

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

Building Science

Multifamily

www.buildingscience.com

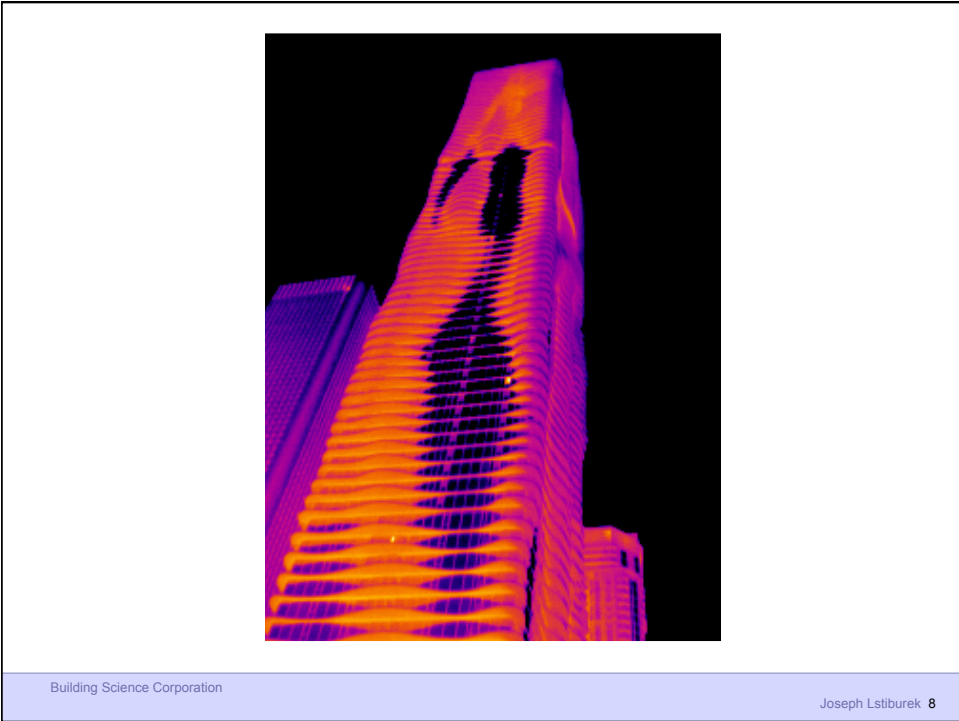
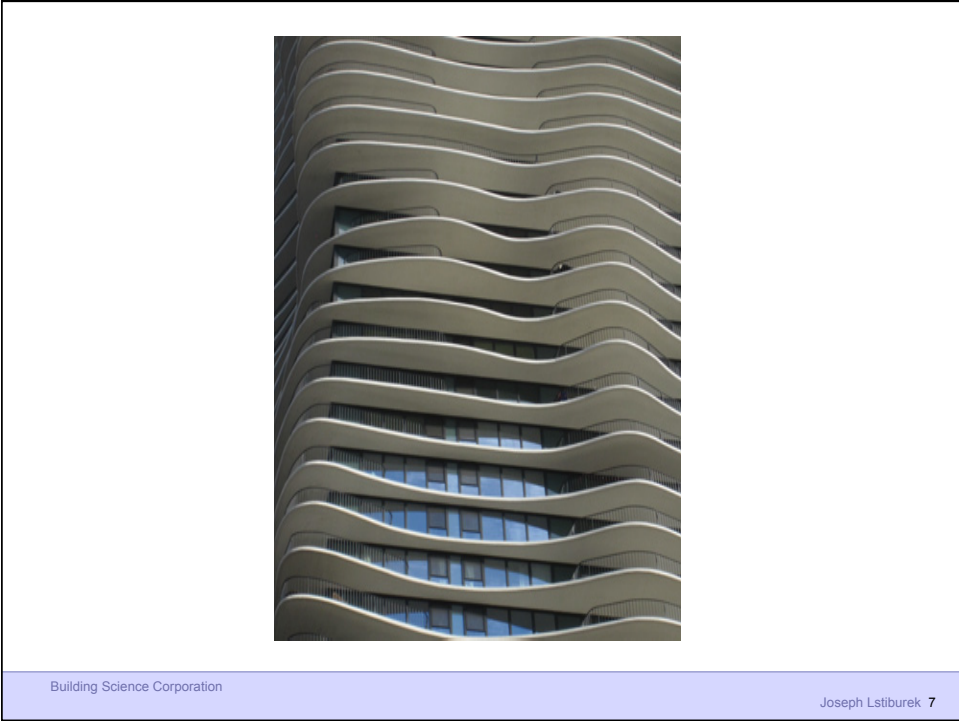


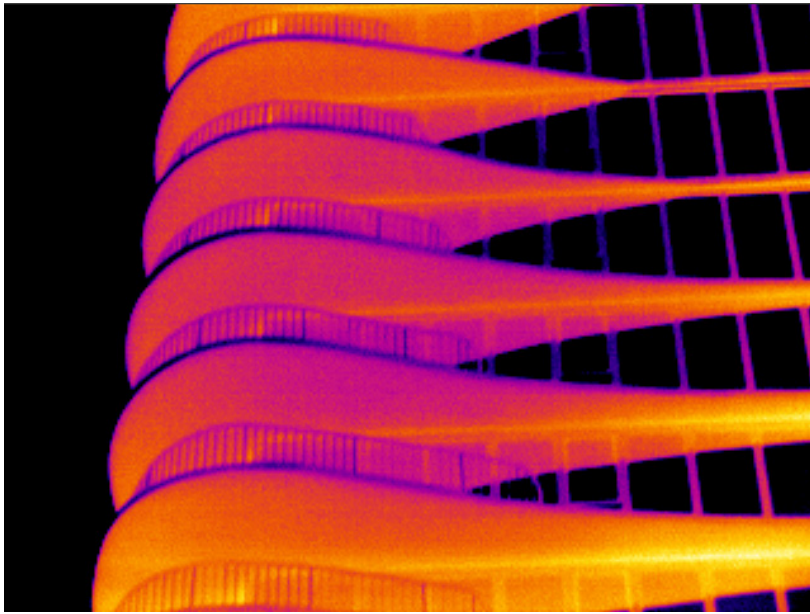
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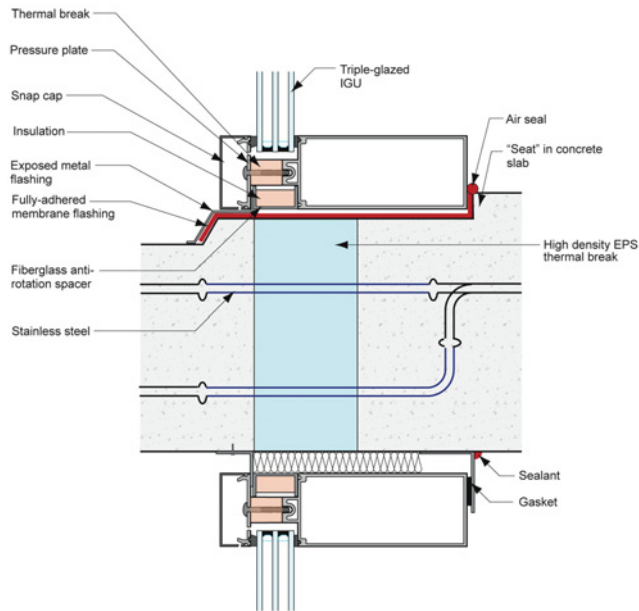
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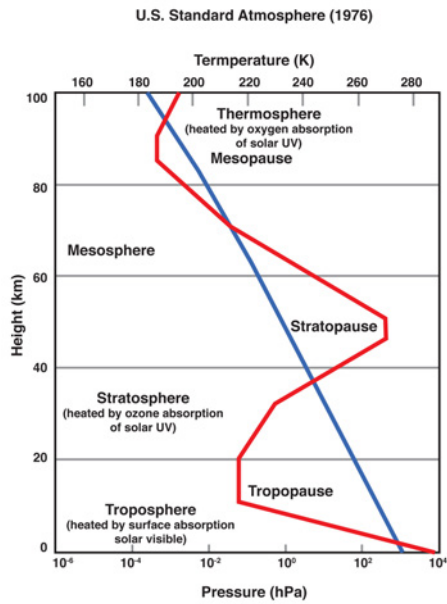
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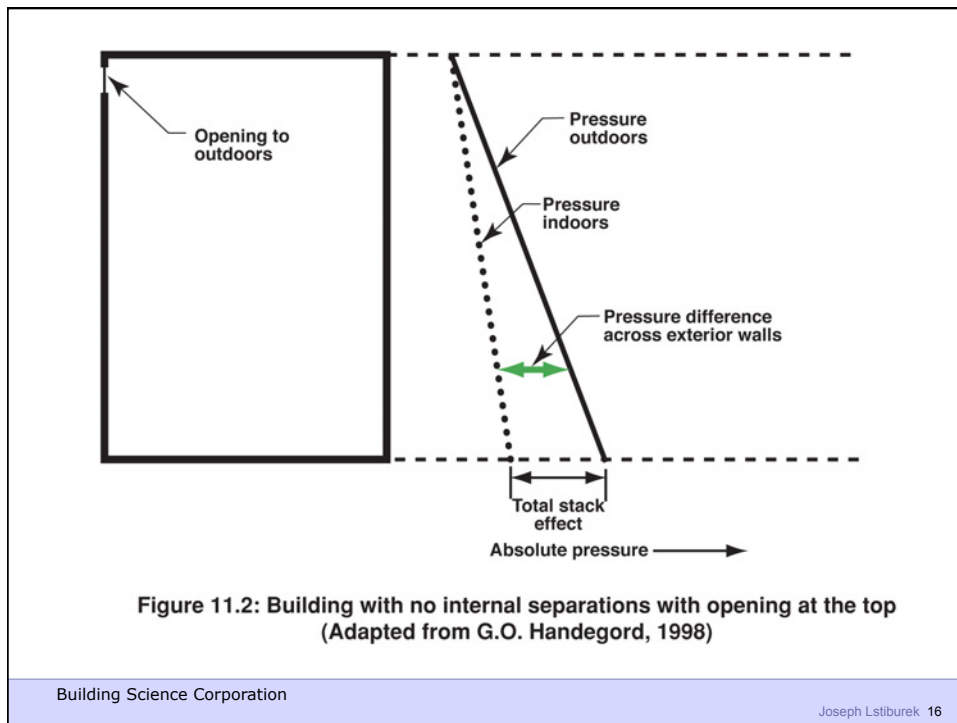
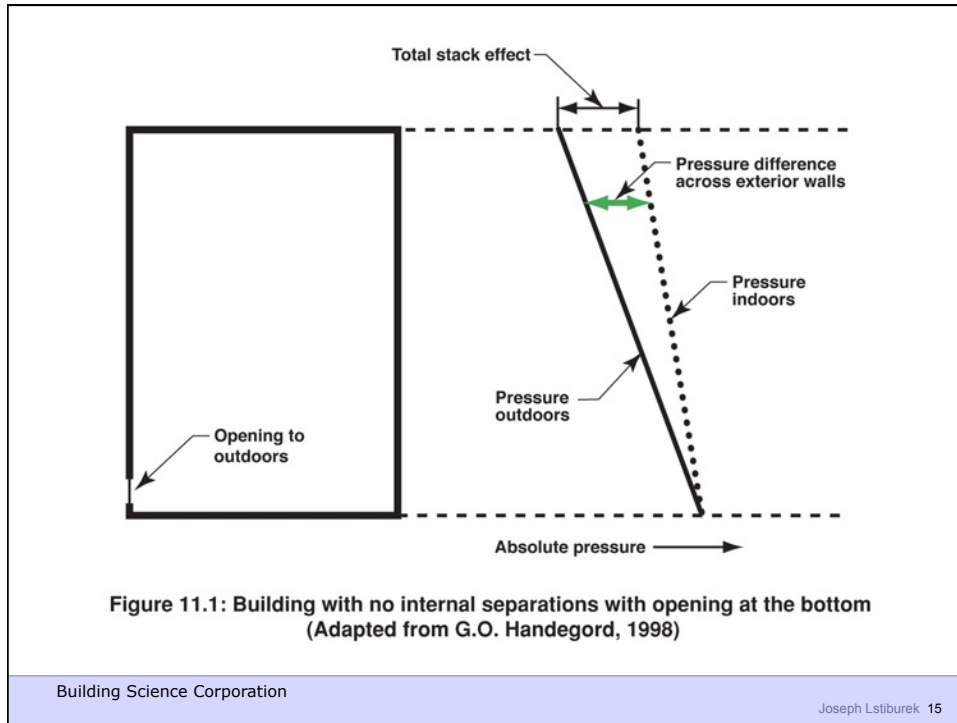


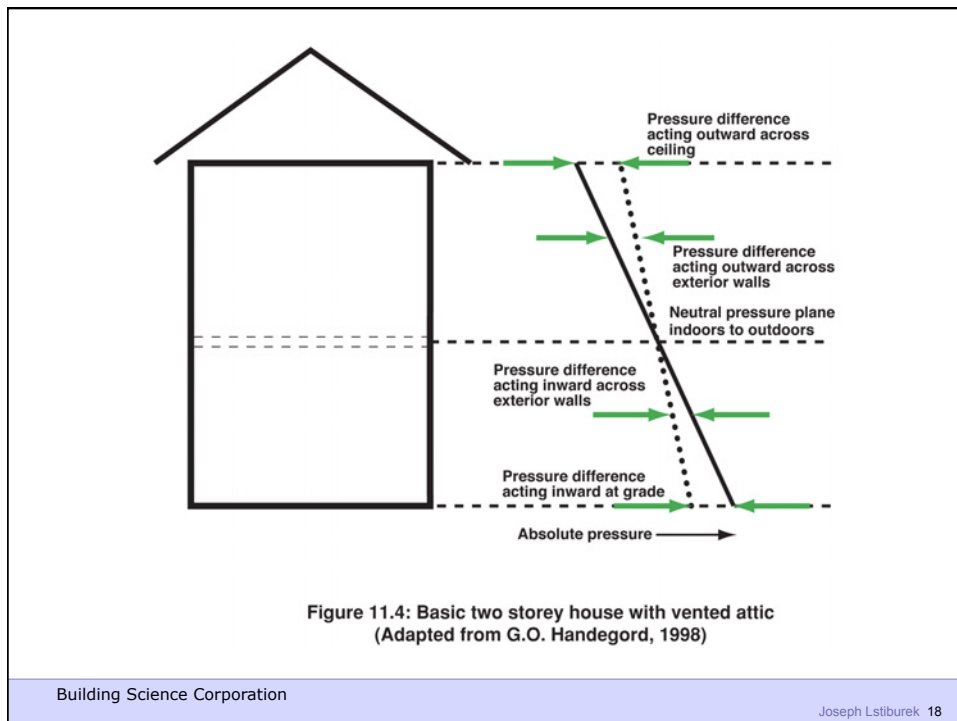
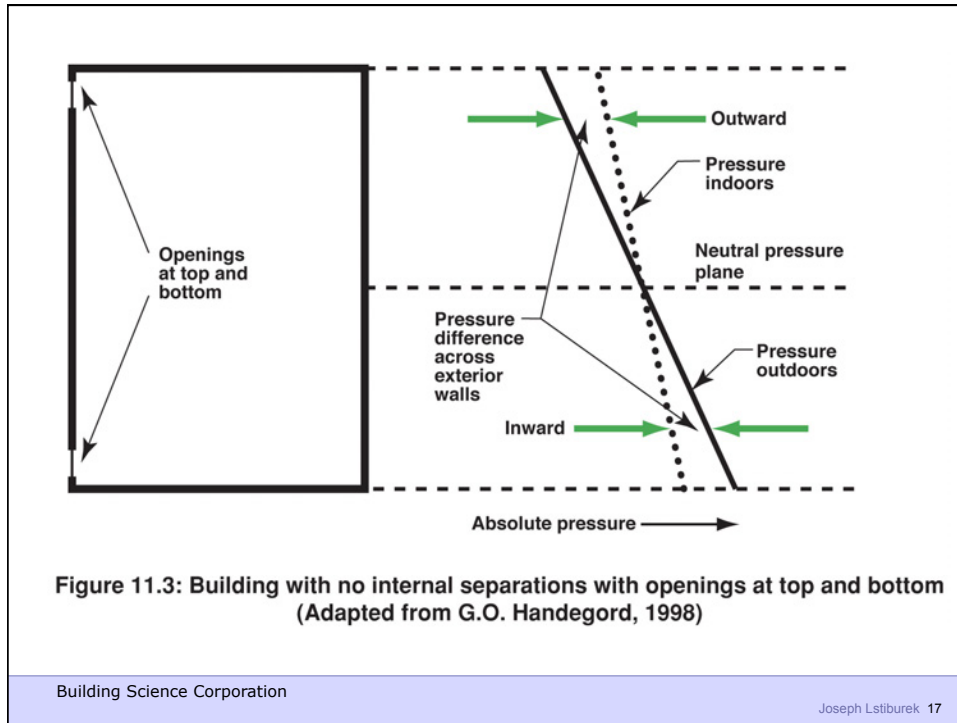
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Lapse Rate









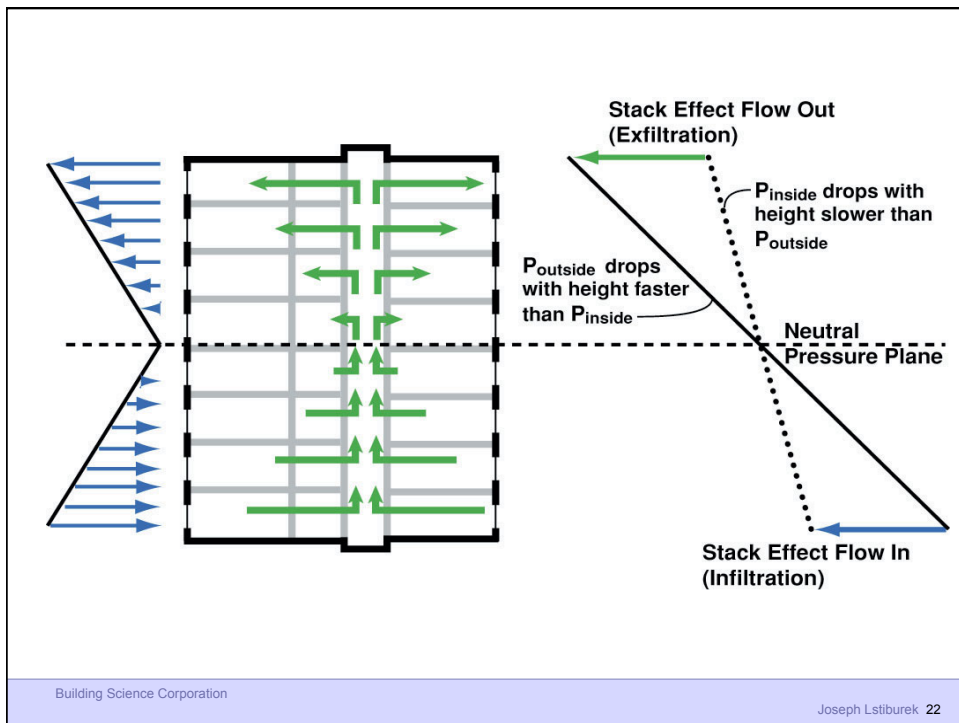
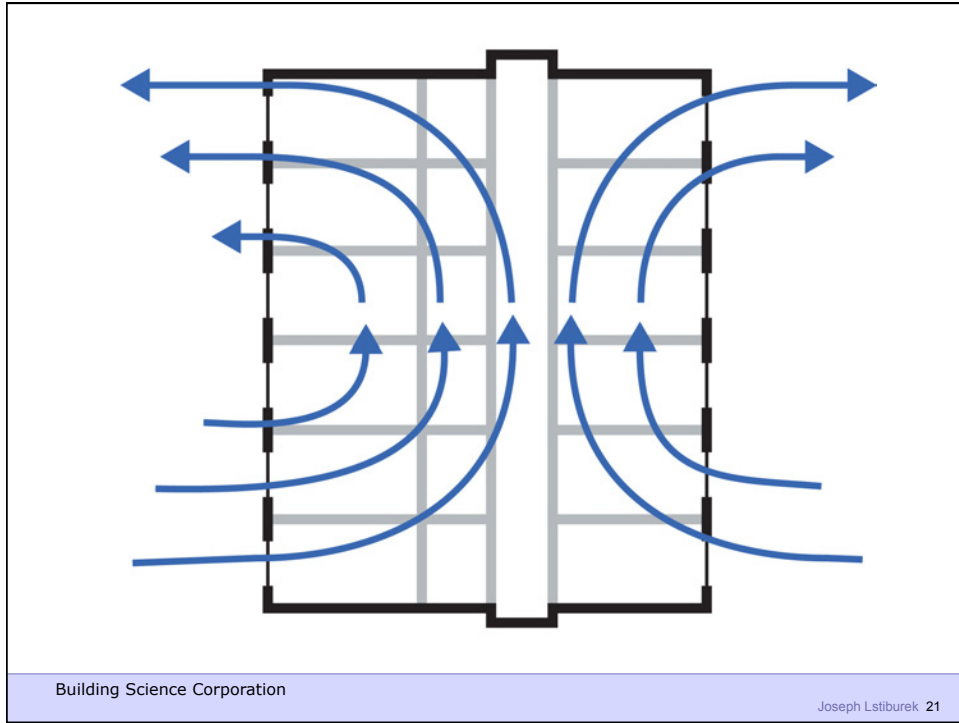
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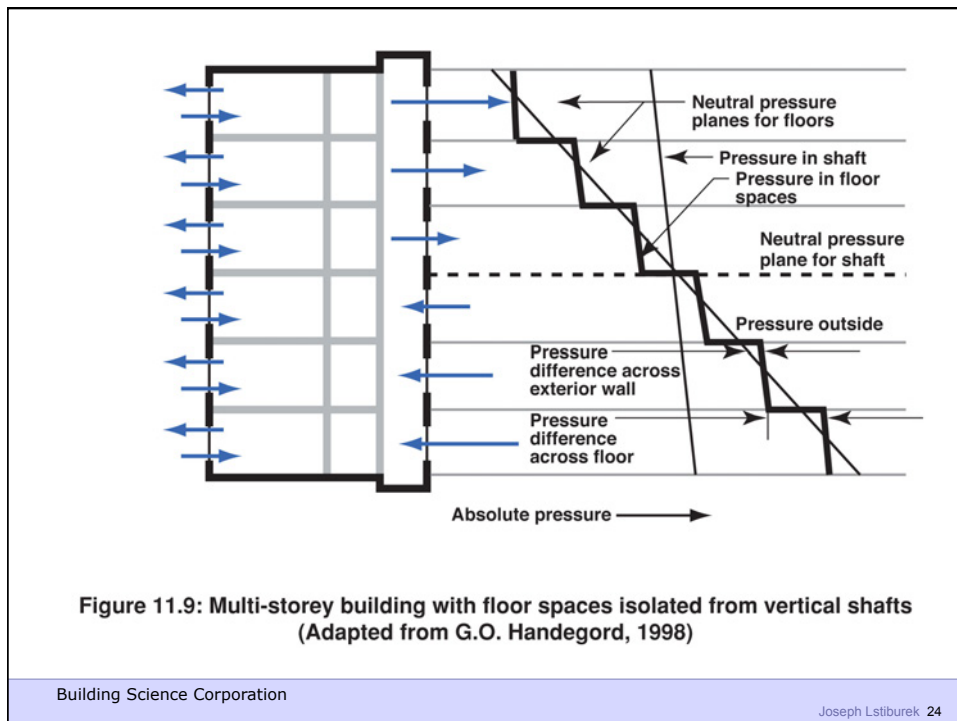
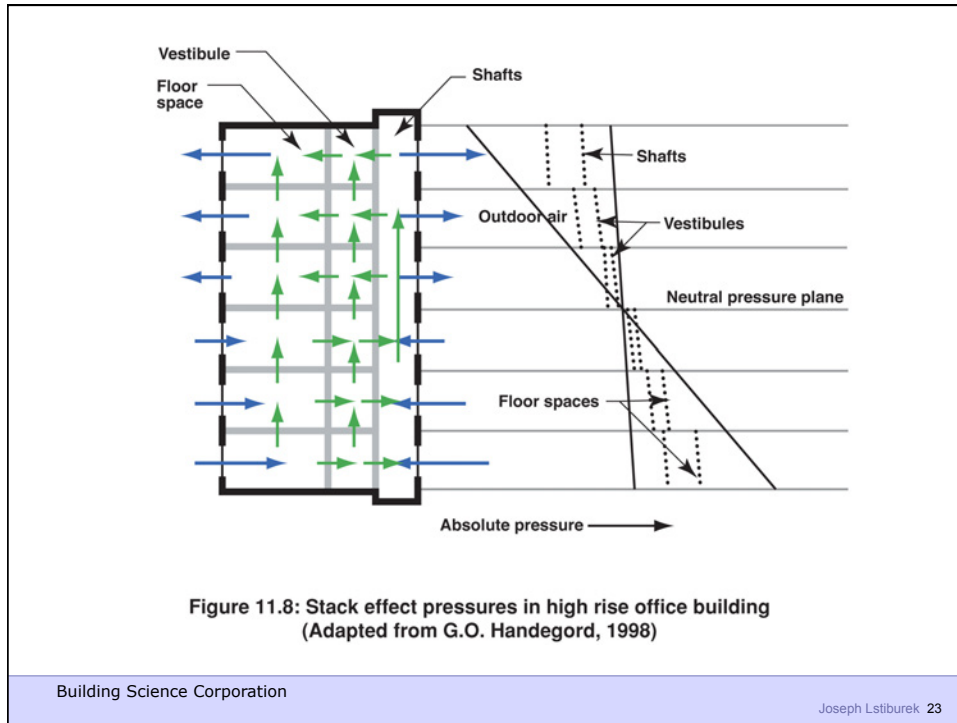
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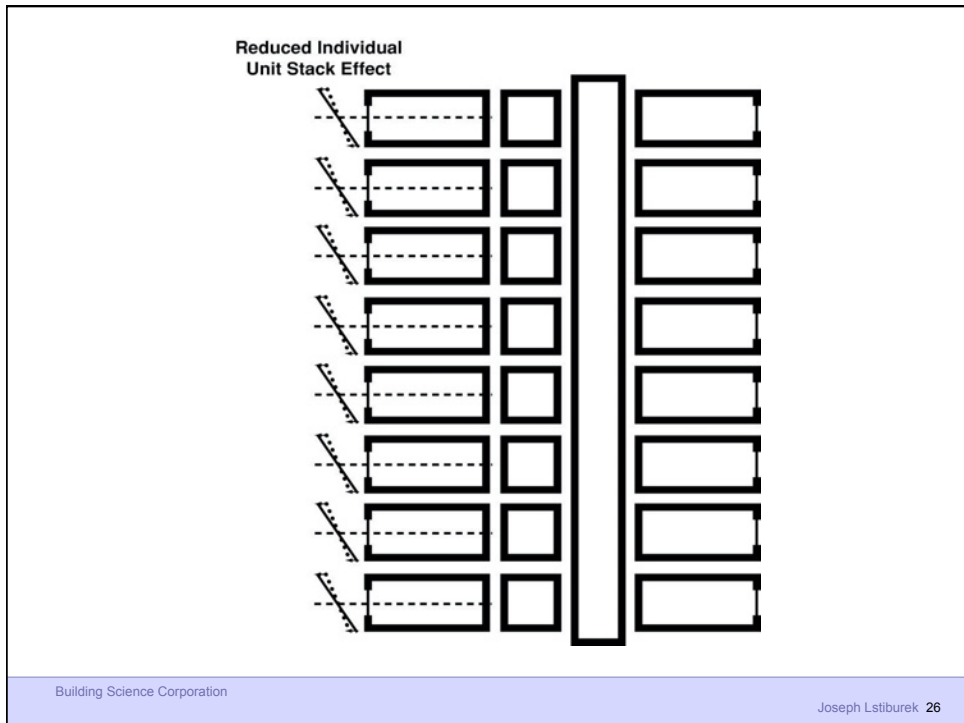
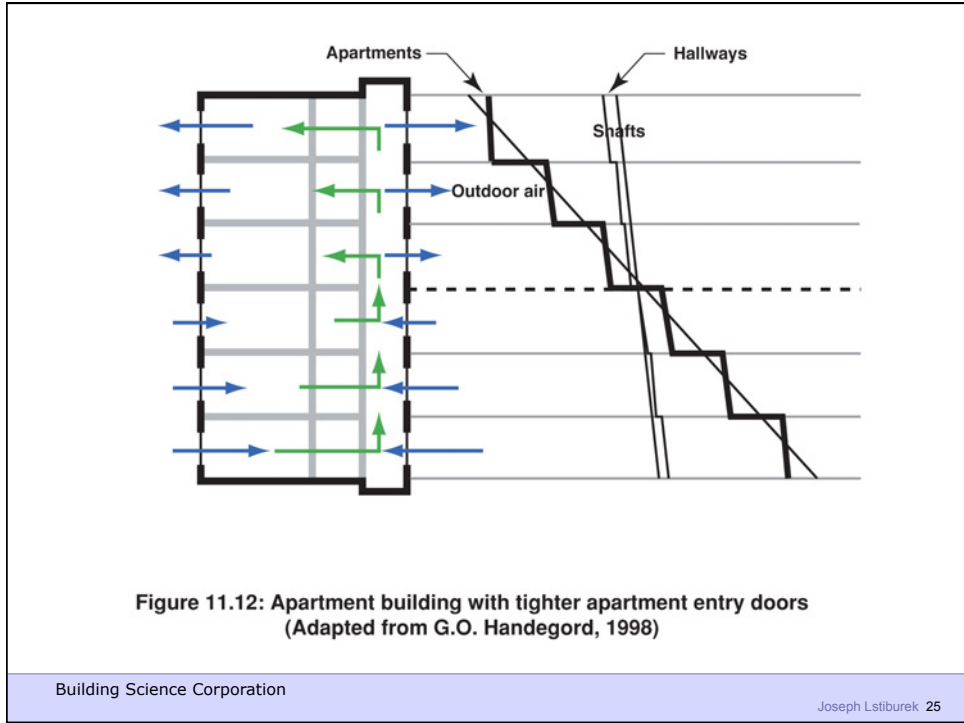


