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

Building Science

Adventures In Building Science

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The Three Biggest Problems In Buildings Are Water, Water and Water…

80 Percent of all Construction Problems are Related to Water

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Water Control Layer
Air Control Layer
Vapor Control Layer
Thermal Control Layer

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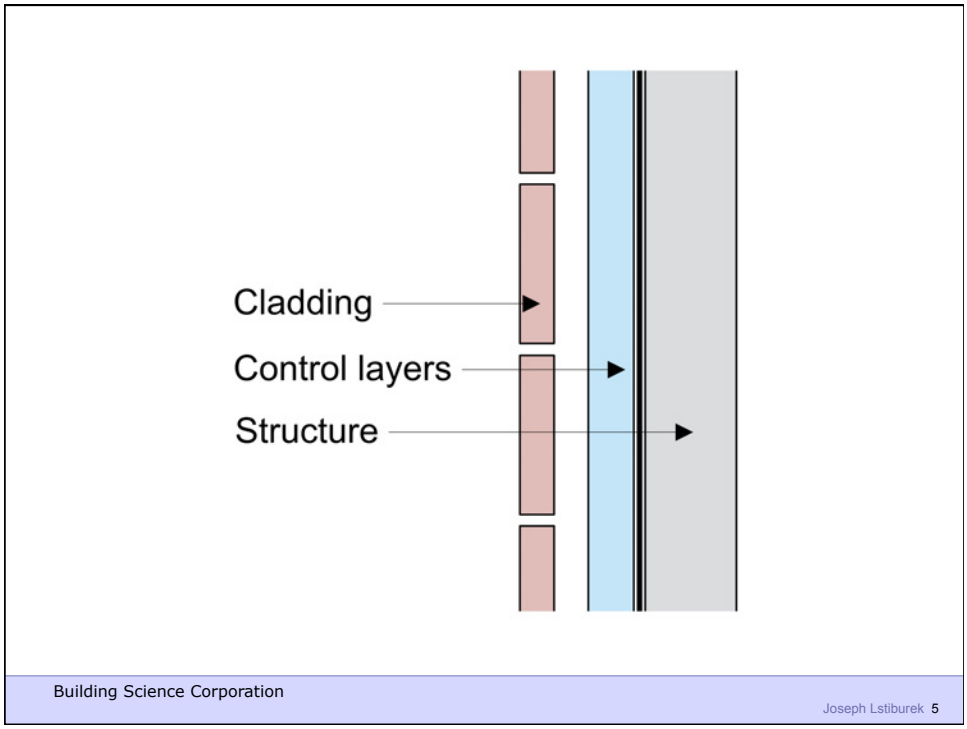
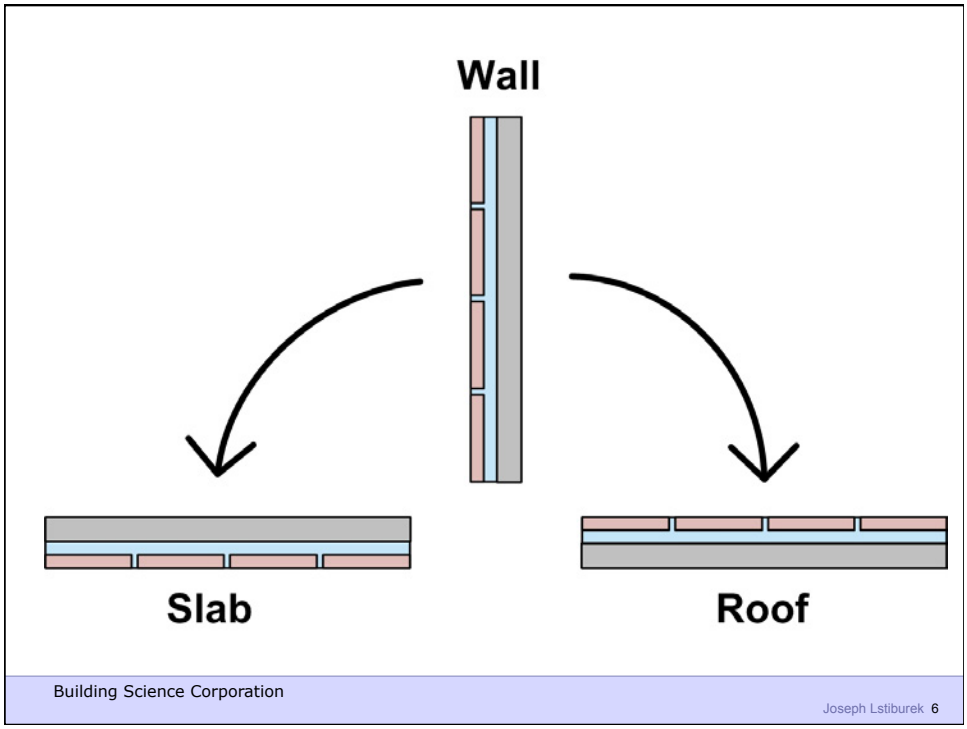

Cladding
Control layers
Structure
Building Science Corporation
Joseph Lstiburek 5


Wall
Slab
Roof
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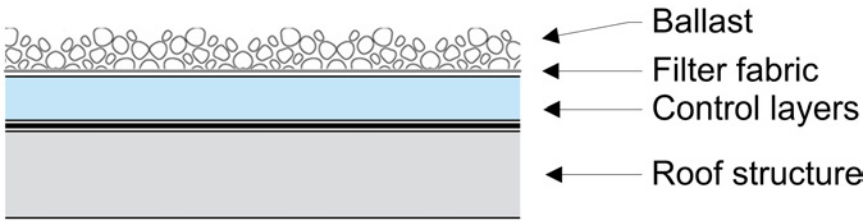

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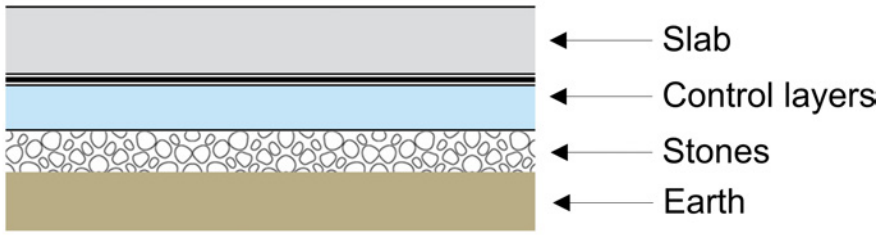

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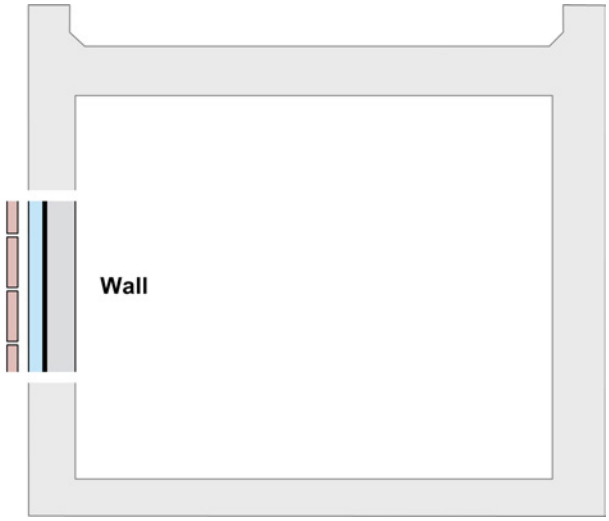
Joseph Lstiburek 9



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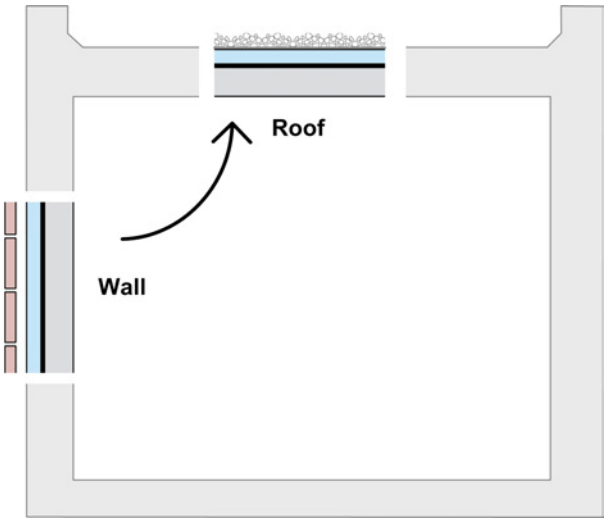

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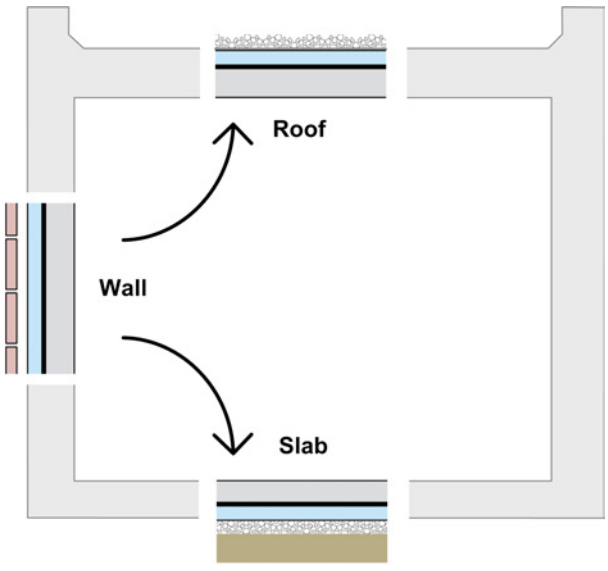

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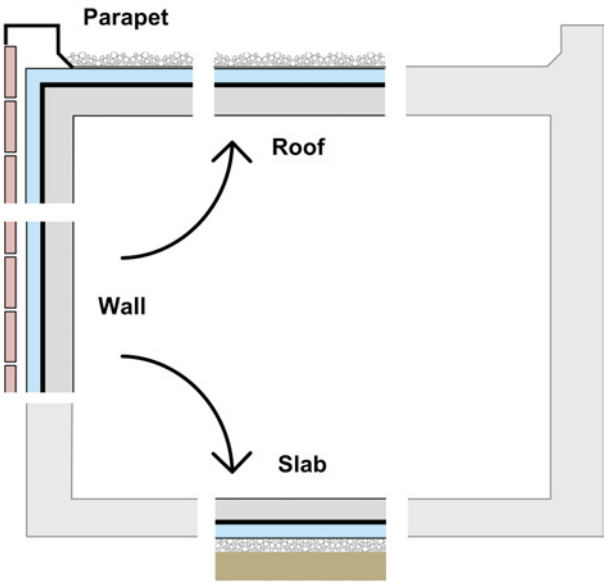

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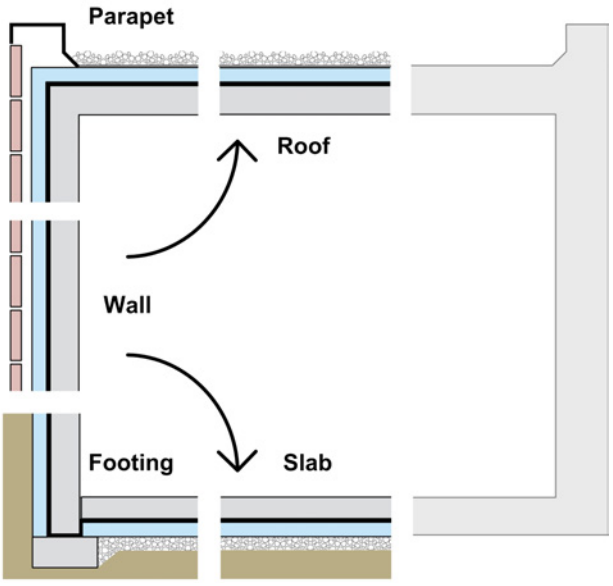

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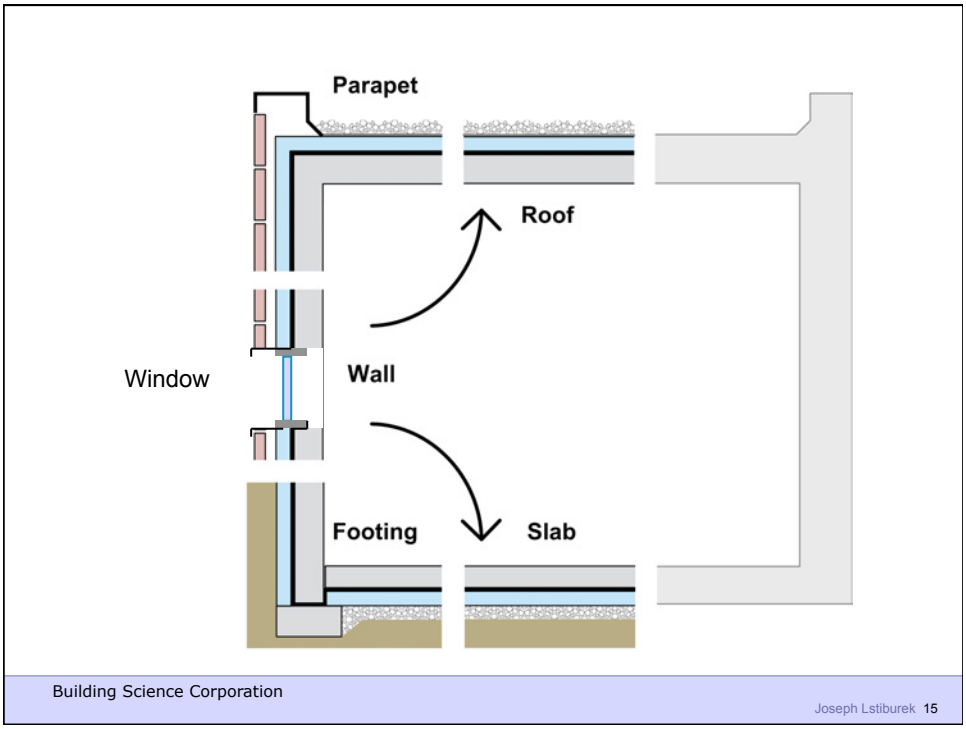

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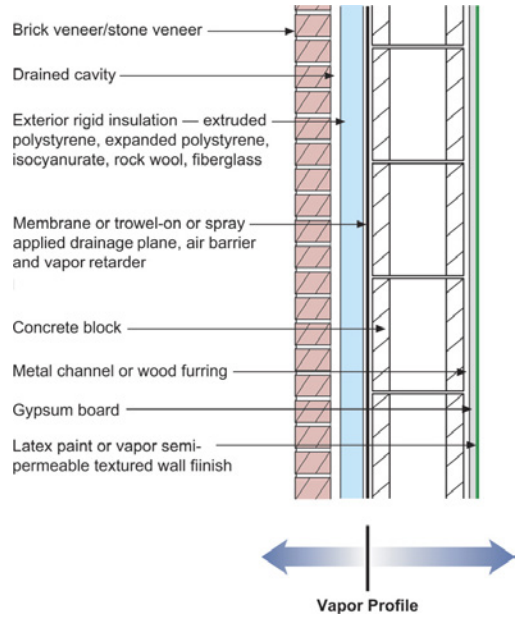

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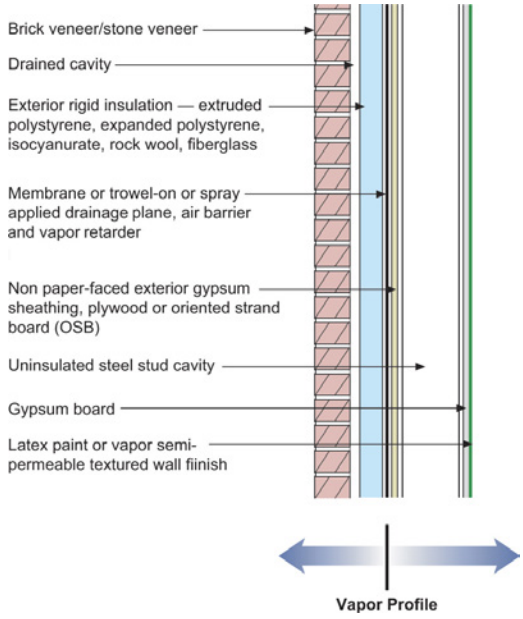

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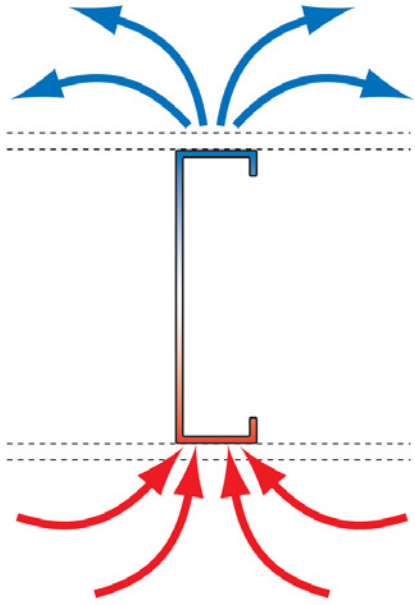

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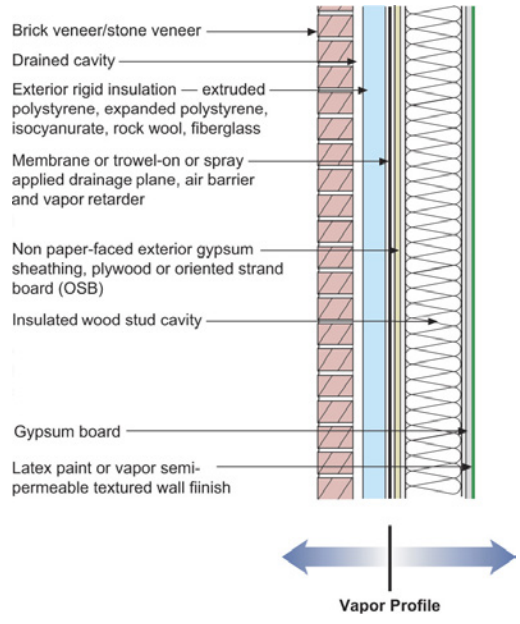

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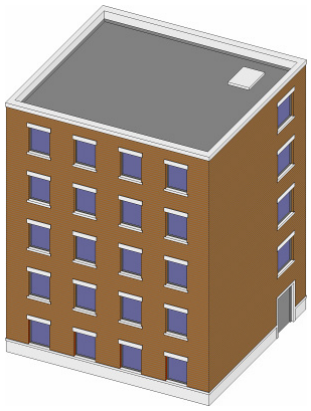
Commercial Enclosure: Simple Layers



- Structure
- Rain/Air/Vapor
- Insulation
- Finish

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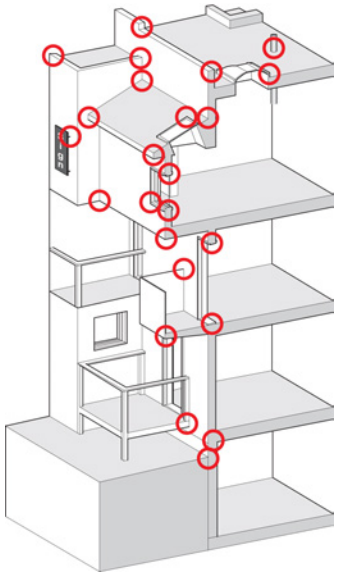

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Joseph Lstiburek 24

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Joseph Lstiburek 26

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Joseph Lstiburek 27

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Building Science 2007

Joseph Lstiburek – Rain Control 29

Building Science 2007

Joseph Lstiburek – Rain Control 30

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Joseph Lstiburek – Rain Control 31

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Joseph Lstiburek 32

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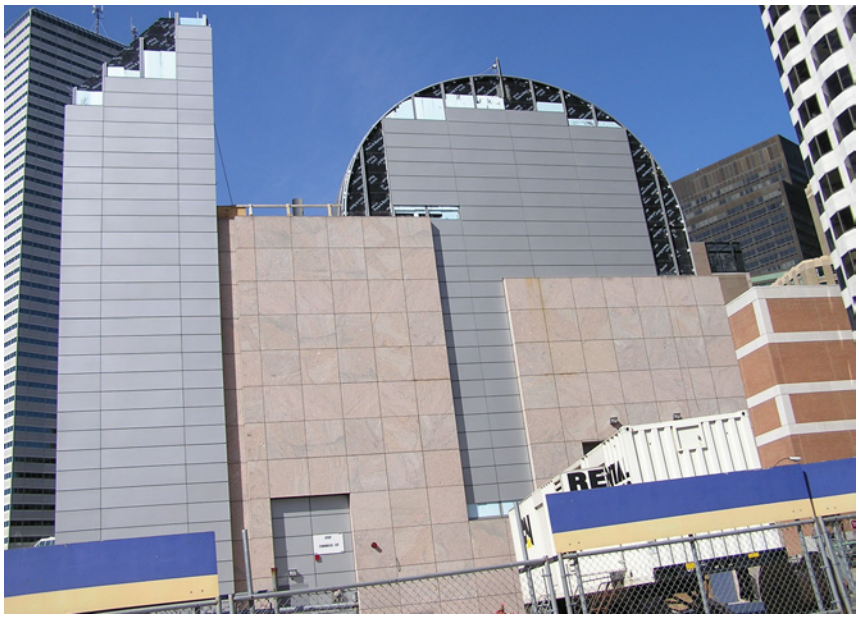
Joseph Lstiburek 33



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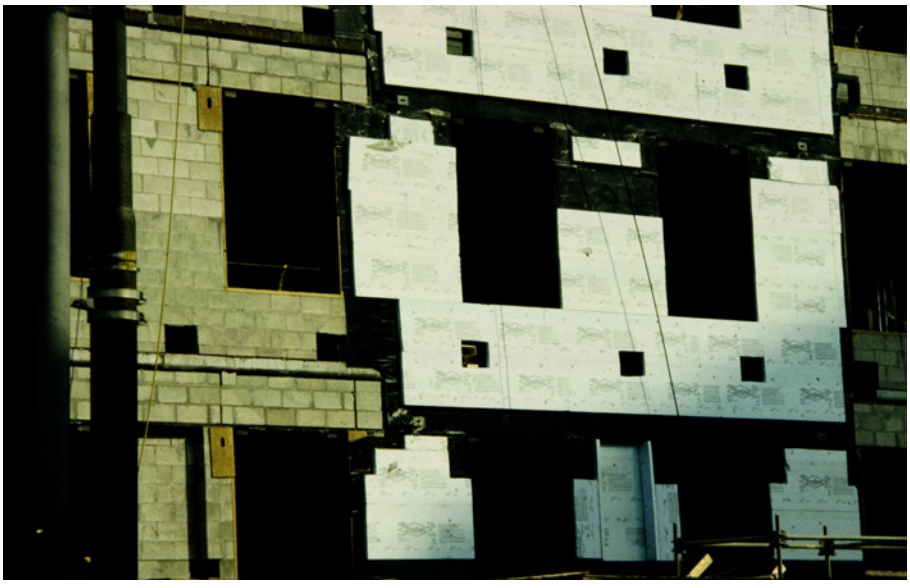

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Joseph Lstiburek 37

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Joseph Lstiburek 38

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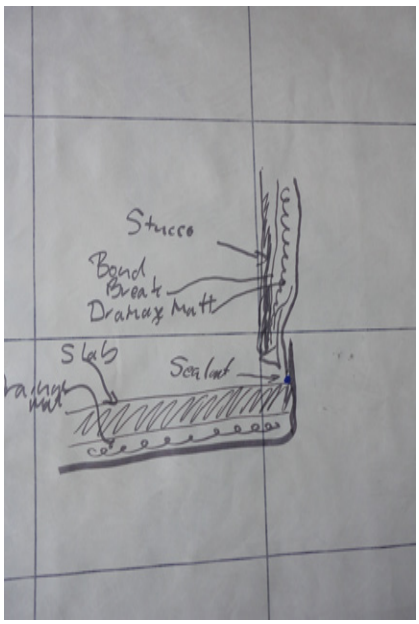
Joseph Lstiburek 52



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Joseph Lstiburek 55

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Joseph Lstiburek 56

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Joseph Lstiburek 57

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Joseph Lstiburek – HVAC 58

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Joseph Lstiburek 59

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Joseph Lstiburek 60

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Joseph Lstiburek – HVAC 61

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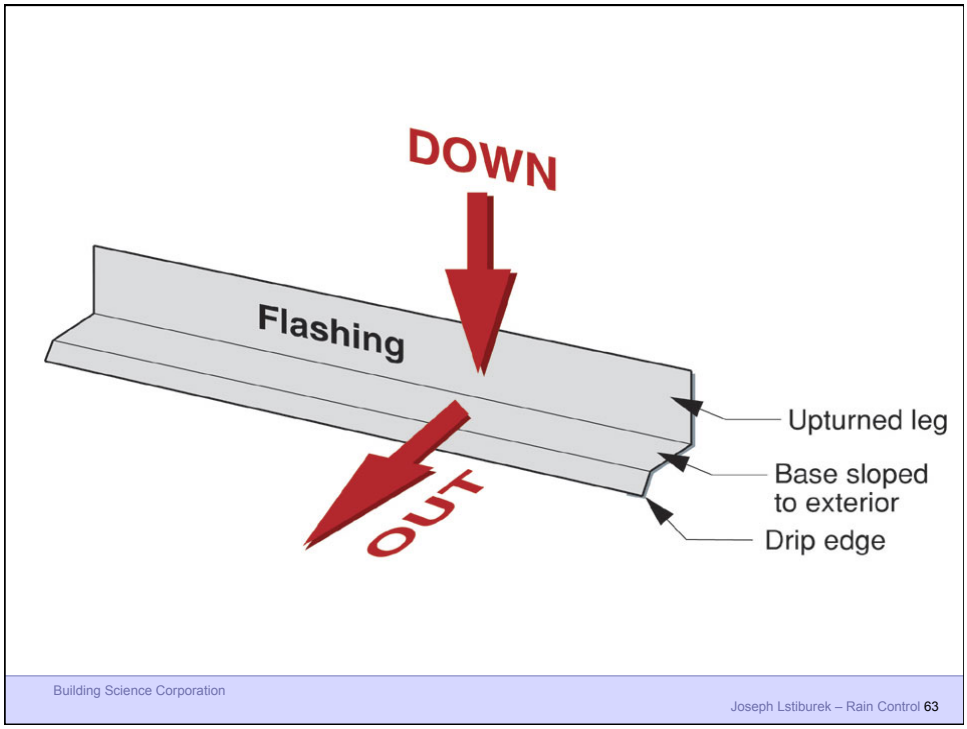
Joseph Lstiburek 62


DOWN
Flashing
OUT
Upturned leg
Base sloped to exterior
Drip edge
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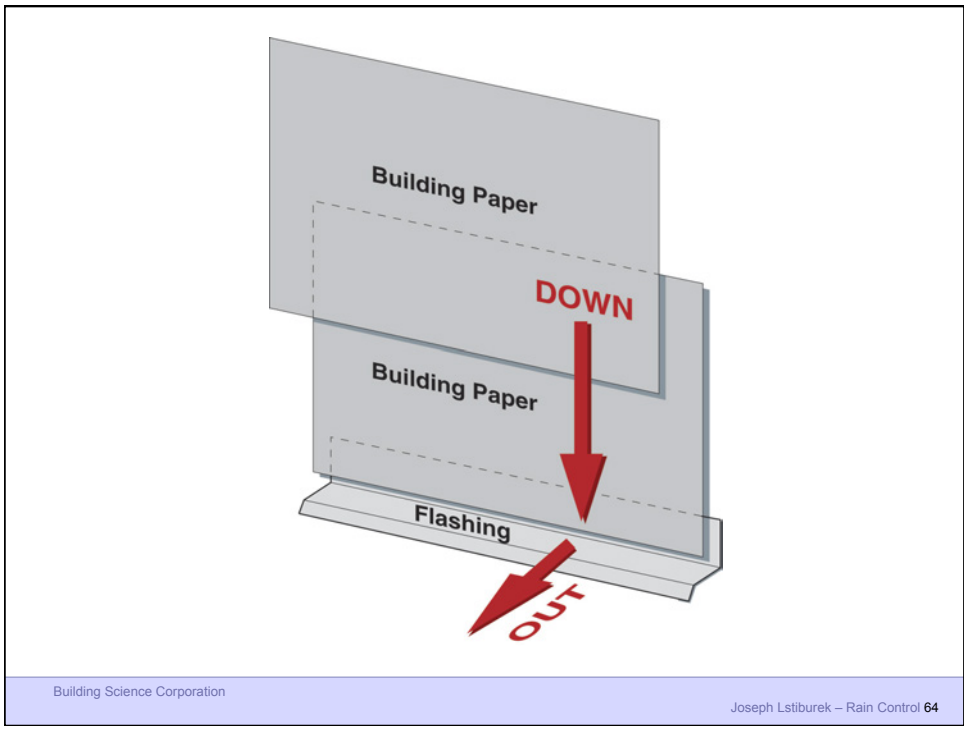
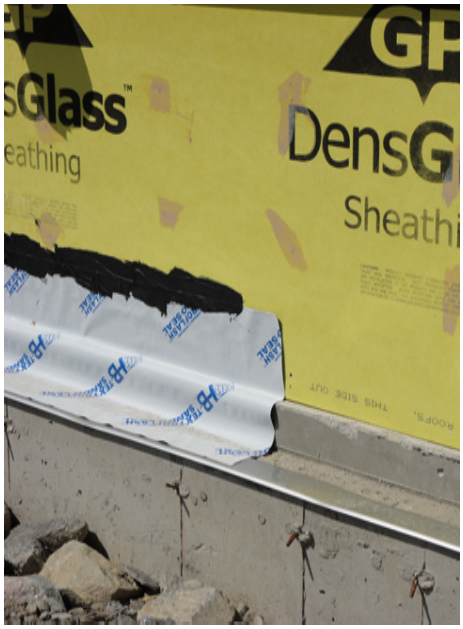
Joseph Lstiburek – Rain Control 63


Building Paper
DOWN
Building Paper
Flashing
OUT
Building Science Corporation
Joseph Lstiburek – Rain Control 64



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Joseph Lstiburek 66

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Joseph Lstiburek – Rain Control 67

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Joseph Lstiburek – Rain Control 68

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Joseph Lstiburek – Rain Control 69

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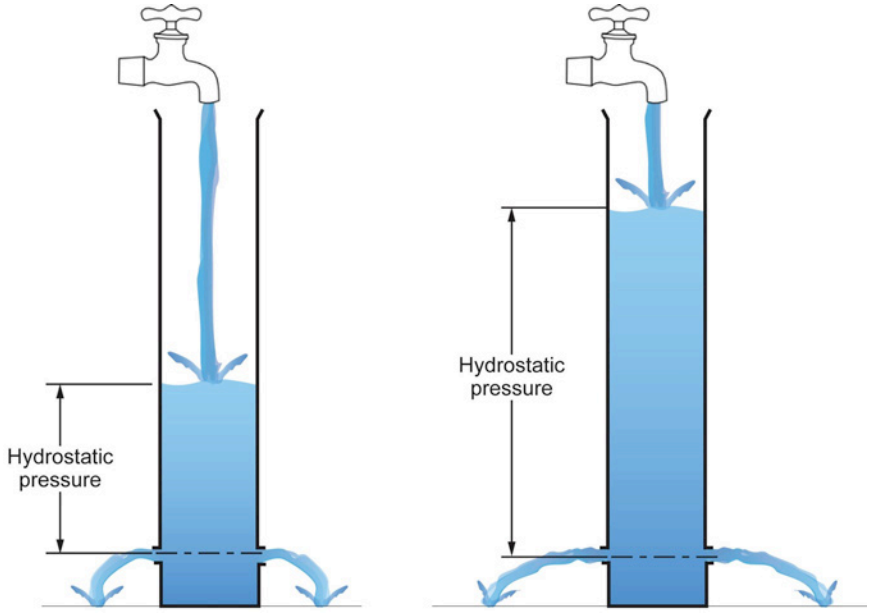
Joseph Lstiburek – Rain Control 70



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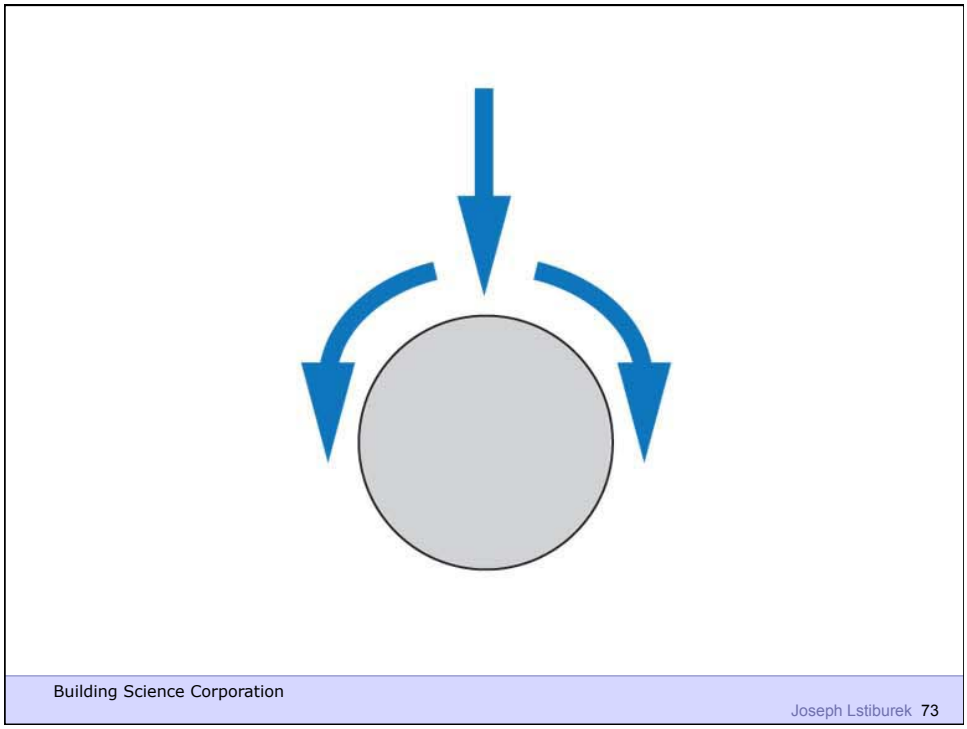
Joseph Lstiburek 72



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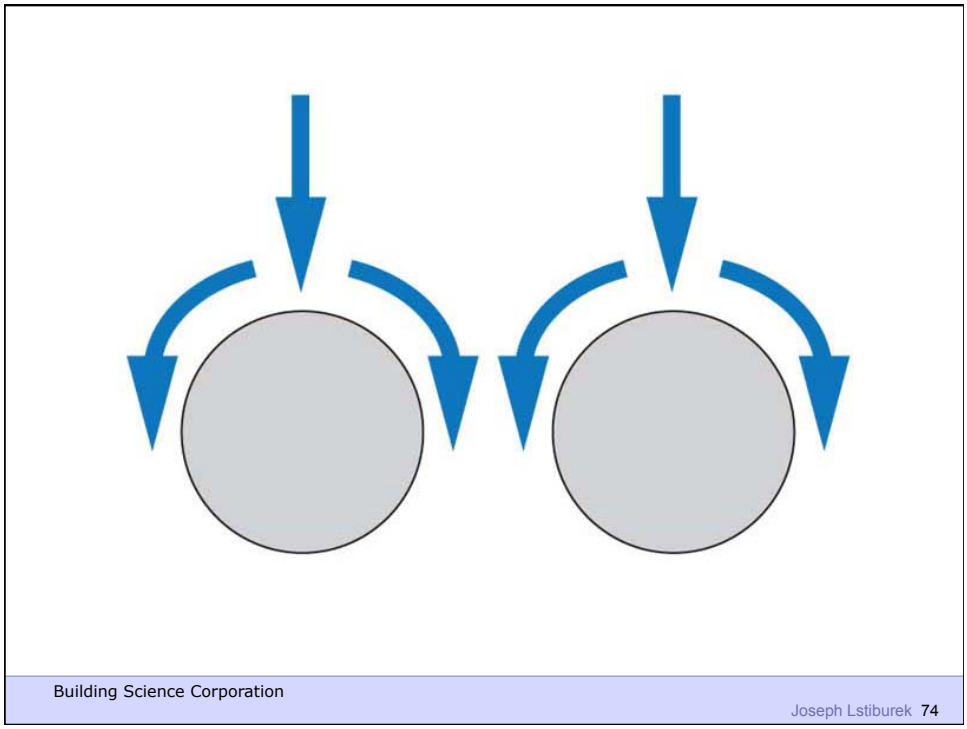

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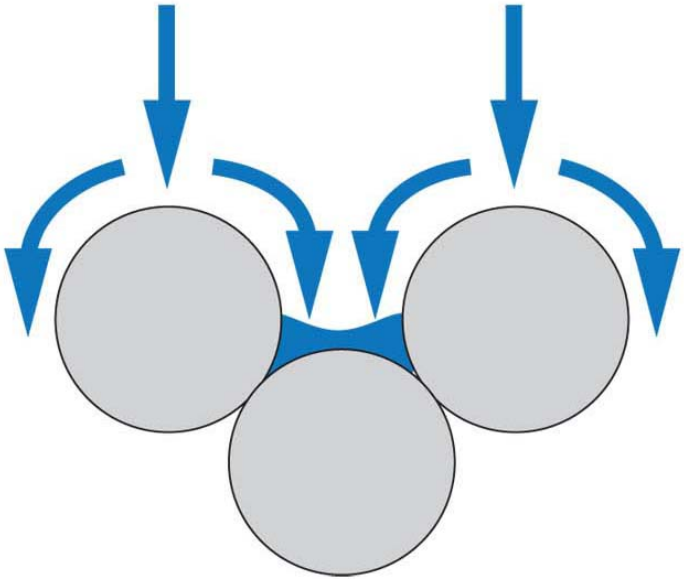

