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

Building Science

Adventures In Building Science

www.buildingscience.com

Order of Magnitude

1 to 10

10 to 100

100 to 1000

1000 to 10000

First Order Effects, Second Order Effects….

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Arrhenius Equation

For Every 10 Degree K Rise Activation Energy Doubles

$$k = Ae^{-E_a/(RT)}$$

Damage Functions
Water
Heat
Ultra-violet Radiation

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Vapor Pressure and Relative Humidity

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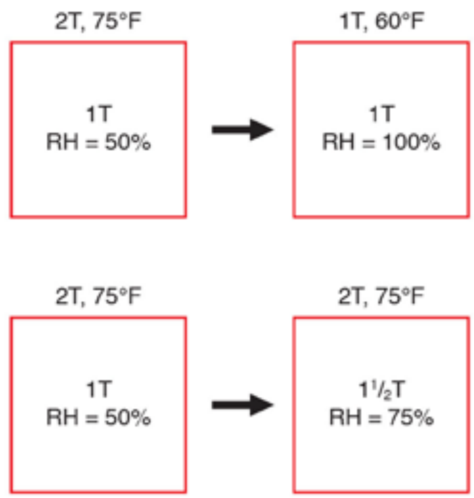

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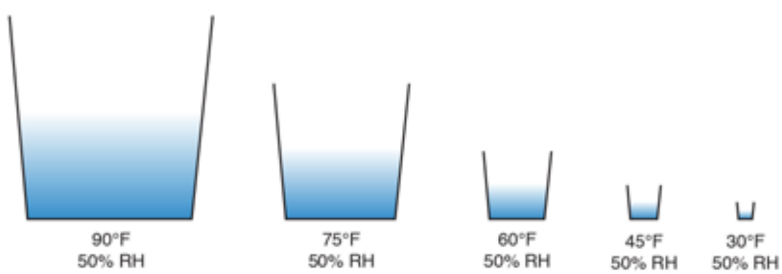

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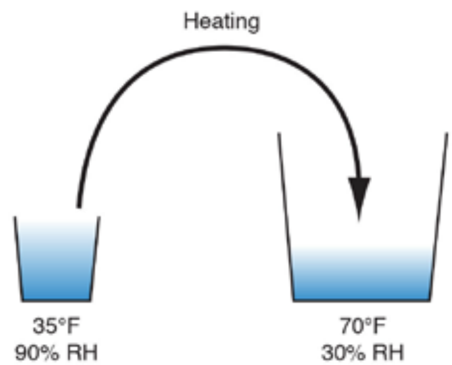

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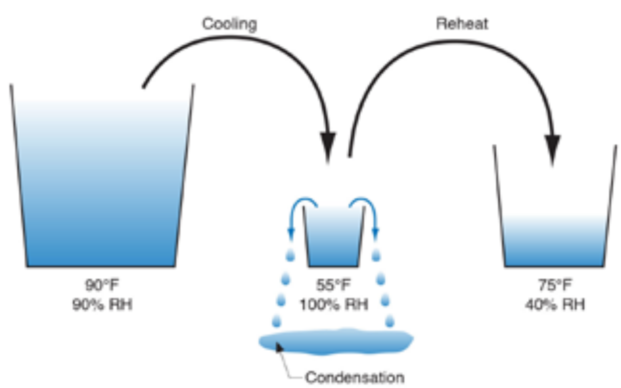

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Laws of Thermodynamics

Zeroth Law – A=B and B=C therefore A=C
First Law - Conservation of Energy
Second Law - Entropy
Third Law – Absolute Zero

2^{nd} Law of Thermodynamics

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In an isolated system, a process can occur only if it increases the total entropy of the system

Rudolf Clausius

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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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Moisture Flow Is From Warm To Cold

Moisture Flow Is From More To Less

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Moisture Flow Is From Warm To Cold
Moisture Flow Is From More To Less

Thermal Gradient – Thermal Diffusion
Concentration Gradient – Molecular Diffusion

Moisture Flow Is From Warm To Cold
Moisture Flow Is From More To Less

Thermal Gradient – Thermal Diffusion
Concentration Gradient – Molecular Diffusion

Vapor Diffusion

Thermodynamic Potential

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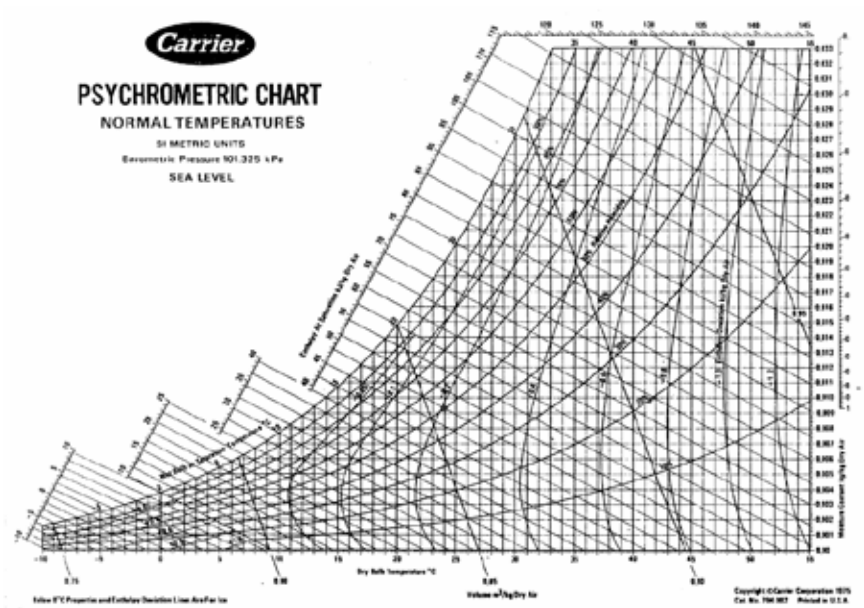

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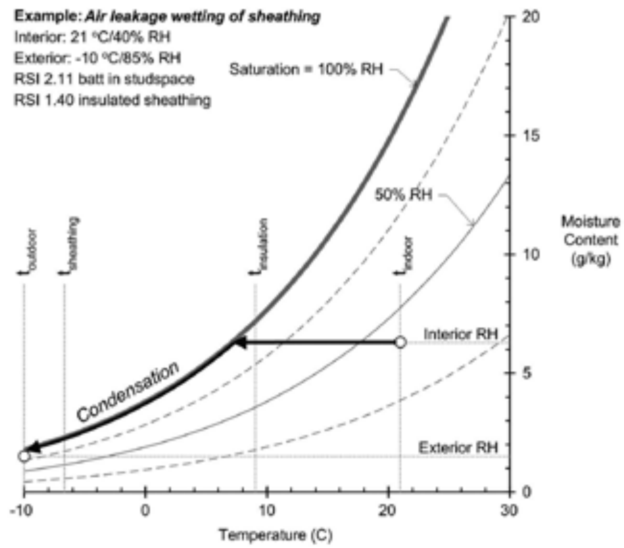

Cooling and condensation
From Straube & Burnett, 2005

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Sorption Isotherms

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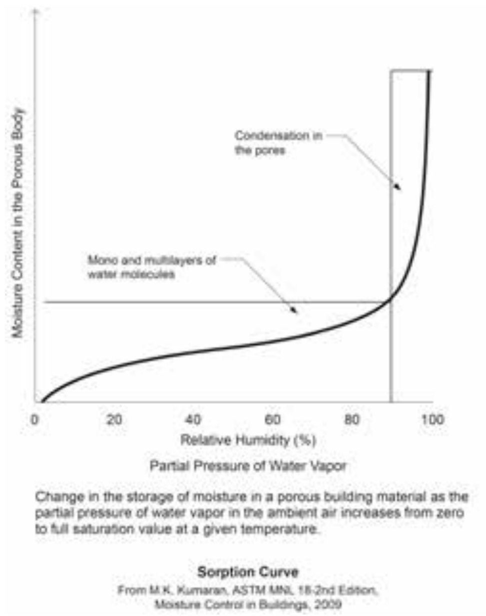

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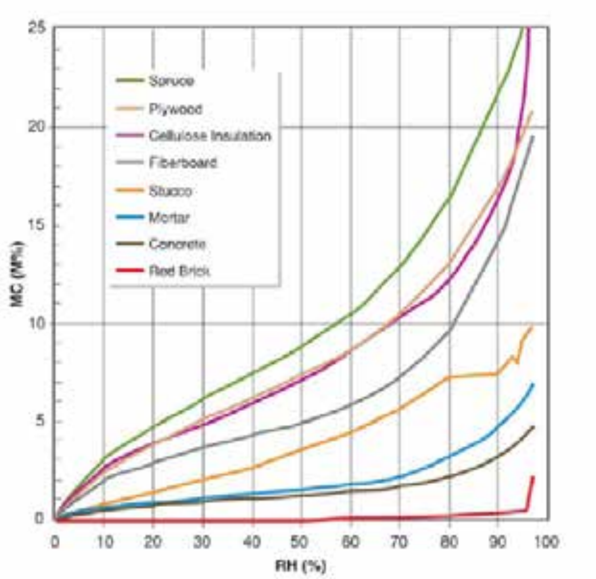

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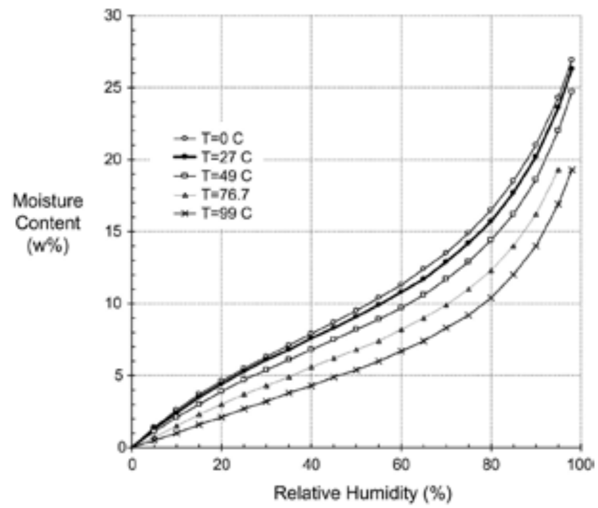

Average sorption isotherm for wood as a function of temperature
From Straube & Burnett, 2005

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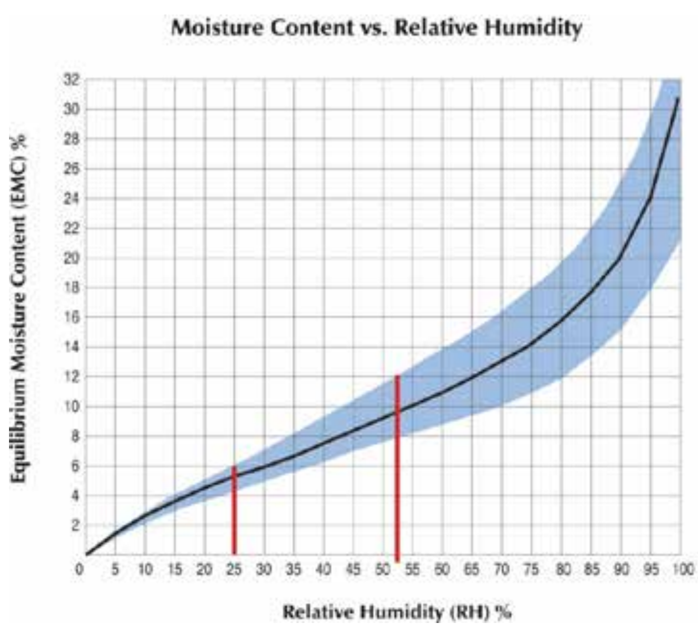

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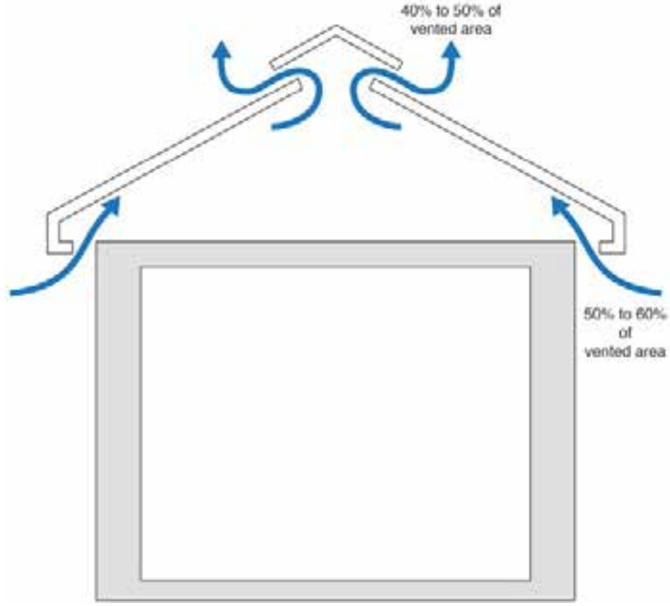

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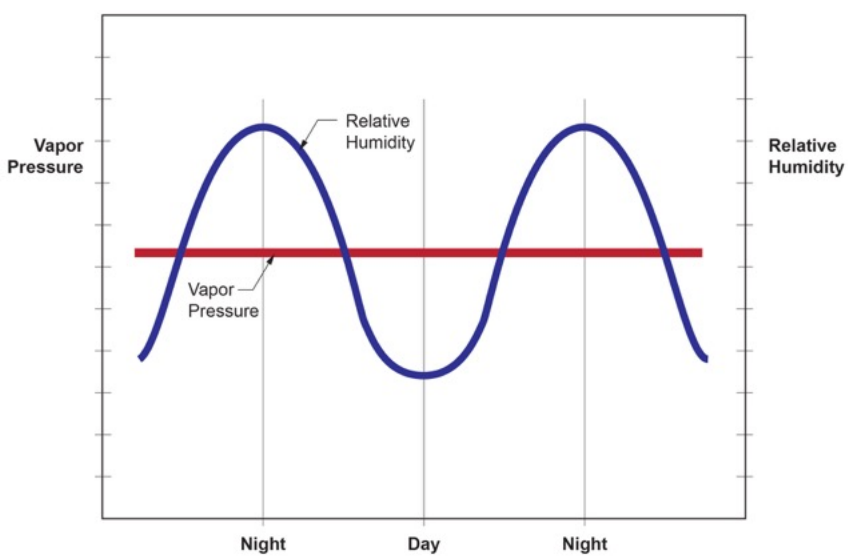

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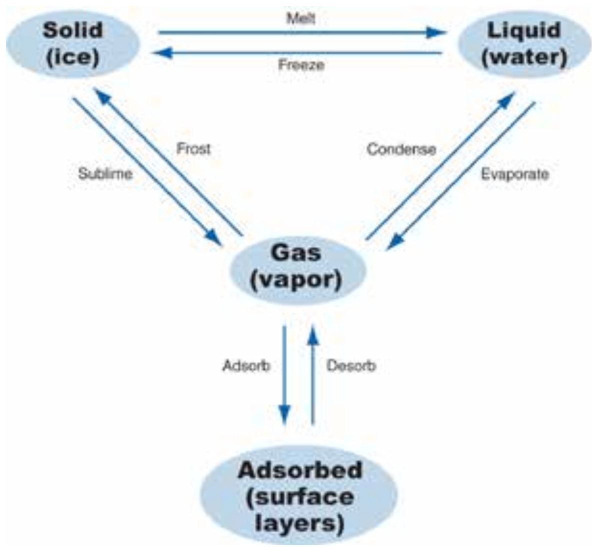

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Moisture Transport in Porous Media

Phase	Transport Process	Driving Potential
Vapor	Diffusion	Vapor Concentration
Adsorbate	Surface Diffusion	Concentration
Liquid	Capillary Flow	Suction Pressure
	Osmosis	Solute Concentration

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Moisture Transport in Assemblies

Phase	Transport Process	Driving Potential
Vapor	Diffusion	Vapor Concentration
	Convective Flow	Air Pressure
Adsorbate	Surface Diffusion	Concentration
Liquid	Capillary Flow	Suction Pressure
	Osmosis	Solute Concentration
	Gravitational Flow	Height
	Surface Tension	Surface Energy
	Momentum	Kinetic Energy
	Convective Flow	Air Pressure

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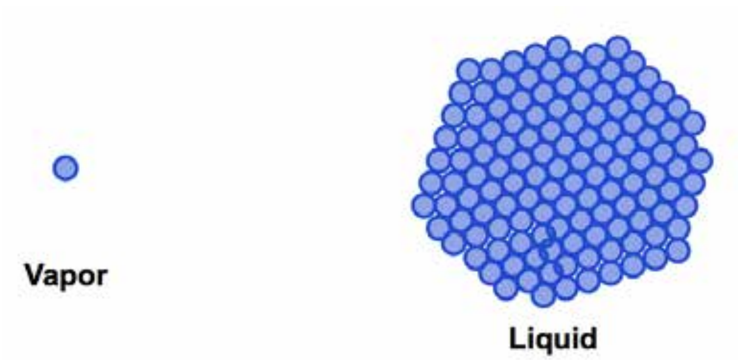

