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

Building Science

Adventures In Building Science

www.buildingscience.com

Buildings Get Wet From The Outside

Buildings Get Wet From The Inside

Buildings Start Out Wet

Wet Happens

Buildings Must Be Designed To Dry

Buildings Can Dry To The Outside

Buildings Can Dry To The Inside

Buildings Can Dry To Both Sides

2nd Law of Thermodynamics

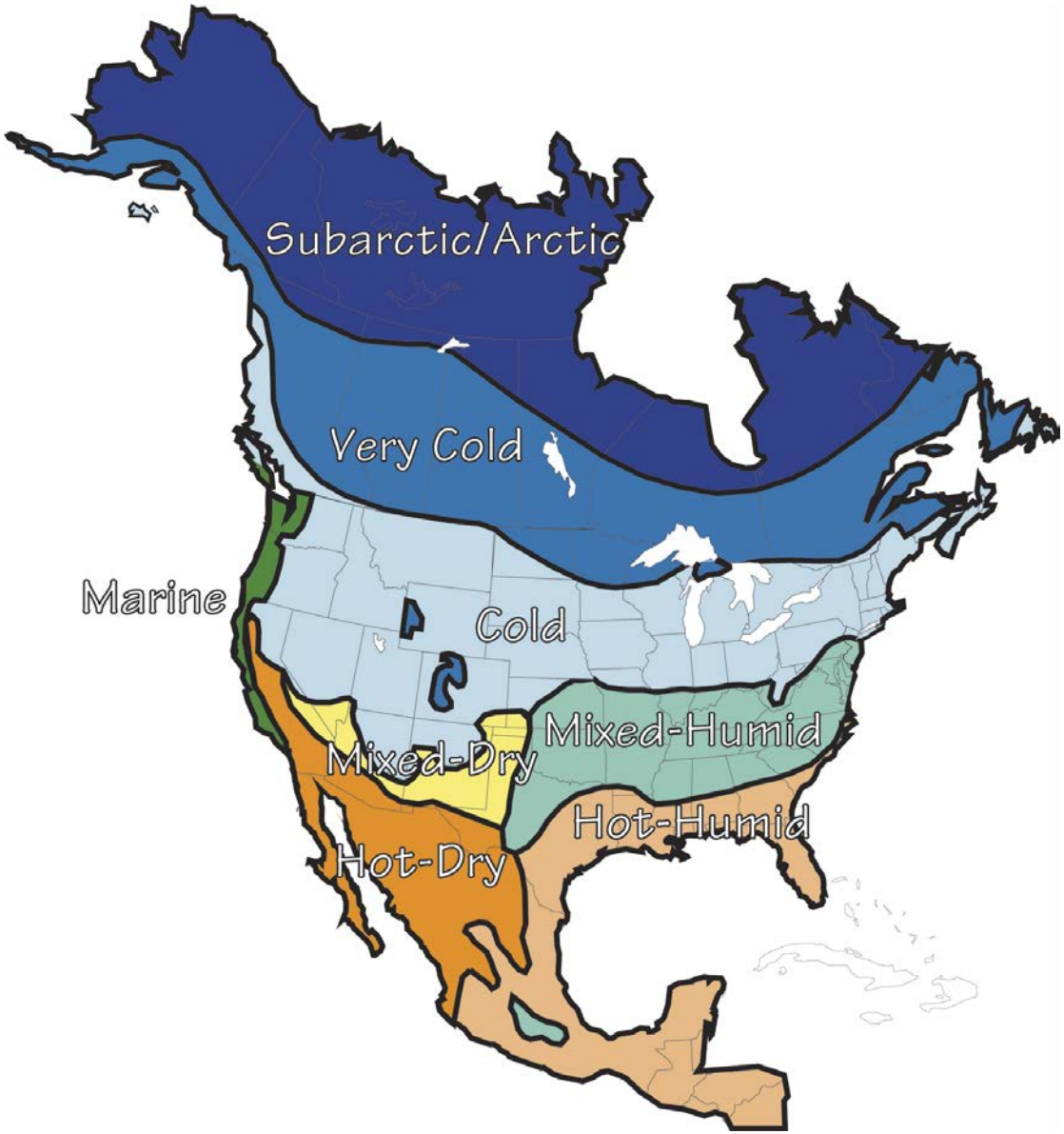
Heat Flow Is From Warm To Cold

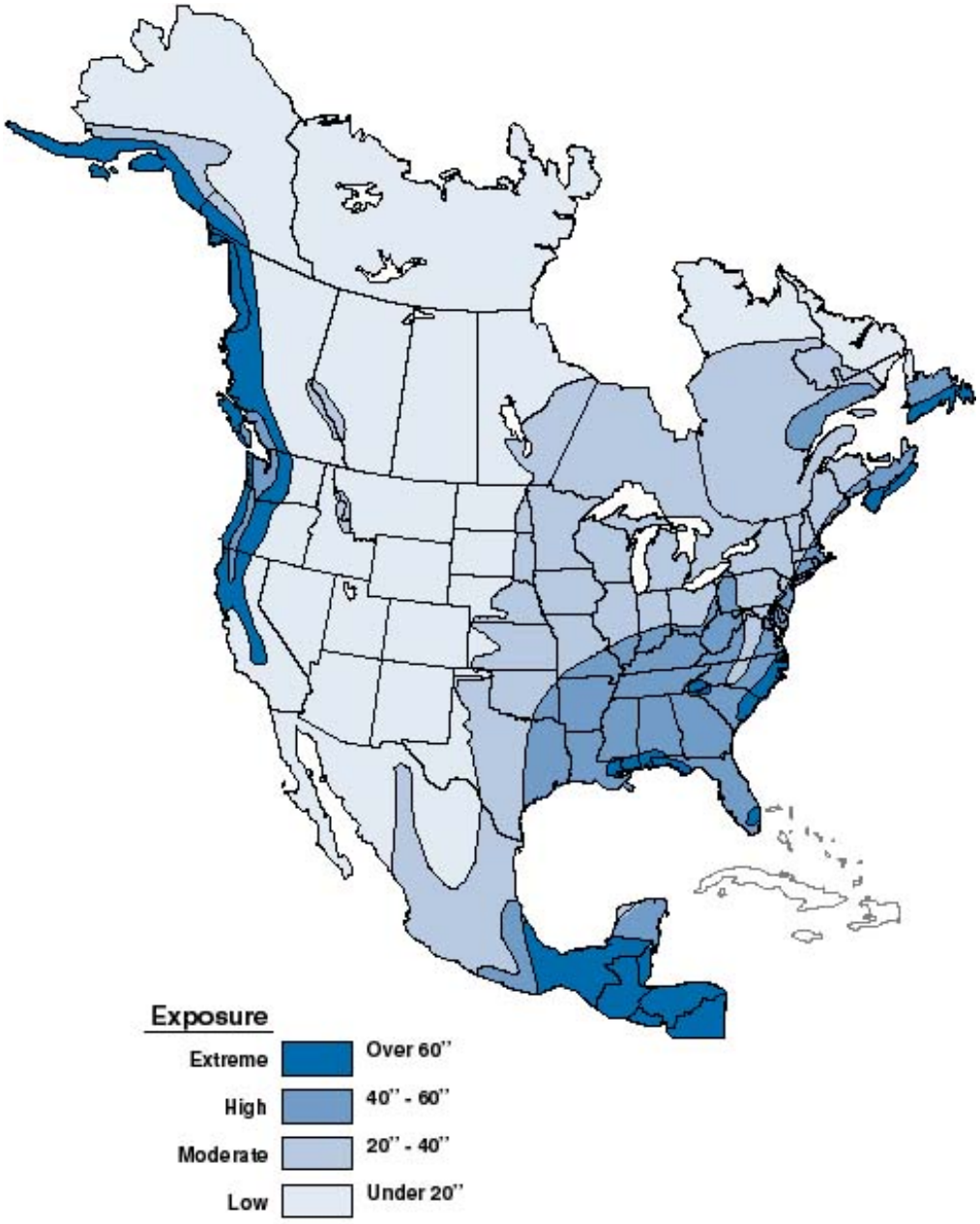
Moisture Flow Is From Warm To Cold

Moisture Flow Is From More To Less

Air Flow Is From A Higher Pressure to a Lower Pressure

Gravity Acts Down


Subarctic/Arctic
Very Cold
Marine
Cold
Mixed-Humid
Mixed-Dry
Hot-Humid
Hot-Dry

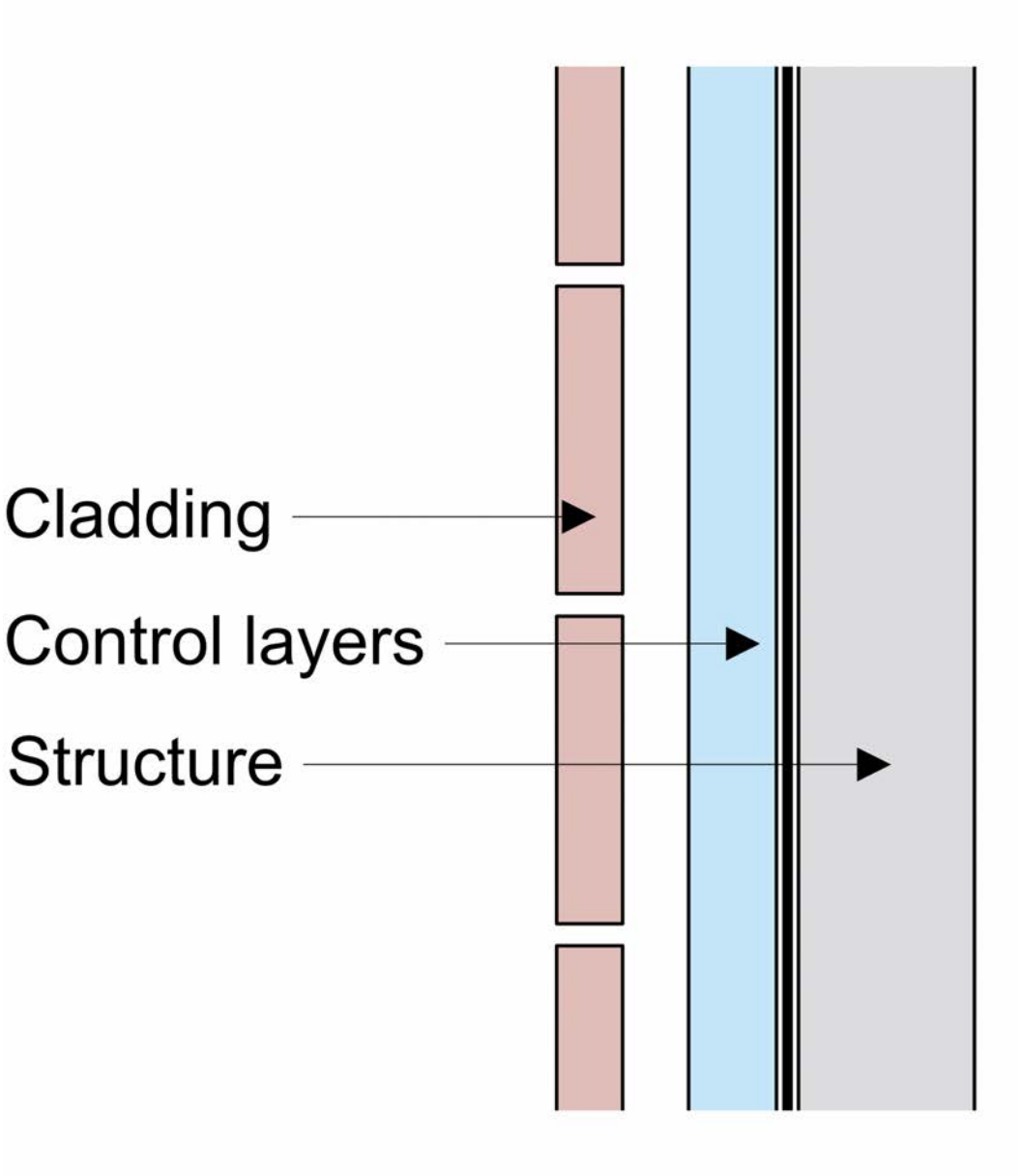

Exposure
Extreme
Over 60''
High
40'' - 60''
Moderate
20'' - 40''
Low
Under 20''