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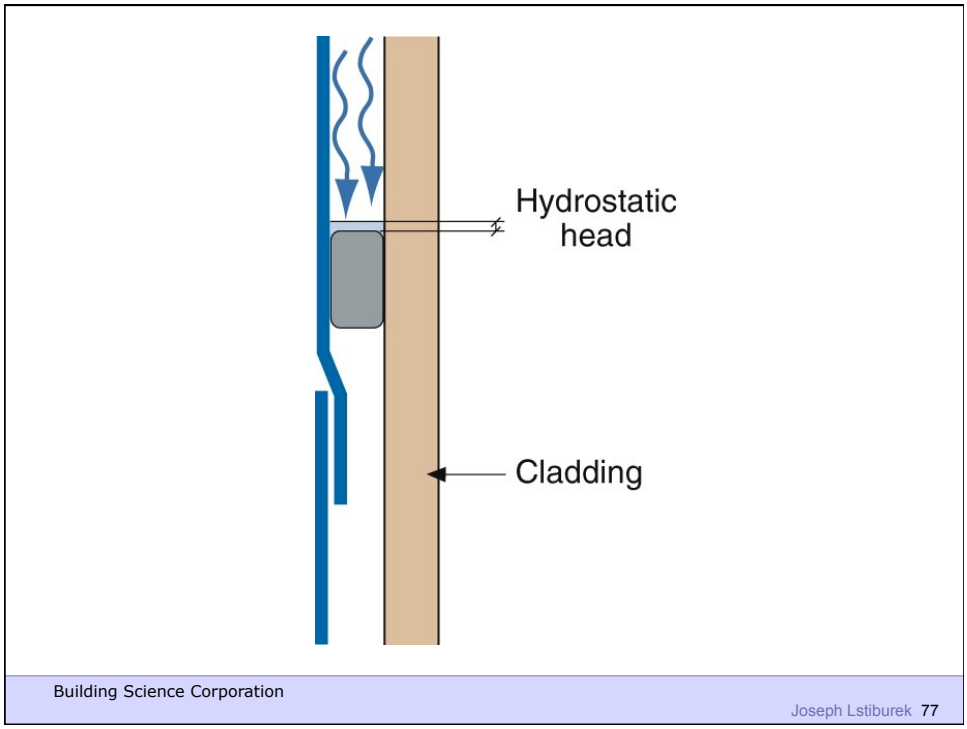
Joseph Lstiburek 76



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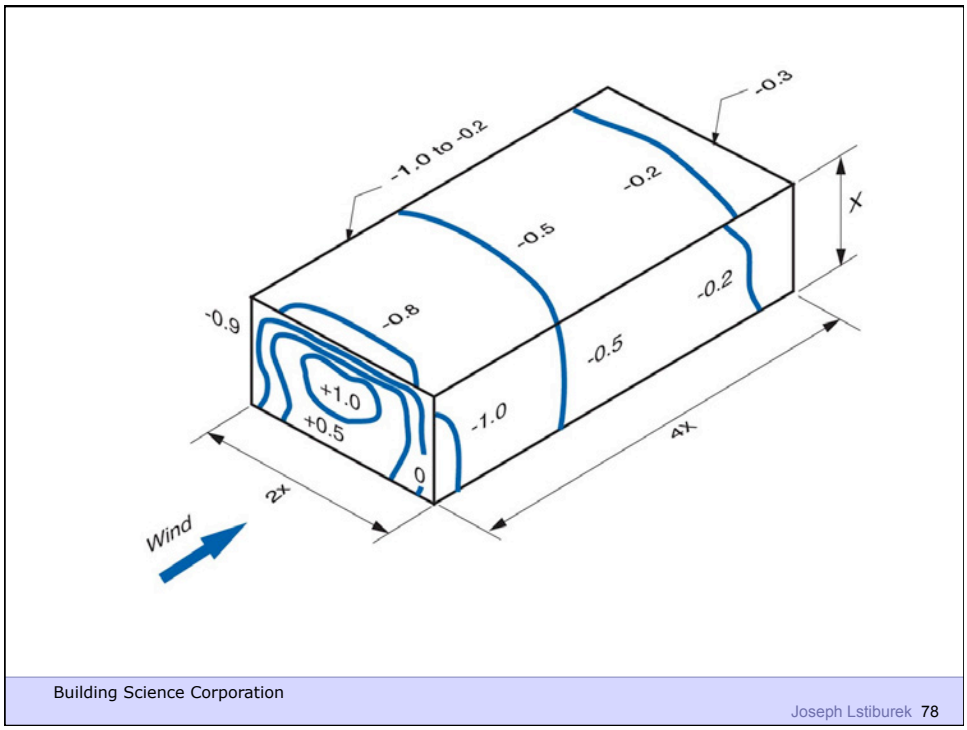

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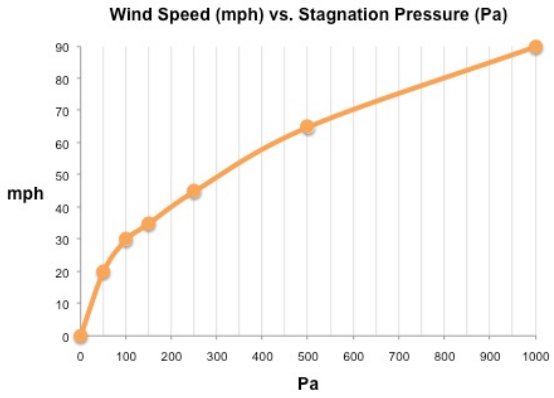
Pascals	mph
50 Pa =	20 mph
100 Pa =	30 mph
150 Pa =	35 mph
250 Pa =	45 mph
500 Pa =	65 mph
1,000 Pa =	90 mph



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Joseph Lstiburek 80

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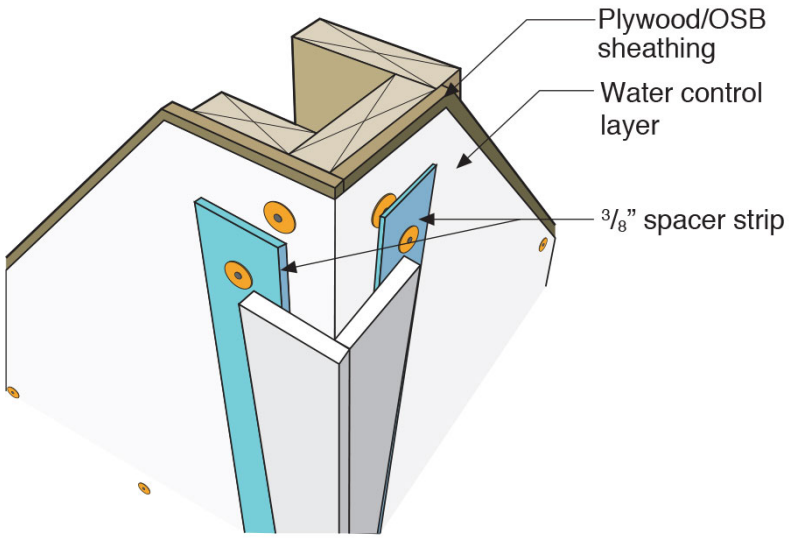
Joseph Lstiburek – Rain Control 81



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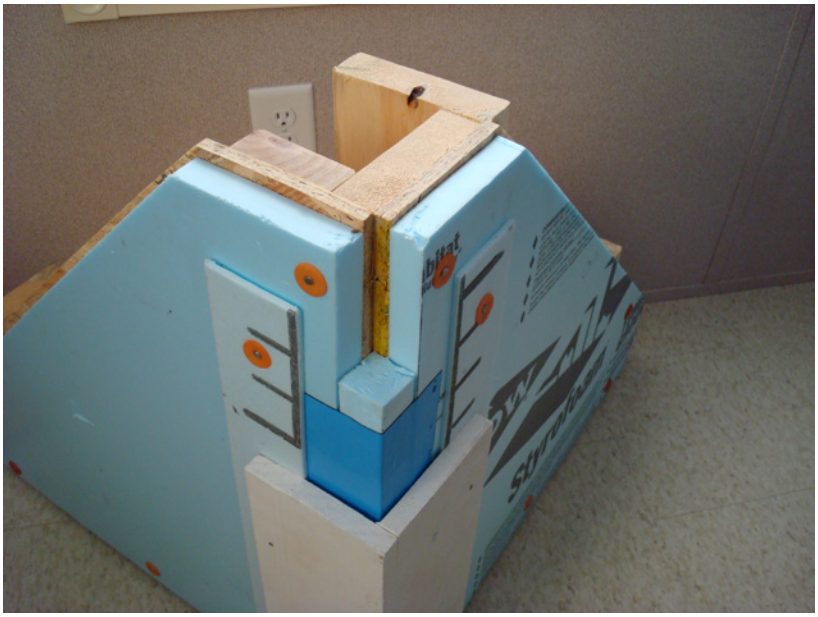

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Joseph Lstiburek 83

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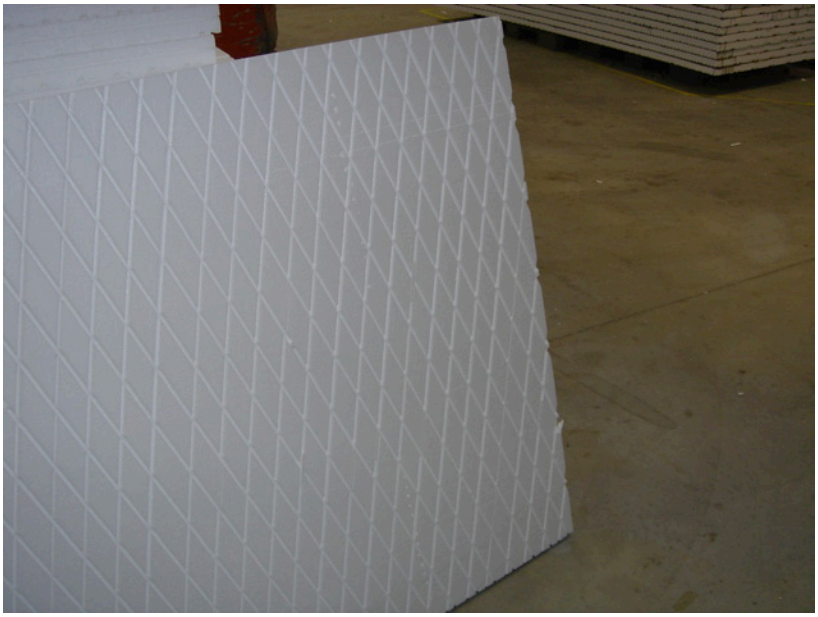

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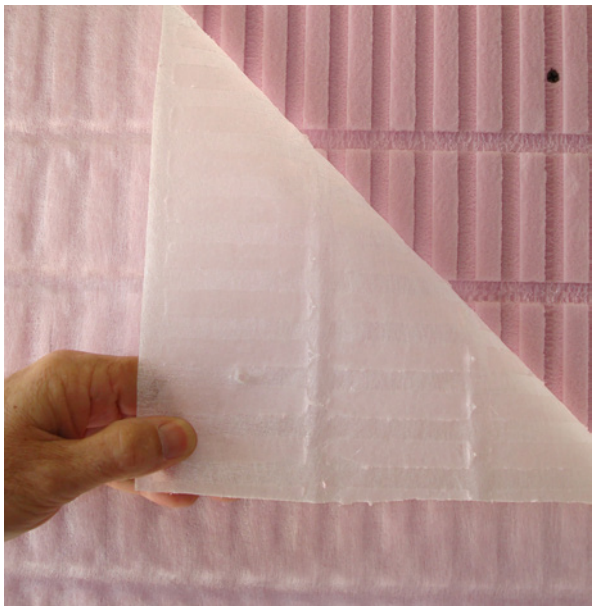

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Joseph Lstiburek 88

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Joseph Lstiburek 89

Rain Screen

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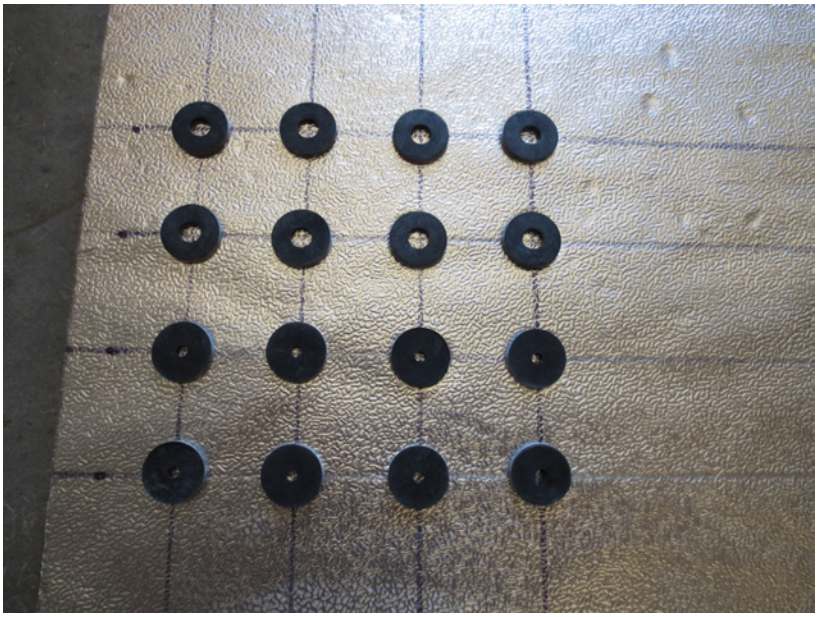
Joseph Lstiburek 90



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Beer Screen?

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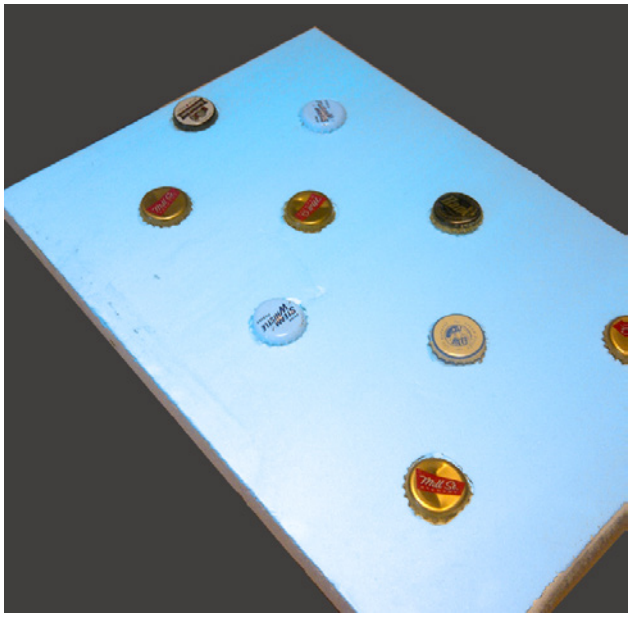

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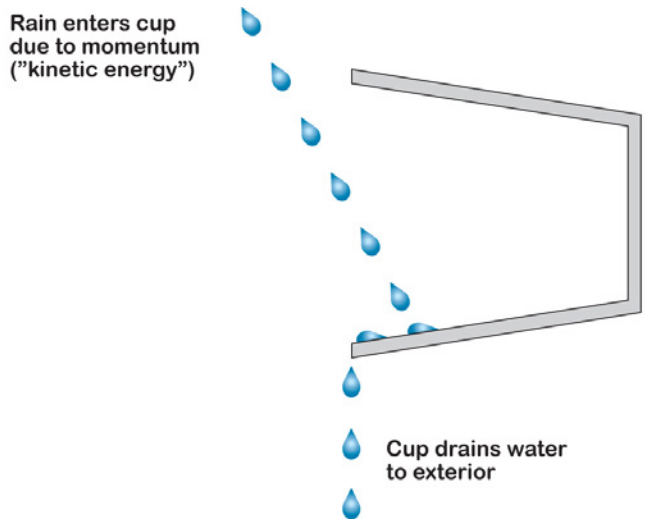

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2011

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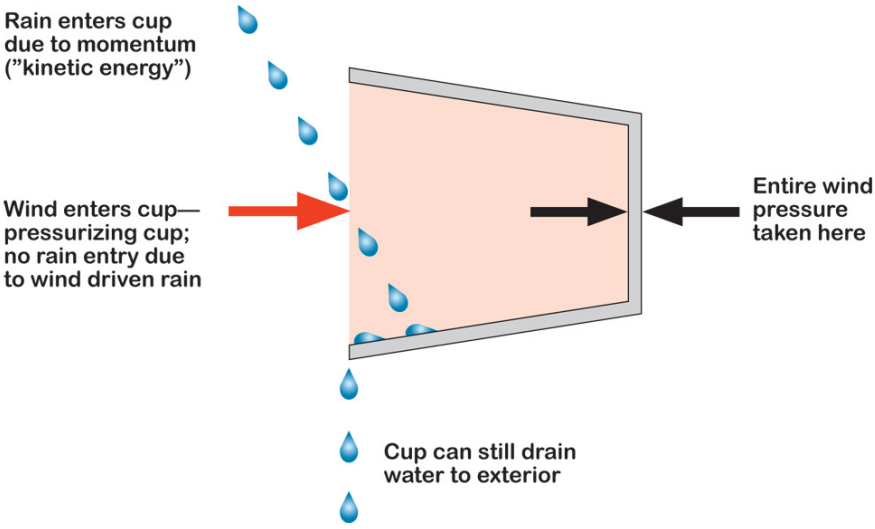

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2011
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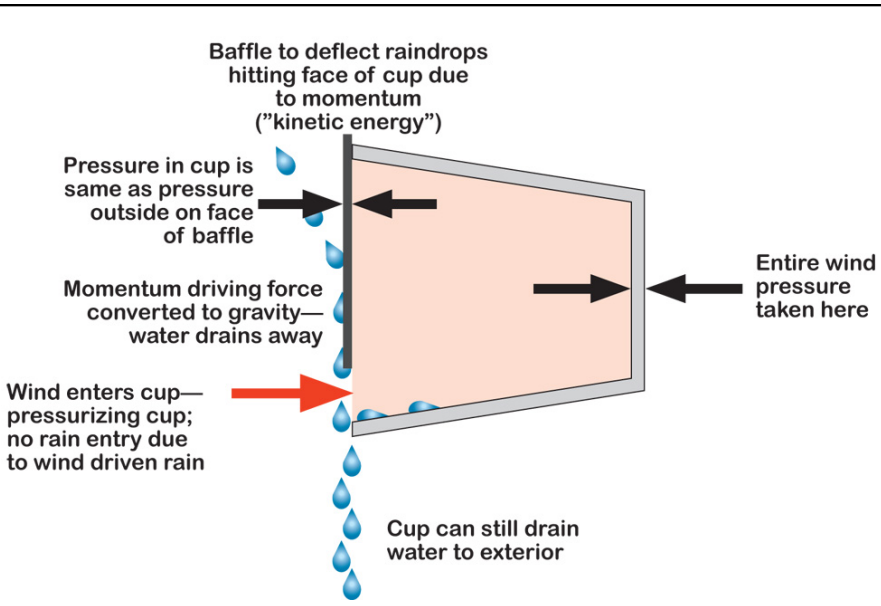

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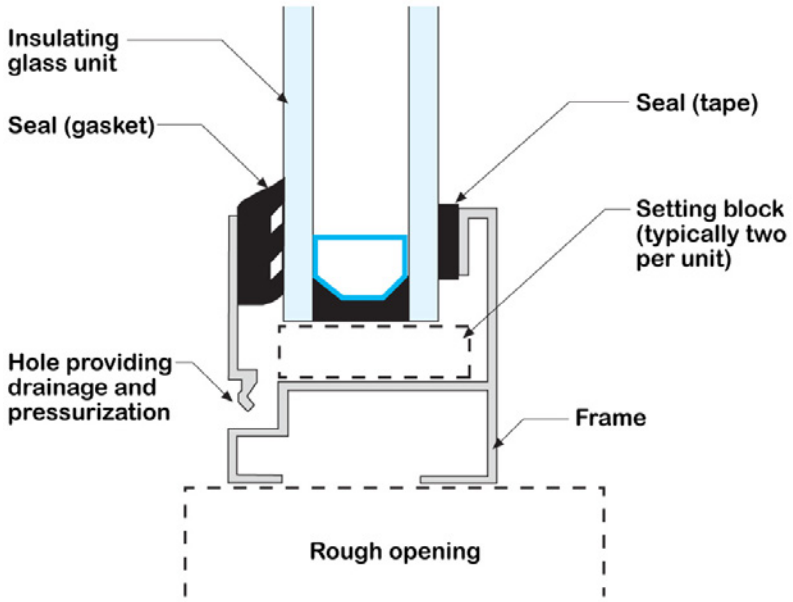

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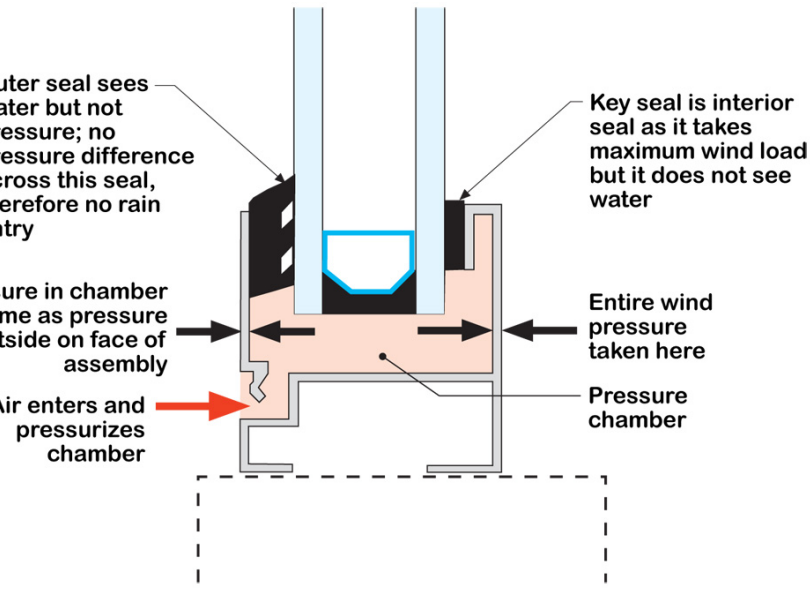

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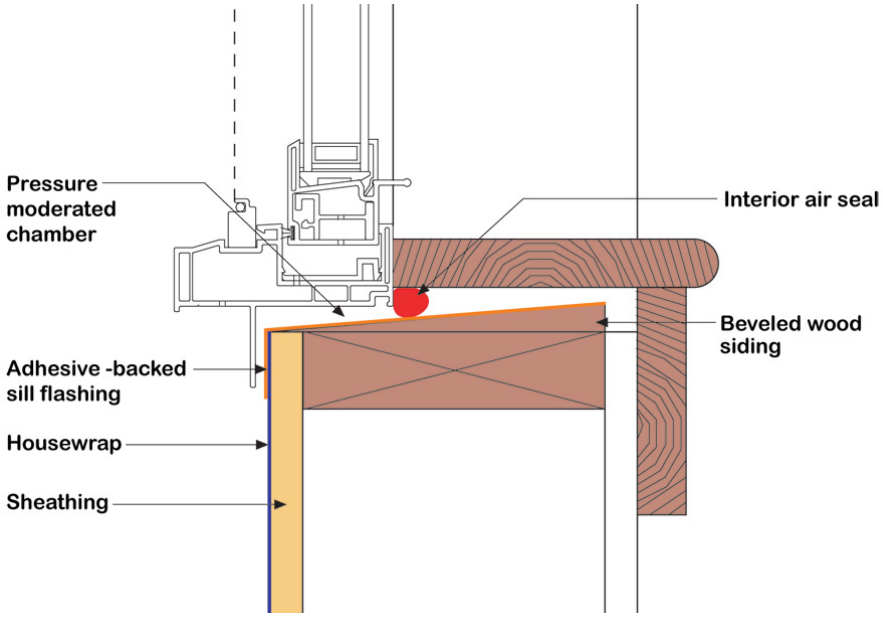

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Joseph Lstiburek 101

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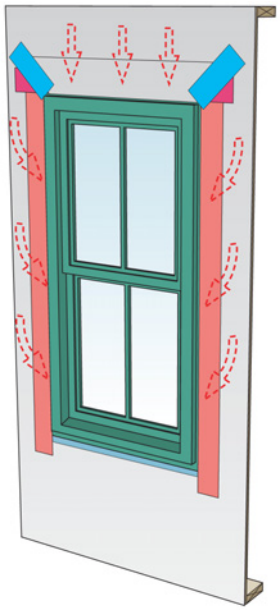
Joseph Lstiburek 102

Building Science Corporation
Joseph Lstiburek 103



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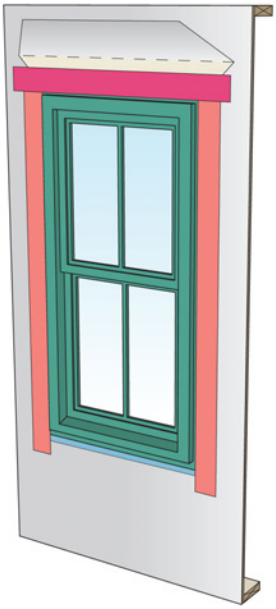

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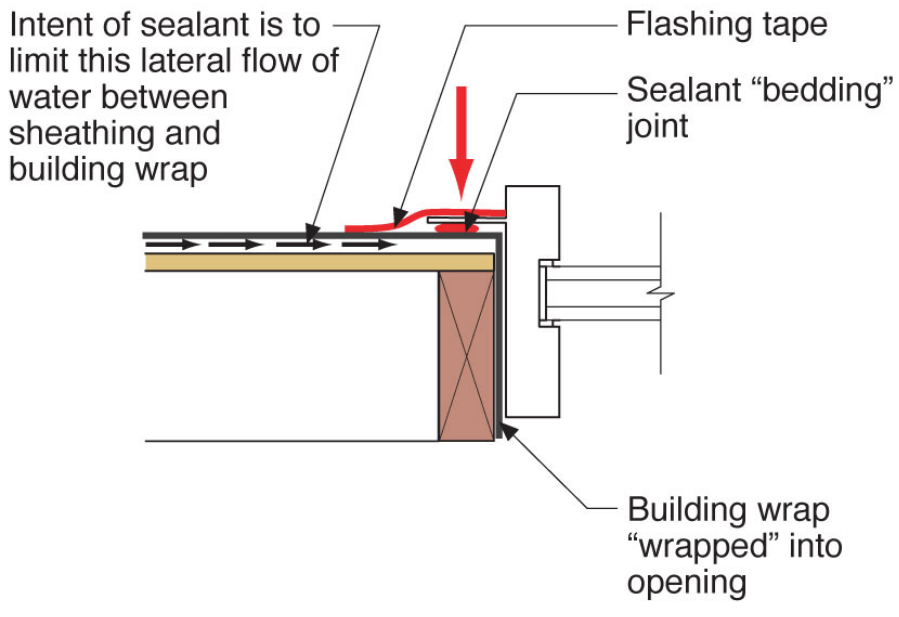

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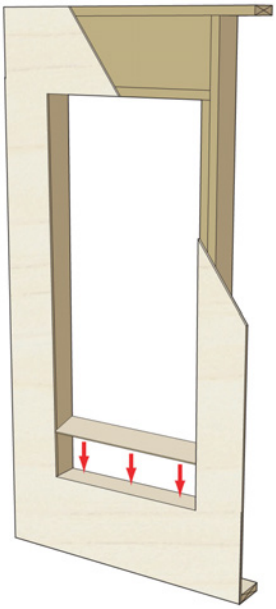

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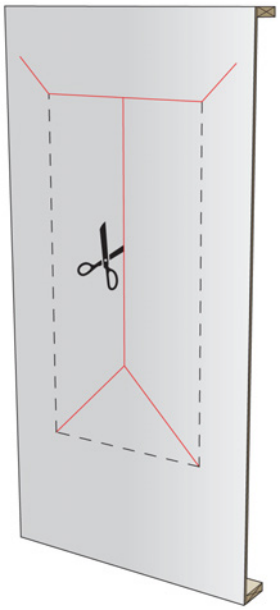

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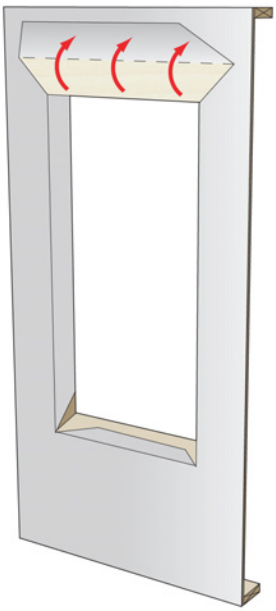

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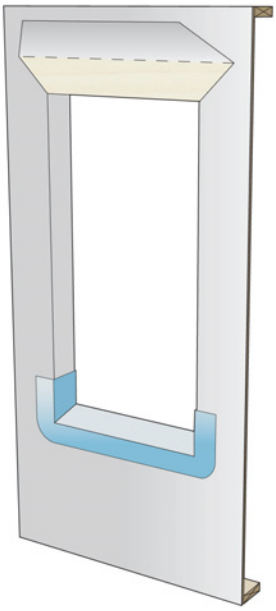

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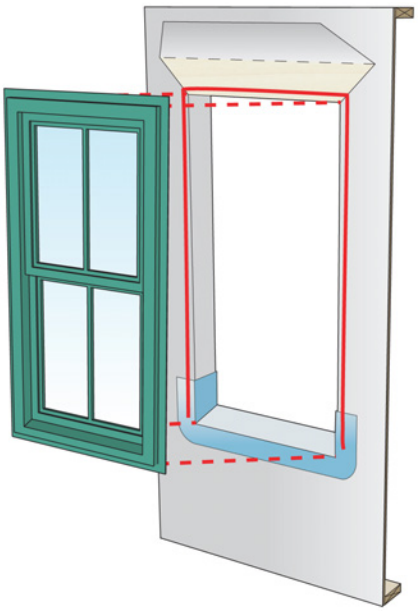

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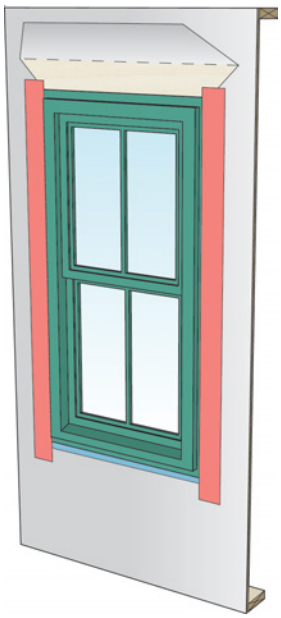

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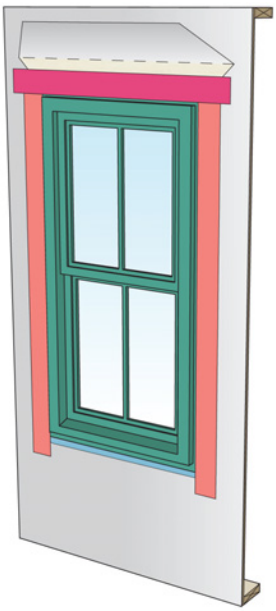

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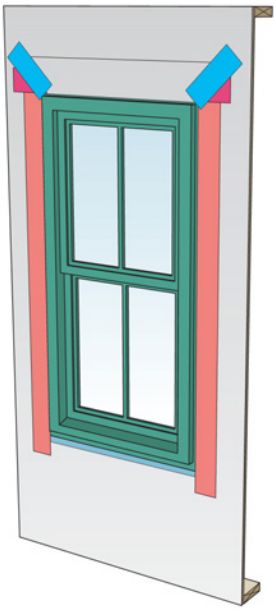

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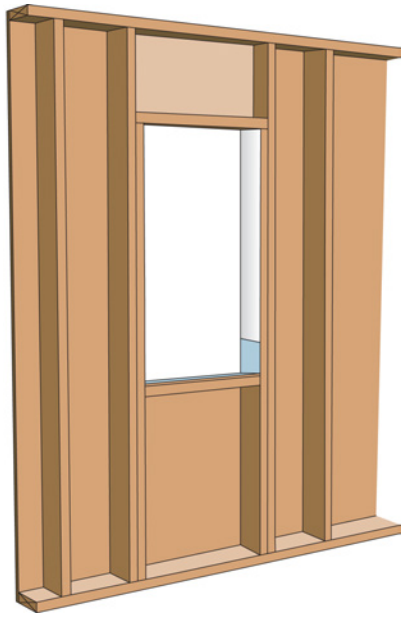

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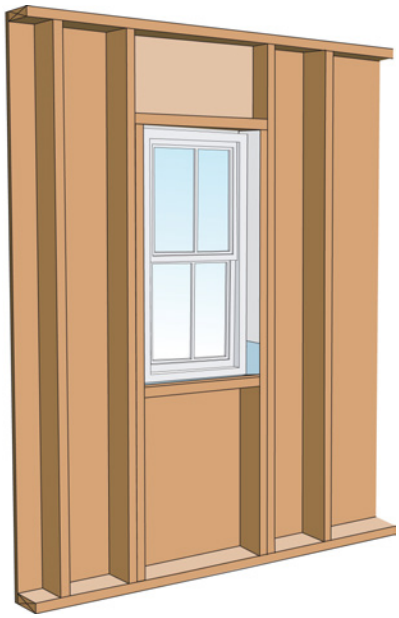

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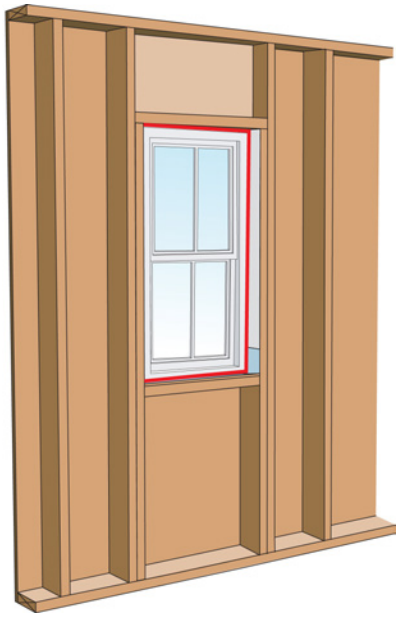
Joseph Lstiburek 116



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Joseph Lstiburek 118

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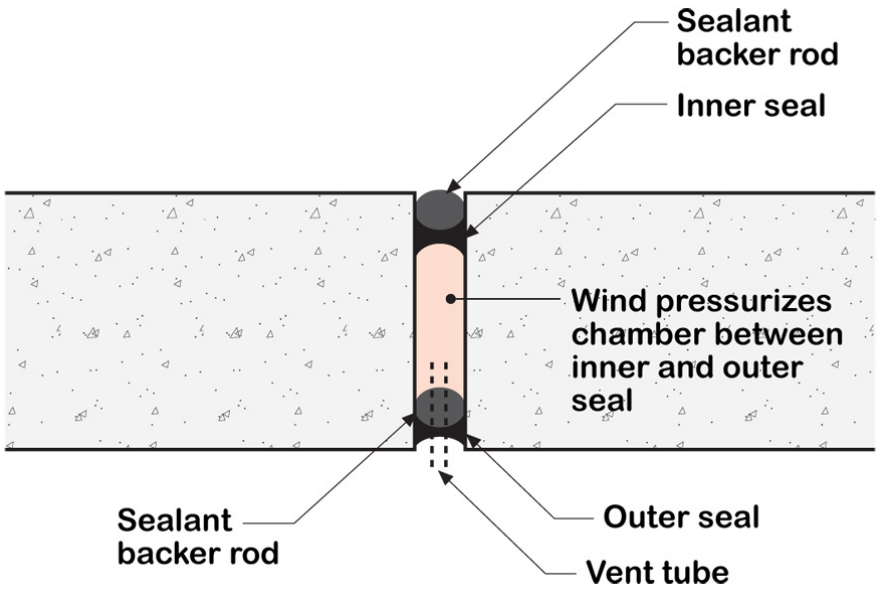
Joseph Lstiburek 119



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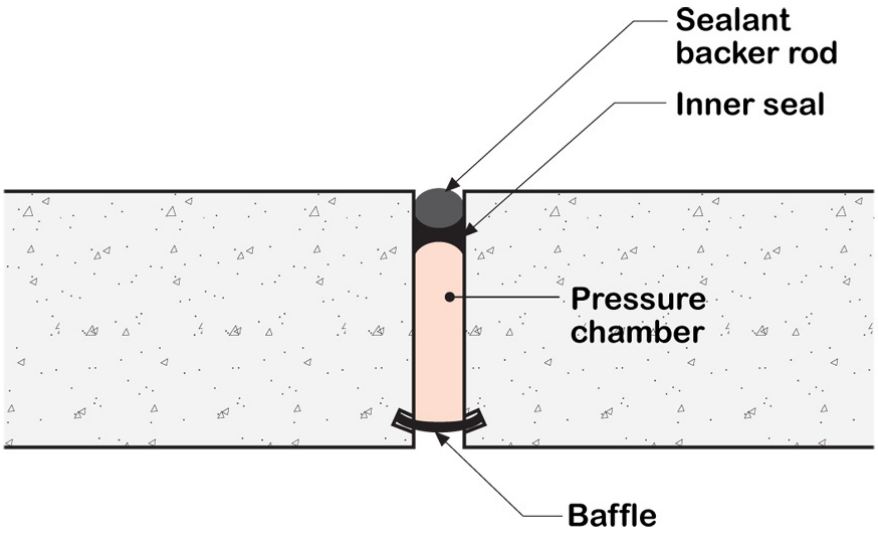

