

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

Building Science

Adventures In Building Science

www.buildingscience.com

Build Tight - Ventilate Right

Building Science Corporation


Joseph Lstiburek 2

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

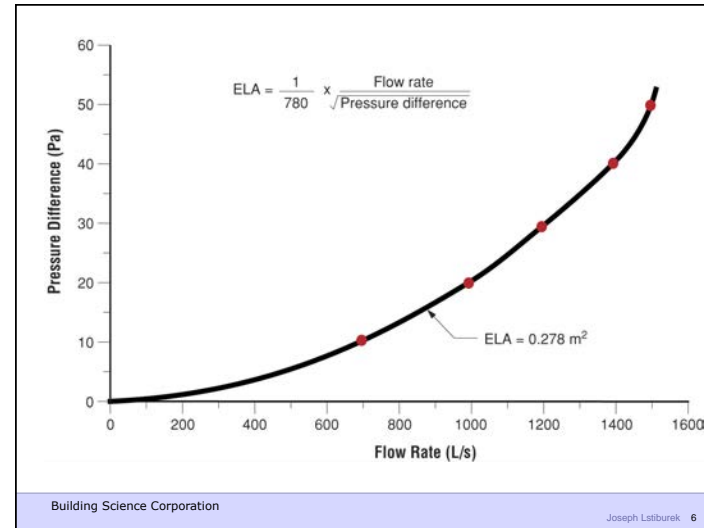
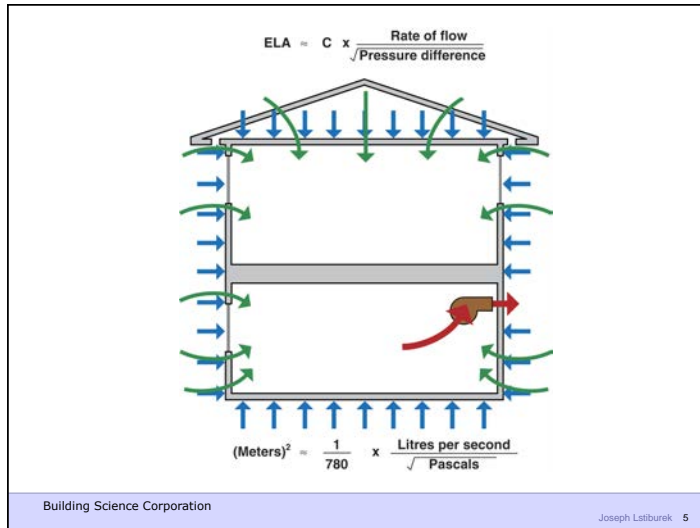
Building Science Corporation

Joseph Lstiburek 3



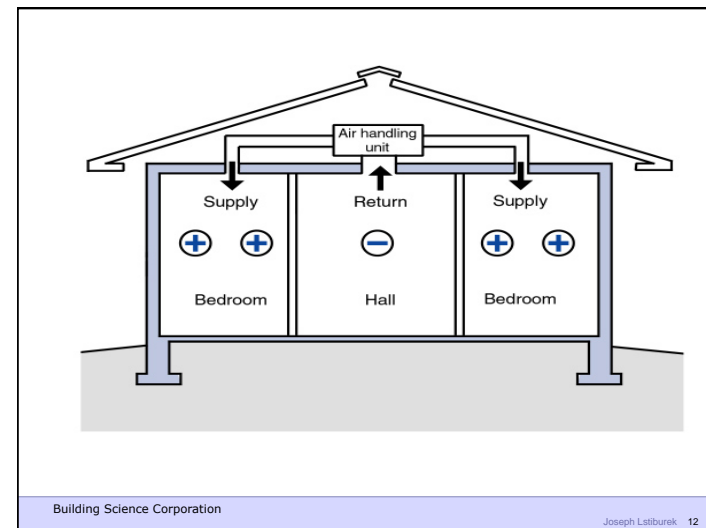
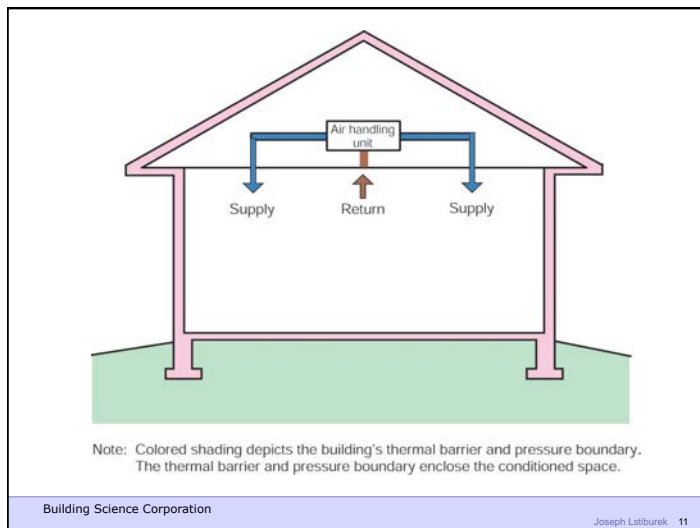
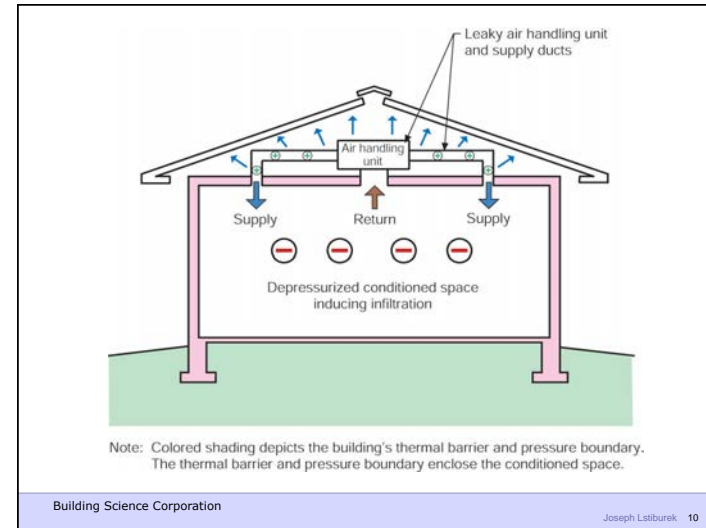
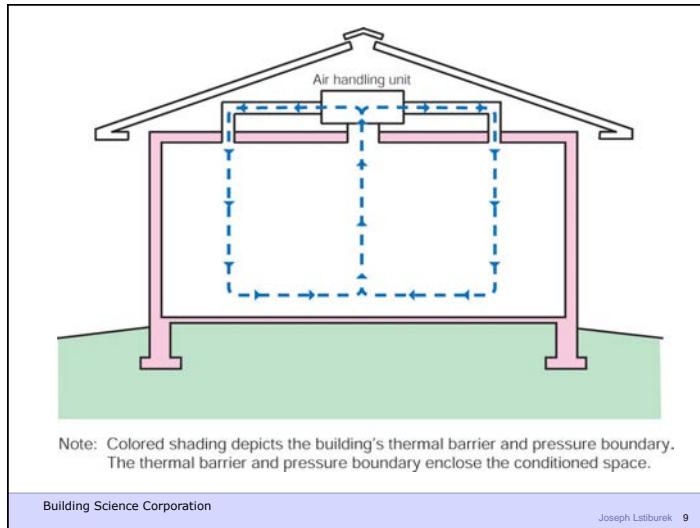
Building Science Corporation

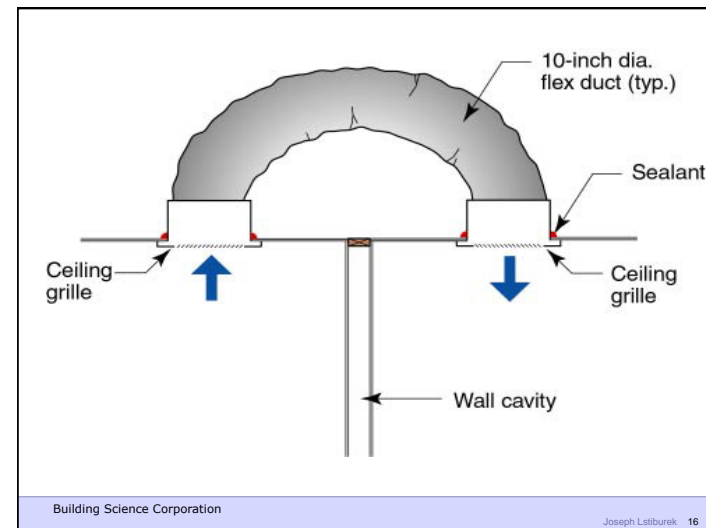
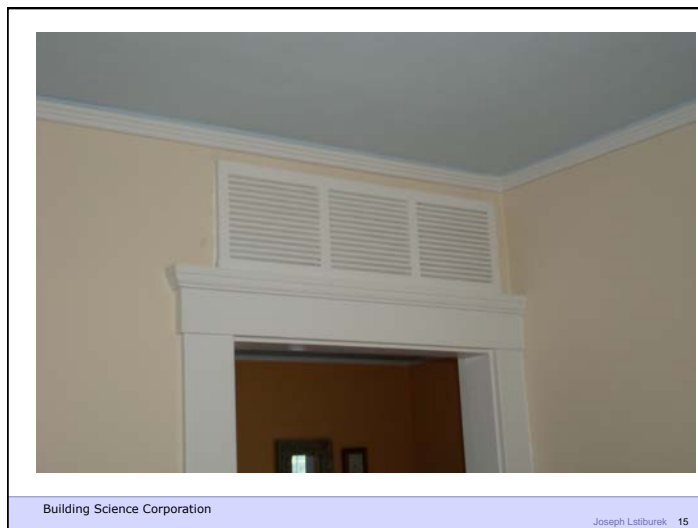
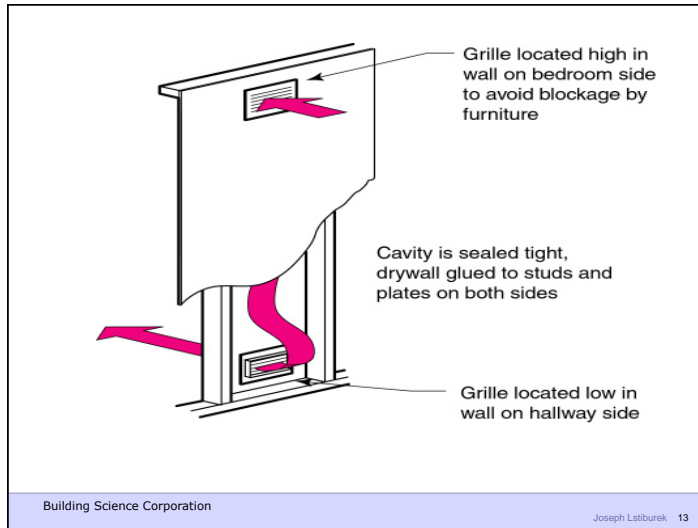
Joseph Lstiburek 4