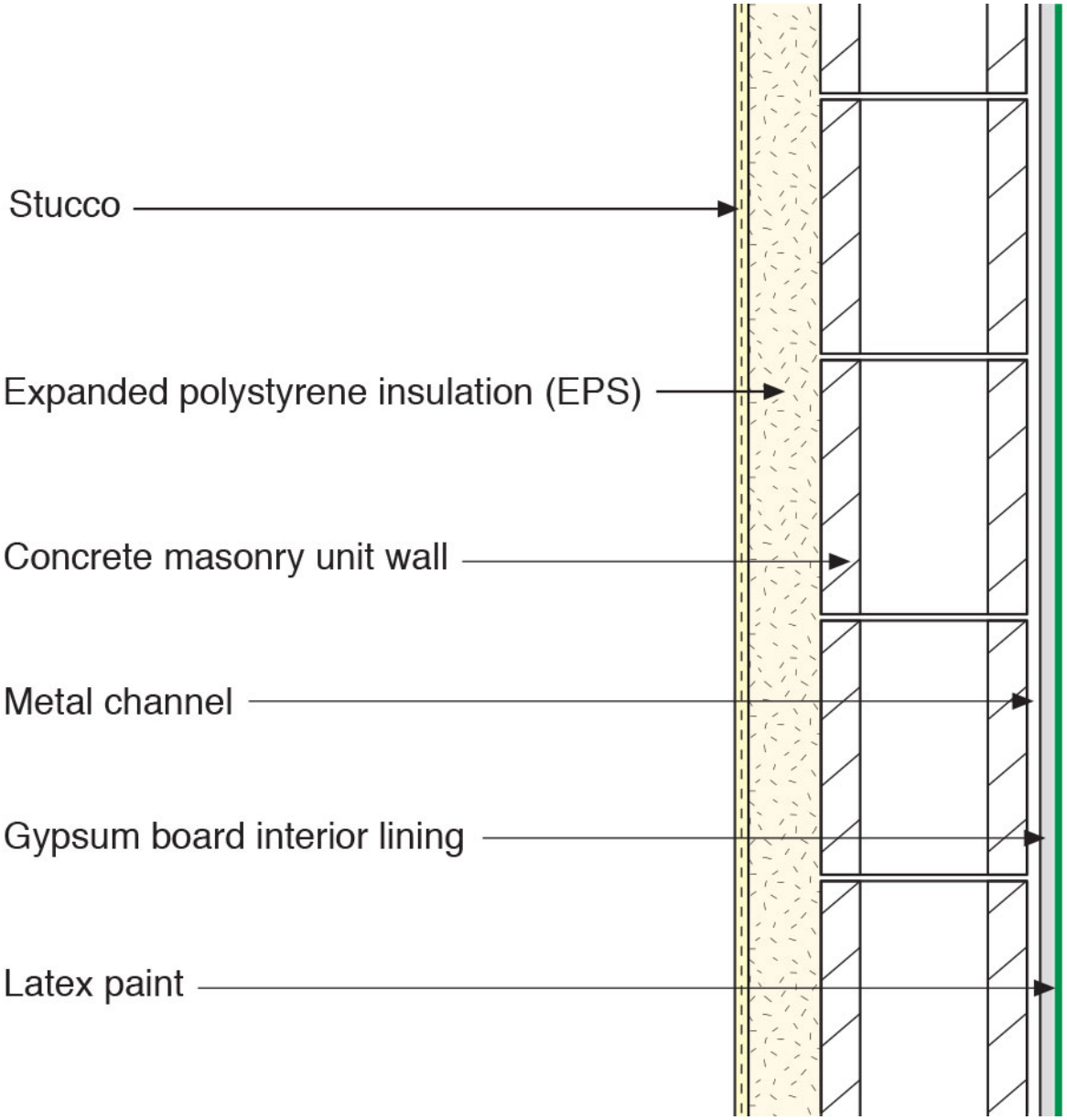
Water Control Layer

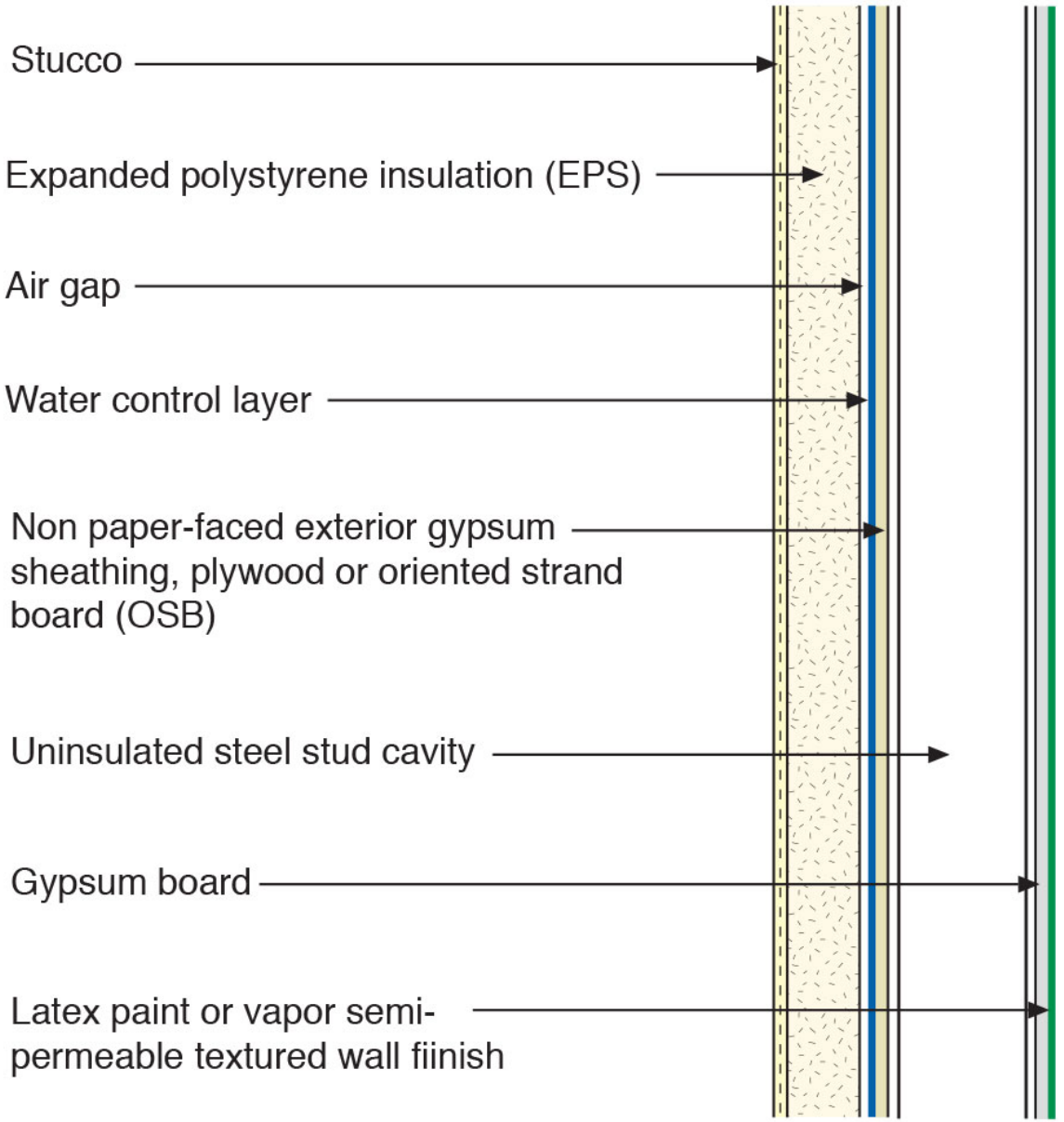
Air Control Layer

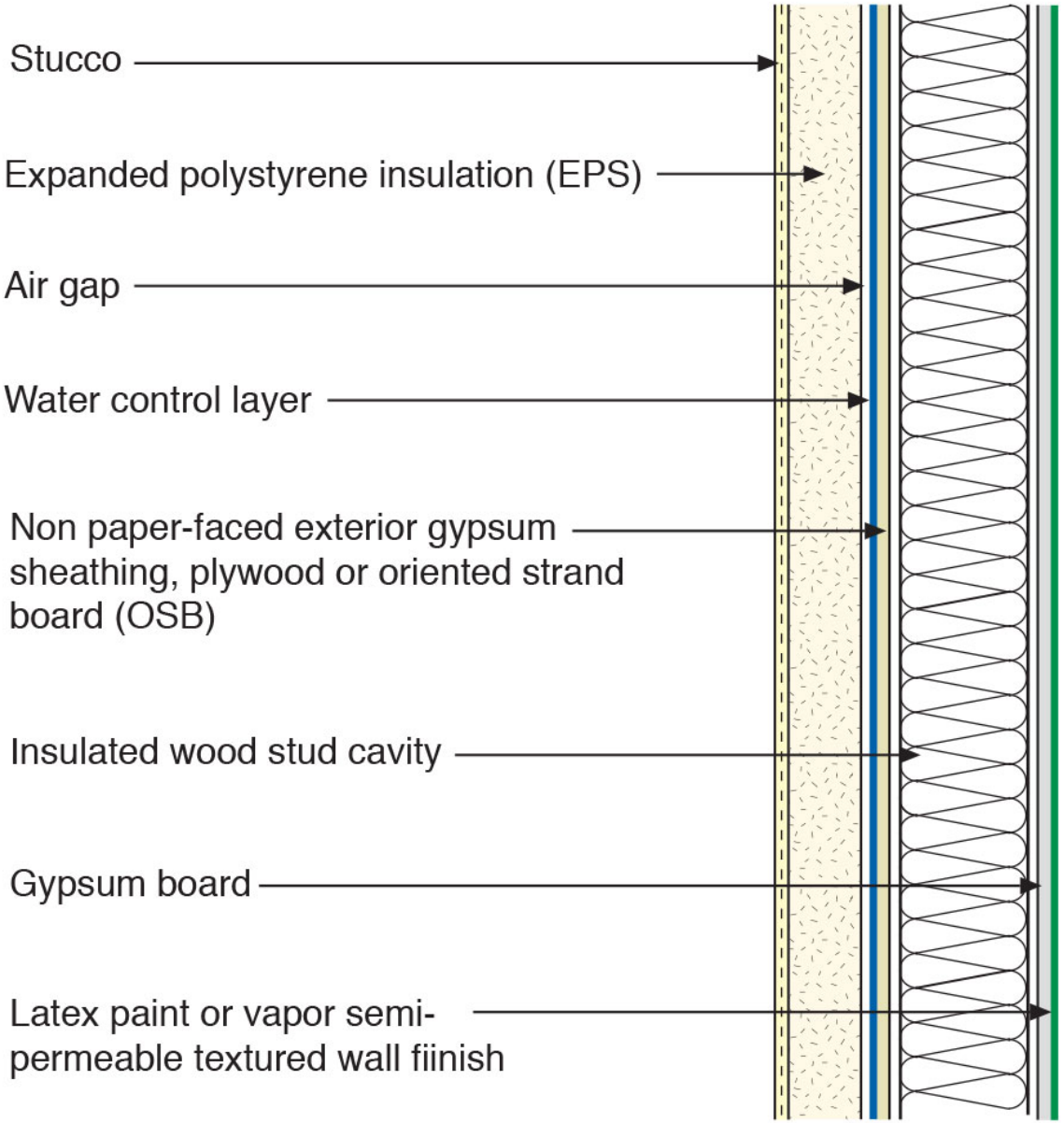
Vapor Control Layer

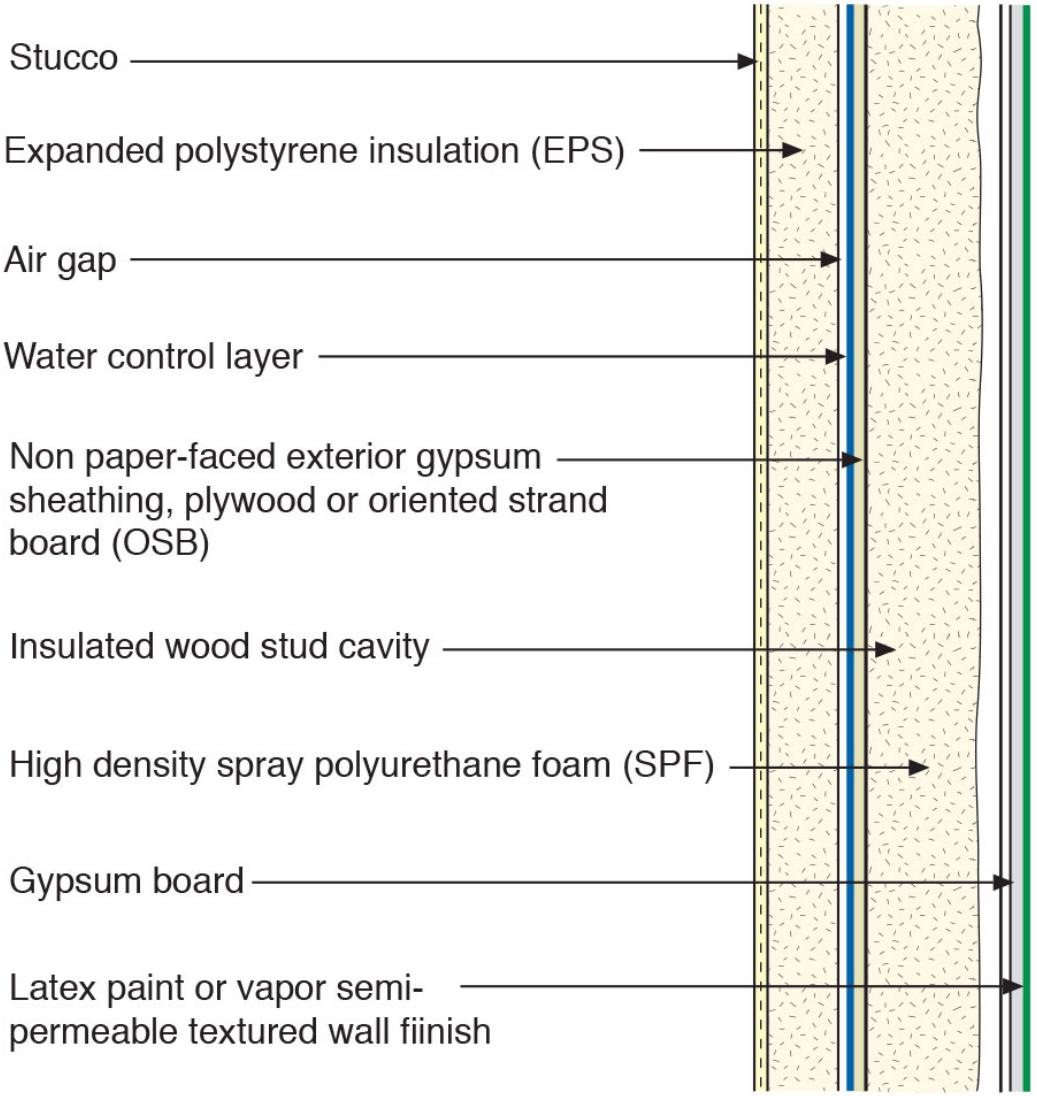
Thermal Control Layer


Cladding
Control layers
Structure


Stucco
Expanded polystyrene insulation (EPS)
Concrete masonry unit wall
Metal channel
Gypsum board interior lining
Latex paint

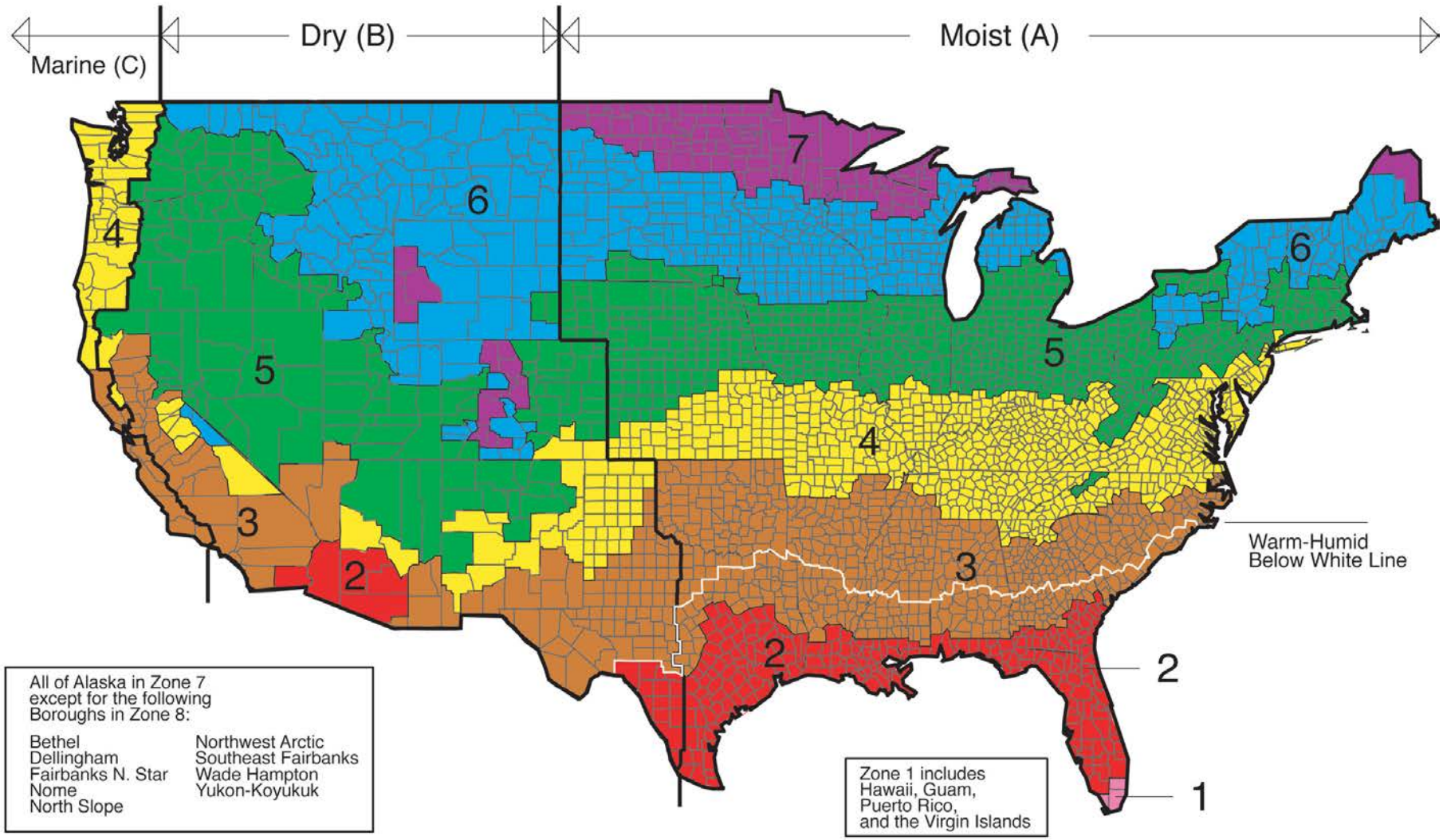

Stucco
Expanded polystyrene insulation (EPS)
Air gap
Water control layer
Non paper-faced exterior gypsum sheathing, plywood or oriented strand board (OSB)
Uninsulated steel stud cavity
Gypsum board
Latex paint or vapor semi-permeable textured wall fiinish