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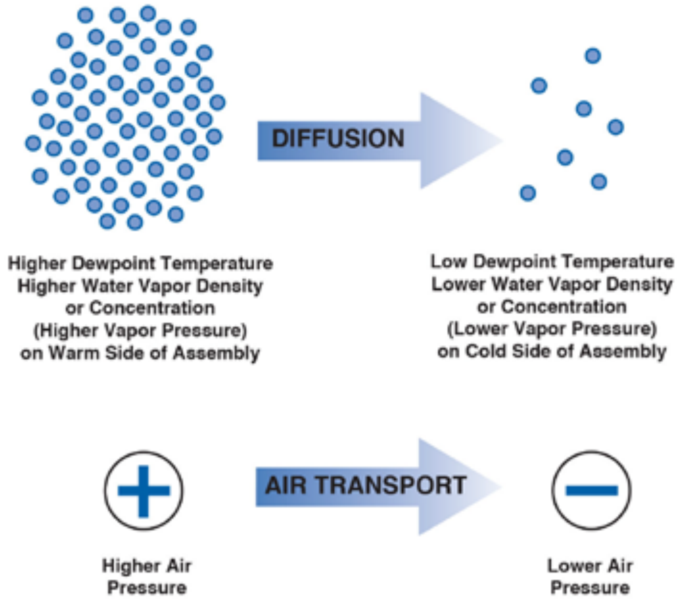

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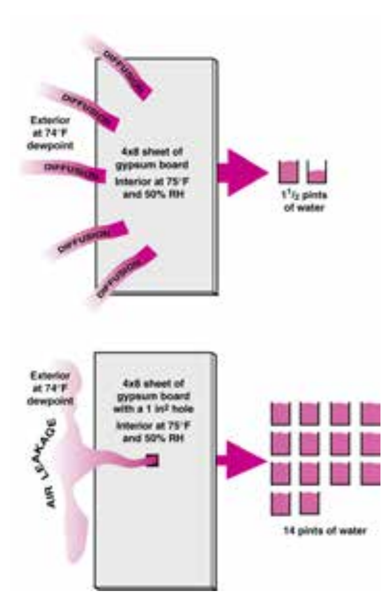

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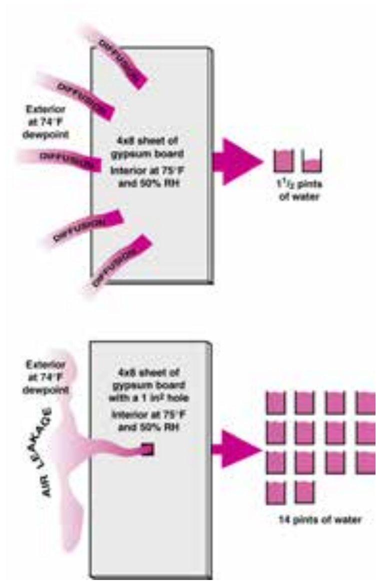

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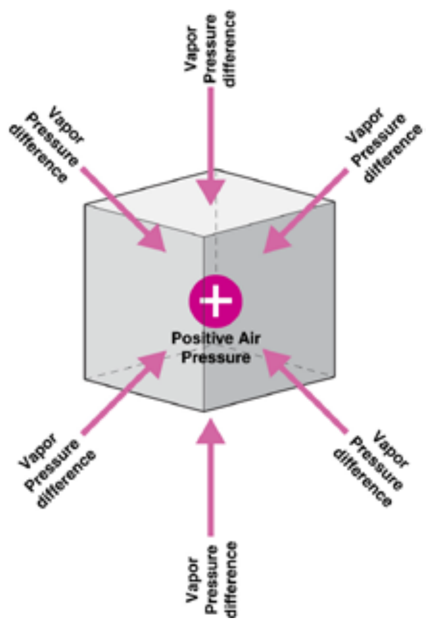

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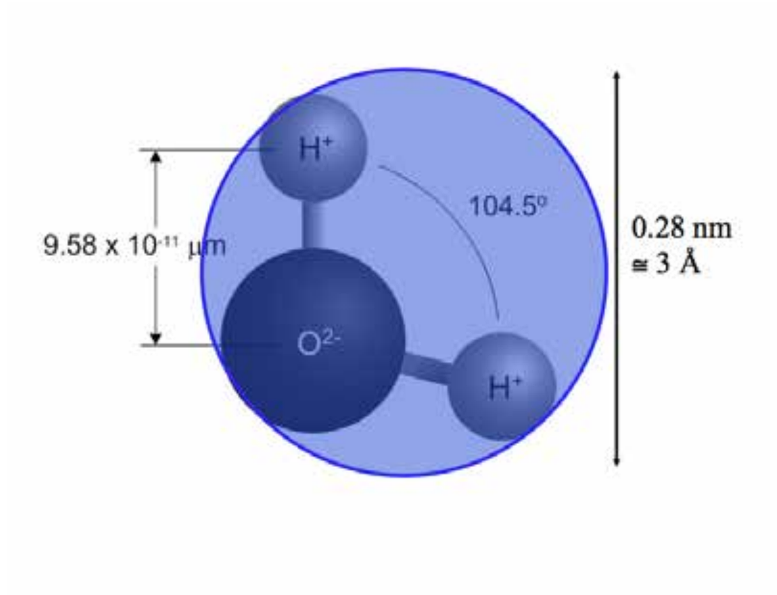

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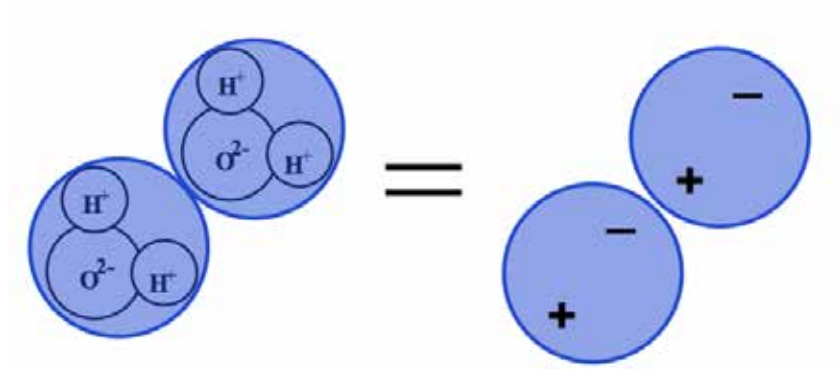

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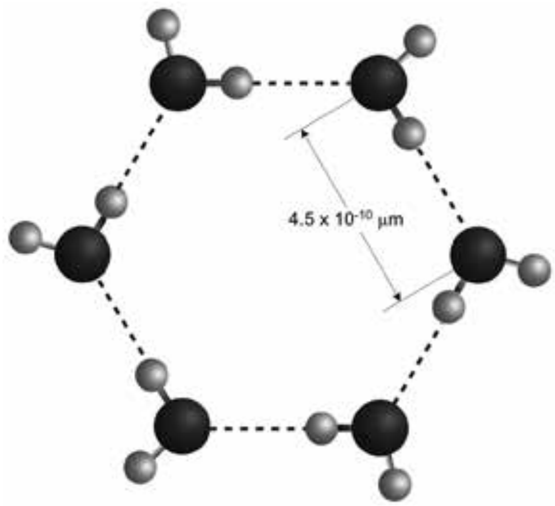

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- "non-wetable" surface
- water repellant surface
- hygrophobic surface
- water more attracted to itself than to surface
- surface energy of water greater than surface energy of surface
- water "beads up"
- "greasy" surface
- high contact angle "θ"

- "wetable" surface
- non-water repellant surface
- hygroscobic surface
- water more attracted to surface than itself
- surface energy of surface greater than surface energy of water
- water "spreads out"
- "non-greasy" surface
- low contact angle "θ"

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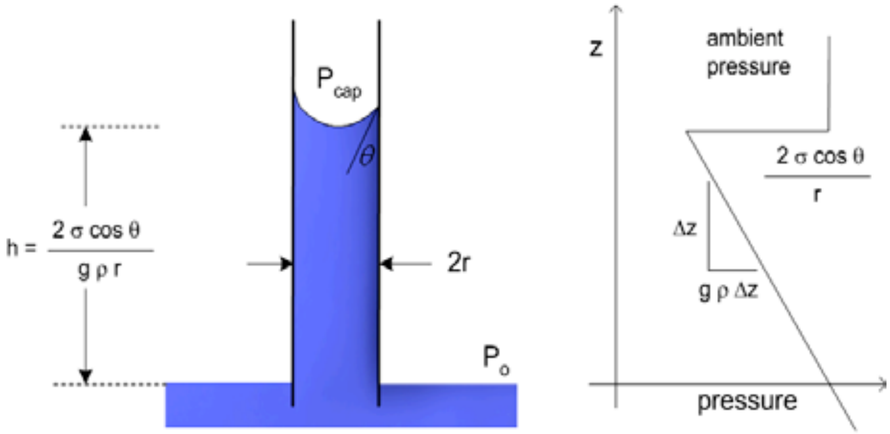
Calculating capillary rise



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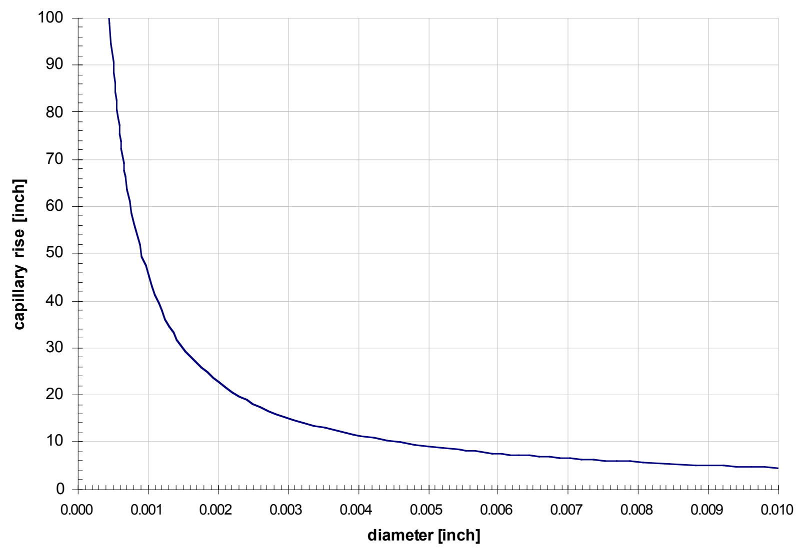
Capillary rise versus diameter



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Heat
Air
Moisture

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HAM

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Hygrothermal Analysis

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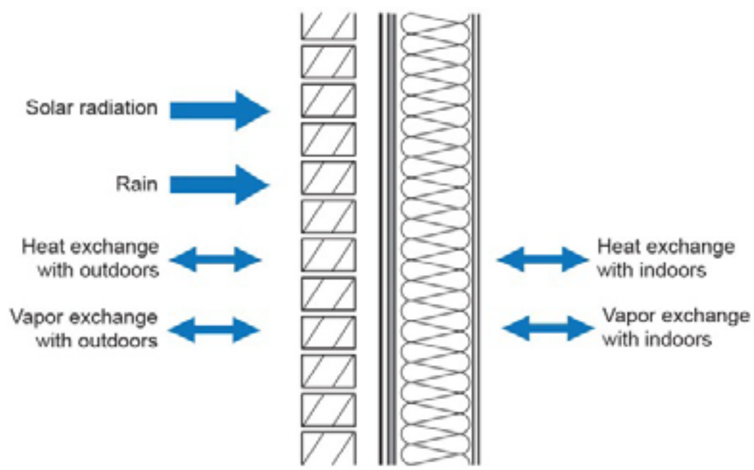

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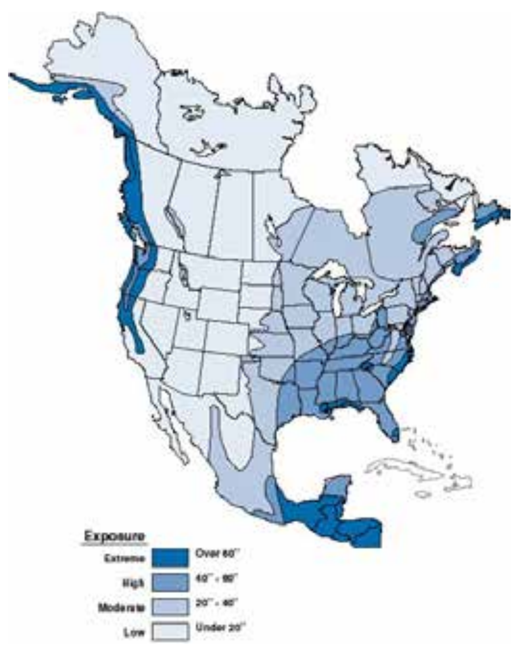

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Don’t Do Stupid Things

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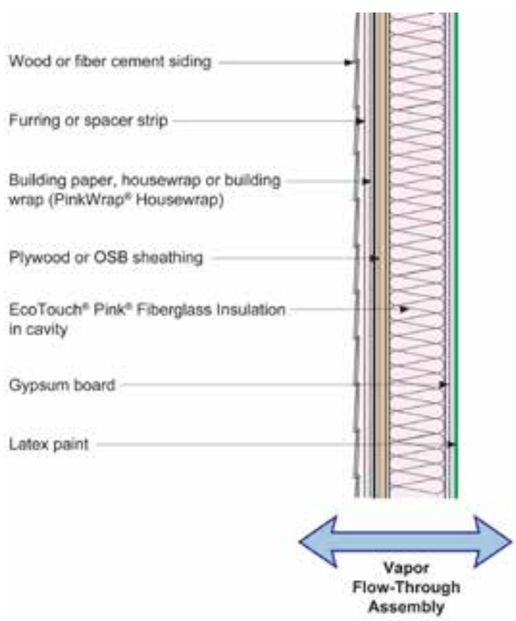

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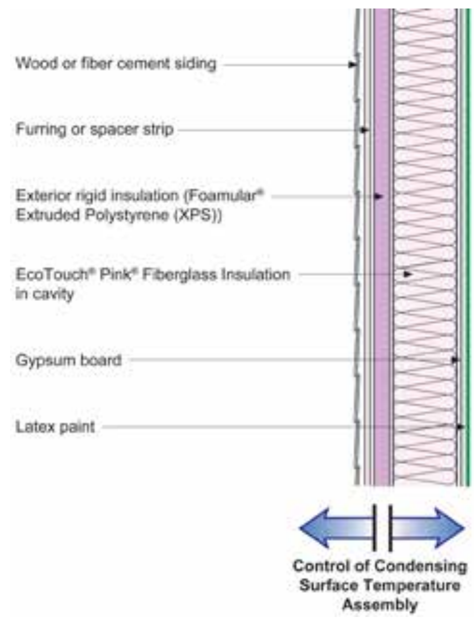

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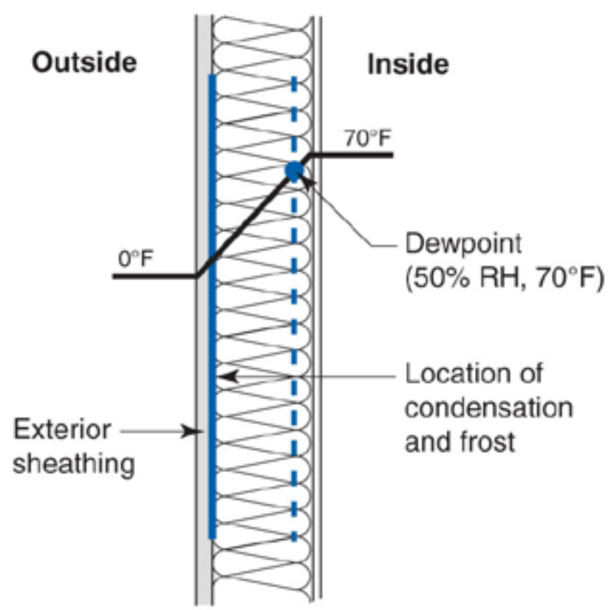