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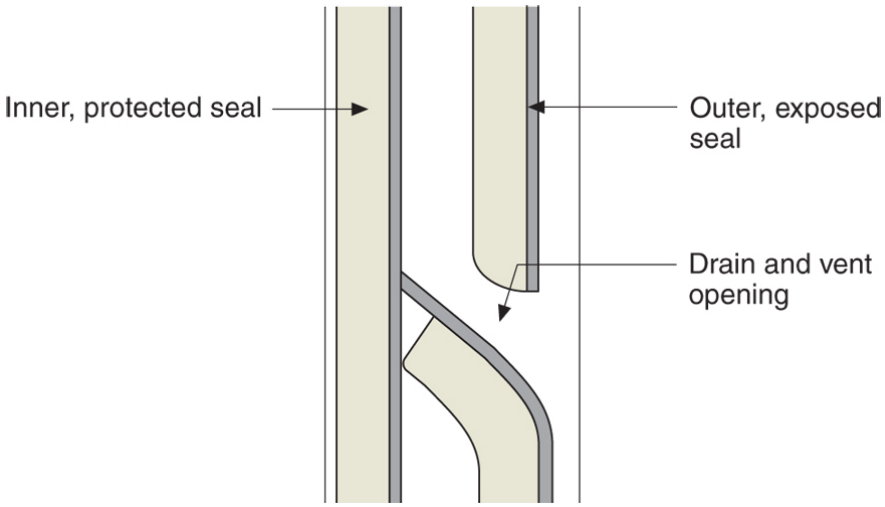

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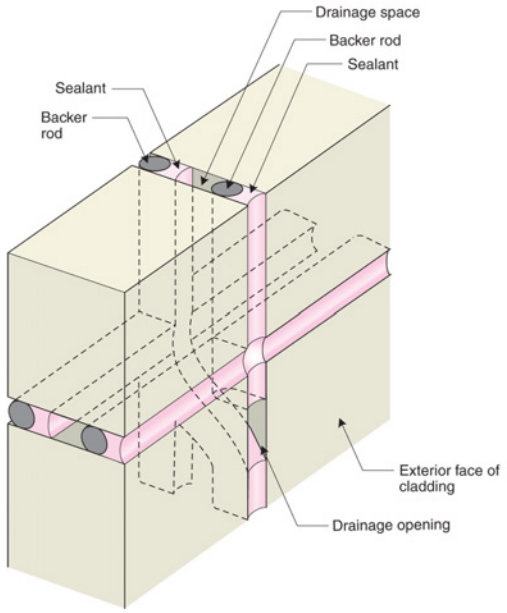

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Joseph Lstiburek 124

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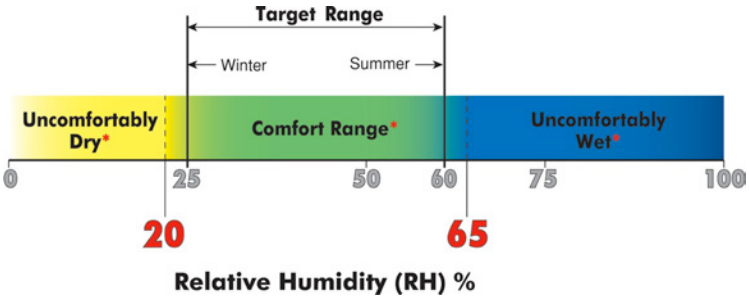
Joseph Lstiburek 125

Building Science Corporation

Joseph Lstiburek 126

Building Science Corporation

Joseph Lstiburek 127



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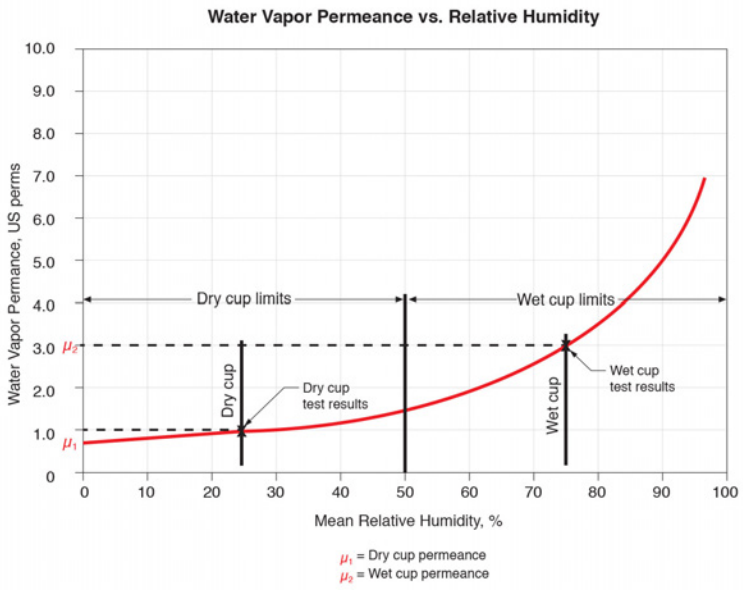

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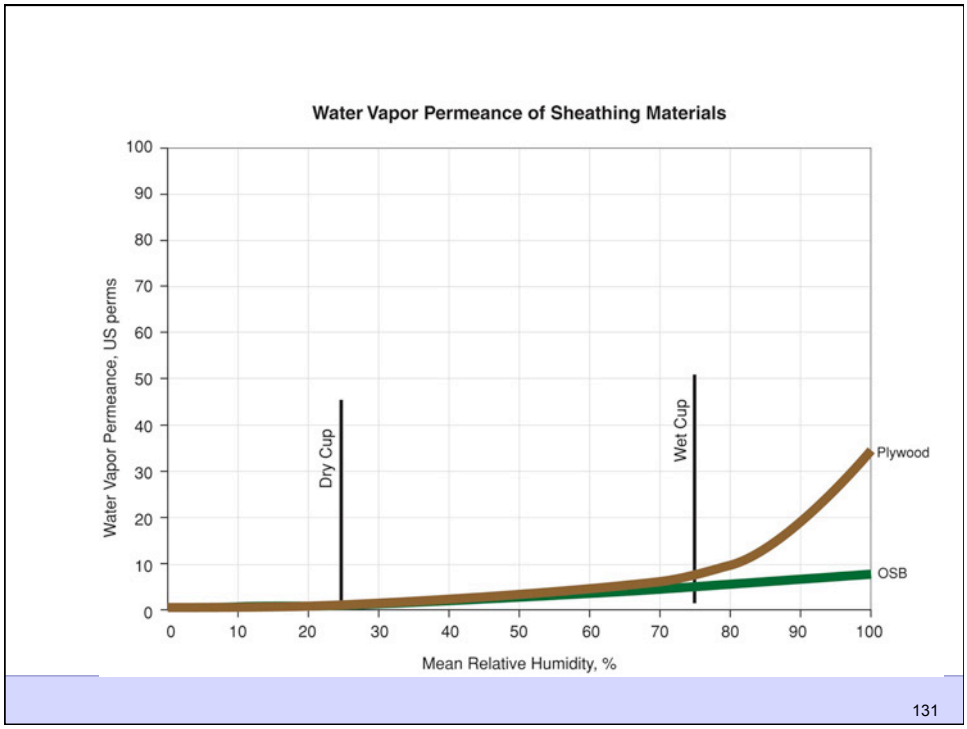
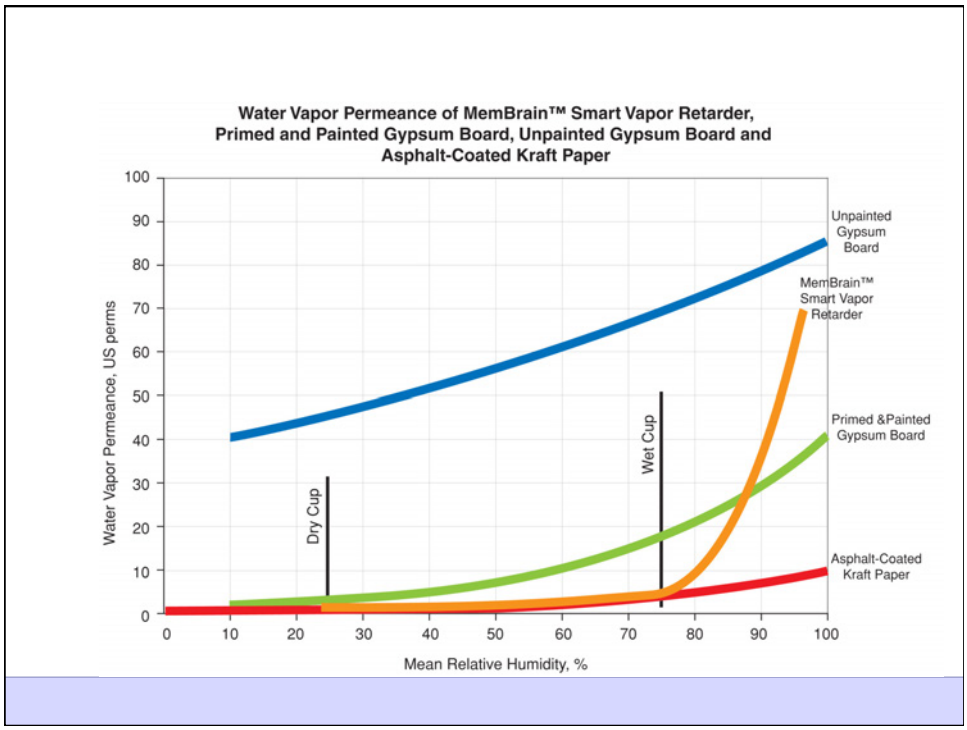
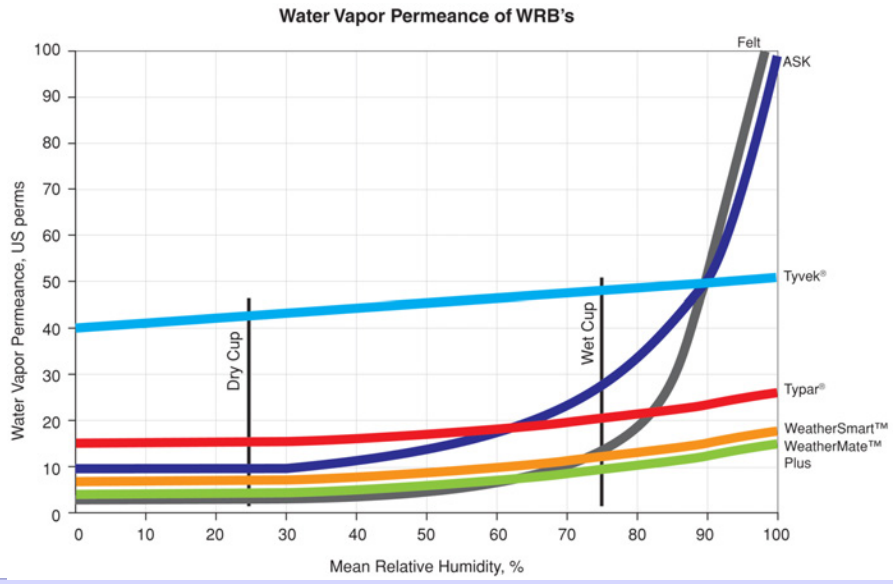
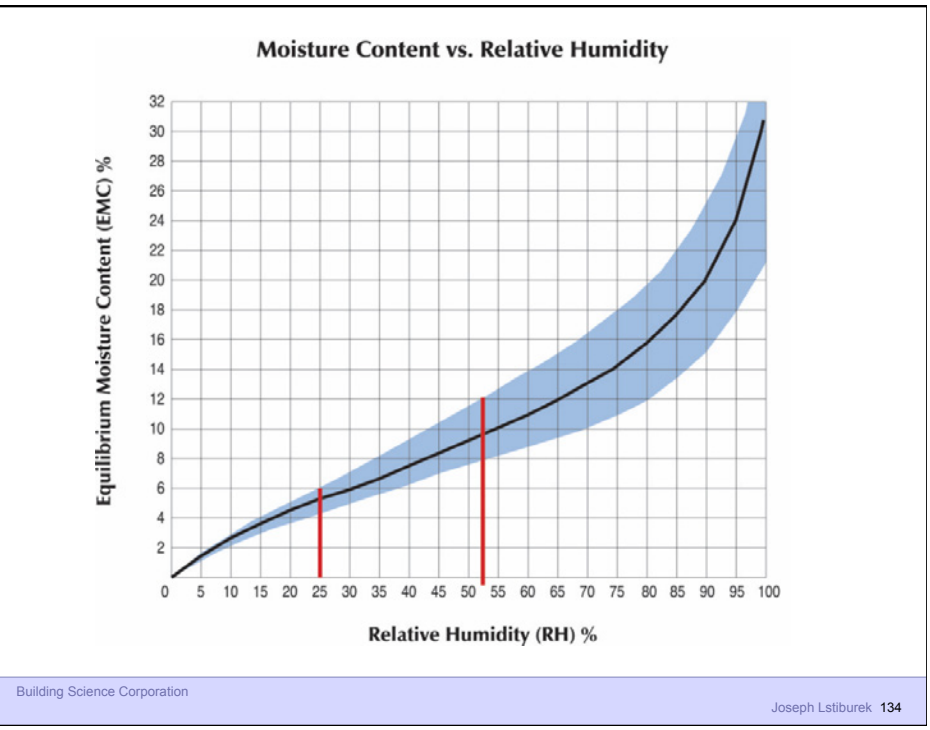
Joseph Lstiburek 129


Water Vapor Permeance of Sheathing Materials
Water Vapor Permeance, US perms
Mean Relative Humidity, %
Dry Cup
Wet Cup
Plywood
OSB
0
10
20
30
40
50
60
70
80
90
100

131


Water Vapor Permeance of MemBrain™ Smart Vapor Retarder, Primed and Painted Gypsum Board, Unpainted Gypsum Board and Asphalt-Coated Kraft Paper
Water Vapor Permeance, US perms
Mean Relative Humidity, %
Dry Cup
Wet Cup
Unpainted Gypsum Board
MemBrain™ Smart Vapor Retarder
Primed &Painted Gypsum Board
Asphalt-Coated Kraft Paper
0
10
20
30
40
50
60
70
80
90
100


Water Vapor Permeance of WRB's
Water Vapor Permeance, US perms
Mean Relative Humidity, %
Dry Cup
Wet Cup
Felt
ASK
Tyvek®
Typar®
WeatherSmart™
WeatherMate™
Plus
0
10
20
30
40
50
60
70
80
90
100


Moisture Content vs. Relative Humidity
Equilibrium Moisture Content (EMC) %
Relative Humidity (RH) %
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32
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panago

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Joseph Lstiburek 137

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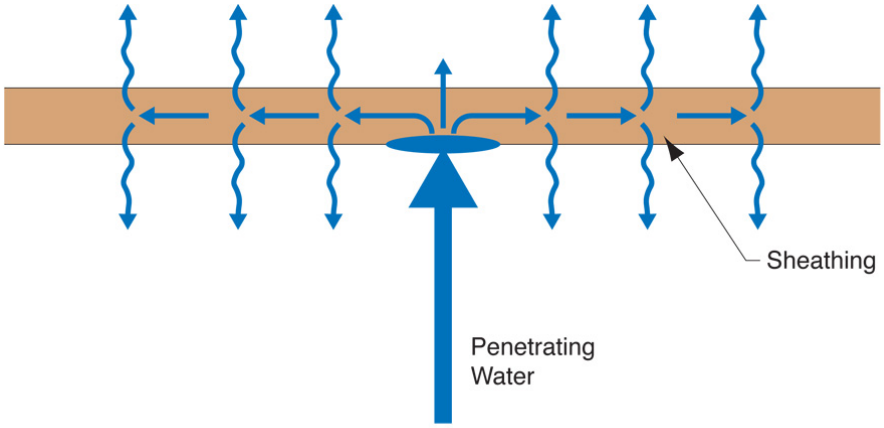
Joseph Lstiburek 138

Building Science Corporation
Joseph Lstiburek 139

Building Science Corporation
Joseph Lstiburek 140

Building Science Corporation
Joseph Lstiburek 141

Building Science Corporation
Joseph Lstiburek 142



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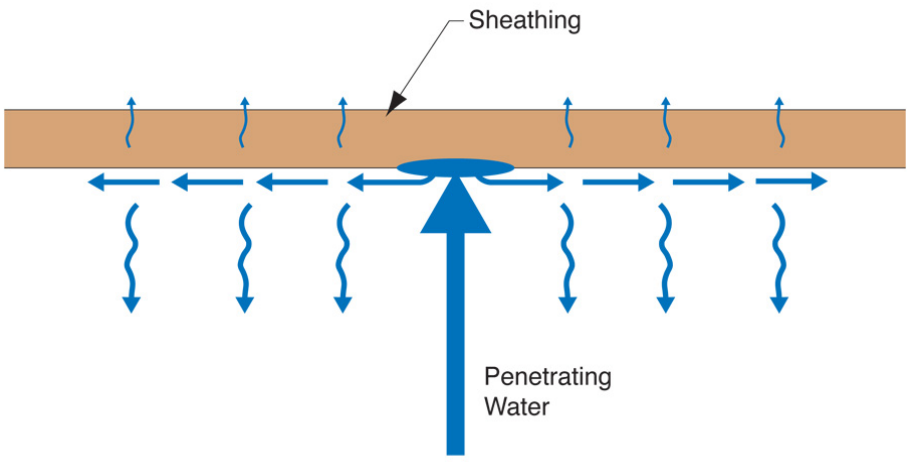

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Joseph Lstiburek – Rain Control 145

Building Science Corporation

Joseph Lstiburek 146

Building Science Corporation
2010 Joseph Lstiburek 147

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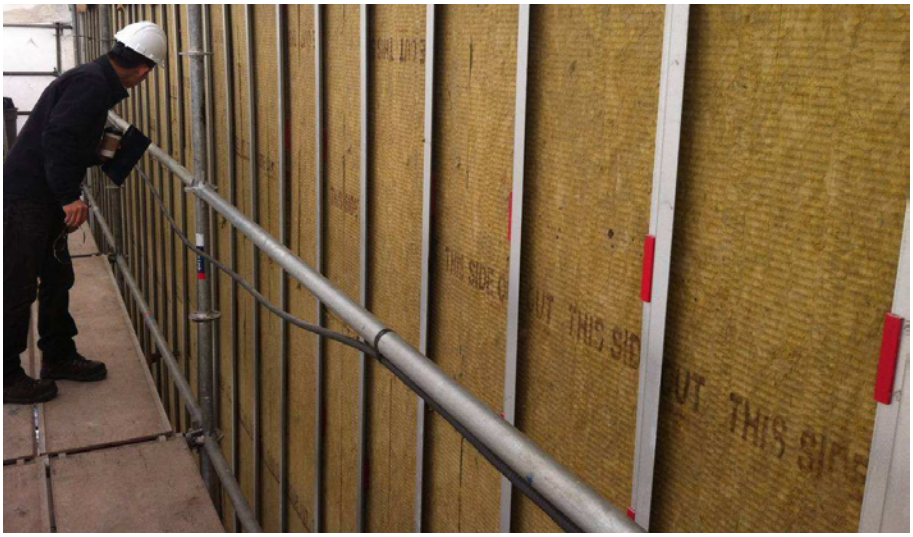
Joseph Lstiburek 149

150



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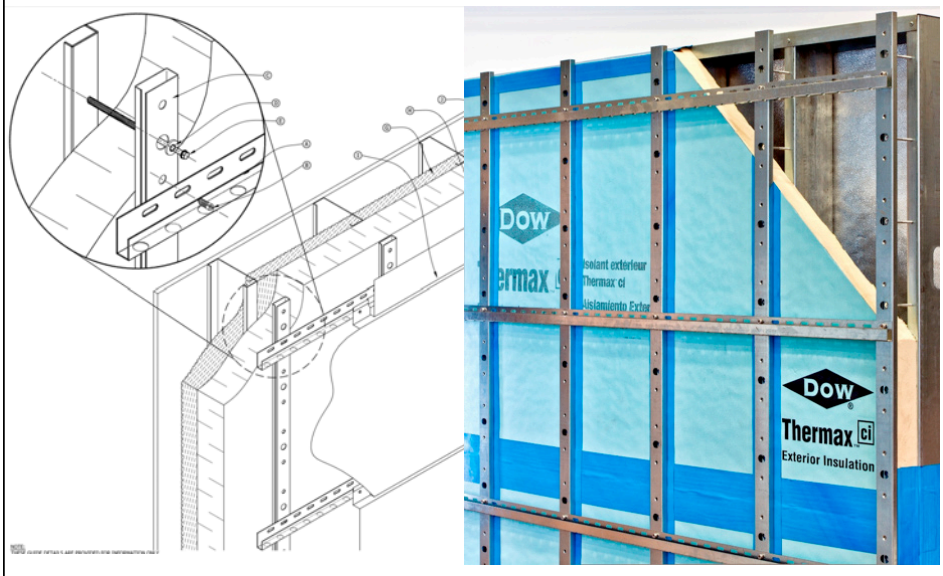
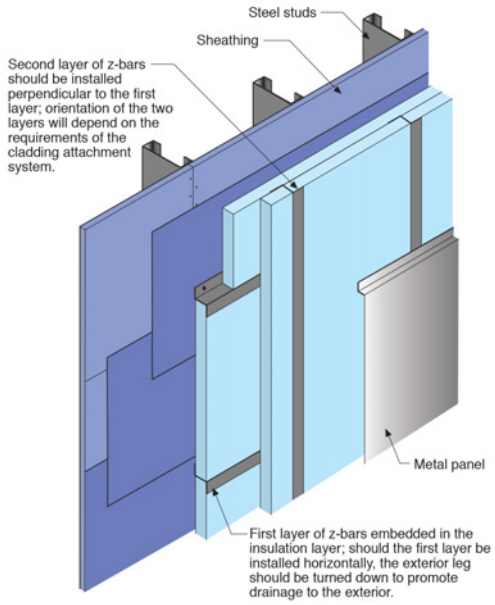
Joseph Lstiburek 151





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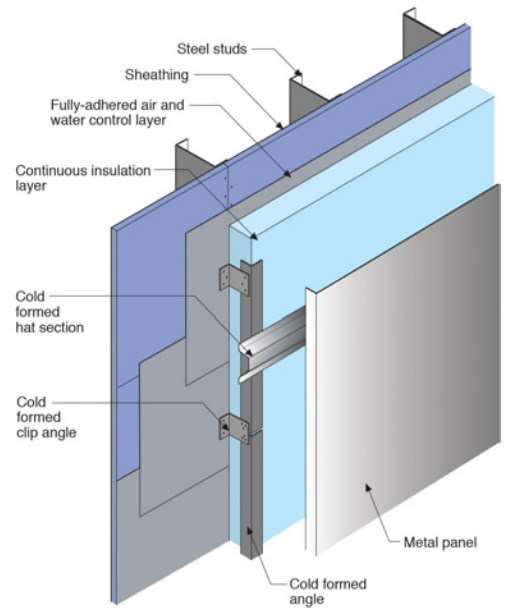
Joseph Lstiburek 153



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Joseph Lstiburek – Rain Control 155

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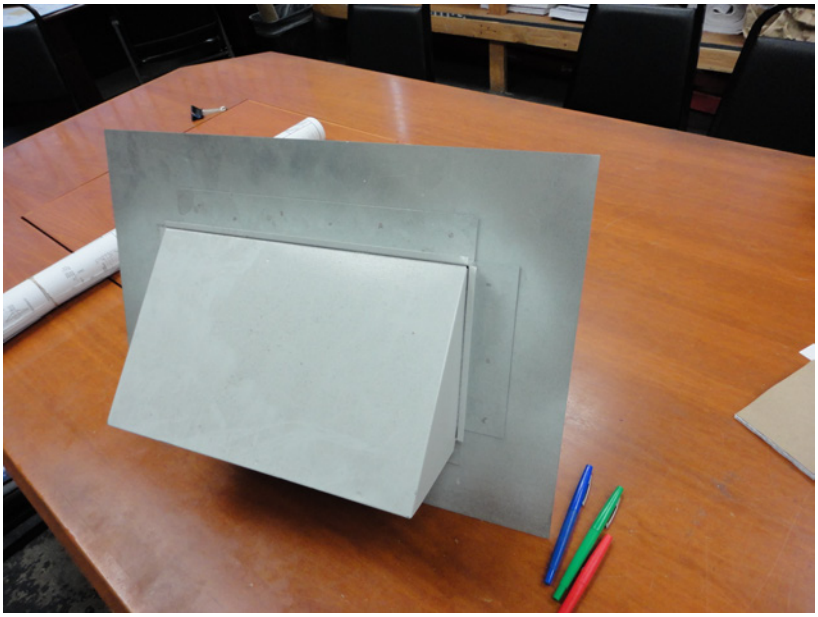
Joseph Lstiburek – Rain Control 156



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Joseph Lstiburek – Rain Control 158

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Joseph Lstiburek – Rain Control 161

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

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Multifamily

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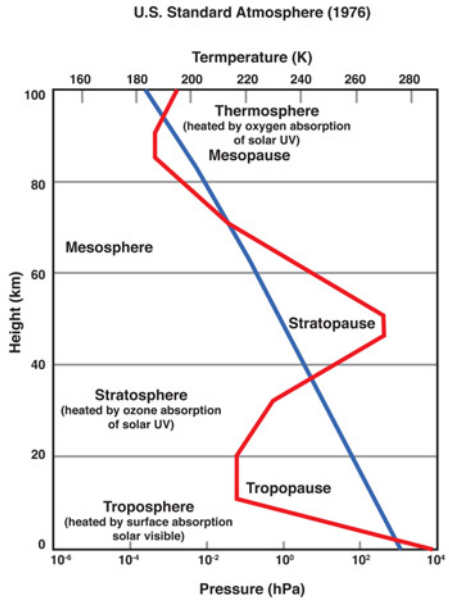
Lapse Rate



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Joseph Lstiburek 3

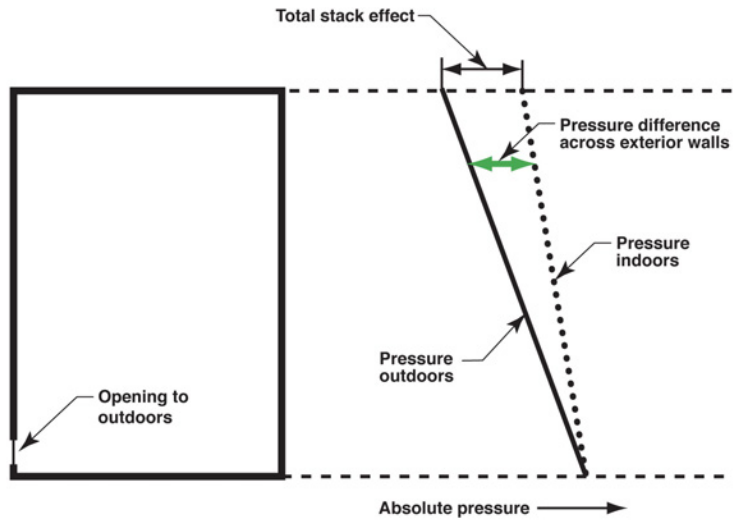

Figure 11.1: Building with no internal separations with opening at the bottom
(Adapted from G.O. Handegord, 1998)

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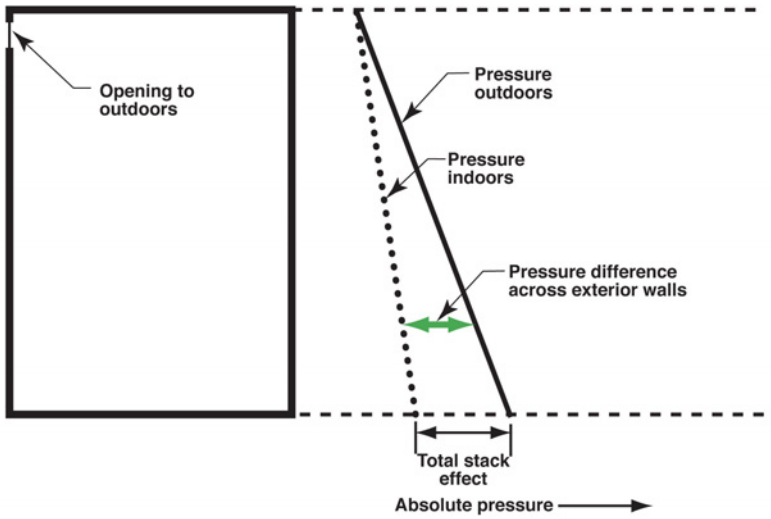

Figure 11.2: Building with no internal separations with opening at the top
(Adapted from G.O. Handegord, 1998)

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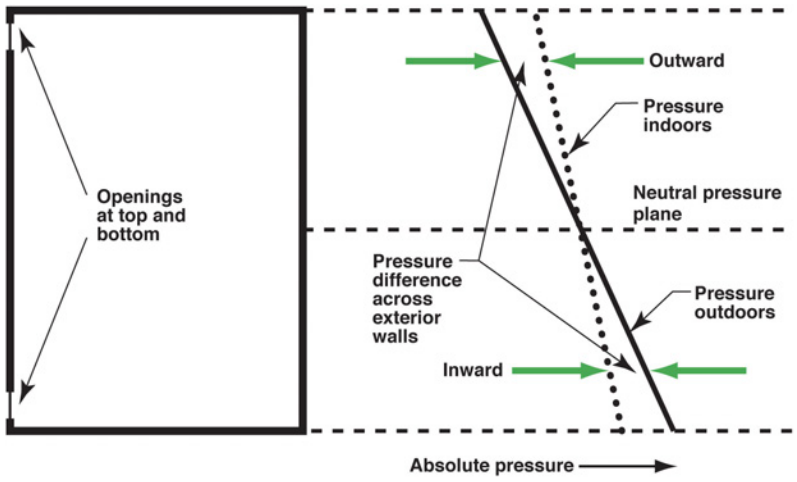

Figure 11.3: Building with no internal separations with openings at top and bottom
(Adapted from G.O. Handegord, 1998)

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Joseph Lstiburek 6

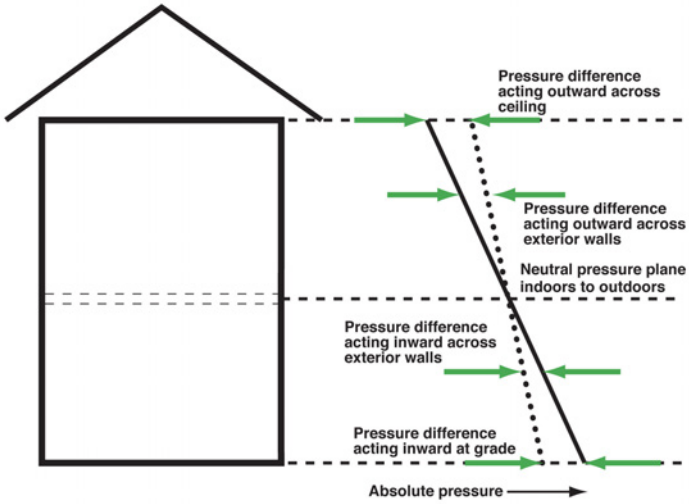

Figure 11.4: Basic two storey house with vented attic
(Adapted from G.O. Handegord, 1998)

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Joseph Lstiburek 8

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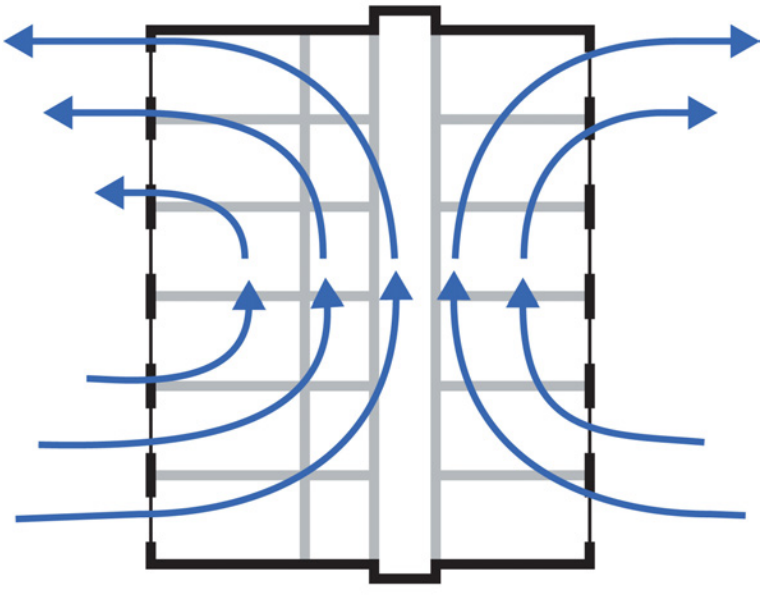
Joseph Lstiburek 9



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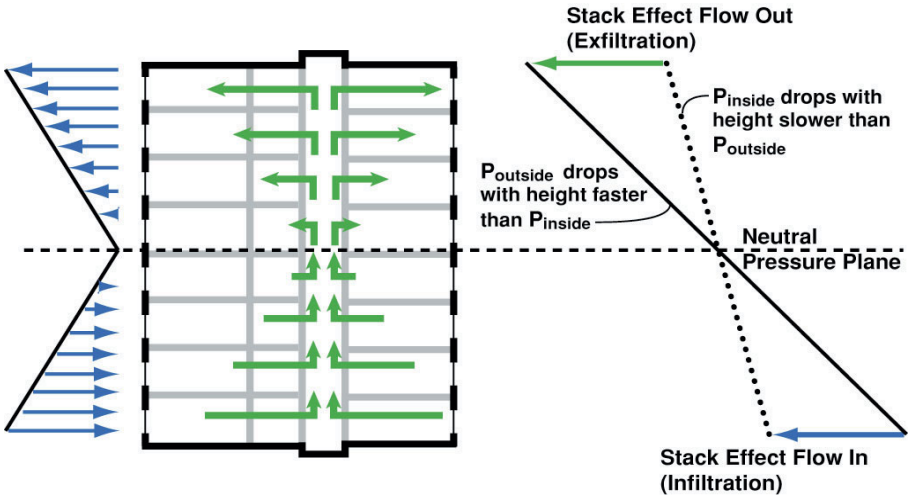
Joseph Lstiburek 10



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Joseph Lstiburek 11

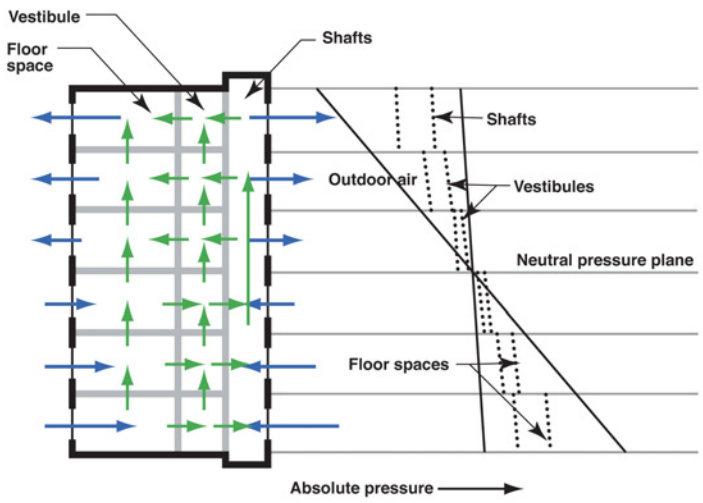

Figure 11.8: Stack effect pressures in high rise office building
(Adapted from G.O. Handegord, 1998)

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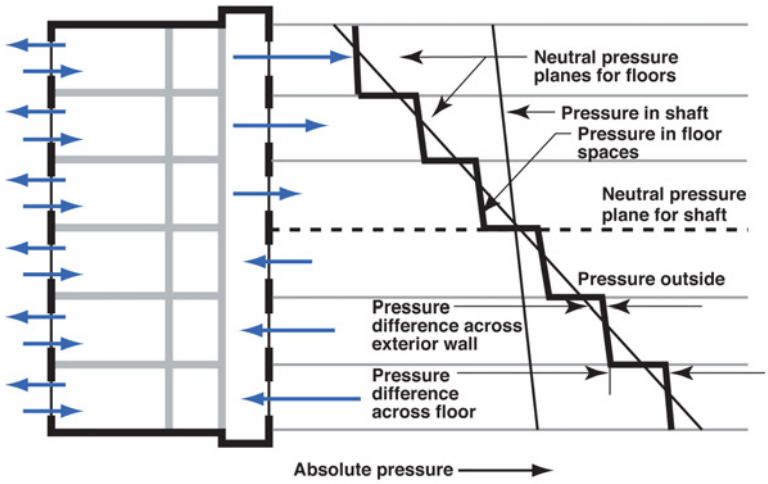

Figure 11.9: Multi-storey building with floor spaces isolated from vertical shafts (Adapted from G.O. Handegord, 1998)