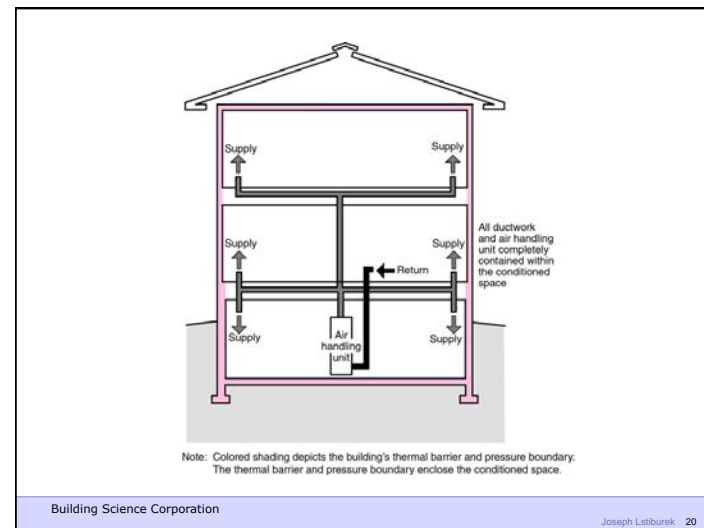
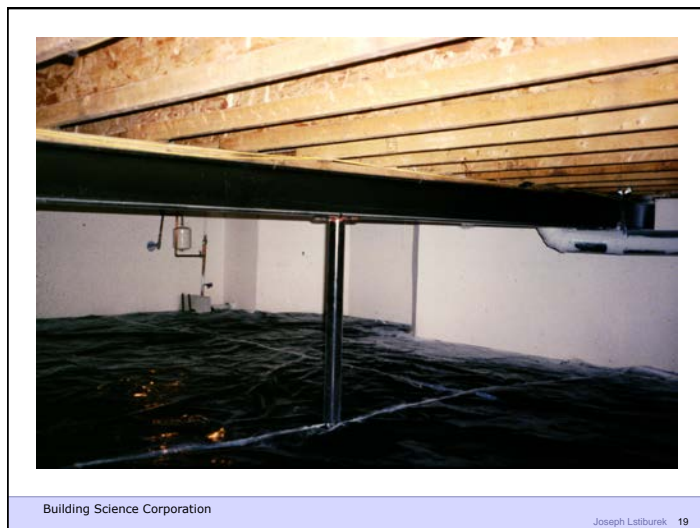
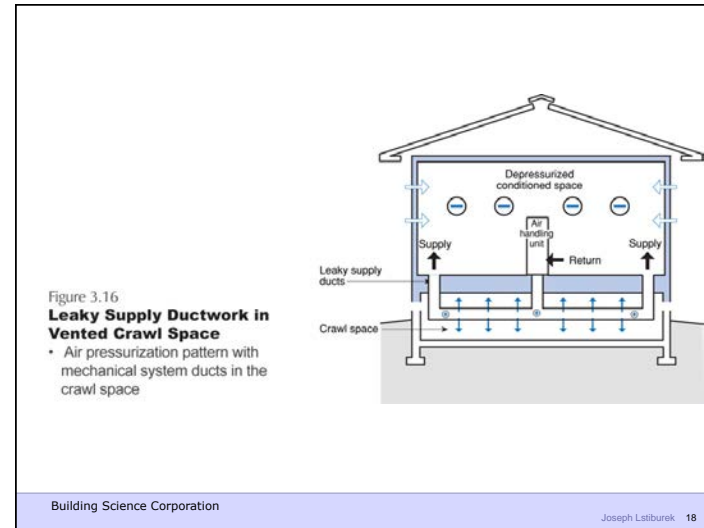
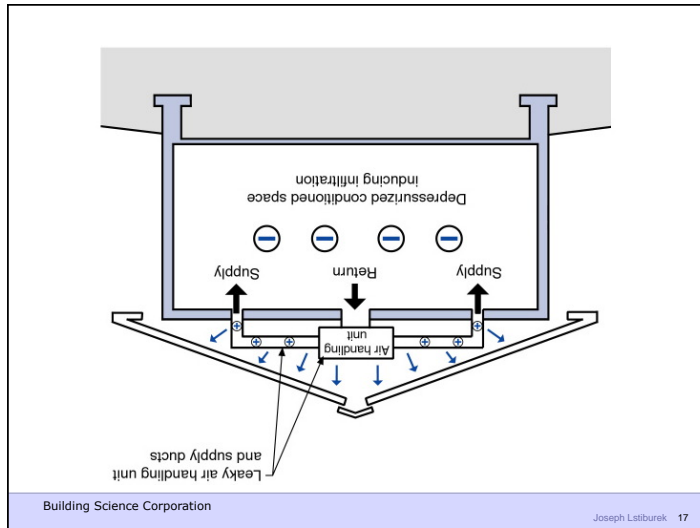


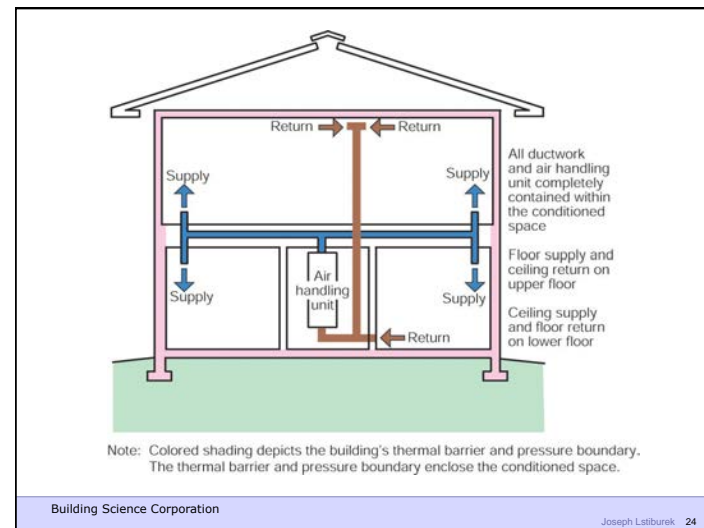
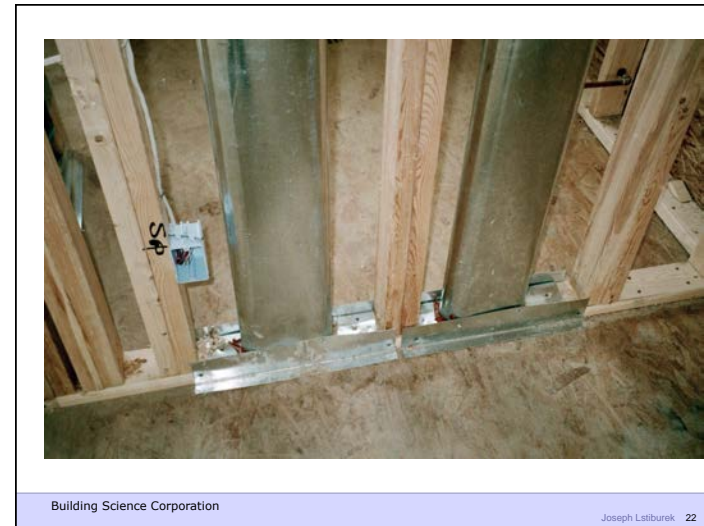
Duct Leakage Should Be Less Than 5% of Rated Flow As Tested by Pressurization To 25 Pascals