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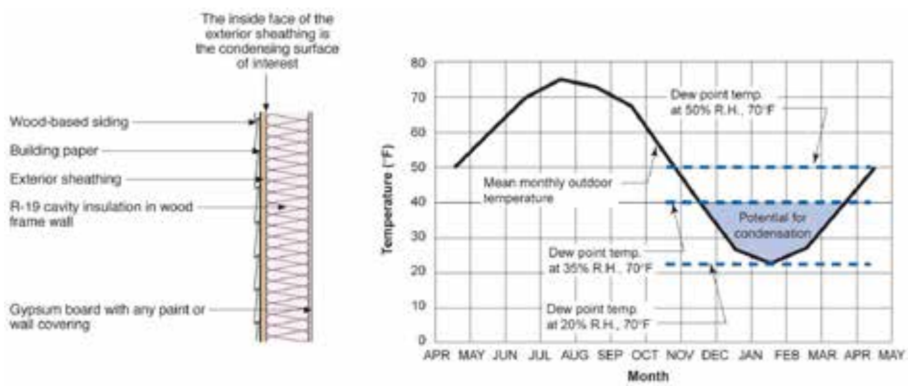

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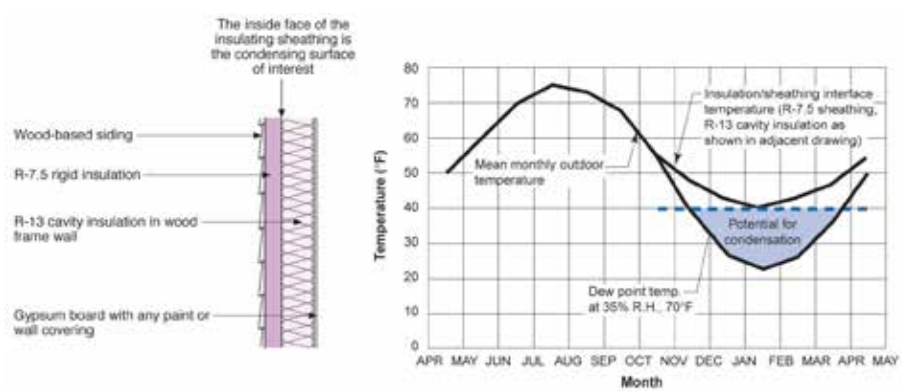

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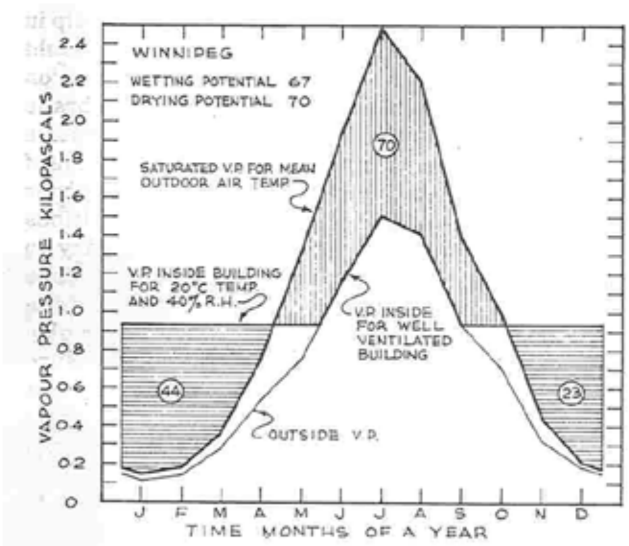
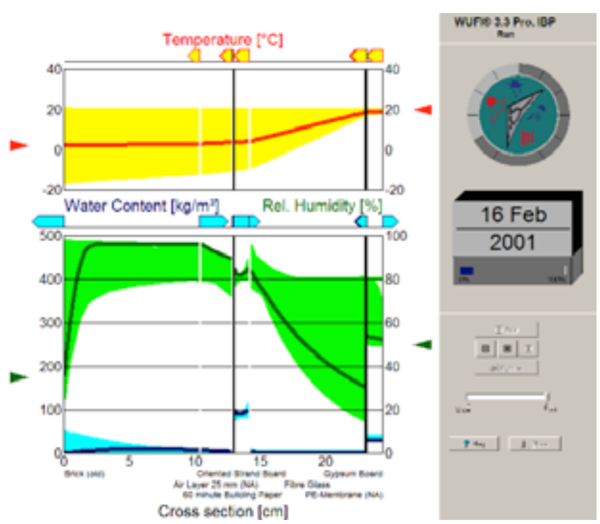


Figure 8-7. Outside vapour pressure, saturated vapour pressure and inside vapour pressure for Winnipeg.

61



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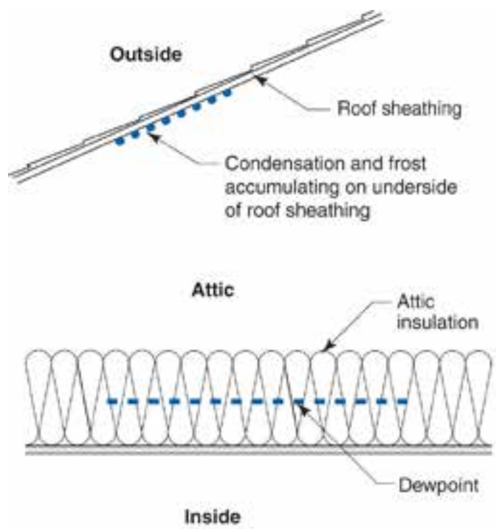

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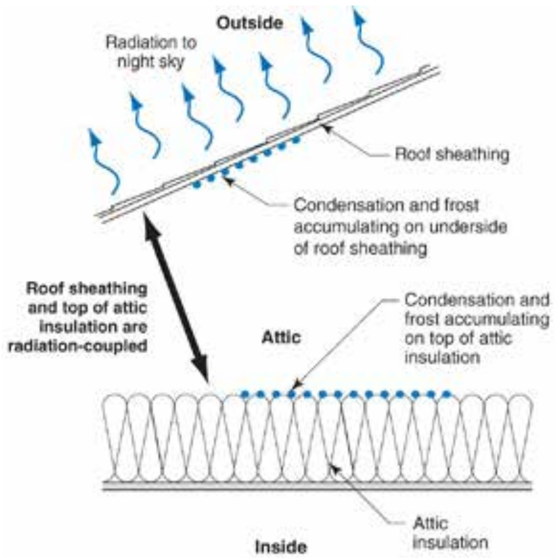

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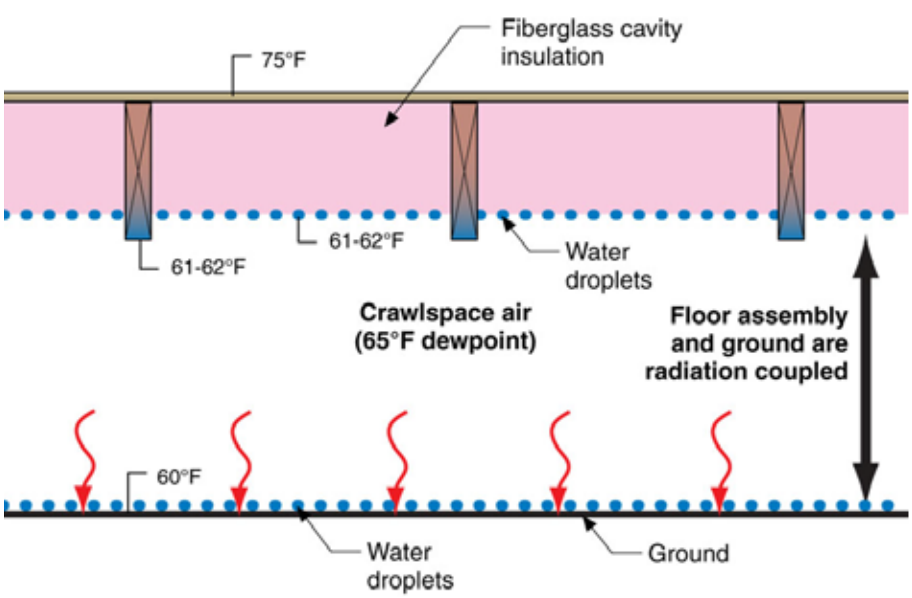

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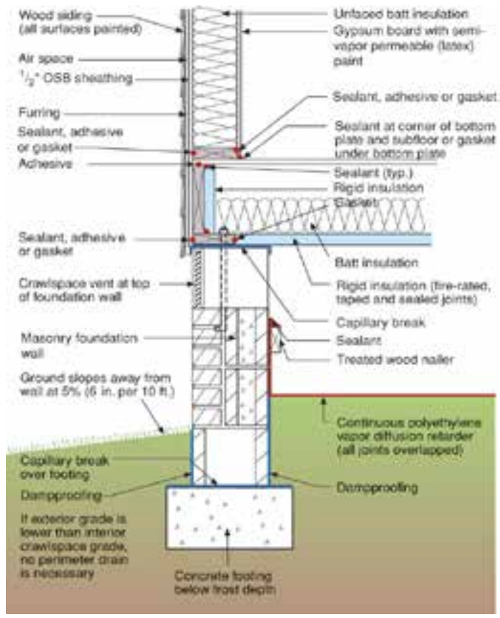

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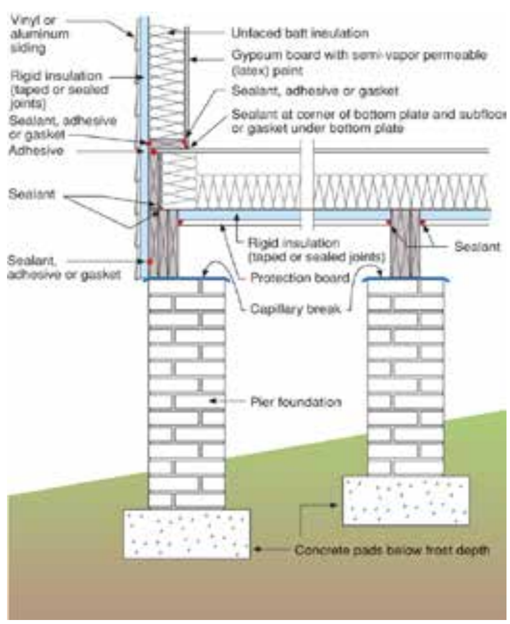

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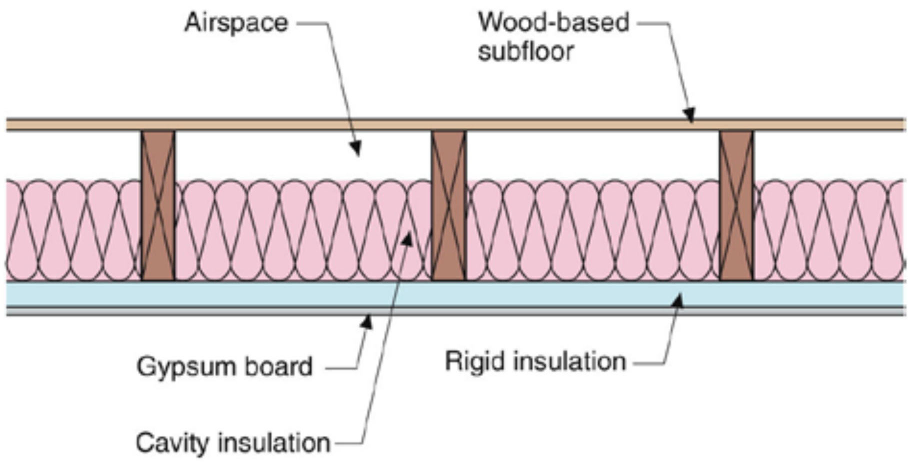

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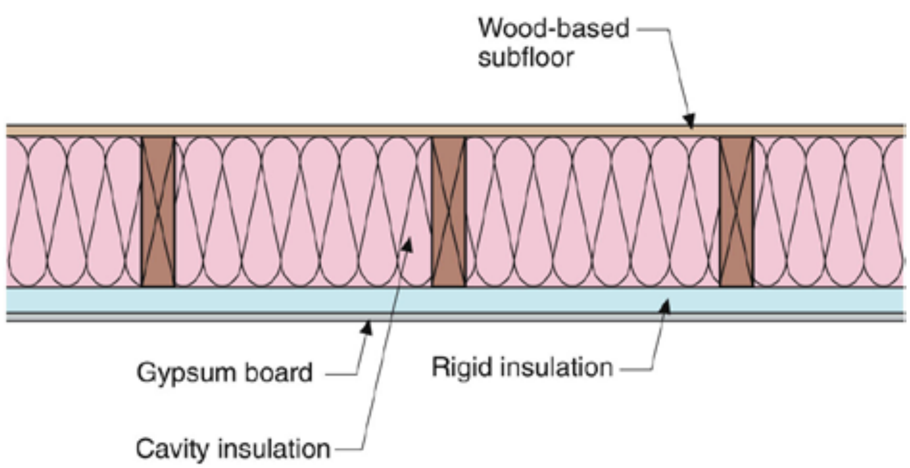

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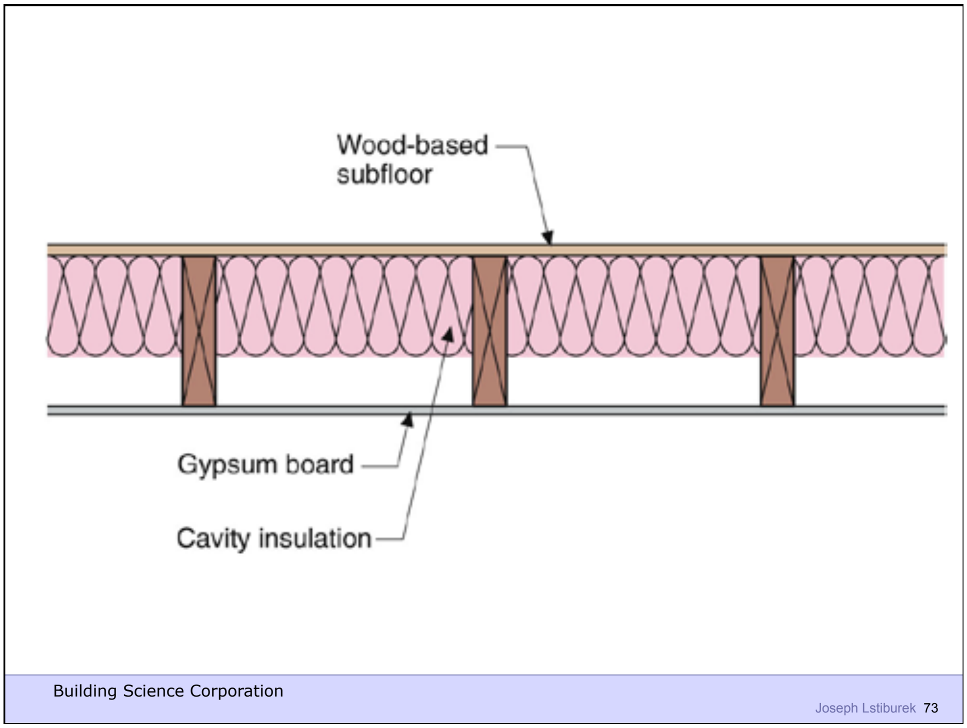
Wood-based
subfloor
Gypsum board
Cavity insulation
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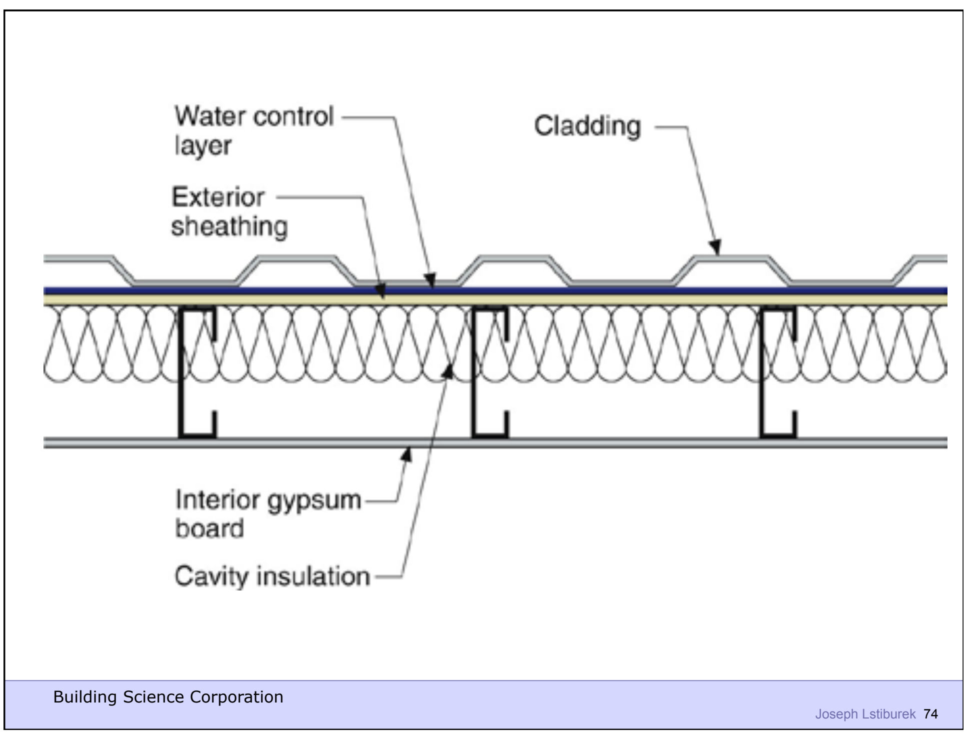
Water control
layer
Cladding
Exterior
sheathing
Interior gypsum
board
Cavity insulation
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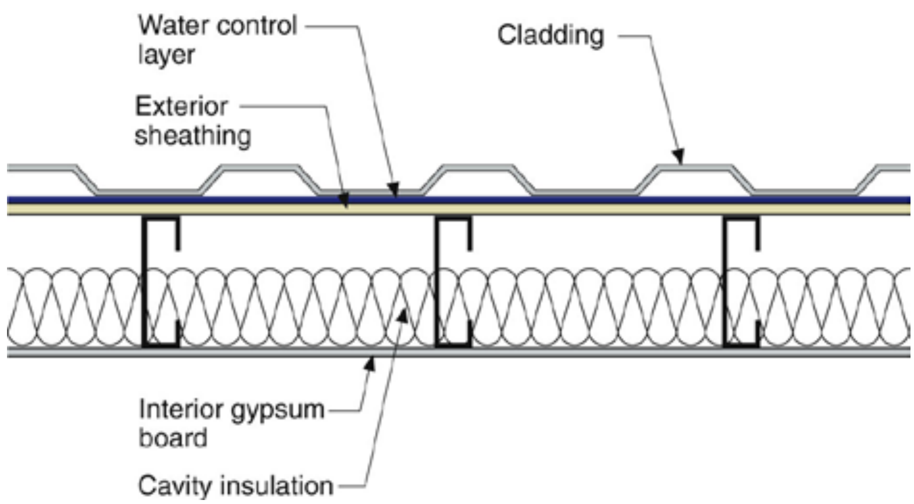