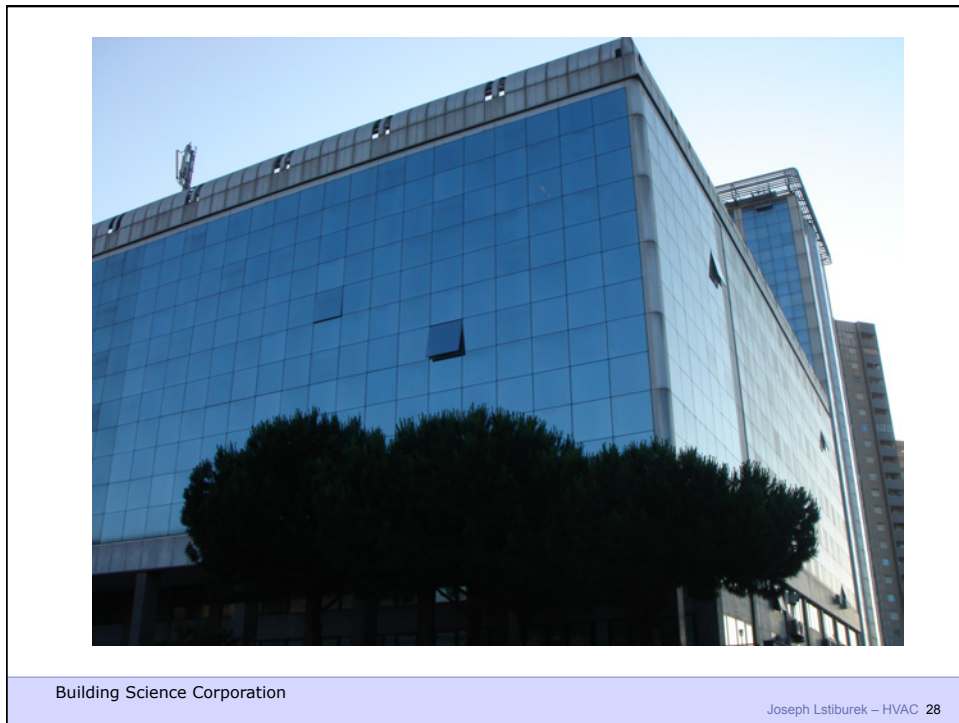
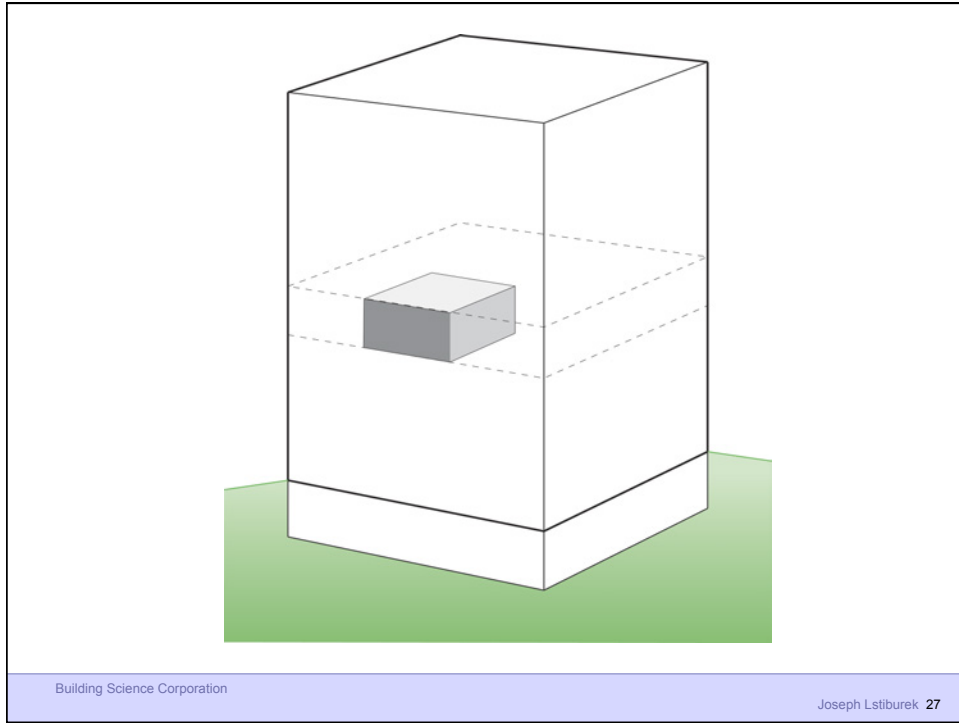
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Build Tight - Ventilate Right

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Build Tight - Ventilate Right

How Tight?

What's Right?

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Air Barrier Metrics

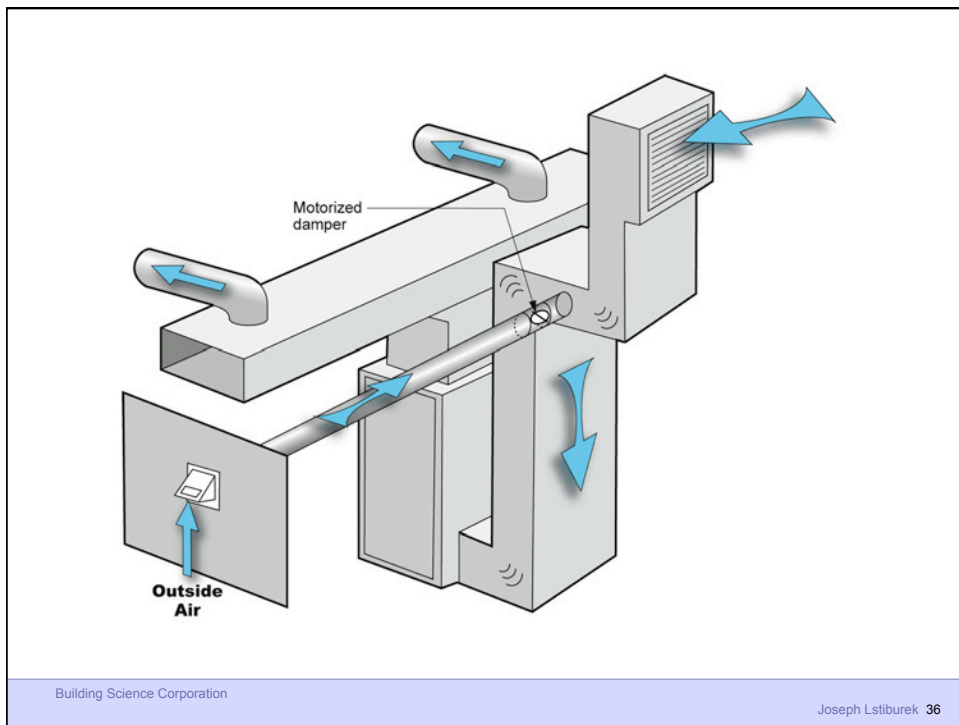
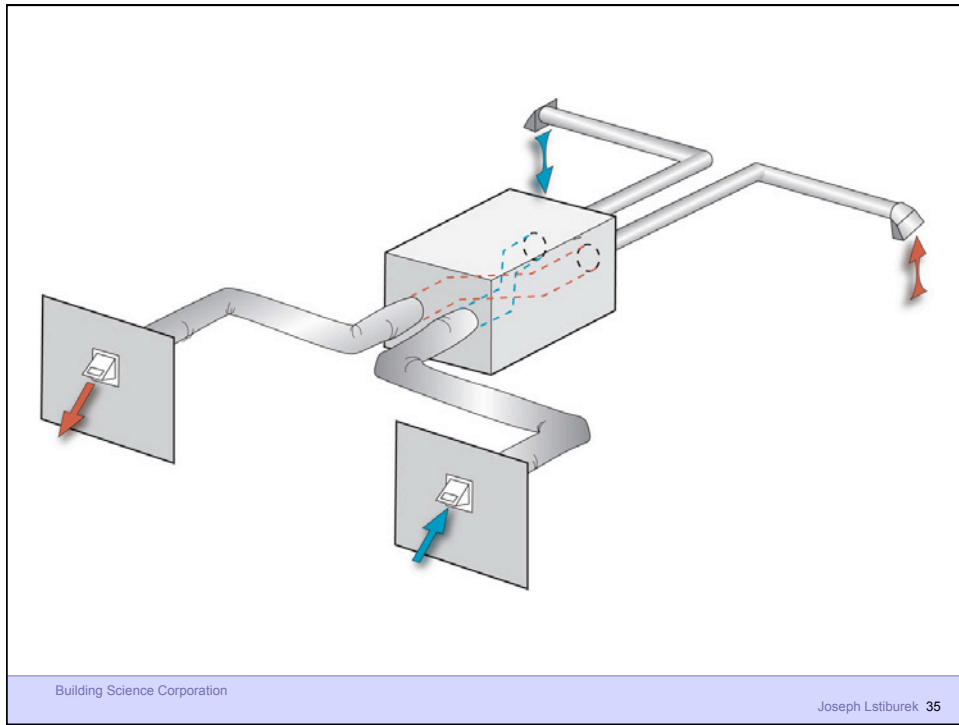
Material	0.02 I/(s-m ²) @ 75 Pa
Assembly	0.20 I/(s-m ²) @ 75 Pa
Enclosure	2.00 I/(s-m ²) @ 75 Pa
	0.35 cfm/ft ² @ 50 Pa
	0.25 cfm/ft ² @ 50 Pa
	0.15 cfm/ft ² @ 50 Pa

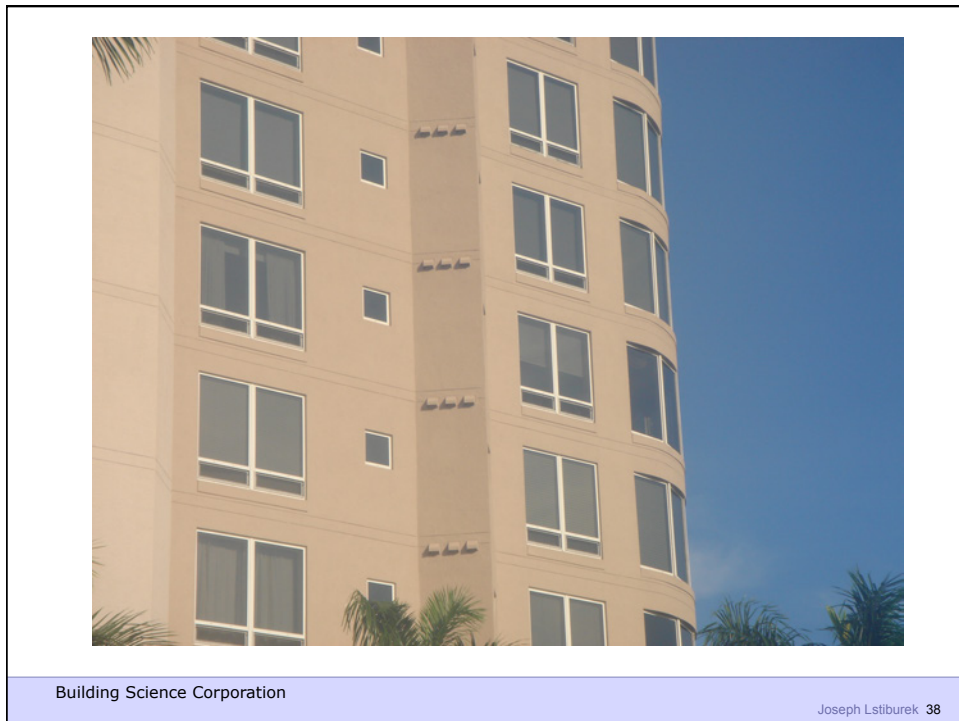
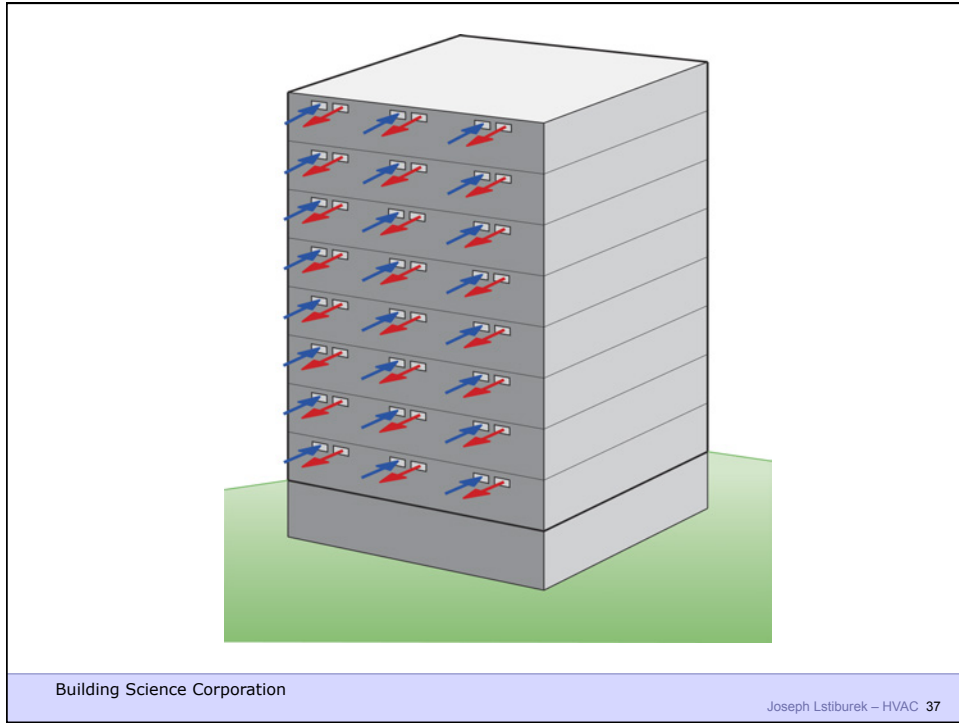
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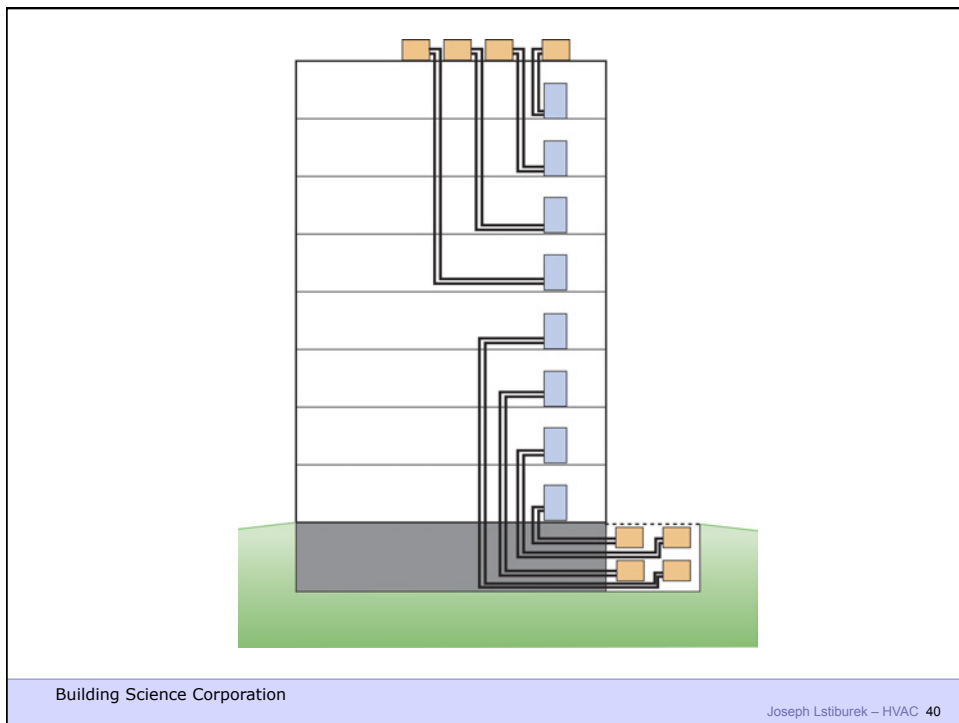
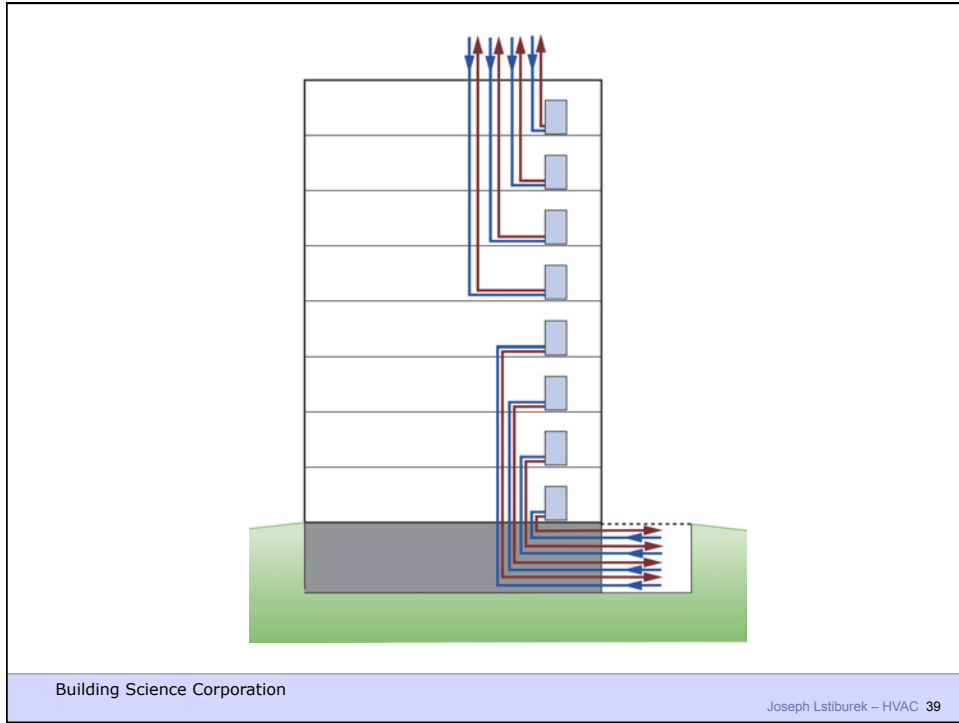
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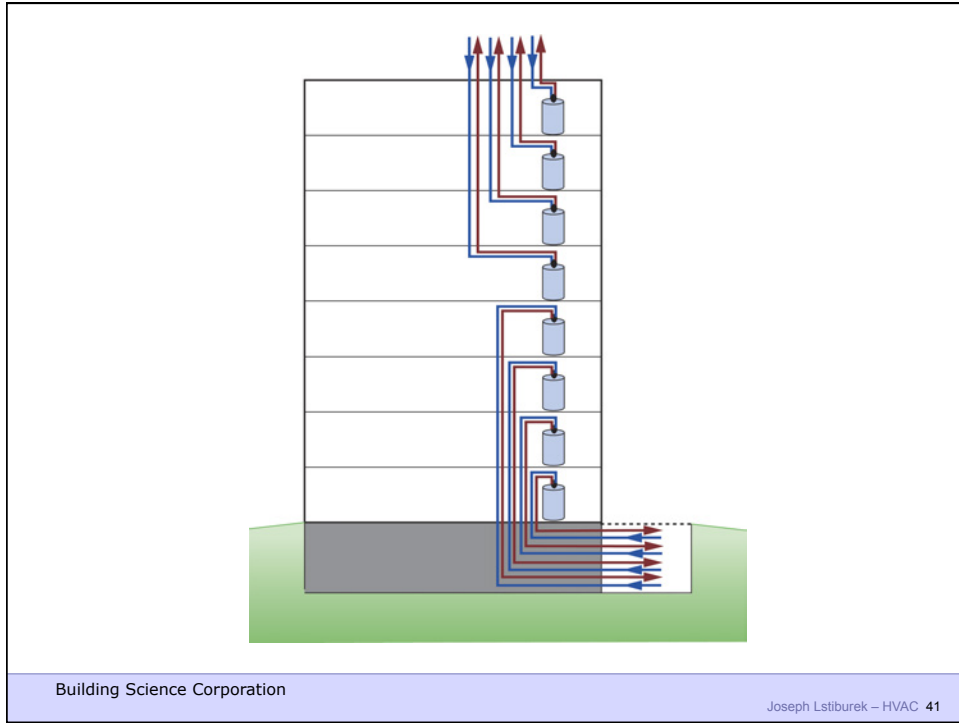
Getting rid of big holes	3 ach@50
Getting rid of smaller holes	1.5 ach@50
Getting German	0.6 ach@50