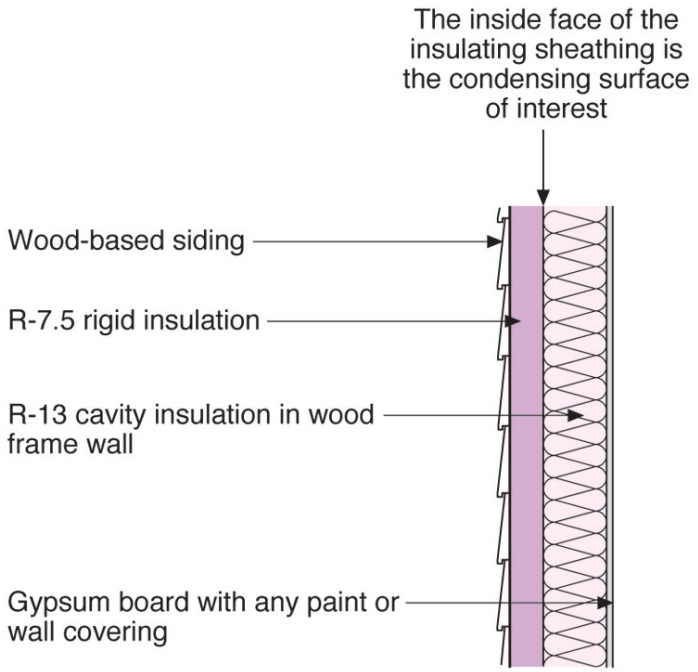

Stucco
Expanded polystyrene insulation (EPS)
Air gap
Water control layer
Non paper-faced exterior gypsum sheathing, plywood or oriented strand board (OSB)
Insulated wood stud cavity
Gypsum board
Latex paint or vapor semi-permeable textured wall fiinish

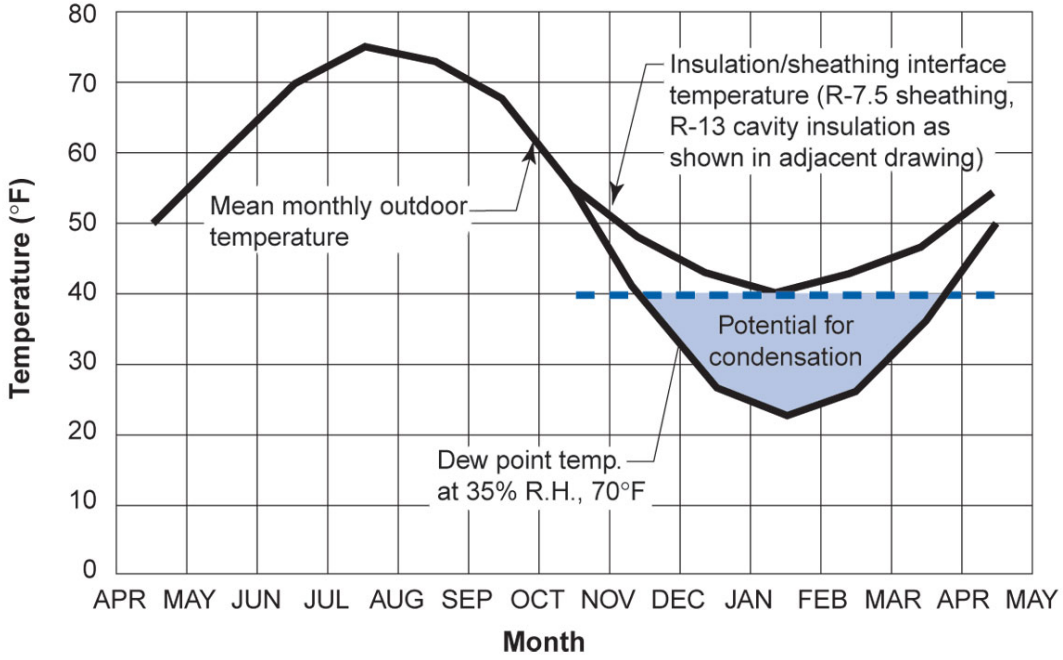

Stucco
Expanded polystyrene insulation (EPS)
Air gap
Water control layer
Non paper-faced exterior gypsum sheathing, plywood or oriented strand board (OSB)
Insulated wood stud cavity
High density spray polyurethane foam (SPF)
Gypsum board
Latex paint or vapor semi-permeable textured wall fiinish

Don’t Do Stupid Things


GUARDIAN


Marine (C)
Dry (B)
Moist (A)
7
6
4
5
3
2
1
Warm-Humid
Below White Line
All of Alaska in Zone 7
except for the following
Boroughs in Zone 8:
Bethel
Dellingham
Fairbanks N. Star
Nome
North Slope
Northwest Arctic
Southeast Fairbanks
Wade Hampton
Yukon-Koyukuk
Zone 1 includes
Hawaii, Guam,
Puerto Rico,
and the Virgin Islands

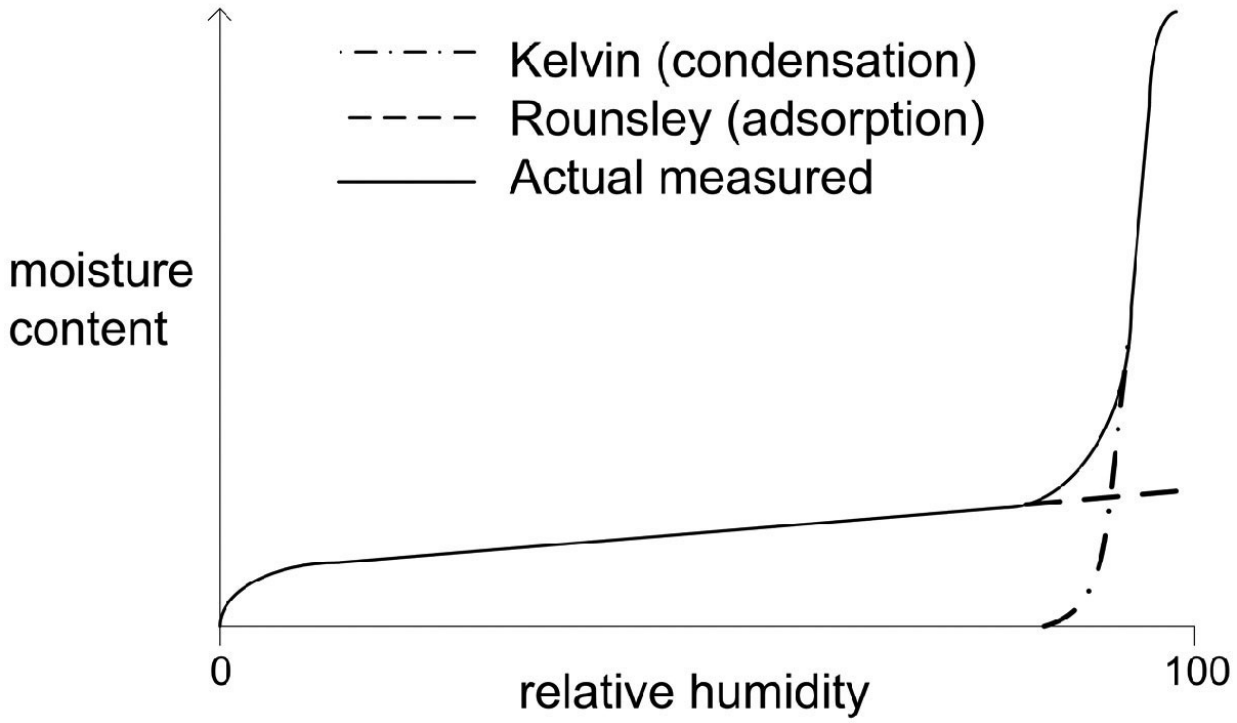

The inside face of the insulating sheathing is the condensing surface of interest
Wood-based siding
R-7.5 rigid insulation
R-13 cavity insulation in wood frame wall
Gypsum board with any paint or wall covering


Temperature (°F)
80
70
60
50
40
30
20
10
0
APR MAY JUN JUL AUG SEP OCT NOV DEC JAN FEB MAR APR MAY
Month
Insulation/sheathing interface temperature (R-7.5 sheathing, R-13 cavity insulation as shown in adjacent drawing)
Mean monthly outdoor temperature
Potential for condensation
Dew point temp. at 35% R.H., 70°F

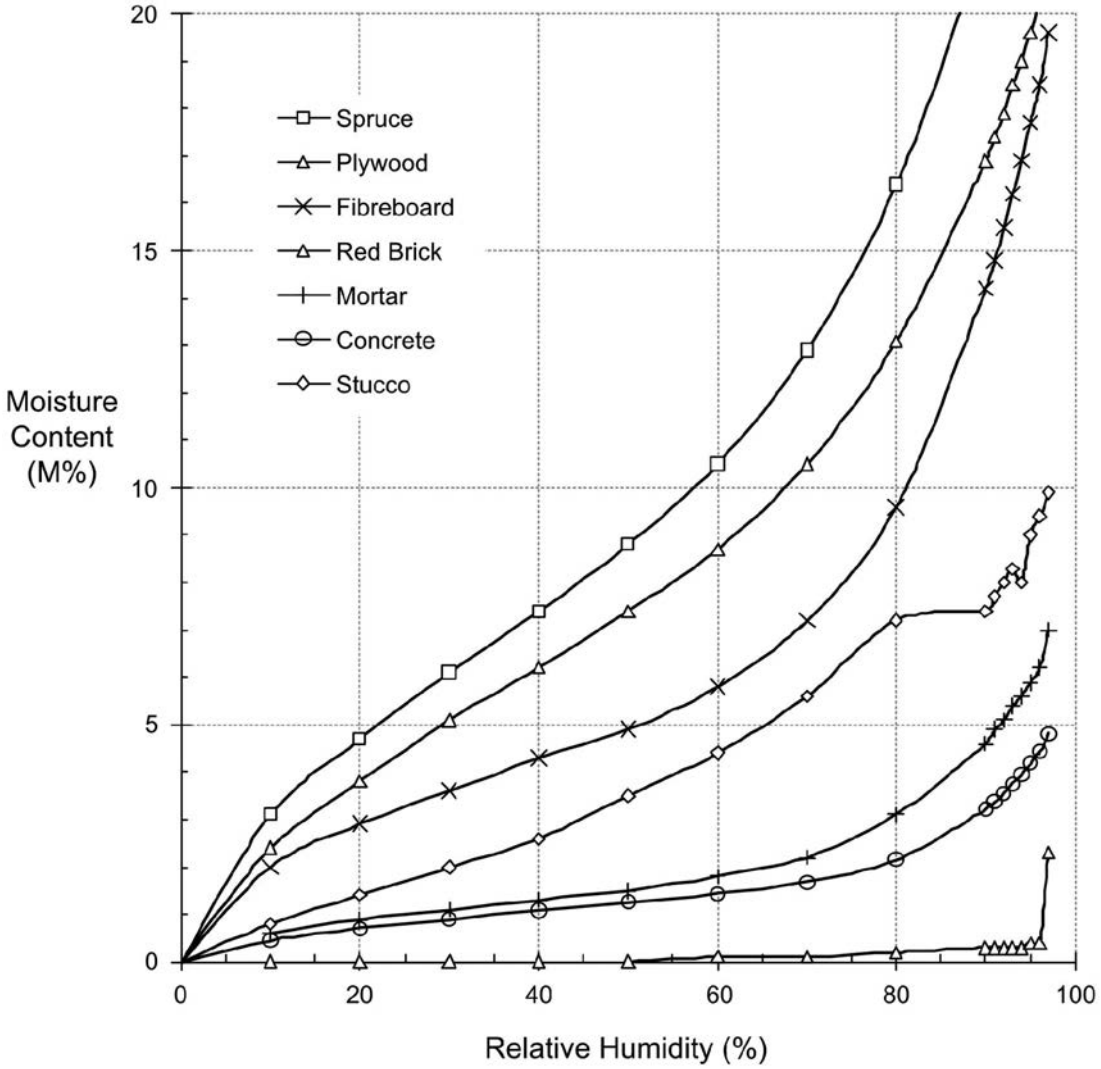
Insulation for Condensation Control*

Climate Zone	Rigid Board or Air Impermeable Insulation	Total Cavity Insulation	Total Wall Assembly Insulation	Ratio of Rigid Board Insulation or Air Impermeable R-Value to Total Insulation R-Value
4C	R-2.5	R-13	R-15.5	15%
	R-3.75	R-20	R-23.75	15%
5	R-5	R-13	R-18	30%
	R-7.5	R-20	R-27.5	30%
6	R-7.5	R-13	R-20.5	35%
	R-11.25	R-20	R-31.25	35%
7	R-10	R-13	R-28	45%
	R-15	R-20	R-35	45%
8	R-15	R-13	R-28	50%
	R-20	R-20	R-40	50%

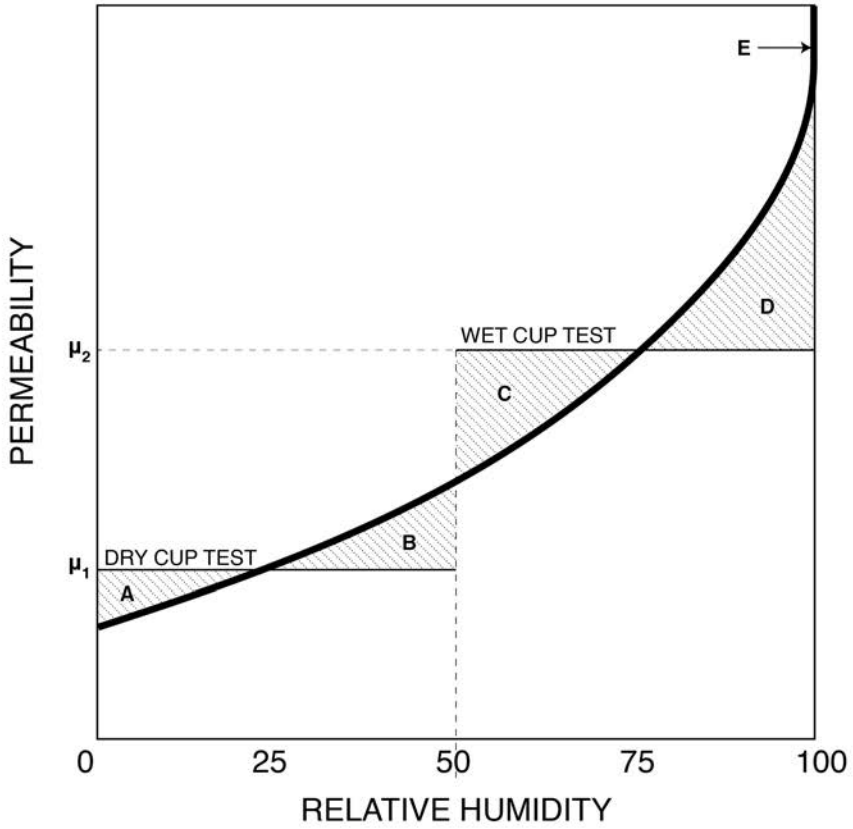
*Adapted from Table R 702.1 2015 International Residential Code



Typical predicted sorption isotherm according to Kelvin equation and modified BET theory
From Straube & Burnett, 2005



Sorption isotherm for several building materials [Kumaran 2002]
From Straube & Burnett, 2005



A - Single-layer of absorbed molecules
B - Multiple layers of absorbed molecules
C - Interconnected layers (internal capillary condensation)
D - Free water in pores, capillary suction
E - Supersaturated regime

Relationship between Dry Cup and Wet Cup
Adapted from Joy & Wilson, 1963


R-11 3½"
OWENS-CORNING
Fiberglas
Building
Insulation
FIBERGLAS
ASSURED THERMAL
PERFORMANCE

Current Problems With Traditional Stucco

Current Problems With Traditional Stucco

Vancouver Condo Crisis….

Should Have Put Everyone on Notice


6'8" CLEARANCE 2.0m

What Happened In Vancouver?