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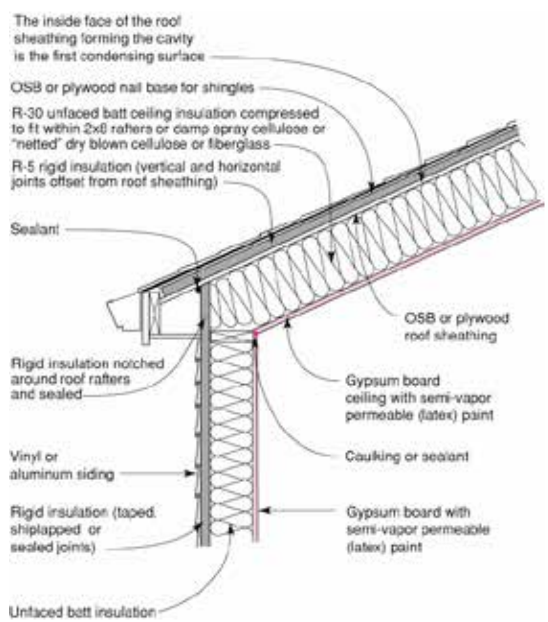

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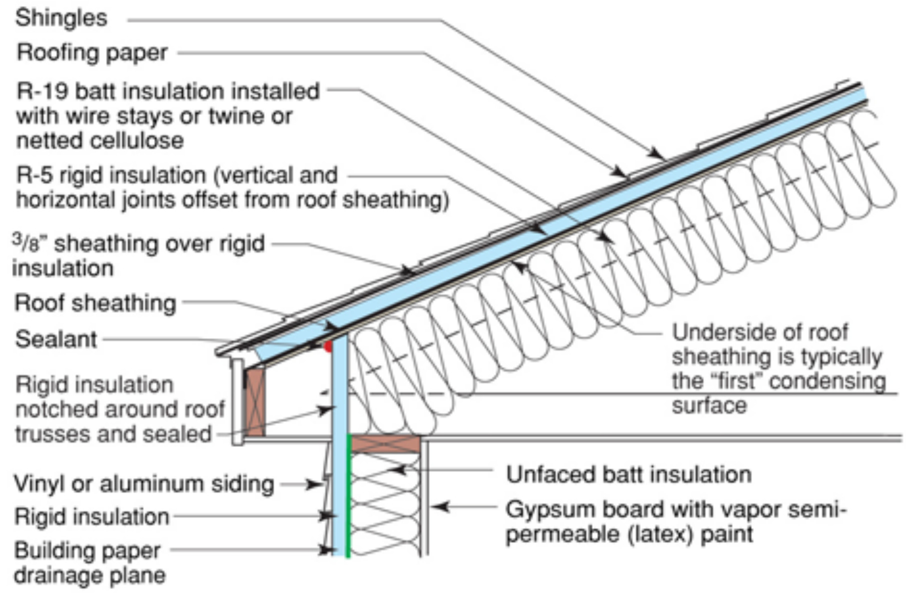

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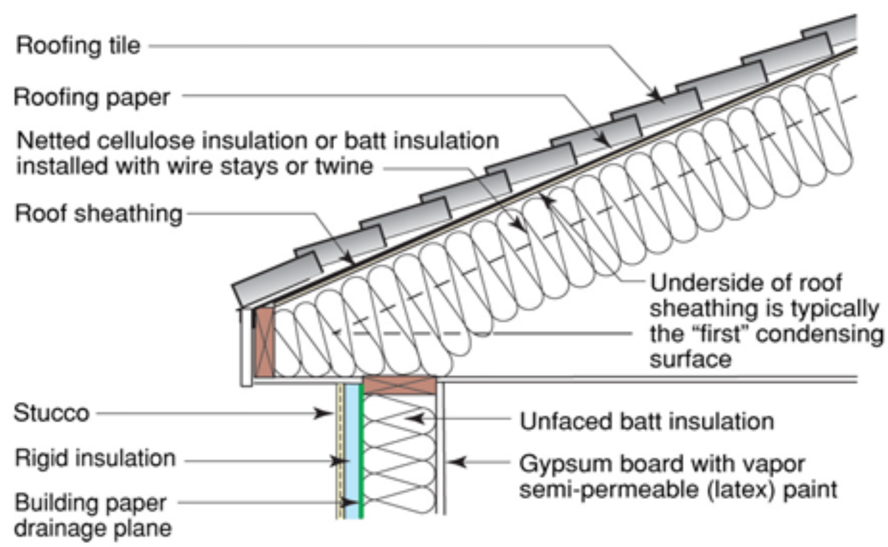

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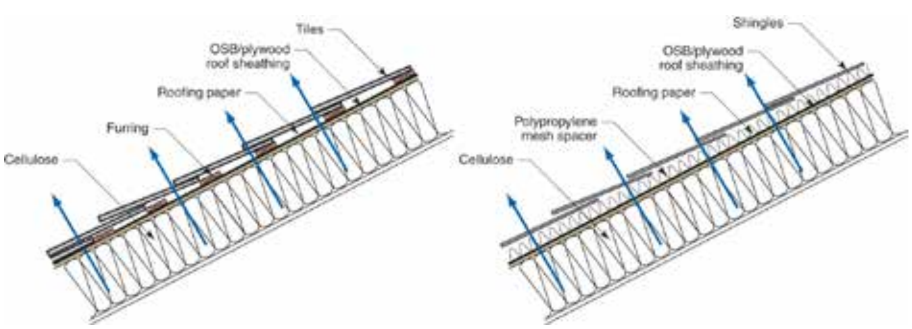

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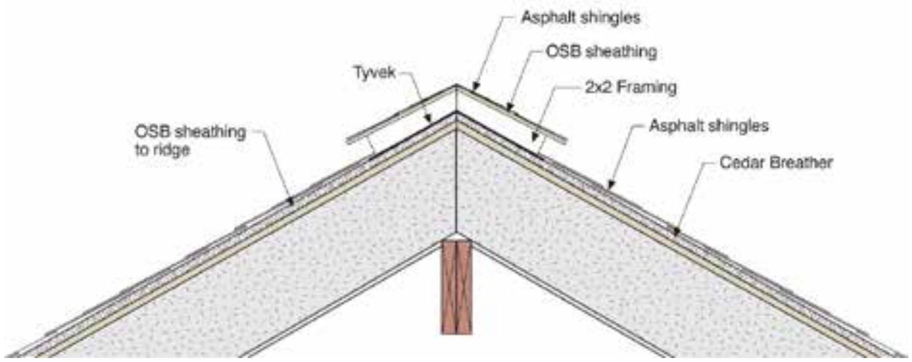

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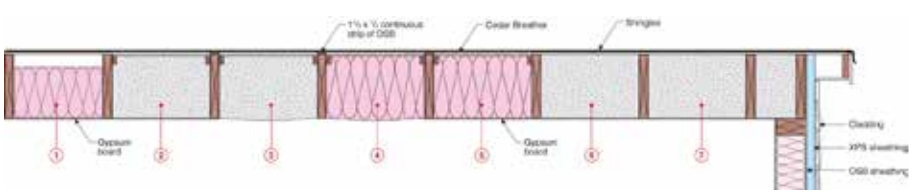

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Joseph Lstiburek 84

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Joseph Lstiburek 85

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Joseph Lstiburek 86

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Joseph Lstiburek 87

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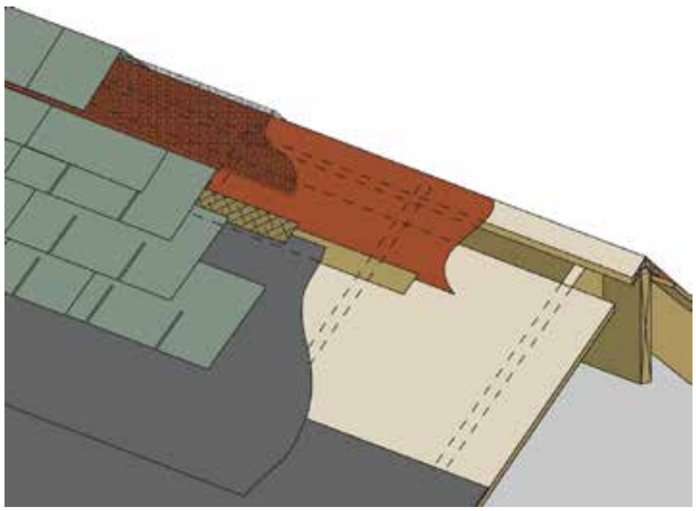
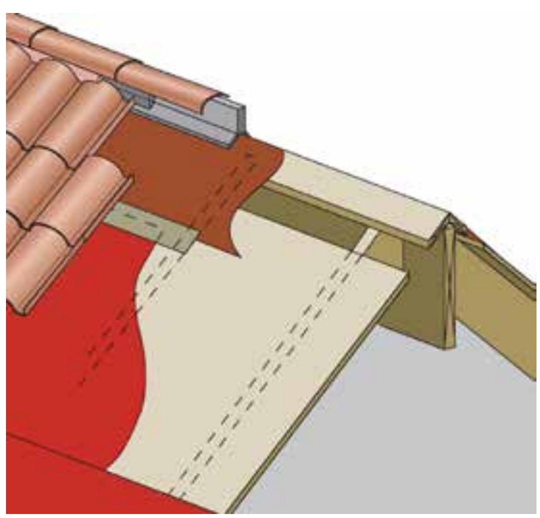
Joseph Lstiburek 88





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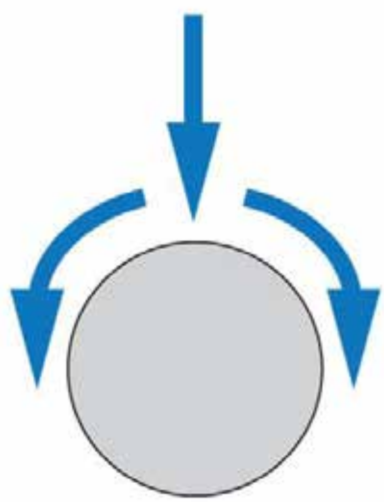

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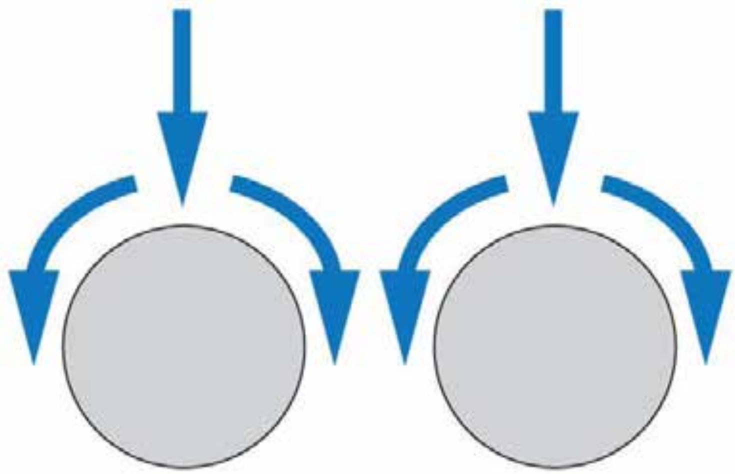

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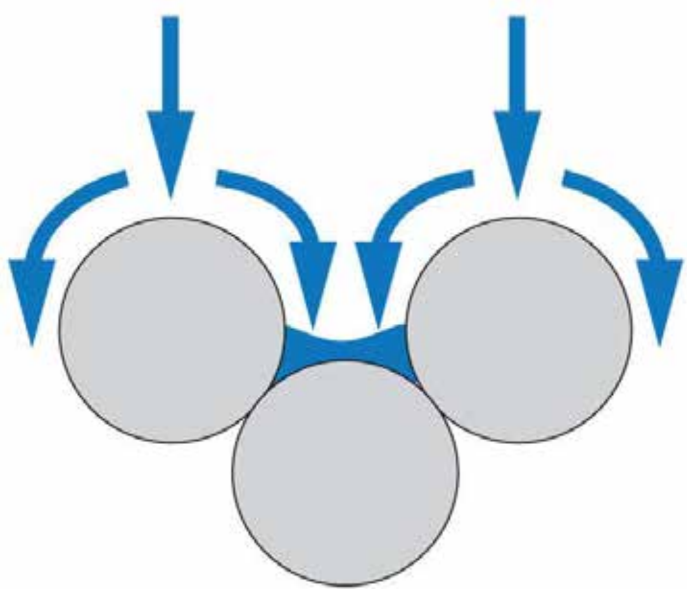

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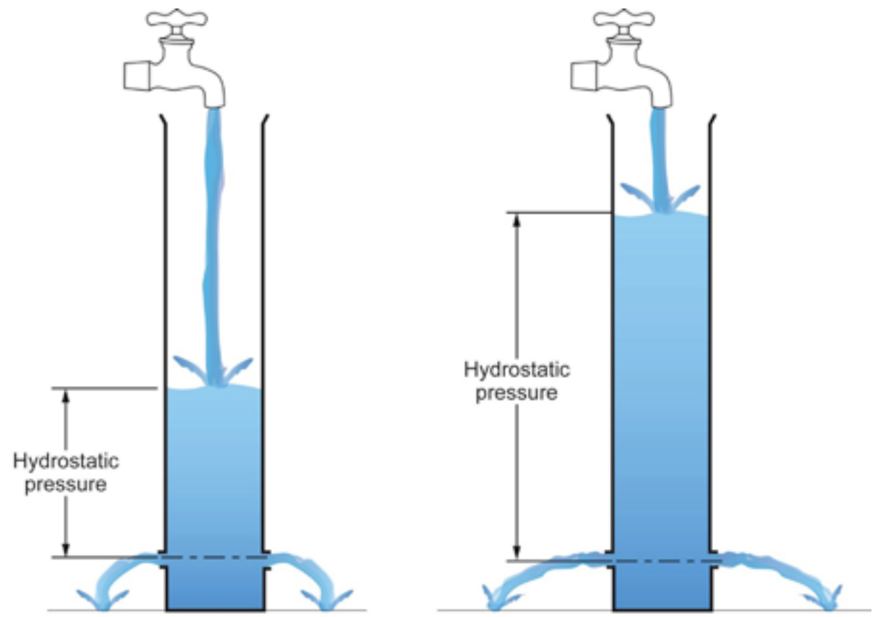