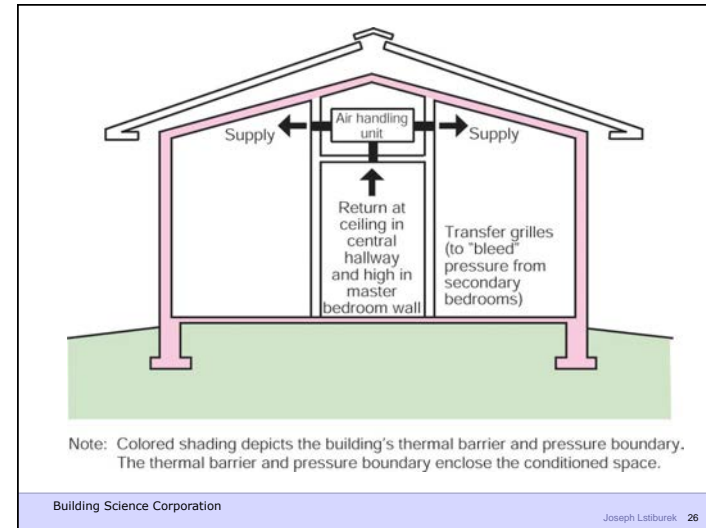
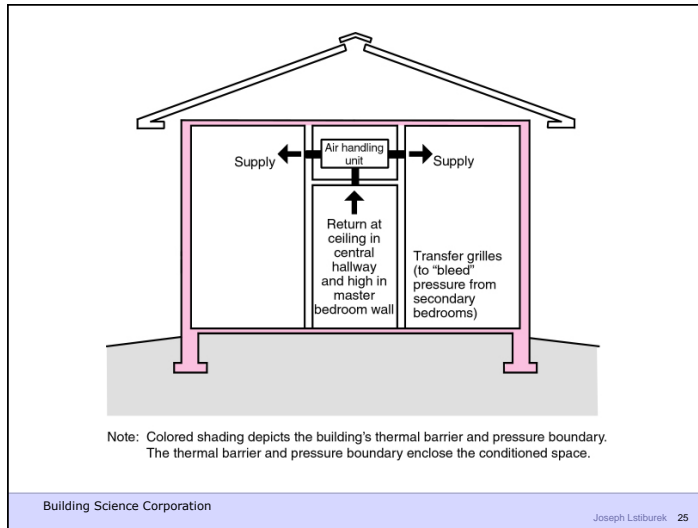
Building Science Corporation Joseph Lstiburek 8

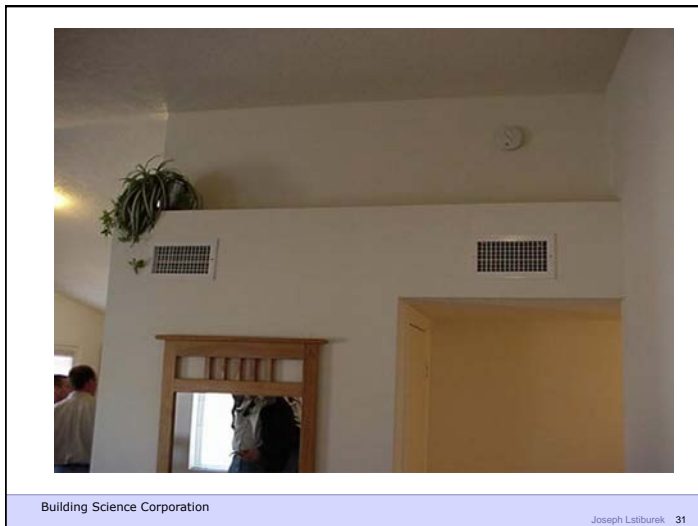
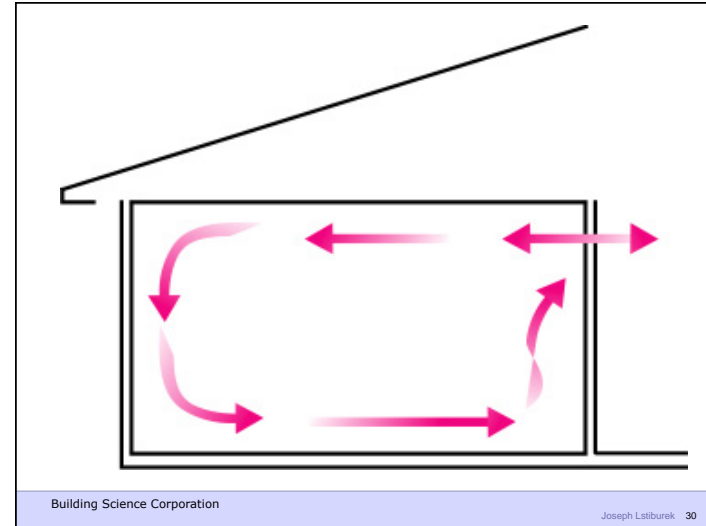


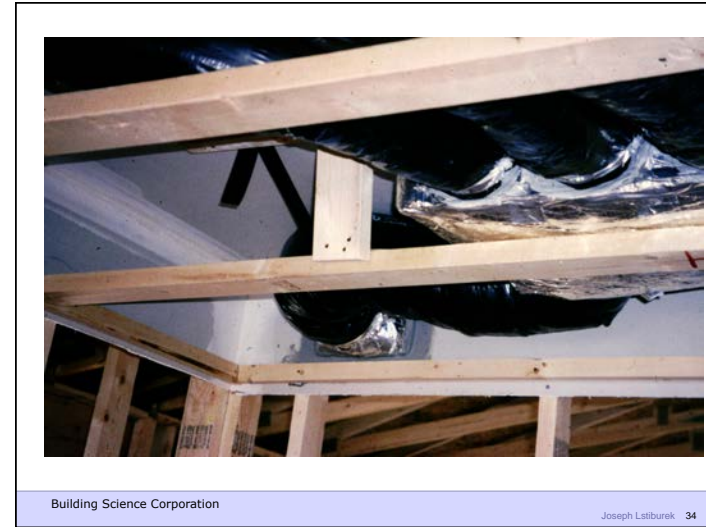


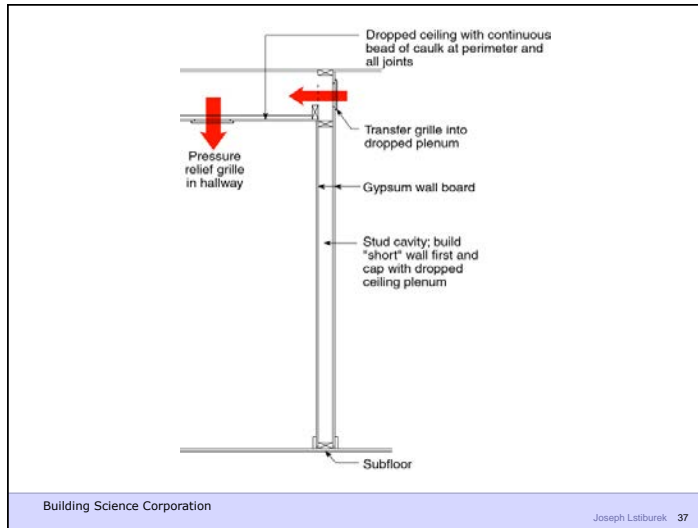












Building Science Corporation

Joseph Lstiburek 37

Ventilation Rates Are Based on Odor Control

Building Science Corporation

Joseph Lstiburek 38

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

Building Science Corporation

Joseph Lstiburek 39

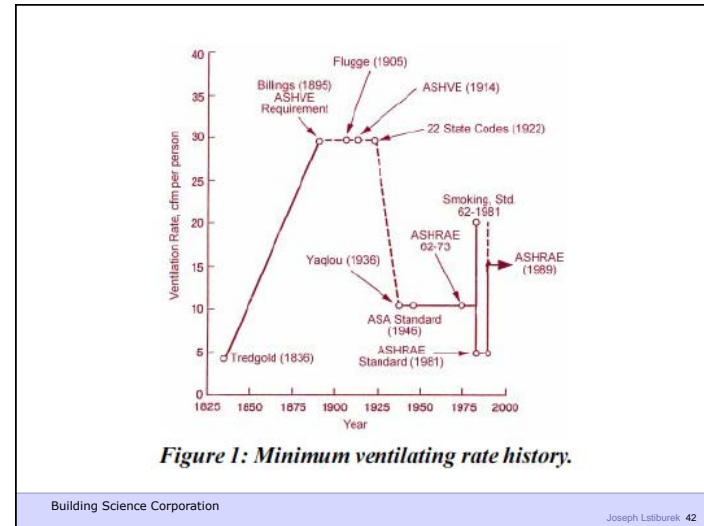
Ventilation Rates Are Based on Odor Control
 Health Science Basis for Ventilation Rates is
 Extremely Limited
 Almost Nothing Cited Applies to Housing

