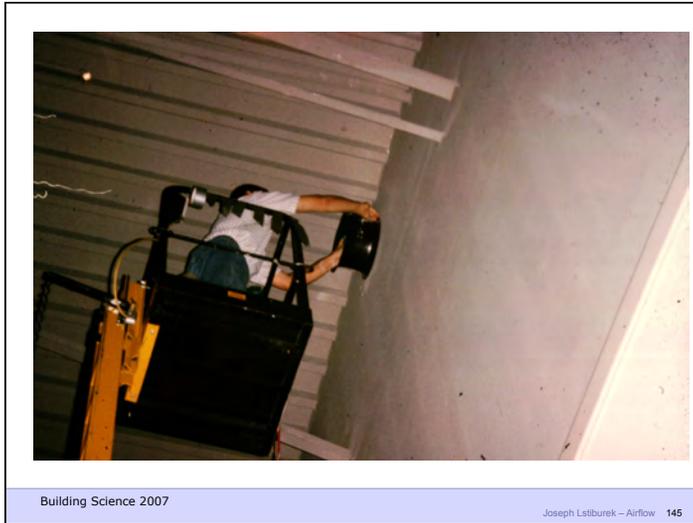












$$Q = C_E A_E \Delta P_E^n = C_I A_I \Delta P_I^n$$

$$\frac{C_E A_E}{C_I A_I} = \frac{\Delta P_I^n}{\Delta P_E^n}$$

$$\cong \frac{A_E}{A_I} = \left(\frac{\Delta P_I}{\Delta P_E} \right)^n$$

$$\cong \left(\frac{A_E}{A_I} \right)^{\frac{1}{n}} = \frac{\Delta P_I}{\Delta P_E}$$