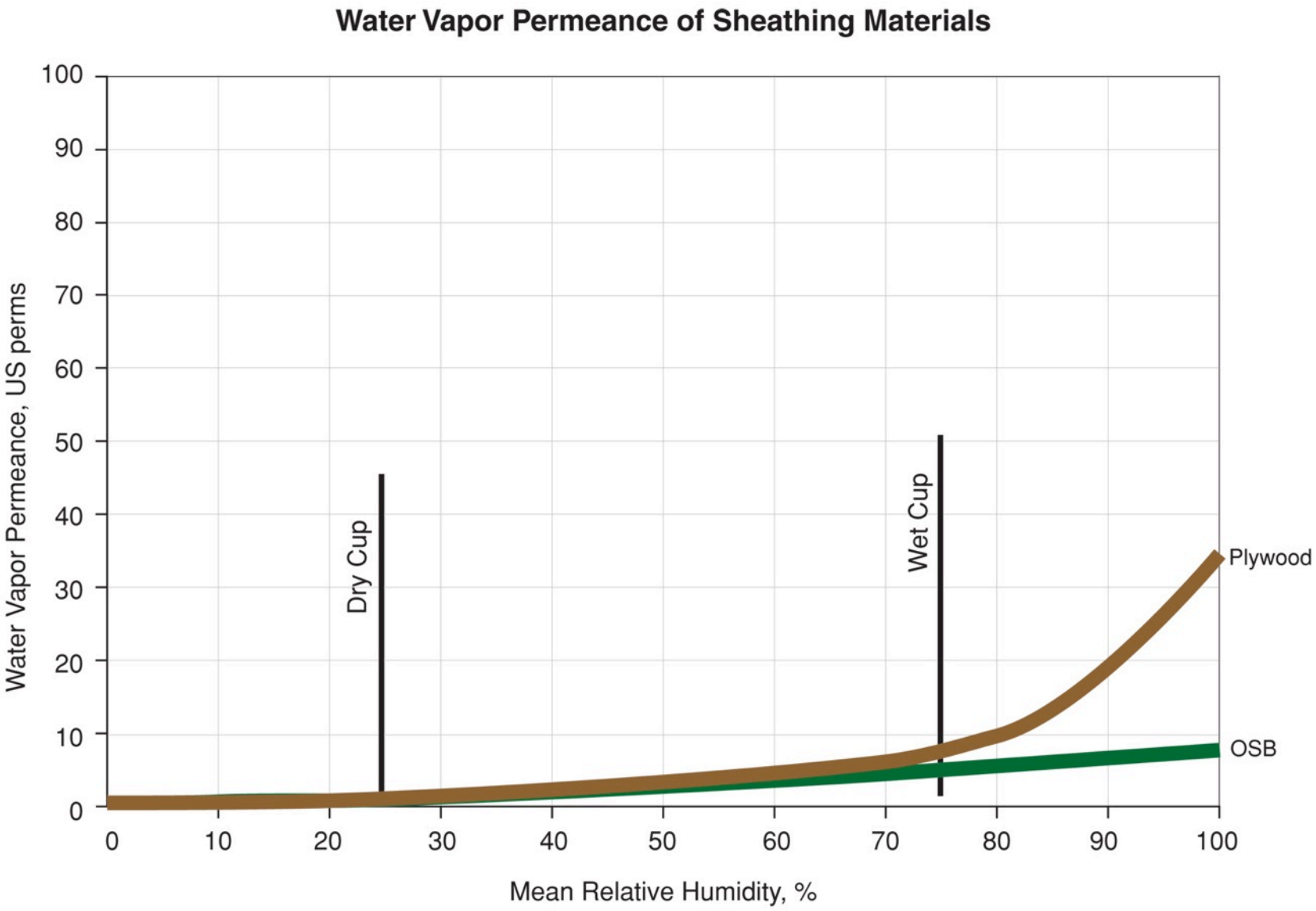
OSB Instead of Plywood

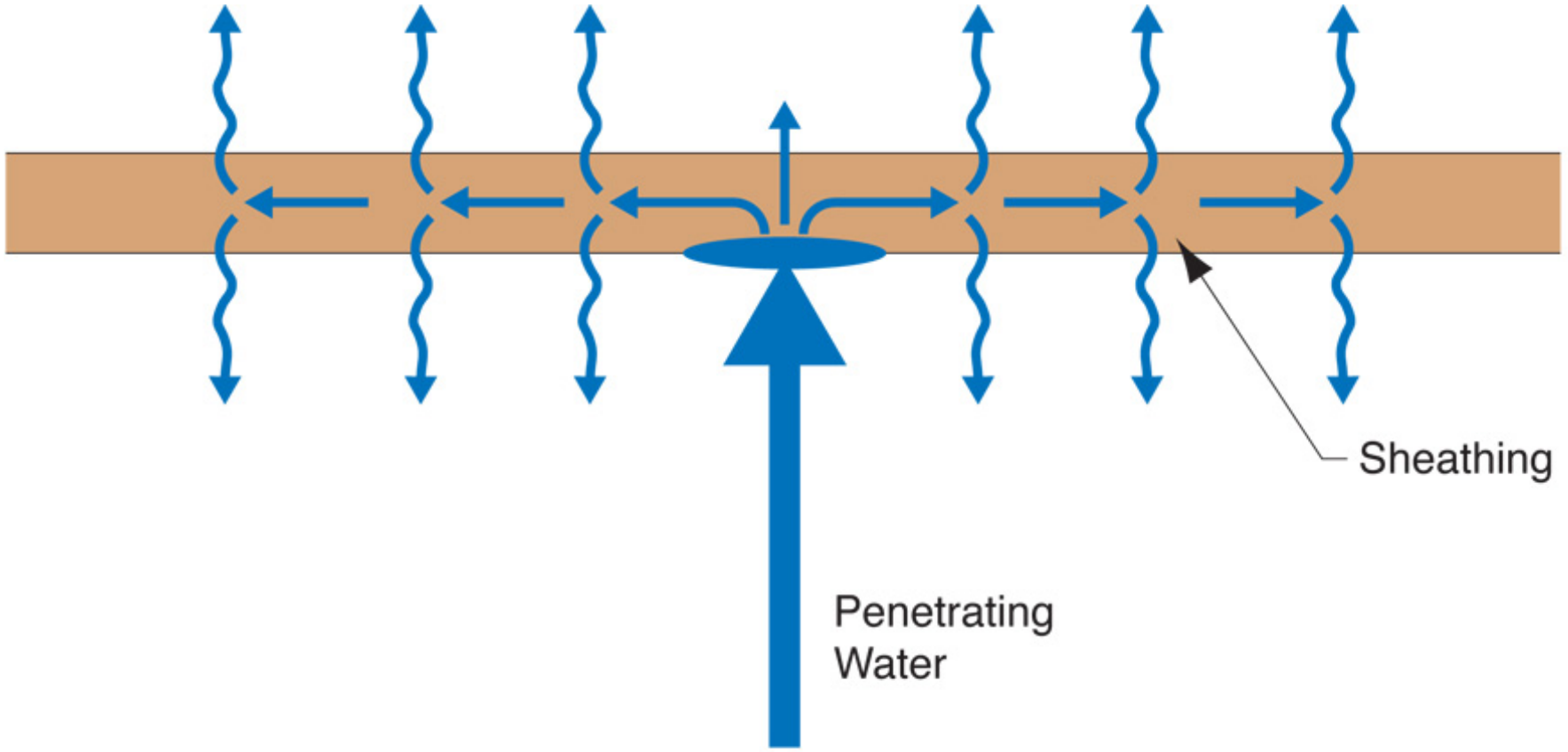
Non Traditional Building Wraps

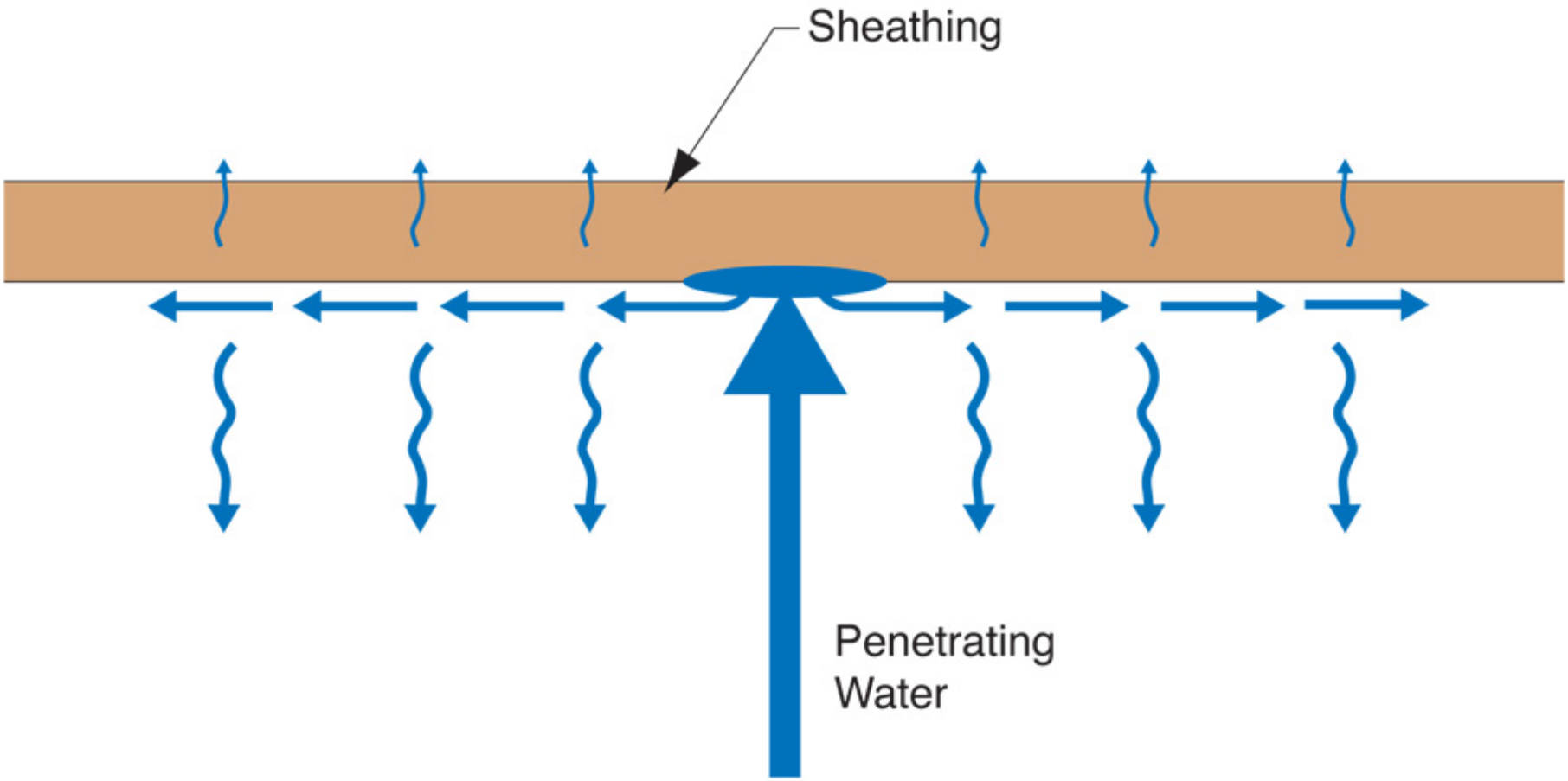
Interior Vapor Barriers

Increased Thermal Resistance

Portland Cement Instead of Lime

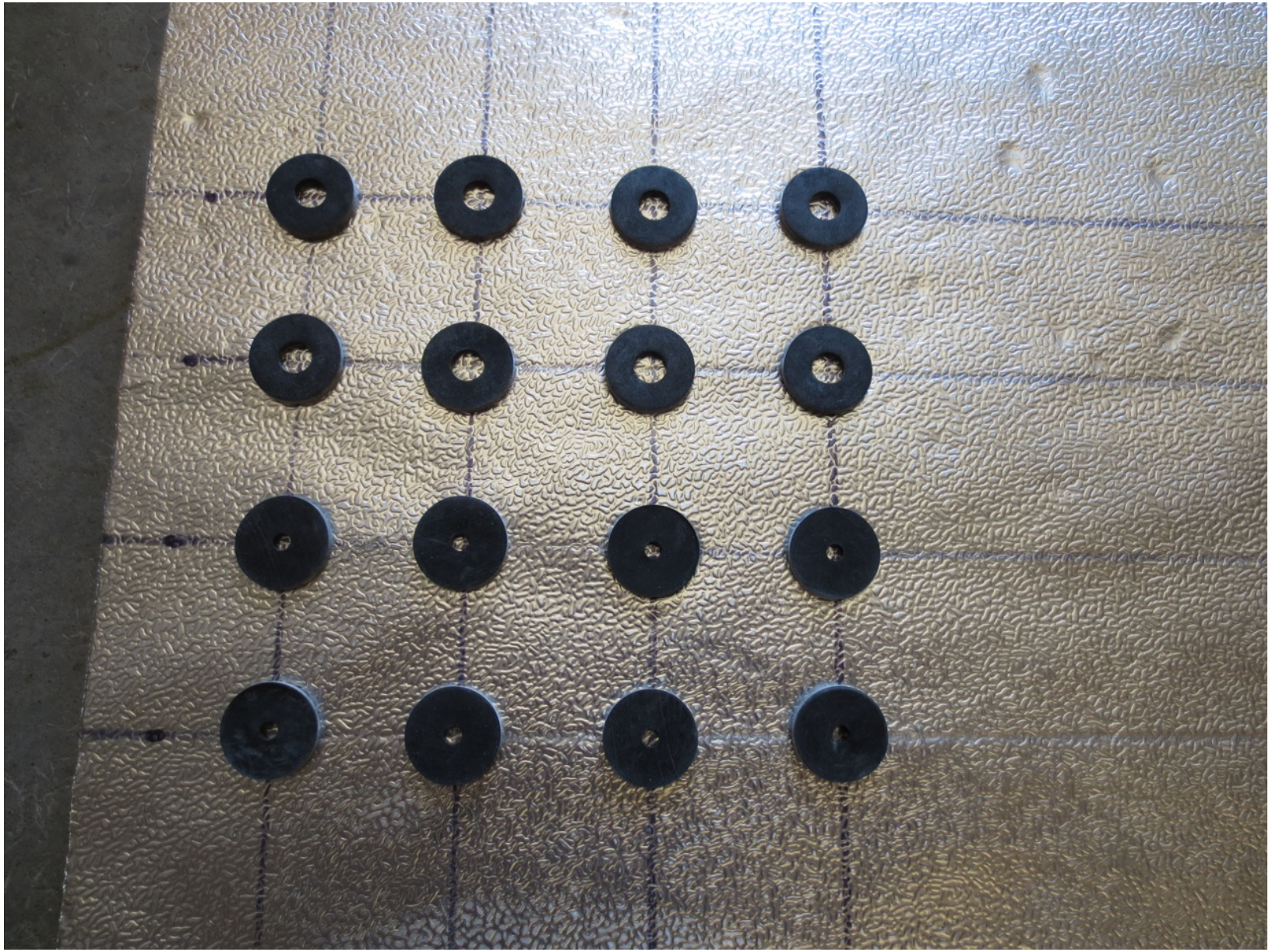

Water Vapor Permeance of Sheathing Materials
Water Vapor Permeance, US perms
100
90
80
70
60
50
40
30
20
10
0
Dry Cup
Wet Cup
Plywood
OSB
0
10
20
30
40
50
60
70
80
90
100
Mean Relative Humidity, %