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











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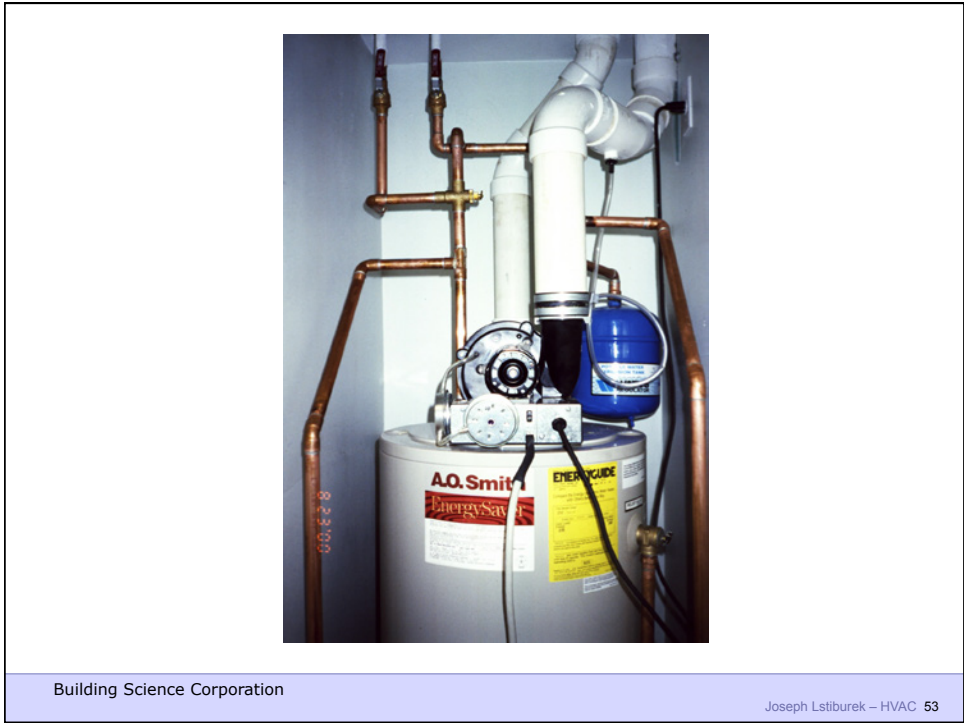
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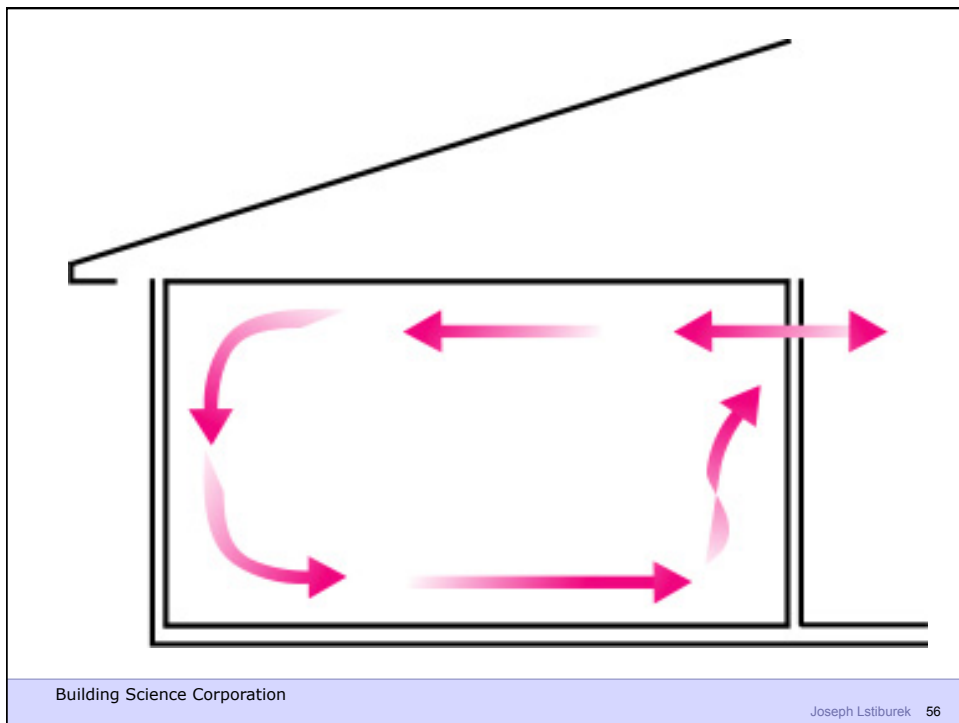
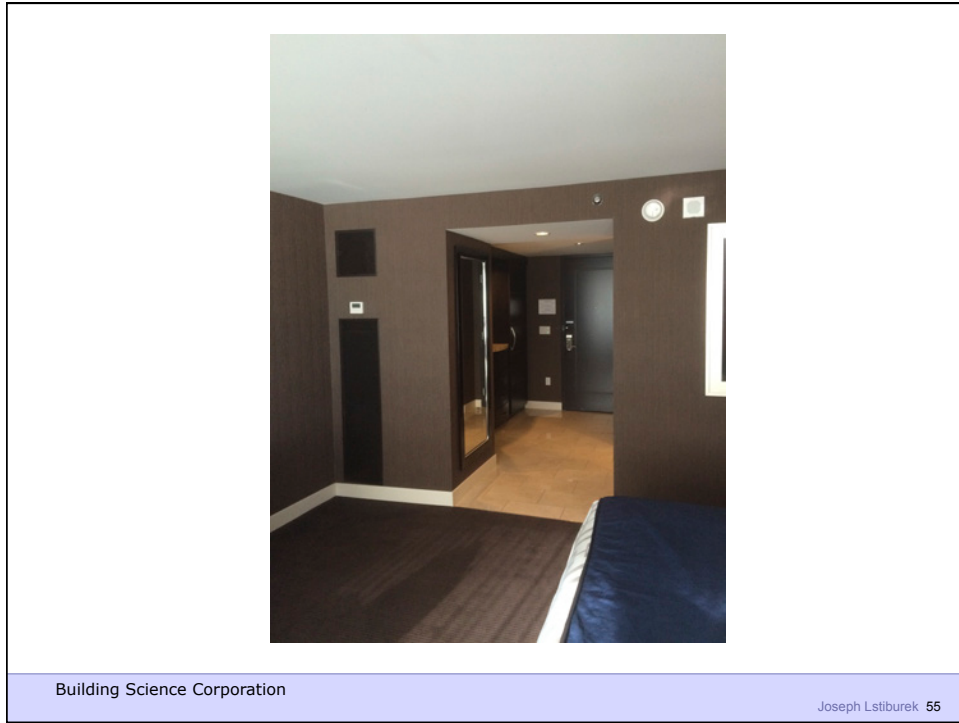
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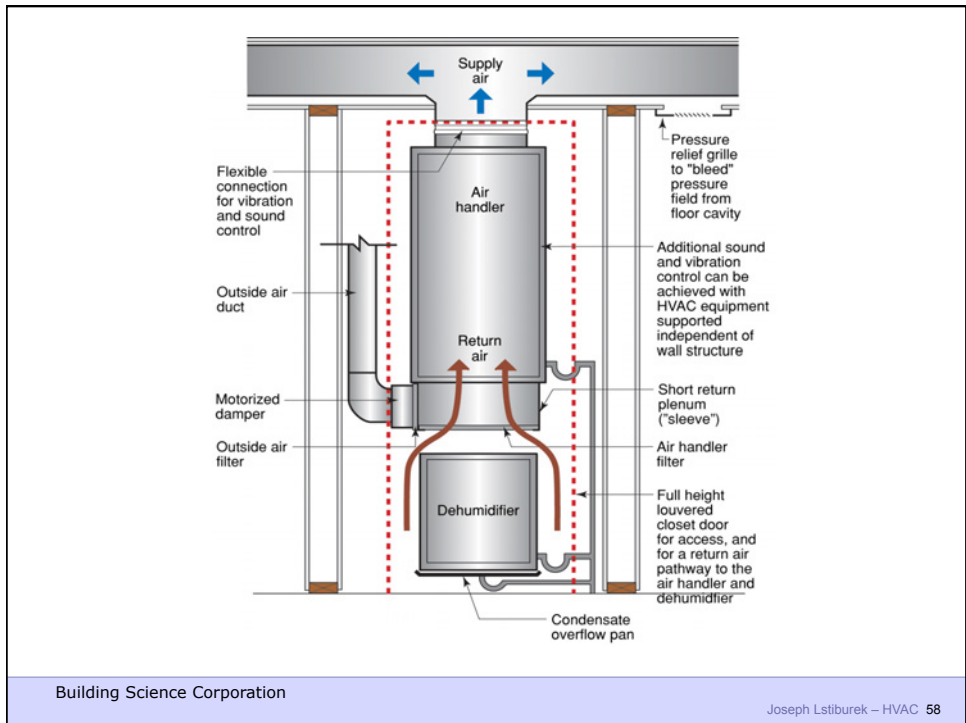
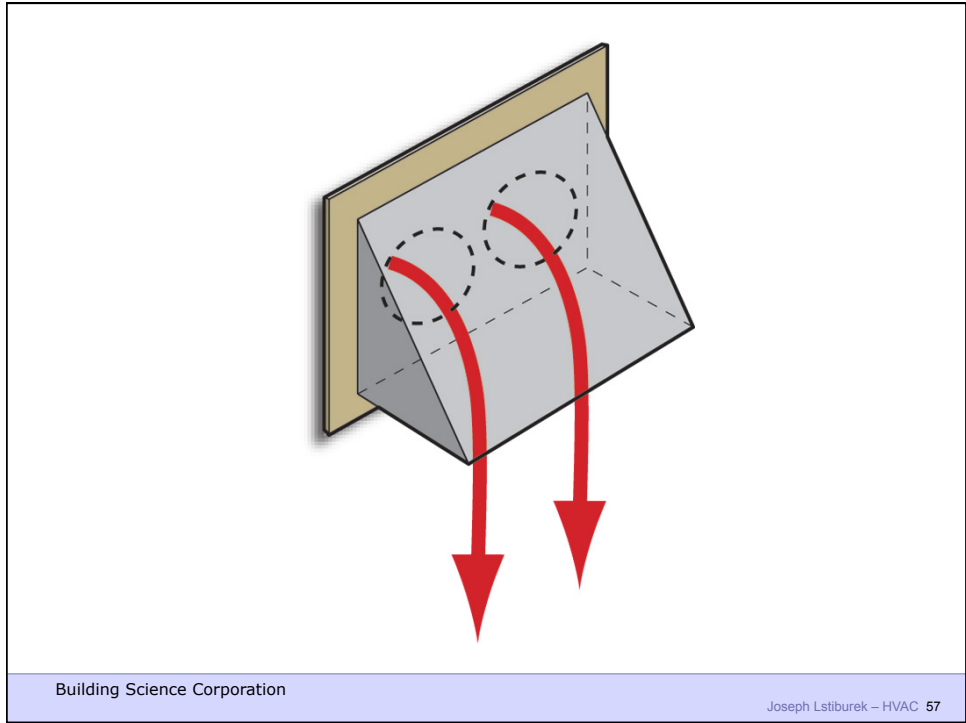


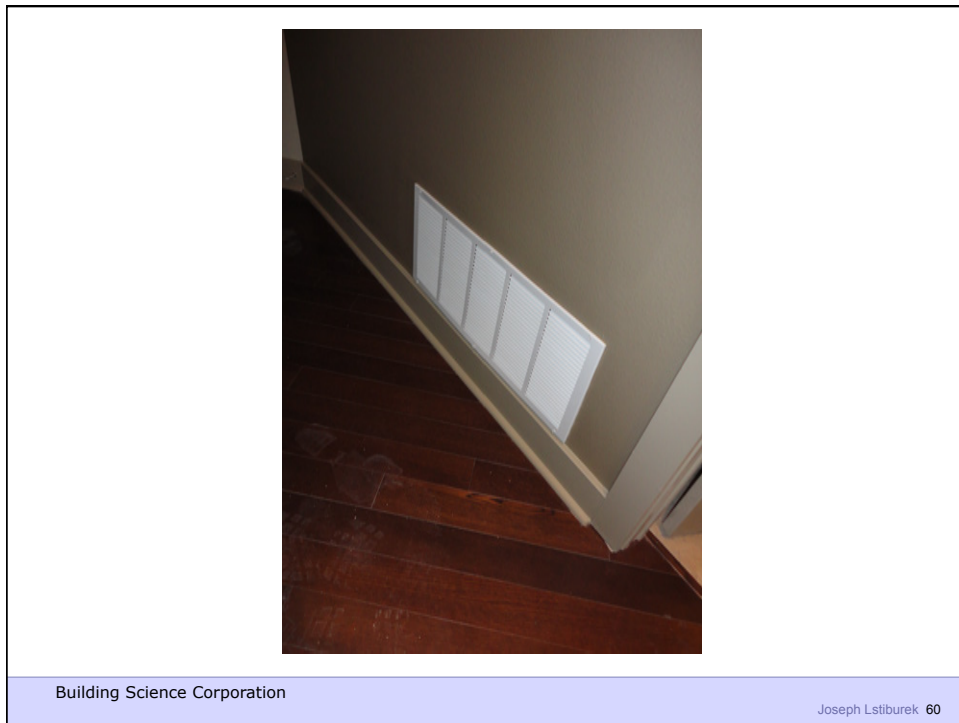
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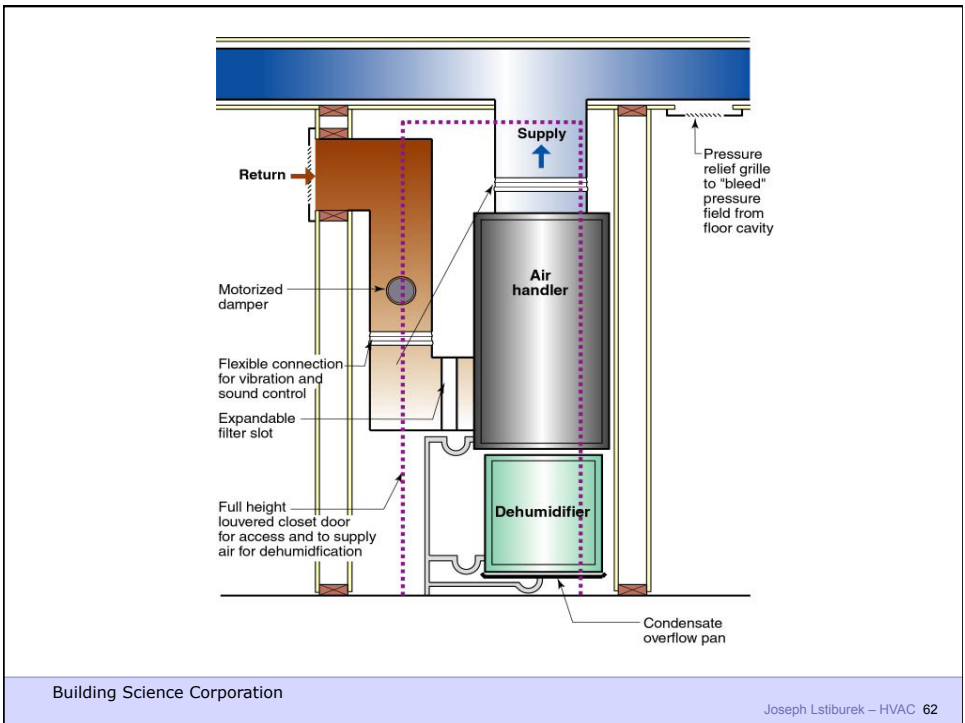
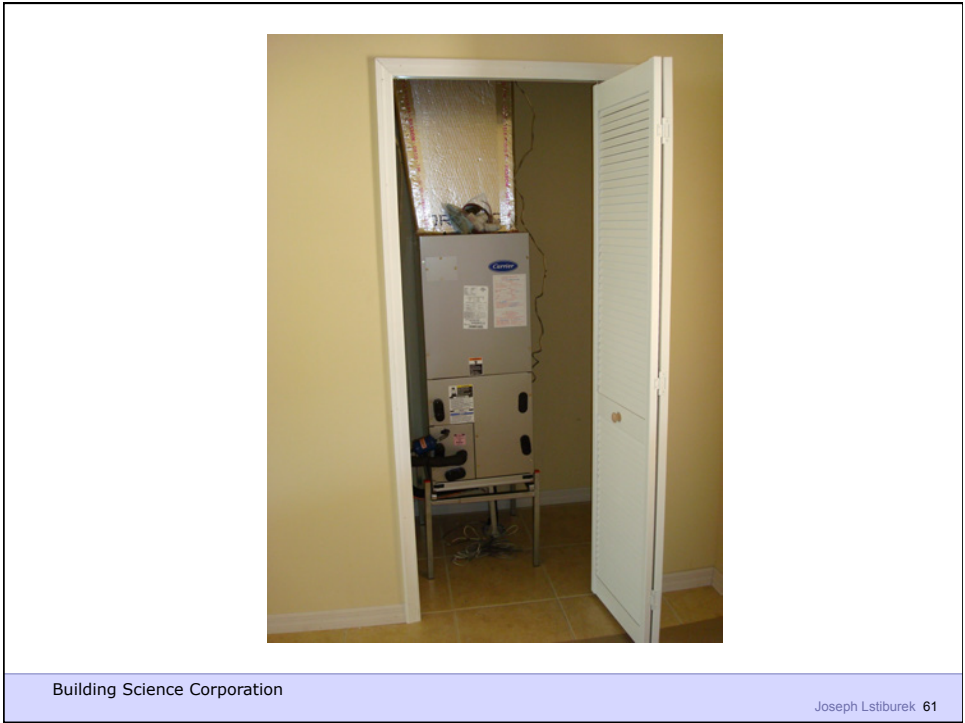
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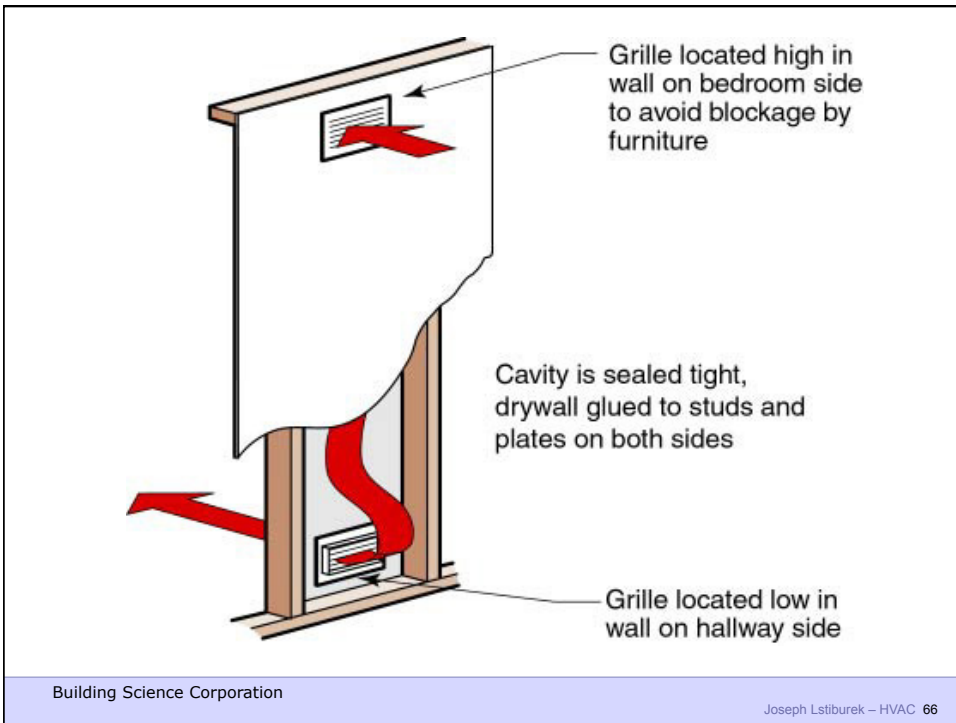
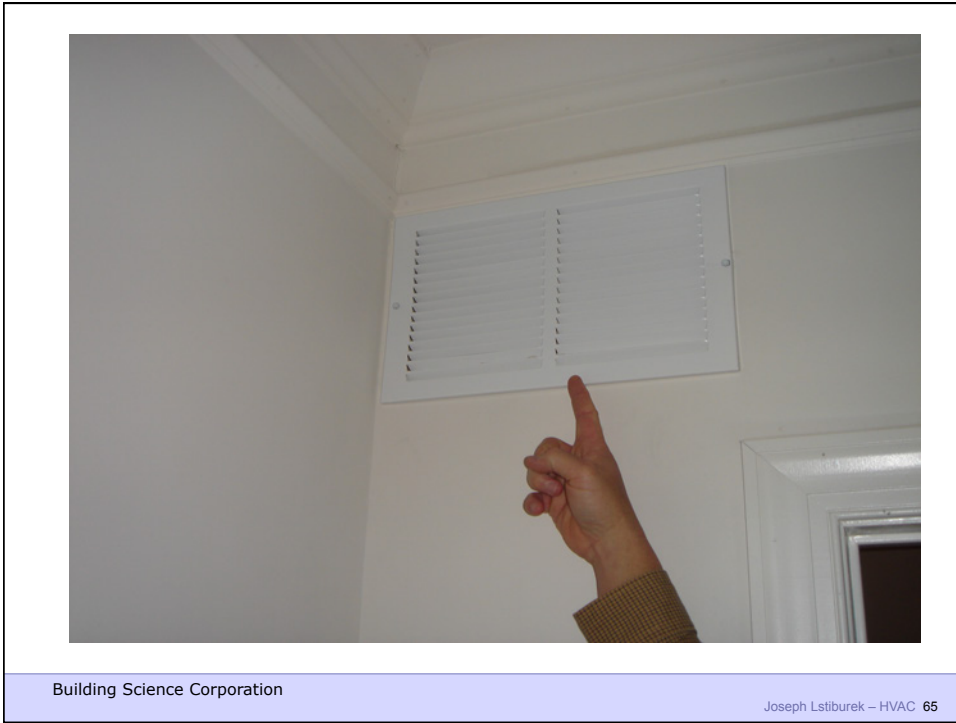