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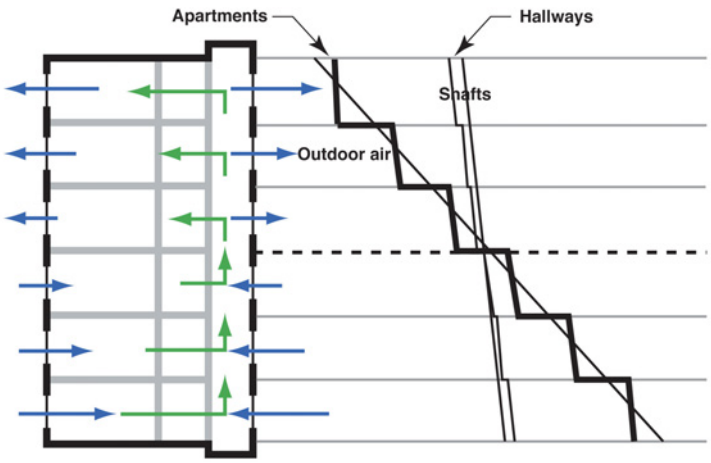

Figure 11.12: Apartment building with tighter apartment entry doors (Adapted from G.O. Handegord, 1998)

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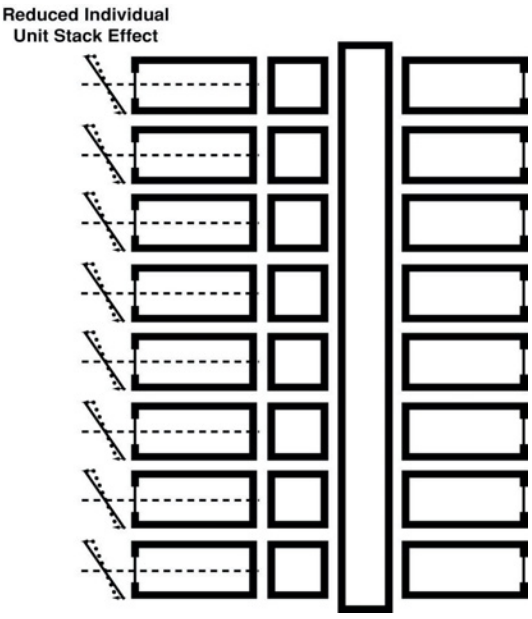

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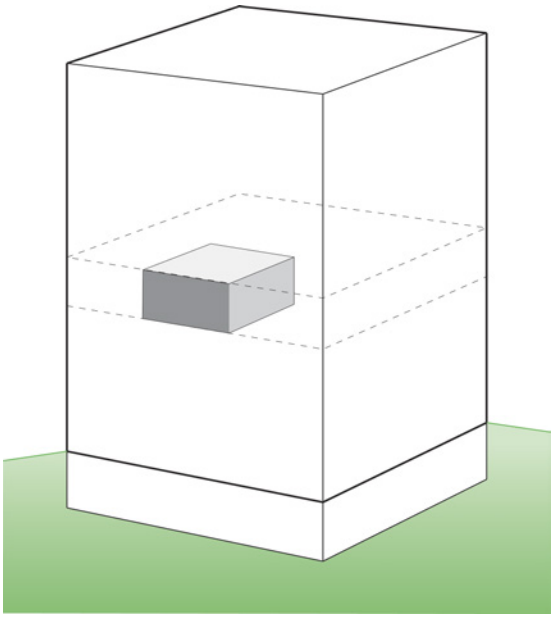
Joseph Lstiburek 15



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Joseph Lstiburek – HVAC 18

Build Tight - Ventilate Right

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

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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Joseph Lstiburek 22

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

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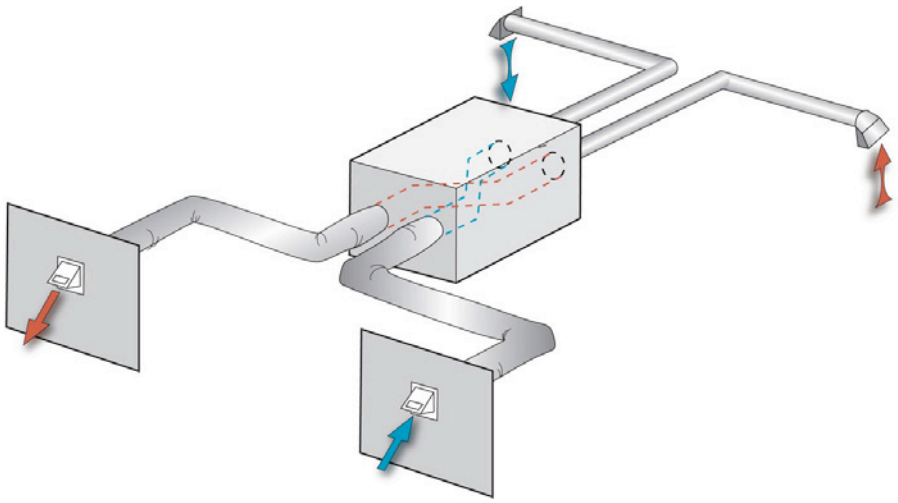
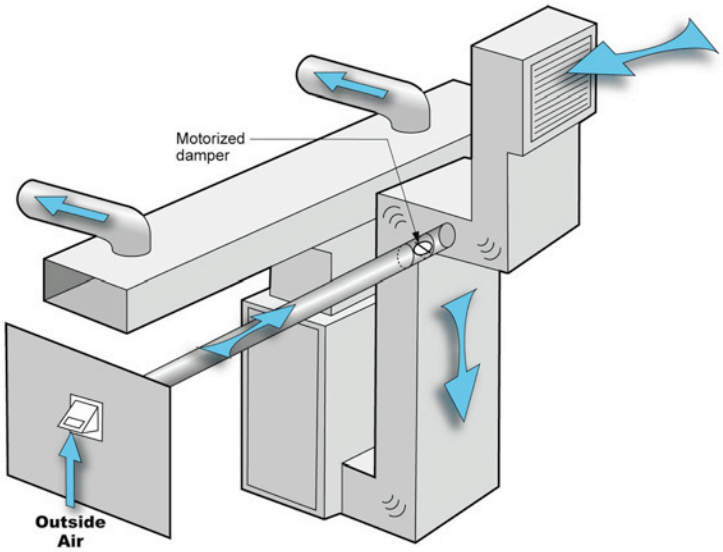


Building Science Corporation
Joseph Lstiburek 24



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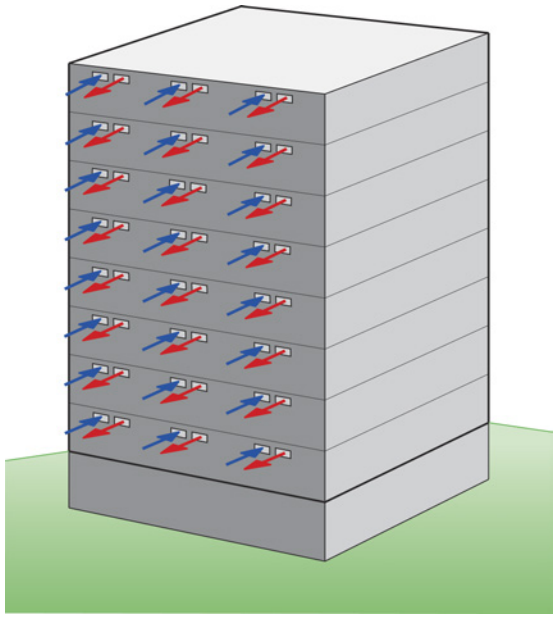
Joseph Lstiburek 25



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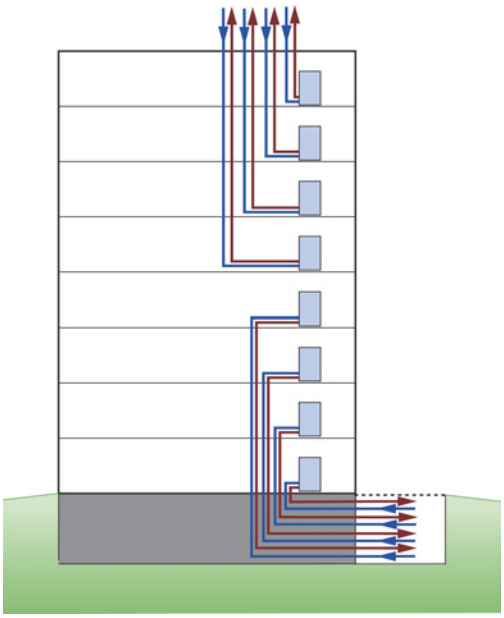
Joseph Lstiburek 27



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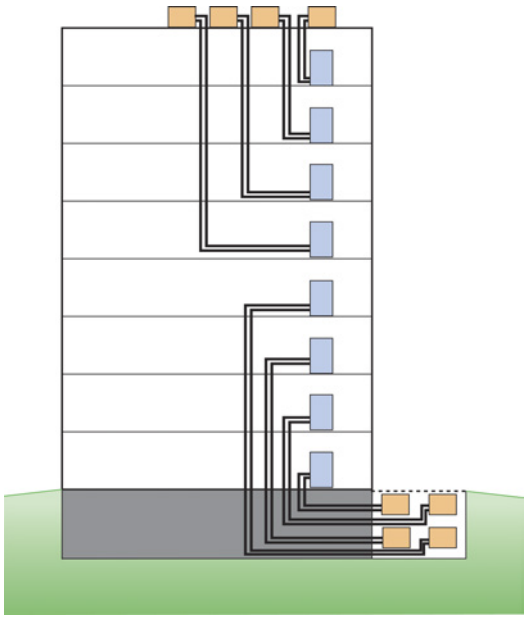

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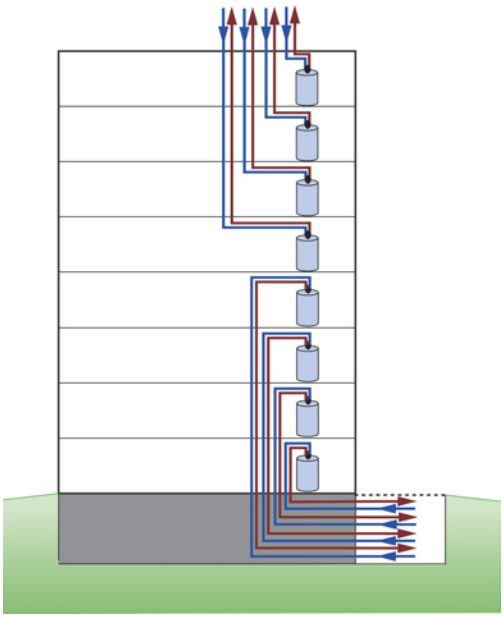

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Joseph Lstiburek – HVAC 31

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Joseph Lstiburek – HVAC 32

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Joseph Lstiburek – HVAC 33

Building Science Corporation

Joseph Lstiburek – HVAC 34

Building Science Corporation

Joseph Lstiburek – HVAC 35

Building Science Corporation

Joseph Lstiburek – HVAC 36

Building Science Corporation

Joseph Lstiburek 37

Building Science Corporation

Joseph Lstiburek 38

Building Science Corporation

Joseph Lstiburek – HVAC 39

Building Science Corporation

Joseph Lstiburek – HVAC 40

Building Science Corporation

Joseph Lstiburek – HVAC 41

Building Science Corporation

Joseph Lstiburek – HVAC 42

Building Science Corporation

Joseph Lstiburek 43

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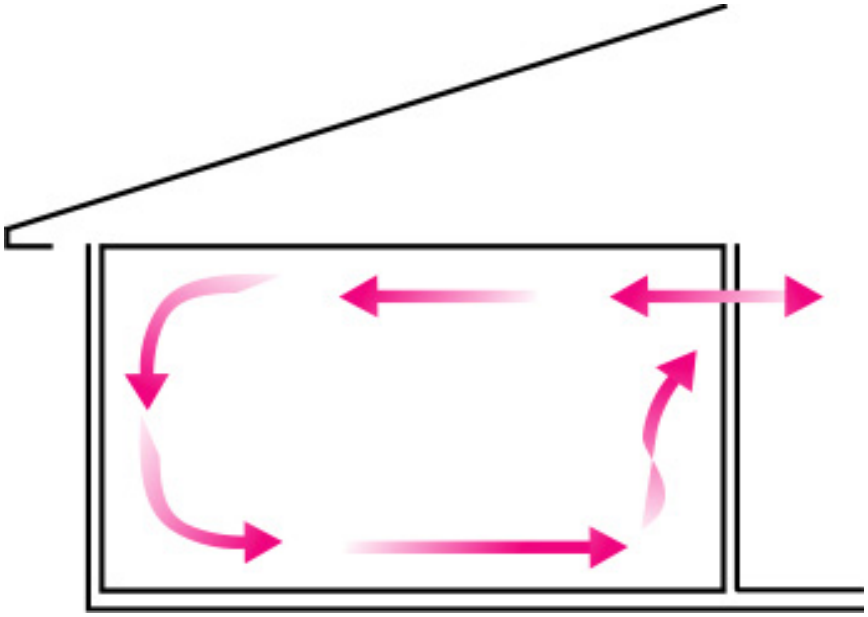
Joseph Lstiburek 44



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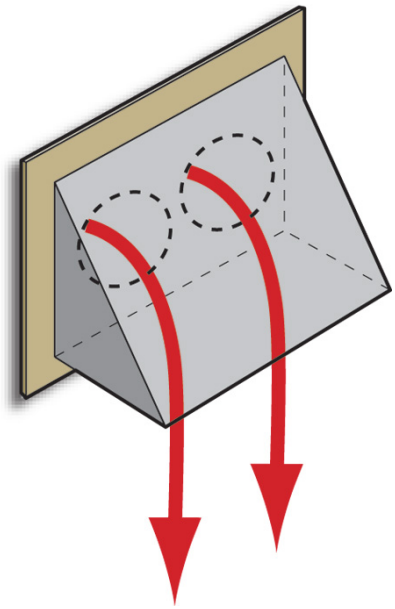
Joseph Lstiburek 45



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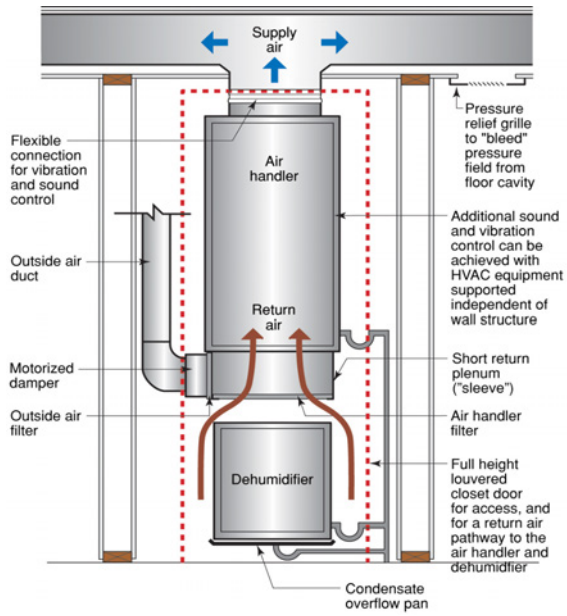

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Joseph Lstiburek – HVAC 47

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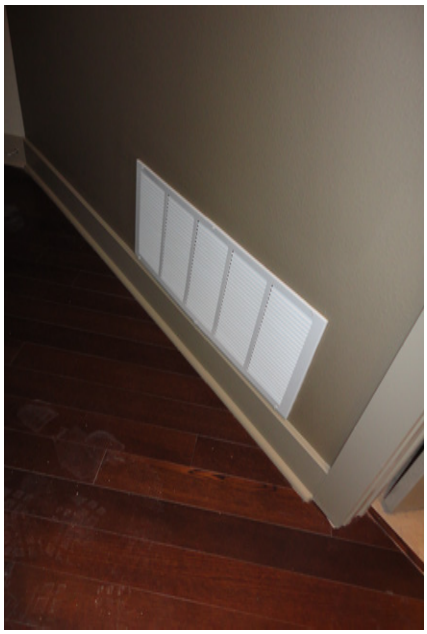
Joseph Lstiburek 48



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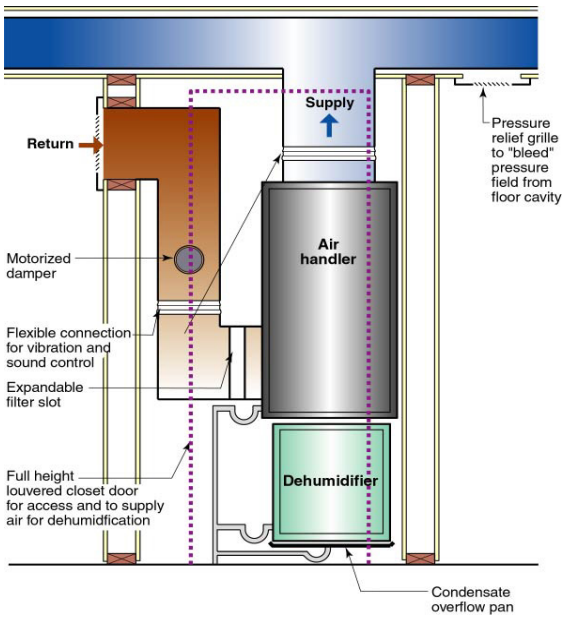
Joseph Lstiburek 50



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Joseph Lstiburek – HVAC 52

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Joseph Lstiburek – HVAC 53

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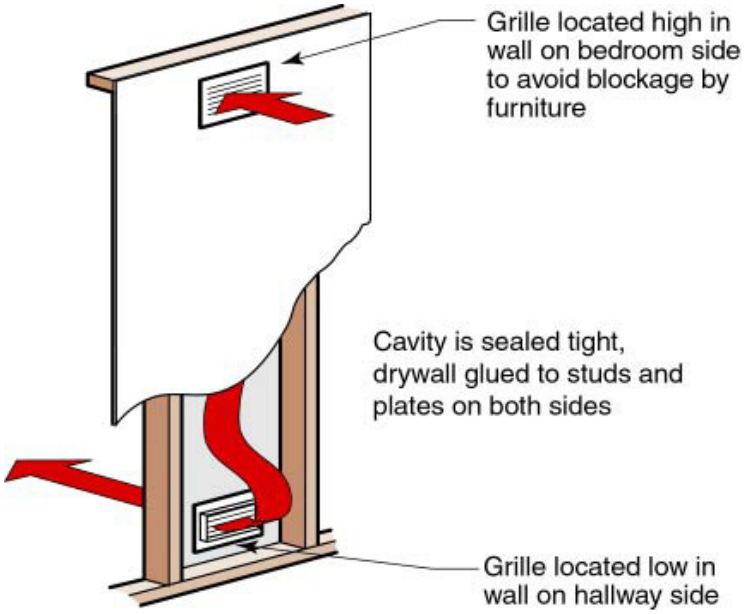
Joseph Lstiburek – HVAC 54



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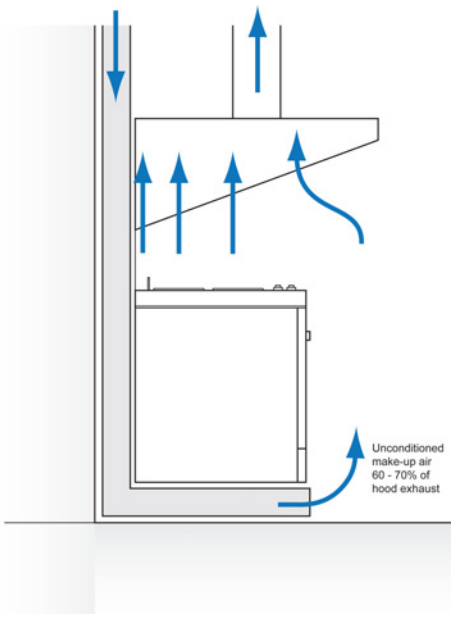
Joseph Lstiburek – HVAC 55



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Joseph Lstiburek 56

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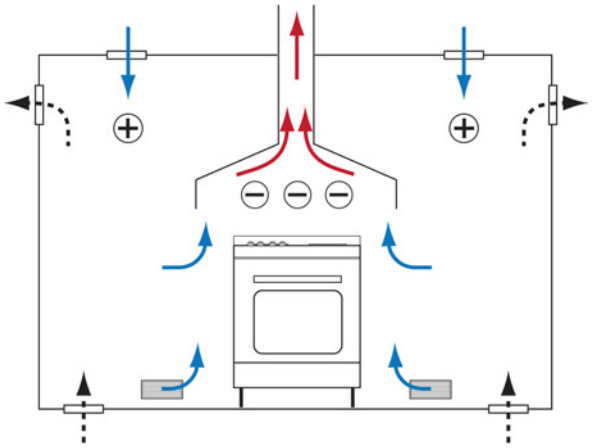
Joseph Lstiburek 57



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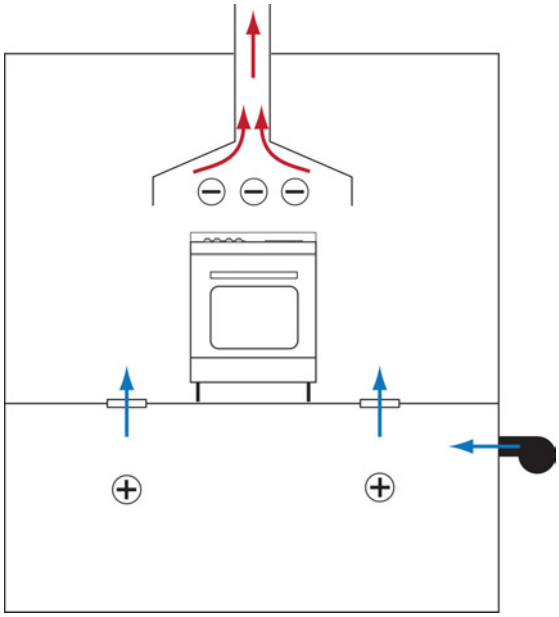

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Joseph Lstiburek 59

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Joseph Lstiburek 60

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Joseph Lstiburek 61

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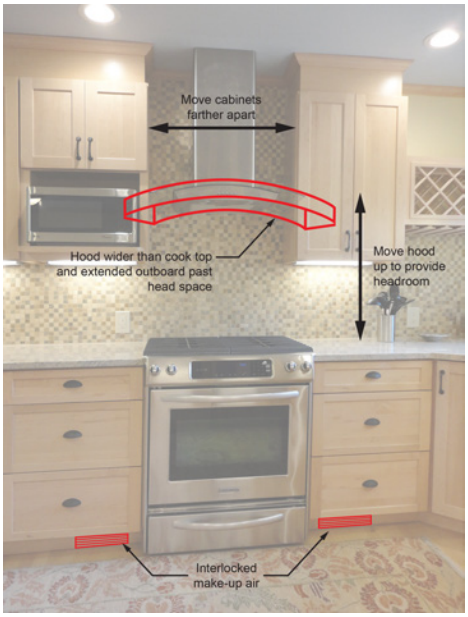
Joseph Lstiburek 62



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Joseph Lstiburek 63

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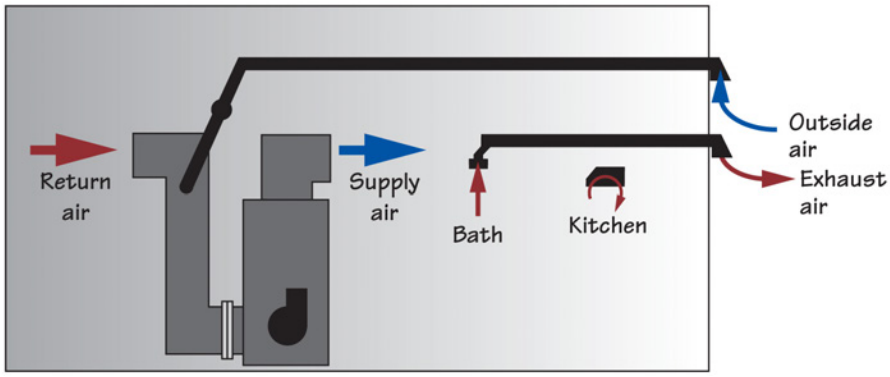
Joseph Lstiburek 64



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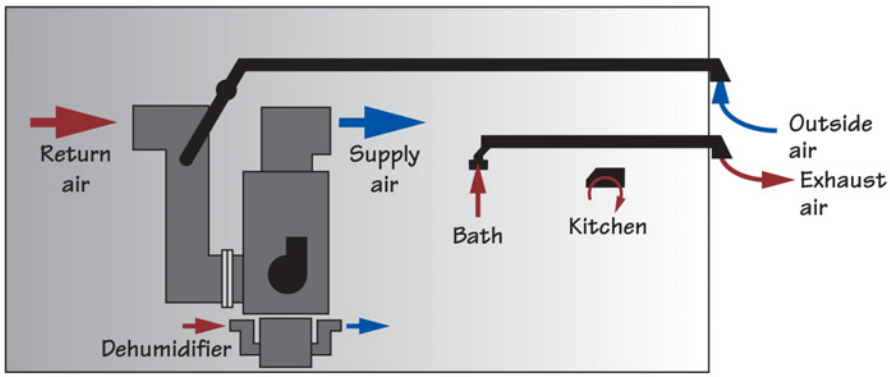

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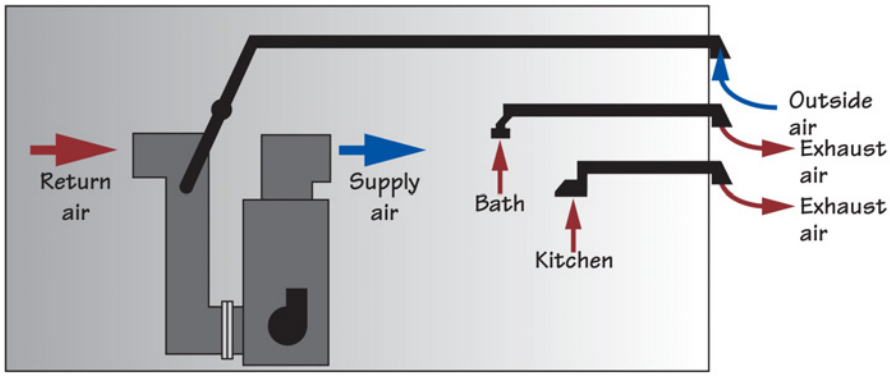

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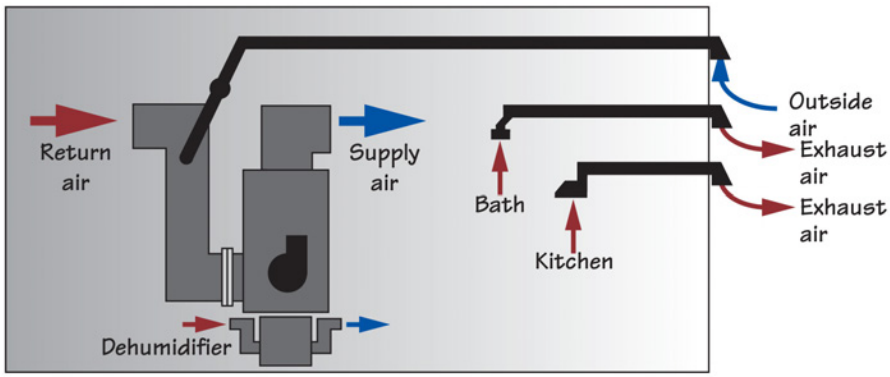

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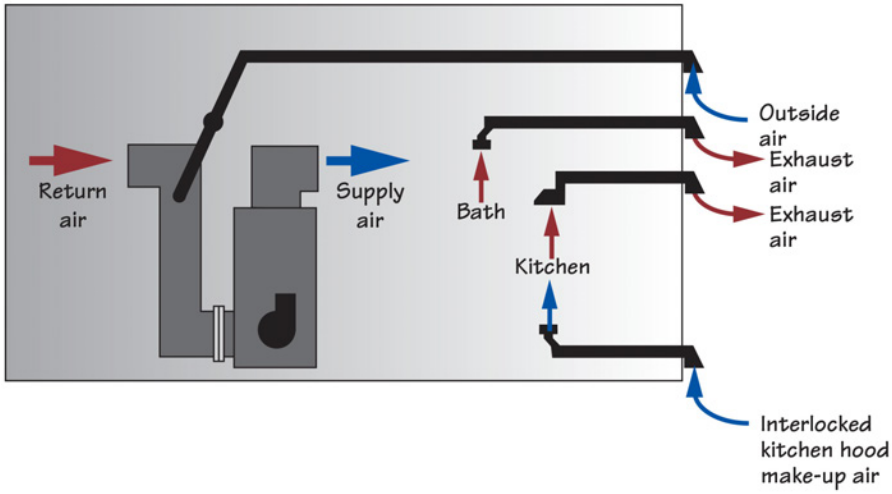

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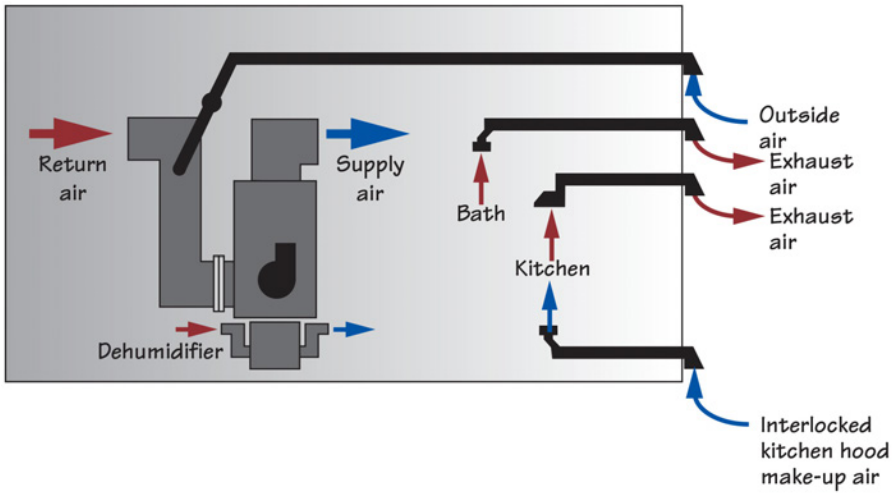

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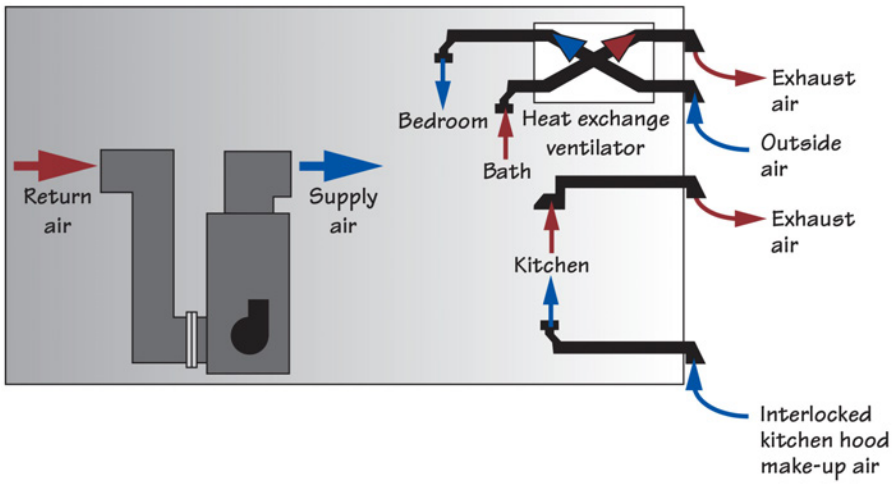

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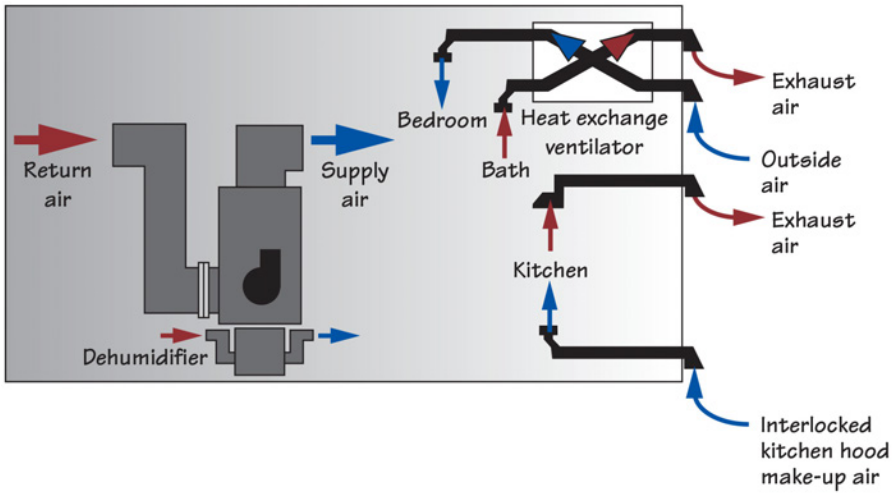
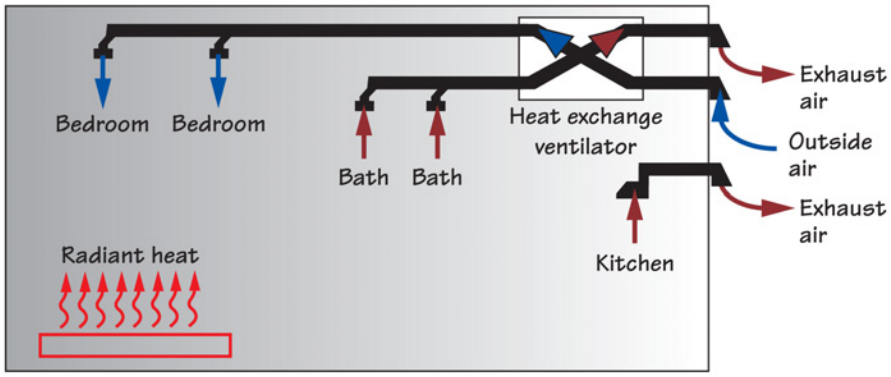


Building Science Corporation
Joseph Lstiburek 72



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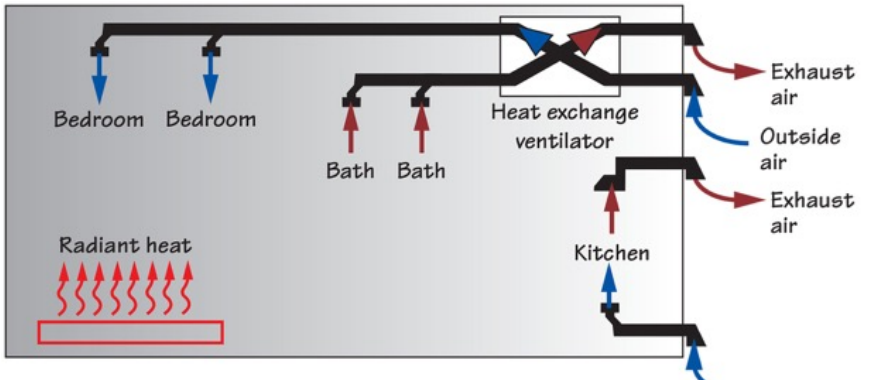
Joseph Lstiburek 73



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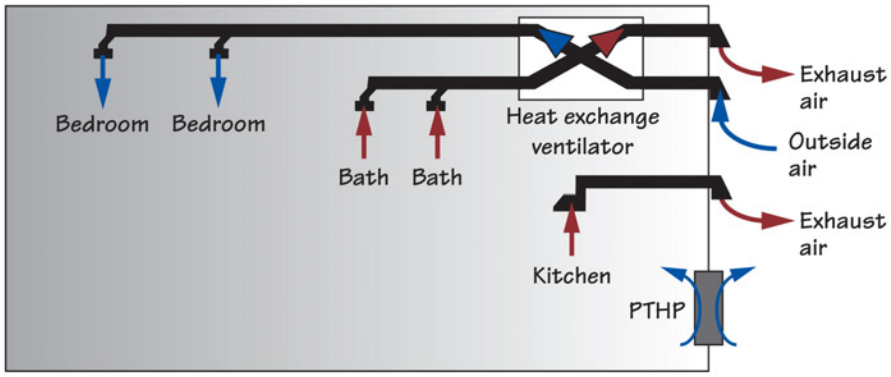
Joseph Lstiburek 74



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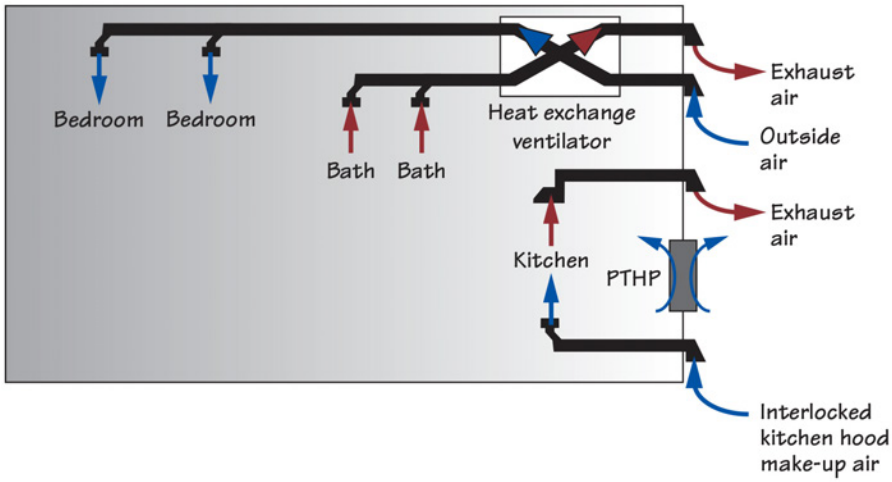