Sheathing
Penetrating
Water


Sheathing
Penetrating
Water


yvek
omeWrap
Tyvek
HomeWrap

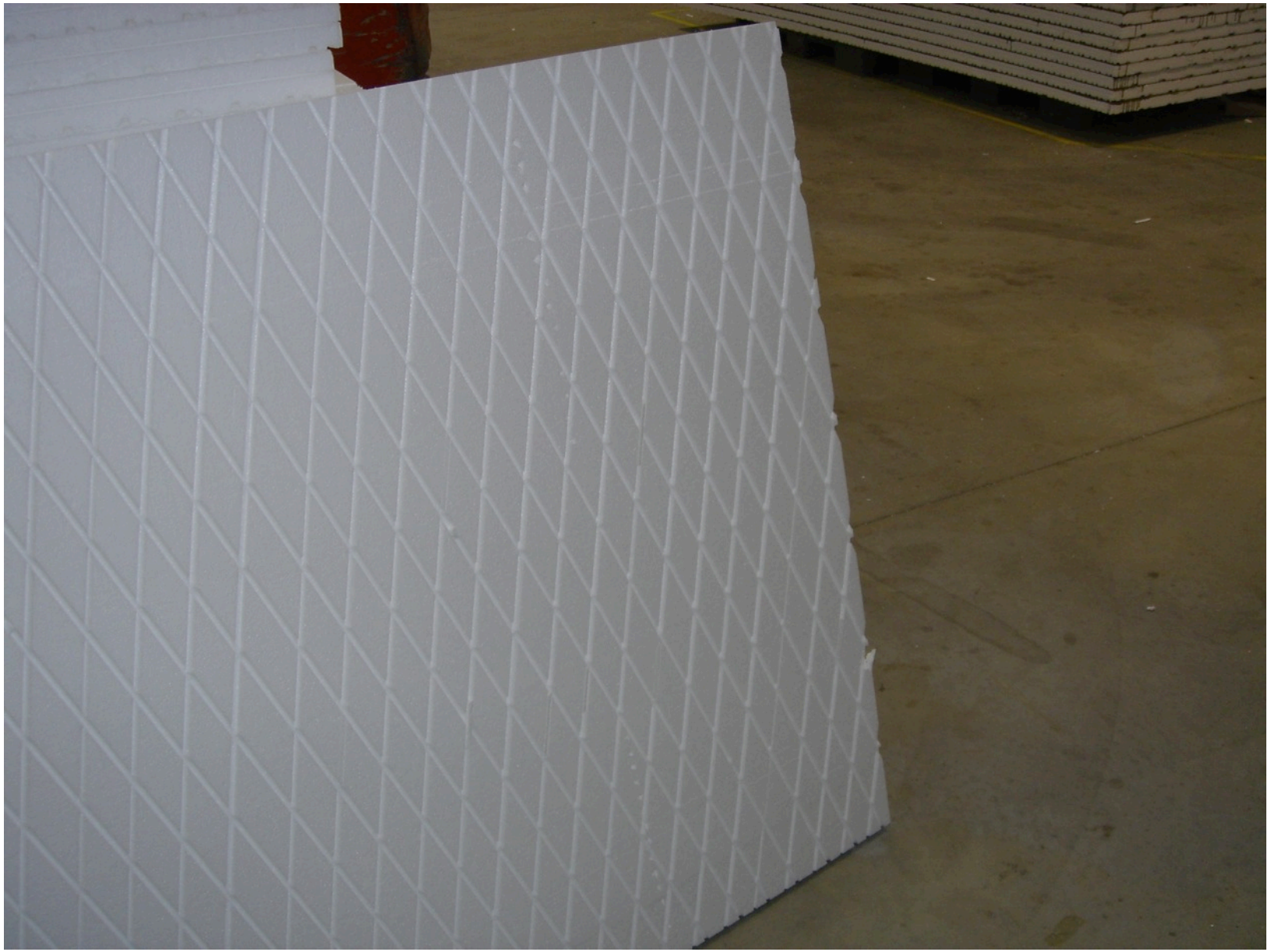
Rain Screen



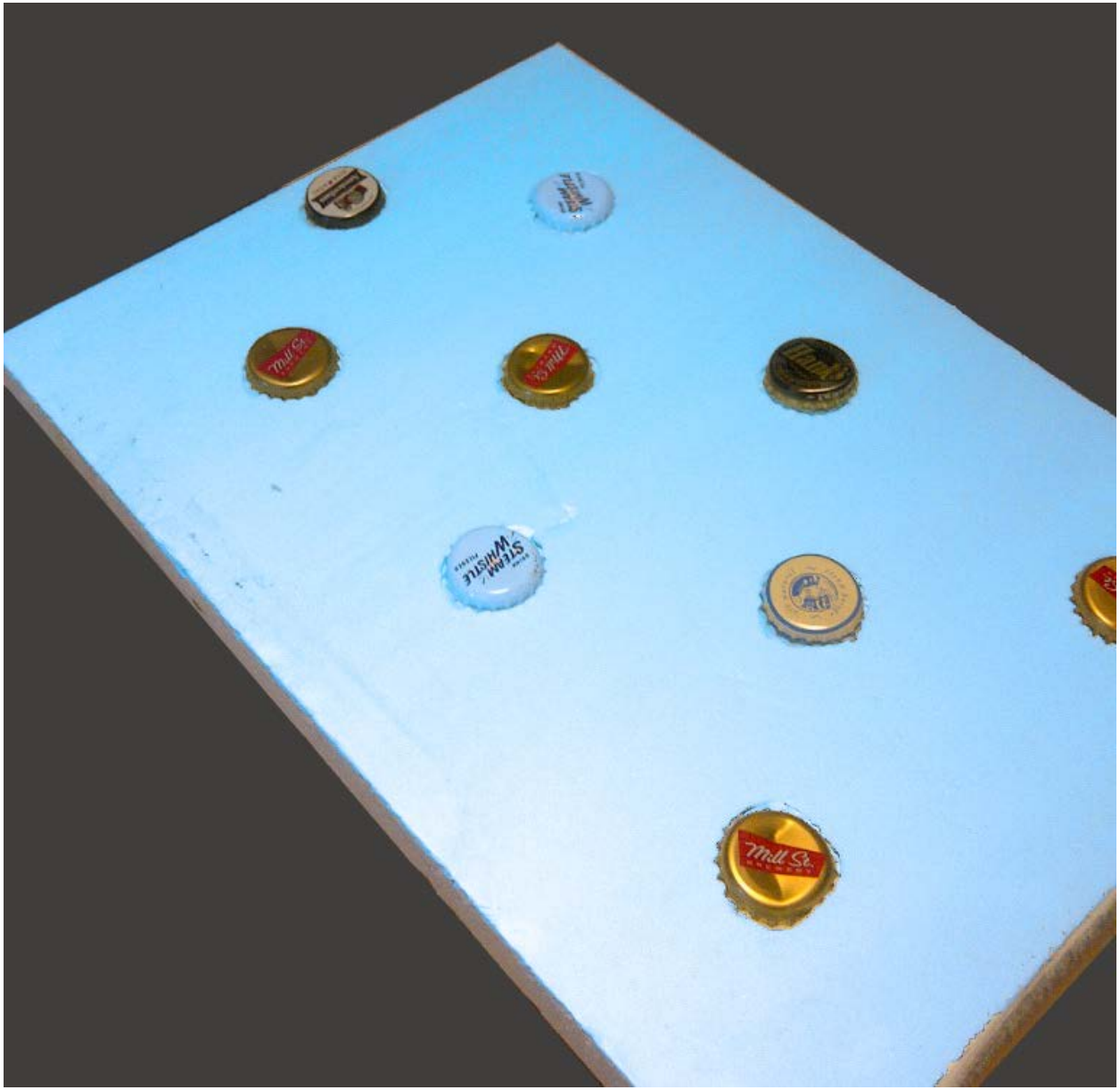

DUPONT

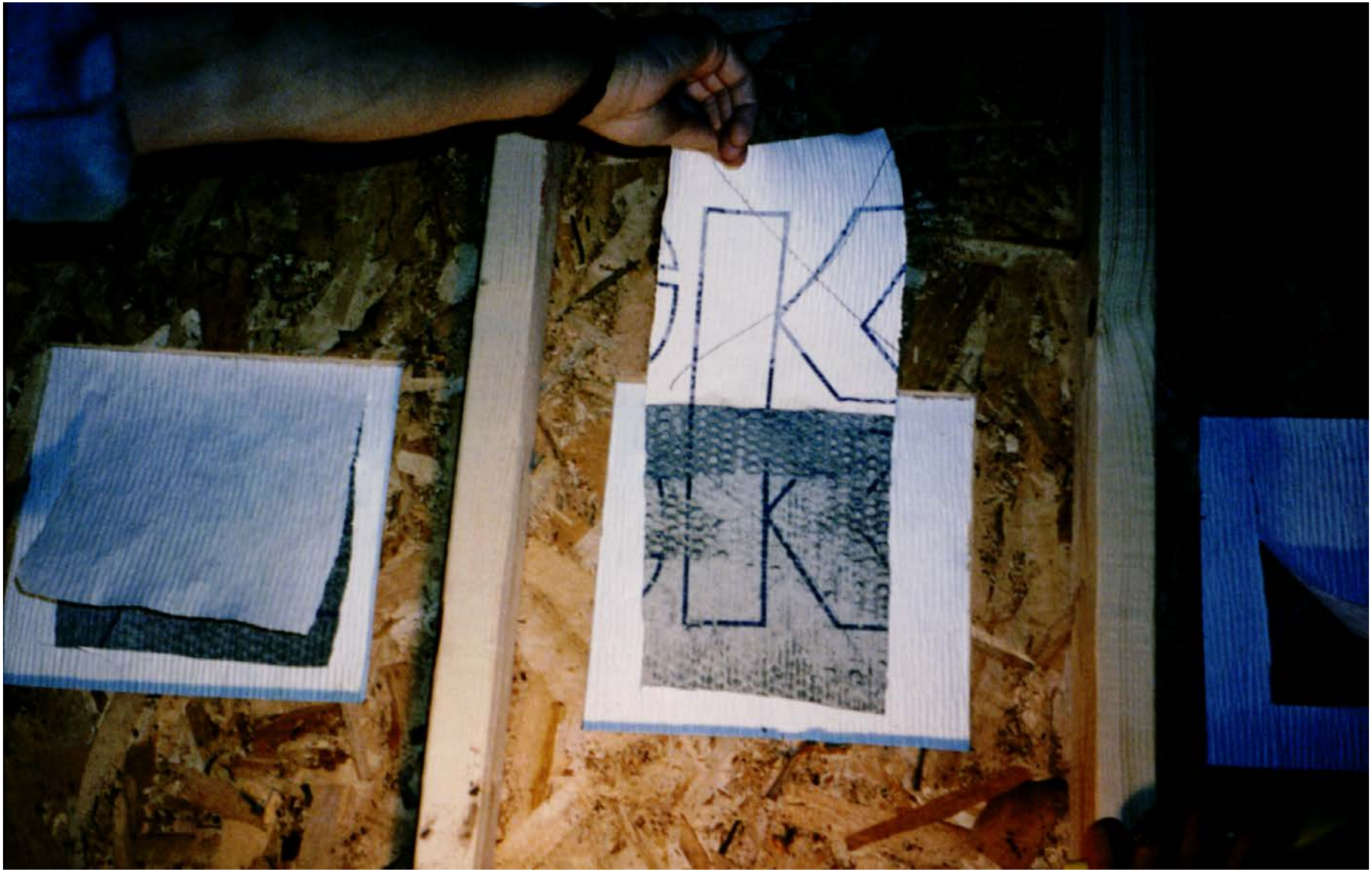

Call 1-800-44TYVEK
WWW.TYVEK.COM

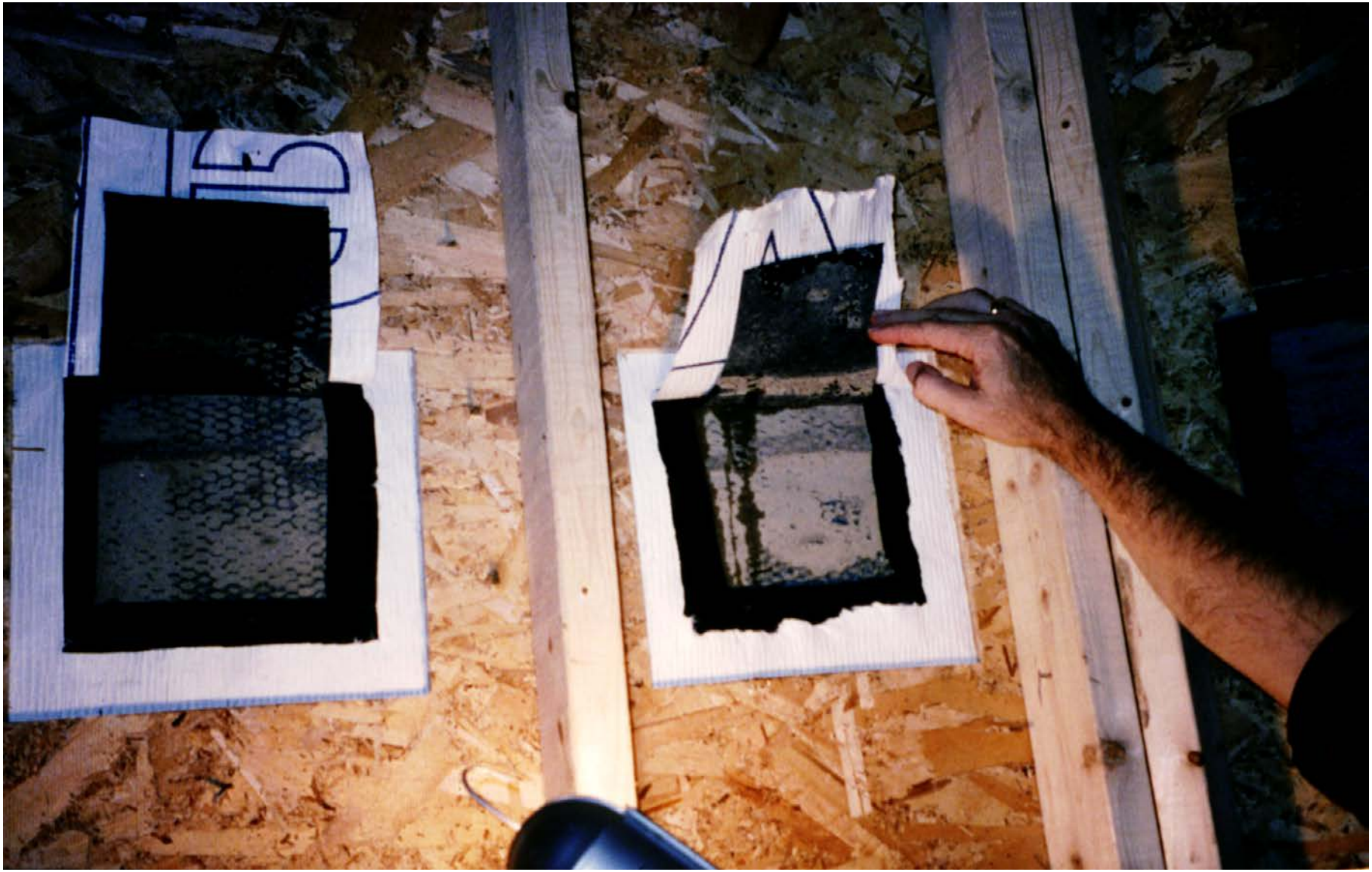

DuPont
Tyvek
Tape
DuPont
Tyvek
Tape

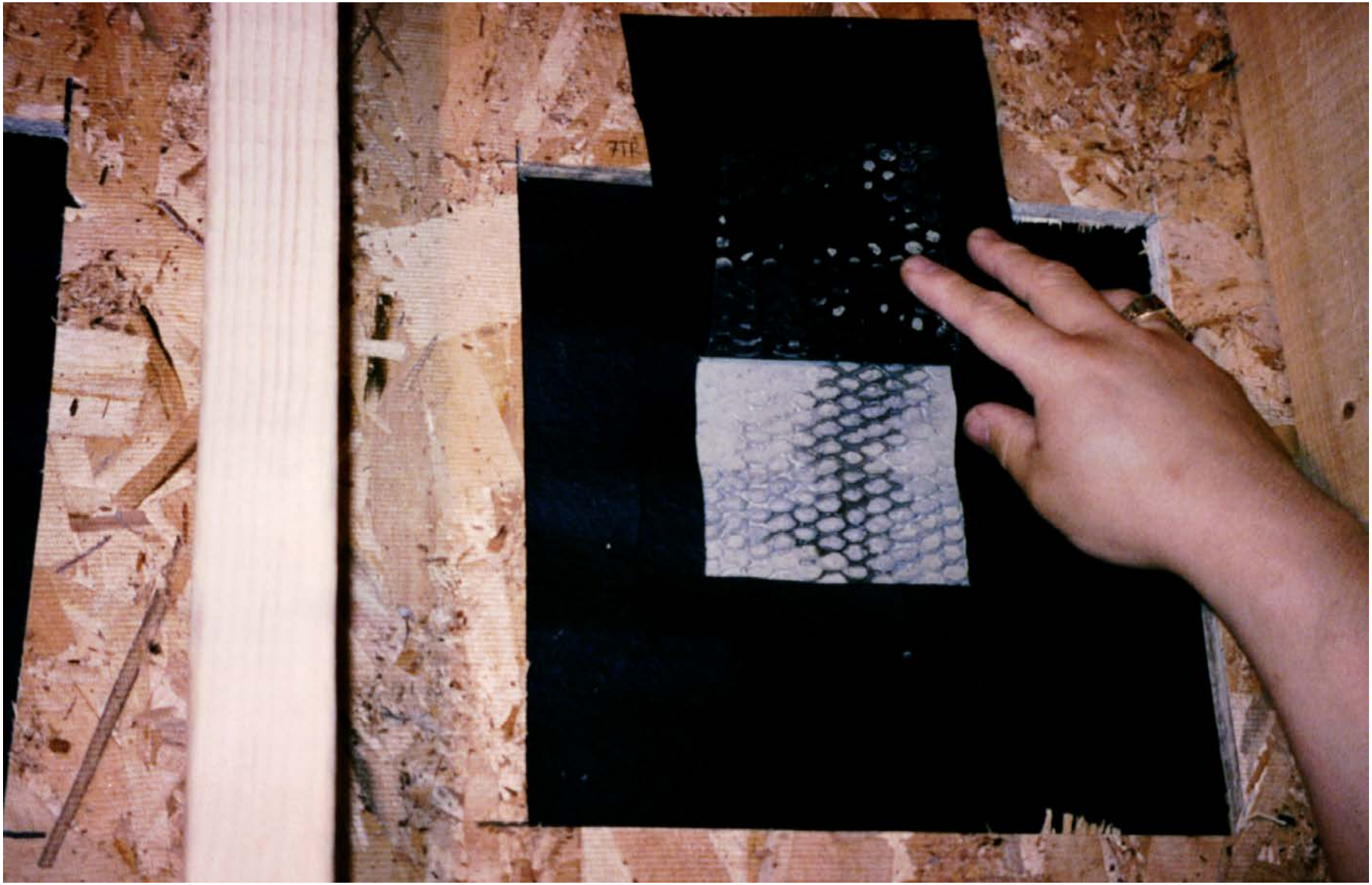


Beer Screen?


Mill St.
Steam Whistle
Mill St.

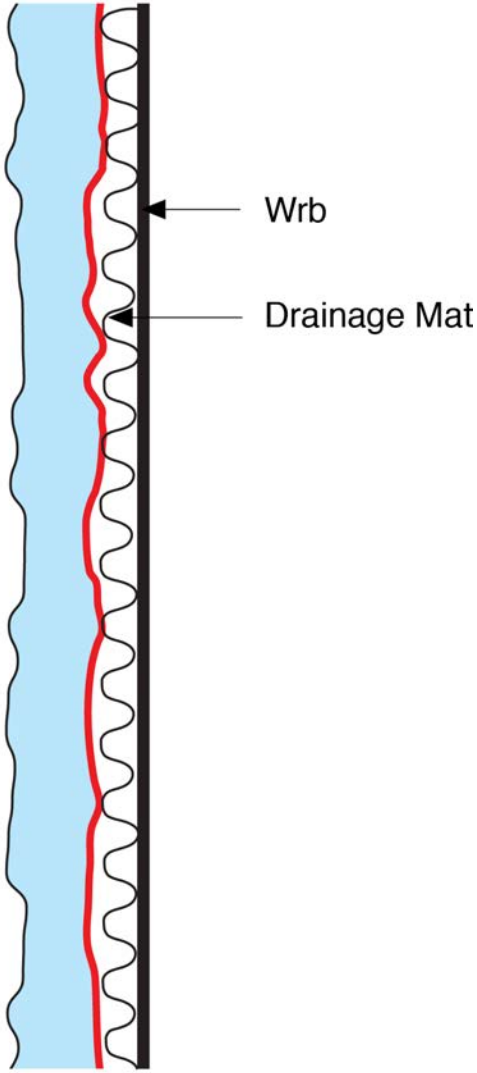






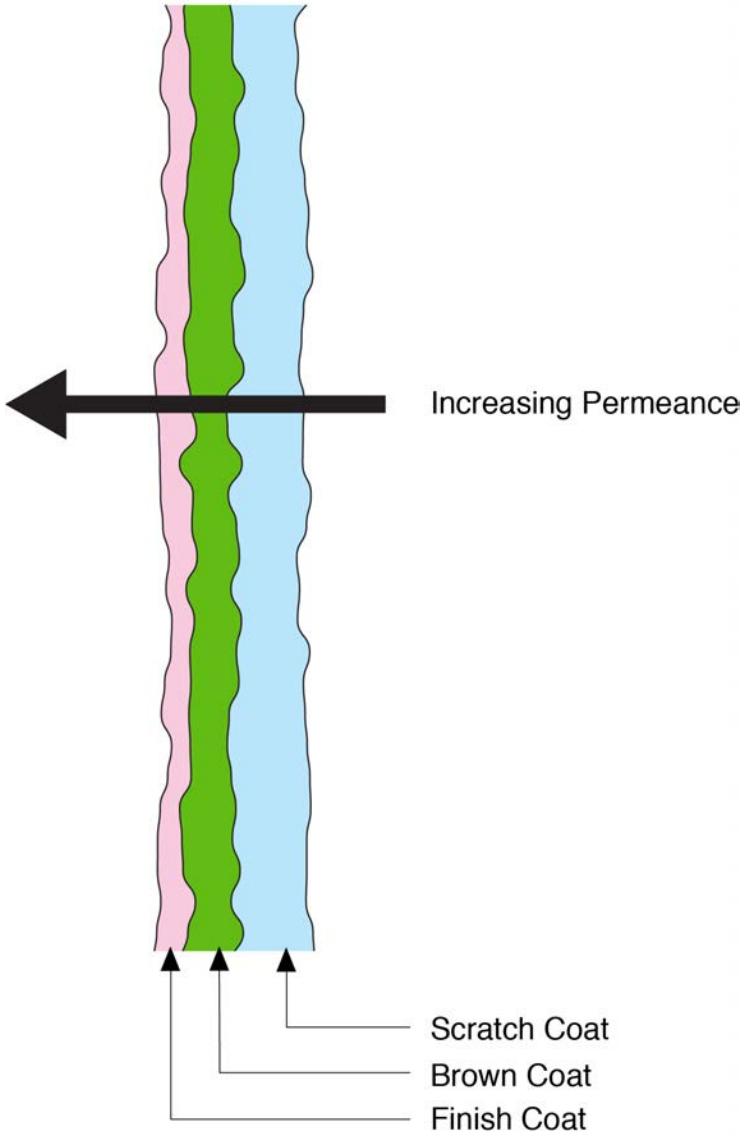

JLG ULTRA
1250AJP
JLG


LOWE'S


Wrb
Drainage Mat


Genie Z-60/34

Traditional Lime Stucco	Greater than 20 perms