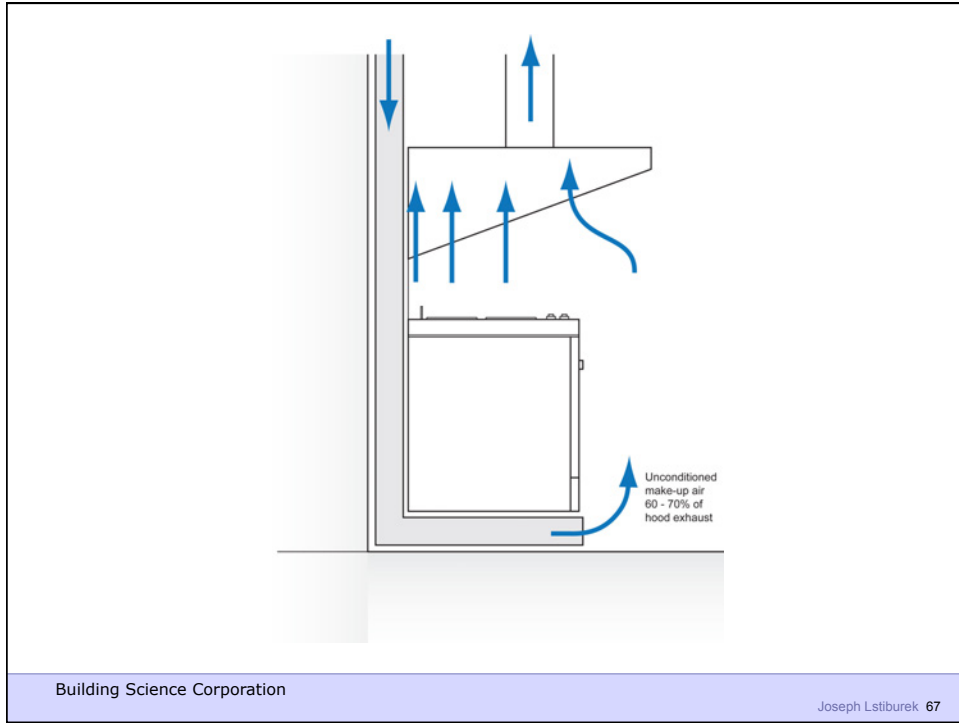


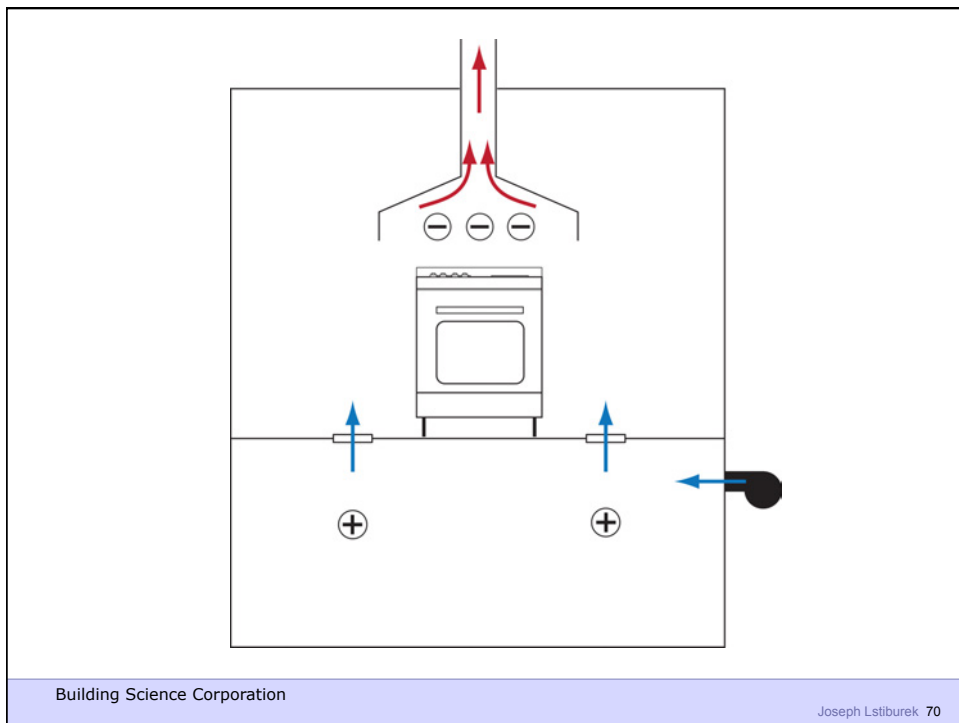
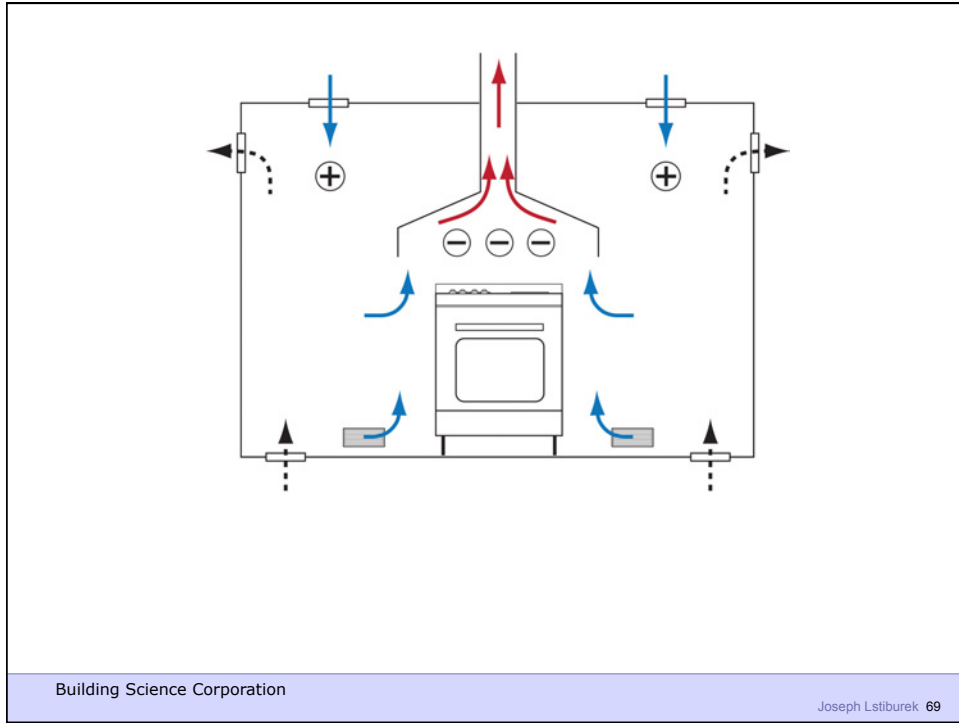














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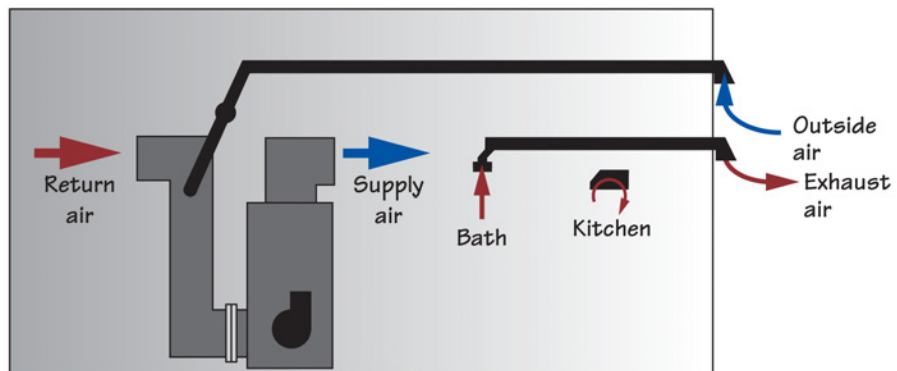
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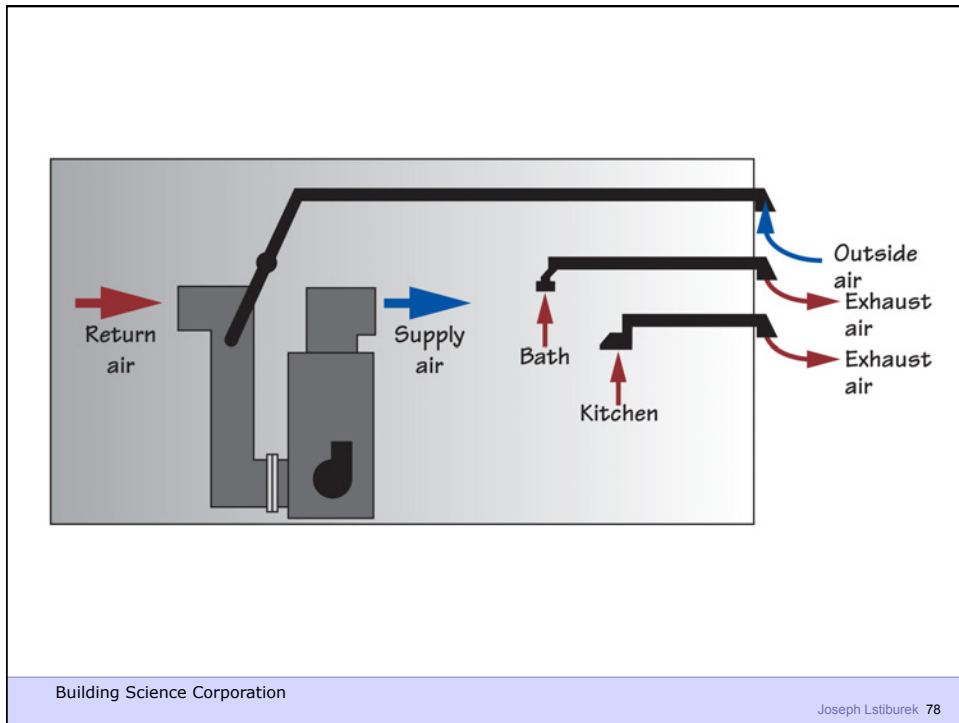
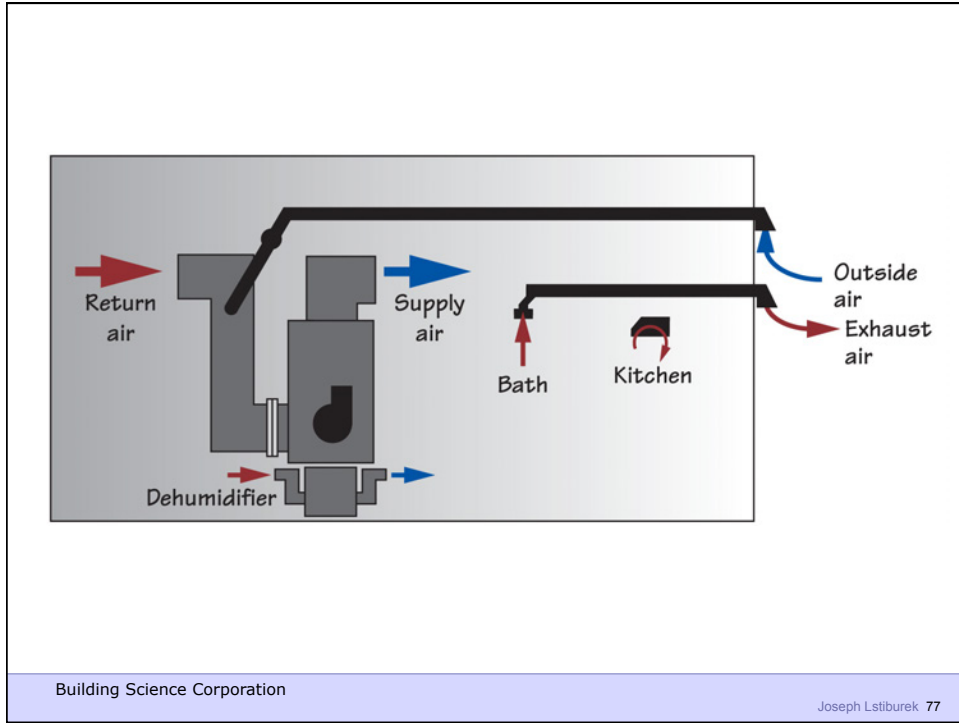
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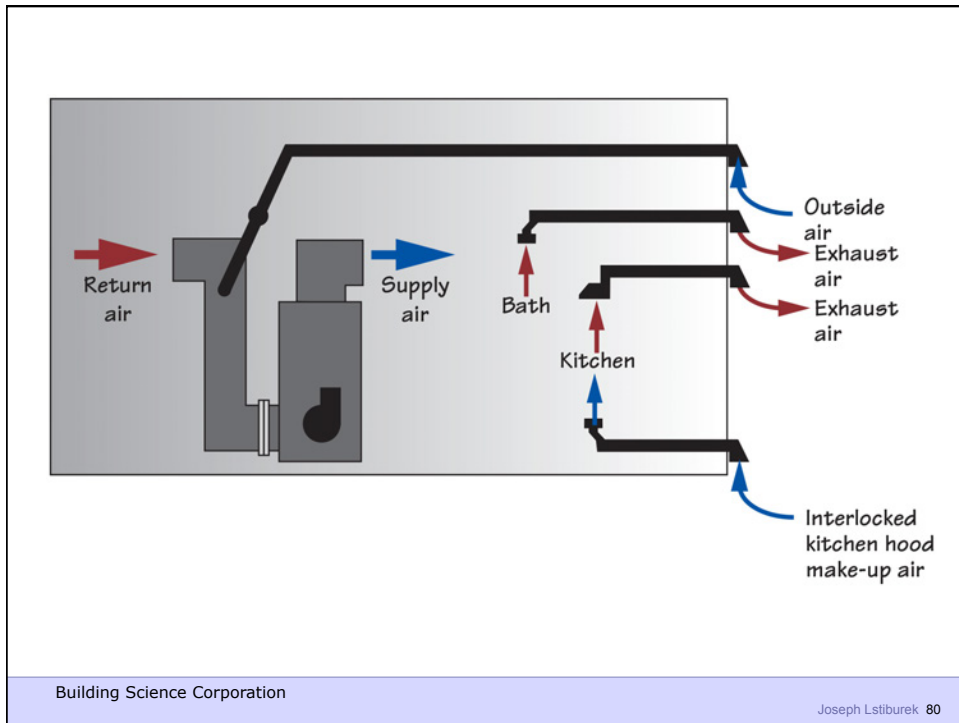
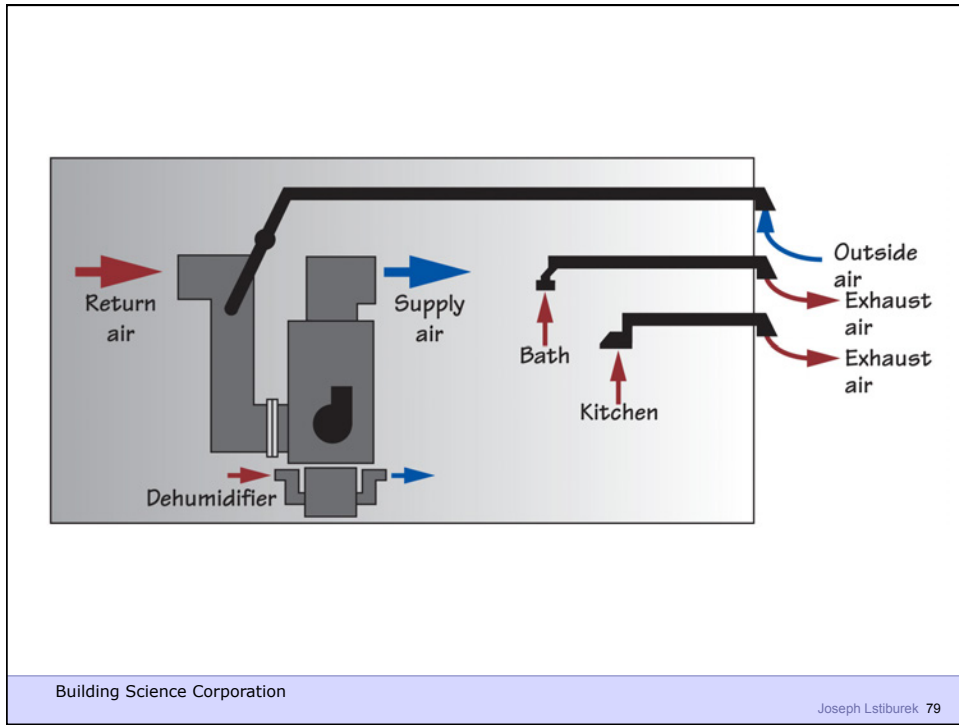
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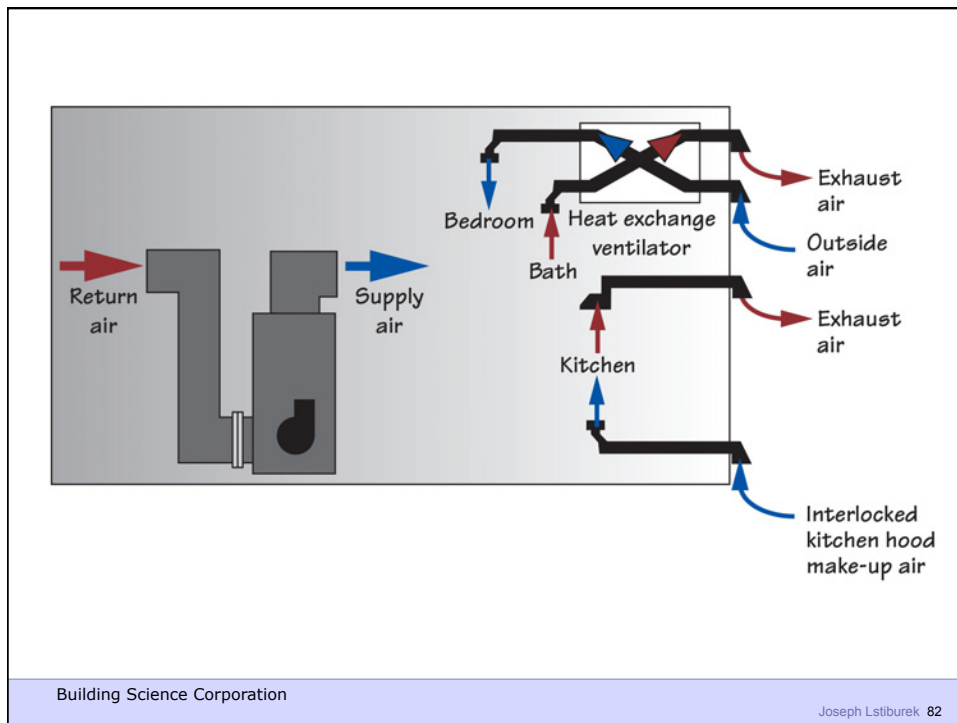
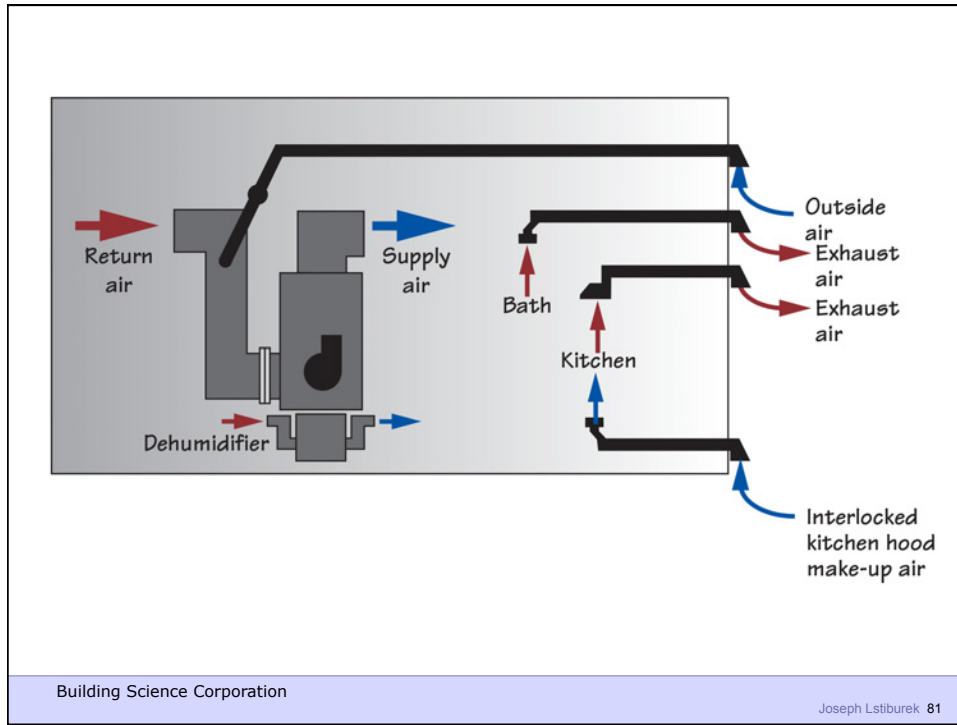