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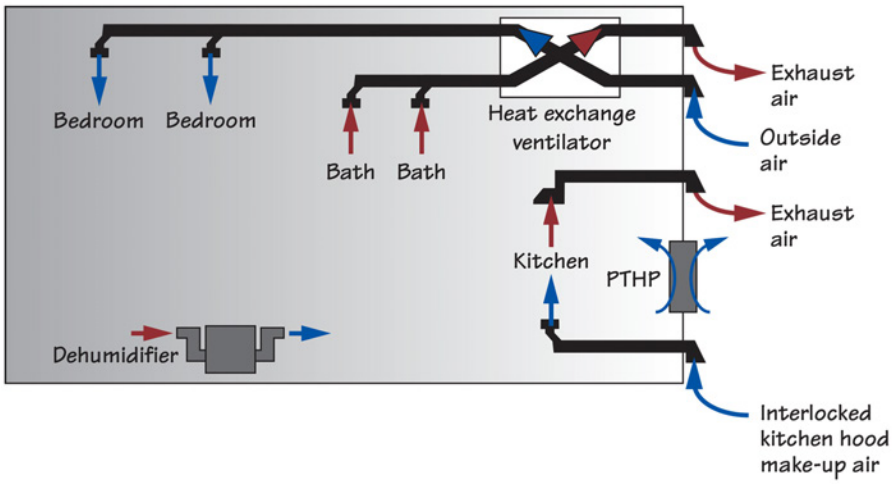

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Joseph Lstiburek 78

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Joseph Lstiburek 79

Building Science Corporation

Joseph Lstiburek 80

Building Science Corporation

Joseph Lstiburek 81

Building Science Corporation

Joseph Lstiburek 82

Building Science Corporation

Joseph Lstiburek 83

Building Science Corporation

Joseph Lstiburek 84

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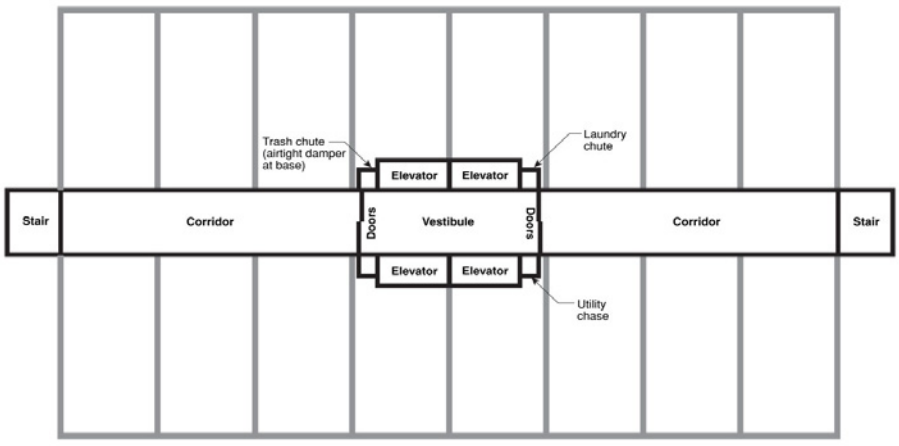
Joseph Lstiburek – HVAC 85



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Joseph Lstiburek – HVAC 86

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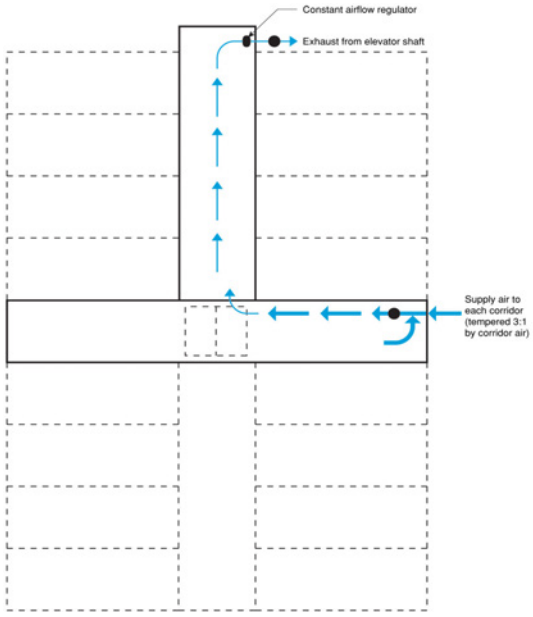
Joseph Lstiburek – HVAC 87



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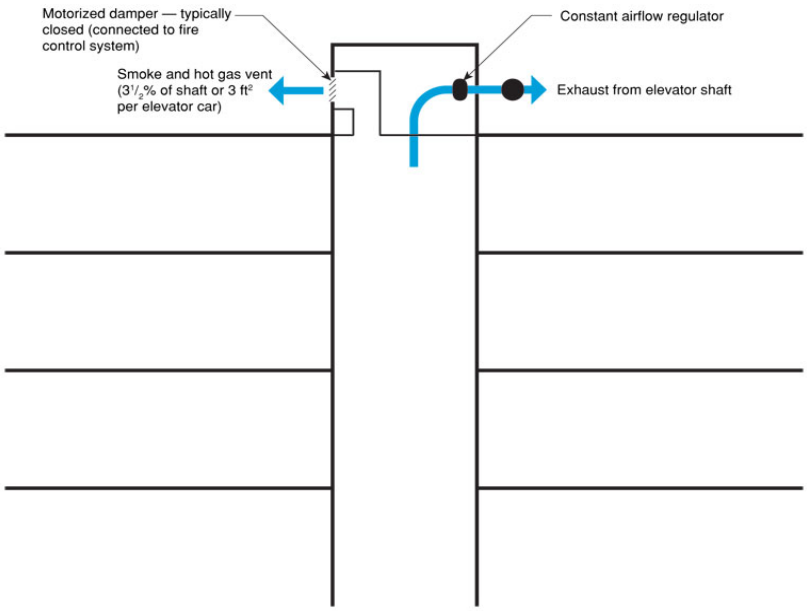
Joseph Lstiburek – HVAC 88



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Joseph Lstiburek – HVAC 89

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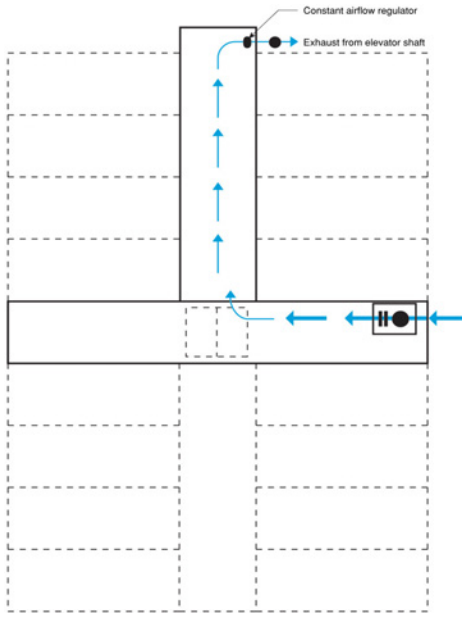
Joseph Lstiburek – HVAC 90



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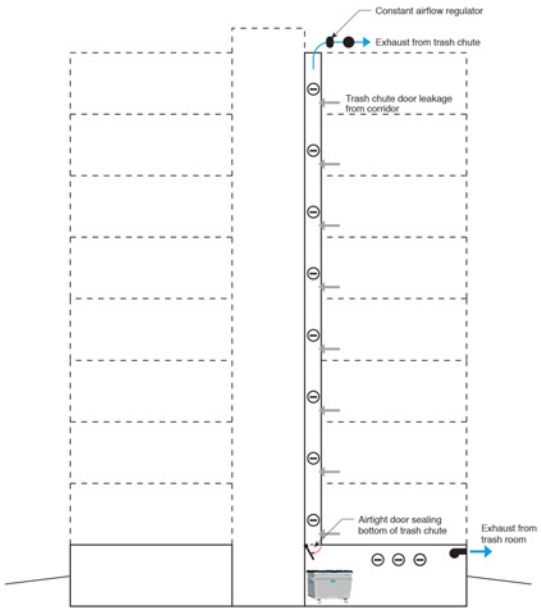

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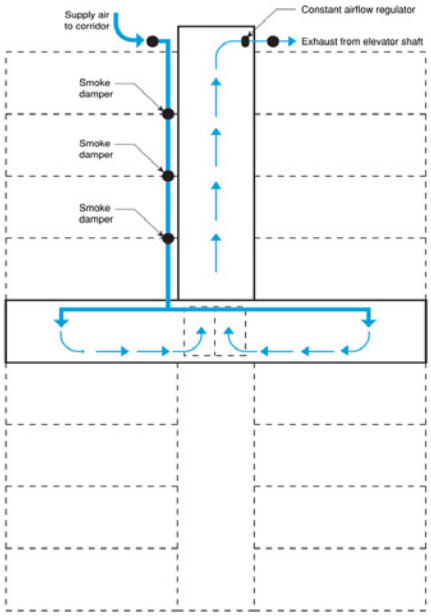
Joseph Lstiburek 93



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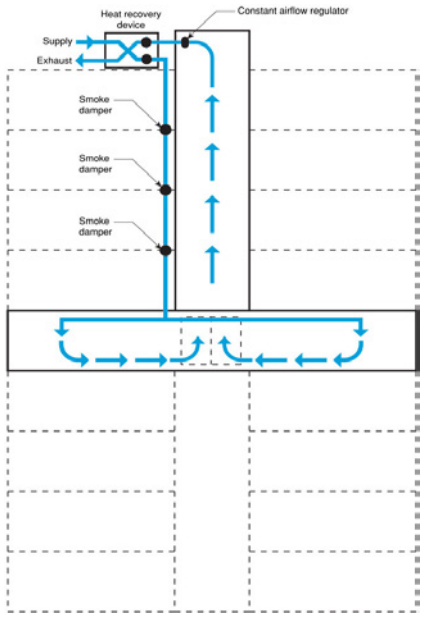

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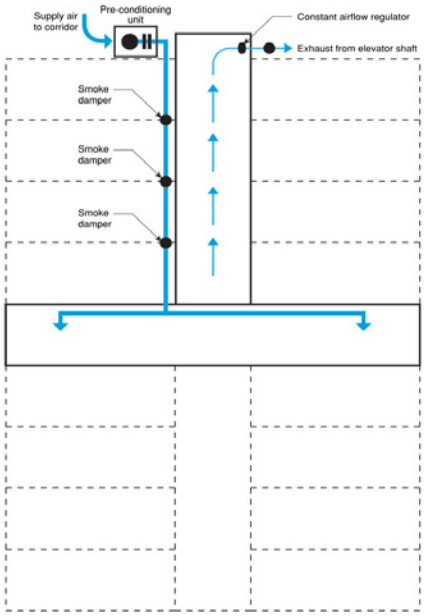

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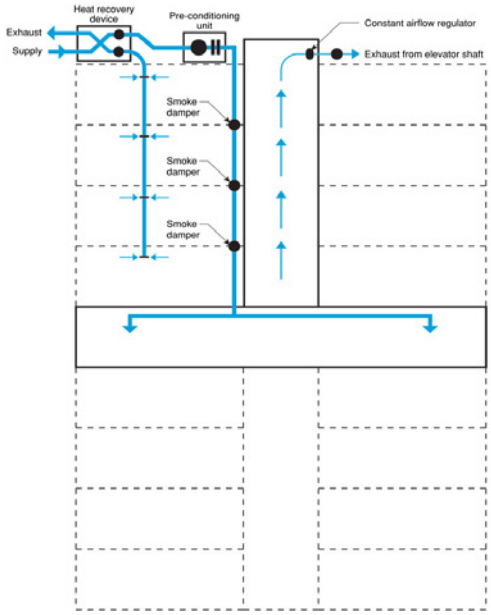

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Joseph Lstiburek – HVAC 98

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Joseph Lstiburek 99

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Joseph Lstiburek 100

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Joseph Lstiburek 101

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Joseph Lstiburek 103

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Joseph Lstiburek 105

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Joseph Lstiburek 106

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Joseph Lstiburek 107

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Joseph Lstiburek 108

Ventilation Rates Are Based on Odor Control

Ventilation Rates Are Based on Odor Control

Health Science Basis for Ventilation Rates is Extremely Limited

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

- 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

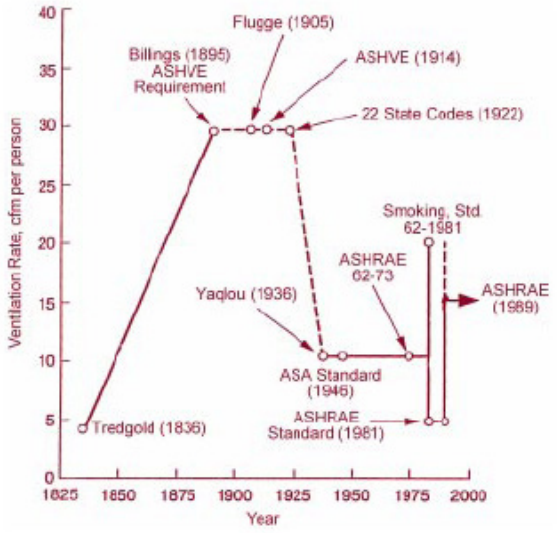

Figure 1: Minimum ventilating rate history.

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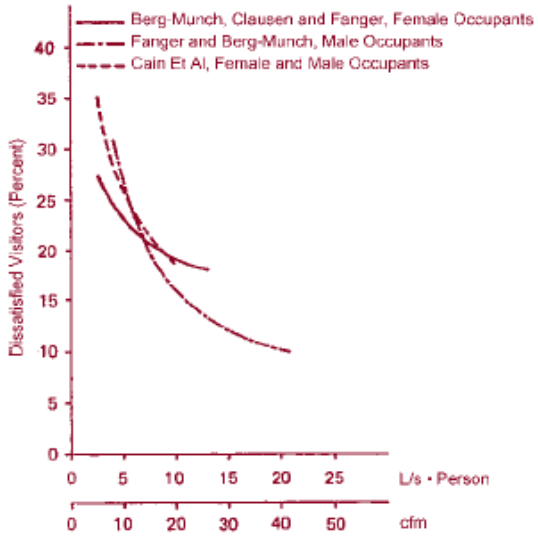

Figure 2: Odor acceptance.

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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

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

Ventilation Rates

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

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Office

Occupant Density

15/1000 ft^2 (67 ft^2/person) 15 cfm/person	62 - 89
5/1000 ft^2 (200 ft^2/person) 17 cfm/person	62.1 - 2007

Correctional Facility Cell

Occupant Density

20/1000 ft^2 (48 ft^2/person) 10 cfm/person	62.1 – 2007

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

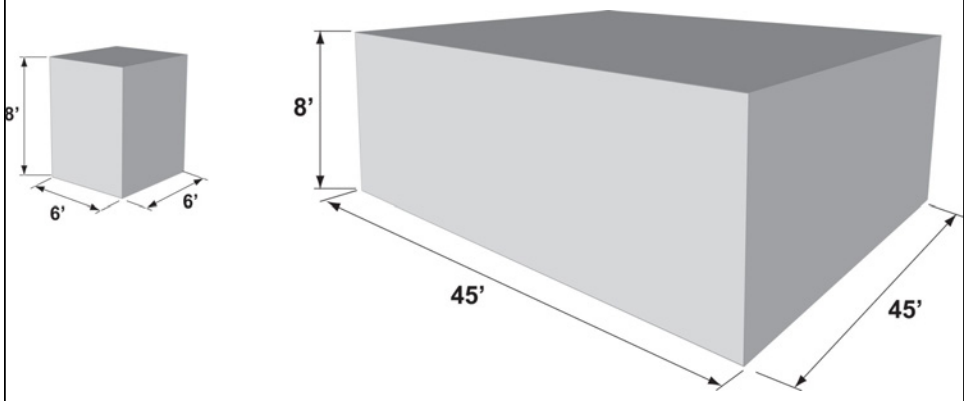
300 ft^3 → 12 cfm/person 37.5 ft^2 53 occupants

Experiment

470 ft^3 → 59 ft^2

200 ft^3 → 25 ft^2

100 ft^3 → 12 ft^2



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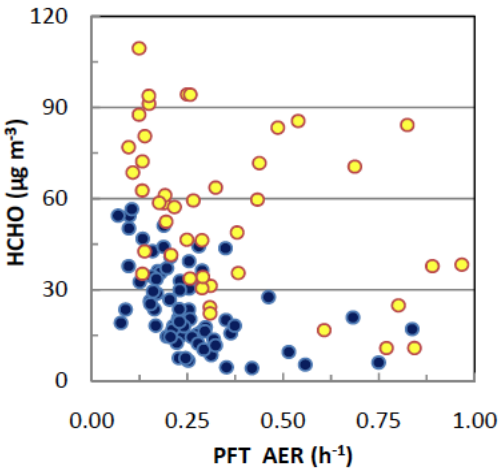

Aubin, D., Won, D.Y., Schleibinger, H., 2010

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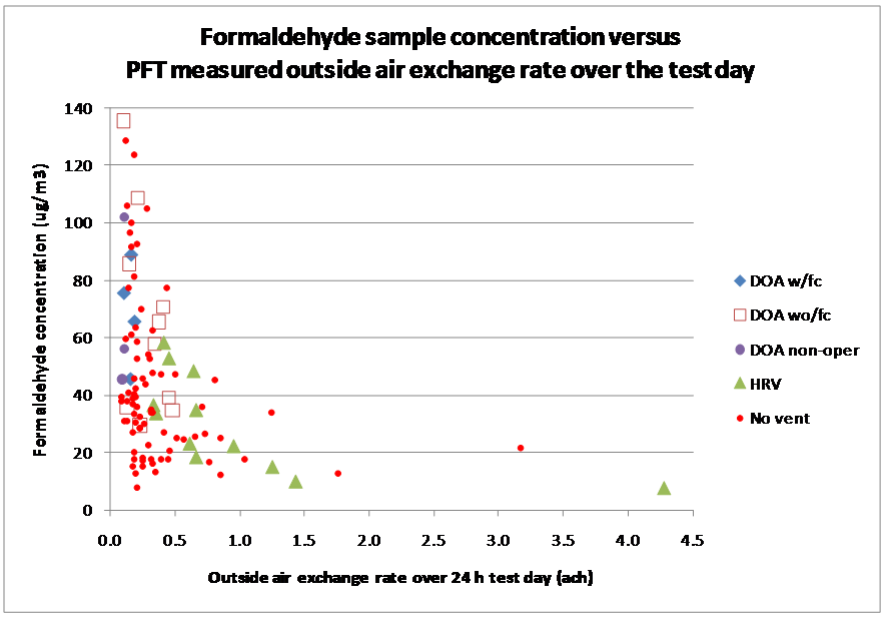

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Table 1. Summary of the air changes rates measured during the winter 2009-10 season in Quebec City

Method	ACH (h^{-1})	ACH standard deviation (h^{-1})	number of measurements
SF_6 tracer decay	0.27	0.12	77
perflurocarbon 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?

Air Barrier Metrics

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

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

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Dilution Is Not The Solution To Indoor Pollution

Source Control

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Dilution For People
Source Control For The Building

Best

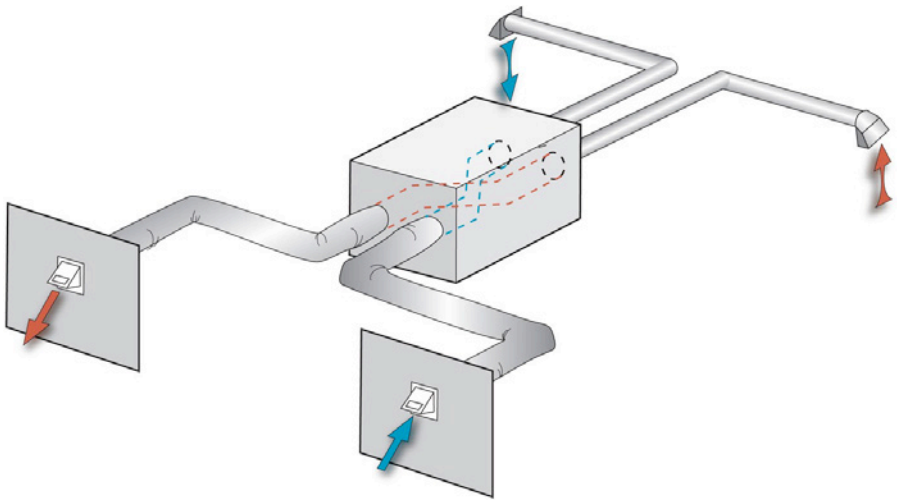
As Tight as Possible - with -
Balanced Ventilation
Energy Recovery
Distribution and Mixing
Source Control - Spot exhaust ventilation
Filtration
Material selection

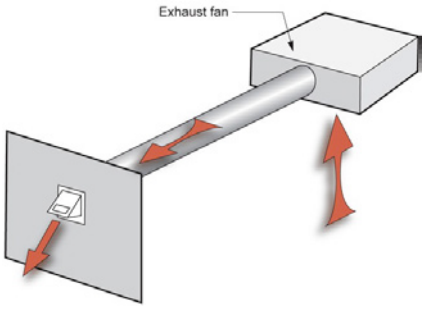
Worst

Leaky - with – Nothing

Spot Ventilation in Bathroom/Kitchen

Exhaust Ventilation – with – No Distribution and No Mixing





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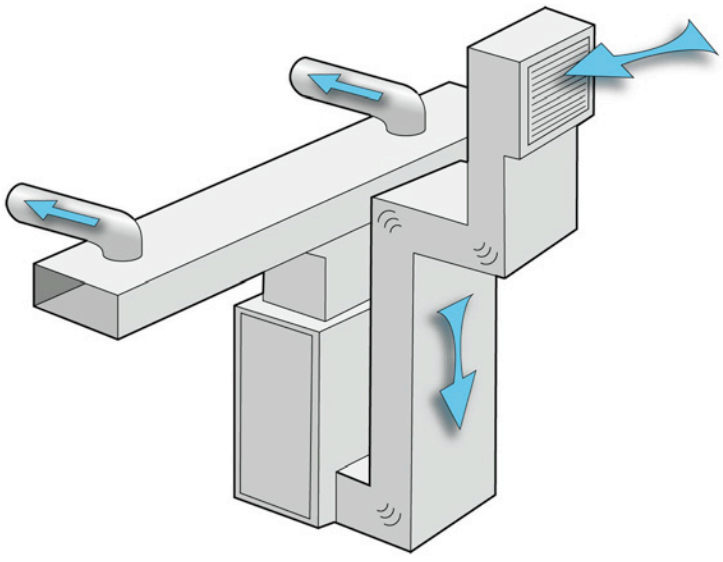

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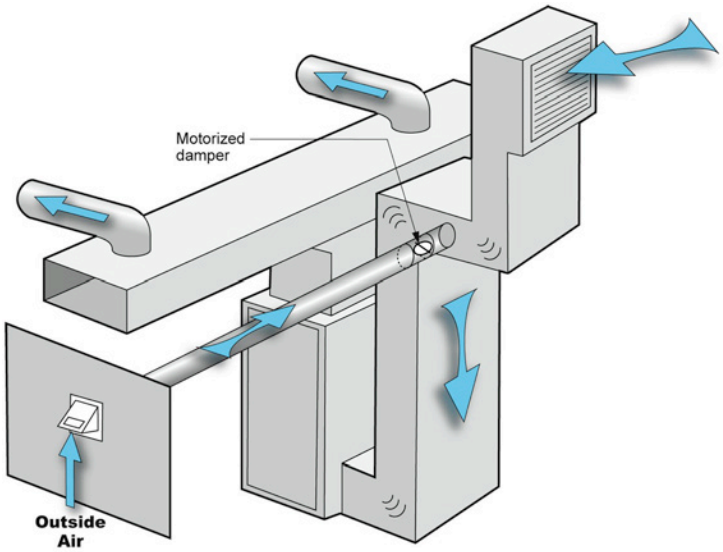

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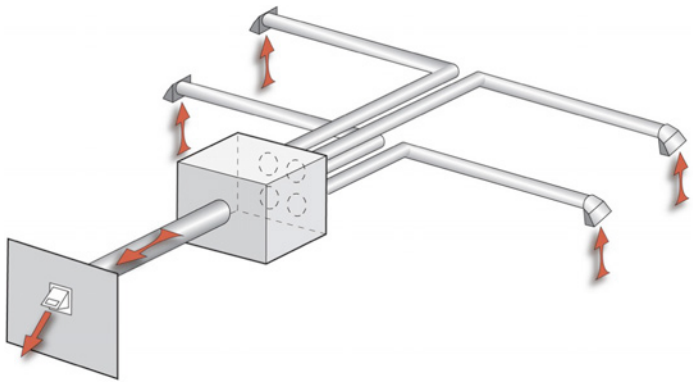
Joseph Lstiburek 135



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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

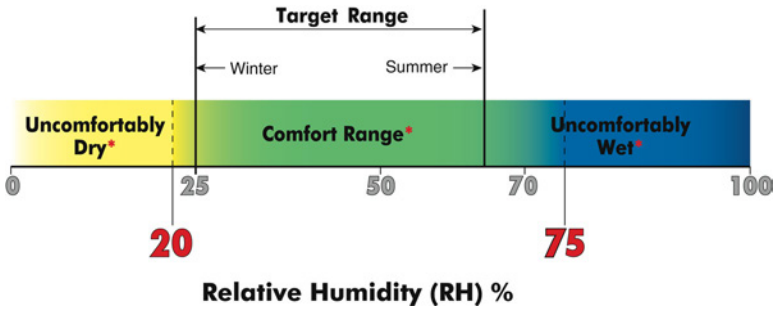
Occupancy is deemed to be the number of bedrooms plus one

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

The Cult of The Blower Door

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

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



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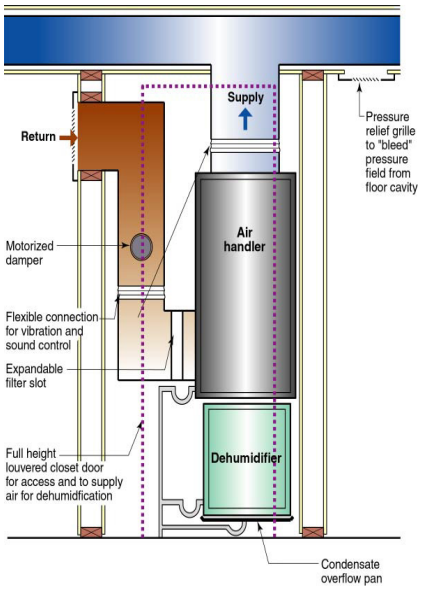
Recommended Range of Relative Humidity
Above 25 percent during winter
Below 70 percent during summer



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

Building Science

Adventures In Building Science

www.buildingscience.com

2nd Law of Thermodynamics

Heat Flow Is From Warm To Cold

Moisture Flow Is From Warm To Cold

Moisture Flow Is From More To Less

Air Flow Is From A Higher Pressure to a Lower Pressure

Gravity Acts Down

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Joseph Lstiburek 5

Water Control Layer
Air Control Layer
Vapor Control Layer
Thermal Control Layer

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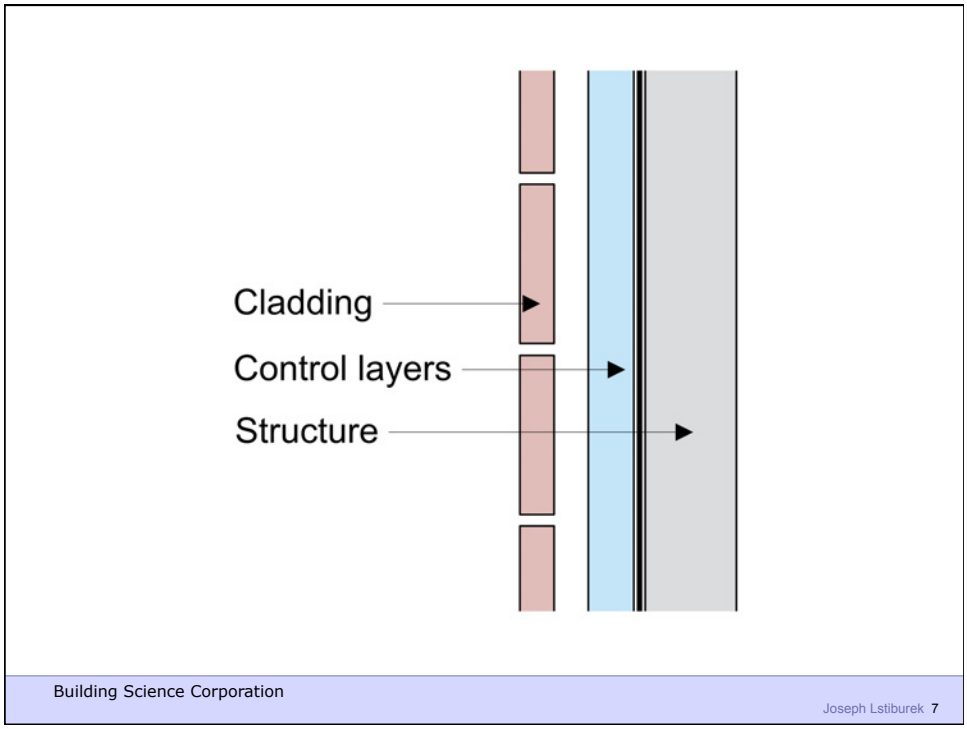
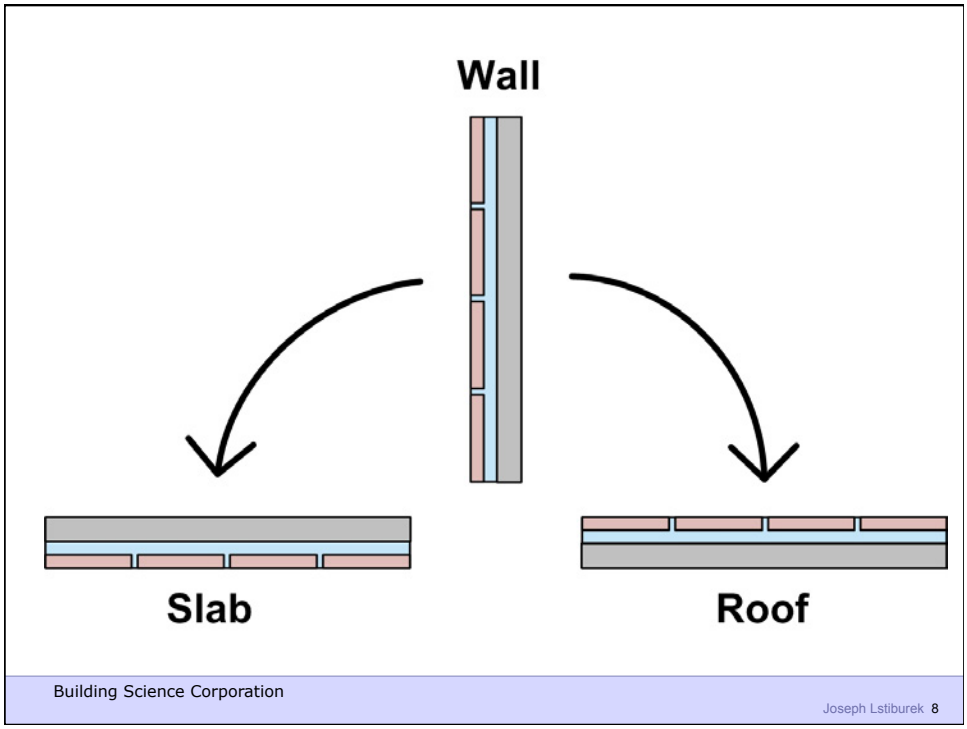
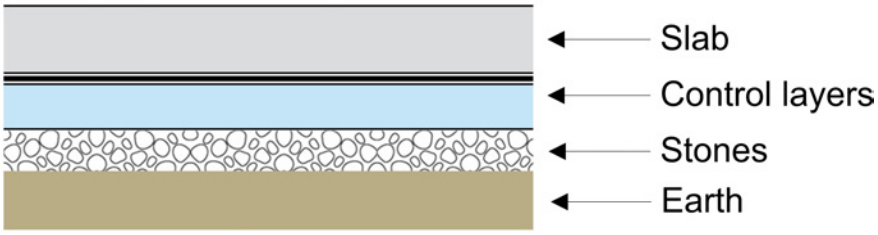
Joseph Lstiburek 6


Cladding
Control layers
Structure
Building Science Corporation
Joseph Lstiburek 7


Wall
Slab
Roof
Building Science Corporation
Joseph Lstiburek 8



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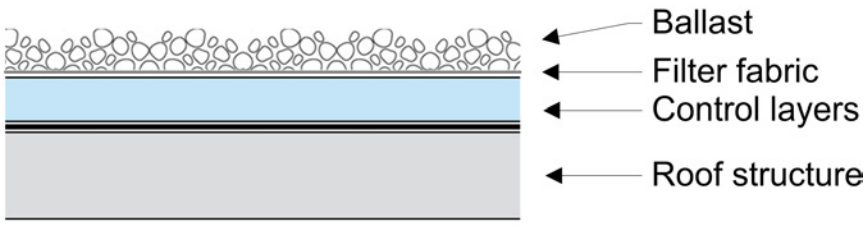
Joseph Lstiburek 9



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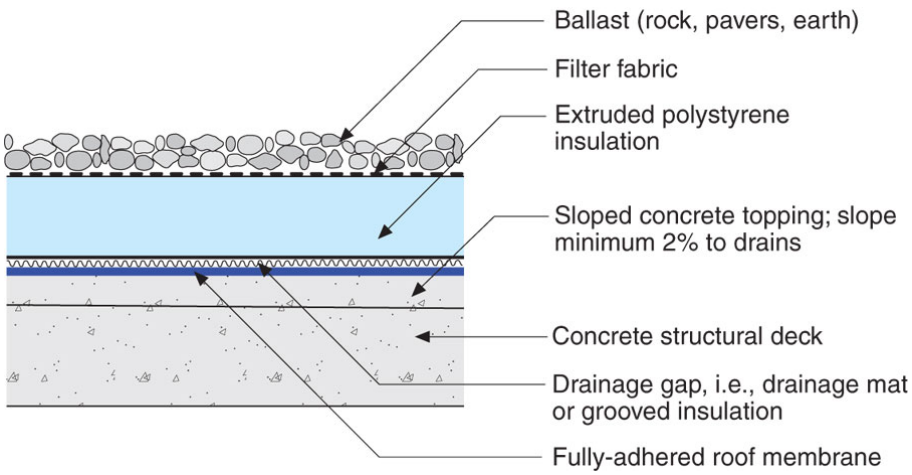
Joseph Lstiburek 10



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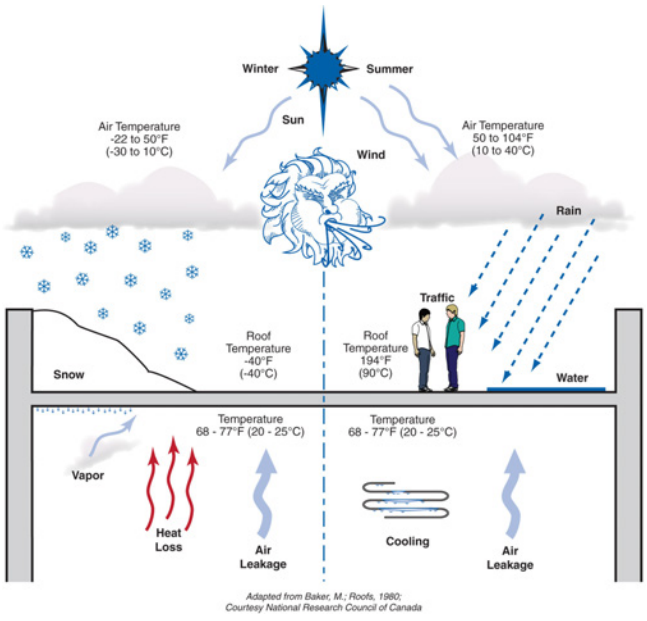
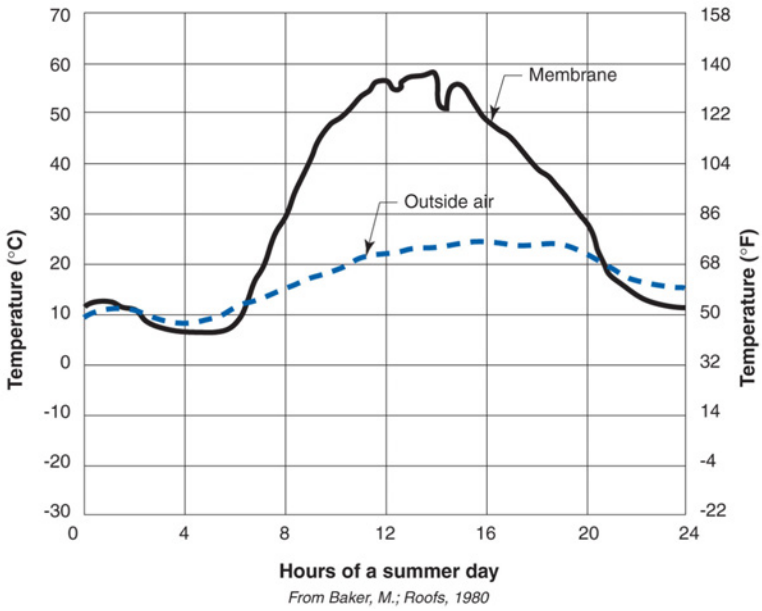
Joseph Lstiburek 11