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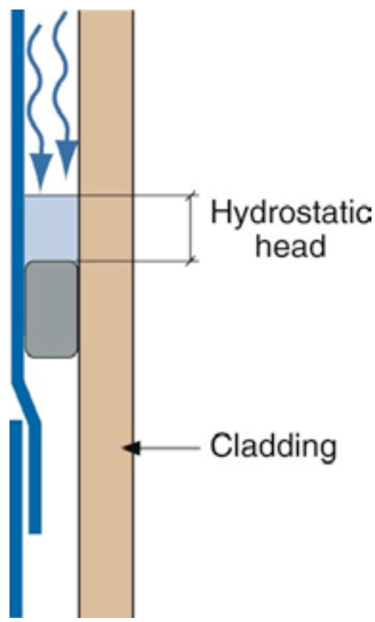

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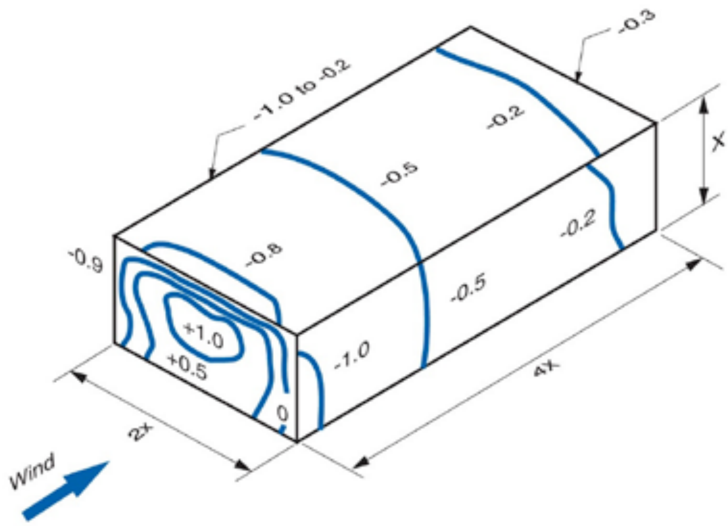

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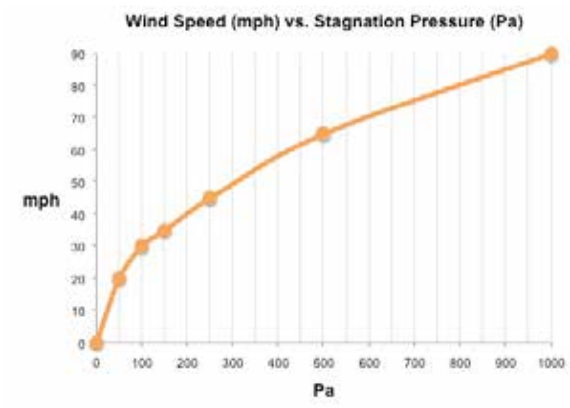
Pascals	mph
50 Pa =	20 mph
100 Pa =	30 mph
150 Pa =	35 mph
250 Pa =	45 mph
500 Pa =	65 mph
1,000 Pa =	90 mph



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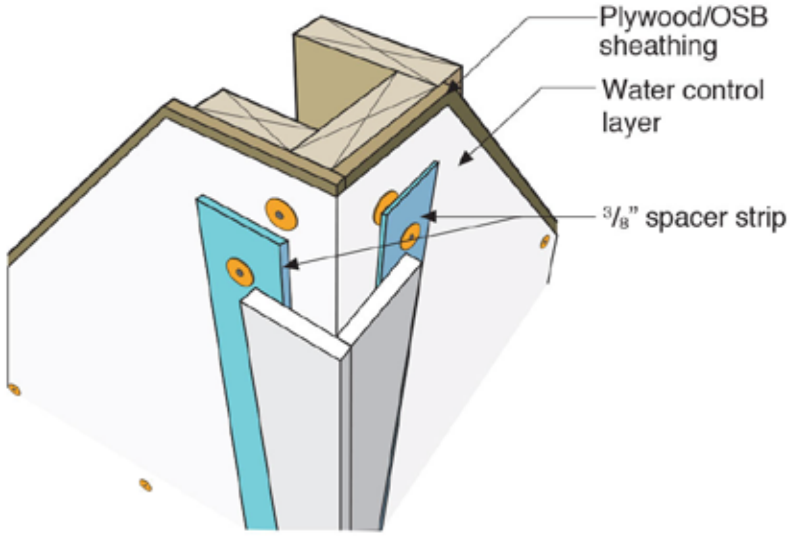
Joseph Lstiburek – Rain Control 101



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Joseph Lstiburek 102

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Joseph Lstiburek 103

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Joseph Lstiburek 104

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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

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Joseph Lstiburek 109

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Joseph Lstiburek 110

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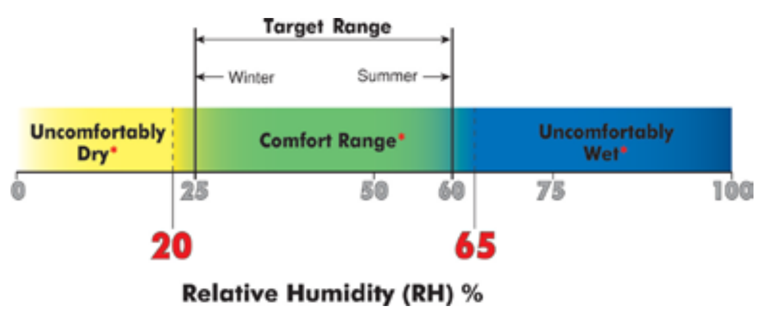
Joseph Lstiburek 111



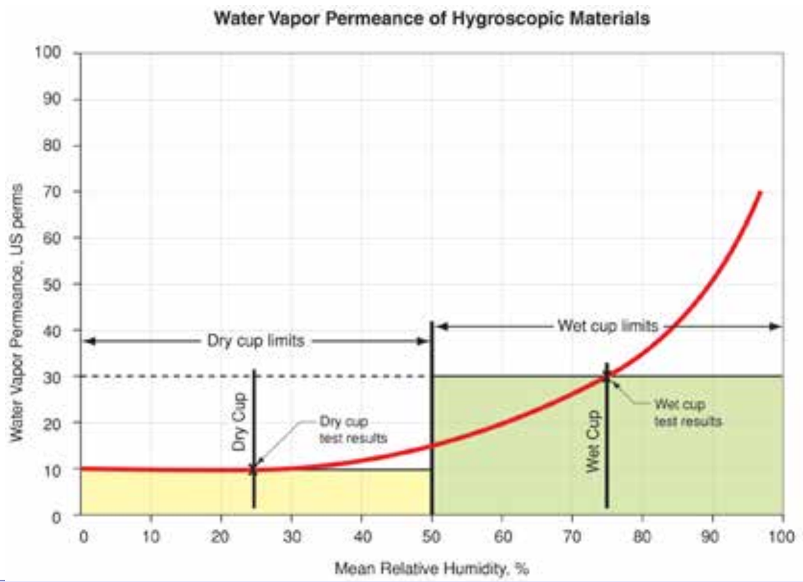
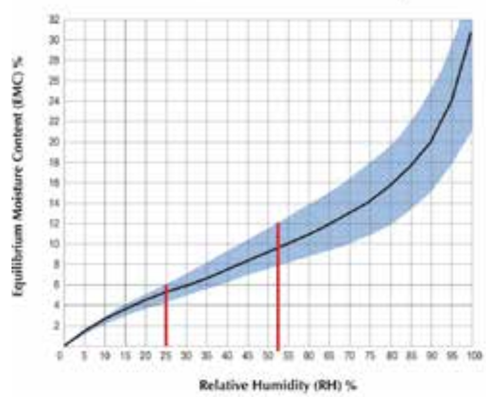
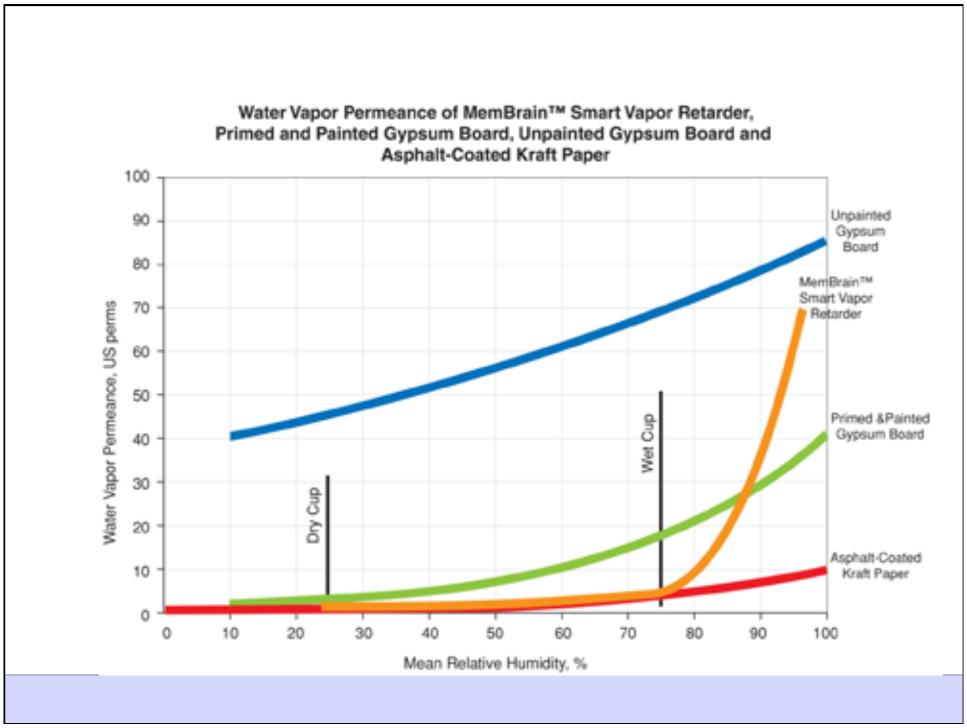


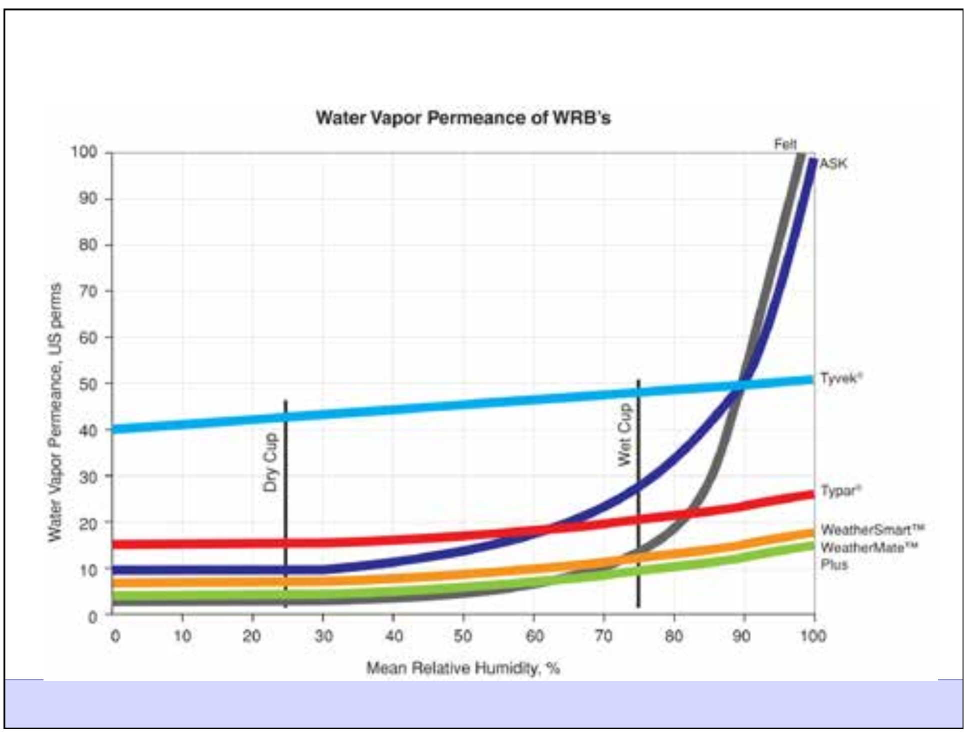
Figure 2
Moisture Content vs. Relative Humidity

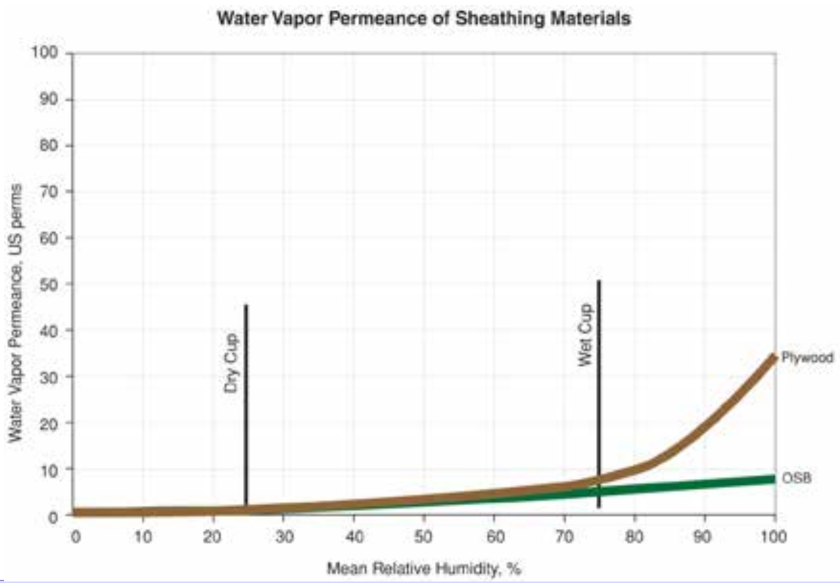


The amount of bound water in wood is determined by the relative humidity (RH) of the surrounding atmosphere; the amount of bound water changes (albeit slowly) as the relative humidity changes. The moisture content of wood, when a balance is established at a given relative humidity, is its equilibrium moisture content (EMC). The solid line represents the curve for white spruce, a typical species with fiber saturation point (FSP) around 30% EMC. For species with a high extractive content, such as mahogany, FSP is around 24%, and for those with low extractive content, such as birch, FSP may be as high as 35%. Although a precise curve cannot be drawn for each species, most will fall within the color band.