Building Science Corporation

Joseph Lstiburek 40

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

Building Science Corporation Joseph Lstiburek 41



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

Building Science Corporation Joseph Lstiburek 43

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

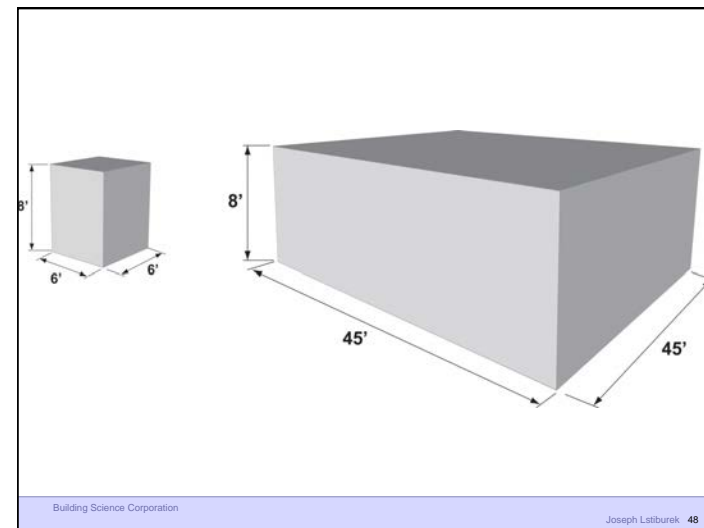
.35 ach	93 cfm	62 - 73	5 cfm/person	20 cfm
.30 ach	80 cfm		10 cfm/person	40 cfm
.25 ach	67 cfm	62 - 89	15 cfm/person	60 cfm
.20 ach	53 cfm	.35 ach	90 cfm	
.15 ach	40 cfm	62.2 - 2010	7.5 cfm/person	50 cfm
		+ 0.01		
		62.2 - 2013	7.5 cfm/person	90 cfm
		+ 0.03		

Building Science Corporation Joseph Lstiburek 44

Office			
Occupant Density			
15/1000 ft ² (67 ft ² /person)	62 - 89		15 cfm/person
5/1000 ft ² (200 ft ² /person)	62.1 - 2007		17 cfm/person
Correctional Facility Cell			
Occupant Density			
20/1000 ft ² (48 ft ² /person)	62.1 - 2007		10 cfm/person

C.P. Yaglou	
Harvard School of Public Health	
1936	
1955	
150 ft ³	→ 20 cfm/person
300 ft ³	→ 12 cfm/person

C.P. Yaglou	
Harvard School of Public Health	
1936	
1955	
150 ft ³ →	20 cfm/person 18.75 ft ² 106 occupants
300 ft ³ →	12 cfm/person 37.5 ft ² 53 occupants
Experiment	
470 ft ³ →	59 ft ²
200 ft ³ →	25 ft ²
100 ft ³ →	12 ft ²



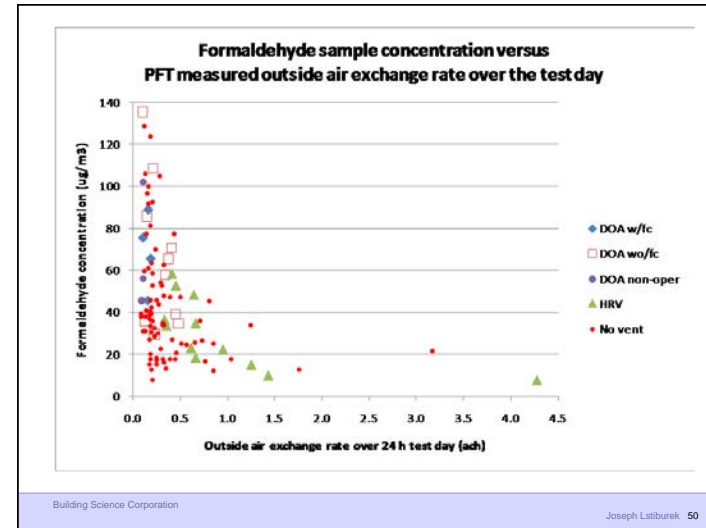
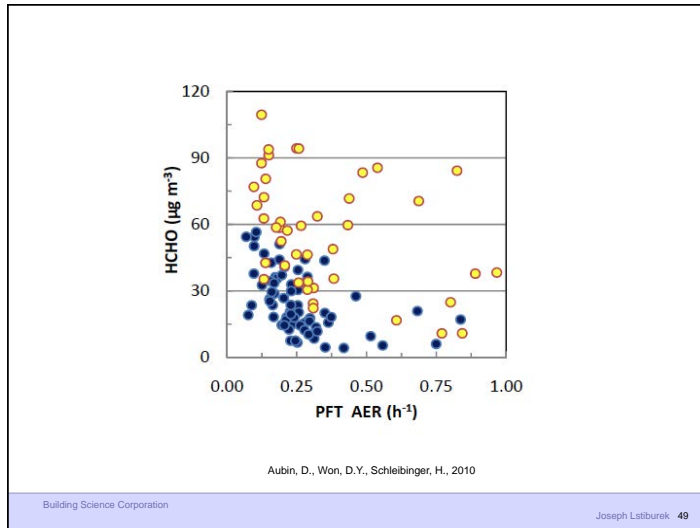


Table 1. Summary of the air changes rates measured during the winter 2009-10 season in Quebec City

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

Building Science Corporation Joseph Lstiburek 51

Build Tight - Ventilate Right

Building Science Corporation Joseph Lstiburek 52

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

Building Science Corporation

Joseph Lstiburek 53

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

Building Science Corporation

Joseph Lstiburek 54

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

Building Science Corporation

Joseph Lstiburek 55

Best

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

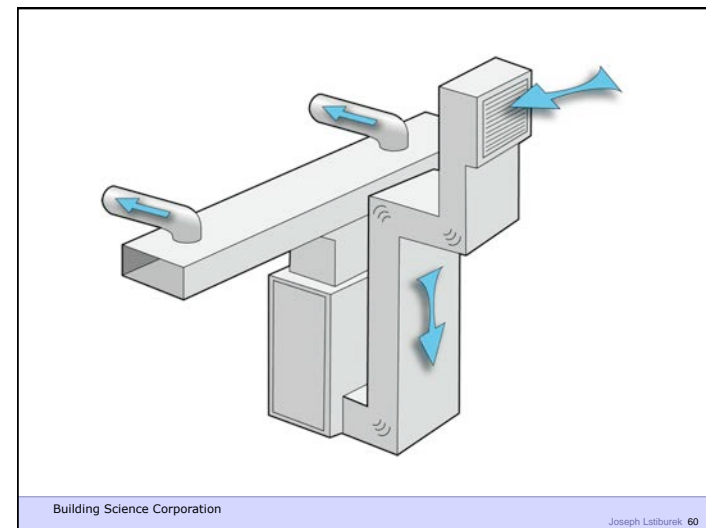
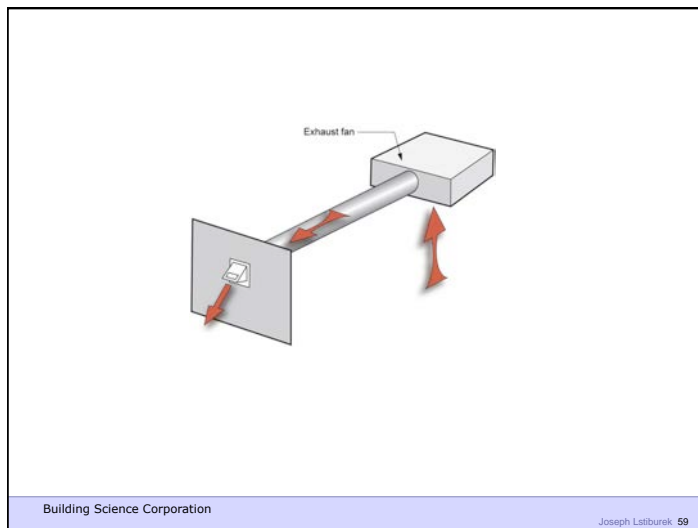
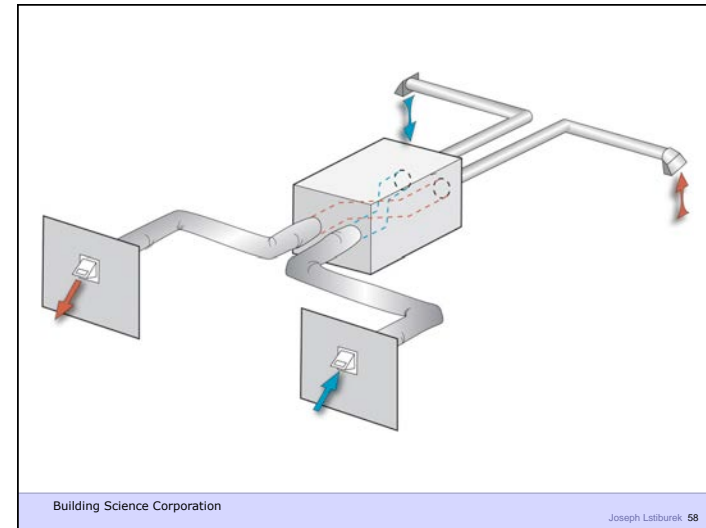
Building Science Corporation