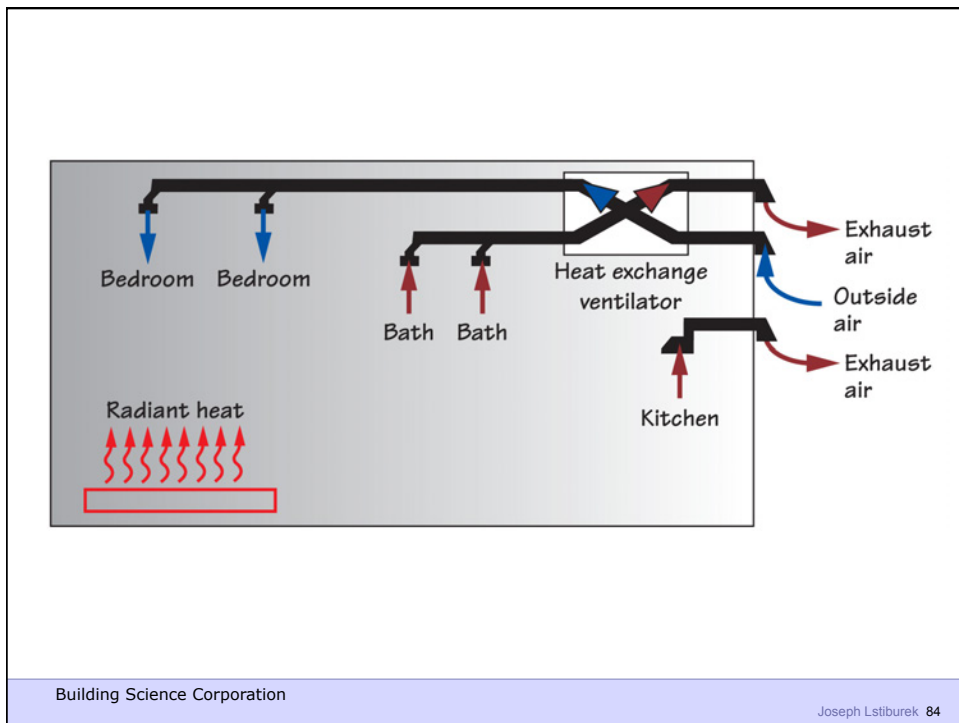
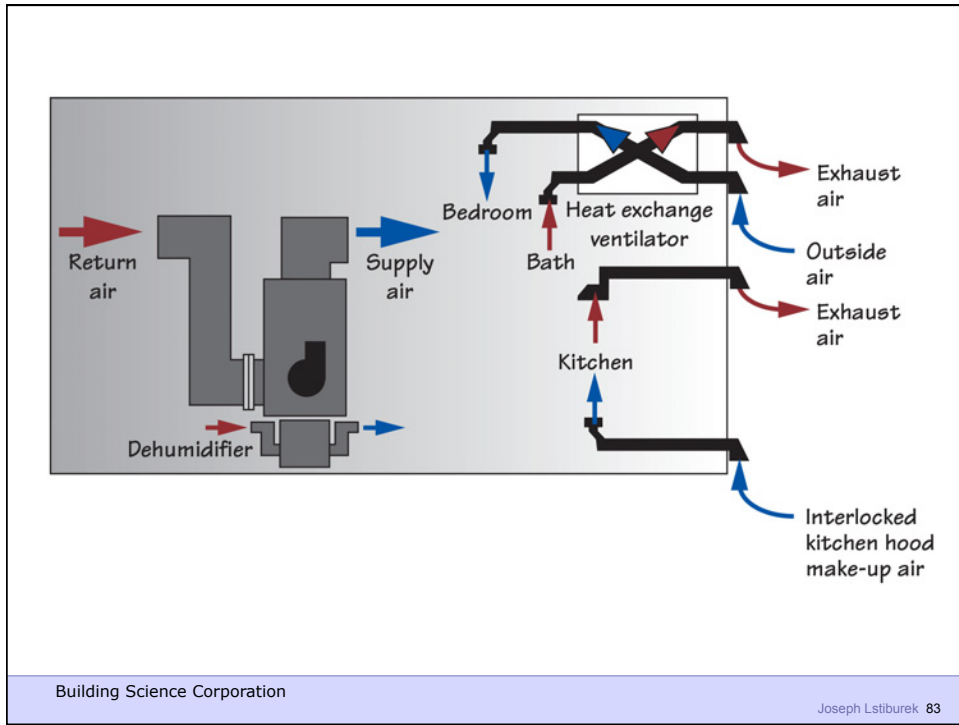
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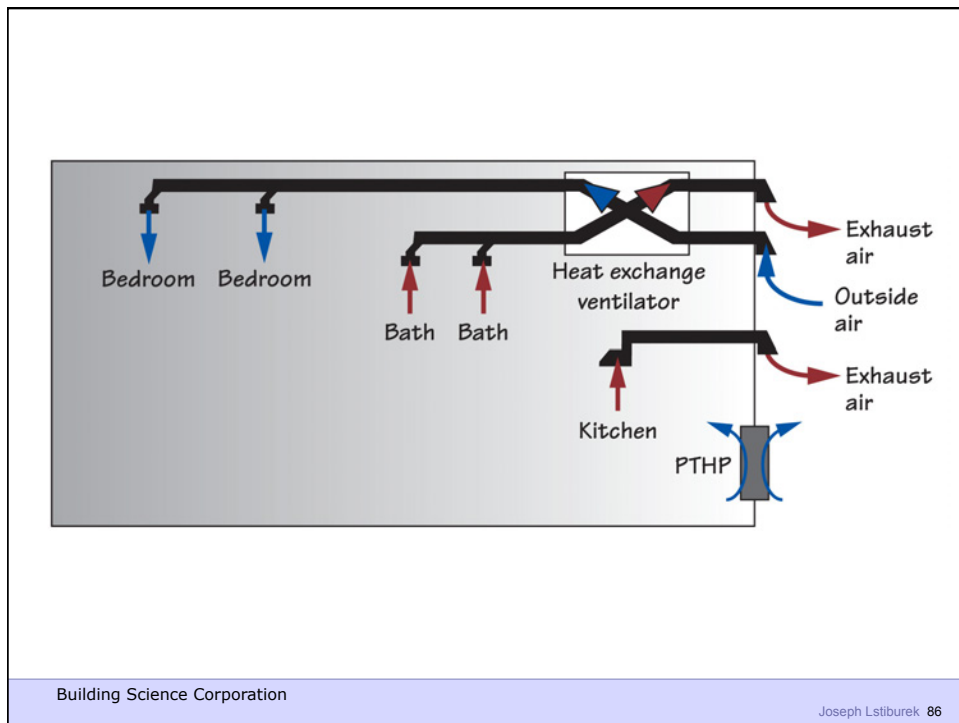
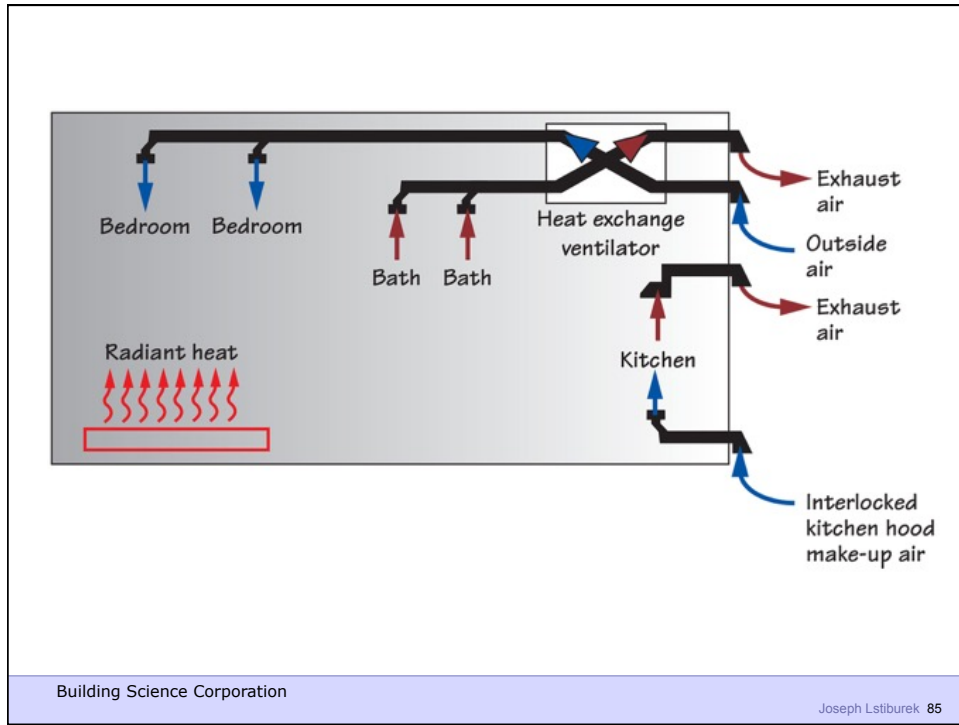
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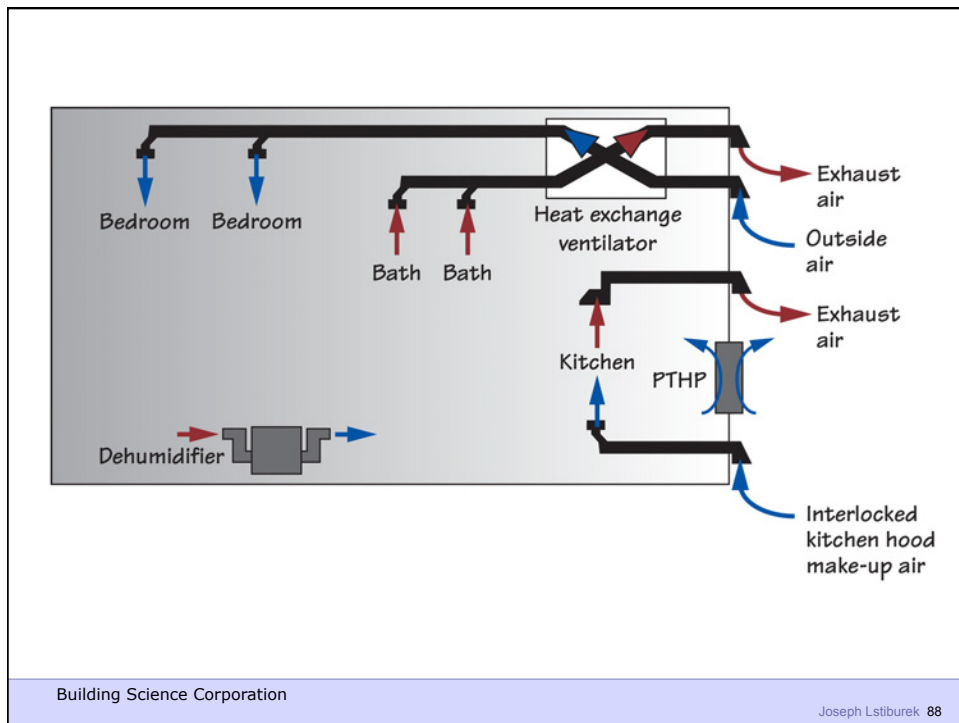
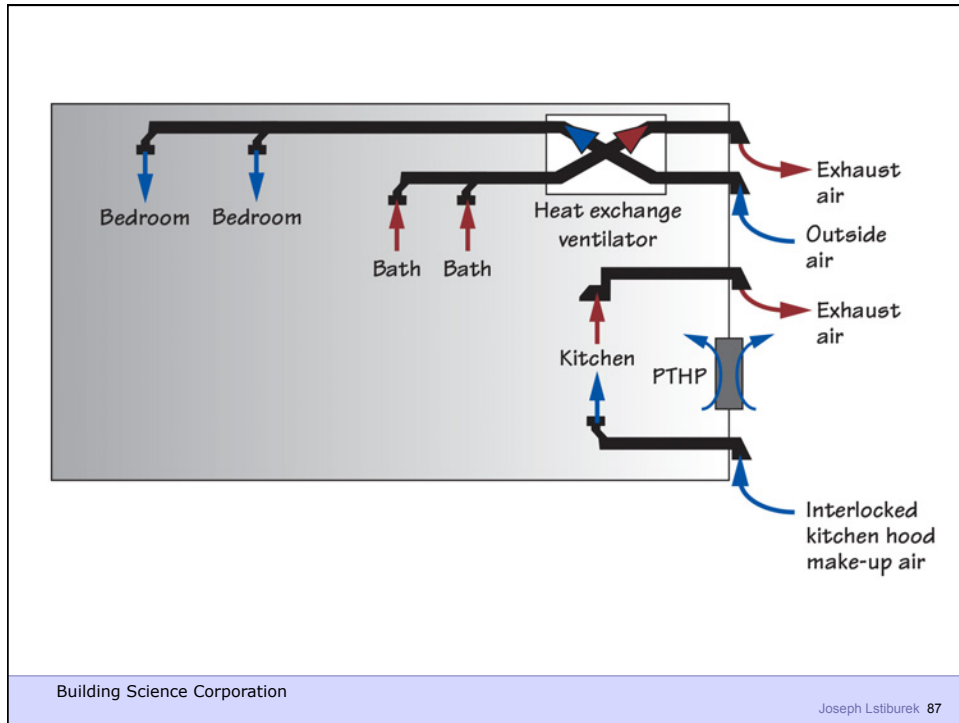














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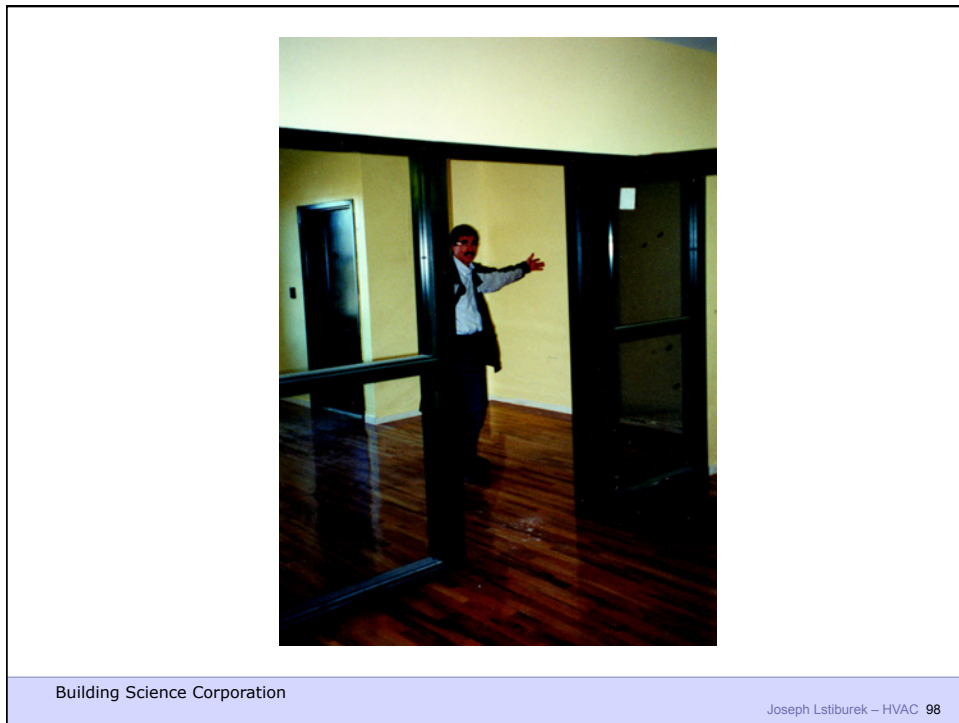
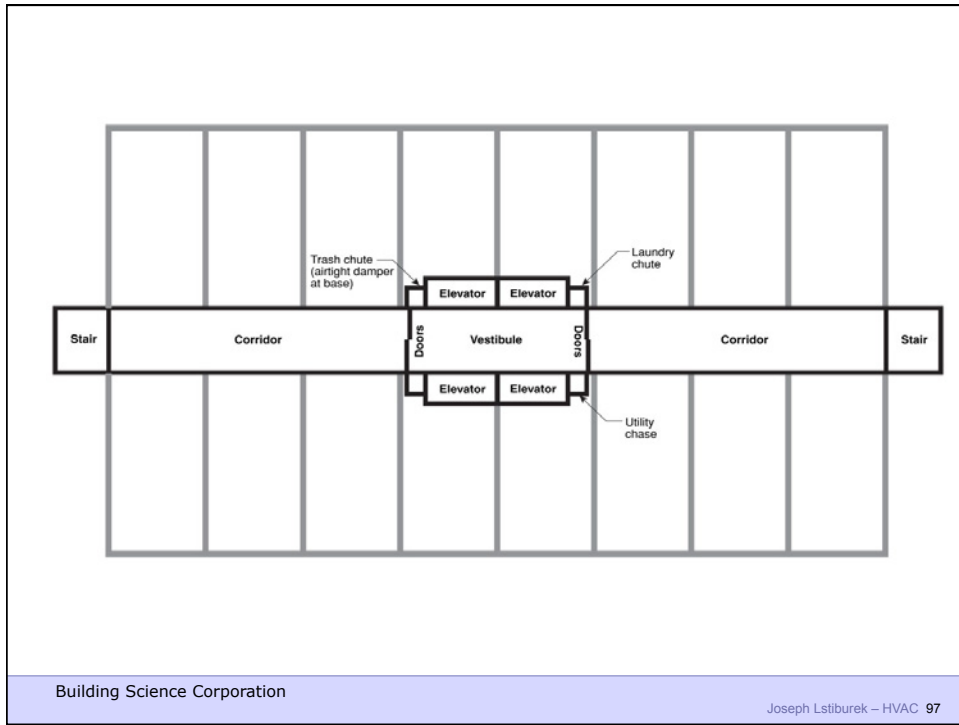
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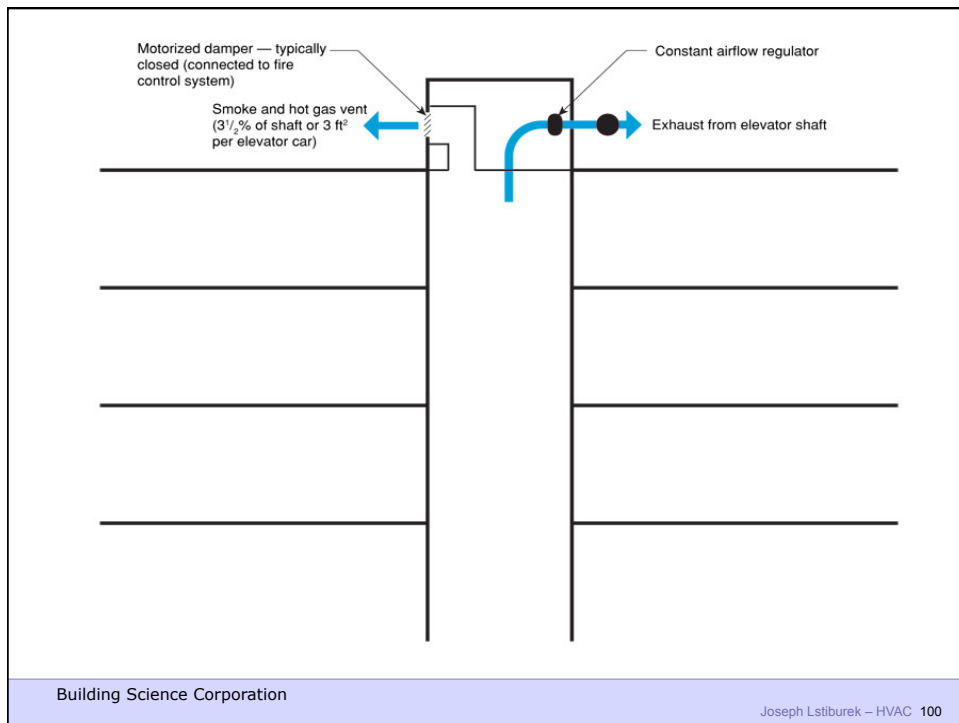
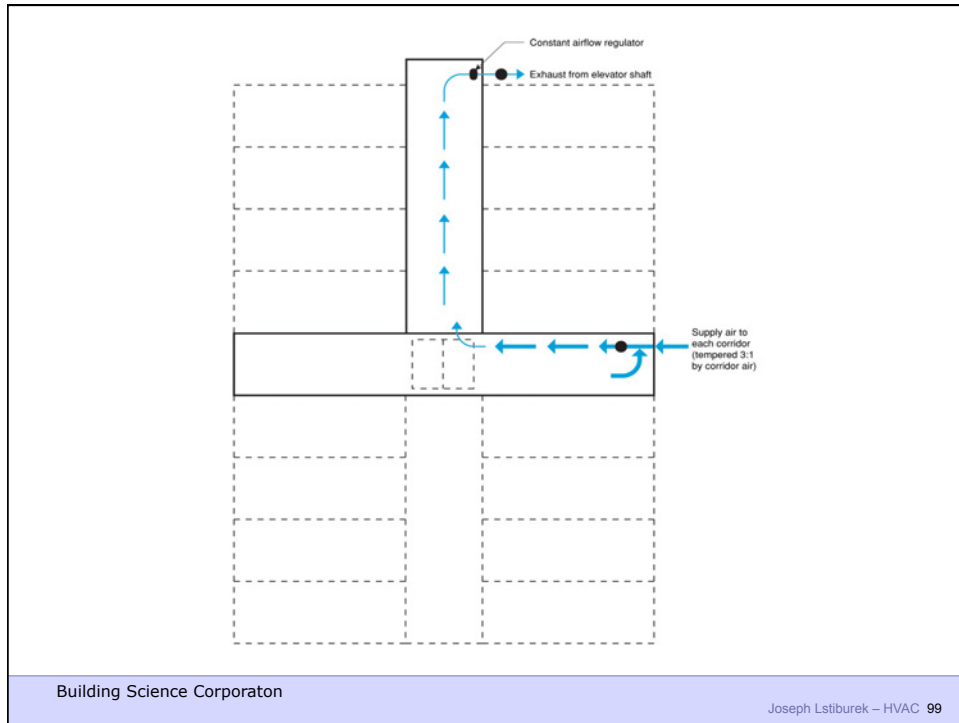
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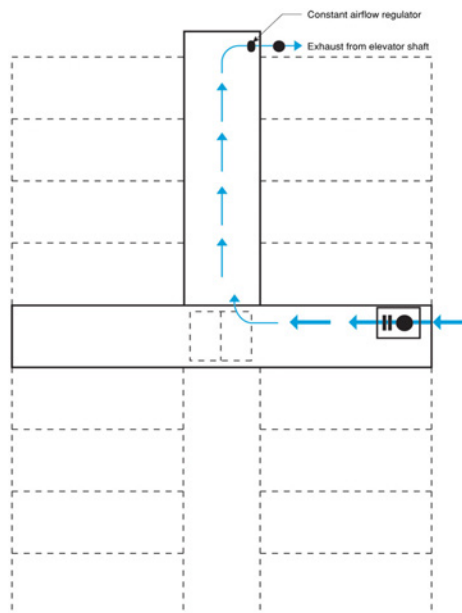






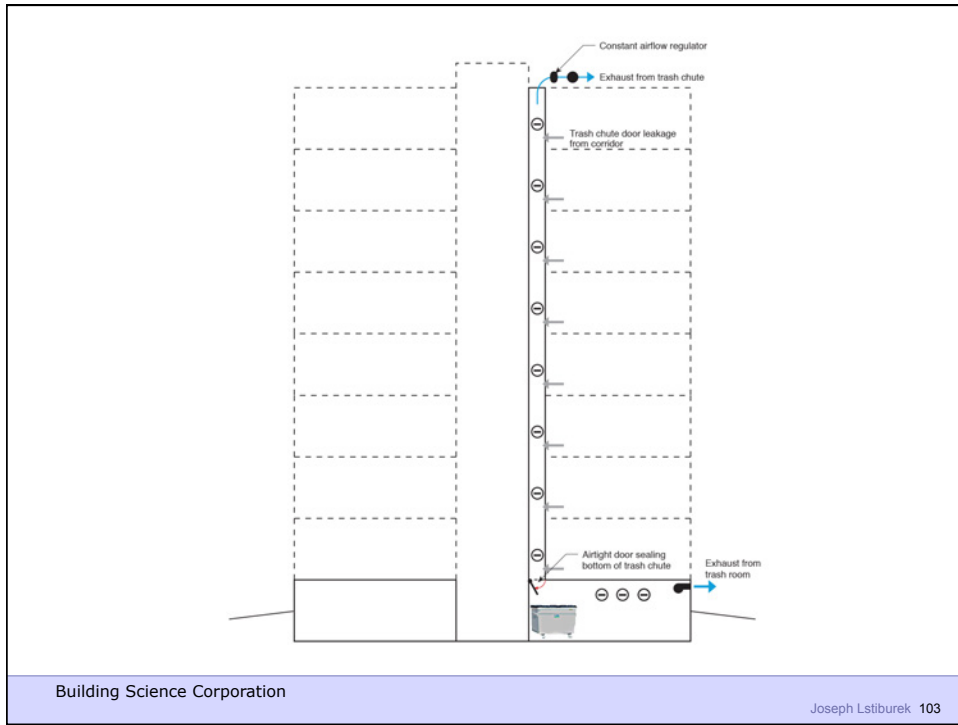
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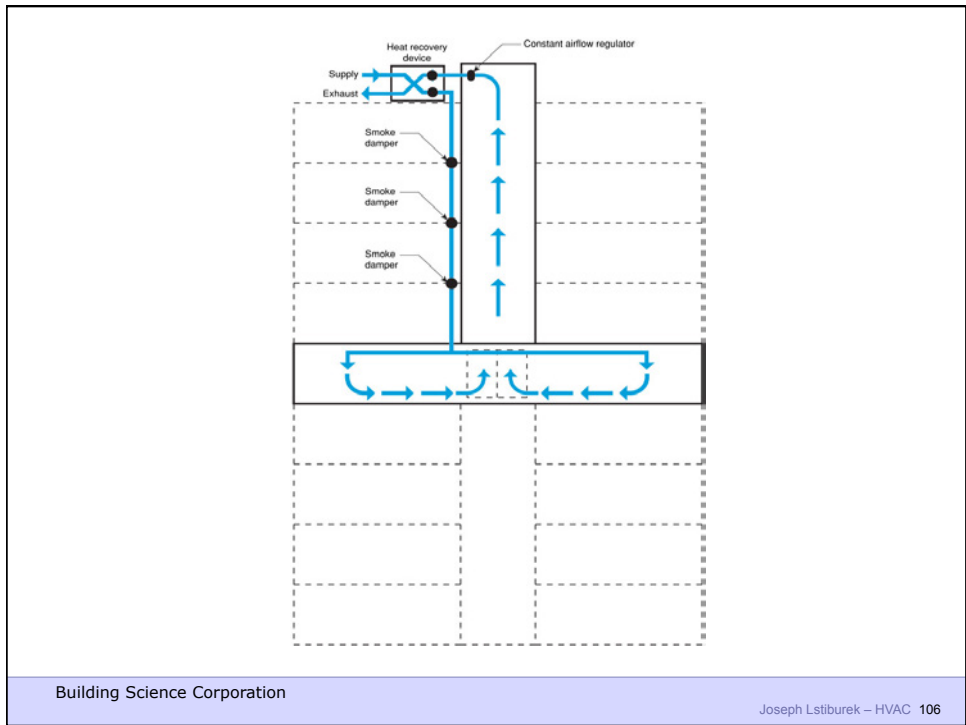
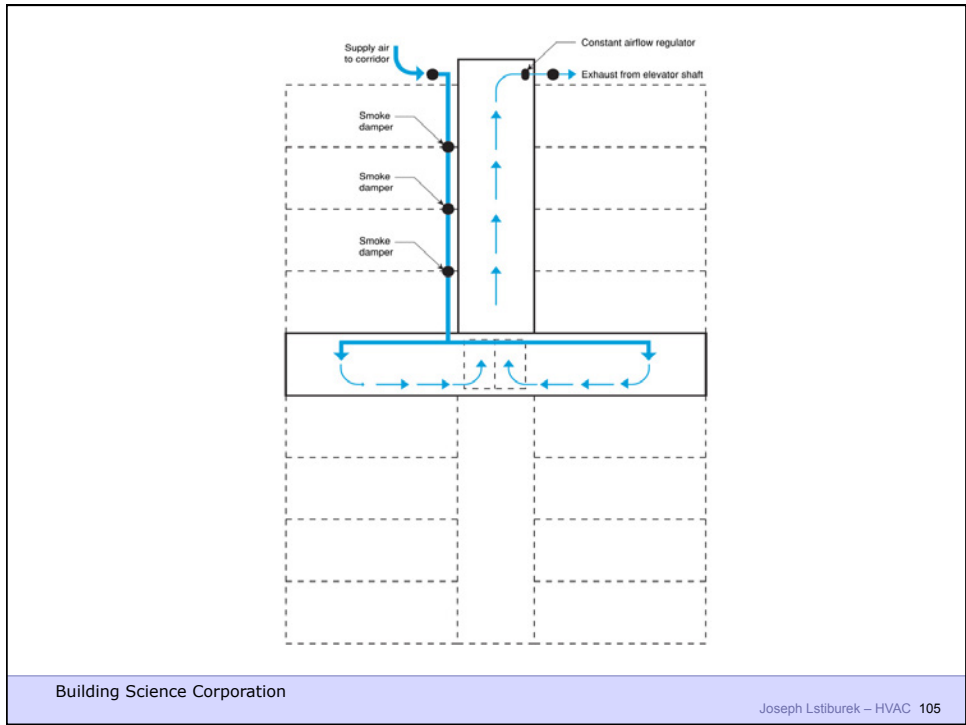
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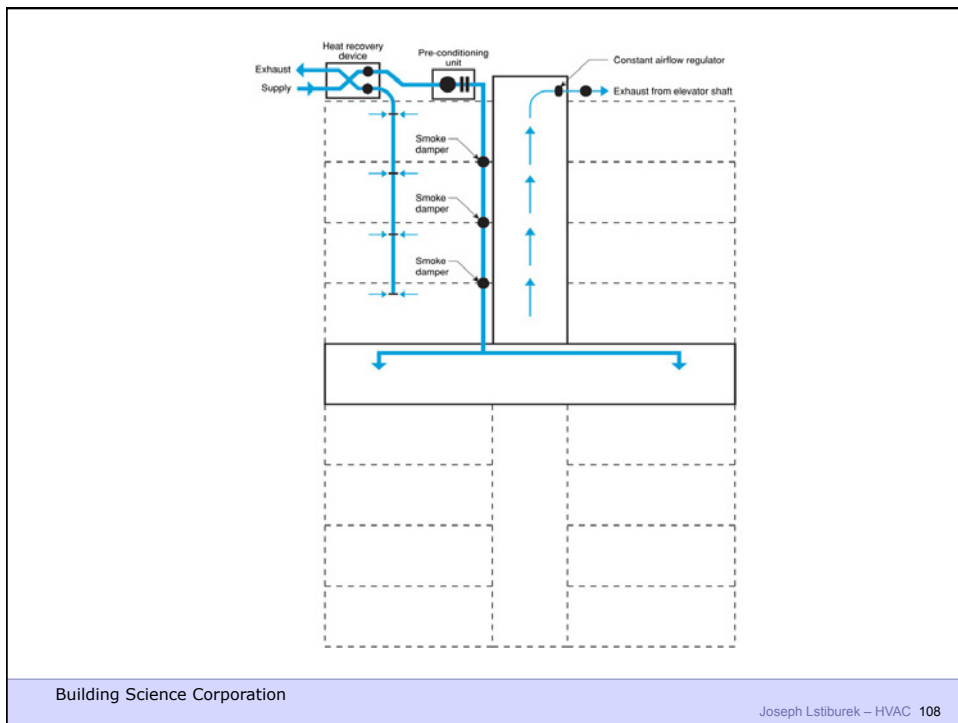
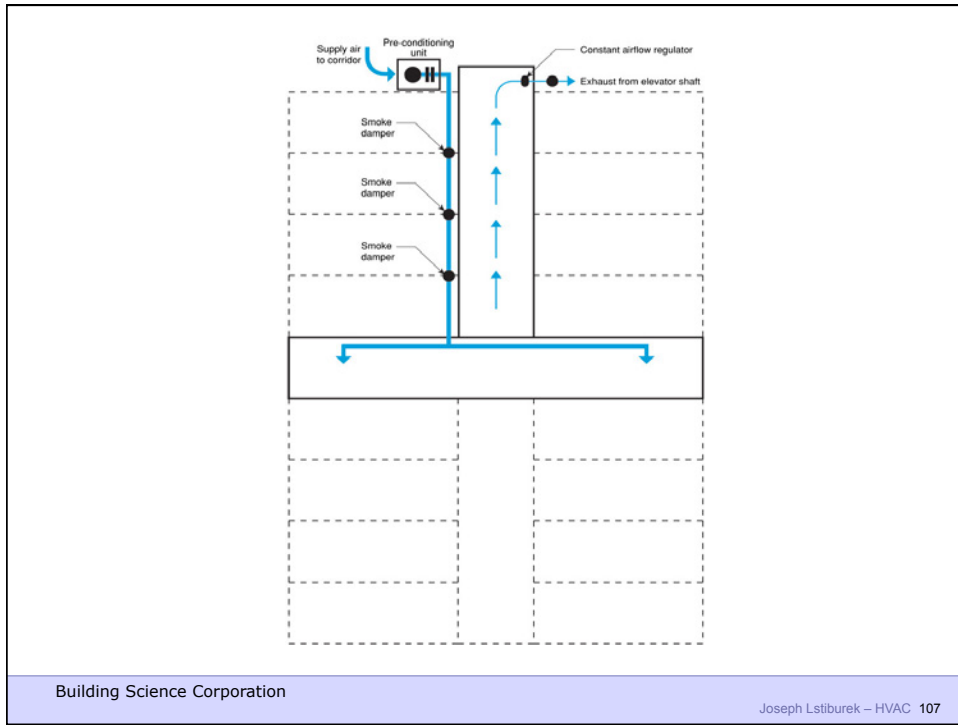