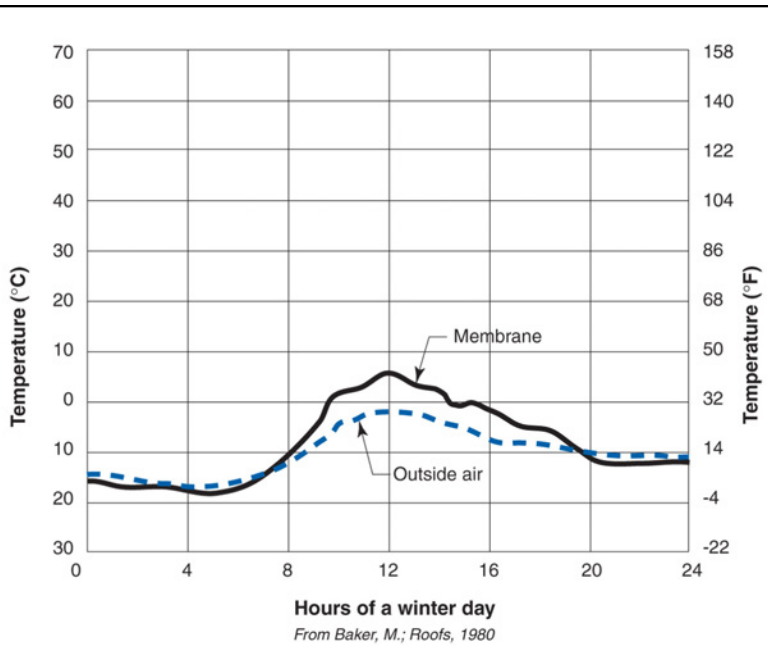
Building Science Corporation

Joseph Lstiburek 12



Building Science Corporation

Joseph Lstiburek 13



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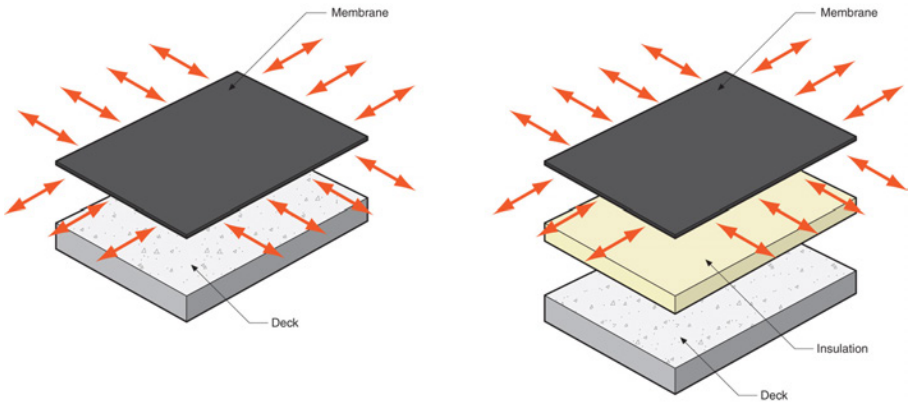
Joseph Lstiburek 14



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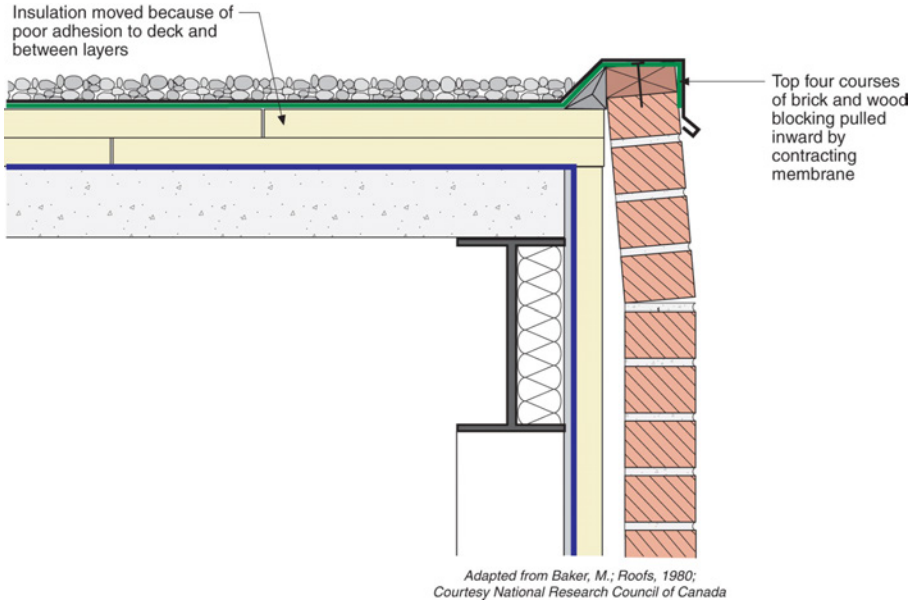
Joseph Lstiburek 15



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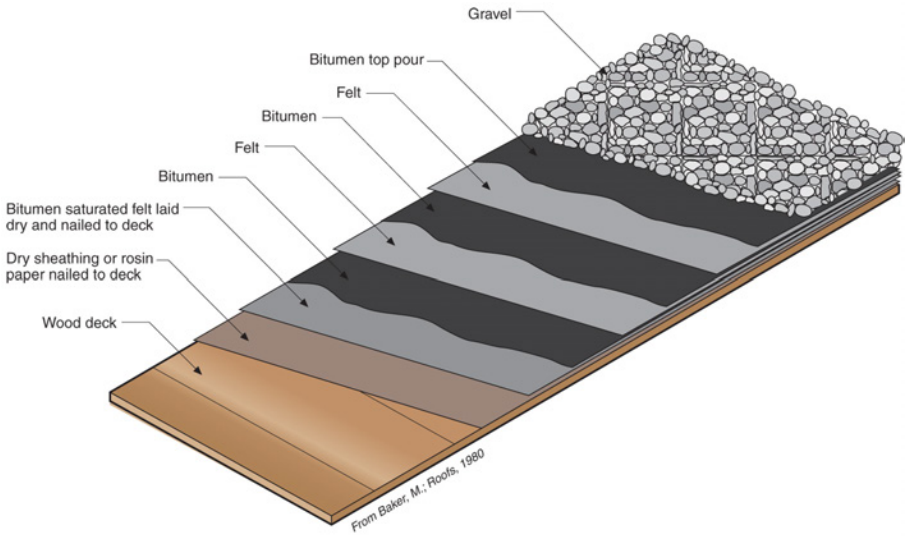
Joseph Lstiburek 16



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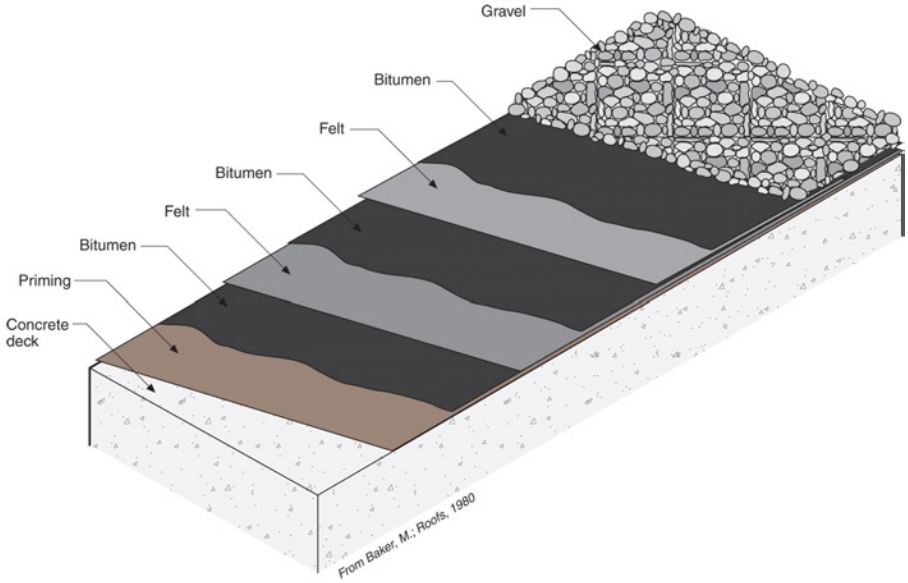
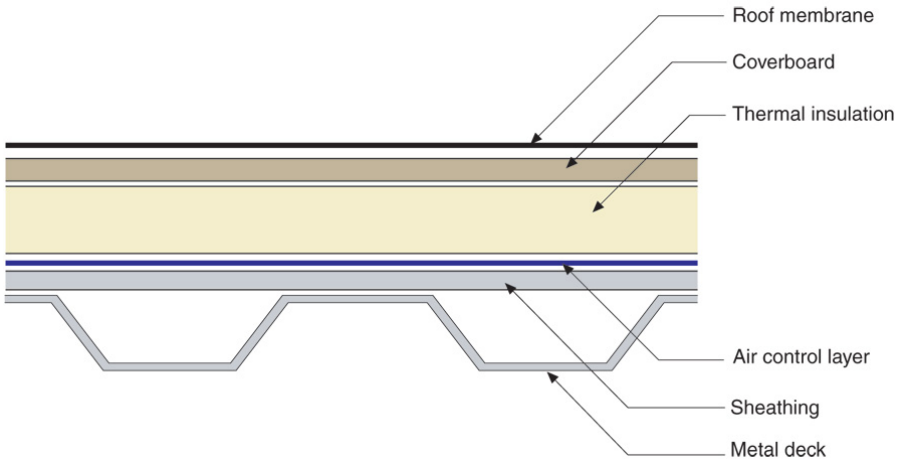
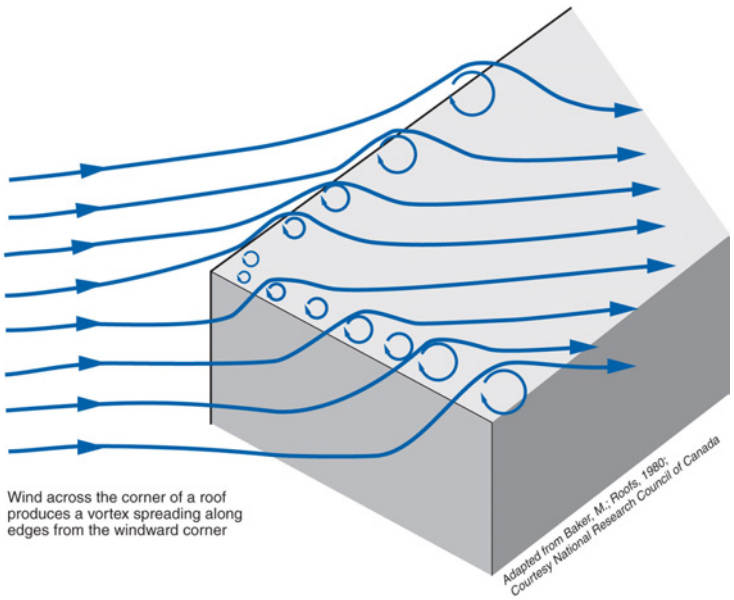
Joseph Lstiburek 17



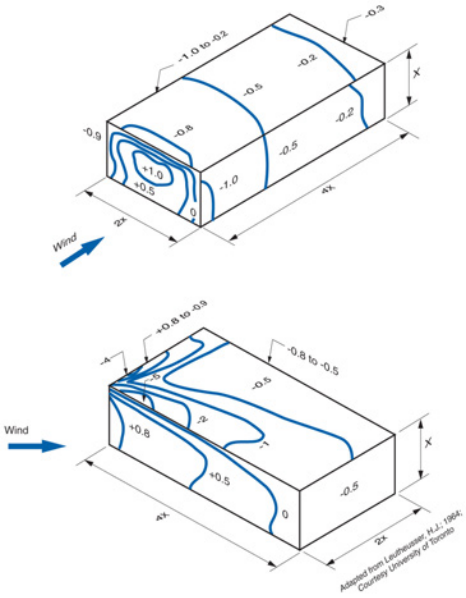
Building Science Corporation
Joseph Lstiburek 18

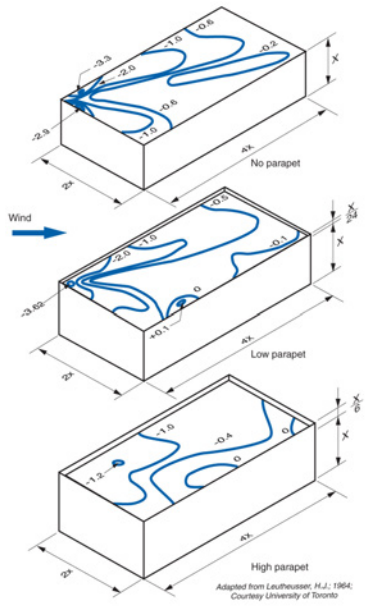


Building Science Corporation
Joseph Lstiburek 19



Building Science Corporation
Joseph Lstiburek 20


-1.0 to -0.2
-0.3
-0.2
-0.5
-0.8
-0.9
+1.0
+0.5
0
-1.0
-0.5
-0.2
X
4X
2X
Wind
+0.8 to -0.3
-0.8 to -0.5
-0.5
+0.8
+0.5
-0.5
Wind
Adapted from Leutheusser, H.J.; 1964; Courtesy University of Toronto


-3.3
-2.0
-1.0
-0.6
-0.2
-0.6
-1.5
-2.3
X
4X
2X
No parapet
Wind
-0.5
-1.0
-2.0
-0.1
-3.6
0
+0.1
X/4
X
Low parapet
-1.0
-0.4
0
-1.2
X/8
High parapet
Adapted from Leutheusser, H.J.; 1964; Courtesy University of Toronto

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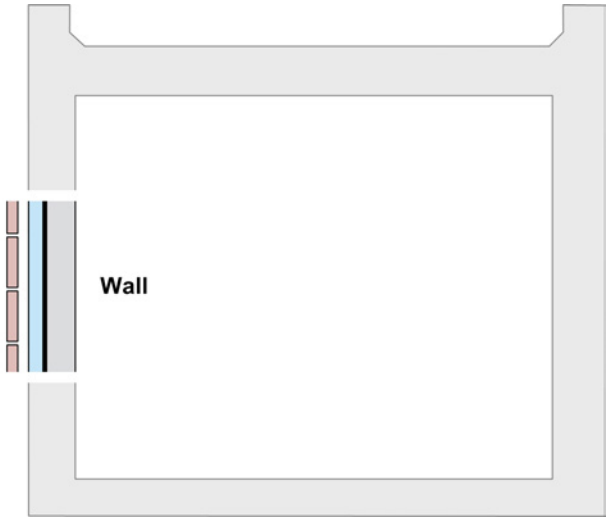
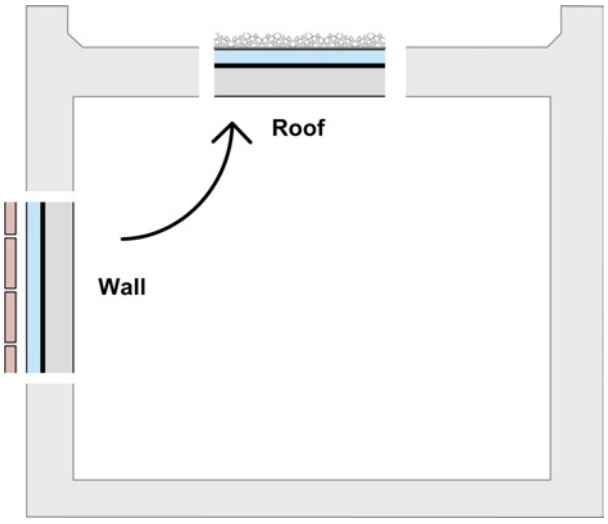
Joseph Lstiburek 23

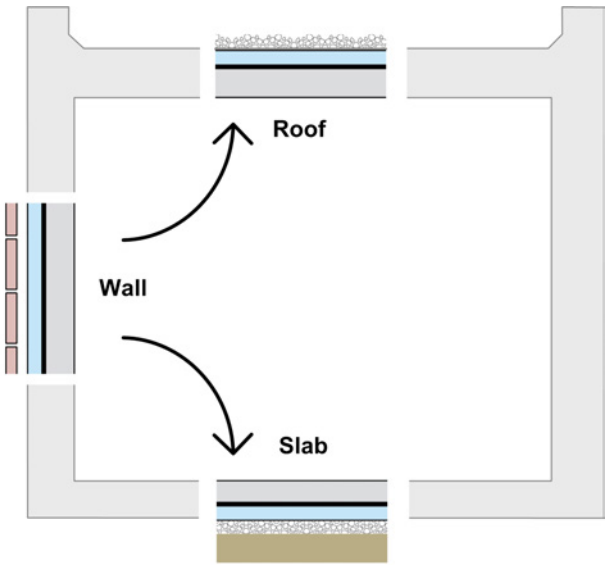


Building Science Corporation

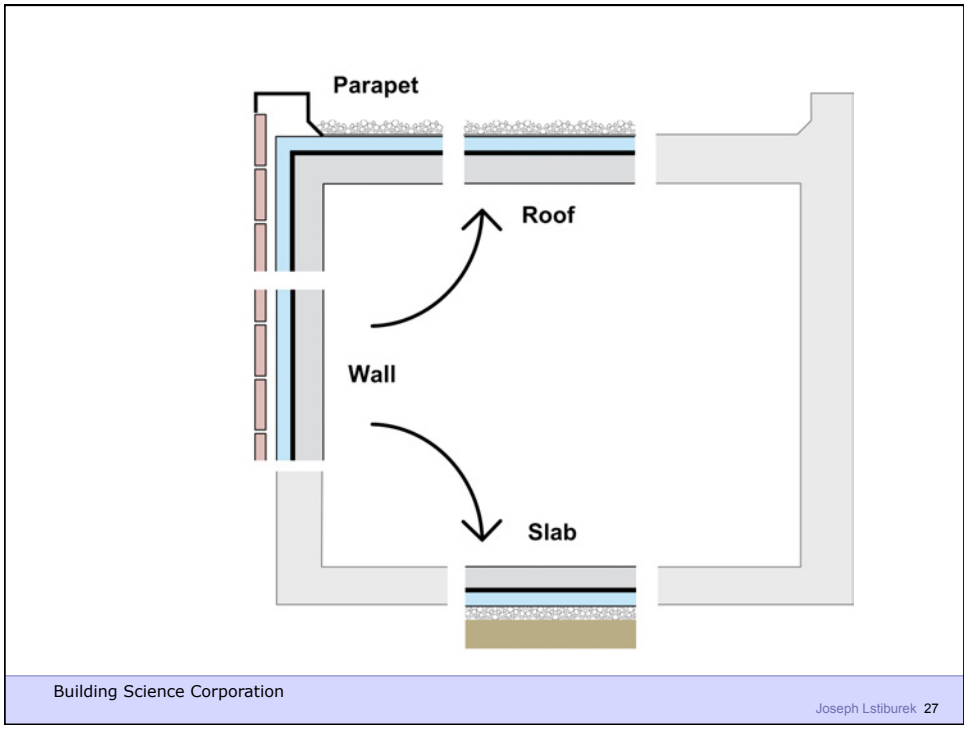
Joseph Lstiburek 24

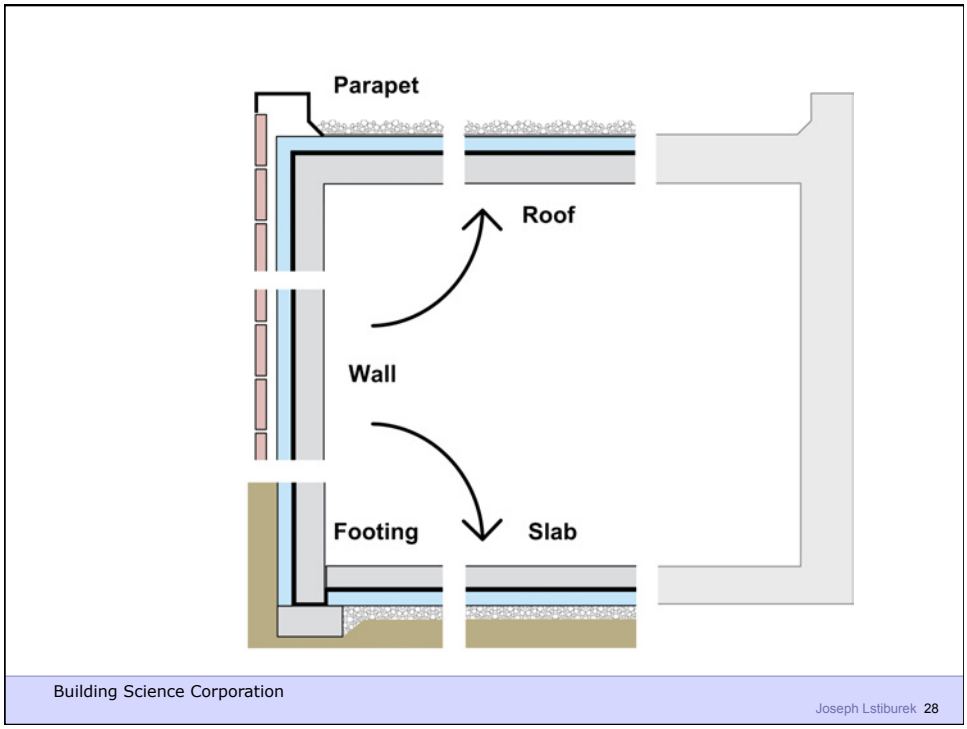


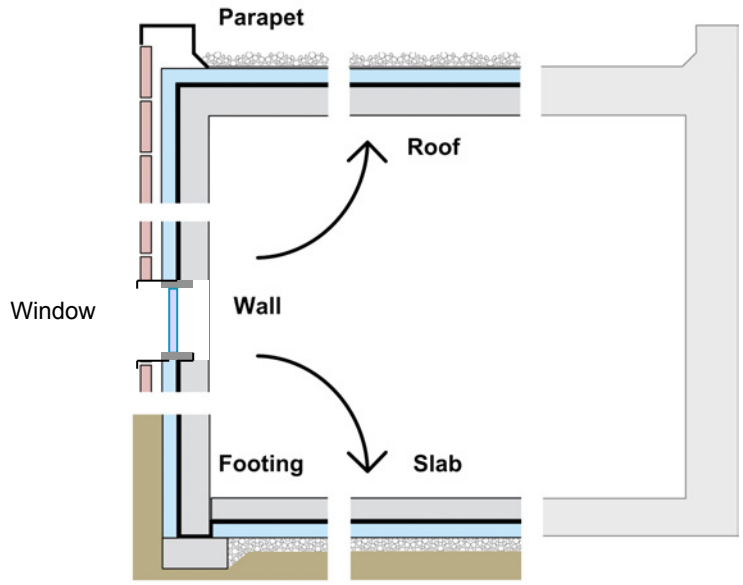
Building Science Corporation
Joseph Lstiburek 25



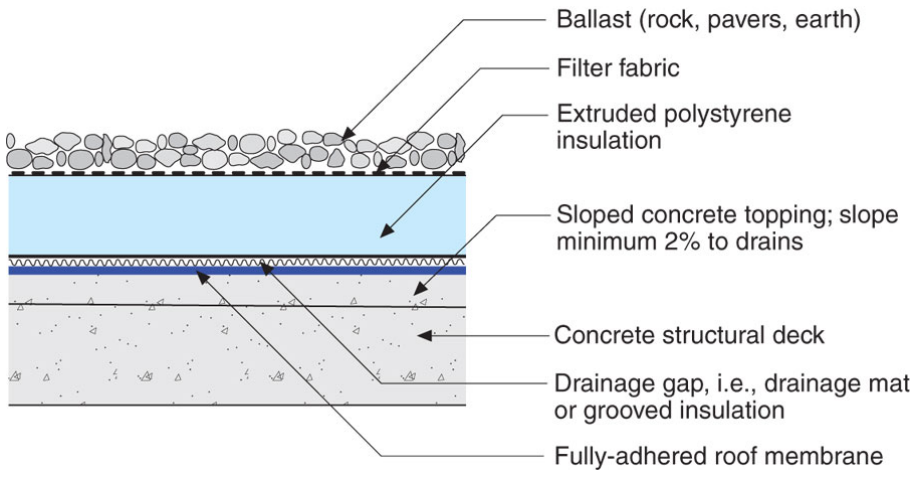
Building Science Corporation
Joseph Lstiburek 26


Parapet
Roof
Wall
Slab
Building Science Corporation
Joseph Lstiburek 27

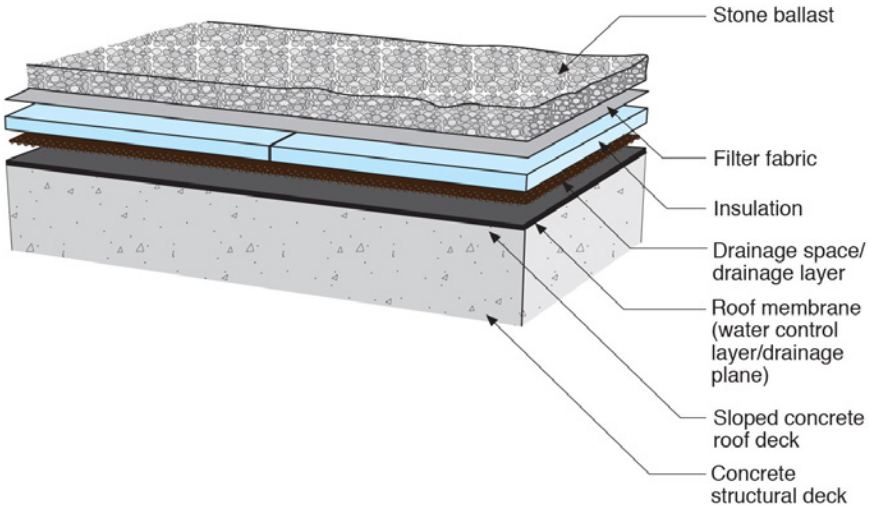

Parapet
Roof
Wall
Footing
Slab
Building Science Corporation
Joseph Lstiburek 28



Building Science Corporation
Joseph Lstiburek 29

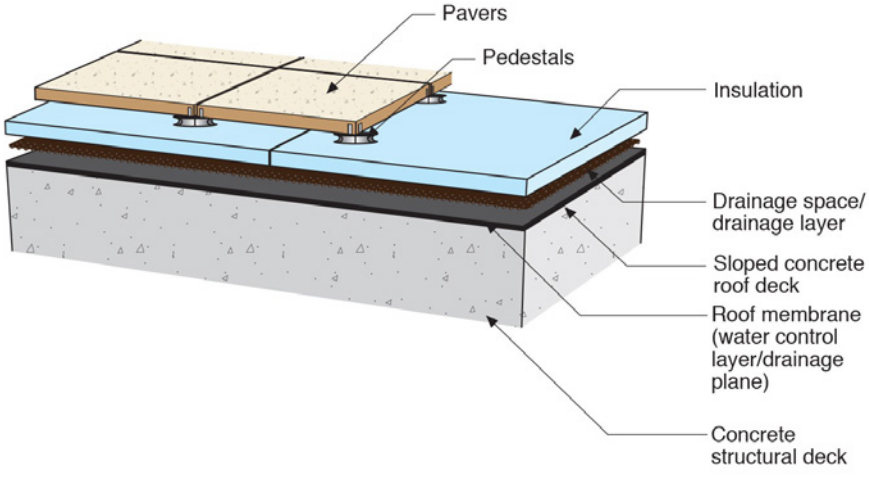


Building Science Corporation
Joseph Lstiburek 30



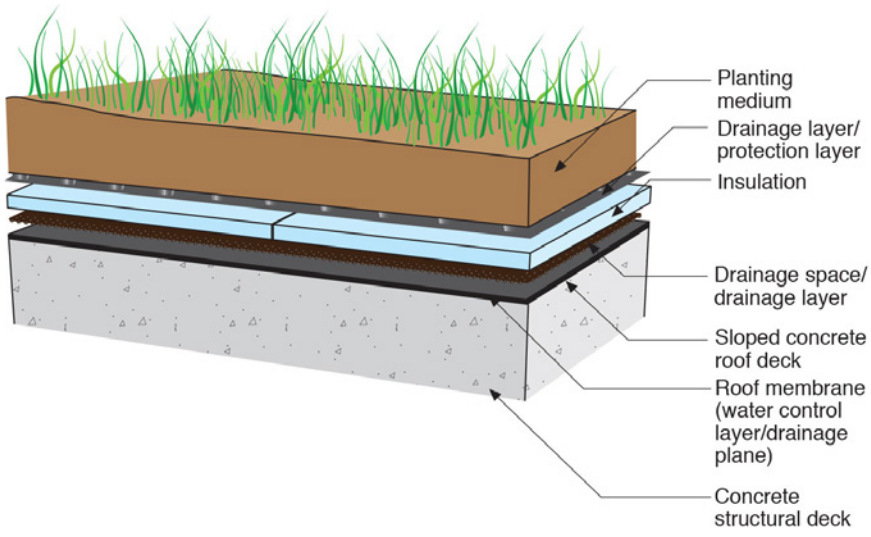
Building Science Corporation

Joseph Lstiburek 31



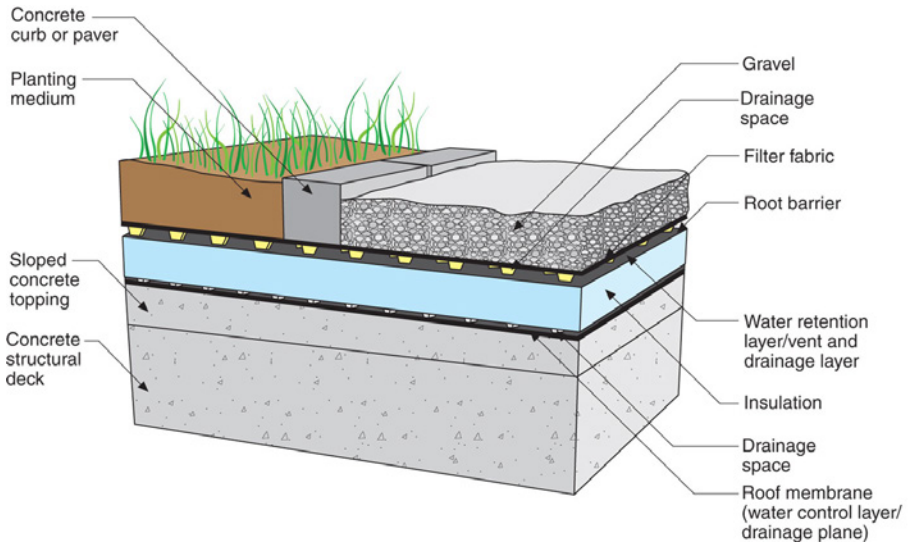
Building Science Corporation

Joseph Lstiburek 32



Building Science Corporation

Joseph Lstiburek 33



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Joseph Lstiburek 34

Building Science Corporation

Joseph Lstiburek 35

Building Science Corporation

Joseph Lstiburek 36

Building Science Corporation

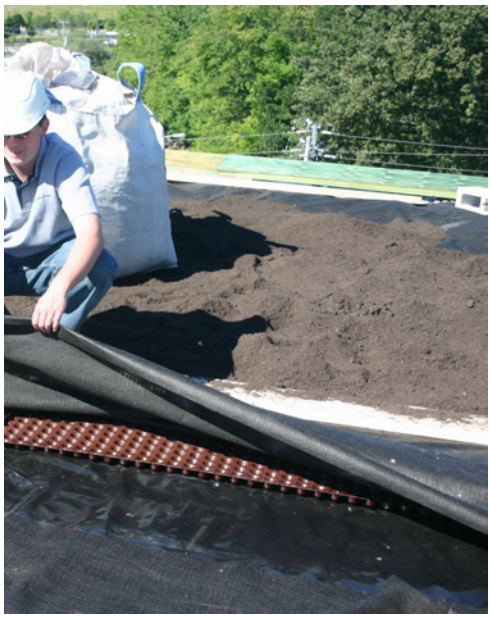
Joseph Lstiburek 37

Building Science Corporation

Joseph Lstiburek 38

Building Science Corporation

Joseph Lstiburek 39



Building Science Corporation

Joseph Lstiburek 40

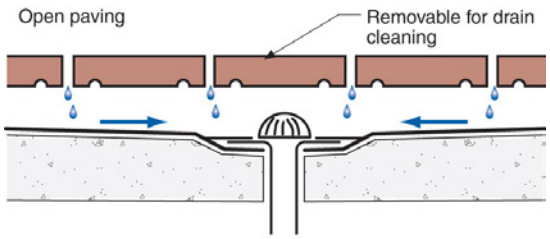
Plaza Decks

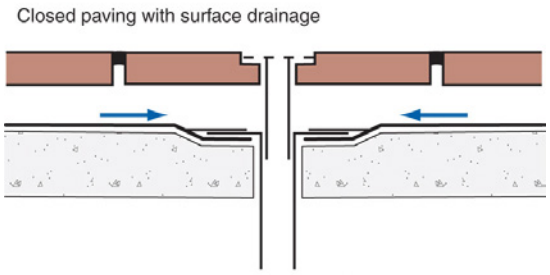
Building Science Corporation

Joseph Lstiburek 41

Building Science Corporation

Joseph Lstiburek 42

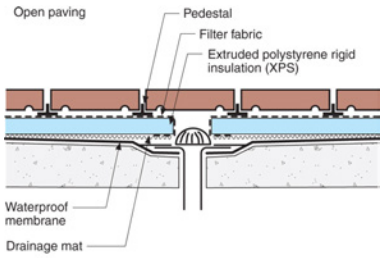


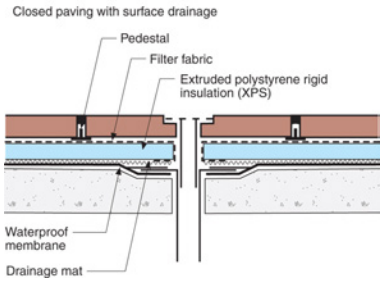


From Baker, M.; Roofs, 1980
Courtesy National Research Council of Canada

Building Science Corporation

Joseph Lstiburek 43





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Joseph Lstiburek 44

Building Science Corporation

Joseph Lstiburek 45

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Joseph Lstiburek 46

Plaza Decks
Gravity
Drainage Space
Capillary Break
Protection
Isolation

Building Science Corporation
Joseph Lstiburek 47

Plaza Decks
Gravity
Drainage Space
Capillary Break
Protection
Isolation
…oh and you better get it right…..