Lime/Portland Cement Stucco	5 to 10 perms
Portland Cement Stucco	1 to 5 perms
Polymer Modification	Less than 1


Increasing Permeance
Scratch Coat
Brown Coat
Finish Coat

Exterior Conditions

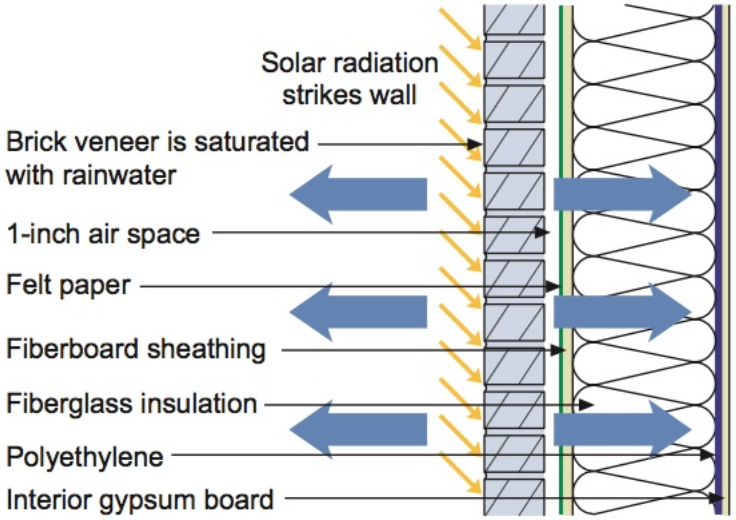
Temperature: 80°F
Relative humidity: 75%
Vapor pressure: 2.49 kPa

Conditions within Cavity:

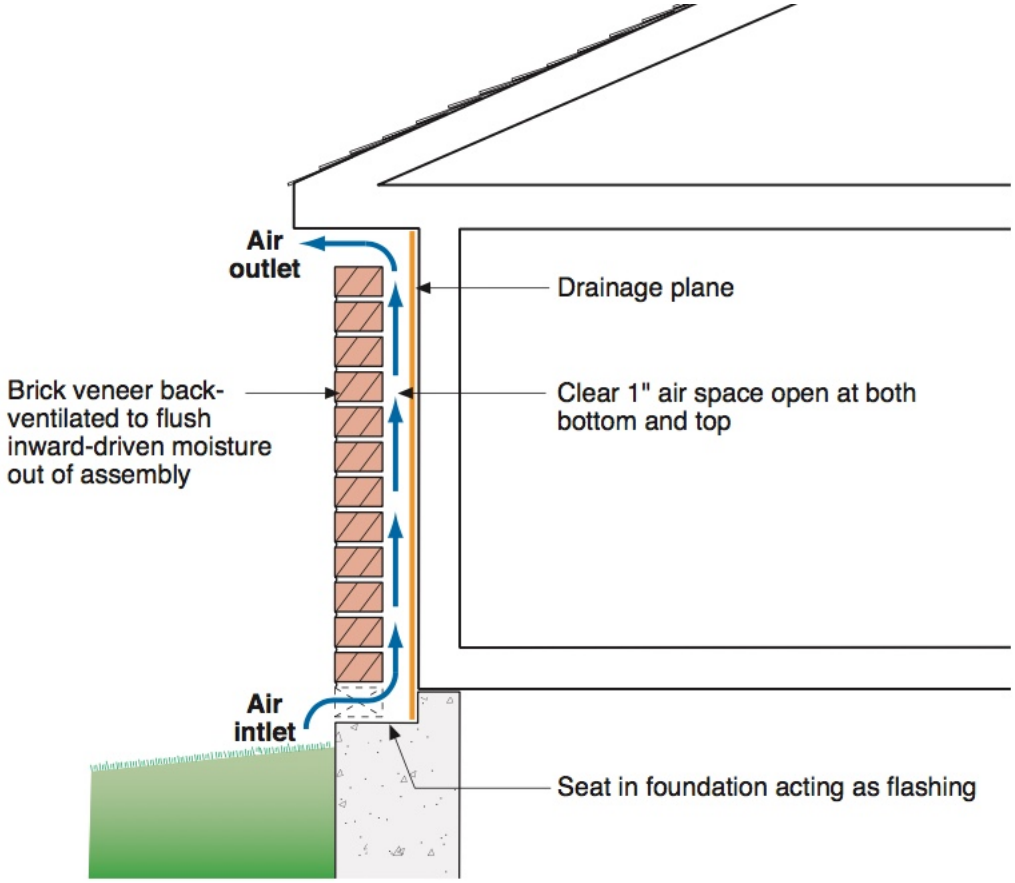
Temperature: 100°F
Relative humidity: 100%
Vapor pressure: 6.45 kPa

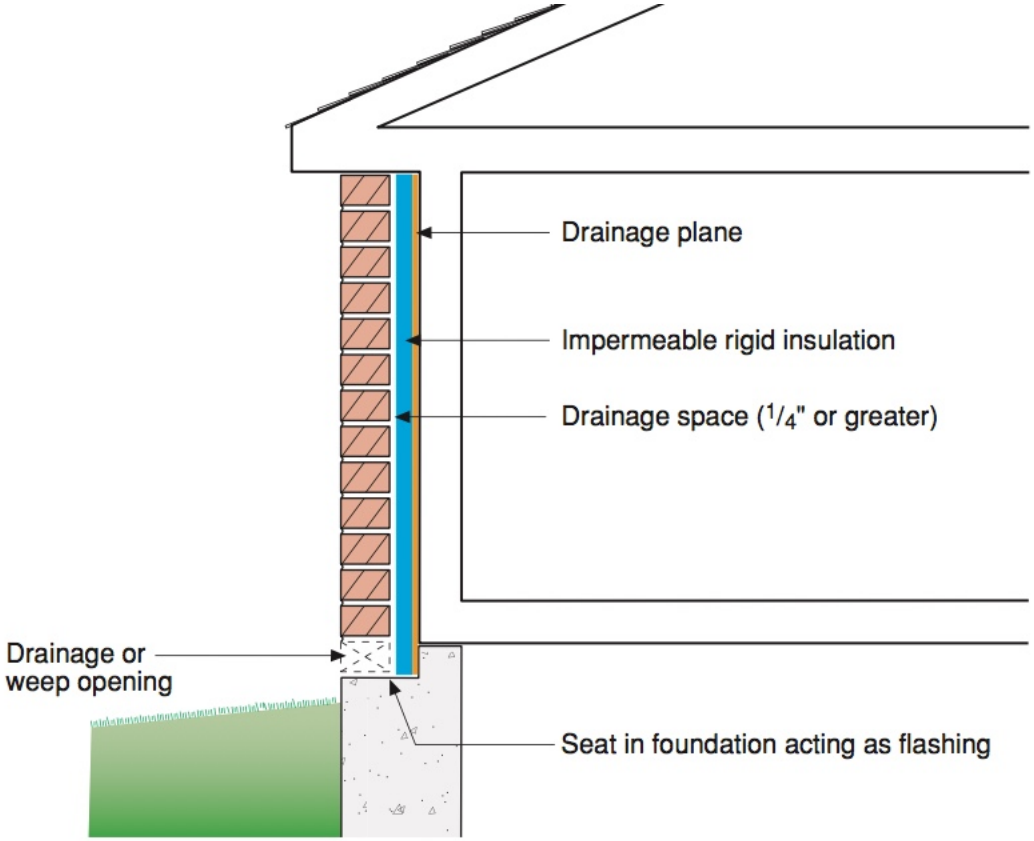
Interior Conditions

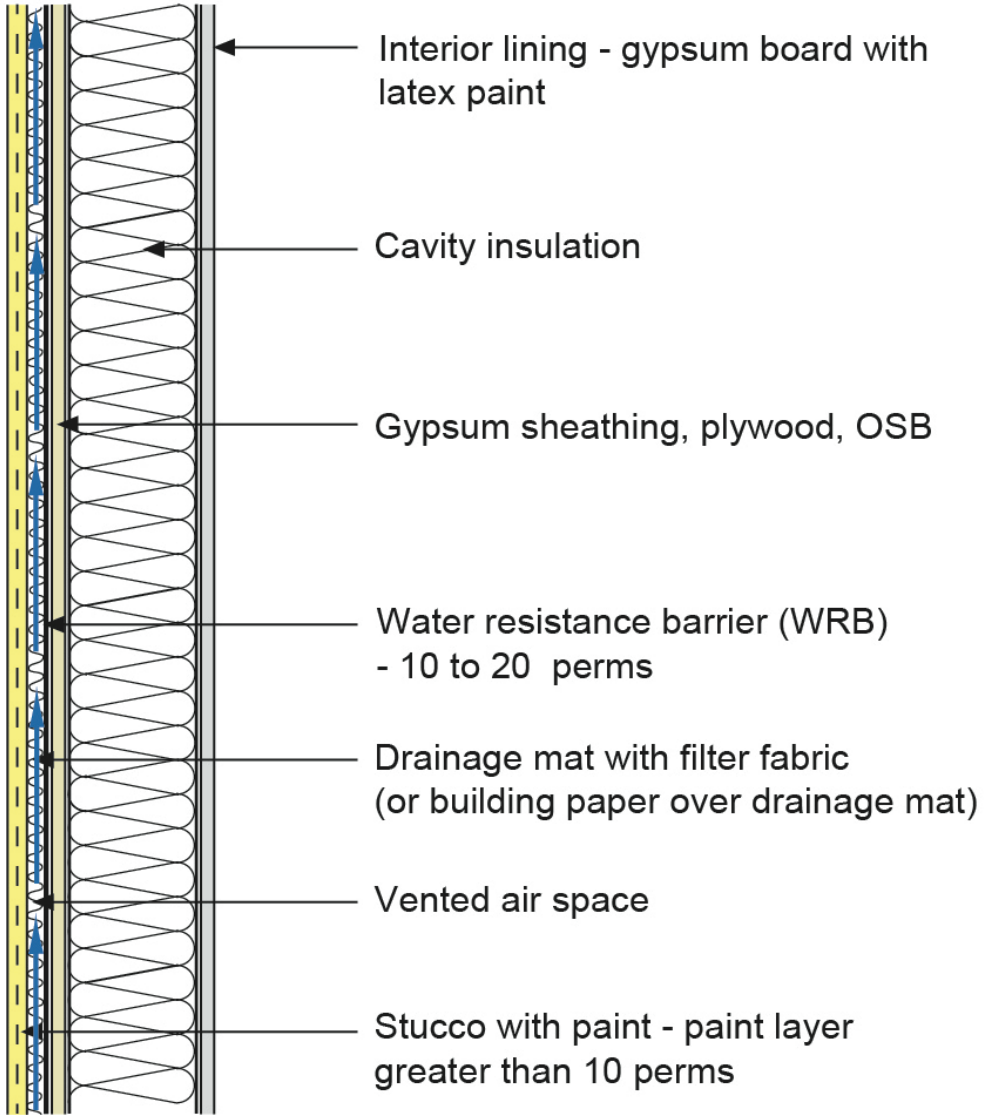
Temperature: 75°F
Relative humidity: 60%
Vapor pressure: 1.82 kPa