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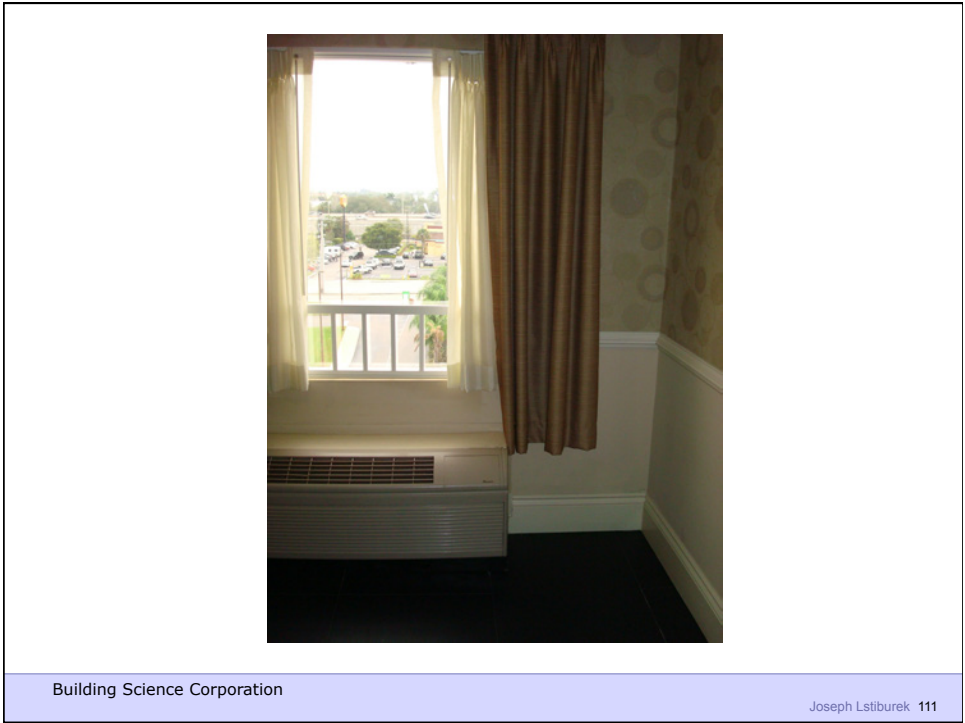
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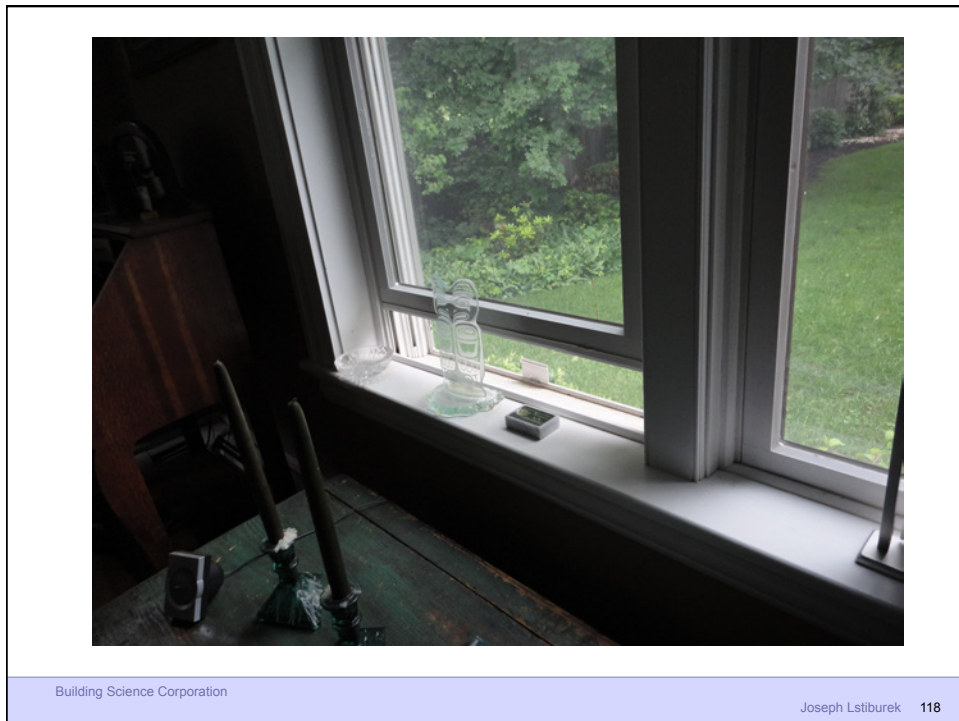
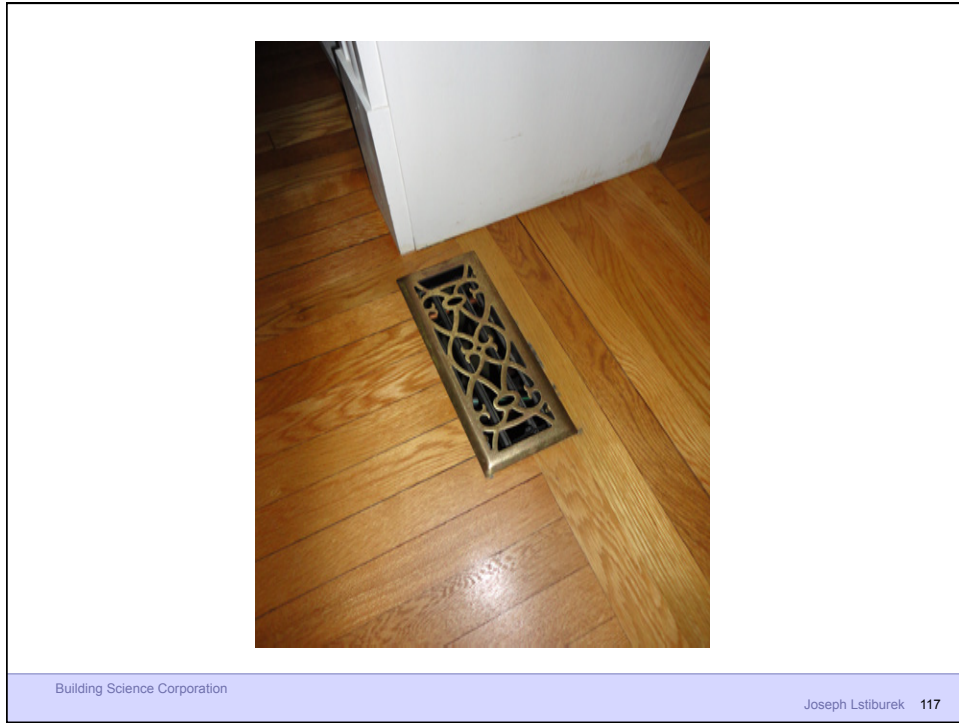
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Ventilation Rates Are Based on Odor Control

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Ventilation Rates Are Based on Odor Control
Health Science Basis for Ventilation Rates is
Extremely Limited

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Ventilation Rates Are Based on Odor Control
Health Science Basis for Ventilation Rates is
Extremely Limited
Almost Nothing Cited Applies to Housing

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Ventilation Rates Are Based on Odor Control
Health Science Basis for Ventilation Rates is
Extremely Limited
Almost Nothing Cited Applies to Housing
The Applicable Studies Focus on Dampness

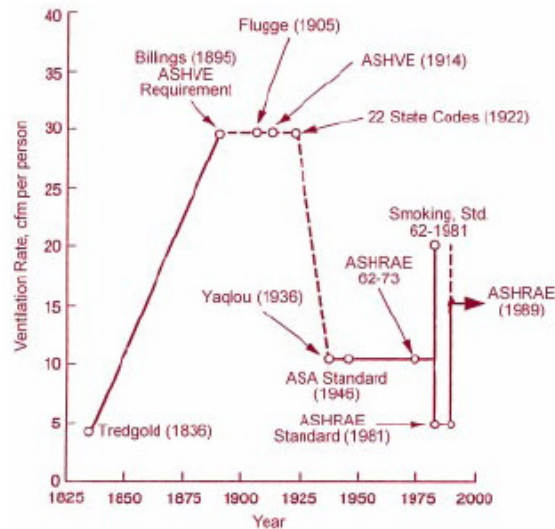
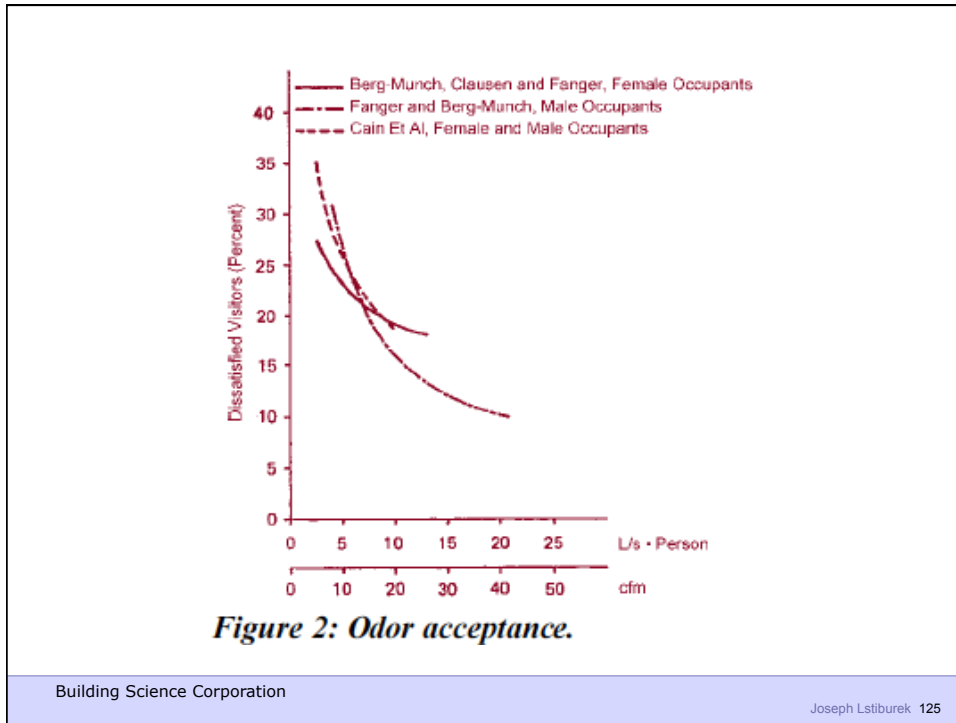


Figure 1: Minimum ventilating rate history.



House
2,000 ft²
3 bedrooms
8 ft. ceiling
Volume: 16,000 ft³

.35 ach 93 cfm
 .30 ach 80 cfm
 .25 ach 67 cfm
 .20 ach 53 cfm
 .15 ach 40 cfm

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House

2,000 ft²
3 bedrooms
8 ft. ceiling
Volume: 16,000 ft³

Ventilation Rates

.35 ach	93 cfm	62 - 73	5 cfm/person	20 cfm
.30 ach	80 cfm		10 cfm/person	40 cfm
.25 ach	67 cfm	62 - 89	15 cfm/person	60 cfm
.20 ach	53 cfm		.35 ach	90 cfm
.15 ach	40 cfm	62.2 - 2010	7.5 cfm/person	50 cfm
			+ 0.01	
		62.2 - 2013	7.5 cfm/person	90 cfm
			+ 0.03	

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Office

Occupant Density

15/1000 ft² (67 ft²/person) 62 - 89
 15 cfm/person

5/1000 ft² (200 ft²/person) 62.1 - 2007
 17 cfm/person

Correctional Facility Cell

Occupant Density

20/1000 ft² (48 ft²/person) 62.1 - 2007
 10 cfm/person

C.P. Yaglou

Harvard School of Public Health

1936

1955

150 ft³ → 20 cfm/person

300 ft³ → 12 cfm/person

C.P. Yaglou

Harvard School of Public Health

1936

1955

150 ft³ → 20 cfm/person 18.75 ft² 106 occupants

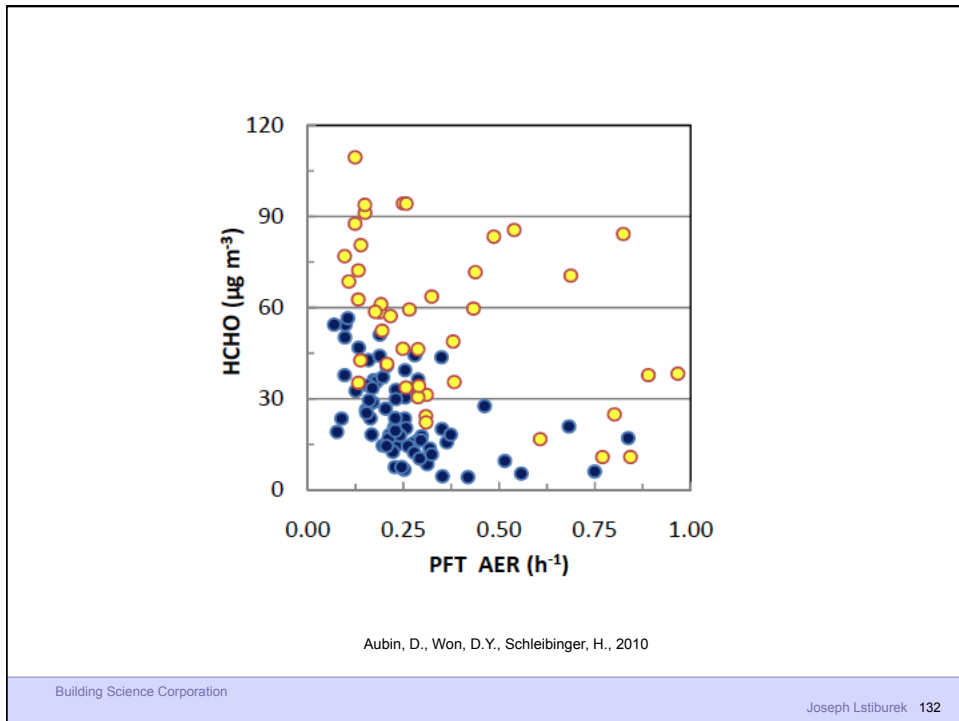
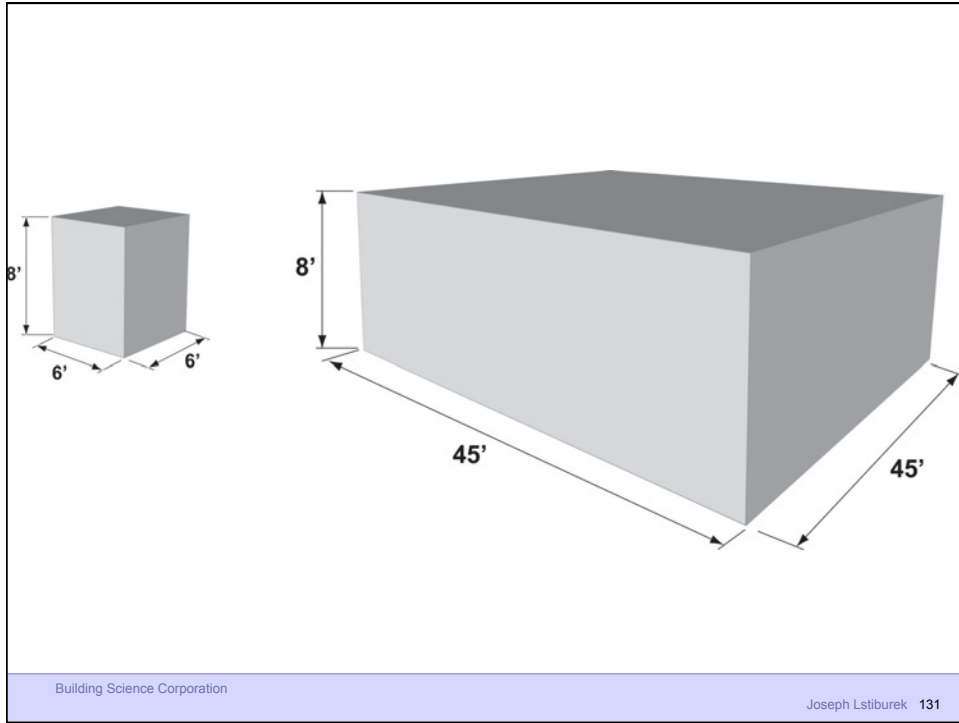
300 ft³ → 12 cfm/person 37.5 ft² 53 occupants

Experiment

470 ft³ → 59 ft²

200 ft³ → 25 ft²

100 ft³ → 12 ft²



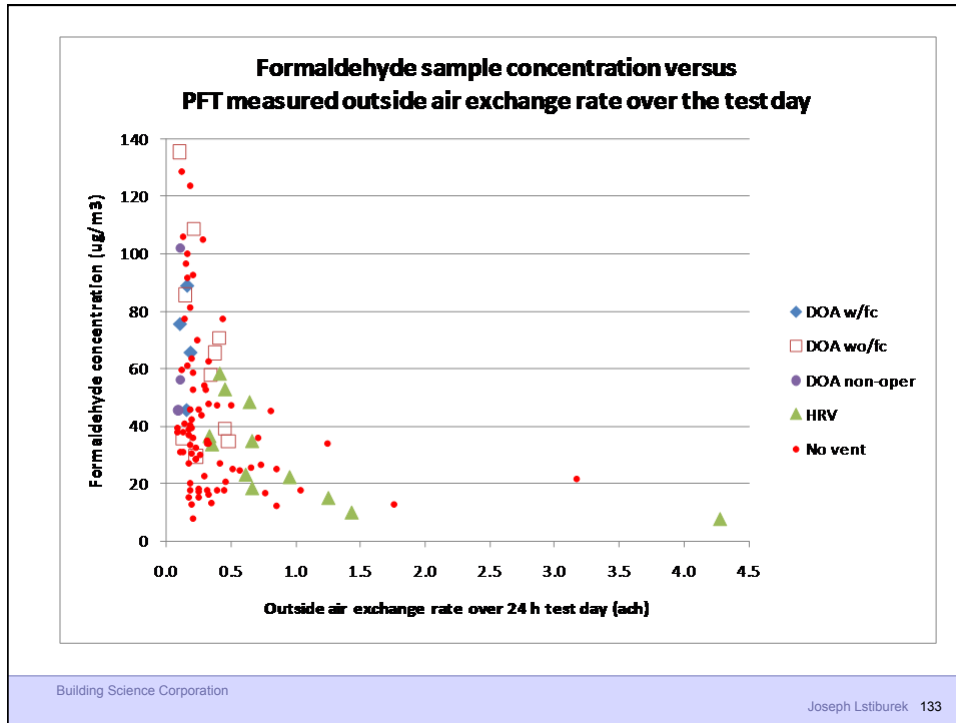


Table 1. Summary of the air changes rates measured during the winter 2009-10 season in Quebec City

Method	ACH (h ⁻¹)	ACH standard deviation (h ⁻¹)	number of measurements
SF ₆ tracer decay	0.27	0.12	77
perfluorocarbon tracer	0.32	0.22	37
blower door at 50 Pa	4.16	2.64	63

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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-m ²) @ 75 Pa
Assembly	0.20 l/(s-m ²) @ 75 Pa
Enclosure	2.00 l/(s-m ²) @ 75 Pa
	0.35 cfm/ft ² @ 50 Pa
	0.25 cfm/ft ² @ 50 Pa
	0.15 cfm/ft ² @ 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

Dilution Is Not The Solution To Indoor Pollution Source Control

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Dilution For People Source Control For The Building