from Hutcheon & Handegord, 1983

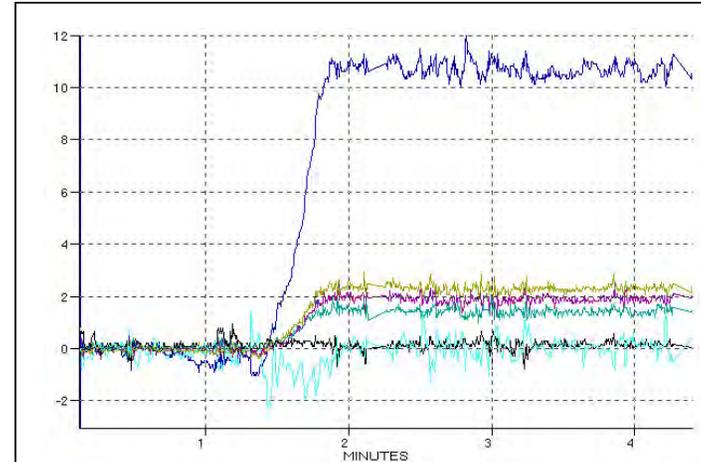
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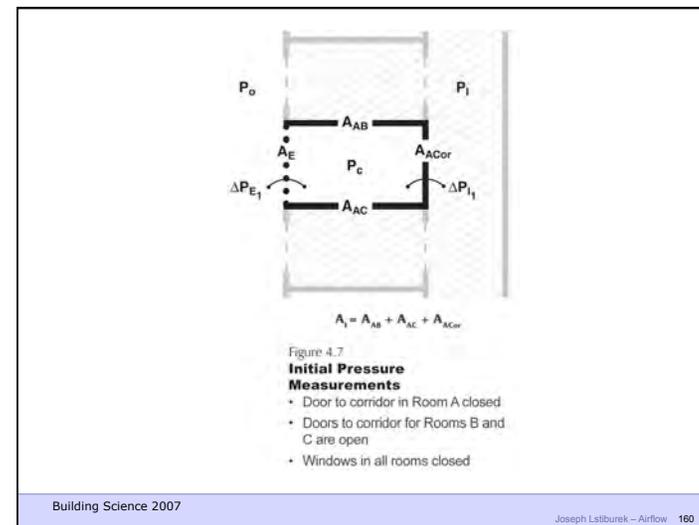
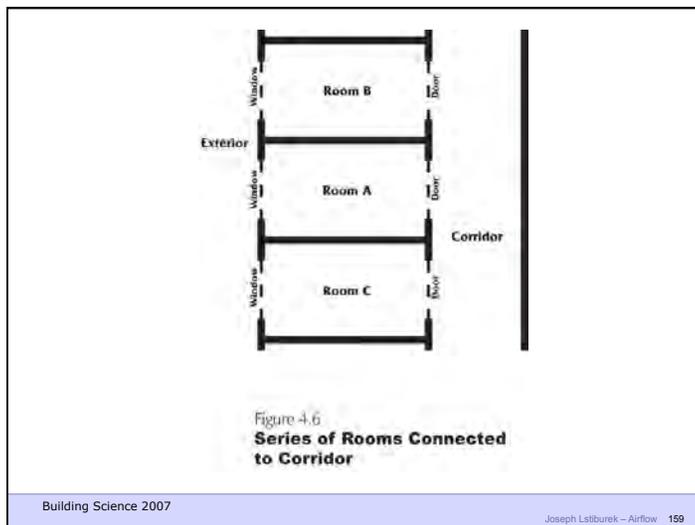
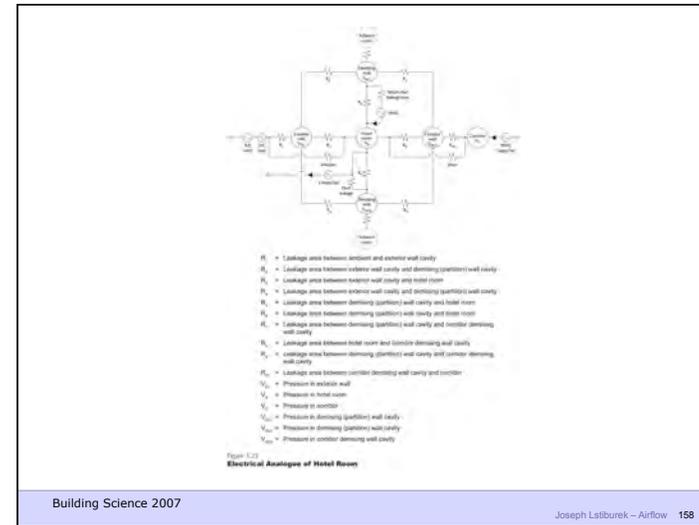
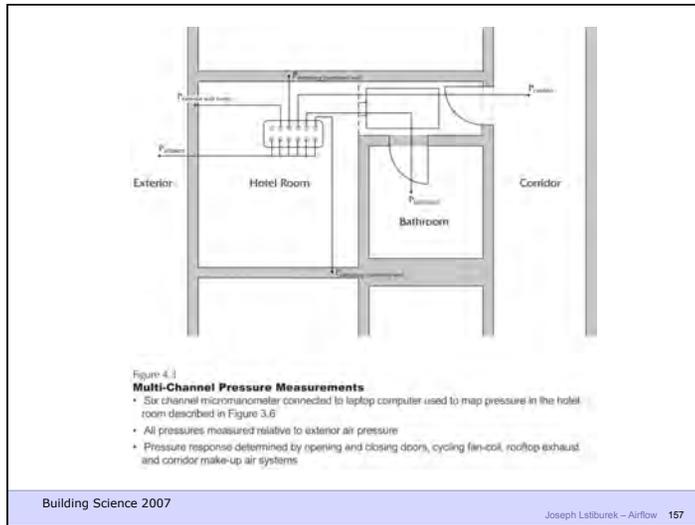
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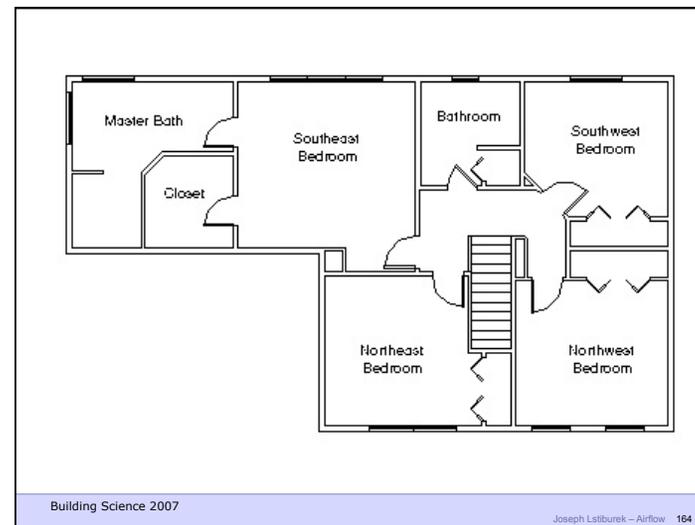
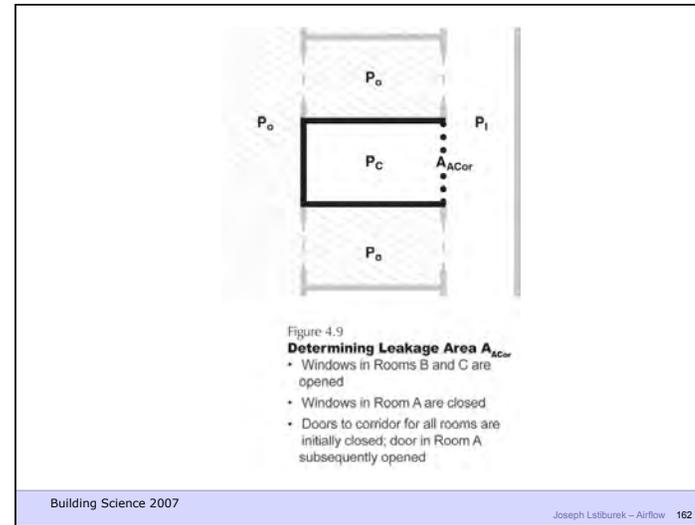
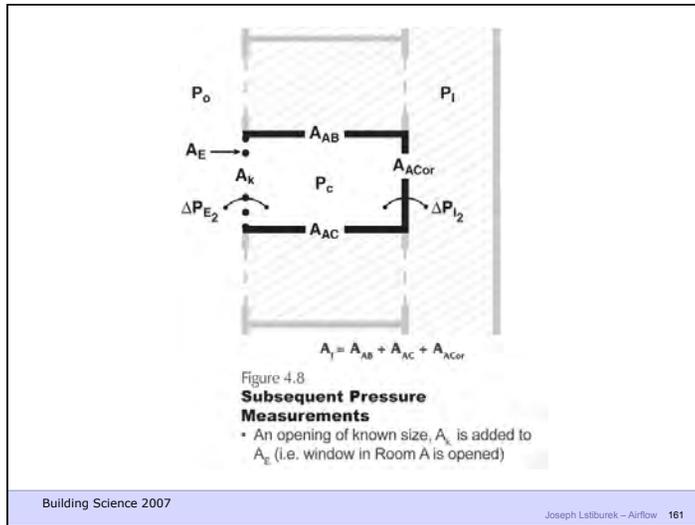