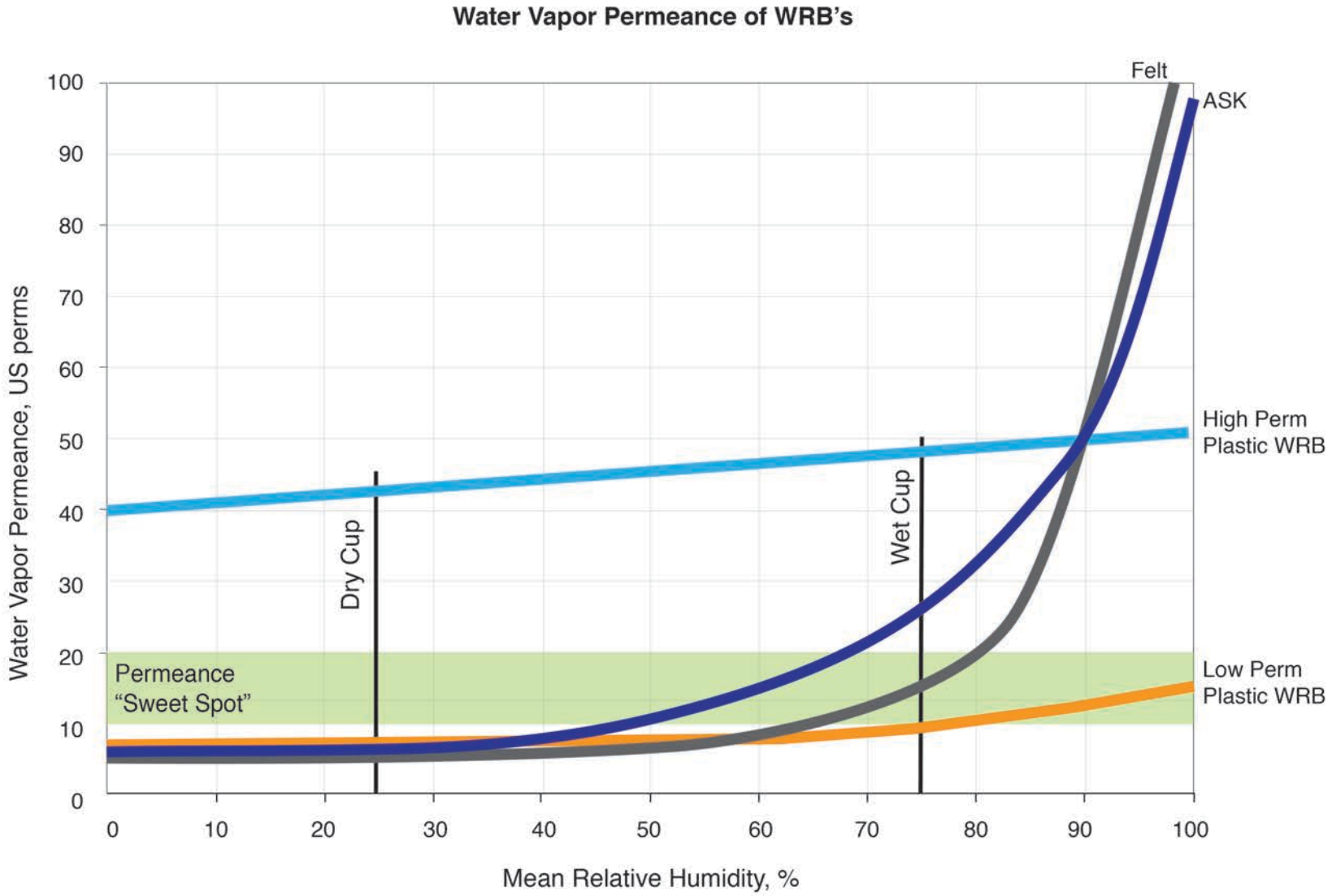


Vapor is driven both inward and outward by a high vapor pressure differential between the brick and the interior and the brick and the exterior.


Air
outlet
Drainage plane
Brick veneer back-
ventilated to flush
inward-driven moisture
out of assembly
Clear 1" air space open at both
bottom and top
Air
intlet
Seat in foundation acting as flashing


Drainage plane
Impermeable rigid insulation
Drainage space (1/4" or greater)
Drainage or
weep opening
Seat in foundation acting as flashing


Interior lining - gypsum board with latex paint
Cavity insulation
Gypsum sheathing, plywood, OSB
Water resistance barrier (WRB) - 10 to 20 perms
Drainage mat with filter fabric (or building paper over drainage mat)
Vented air space
Stucco with paint - paint layer greater than 10 perms


Water Vapor Permeance of WRB's
Water Vapor Permeance, US perms
Mean Relative Humidity, %
Felt
ASK
High Perm
Plastic WRB
Low Perm
Plastic WRB
Dry Cup
Wet Cup
Permeance
"Sweet Spot"
0
10
20
30
40
50
60
70
80
90
100

Fixing Traditional Stucco….

Provide a 3/8 inch air space behind all stucco in regions where it rains more than 20 inches per year

Provide a 3/8 inch air space behind all stucco over three stories

Don’t install interior vapor barriers

Air space can be reduced to 1/16 inch where inward vapor drive is limited

Fixing Traditional Stucco….

EIFS Has None of These Issues….

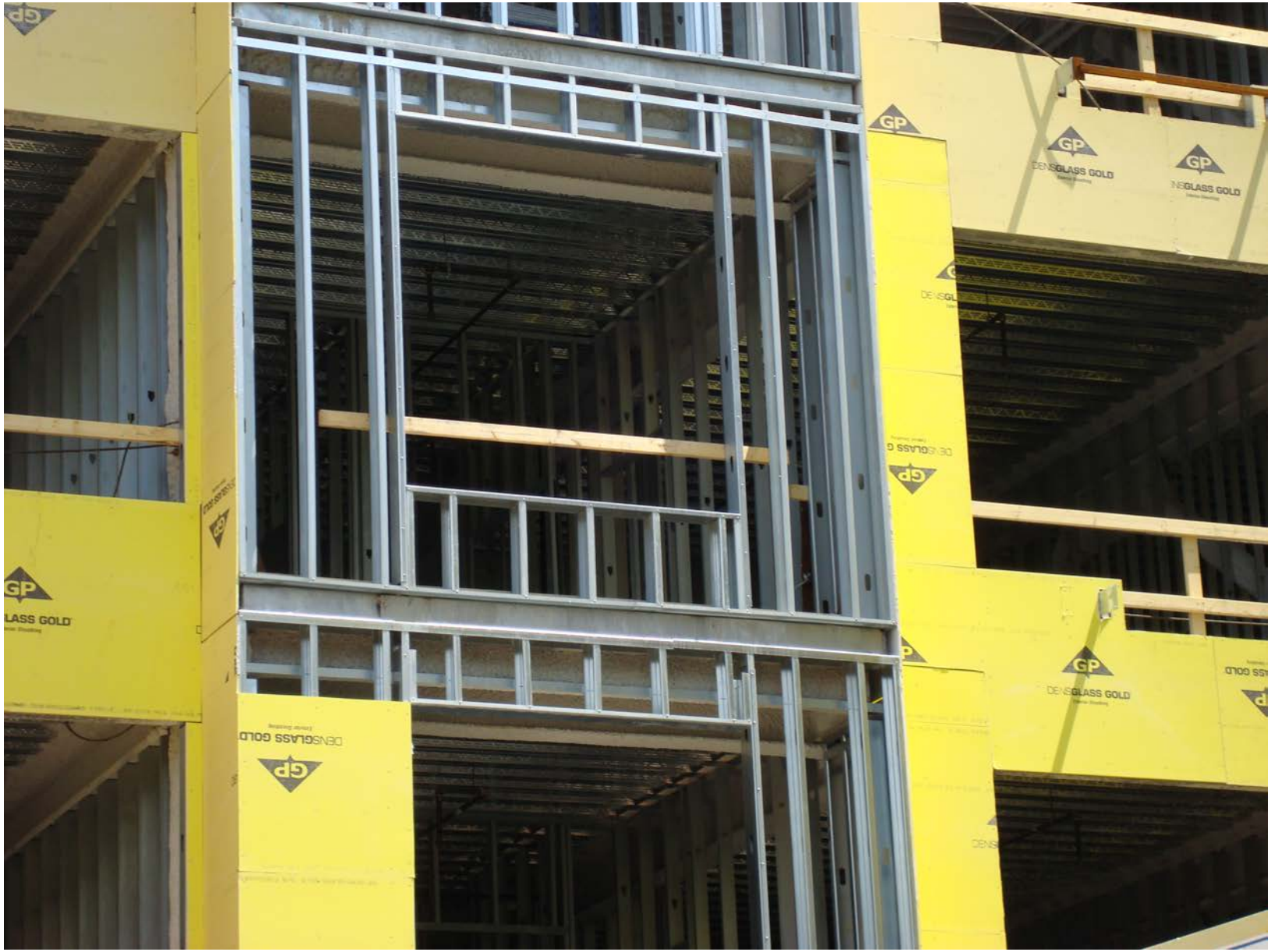
Fixing Traditional Stucco….

EIFS Has None of These Issues….

Except If You are Stupid and Install an Interior Vapor Barrier….