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Joseph Lstiburek 48

Plaza Decks Are Really Protected Membrane Roofs

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Joseph Lstiburek 49

Plaza Decks Are Really Protected Membrane Roofs

Not Easily Serviceable

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Joseph Lstiburek 50

- Plaza Decks Are Really Protected Membrane Roofs
- Not Easily Serviceable
- Should Be Isolated And Protected From All Other Building and Waterproofing Components

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Joseph Lstiburek 51

- Plaza Deck Systems
- Hot Fluid Applied Membranes
- Cold Fluid Applied Membranes

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Joseph Lstiburek 52

Building Science Corporation

Joseph Lstiburek 53

Building Science Corporation

Joseph Lstiburek 54

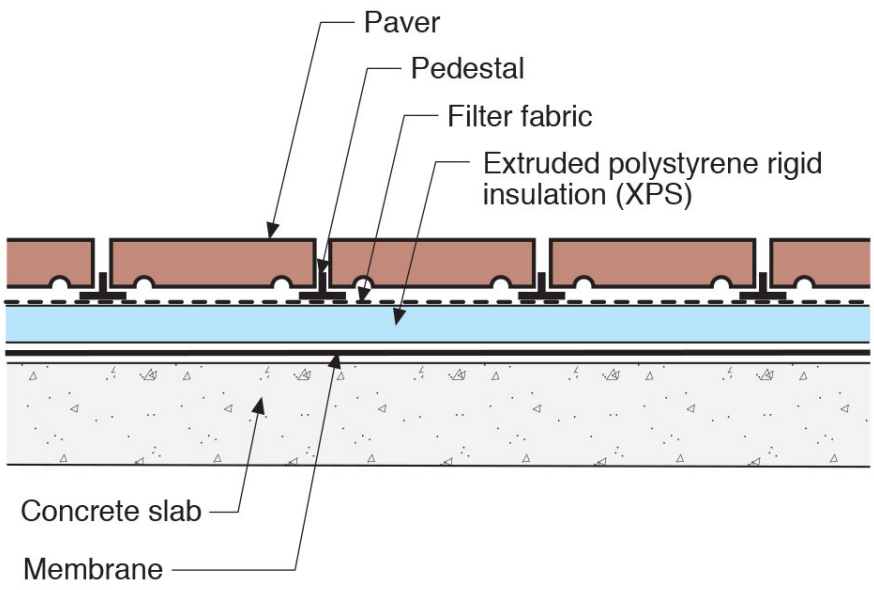
Building Science Corporation

Joseph Lstiburek 55

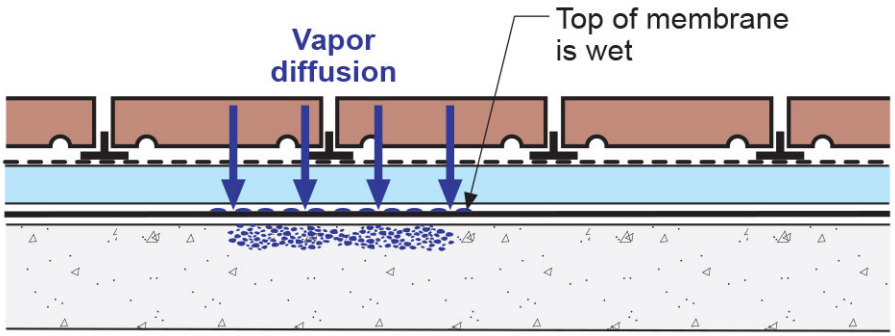
Osmosis

Building Science Corporation

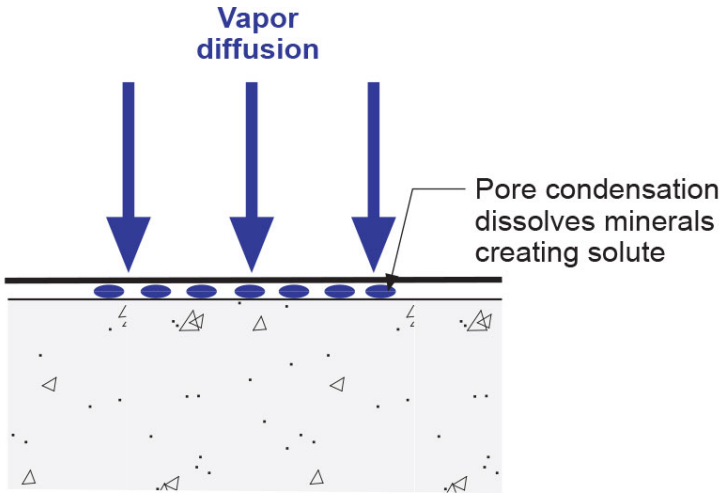
Joseph Lstiburek 56



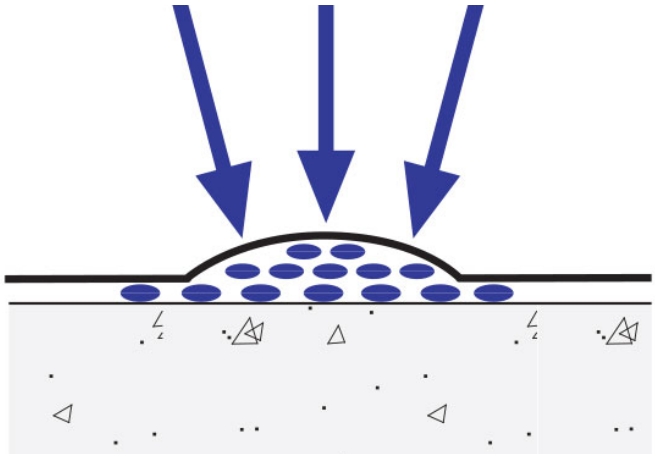
Building Science Corporation
Joseph Lstiburek 57



Building Science Corporation
Joseph Lstiburek 58



Building Science Corporation
Joseph Lstiburek 59



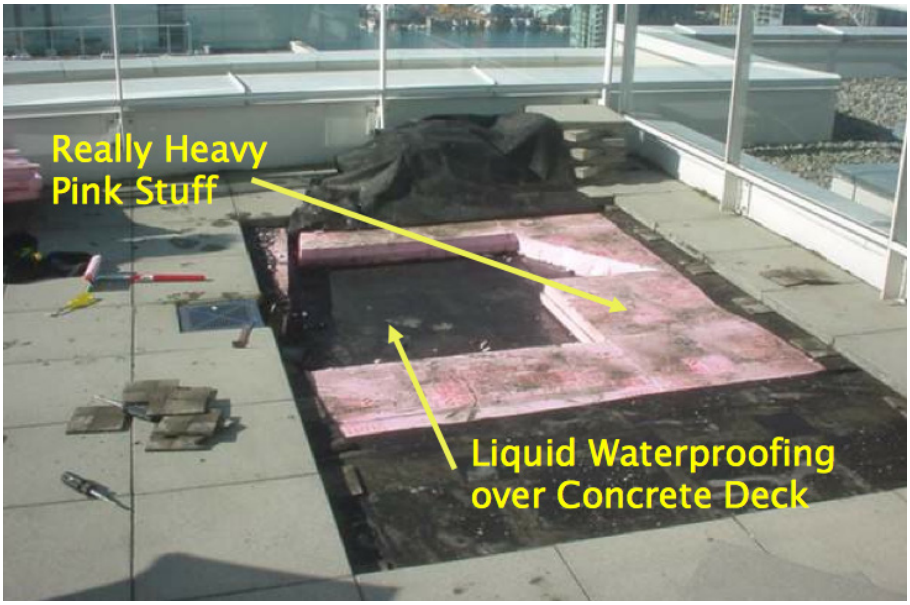
Building Science Corporation
Joseph Lstiburek 60

Building Science Corporation

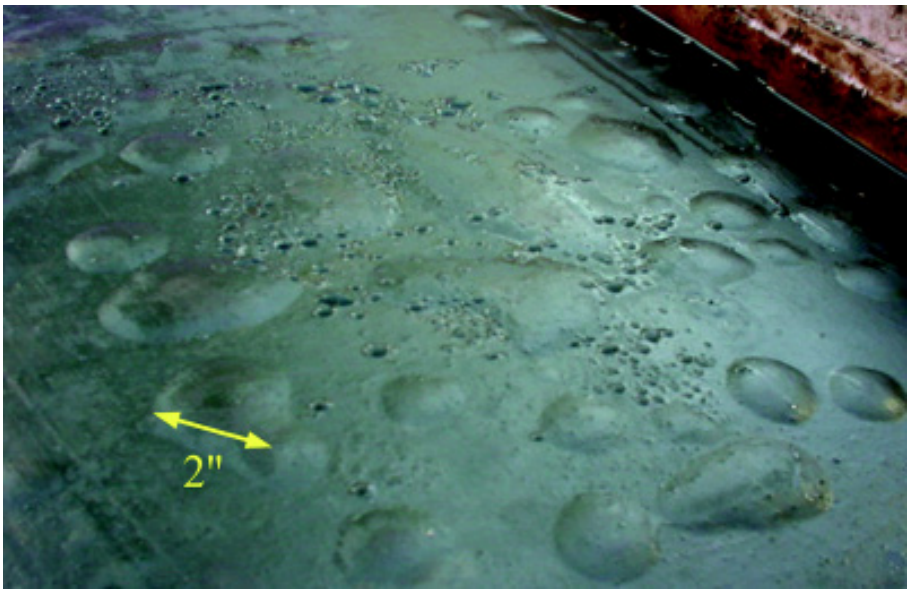
Joseph Lstiburek 61

Building Science Corporation

Joseph Lstiburek 62



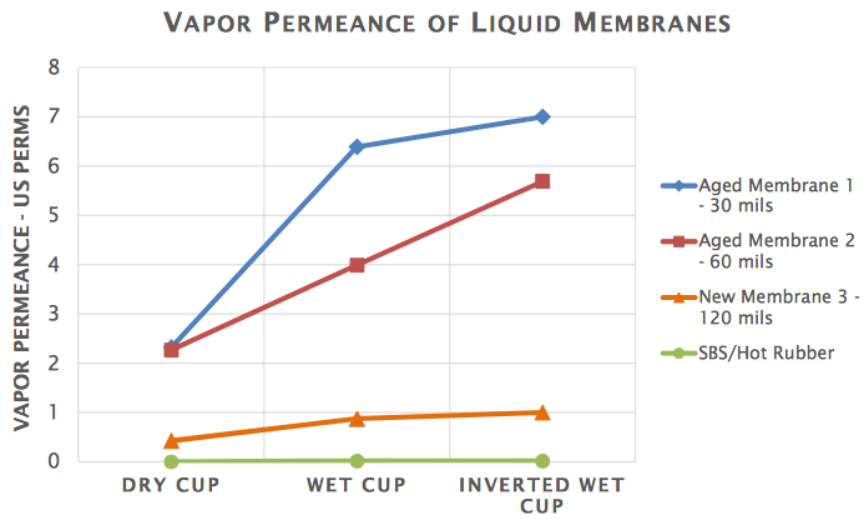
Building Science Corporation
Joseph Lstiburek 63



Building Science Corporation
Joseph Lstiburek 64

Building Science Corporation

Joseph Lstiburek 65



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Joseph Lstiburek 66

What Is Important For Long Term Performance?

Building Science Corporation

Joseph Lstiburek 67

What Is Important For Long Term Performance?

Provide a Protection Layer and Drainage Mat

Building Science Corporation

Joseph Lstiburek 68

What Is Important For Long Term Performance?

Provide a Protection Layer and Drainage Mat

Isolate the System From Other Building Elements Such as Planters, Pools and Landscaping

Building Science Corporation

Joseph Lstiburek 69

What Is Important For Long Term Performance?

Provide a Protection Layer and Drainage Mat

Isolate the System From Other Building Elements Such as Planters, Pools and Landscaping

Provide Curbs at Penetrations

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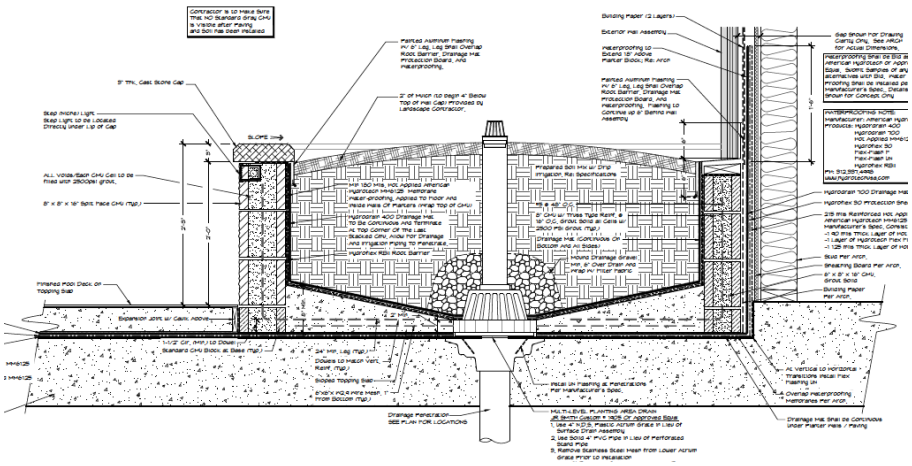
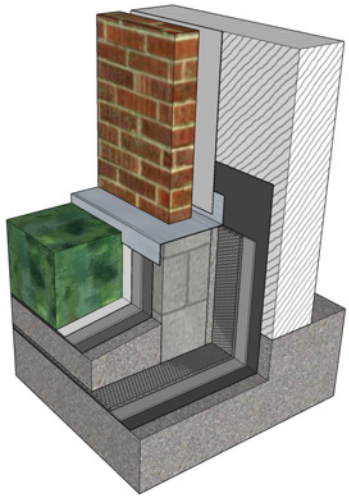
Joseph Lstiburek 70



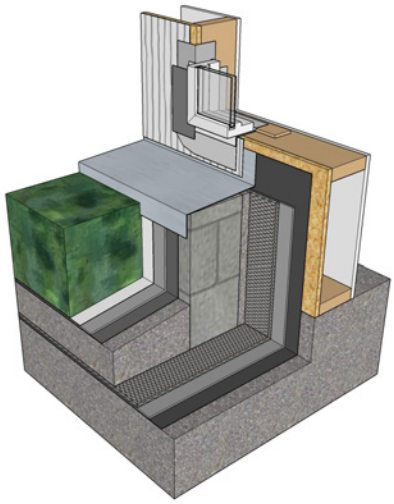
Building Science Corporation

Joseph Lstiburek 71



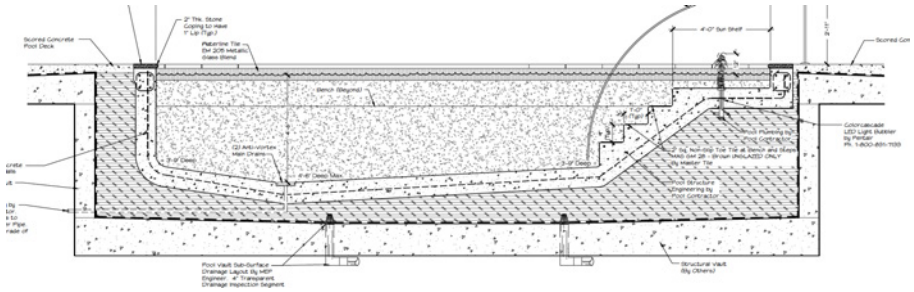
Building Science Corporation

Joseph Lstiburek 72



Building Science Corporation

Joseph Lstiburek 73



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Joseph Lstiburek 74

Plaza Decks
Mil Thickness
Surface Preparation
Crack/Joint Treatment

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Joseph Lstiburek 75

Plaza Decks
Sealant or Cants at Corners and Transitions to Reduce Stress and Increase Water Shedding

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Joseph Lstiburek 76

Plaza Decks
Inspection and Testing

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Joseph Lstiburek 77

Plaza Decks
Inspection and Testing
Check Application Thickness (every 500ft2)

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Joseph Lstiburek 78

Plaza Decks
Inspection and Testing
Check Application Thickness (every 500ft2)
Visually Inspect Entire Membrane

Building Science Corporation
Joseph Lstiburek 79

Plaza Decks
Inspection and Testing
Check Application Thickness (every 500ft2)
Visually Inspect Entire Membrane
Flood Test Areas Prior to Installation of Landscaping

Building Science Corporation
Joseph Lstiburek 80

Building Science Corporation

Joseph Lstiburek 81

Building Science Corporation

Joseph Lstiburek 82

Building Science Corporation

Joseph Lstiburek 83

Building Science Corporation

Joseph Lstiburek 84

Building Science Corporation

Joseph Lstiburek 85

Building Science Corporation

Joseph Lstiburek 86

Building Science Corporation

Joseph Lstiburek 87

Building Science Corporation

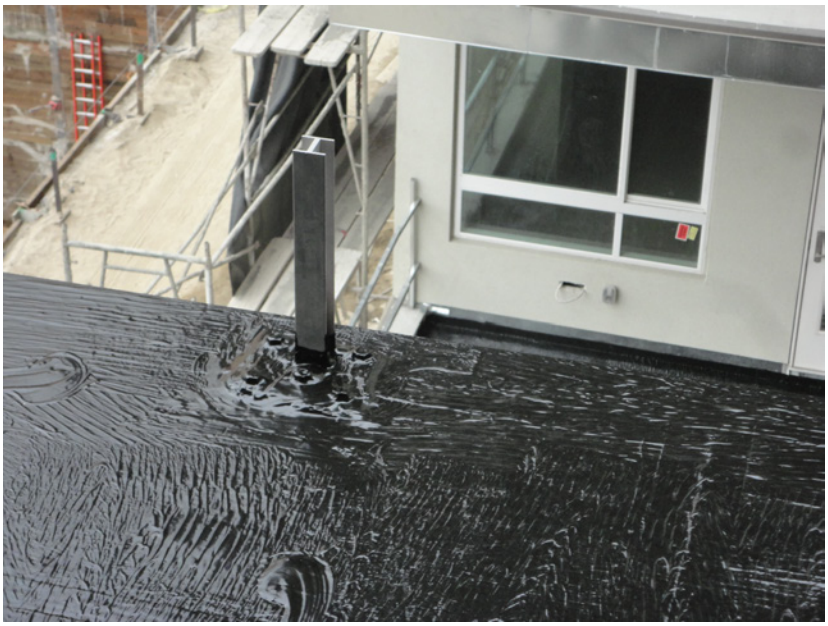
Joseph Lstiburek 88

Building Science Corporation

Joseph Lstiburek 89

Building Science Corporation

Joseph Lstiburek 90



Building Science Corporation

Joseph Lstiburek 91

Building Science Corporation

Joseph Lstiburek 92

Building Science Corporation

Joseph Lstiburek 93

Building Science Corporation

Joseph Lstiburek 94

Building Science Corporation

Joseph Lstiburek 95

Building Science Corporation

Joseph Lstiburek 96

Building Science Corporation

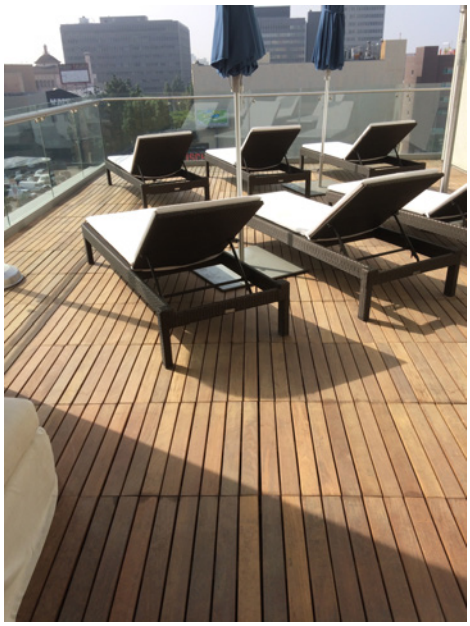
Joseph Lstiburek 97

Building Science Corporation

Joseph Lstiburek 98

Building Science Corporation

Joseph Lstiburek 99



Building Science Corporation

Joseph Lstiburek 100

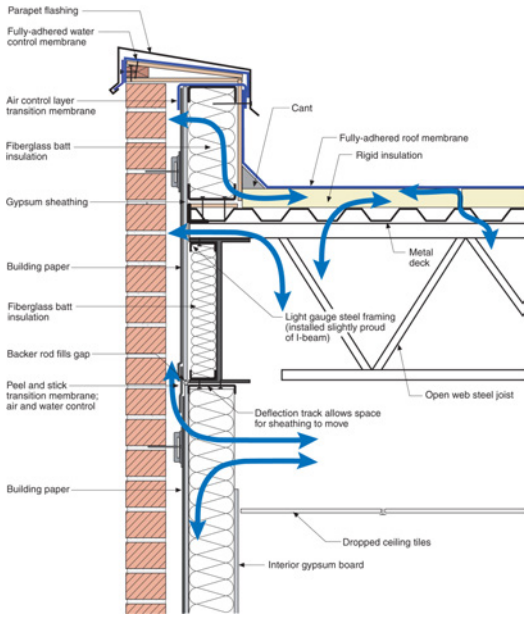
It’s a Case of Black or White

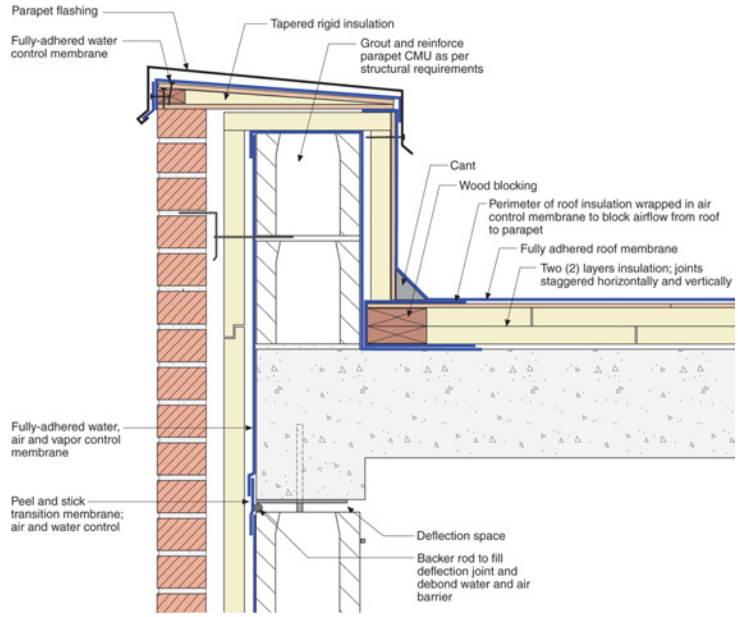
It’s a Case of Black or White
Arrhenius

It's a Case of Black or White

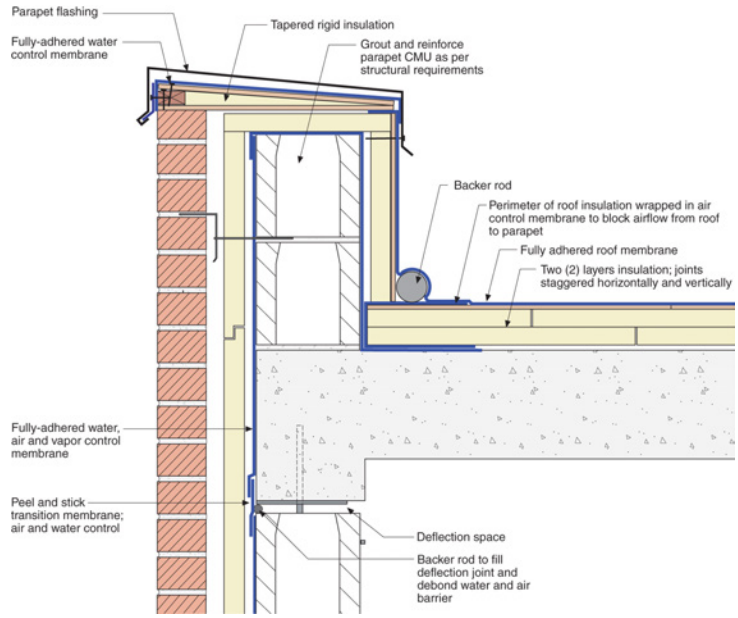
Arrhenius

Every 10 degrees C – double the "badness"

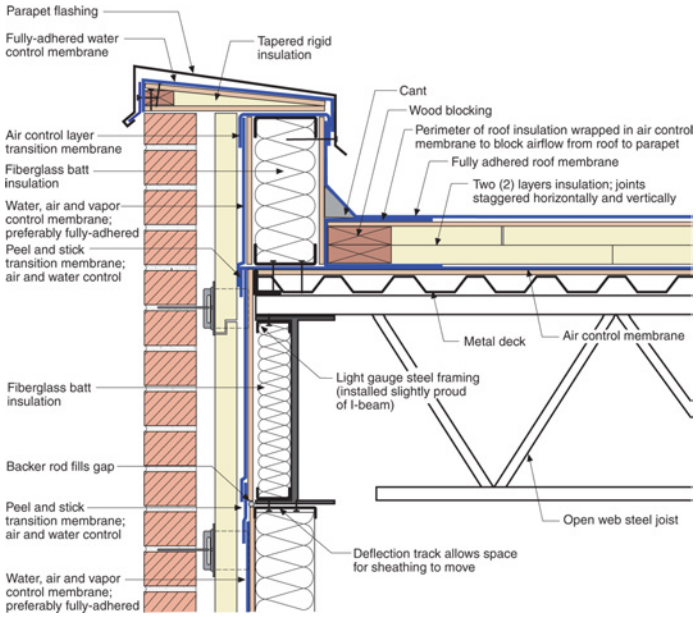




Building Science Corporation Joseph Lstiburek 105

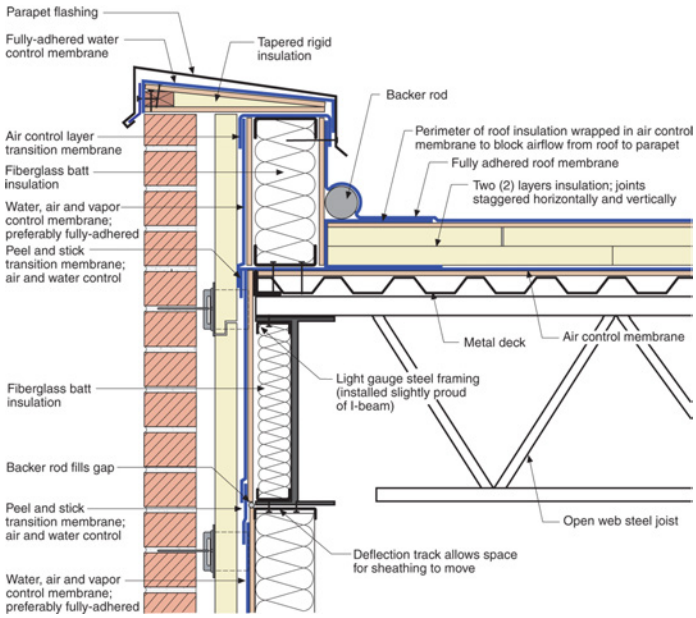


Building Science Corporation Joseph Lstiburek 106



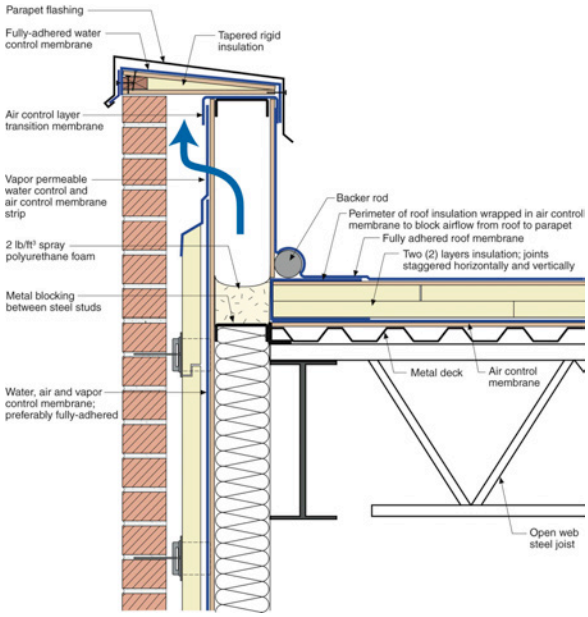
Building Science Corporation

Joseph Lstiburek 107

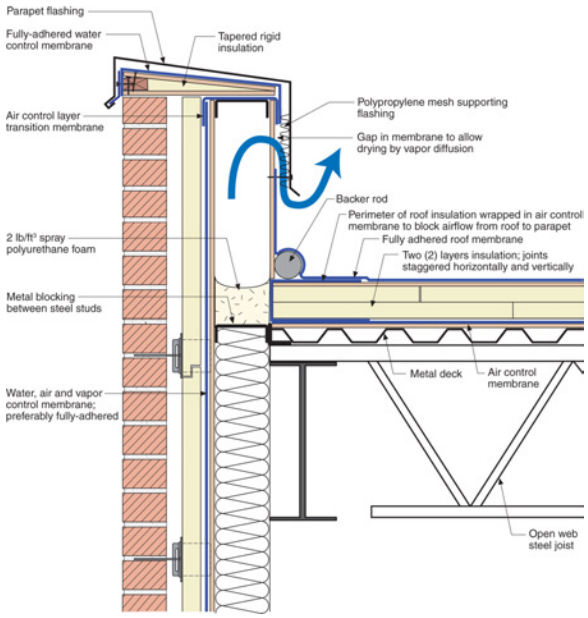


Building Science Corporation

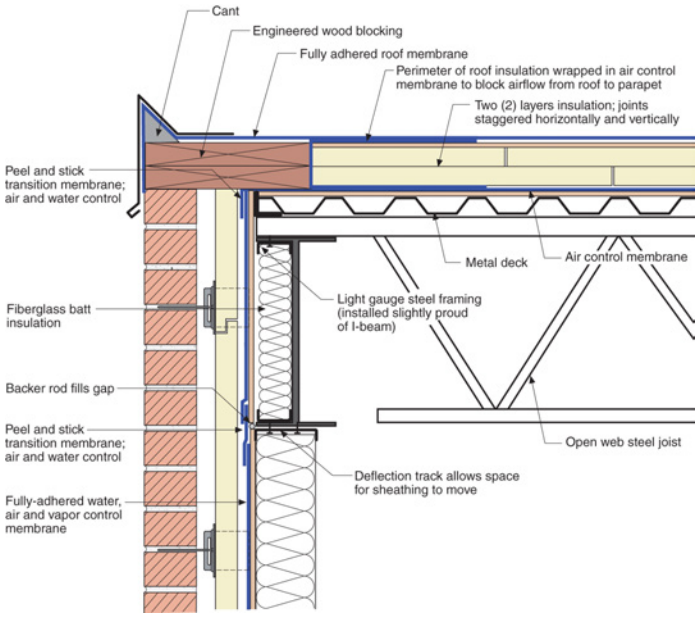
Joseph Lstiburek 108



Building Science Corporation Joseph Lstiburek 109



Building Science Corporation Joseph Lstiburek 110



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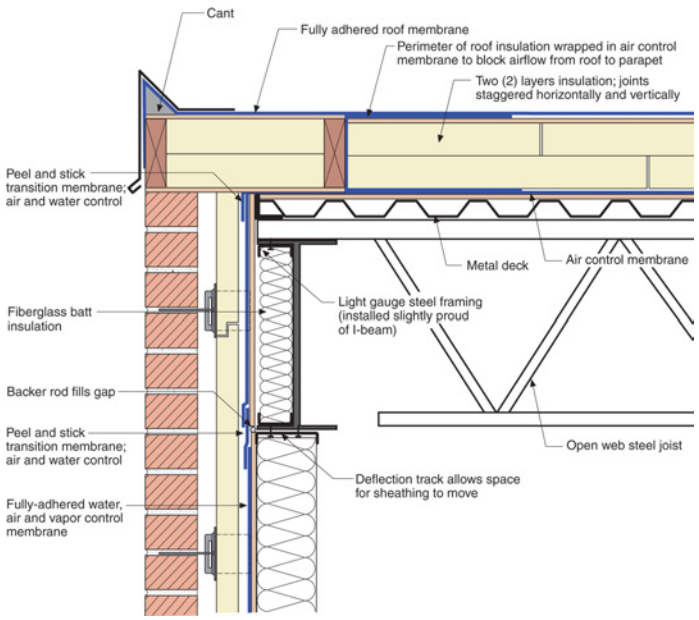

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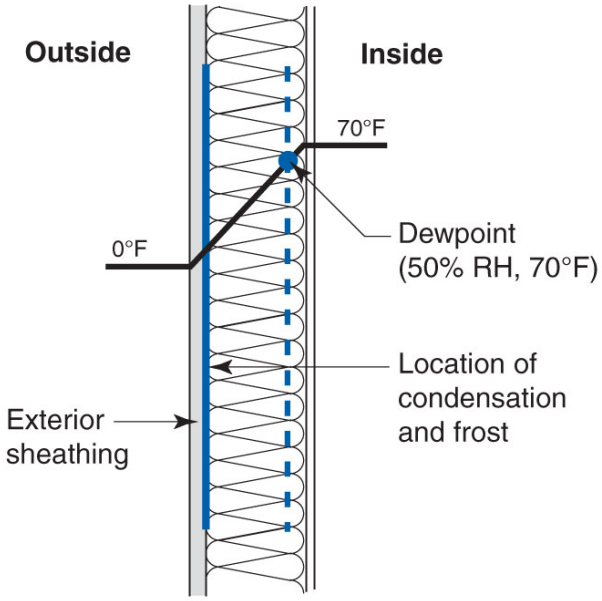

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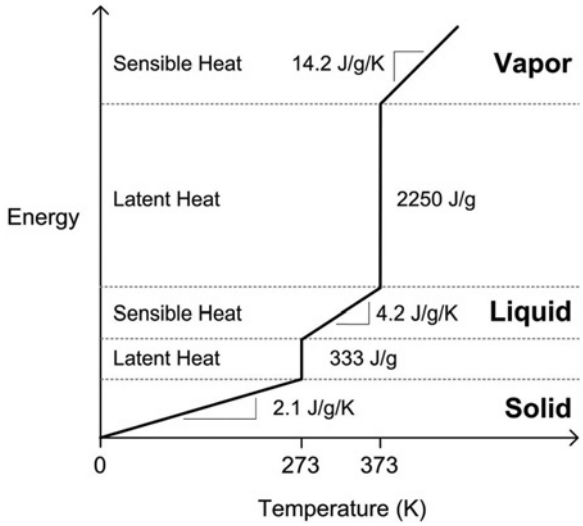

Simple linearized energy-temperature relation for water
From Straube & Burnett, 2005

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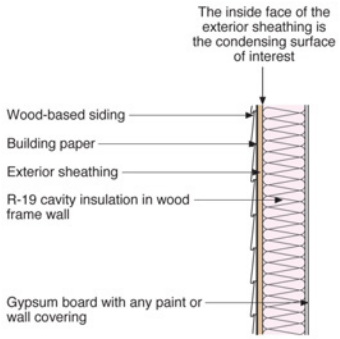

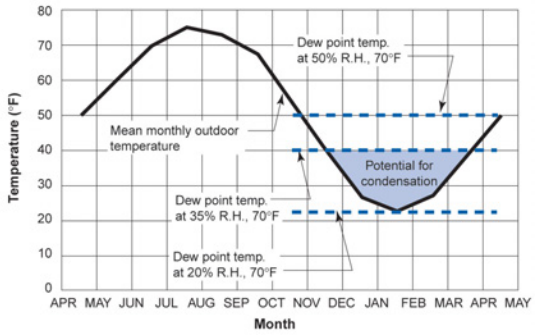

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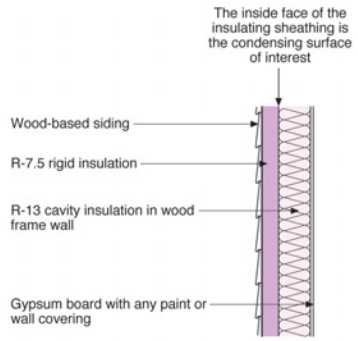

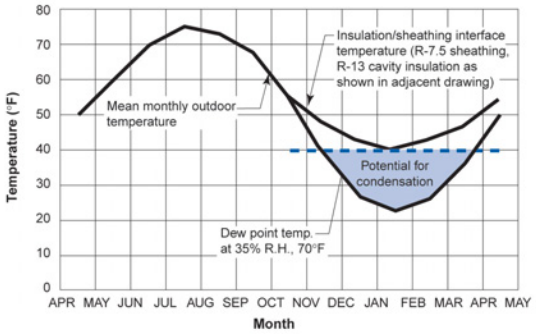

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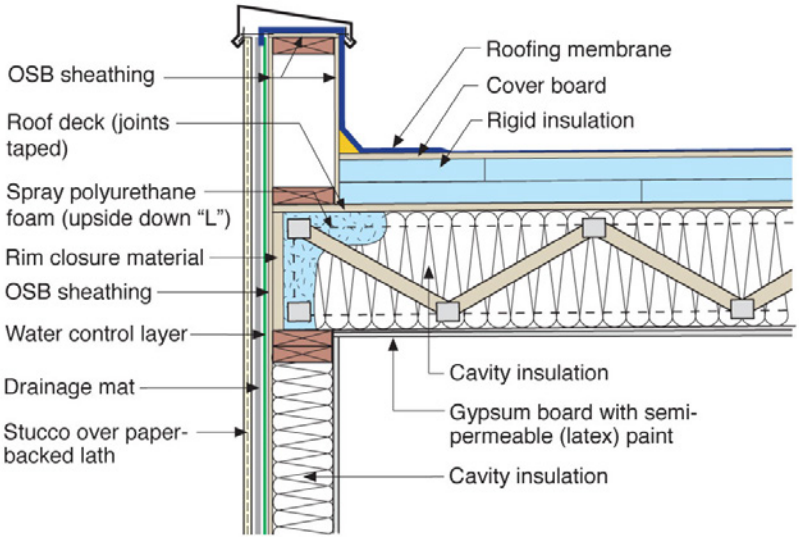

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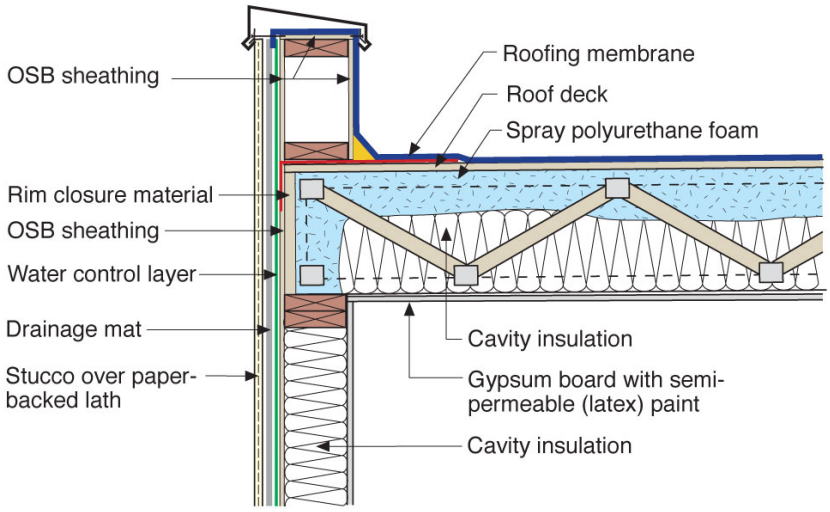

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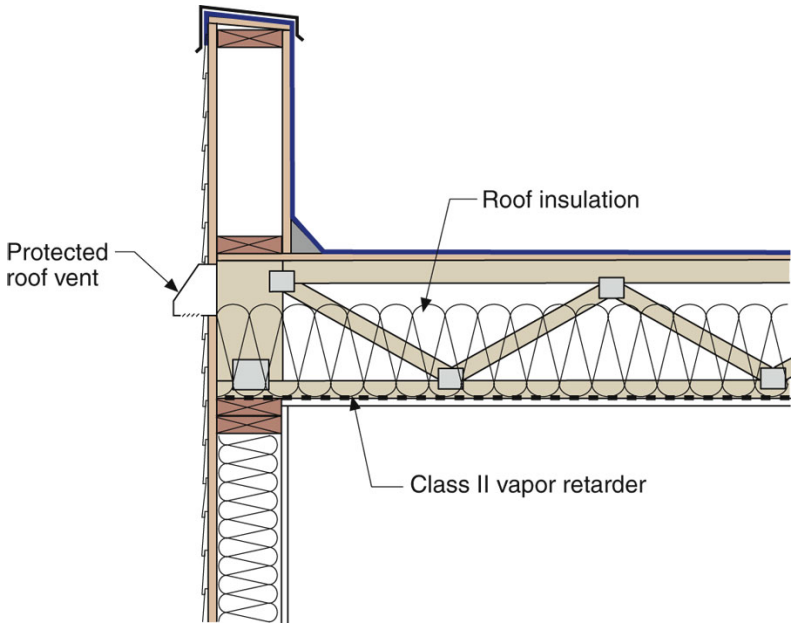