R-11 3½"
OWENS-CORNING
Fiberglas
Building
Insulation


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, %
Unpainted Gypsum Board
MemBrain™ Smart Vapor Retarder
Primed &Painted Gypsum Board
Asphalt-Coated Kraft Paper
Dry Cup
Wet Cup


Water Vapor Permeance of WRB's
Water Vapor Permeance, US perms
Mean Relative Humidity, %
Felt
ASK
Tyvek®
Typar®
WeatherSmart™
WeatherMate™ Plus
Dry Cup
Wet Cup



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Joseph Lstiburek 122

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Joseph Lstiburek 123

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Joseph Lstiburek 124

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Joseph Lstiburek 125

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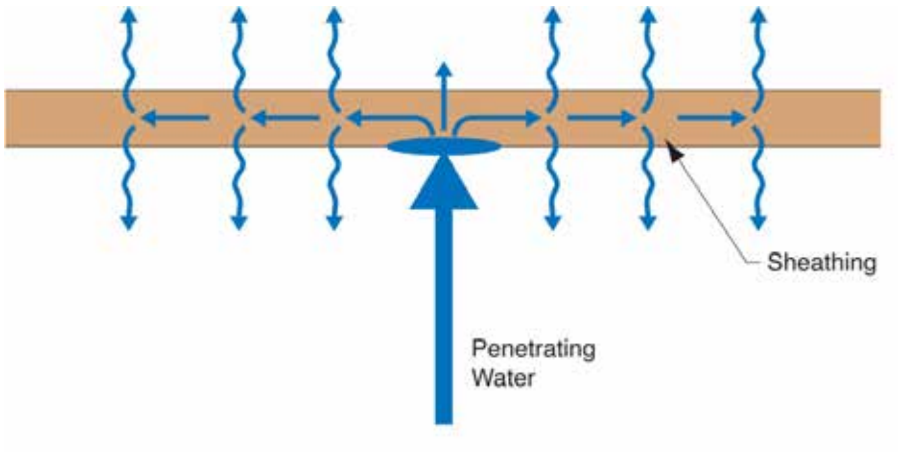
Joseph Lstiburek 126



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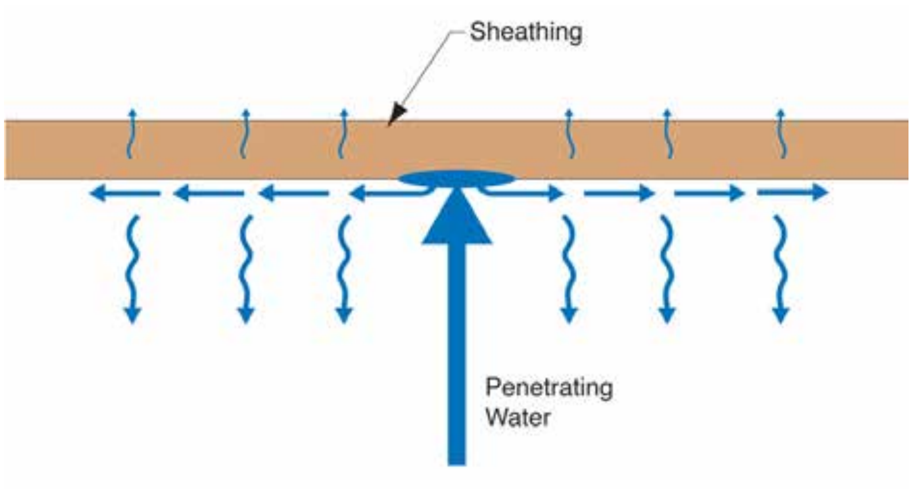

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Joseph Lstiburek – Rain Control 129

Rain Screen

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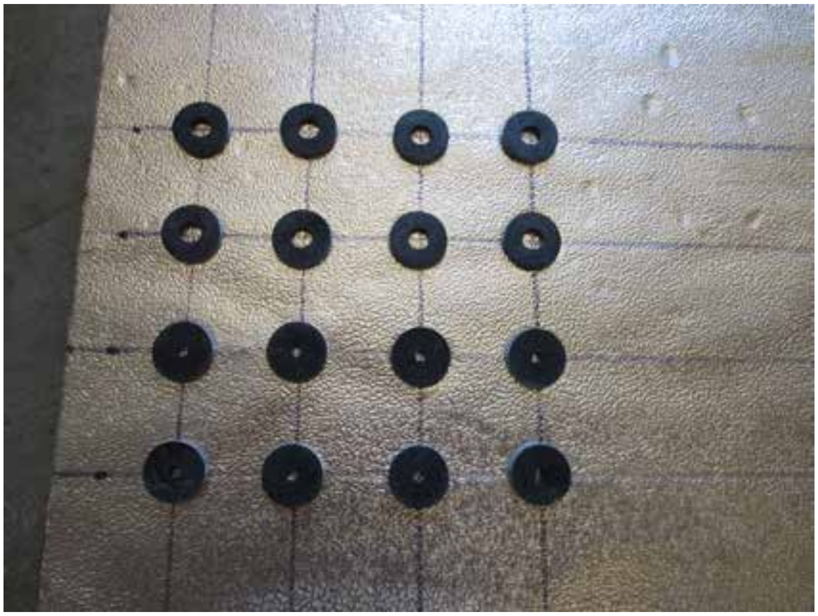
Joseph Lstiburek 130



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Beer Screen?

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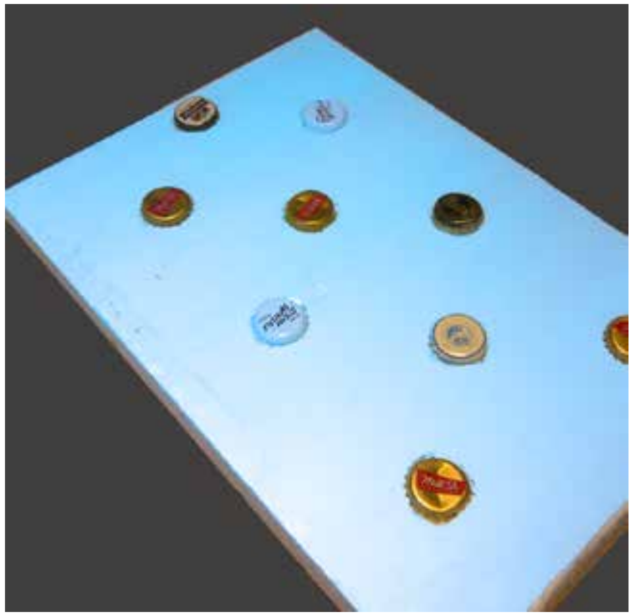
Joseph Lstiburek 132



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Joseph Lstiburek 134

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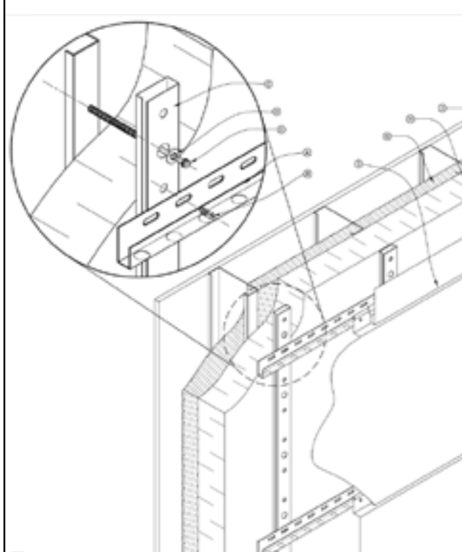
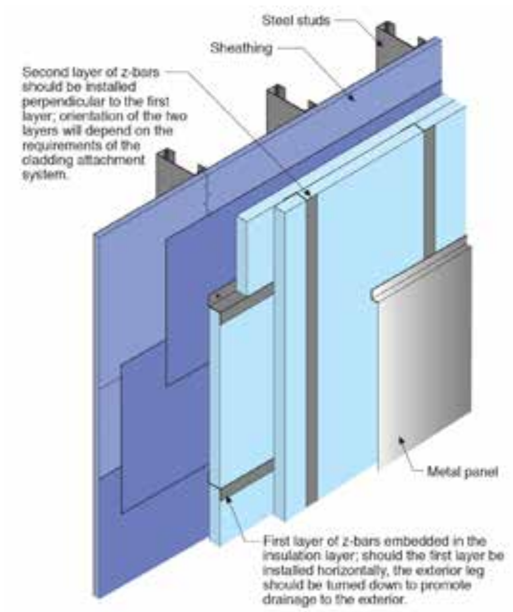
2010

Joseph Lstiburek 135





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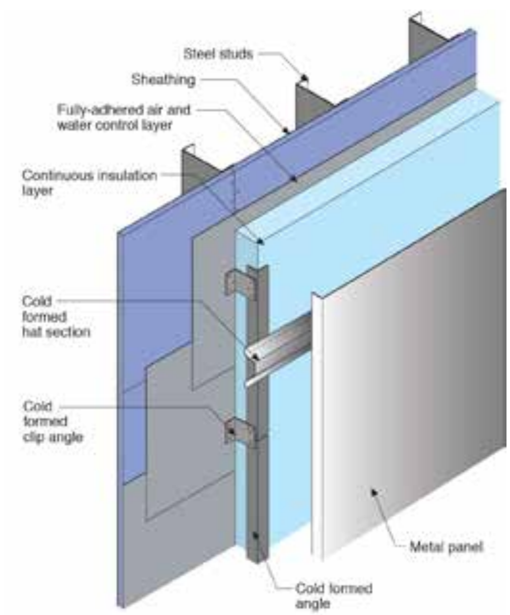

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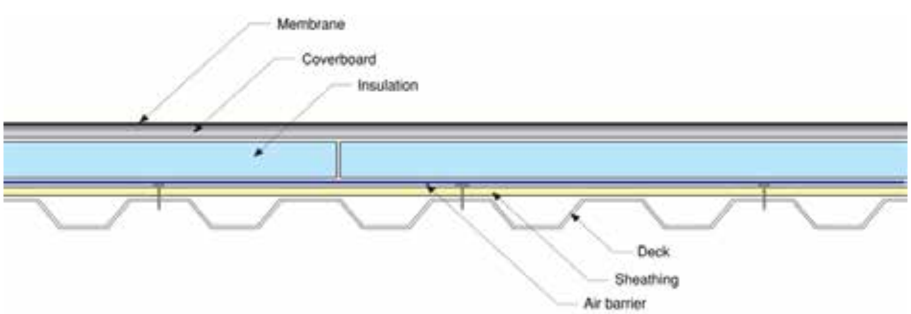
Joseph Lstiburek 139



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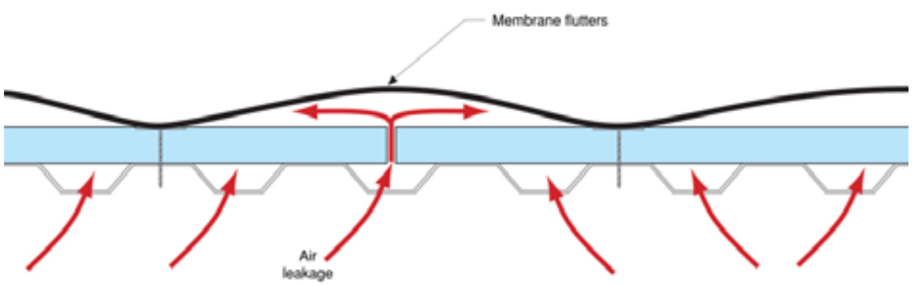
Joseph Lstiburek 141



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Joseph Lstiburek 143

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Joseph Lstiburek 144

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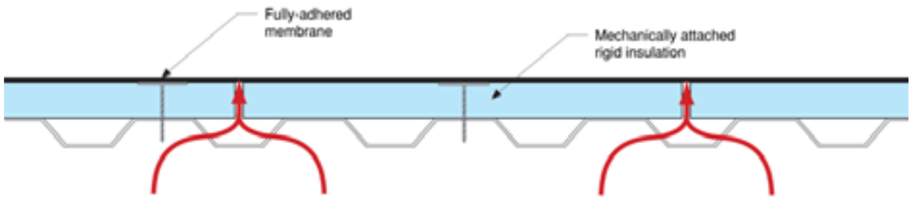
Joseph Lstiburek 145

Building Science Corporation

Joseph Lstiburek 146



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Joseph Lstiburek 148

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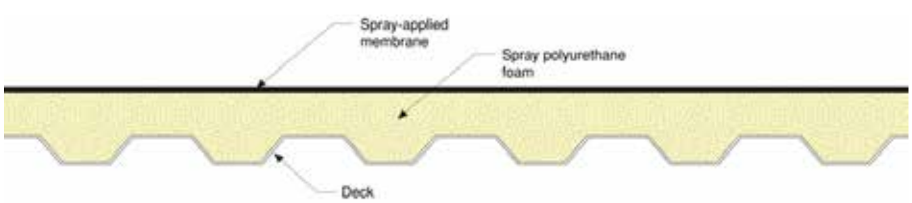
Joseph Lstiburek 149



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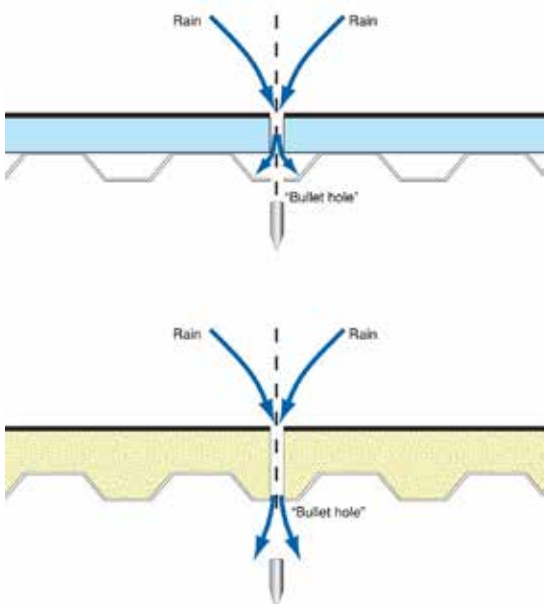
Joseph Lstiburek 151



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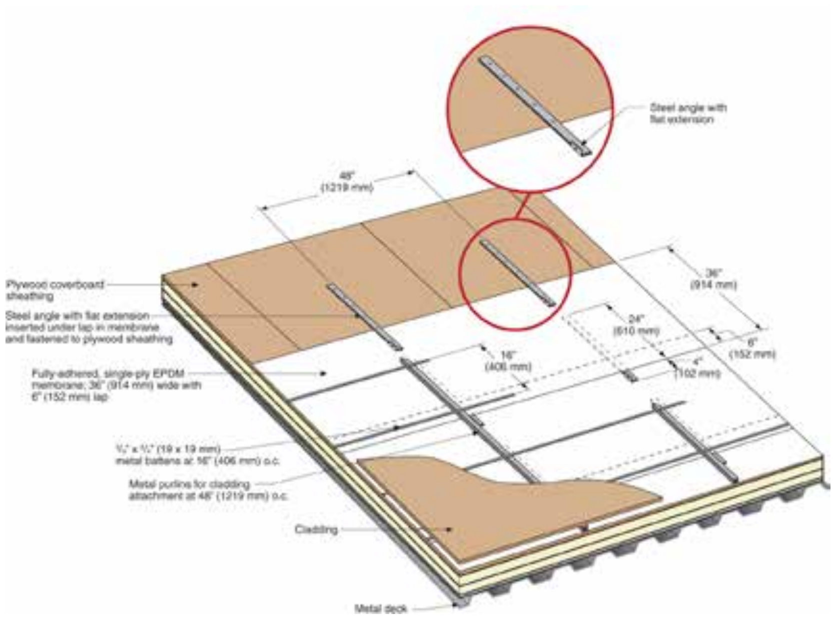
Joseph Lstiburek 153

Building Science Corporation

Joseph Lstiburek 154



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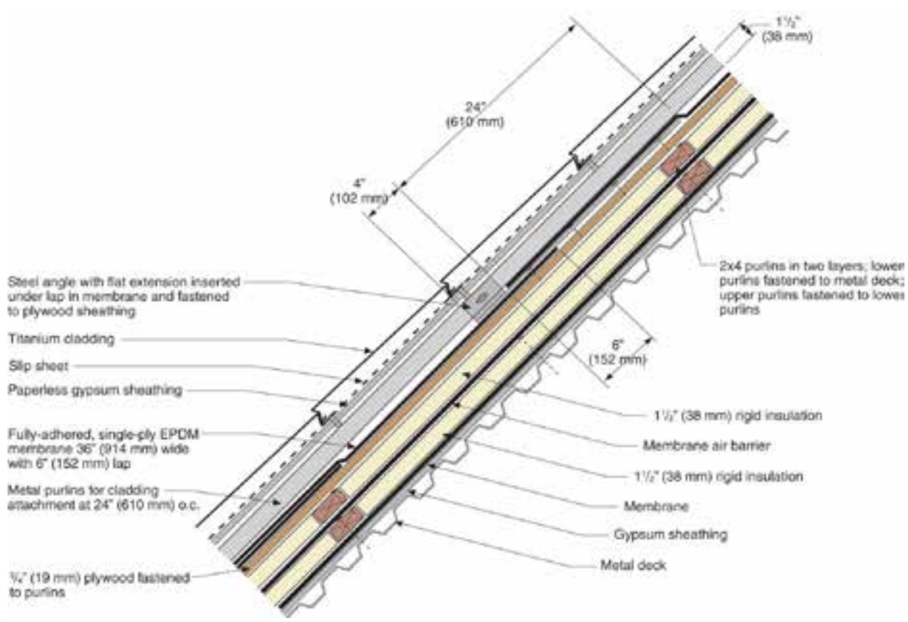
Joseph Lstiburek 155



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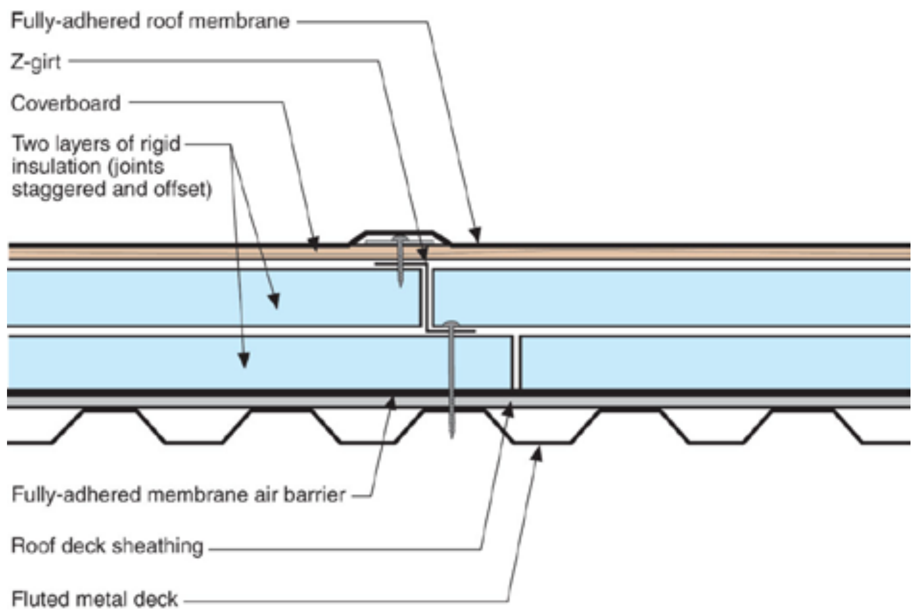
Joseph Lstiburek 156