Don’t Do Stupid Things


ALL VISITORS
MUST SIGN IN
AT
JOHN MORIARTY
AND ASSOCIATES
FIELD OFFICE
CAUTION
HARD HAT
AREA
WORKSITE


GP
DENSGLASS GOLD


DENSGLASS GOLD
Exterior Sheathing
DENSGLASS GOLD
Exterior Sheathing


Blueskin
CAVITY WALL SYSTEMS


REPUBLIC


AVAILAB
978-369-4


DensGlass
GP


MARKET BASKET
DensGlass

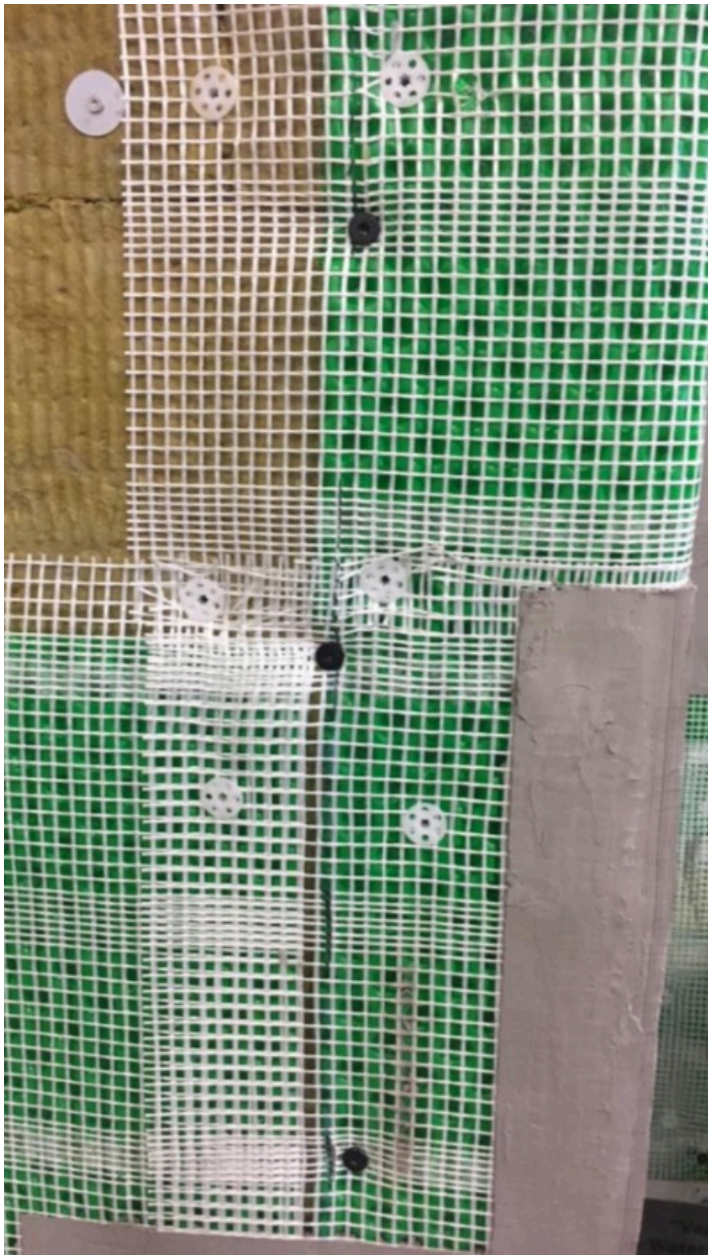

Tyvek

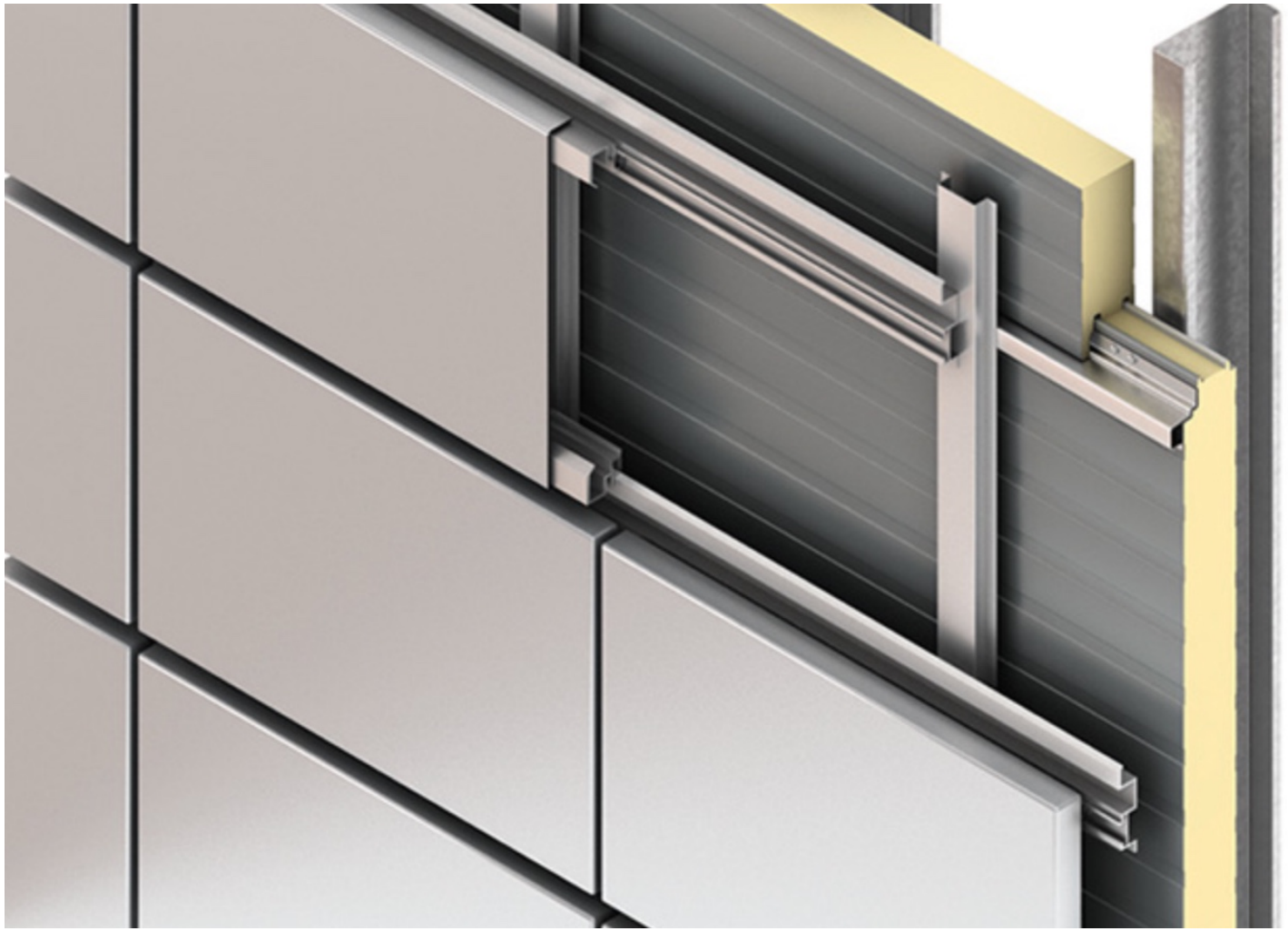

ZIPsystem
ZIPsystem
ZIPsystem
ZIPsystem
ZIPsystem

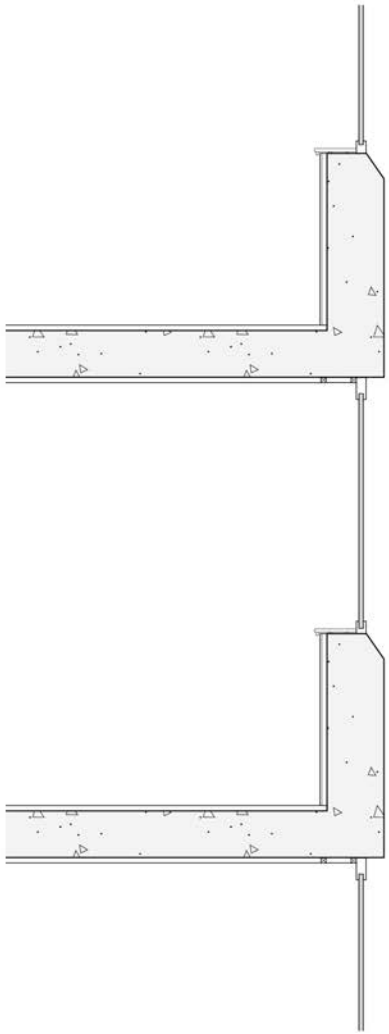

DANGER
CONSTRUCTION
AREA
KEEP OUT
LUCIANO

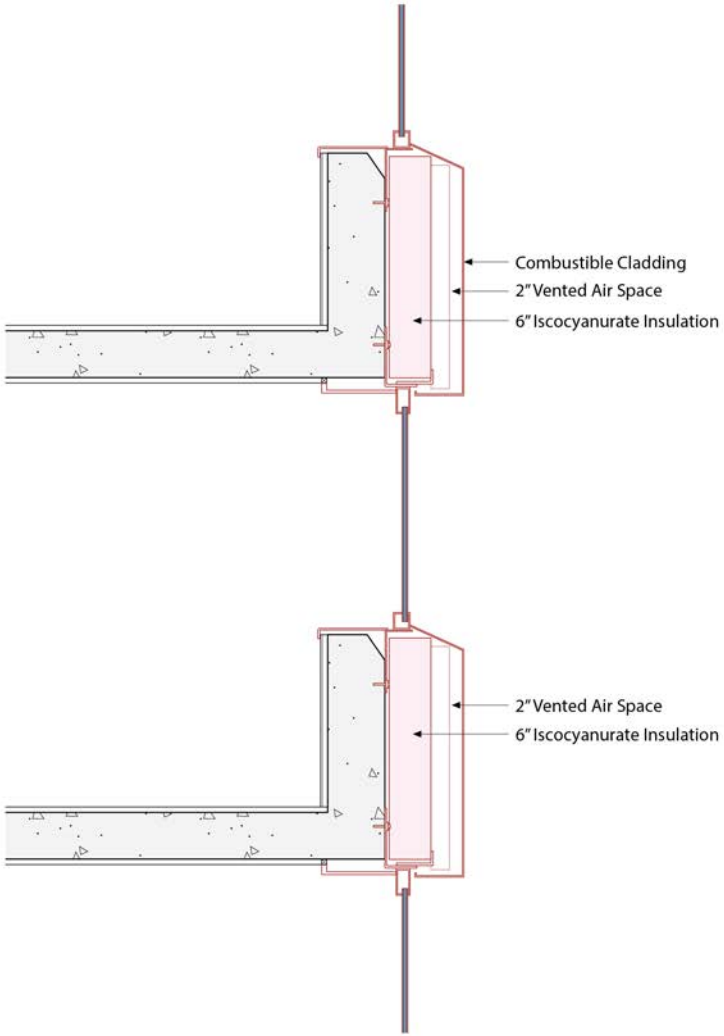

USG
TREMCO
SECUROCK® EXOAIR® 430

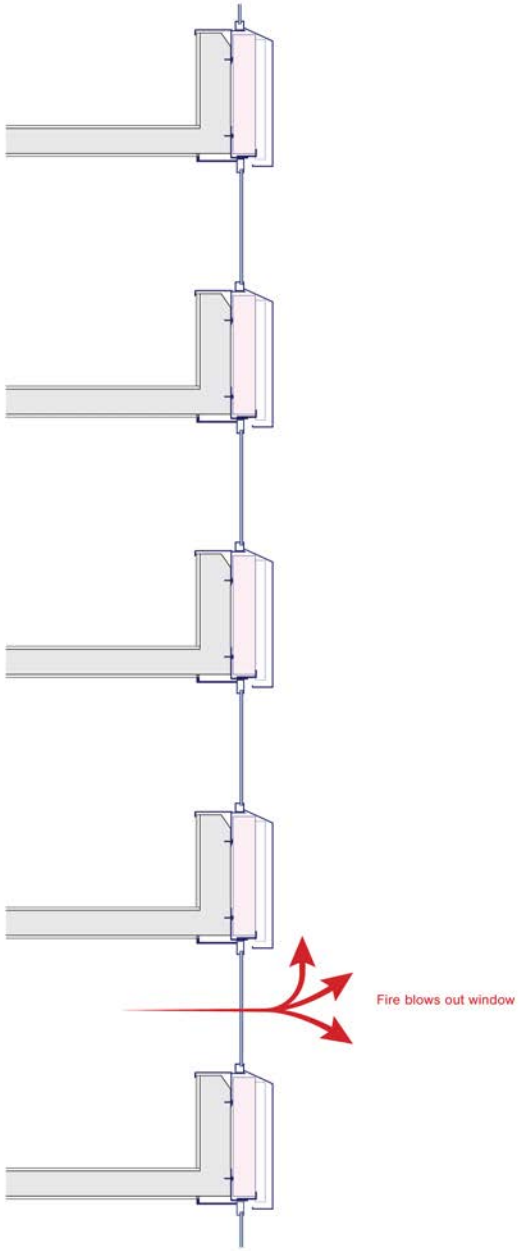

DELTA

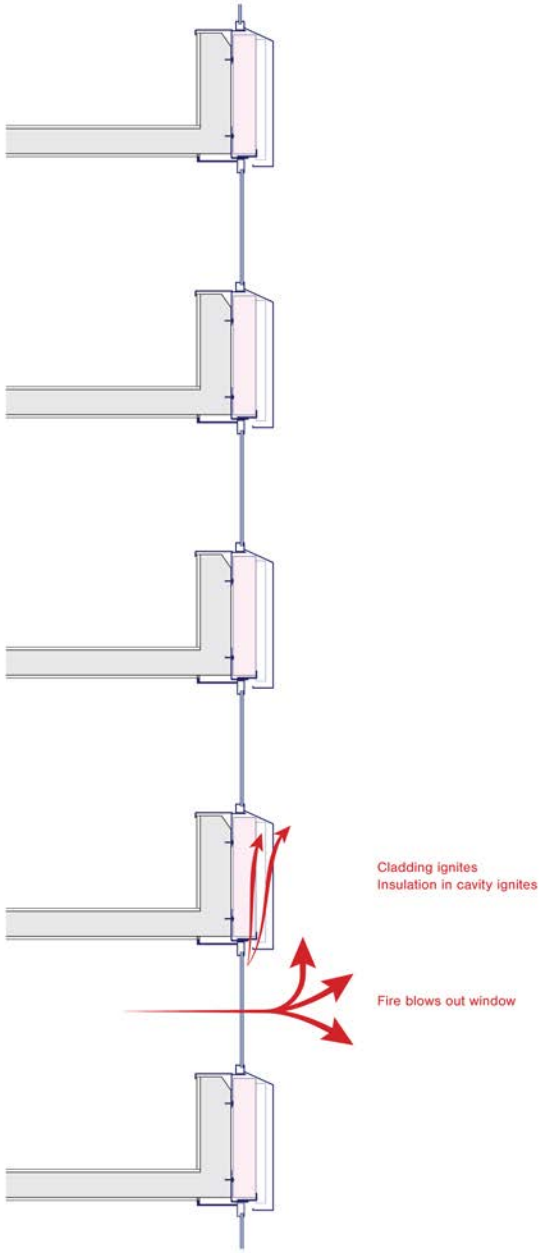


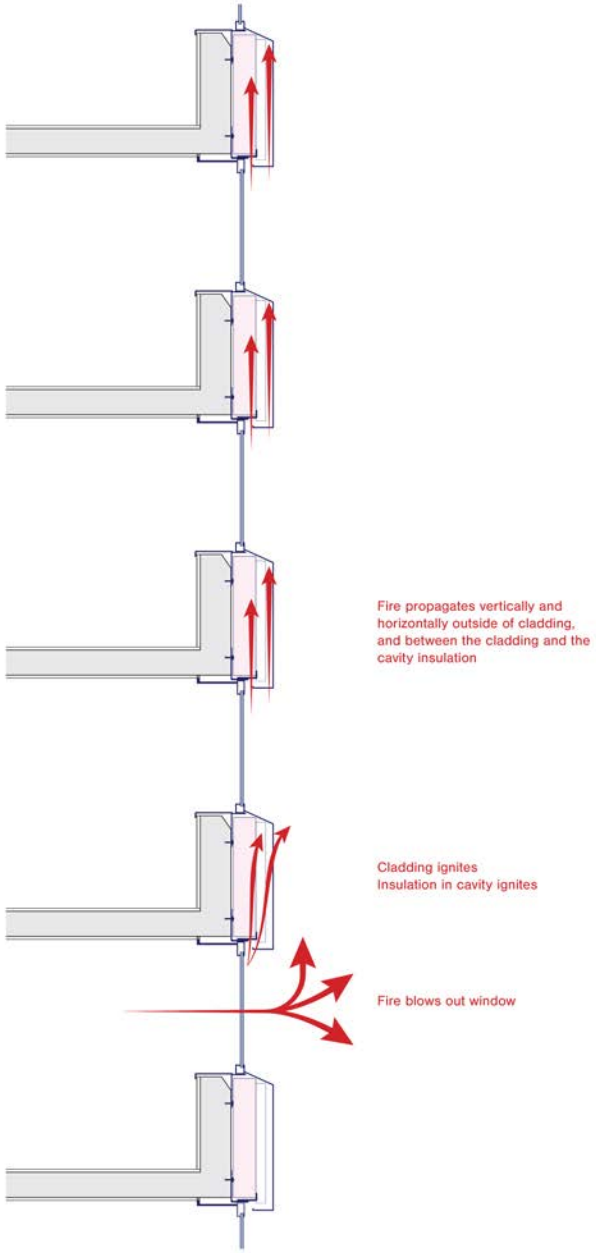


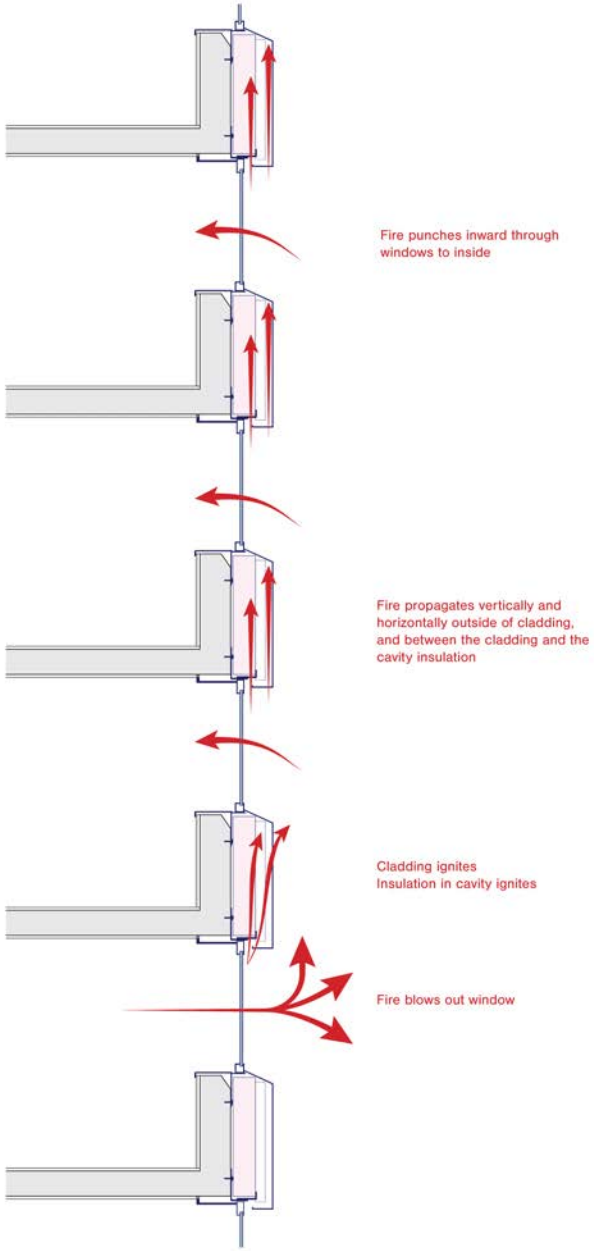



Combustible Cladding
2" Vented Air Space
6" Iscocyanurate Insulation
2" Vented Air Space
6" Iscocyanurate Insulation


Fire blows out window


Cladding ignites
Insulation in cavity ignites
Fire blows out window


Fire propagates vertically and horizontally outside of cladding, and between the cladding and the cavity insulation
Cladding ignites
Insulation in cavity ignites
Fire blows out window


Fire punches inward through windows to inside
Fire propagates vertically and horizontally outside of cladding, and between the cladding and the cavity insulation
Cladding ignites
Insulation in cavity ignites
Fire blows out window