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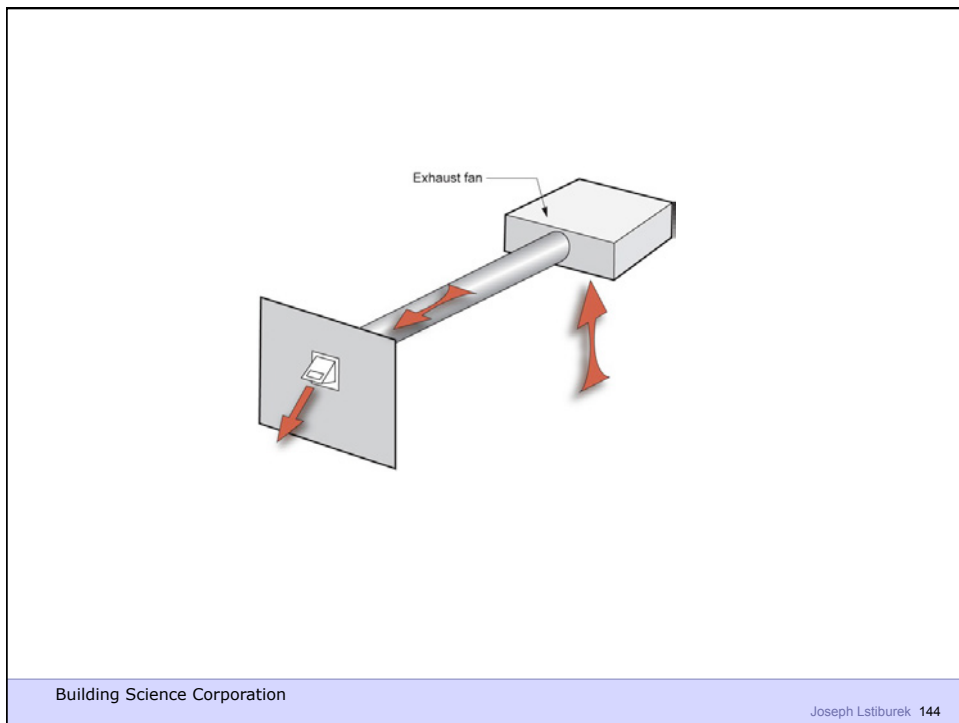
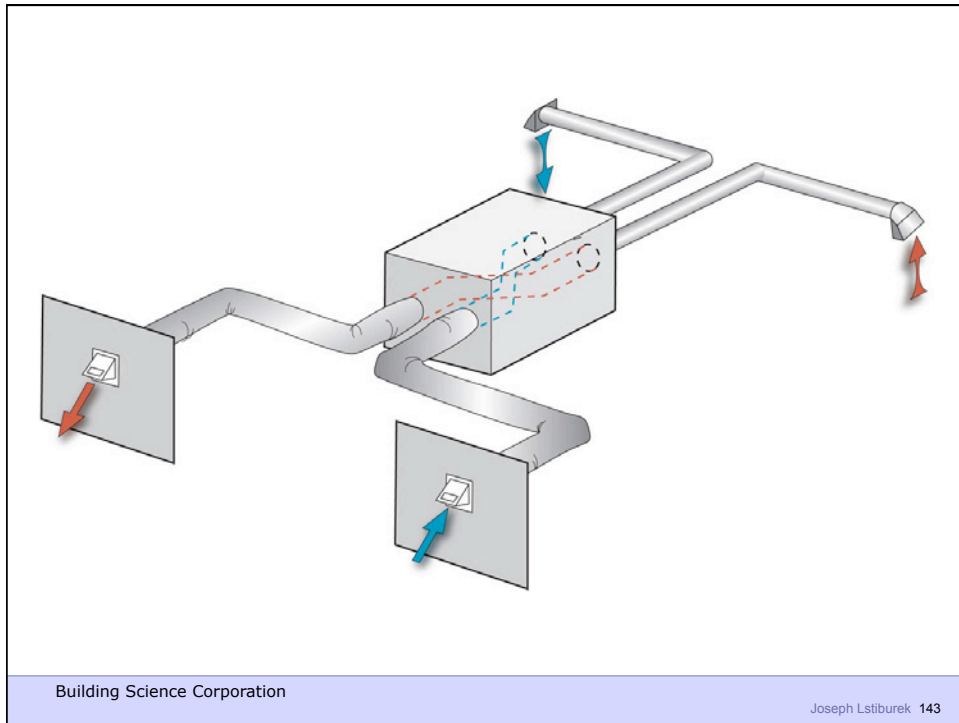
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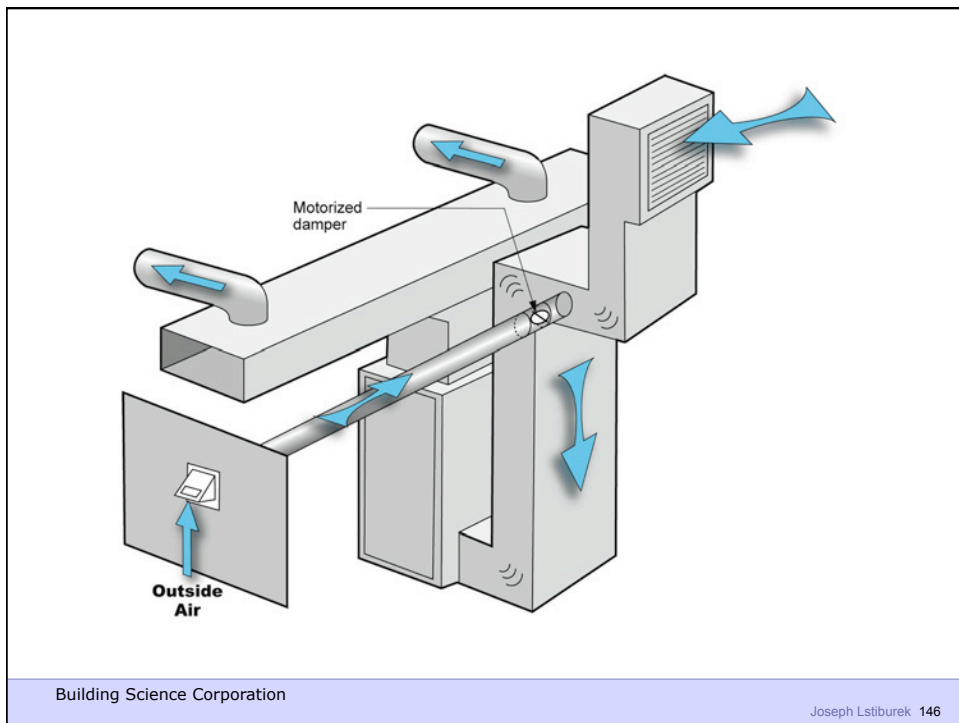
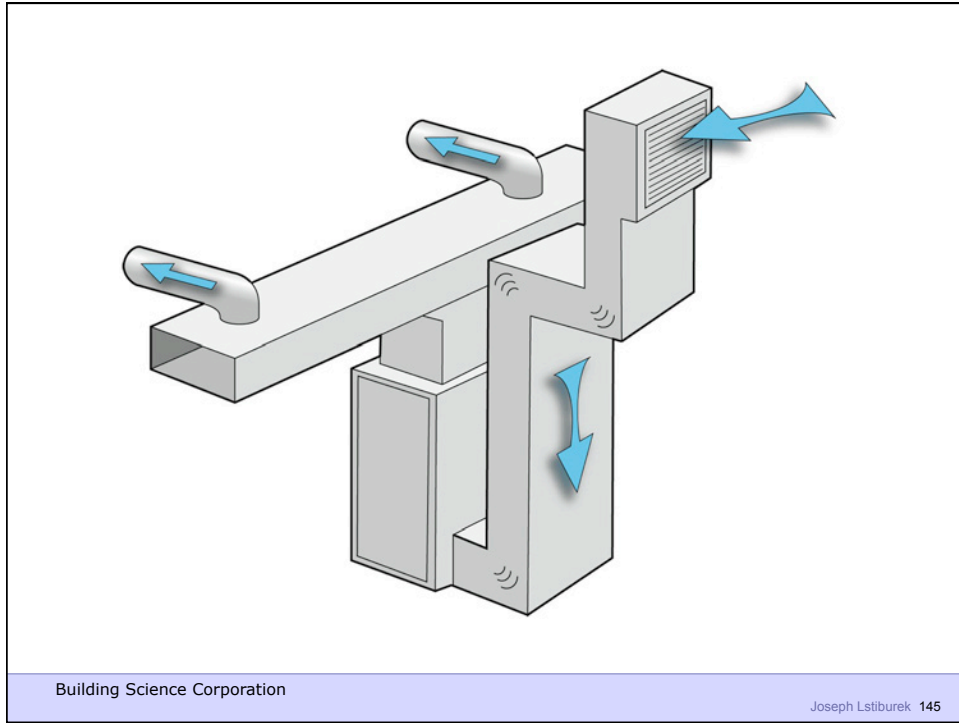
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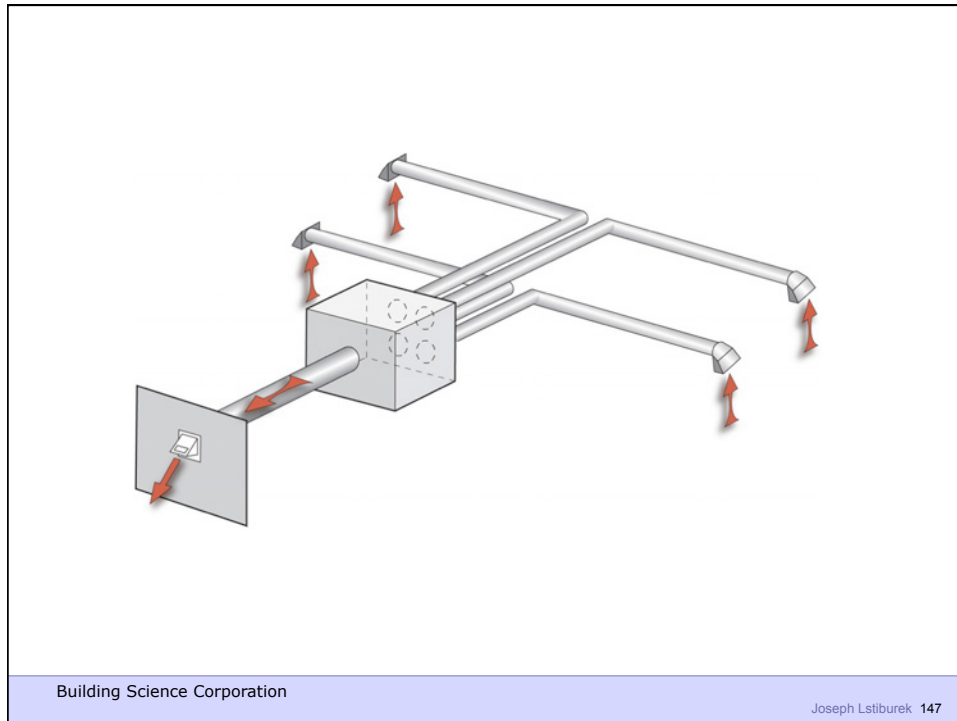
As Tight as Possible - with -
Balanced Ventilation
Energy Recovery
Distribution and Mixing
Source Control - Spot exhaust ventilation
Filtration
Material selection

Worst

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

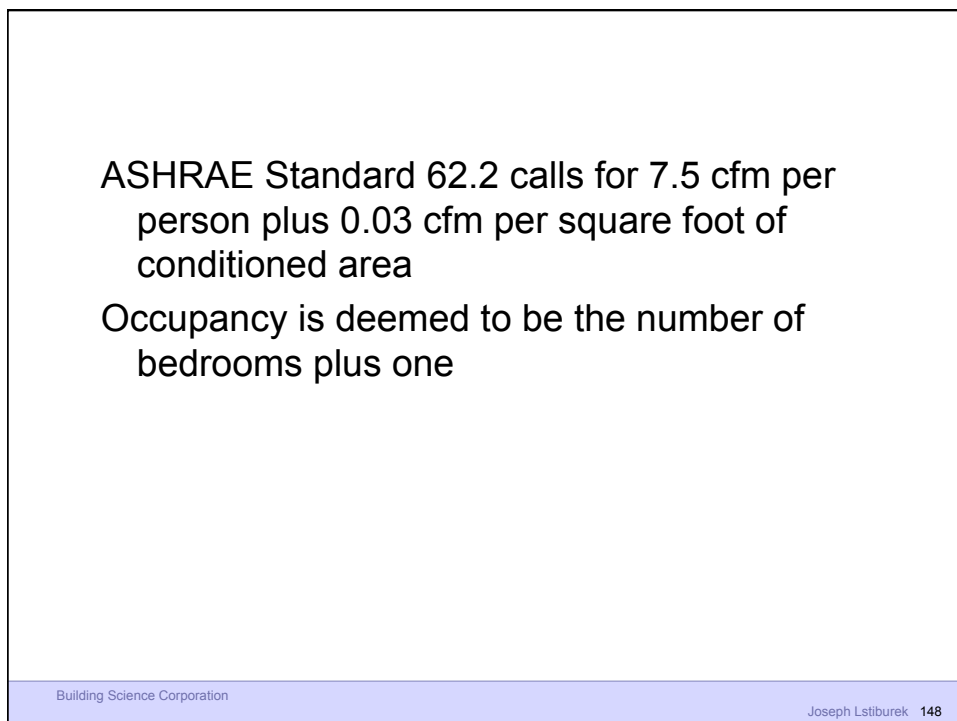






ASHRAE Standard 62.2 calls for 7.5 cfm per
person plus 0.03 cfm per square foot of
conditioned area

Occupancy is deemed to be the number of
bedrooms plus one



ASHRAE Standard 62.2 calls for 7.5 cfm per person plus 0.03 cfm per square foot of conditioned area

Occupancy is deemed to be the number of bedrooms plus one

Outcome is often bad – part load humidity problems, dryness problems, energy problems

The Cult of The Blower Door



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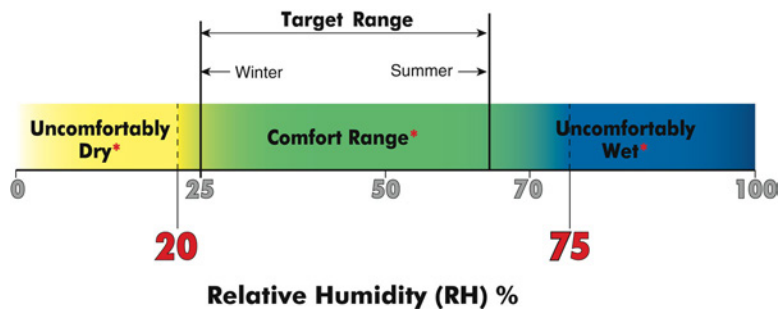
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Blower Door Can't Get You The True ACH On A Short Term Basis – Hour, Day, Week

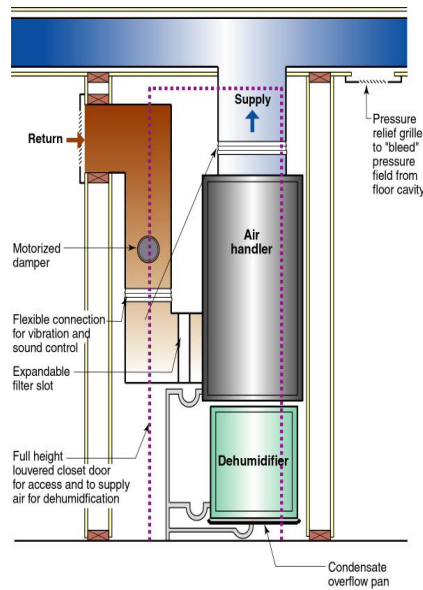
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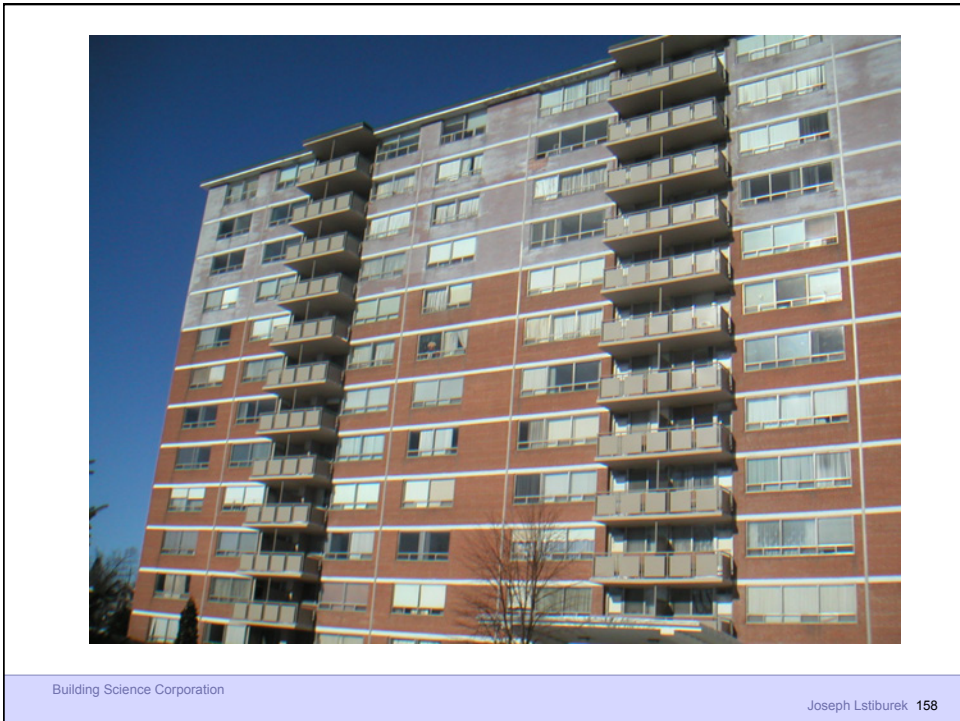
Joseph Lstiburek 152

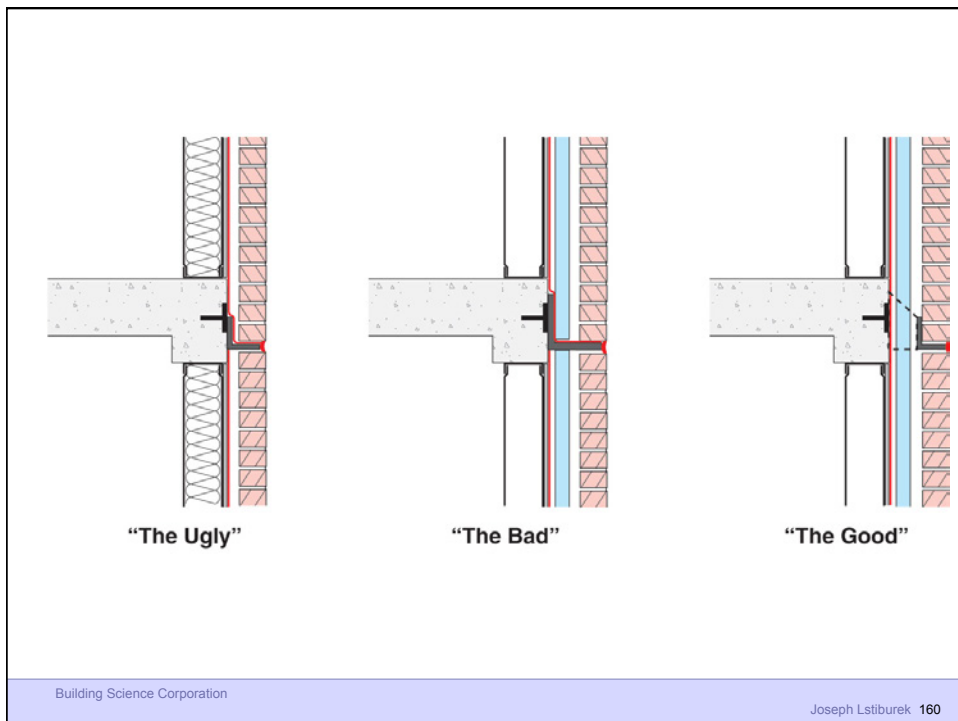
Don't Know Where The Holes Are
Don't Know The Type of Holes
Don't Know The Pressure Across The Holes

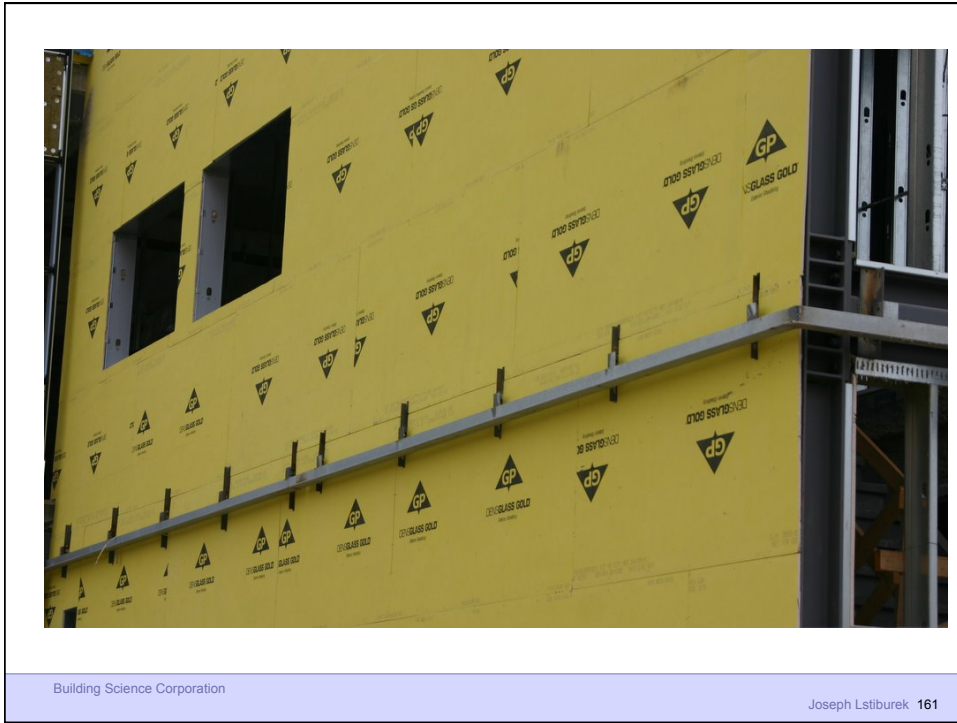


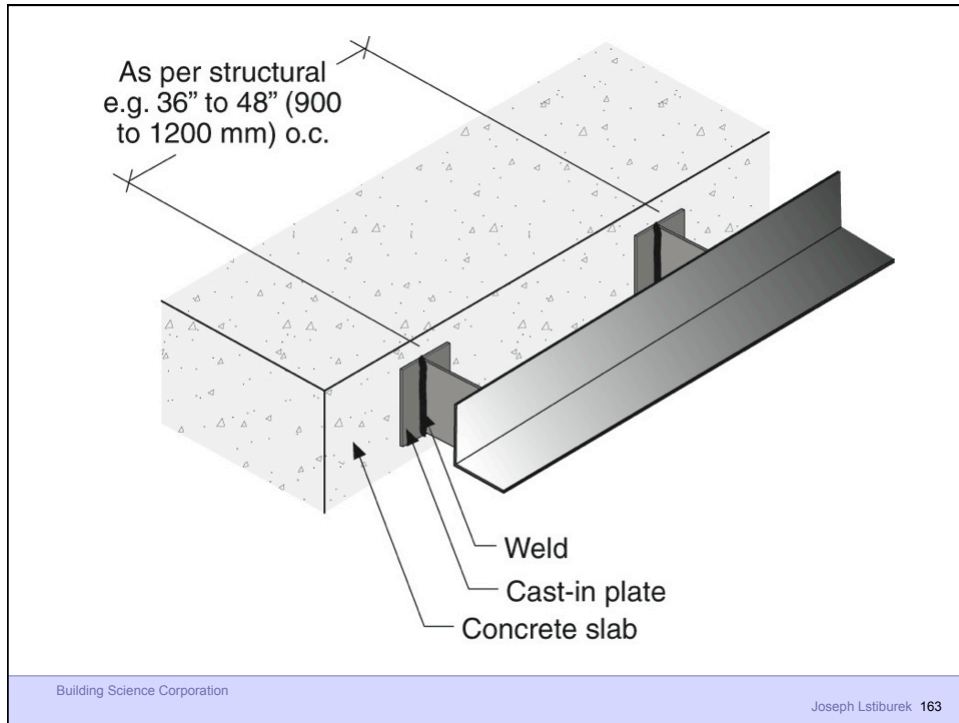
Recommended Range of Relative Humidity
Above 25 percent during winter
Below 70 percent during summer

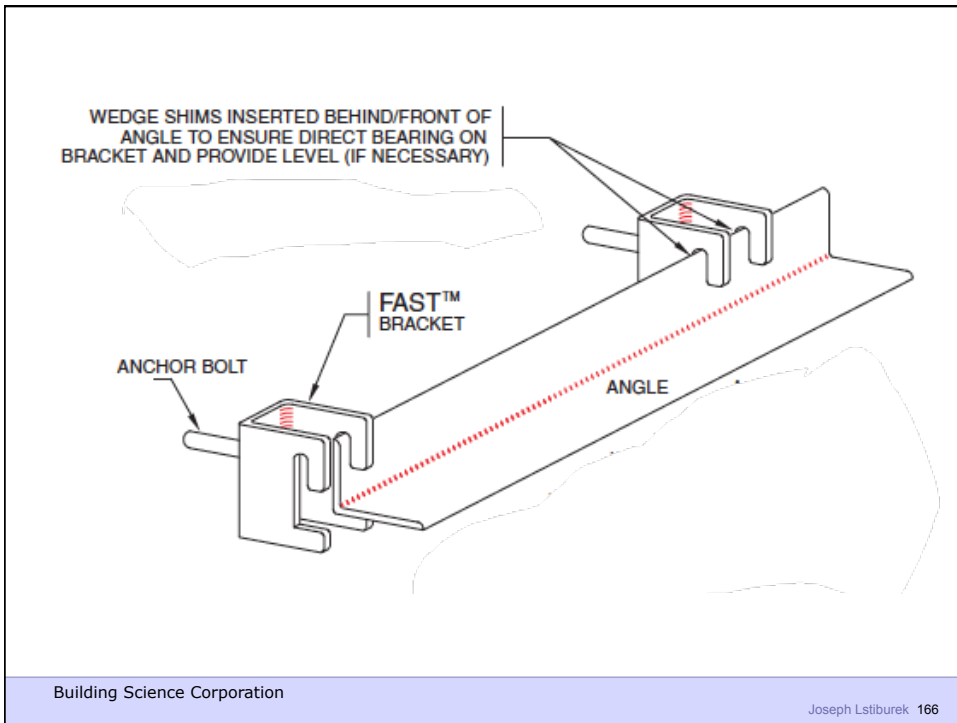
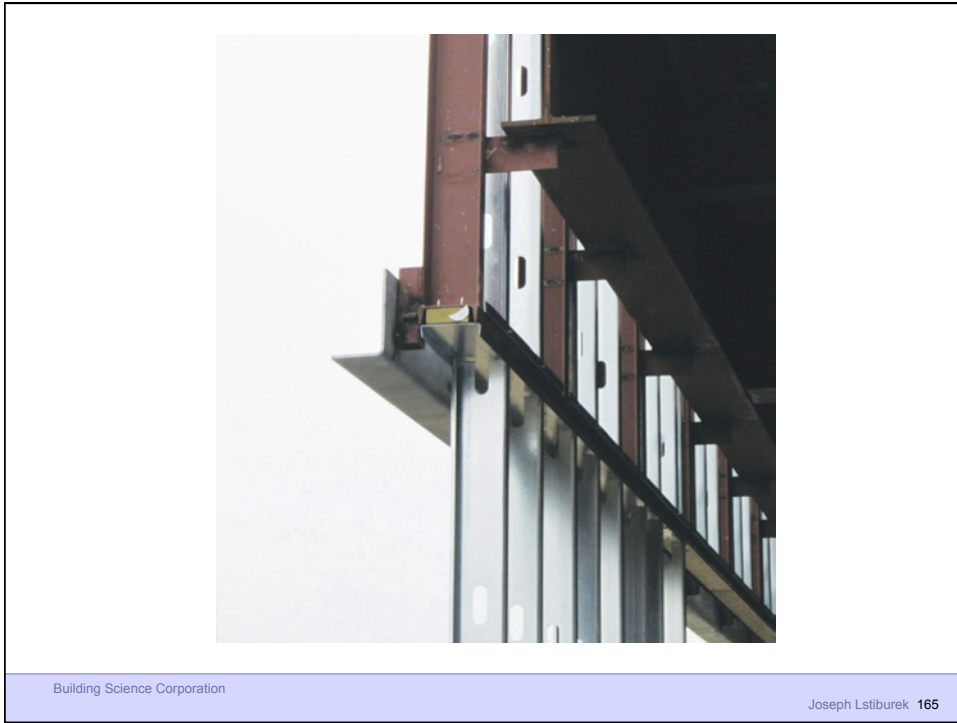