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Balconies

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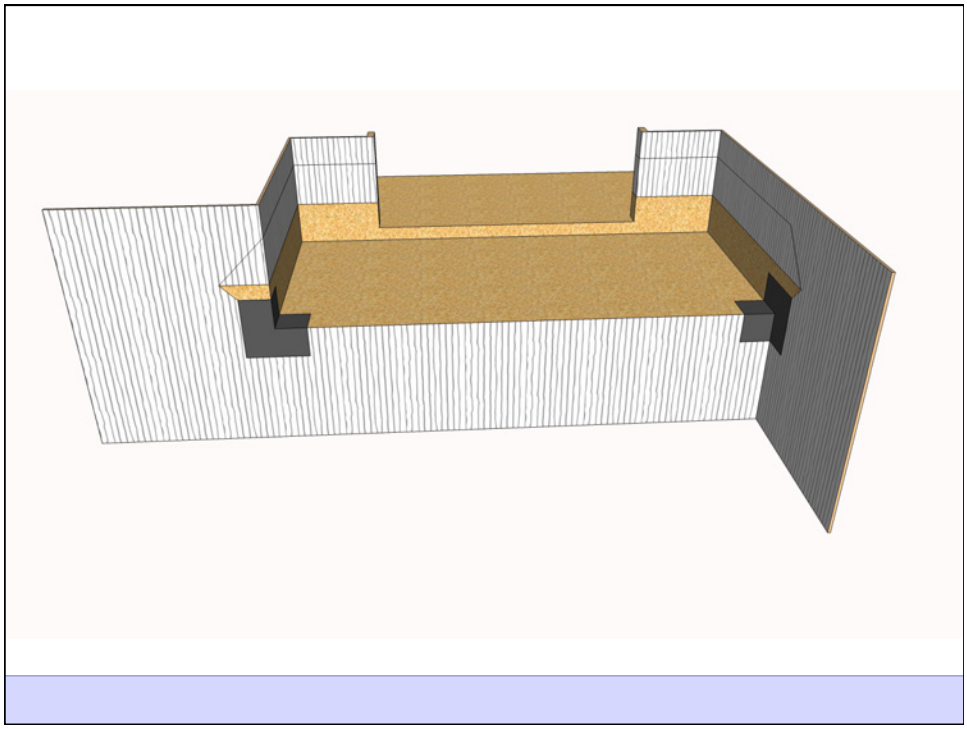

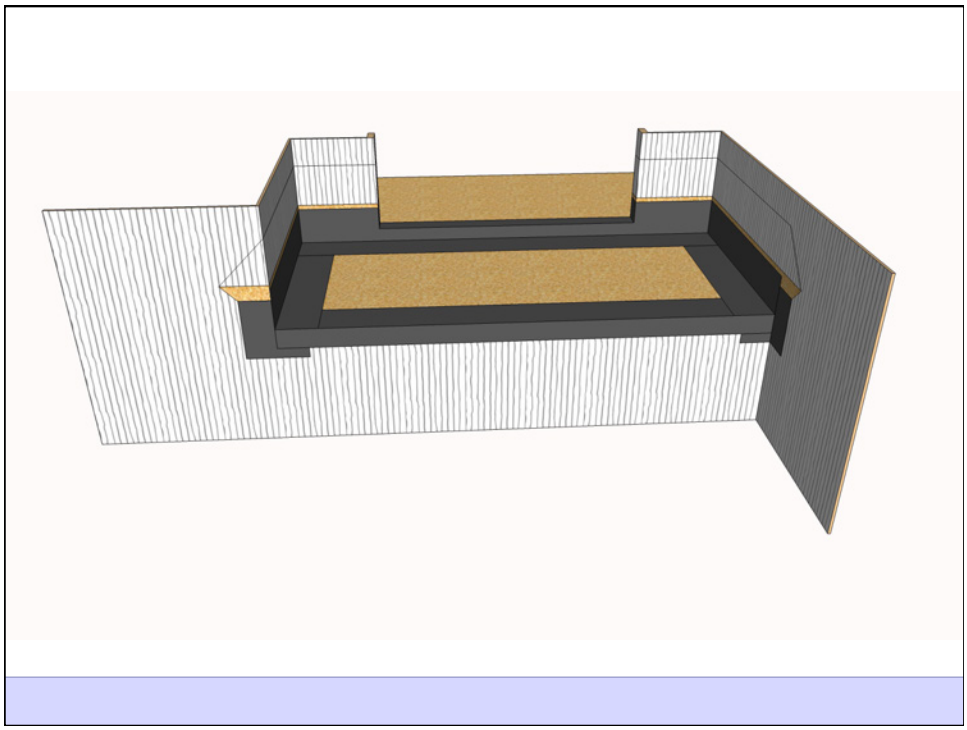

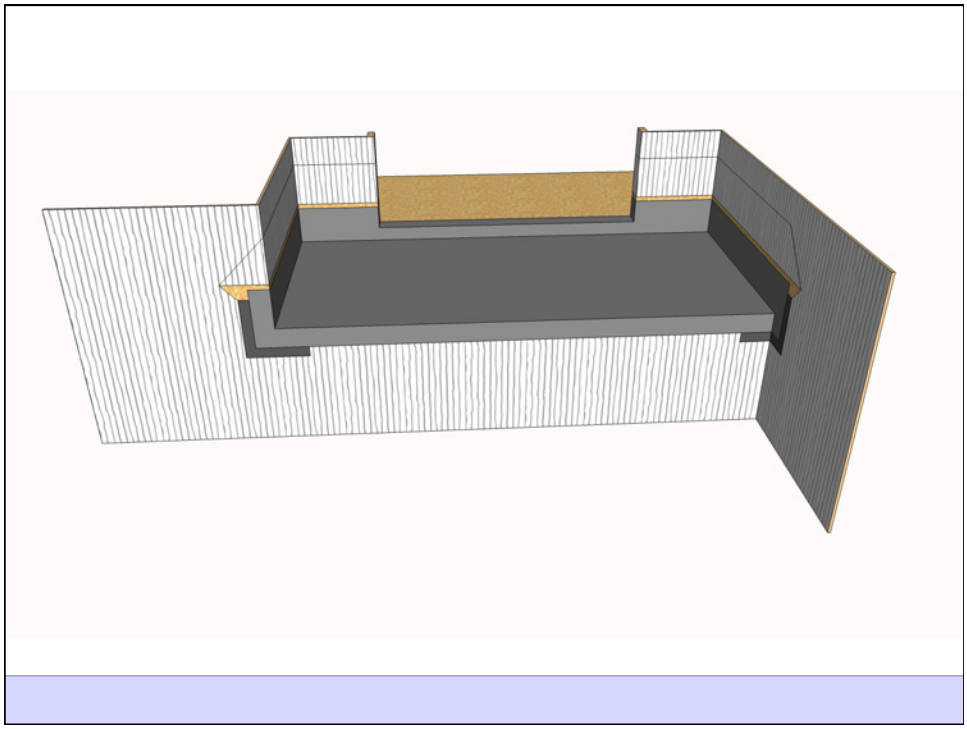

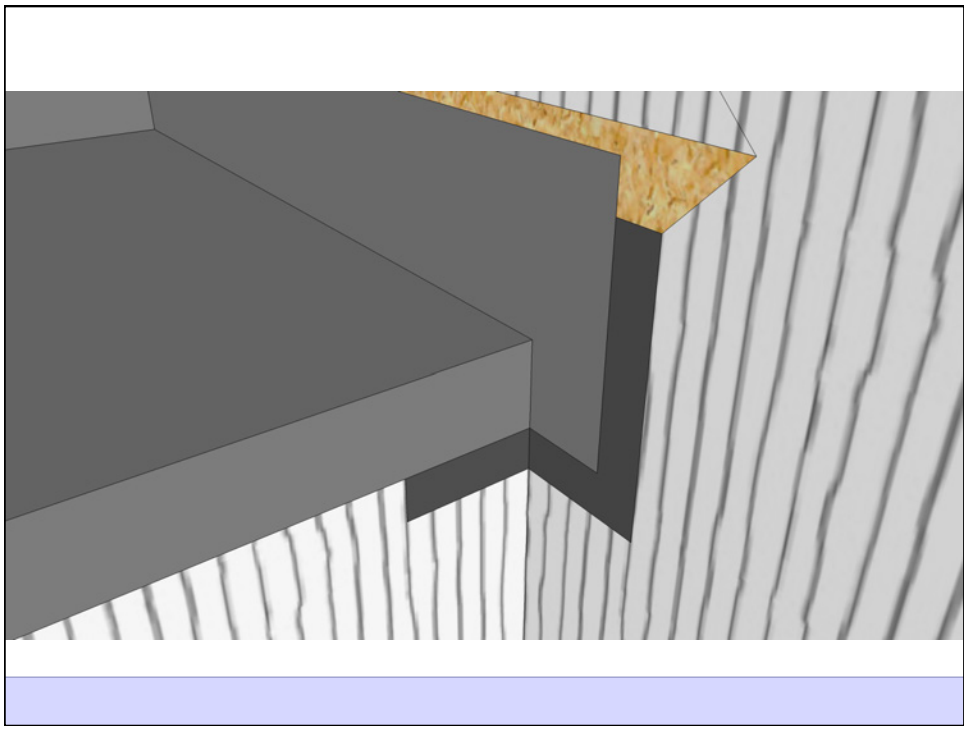

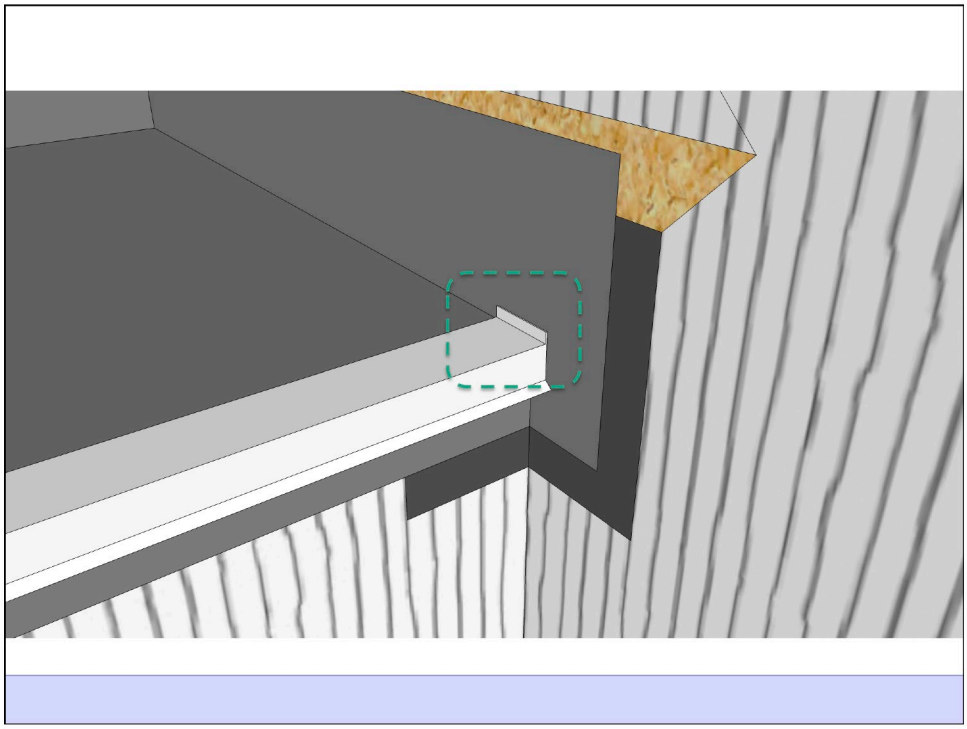

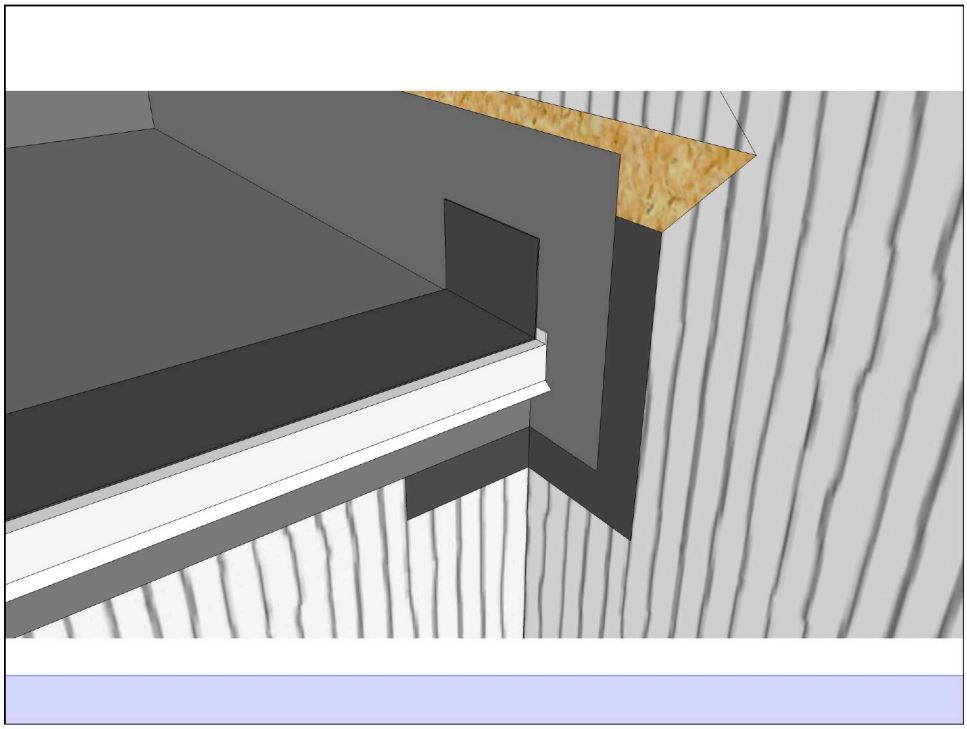

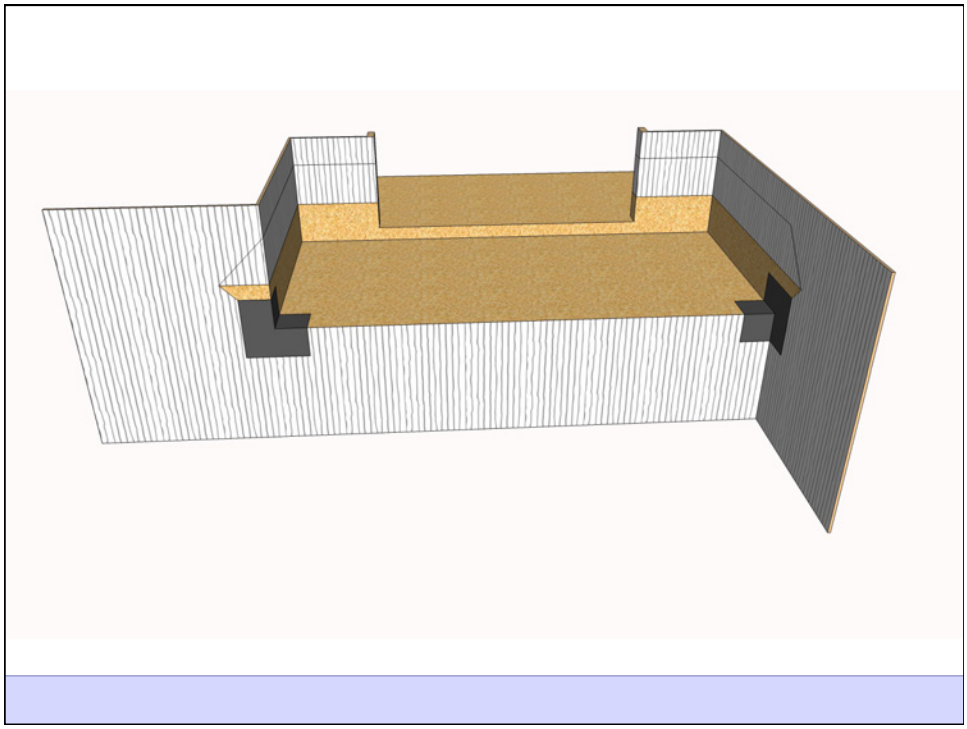

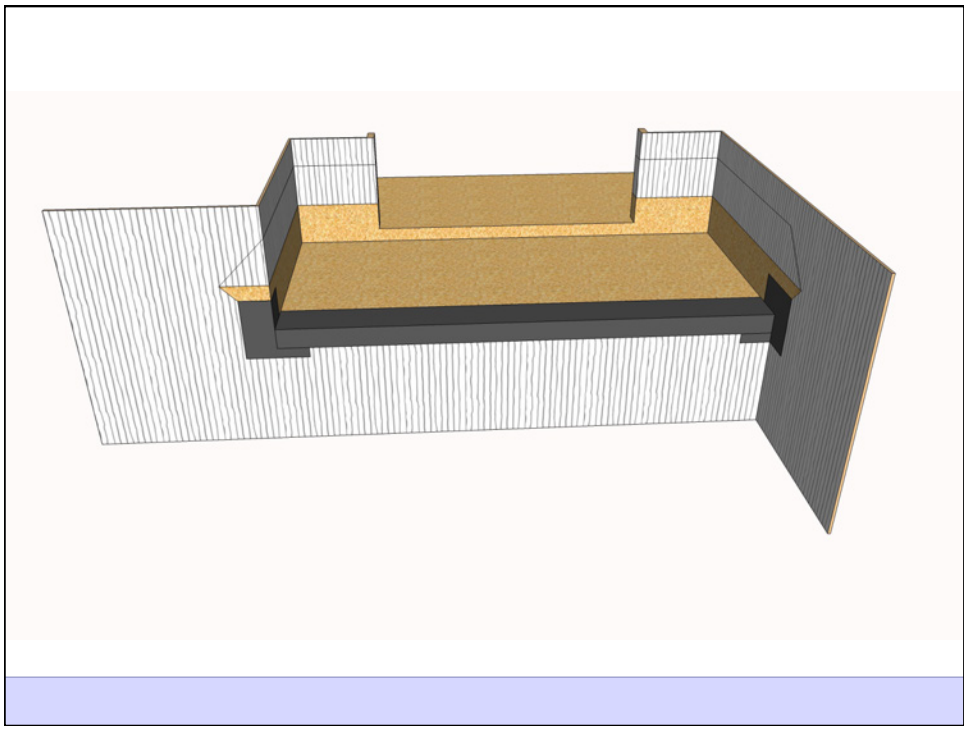

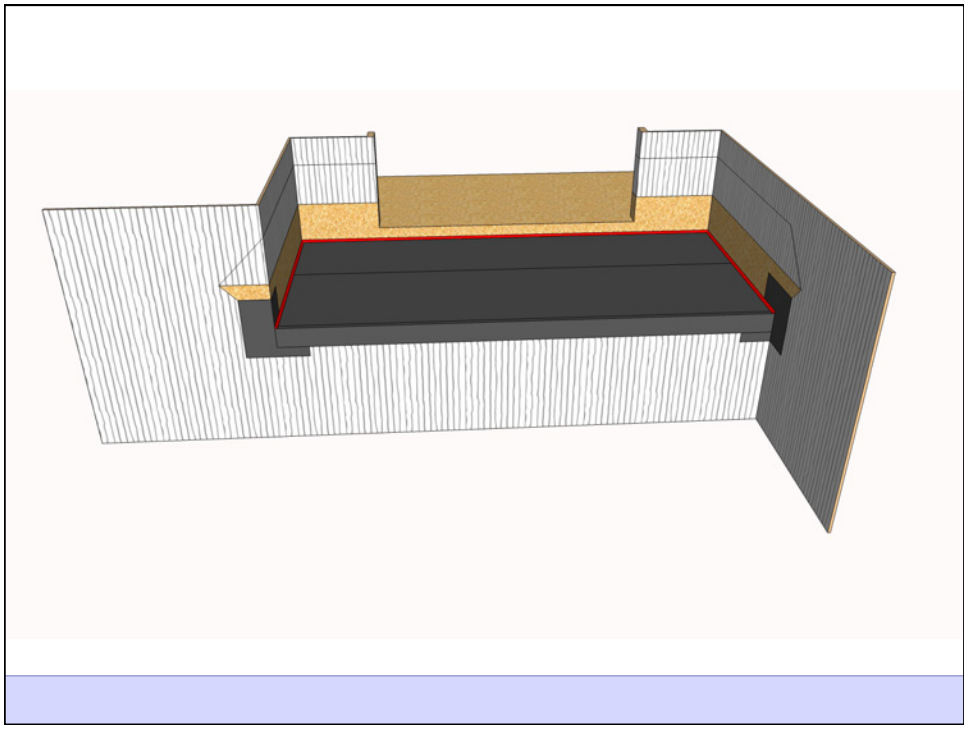

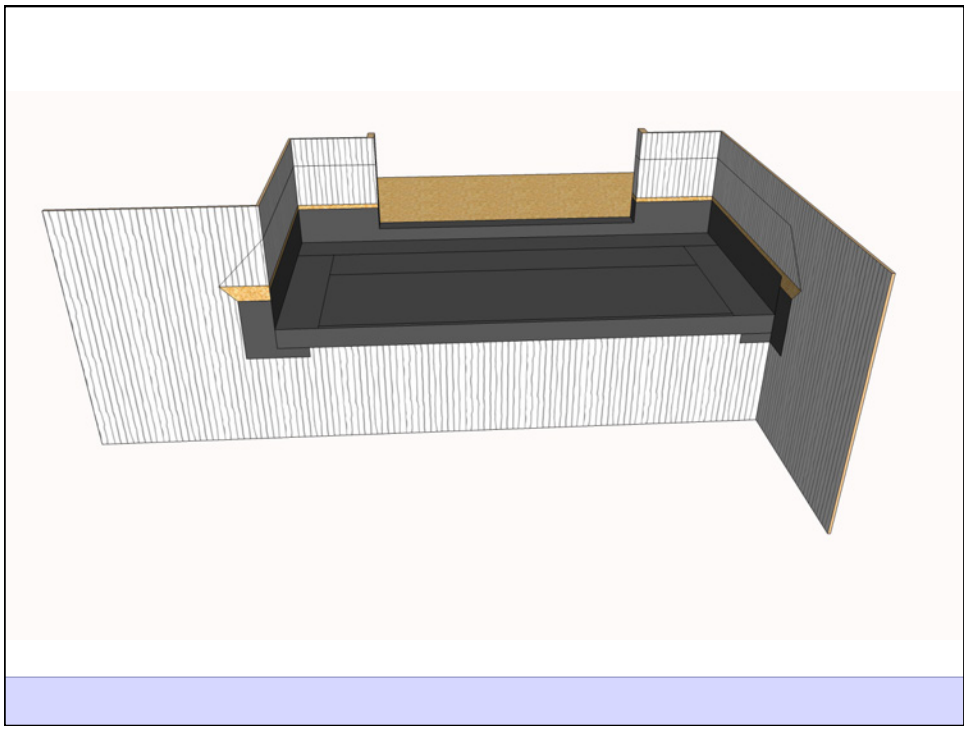

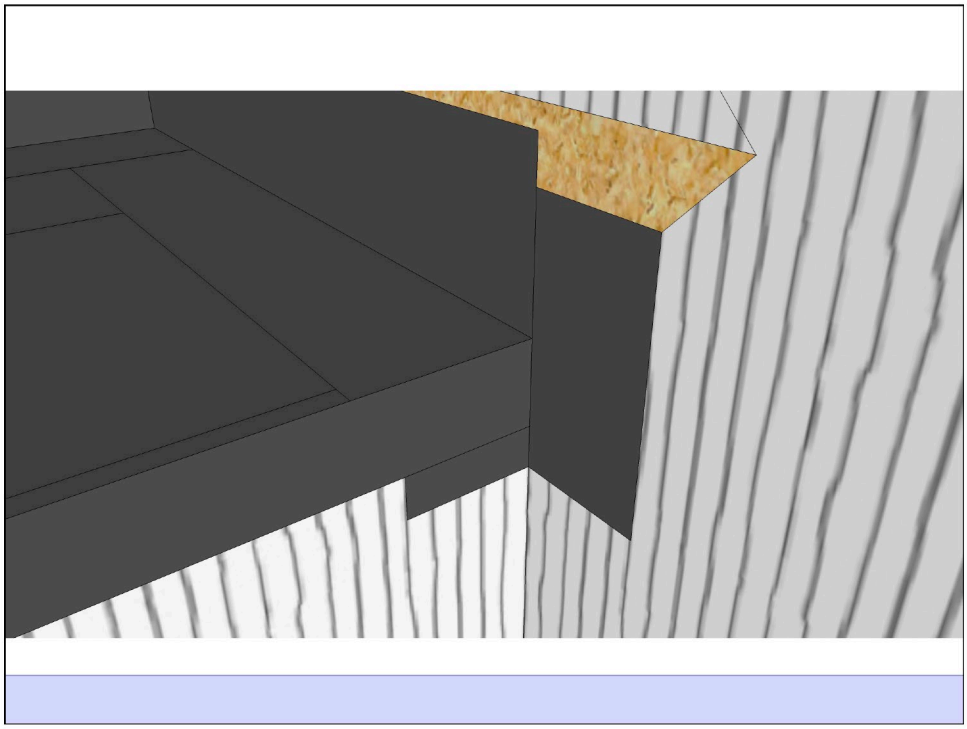

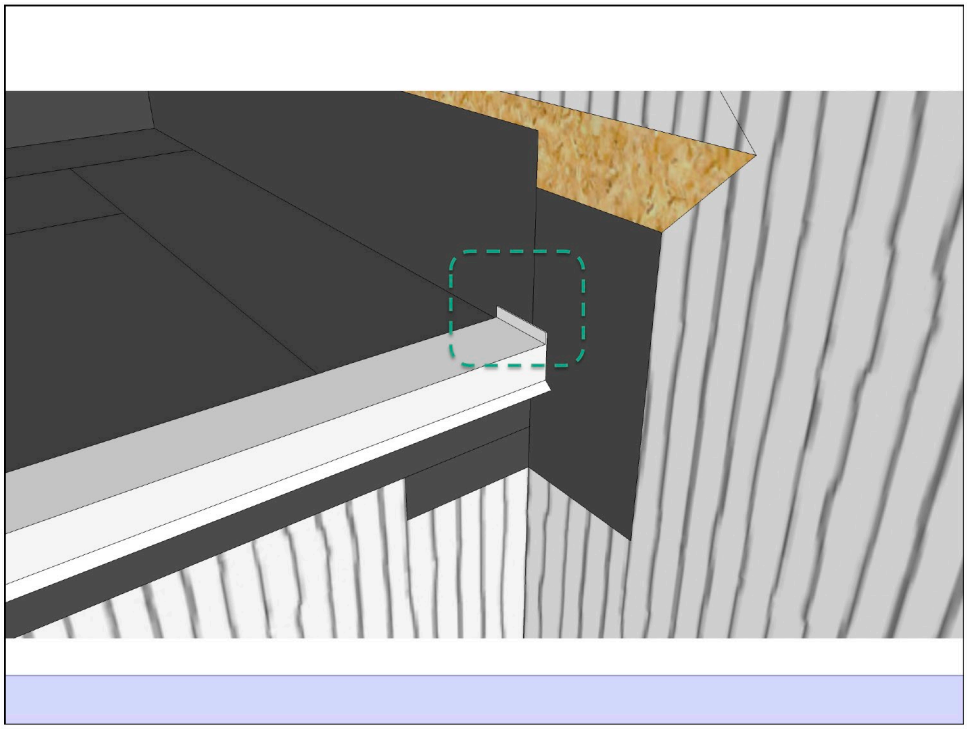

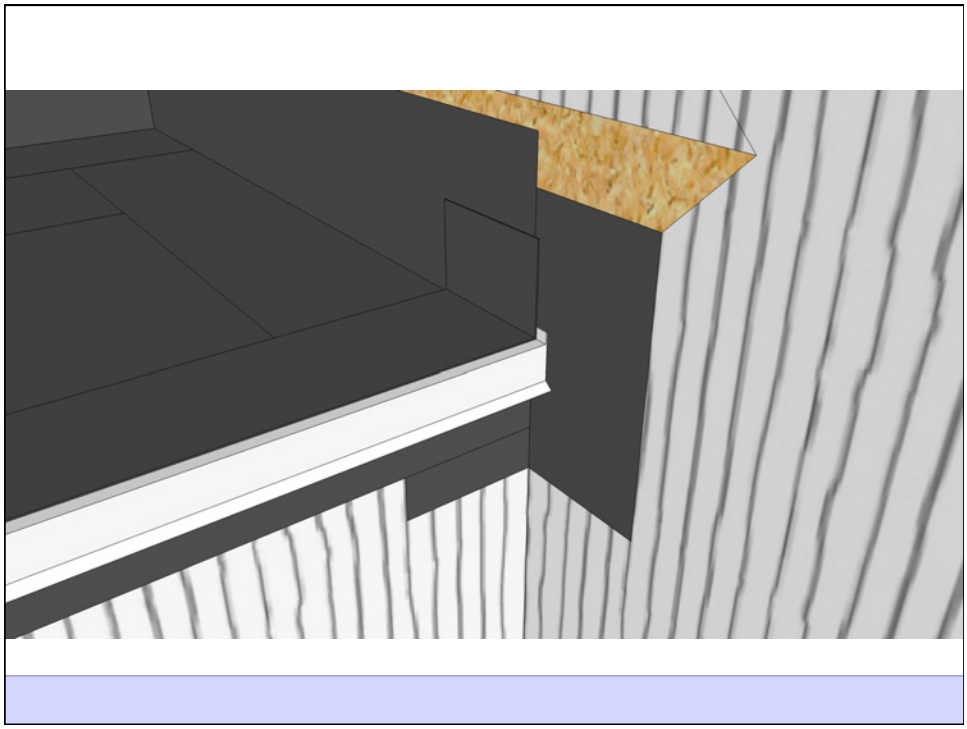

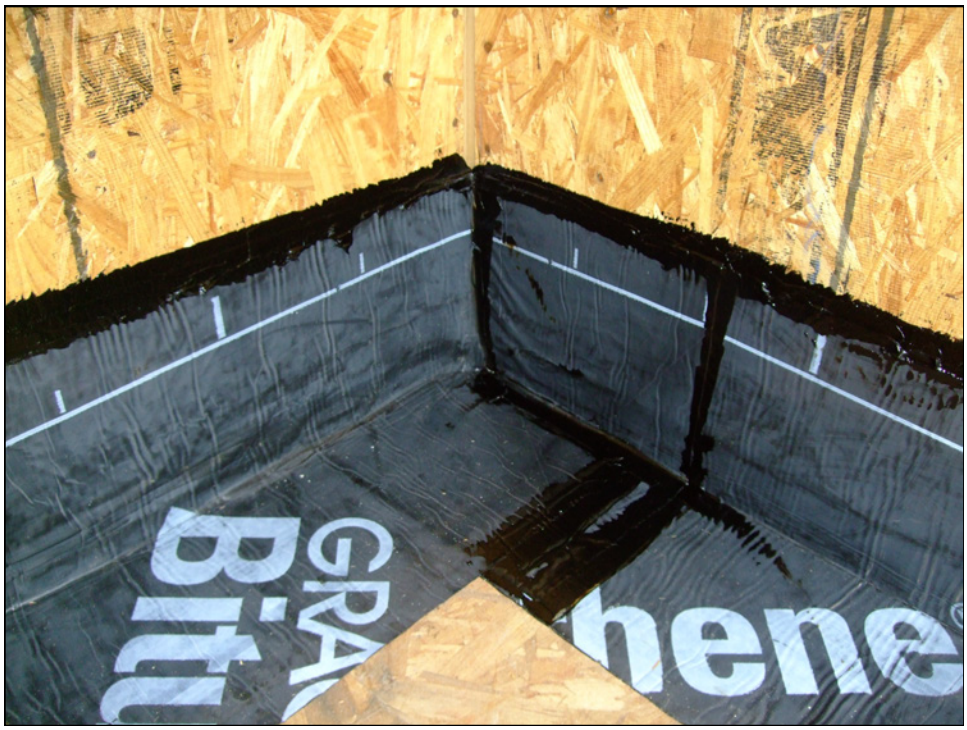
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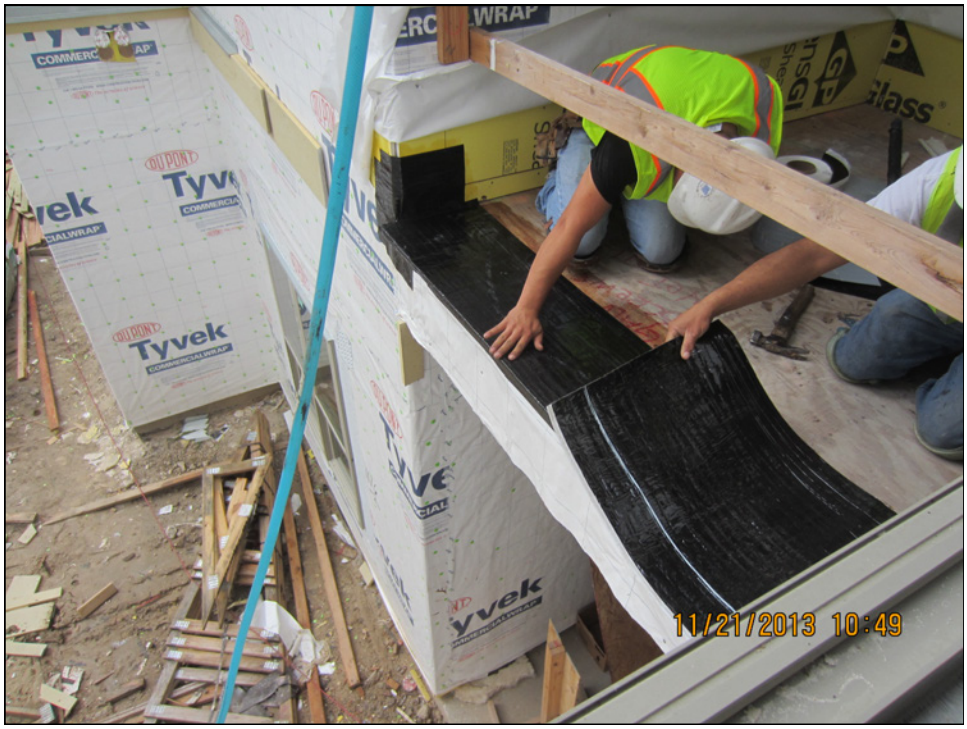
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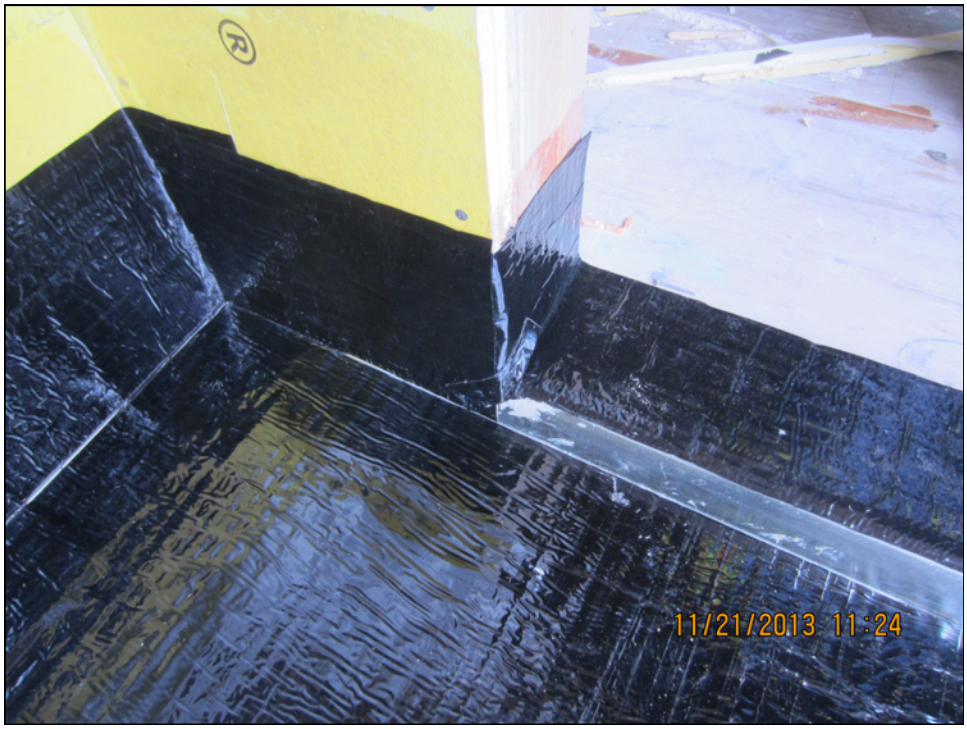
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