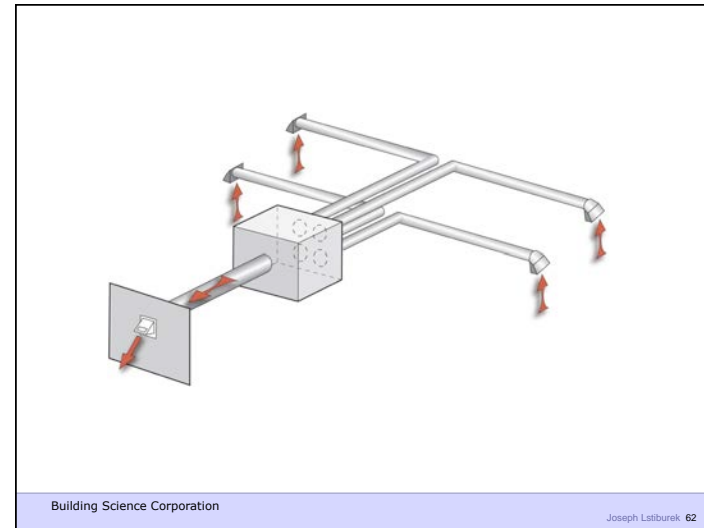
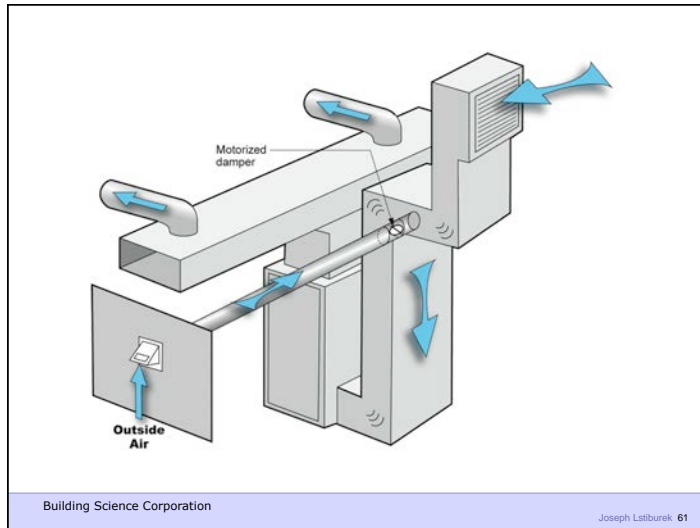
Joseph Lstiburek 56

Worst

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

Building Science Corporation Joseph Lstiburek 57





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

Building Science Corporation
Joseph Lstiburek 63

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

Building Science Corporation
Joseph Lstiburek 64

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

Building Science Corporation

Joseph Lstiburek 65

The Cult of The Blower Door

Building Science Corporation

Joseph Lstiburek 66



Building Science Corporation

Joseph Lstiburek 67

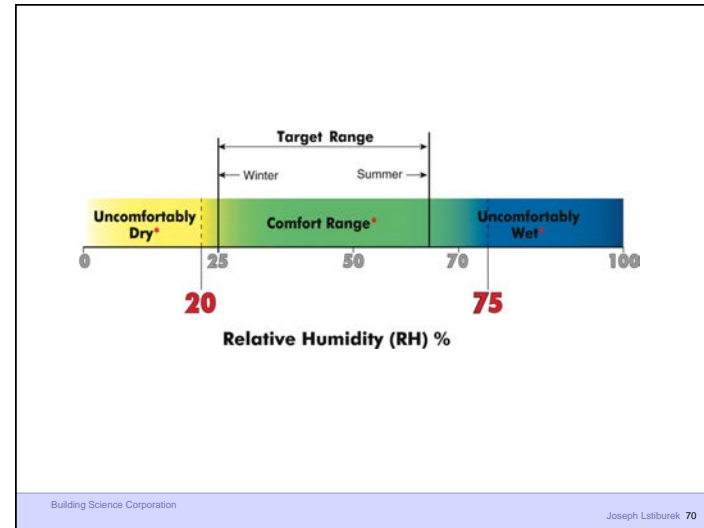
Blower Door Can't Get You The True ACH
On A Short Term Basis – Hour, Day, Week

Building Science Corporation

Joseph Lstiburek 68

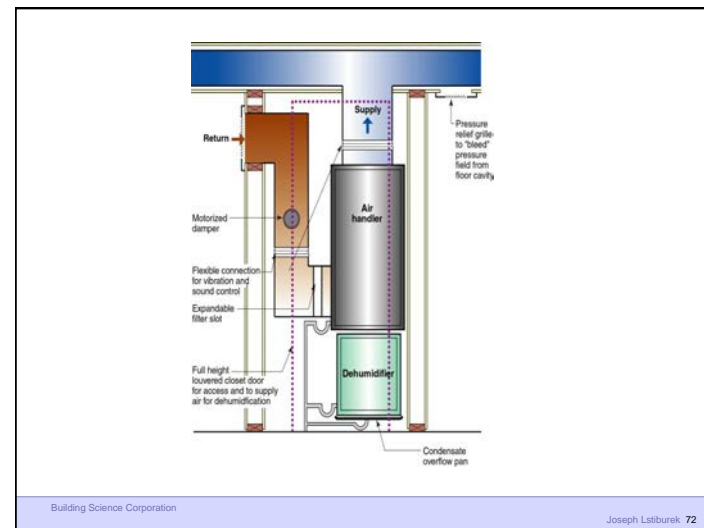
Don't Know Where The Holes Are
 Don't Know The Type of Holes
 Don't Know The Pressure Across The Holes

Building Science Corporation Joseph Lstiburek 69



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

Building Science Corporation Joseph Lstiburek 72





Building Science Corporation

Joseph Lstiburek 73

Barriers – Technology Dehumidification

- Barriers – Cost
- Exhaust \$150
 - Exhaust + Dist \$200
 - Supply + Dist \$200
 - Spot + Ex/Sup + Dist \$500
 - Balanced/ER \$1,250
 - Dehumidification \$250 to \$1,250

Building Science Corporation

Joseph Lstiburek 74



- Tracer gas test of a production 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

Building Science Corporation

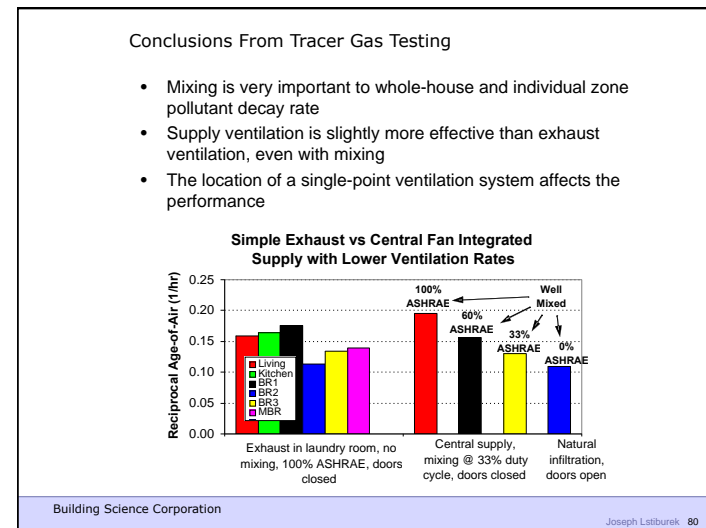
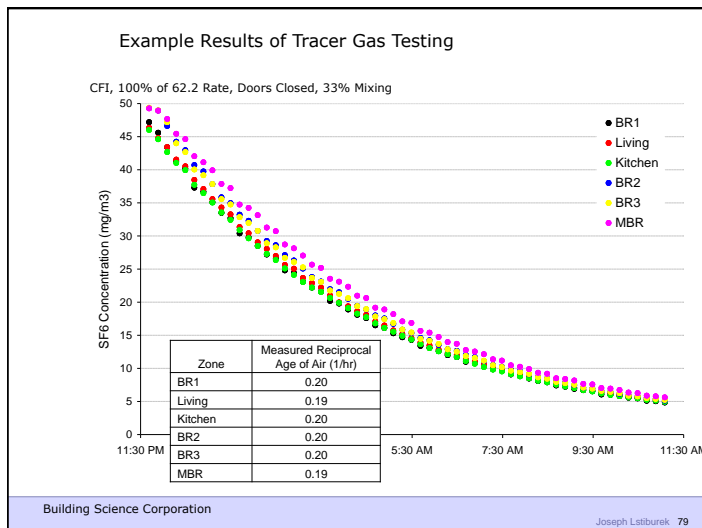
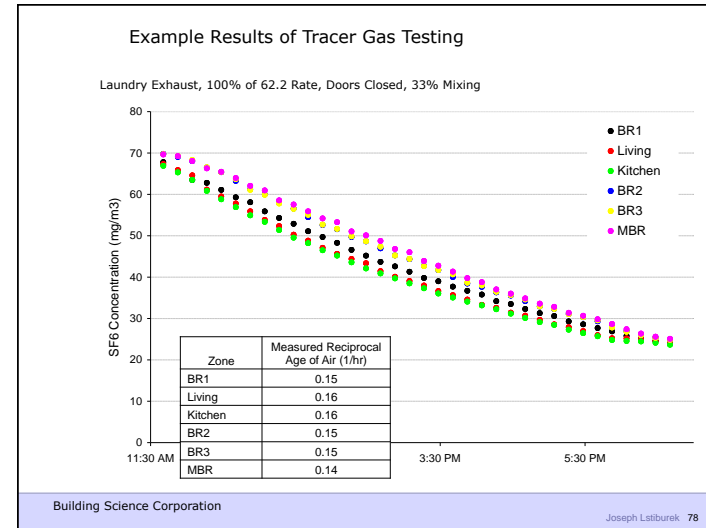
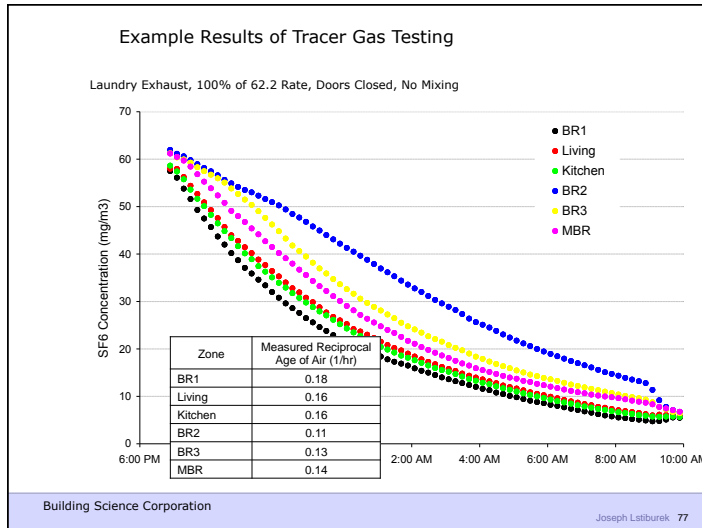
Joseph Lstiburek 75