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Building Science Corporation

Joseph Lstiburek 158

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Joseph Lstiburek 159

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Joseph Lstiburek 160

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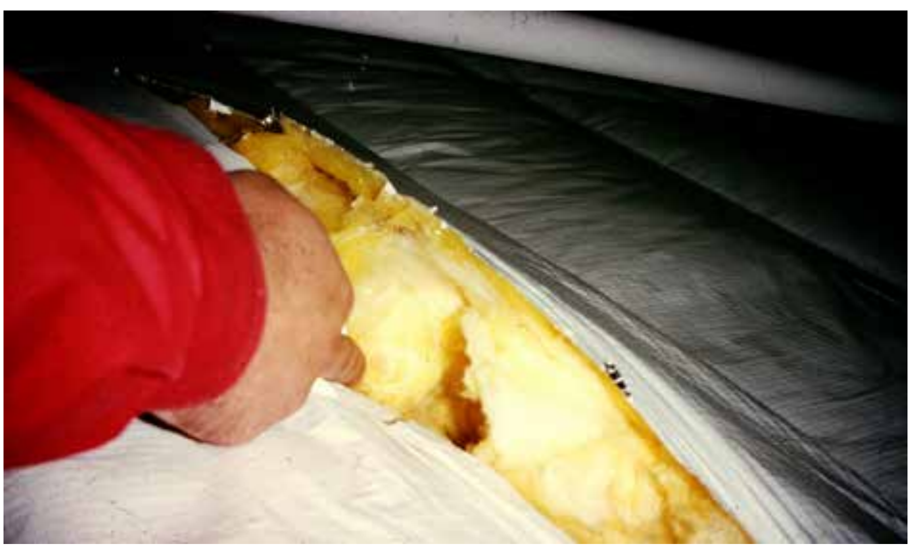
Joseph Lstiburek 161



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Joseph Lstiburek 164

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Joseph Lstiburek 165

Building Science Corporation

Joseph Lstiburek 166

Building Science Corporation

Joseph Lstiburek 167

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Building Science Corporation

Joseph Lstiburek 169

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Joseph Lstiburek 170

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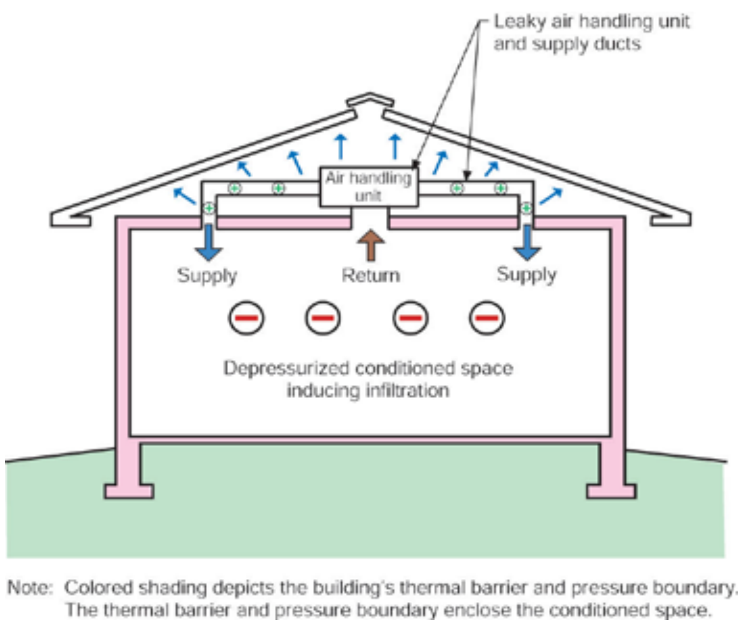
Joseph Lstiburek 171



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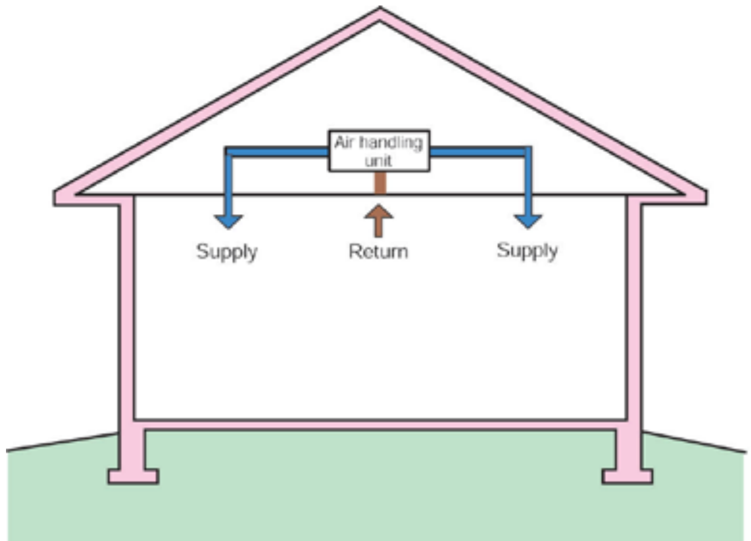

Note: Colored shading depicts the building's thermal barrier and pressure boundary. The thermal barrier and pressure boundary enclose the conditioned space.

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Joseph Lstiburek 178

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Joseph Lstiburek 187

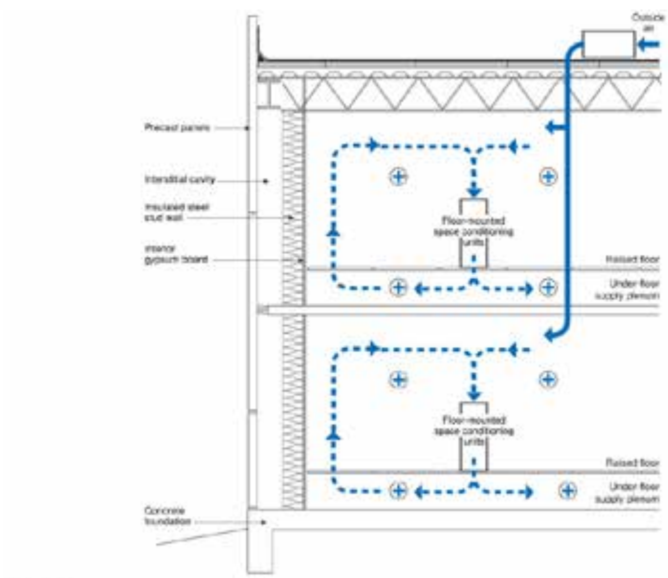

Figure 5.10
HVAC System as Designed

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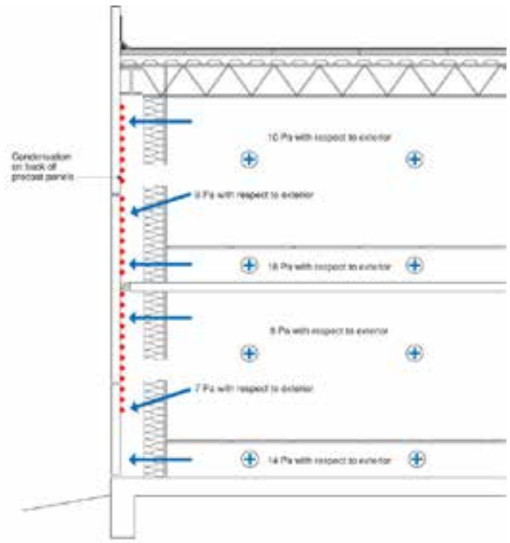

Figure 5.11
Unintended Pressurization of Interstitial Cavity

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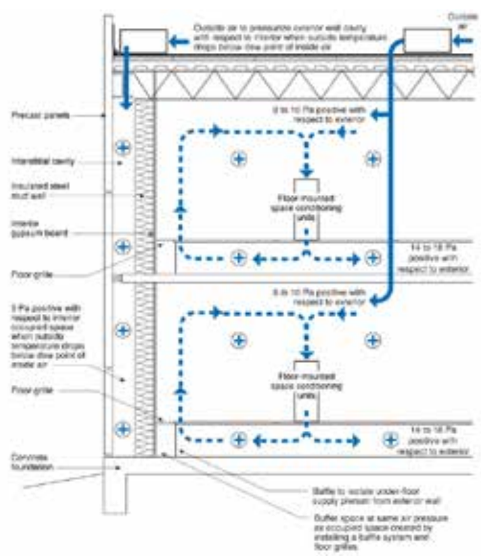

Figure 5.12
Modified Pressure Relationship

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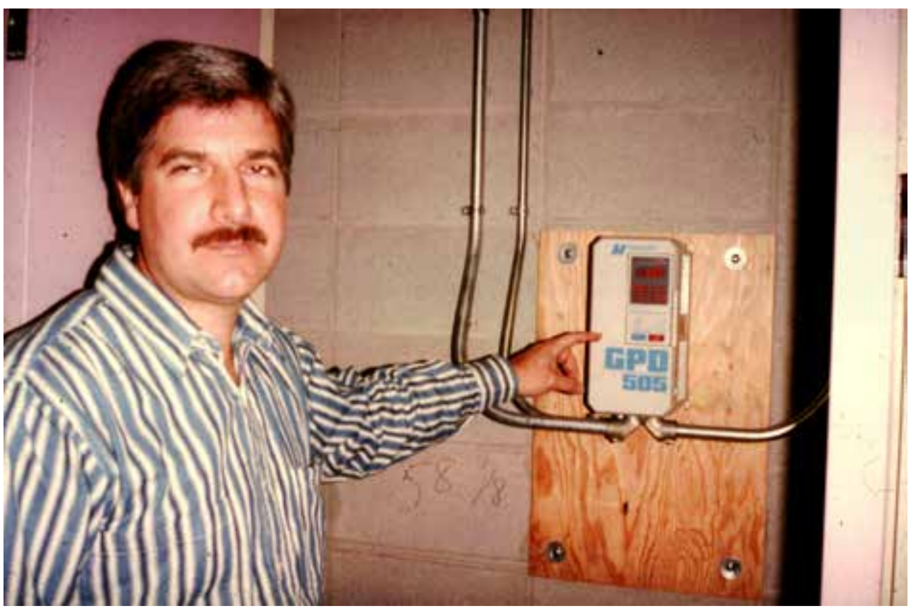

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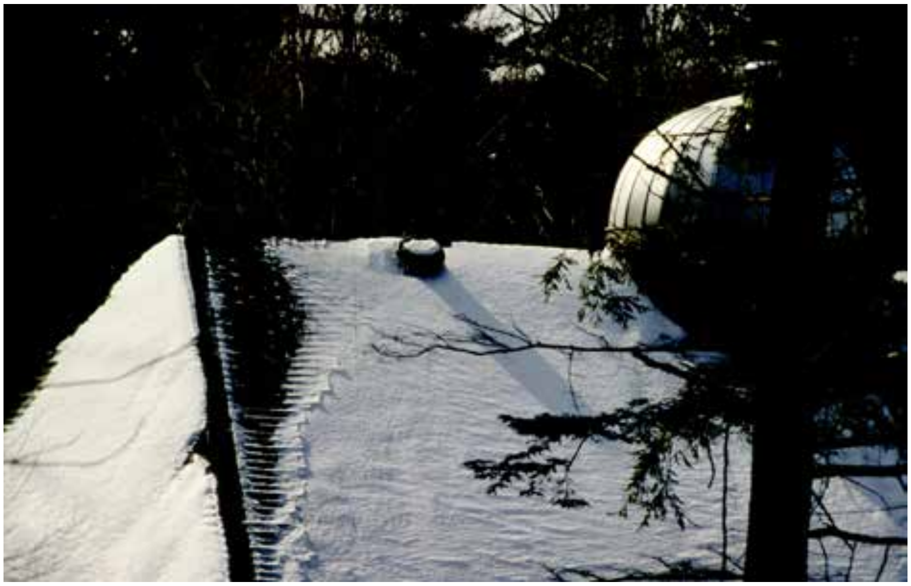
Joseph Lstiburek 193

Building Science Corporation

Joseph Lstiburek 194



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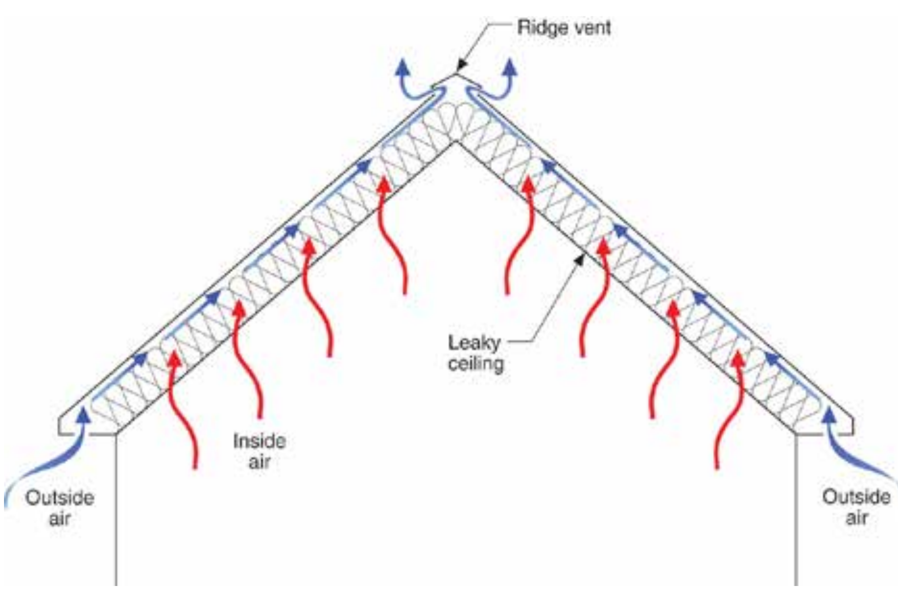

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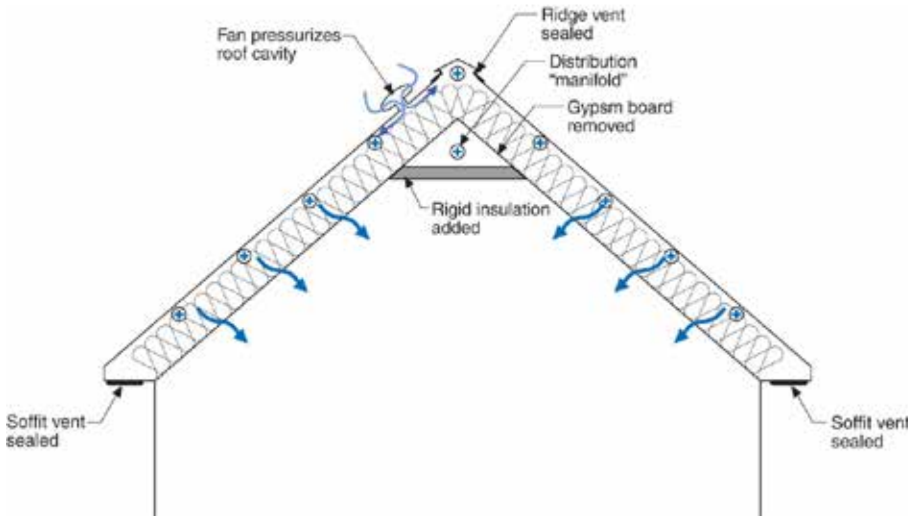

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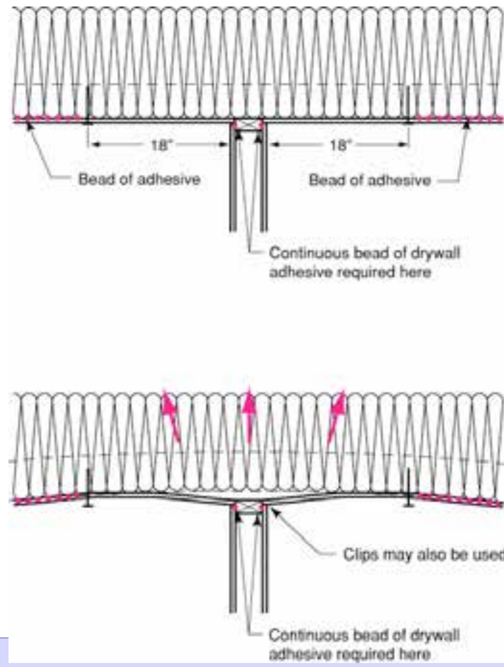
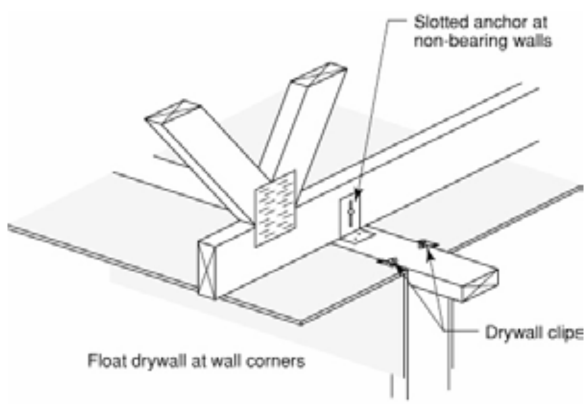

