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

Building Science

Vented and Unvented Roofs

presented by www.buildingscience.com

Code Change

IBC 1202.3 – IRC R806.5 Unvented attic and unvented attic enclosed rafter assemblies.

- vapor diffusion port
- port area 1:600 of the ceiling area
- vapor permeance greater than 20 perms
- roof slope greater than 3:12
- insulation installed directly under the roof deck or at the ceiling
- air supply 50 cfm/1000 ft2 ceiling area where insulation installed directly under the roof deck
- Climate Zones 1, 2 and 3

Vapor Diffusion Port: An assembly constructed or installed within a roof assembly at an opening in the roof deck to conveying water vapor from an unvented attic to the outside atmosphere.

Arrhenius Equation

For Every 10 Degree K Rise

Reaction Rate Doubles

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

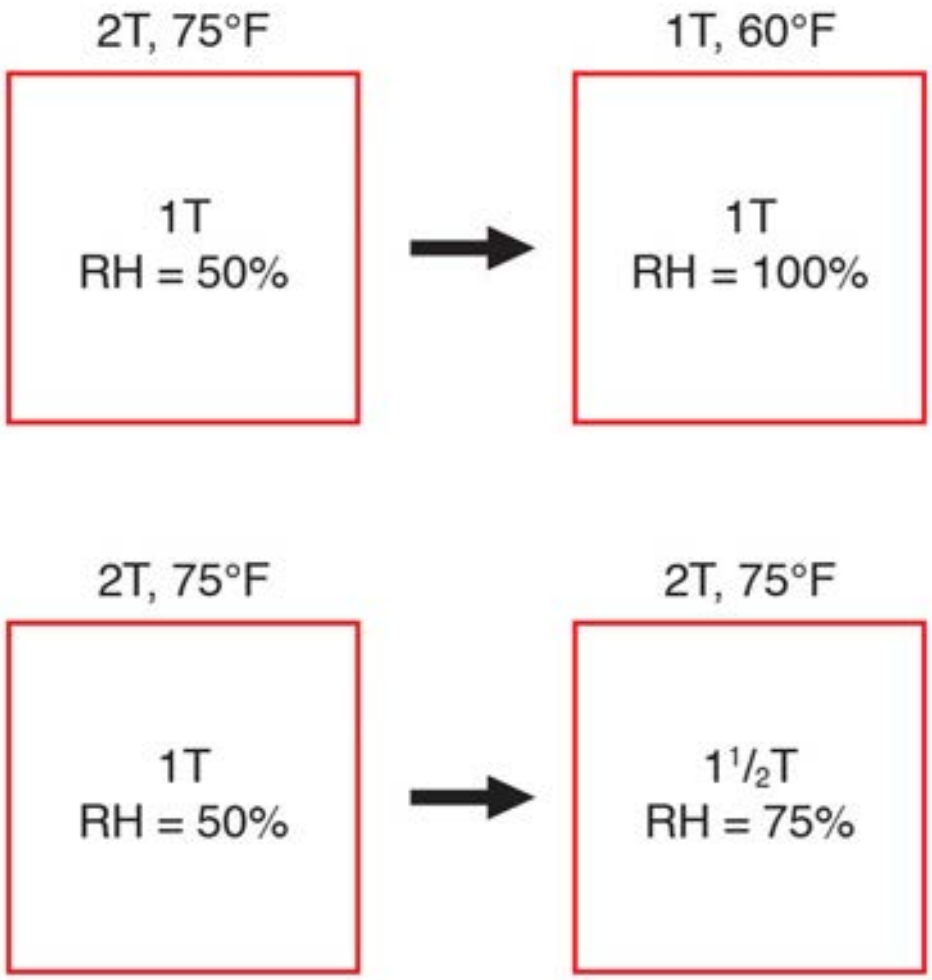
Damage Functions