Floor Plan - 2 Story House

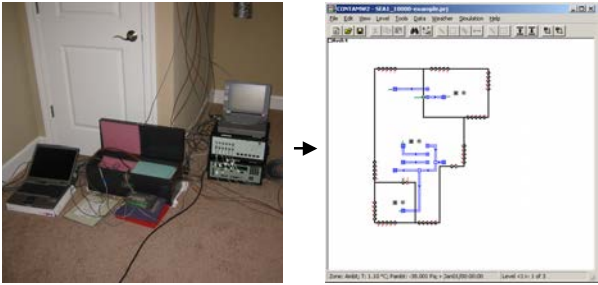


Building Science Corporation

Joseph Lstiburek 76

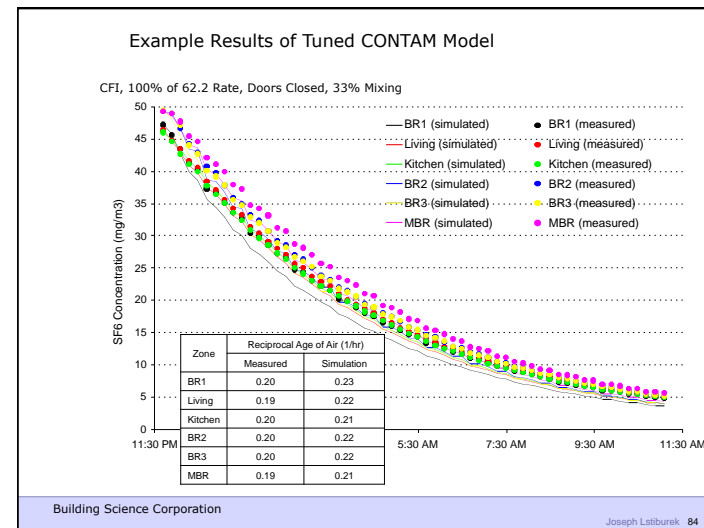
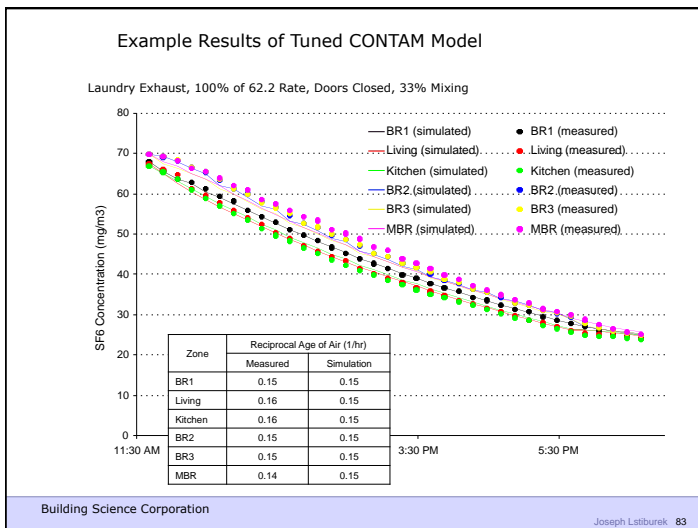
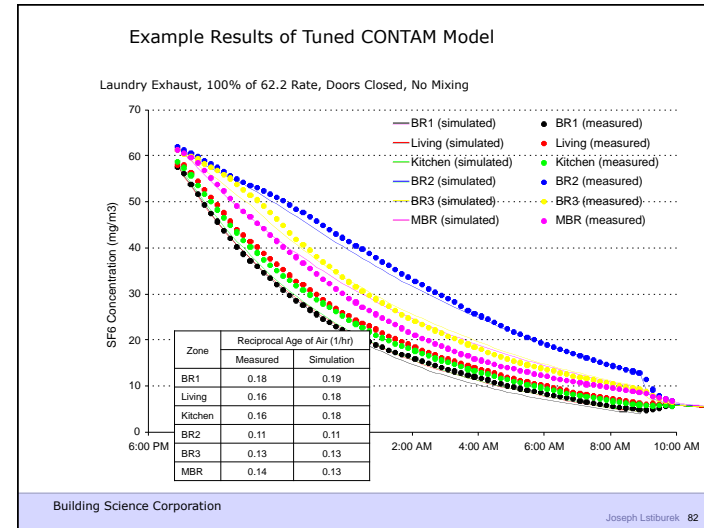


Tuned CONTAM Model



Computer modeling used to replicate field testing (tune the model) and predict performance of systems not tested in the field

Building Science Corporation Joseph Lstiburek 81



Tuned CONTAM Model Applied to Other Systems

Systems Evaluated & Compared:

1. Exhaust ventilation, without central duct system
2. Supply ventilation, without central duct system
3. Exhaust ventilation, with central ducts, standard Tstat
4. Exhaust ventilation, with central ducts, Tstat with timer
5. Supply ventilation, with central ducts, Tstat with timer
6. Fully ducted balanced ventilation system, without central duct system

$Q(v)$ = Ventilation Rate

$Q(\text{fan}) = Q(v) \cdot C(s)$

$C(s)$ = System Coefficient

BSC 01 - 2013 calls for 7.5 cfm per person
plus 0.01 cfm per square foot of
conditioned area

Occupancy is deemed to be the number of
bedrooms plus one

Occupant Rate + Building Rate

$Q(v)$ = Fan Flow Rate

$Q(\text{fan}) = Q(v) \cdot C(d)$

$C(s)$ = System Coefficient

Table 4.1
System Coefficient based on system type¹

System Type	Distributed	Not Distributed
Balanced	1.0	1.25
Not Balanced	1.25	1.5

¹ Where there is whole-building air mixing of at least 70% recirculation turnover each hour, the system coefficient may be reduced by 0.25.

Building Science Corporation Joseph Lstiburek 89

BSC 01-2013
Ventilation for New Low-Rise Residential Building
2,000 ft²
3 bedrooms

20 cfm + 30 cfm = 50 cfm

Mixed, Distributed, Balanced (MDB)
37.5 cfm

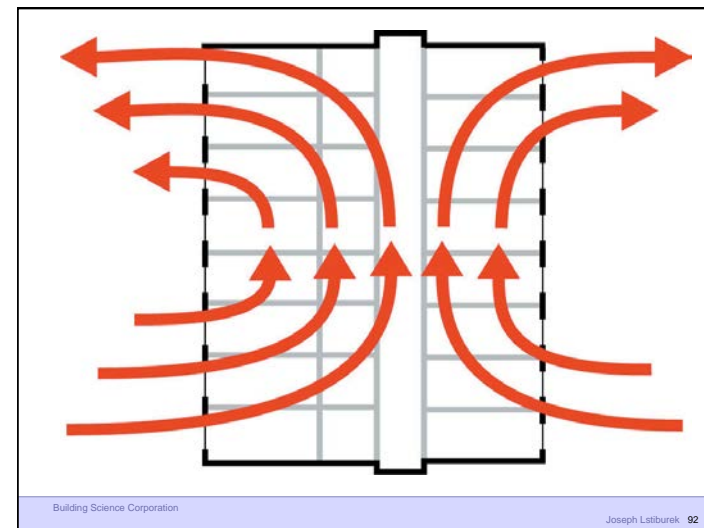
Not Mixed, Not Distributed, Not Balanced
75 cfm