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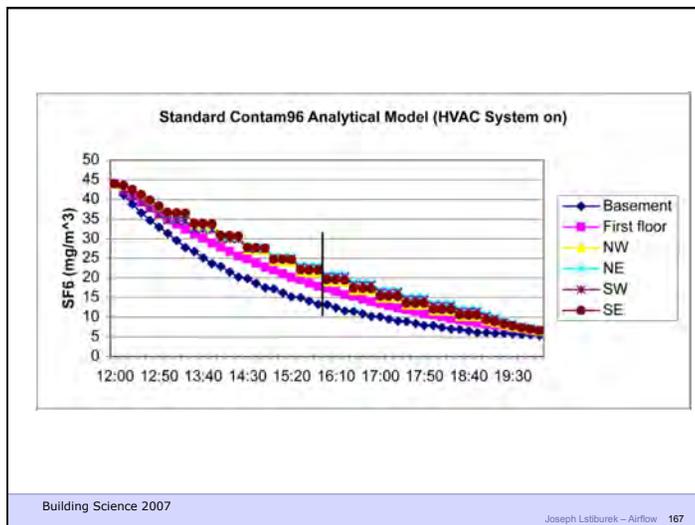
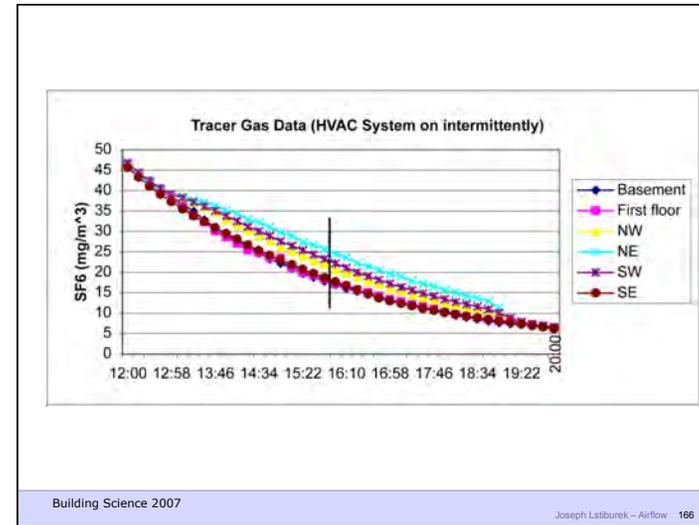
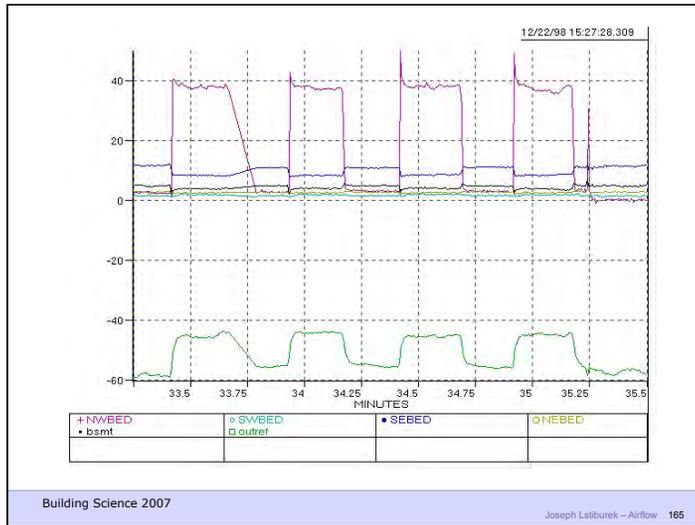


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- Tracer gas test of a production Building America house in Sacramento
- 2-story, 4 bedrooms, ~2500 square feet
- Ventilation systems tested: supply and exhaust ventilation, with and without mixing via central air handler

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