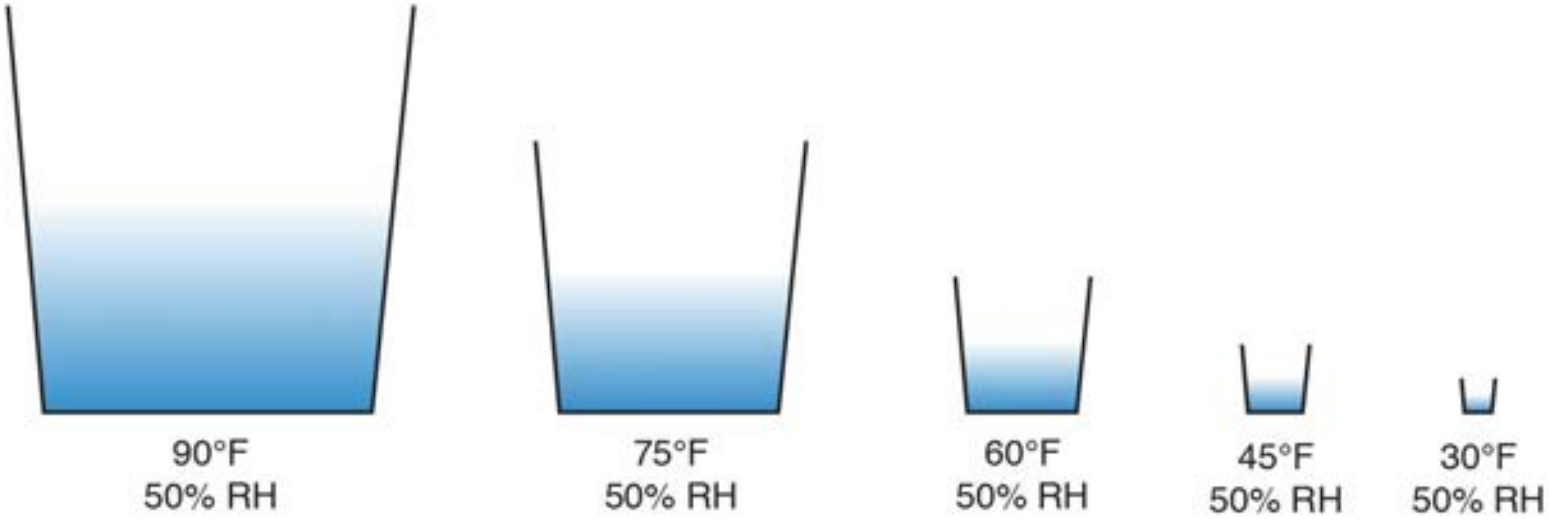
Water

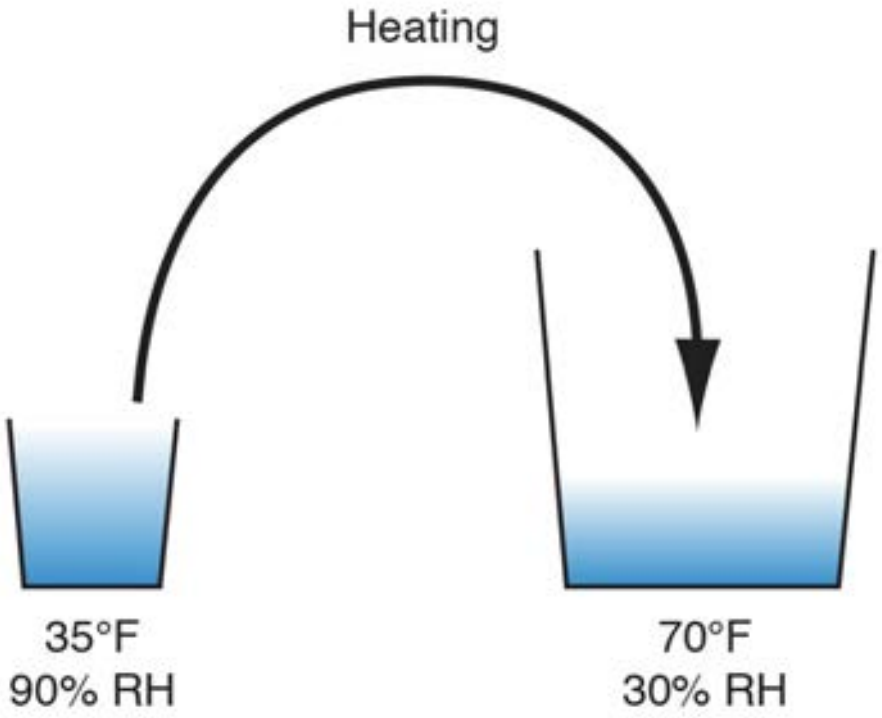
Heat

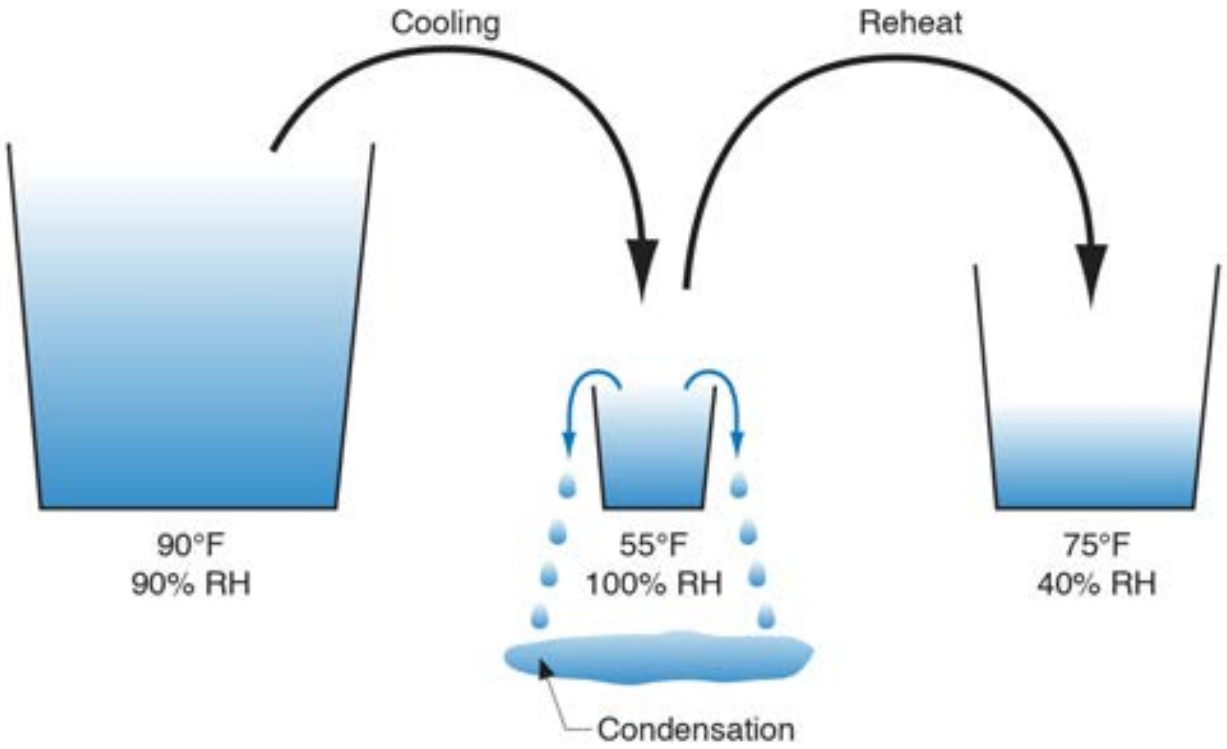
Ultra-violet Radiation

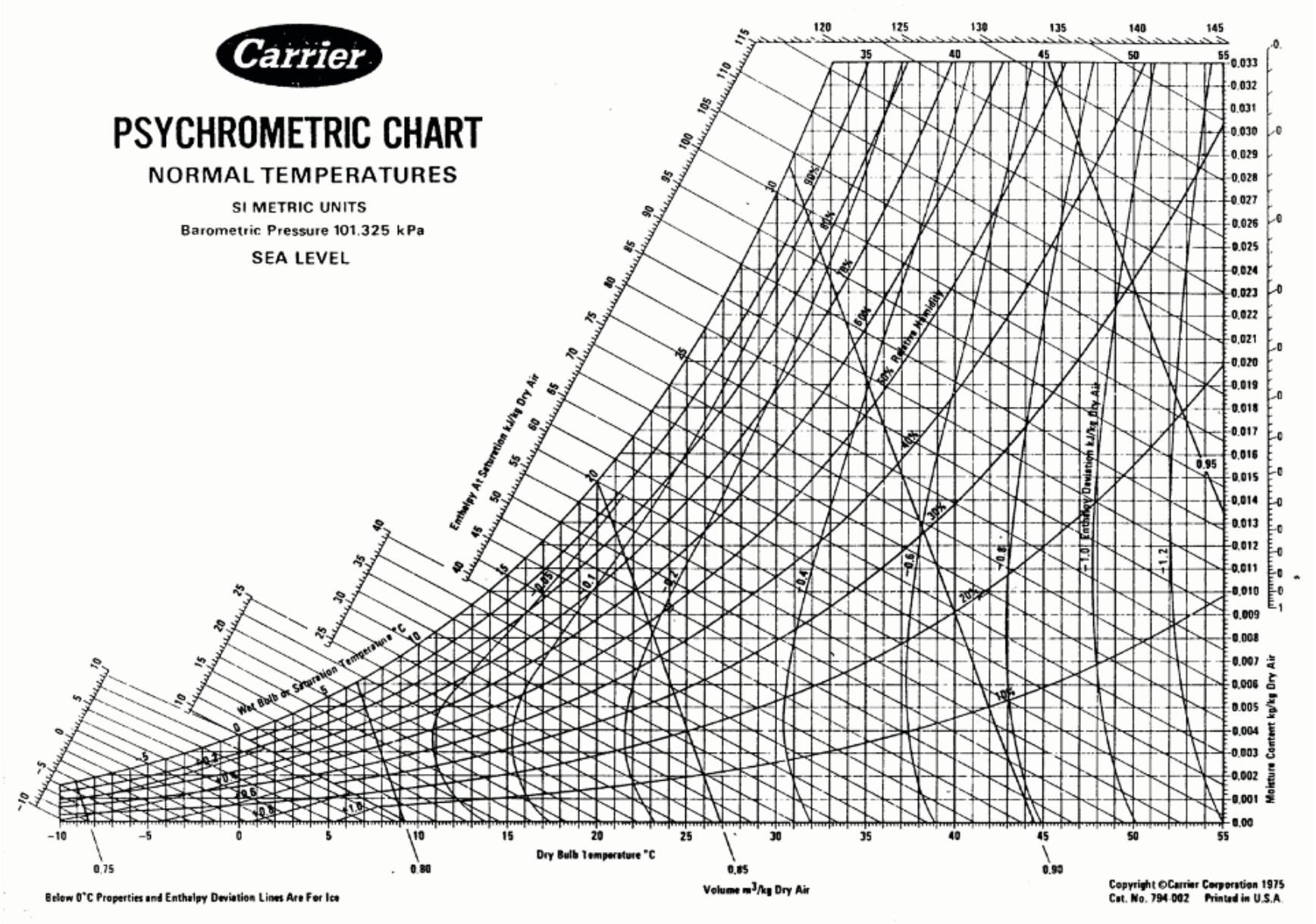
Vapor Pressure and Relative Humidity


2T, 75°F
1T
RH = 50%
1T, 60°F
1T
RH = 100%
2T, 75°F
1T
RH = 50%
2T, 75°F
1 1/2T
RH = 75%