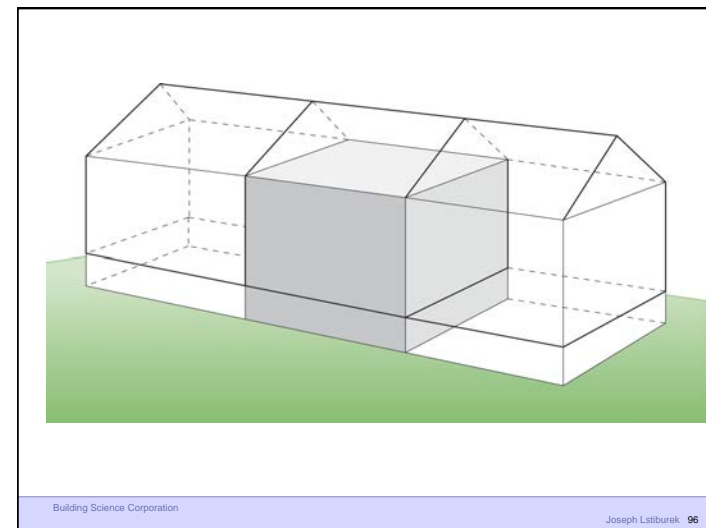
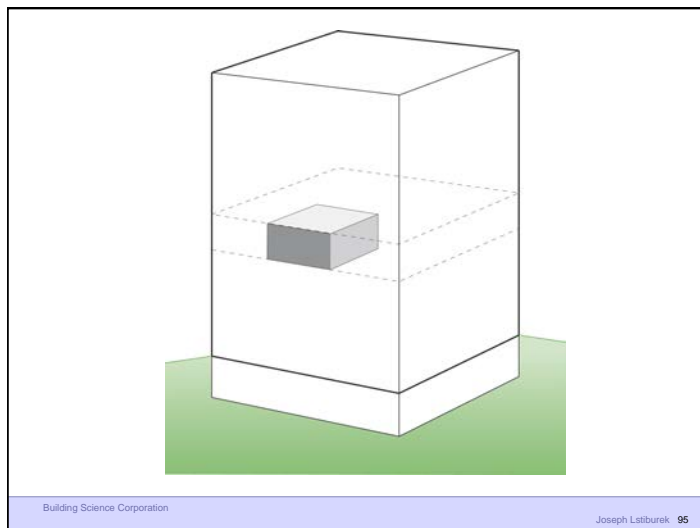
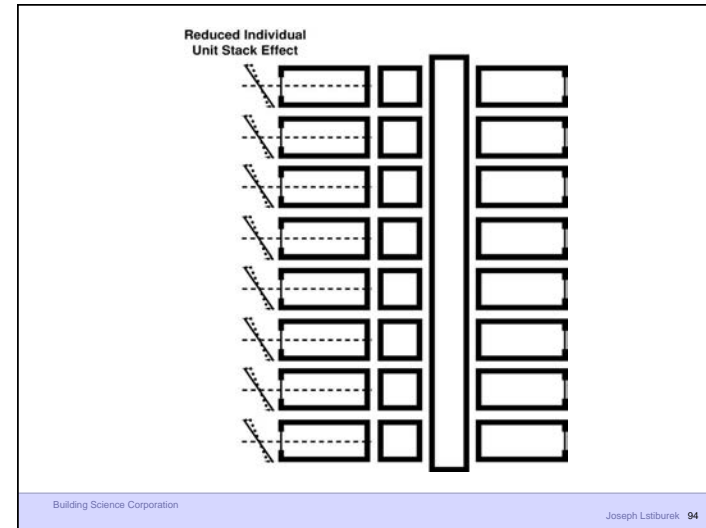
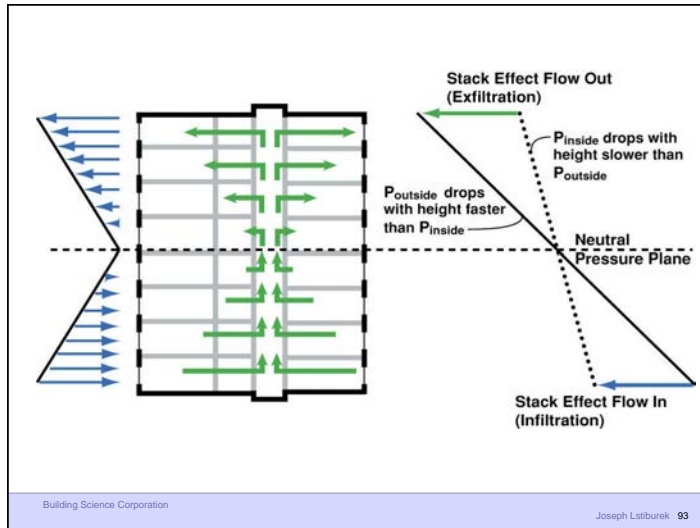
Building Science Corporation

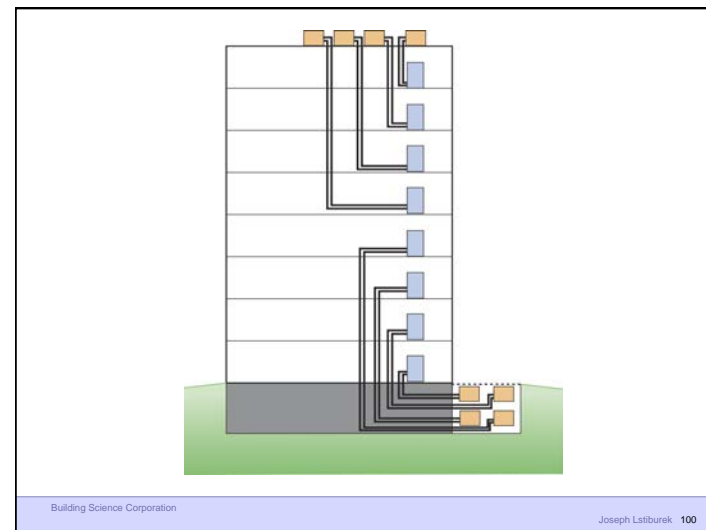
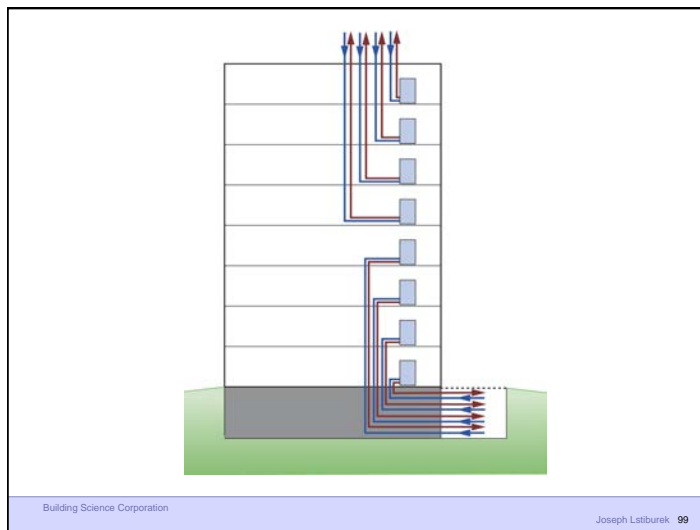
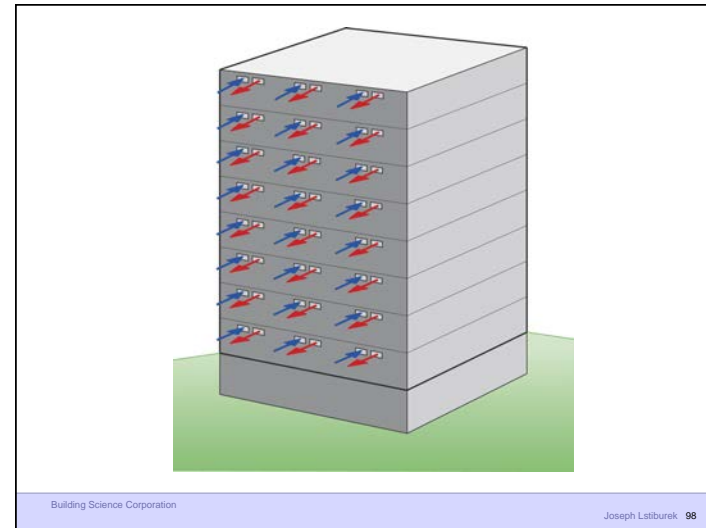
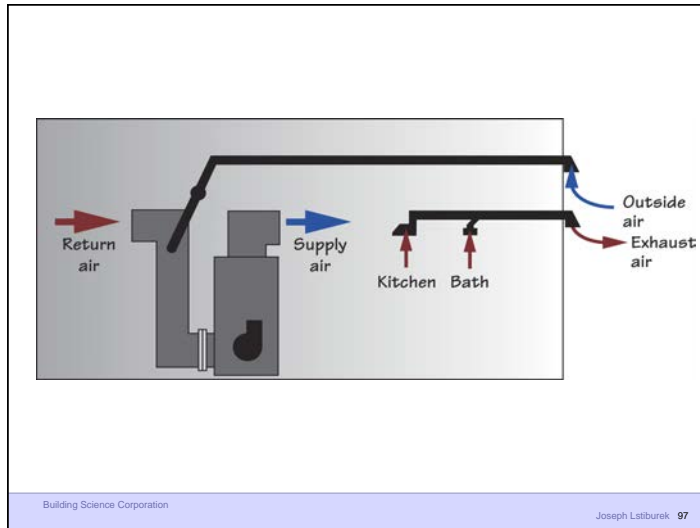
House
2,000 ft²
3 bedrooms
8 ft. ceiling
Volume: 16,000 ft³