18"
18"
Bead of adhesive
Bead of adhesive
Continuous bead of drywall adhesive required here
Clips may also be used
Continuous bead of drywall adhesive required here


Slotted anchor at non-bearing walls
Drywall clips
Float drywall at wall corners

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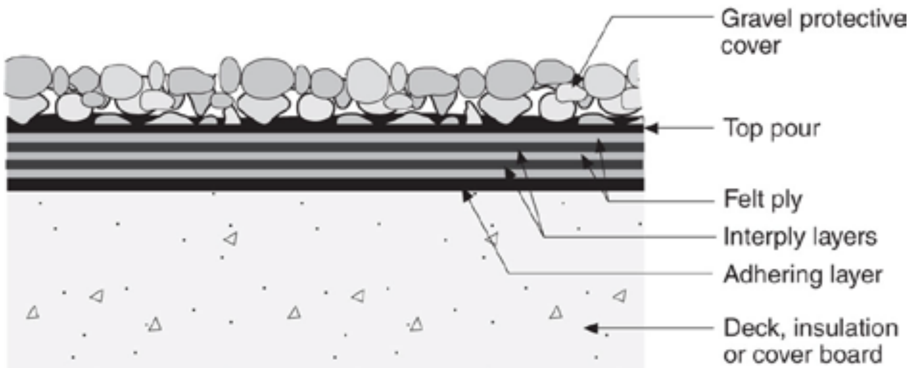

From Baker, M.; Roofs, 1980

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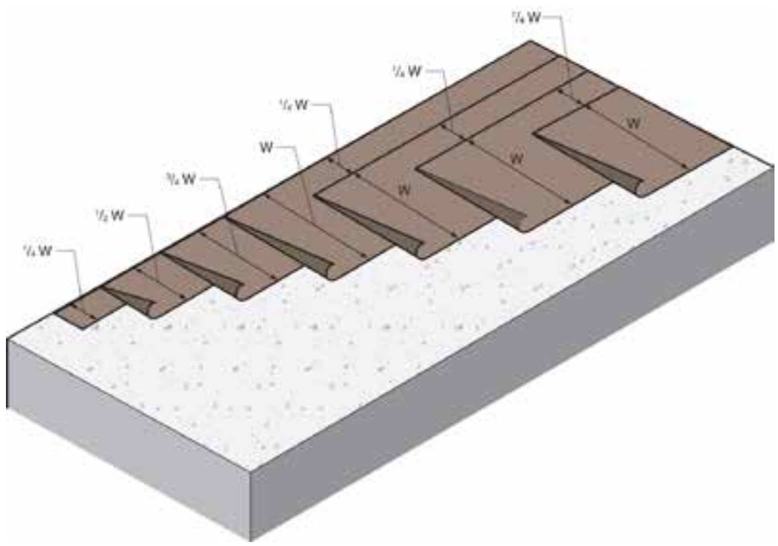

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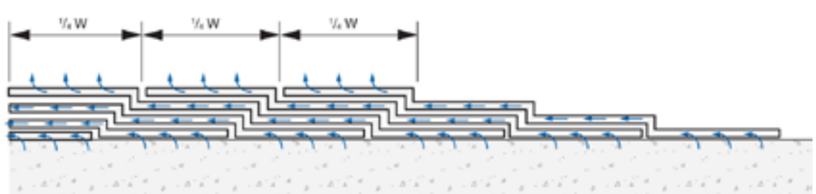

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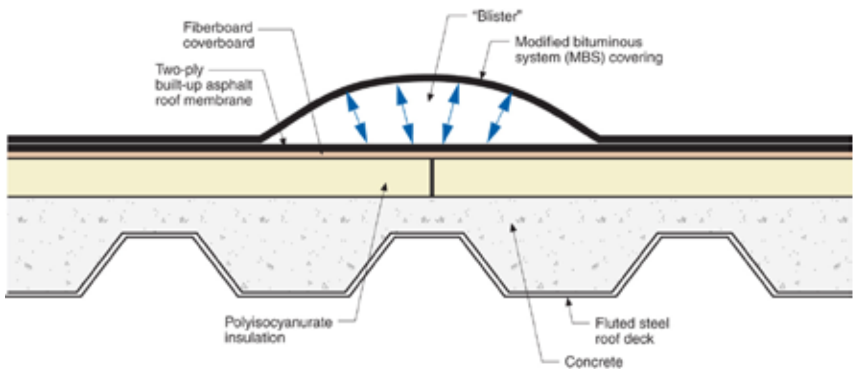
Joseph Lstiburek 210



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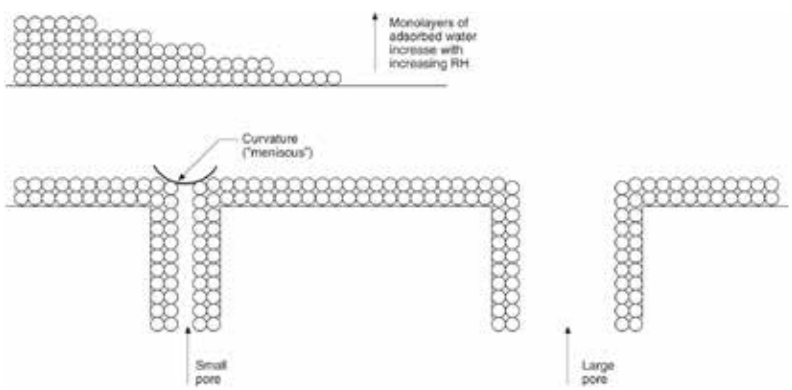

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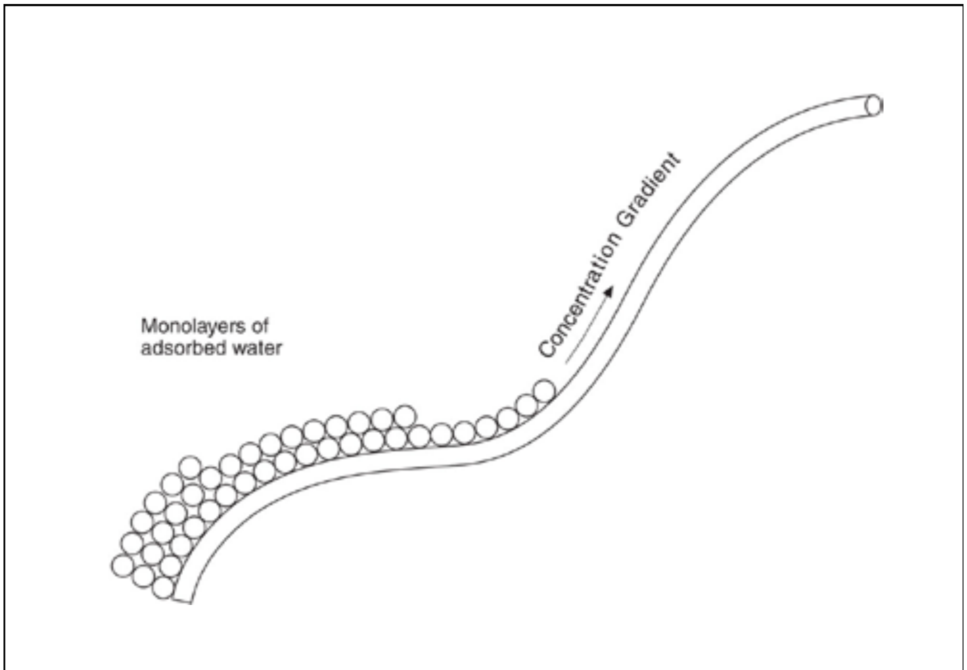

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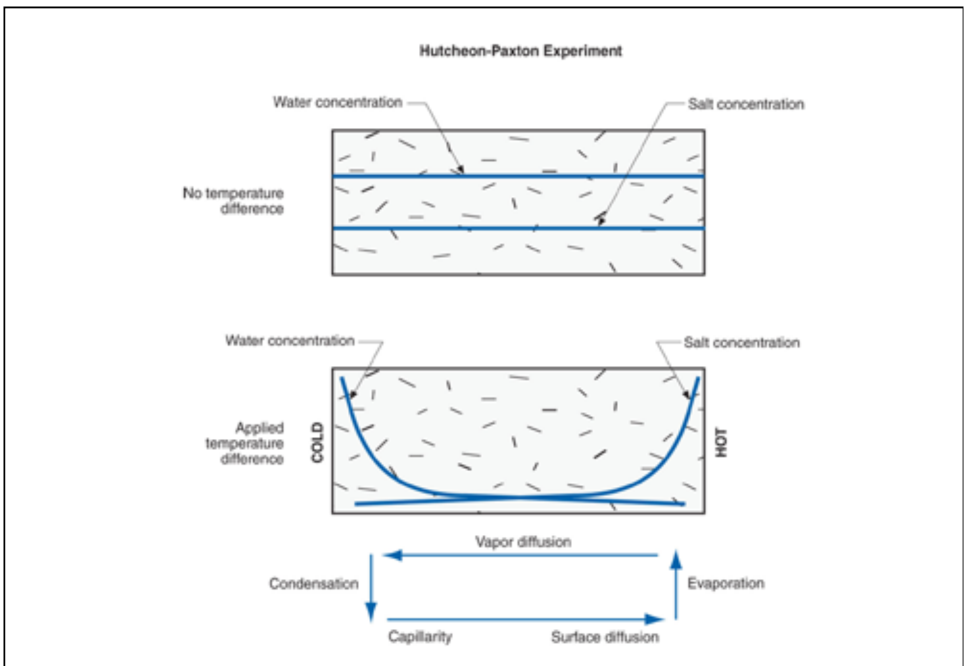

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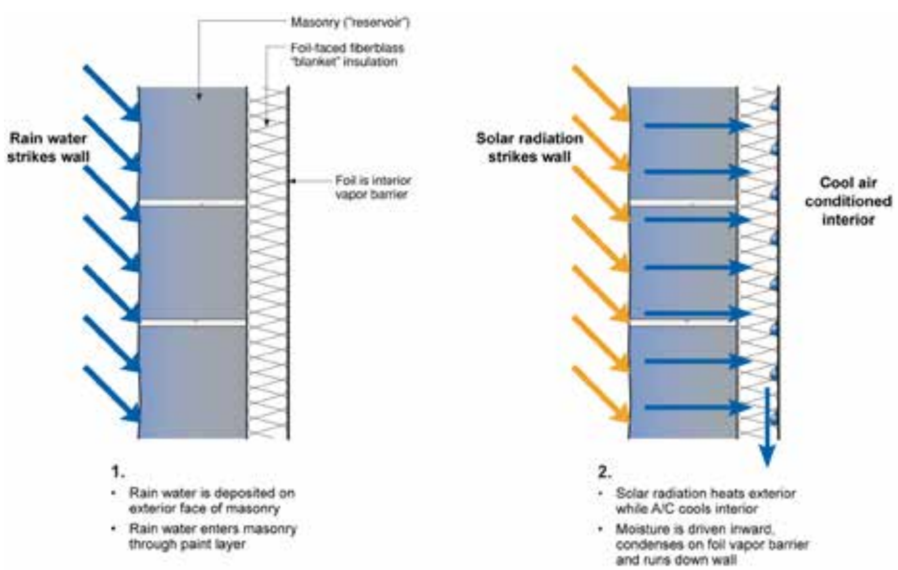
Joseph Lstiburek 215

Building Science Corporation

Joseph Lstiburek 216

Building Science Corporation

Joseph Lstiburek 217



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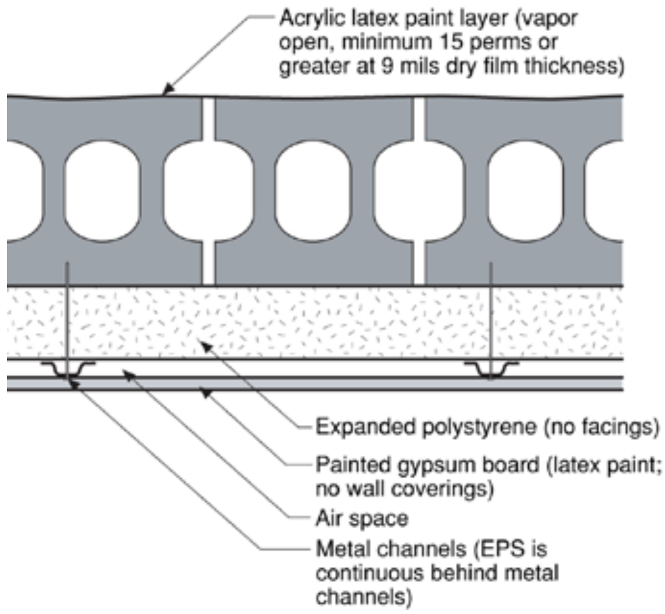

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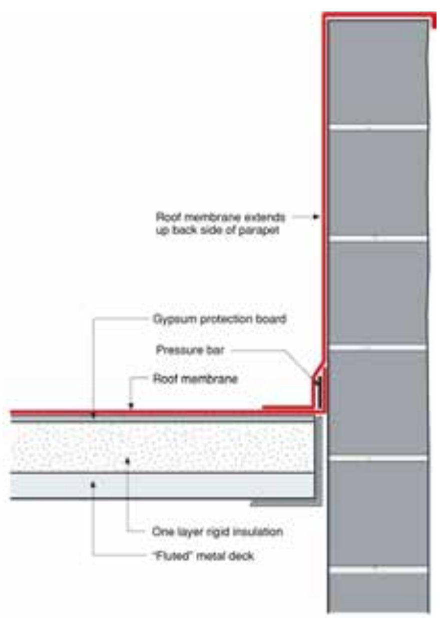

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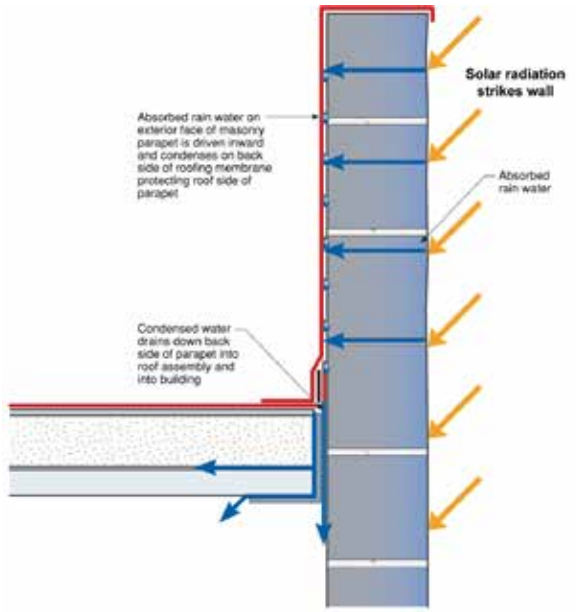

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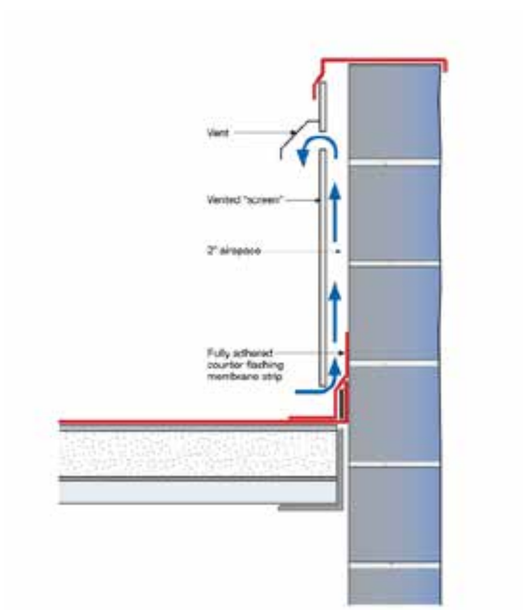
Joseph Lstiburek 221



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