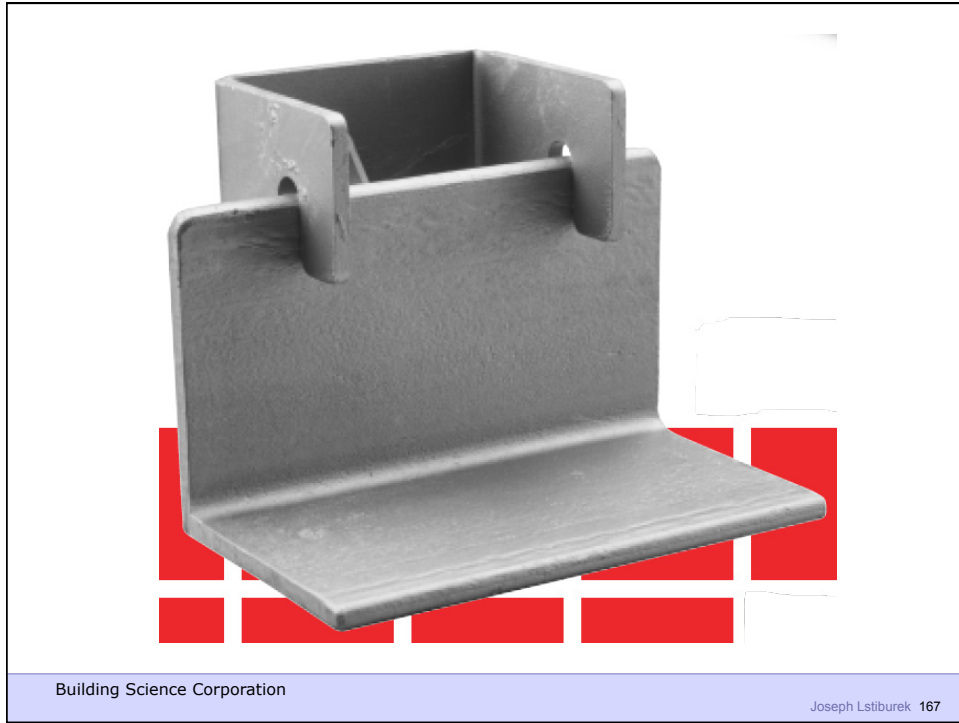


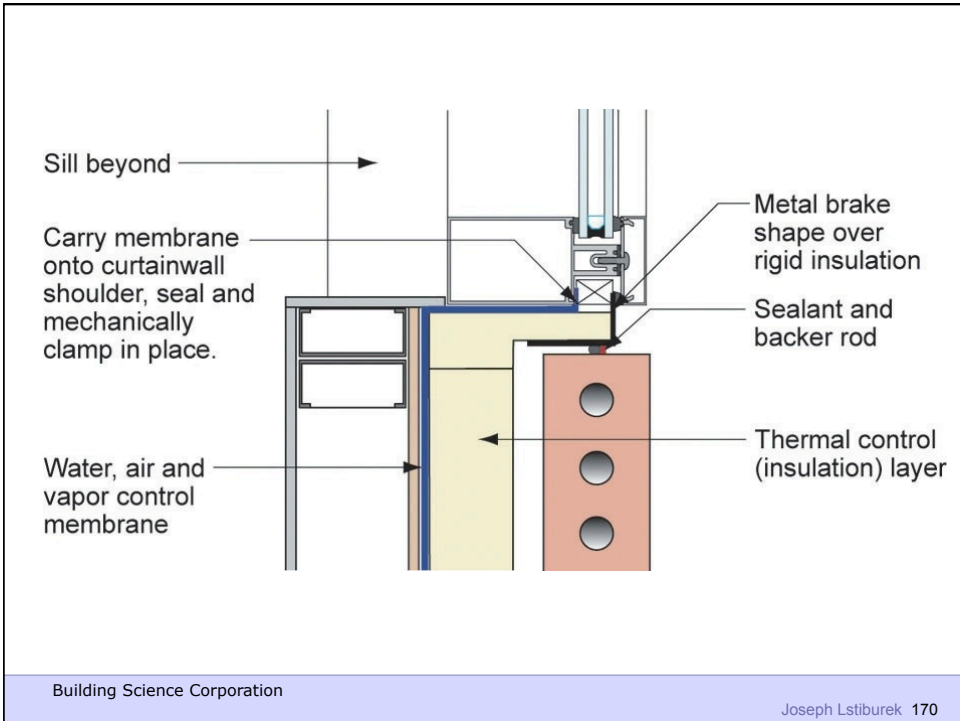


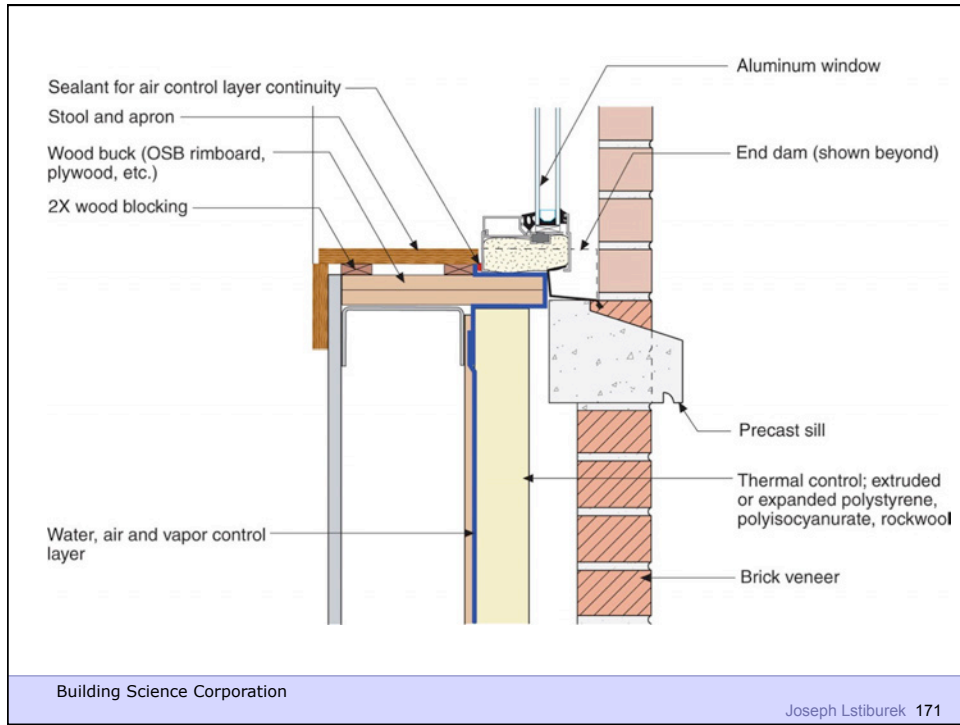


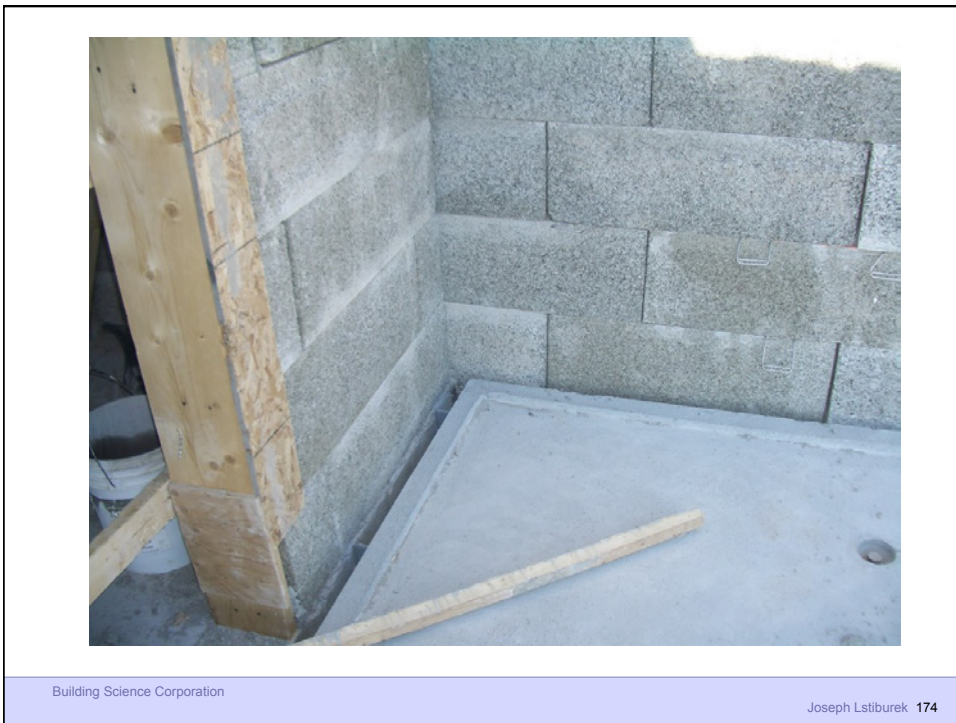
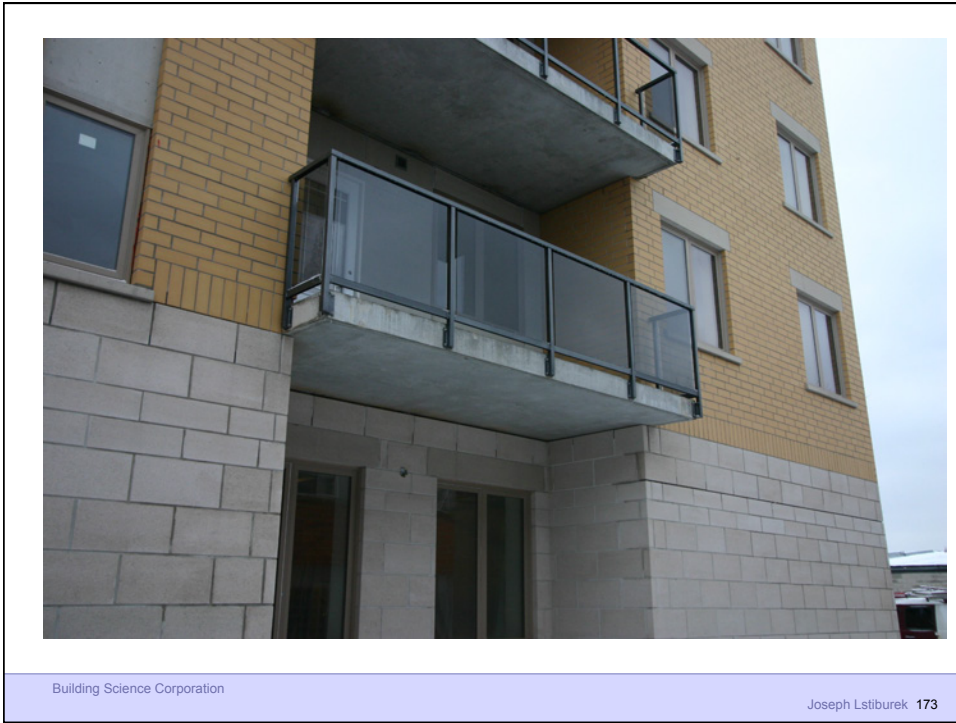


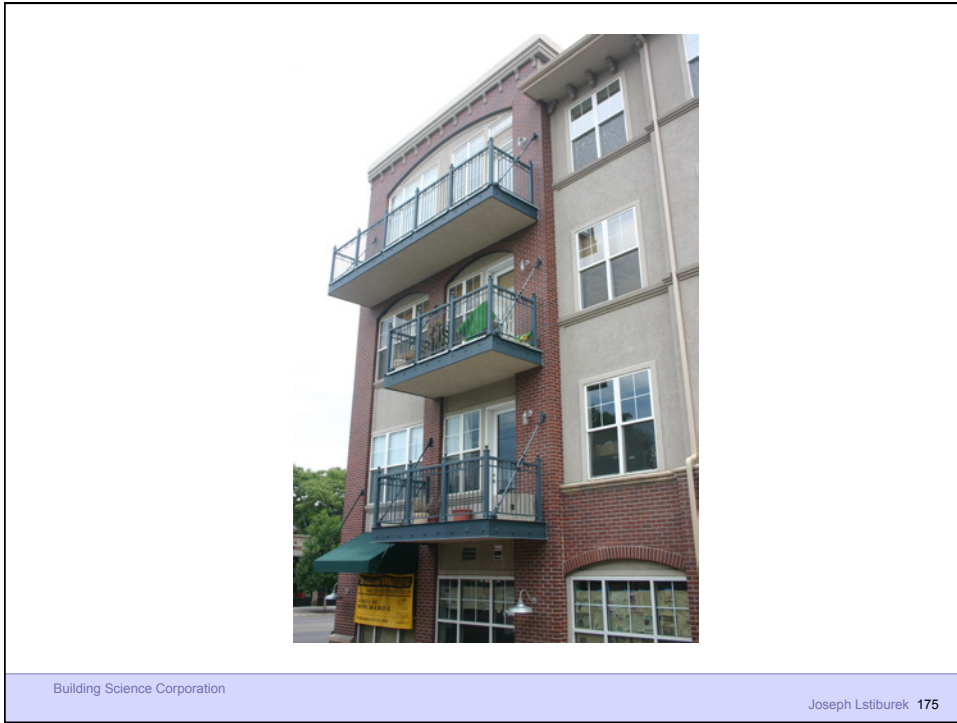














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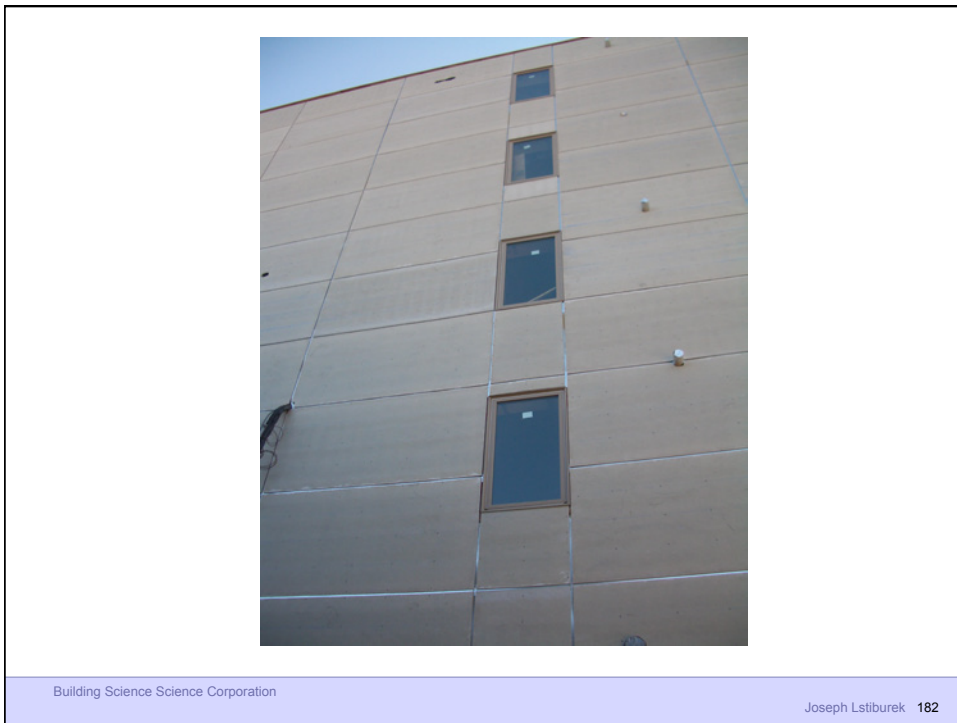
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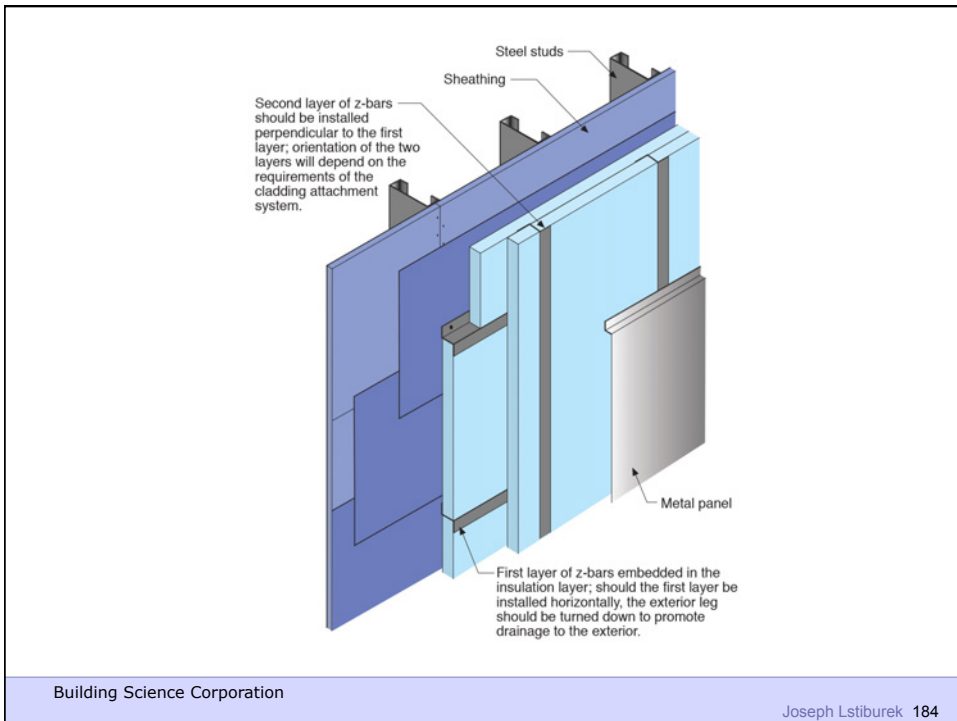
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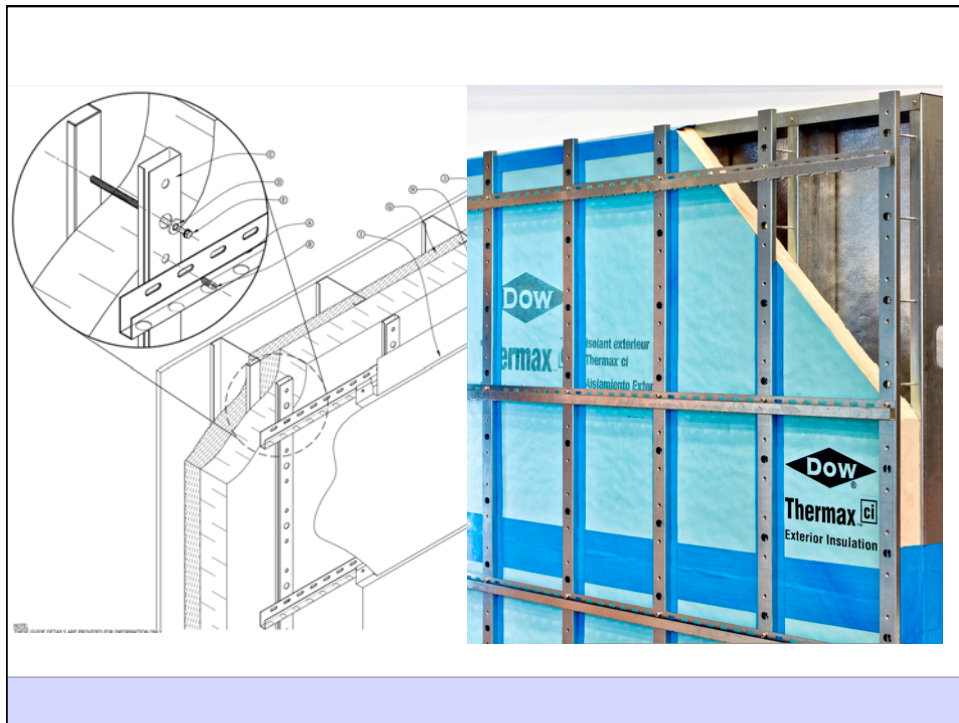
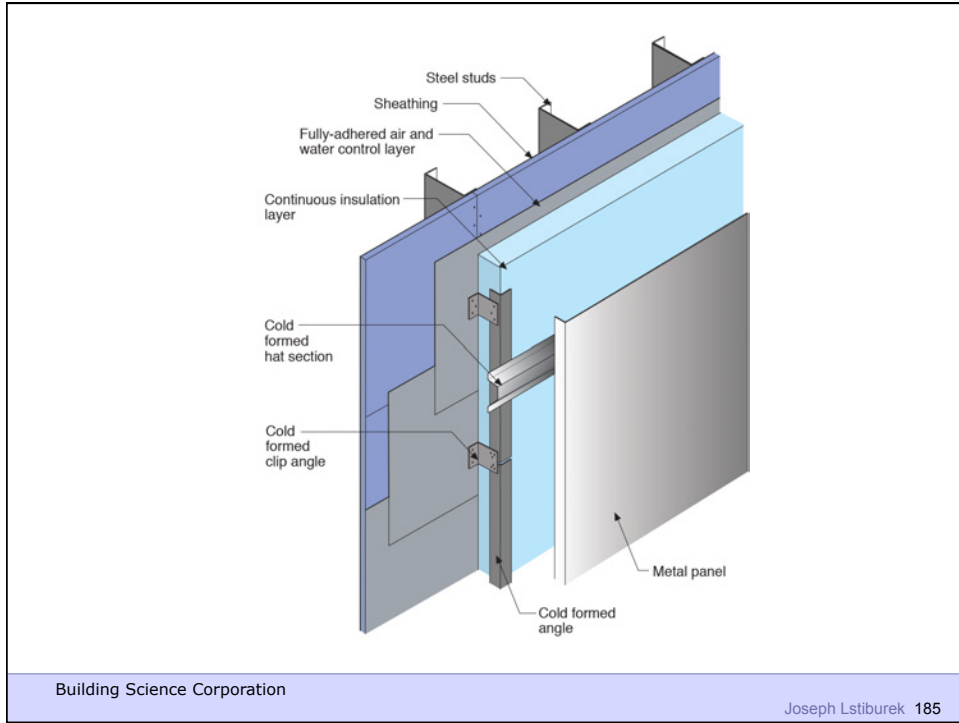


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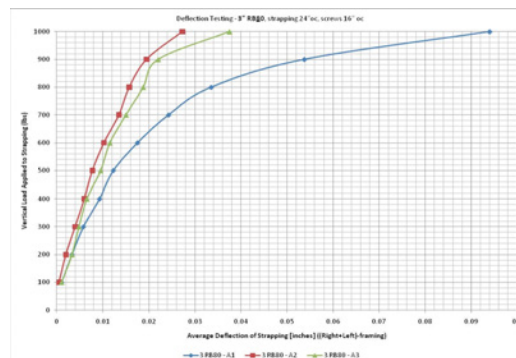
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Rockwool

1x3 furring @ 24" o.c.
#10 screws @ 16" o.c. vertically
Result: 20 psf cladding weight
with < 2/100" deflection





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