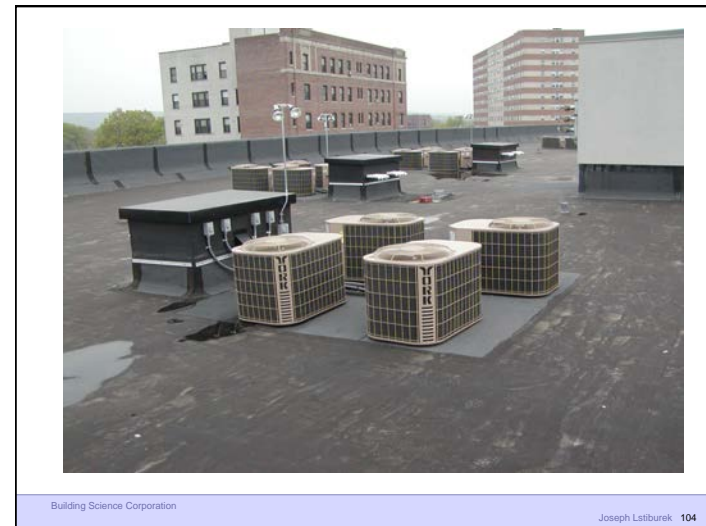
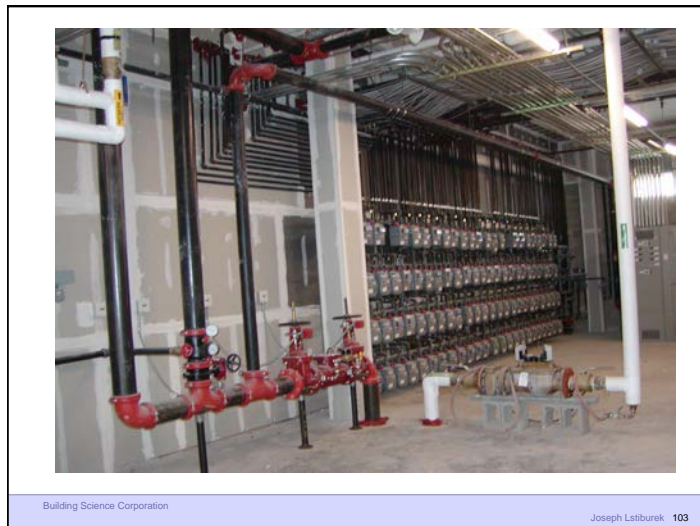
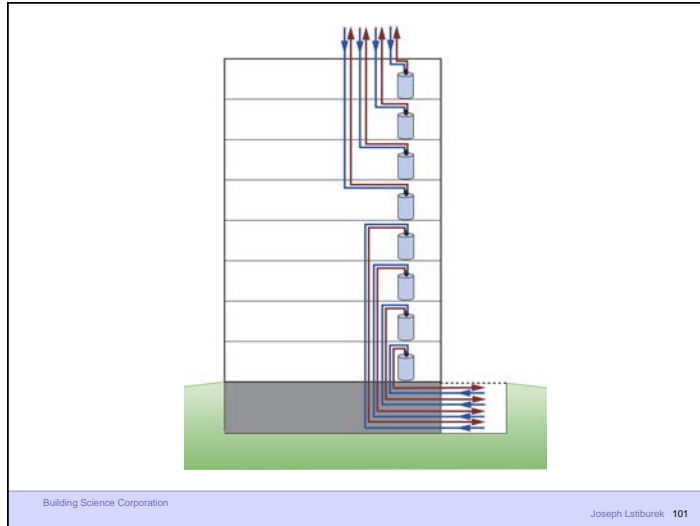
		Ventilation Rates	
.35 ach	93 cfm	62 - 73	5 cfm/person 20 cfm
			10 cfm/person 40 cfm
.30 ach	80 cfm	62 - 89	15 cfm/person 60 cfm
.25 ach	67 cfm		.35 ach 90 cfm
.20 ach	53 cfm	62.2 - 2010	7.5 cfm/person 50 cfm
.15 ach	40 cfm		+ 0.01
		62.2 - 2013	7.5 cfm/person 90 cfm
			+ 0.03
		BSC 01 - 2013	7.5 cfm/person 37 cfm
			+ 0.01 (MBD) 75 cfm

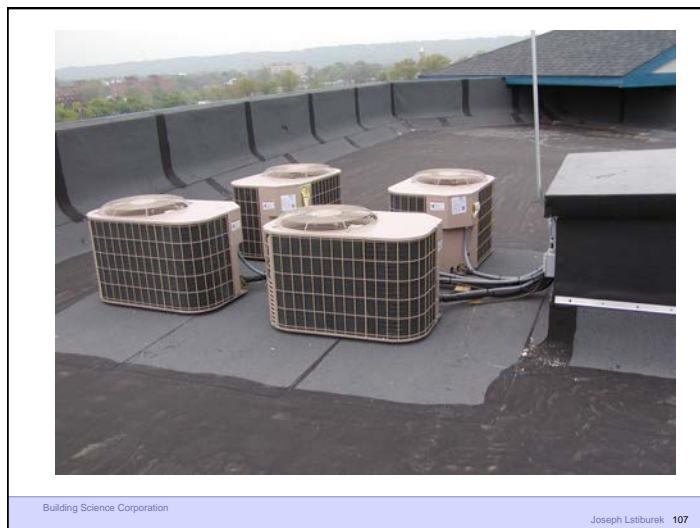
Building Science Corporation Joseph Lstiburek 91

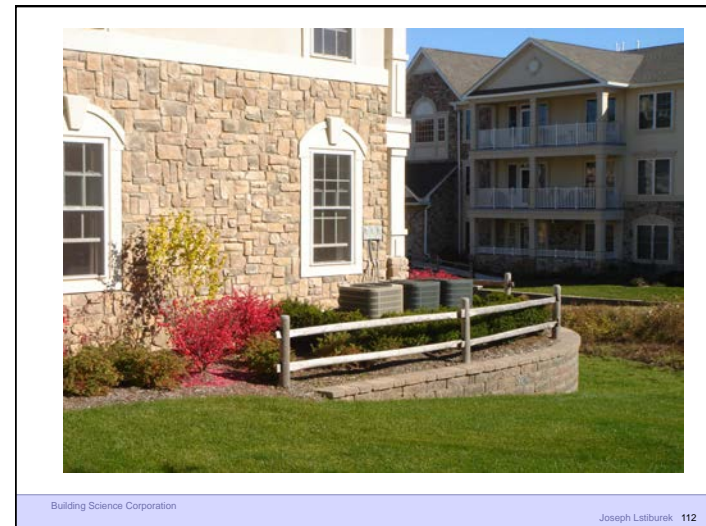
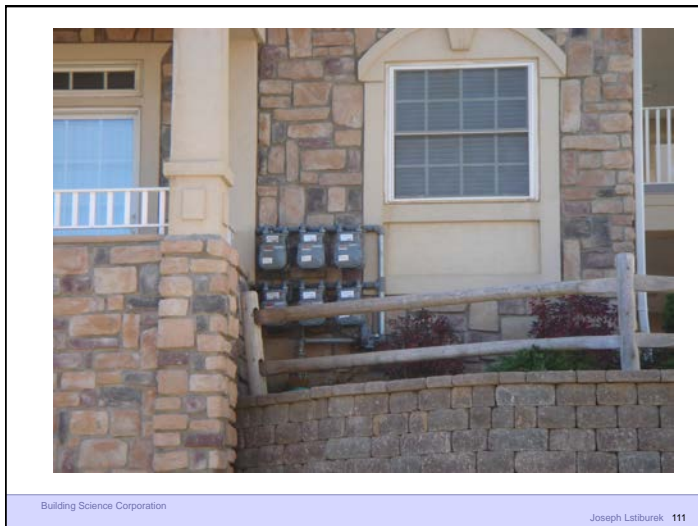
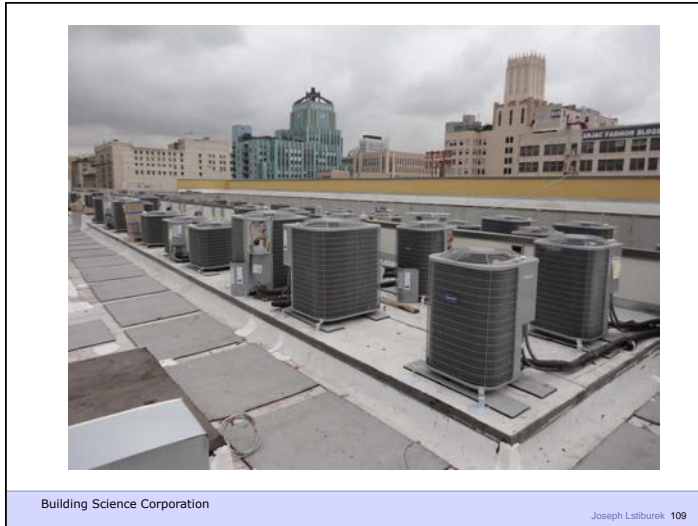


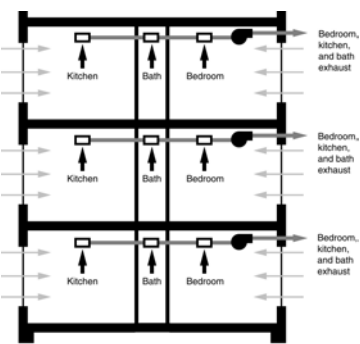












Distributed Ventilation

- Individual unit exhaust ventilation fan exhausts (during occupancy) from each bedroom, bathroom, and kitchen
- Operation of system is time of occupancy sensitive — on only when occupied

Building Science Corporation Joseph Lstiburek 113