90°F
50% RH
75°F
50% RH
60°F
50% RH
45°F
50% RH
30°F
50% RH


Heating
35°F
90% RH
70°F
30% RH


Cooling
Reheat
90°F
90% RH
55°F
100% RH
75°F
40% RH
Condensation


Carrier
PSYCHROMETRIC CHART
NORMAL TEMPERATURES
SI METRIC UNITS
Barometric Pressure 101.325 kPa
SEA LEVEL
Dry Bulb Temperature °C
Wet Bulb or Saturation Temperature °C
Enthalpy At Saturation kJ/kg Dry Air
Moisture Content kg/kg Dry Air
Volume m³/kg Dry Air
Below 0°C Properties and Enthalpy Deviation Lines Are For Ice
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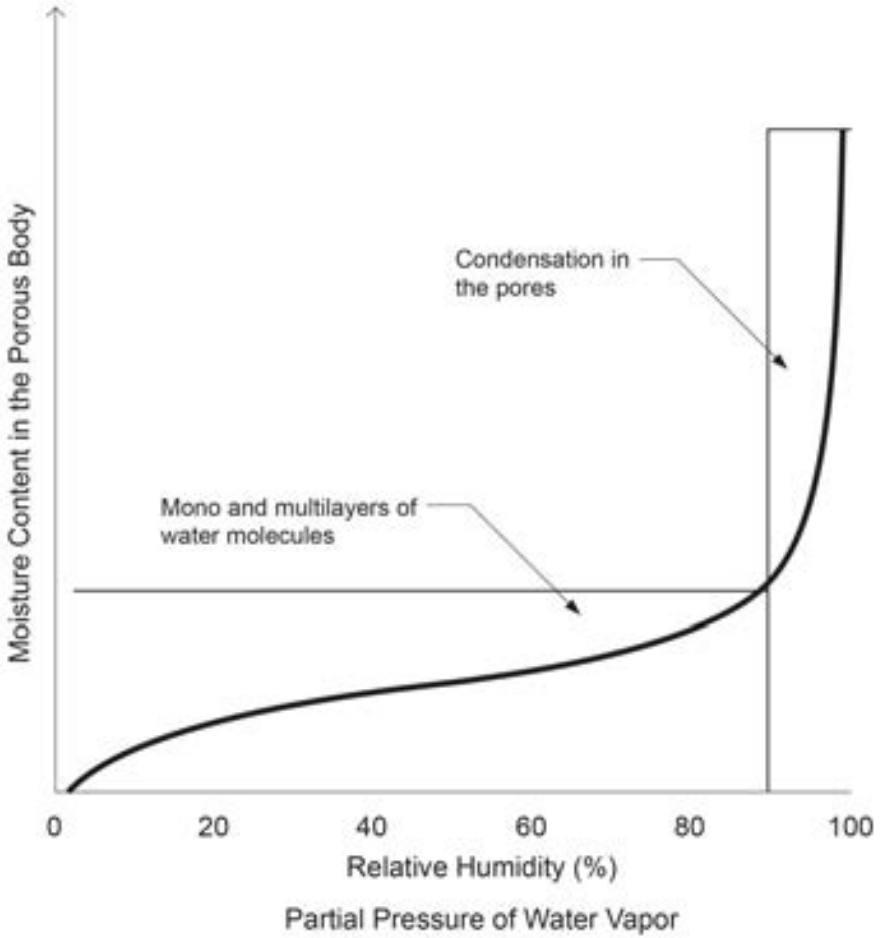
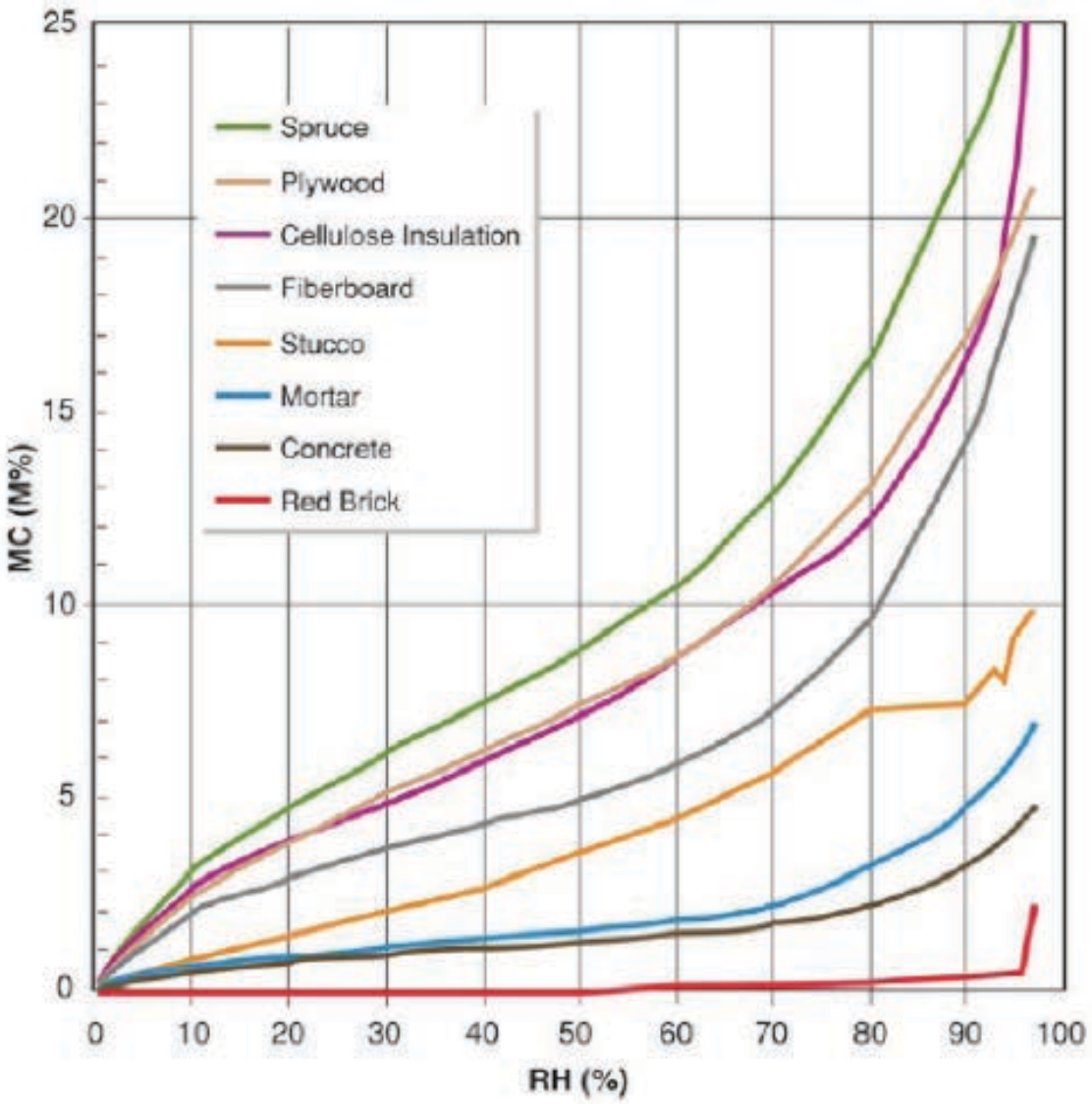
Sorption Isotherms

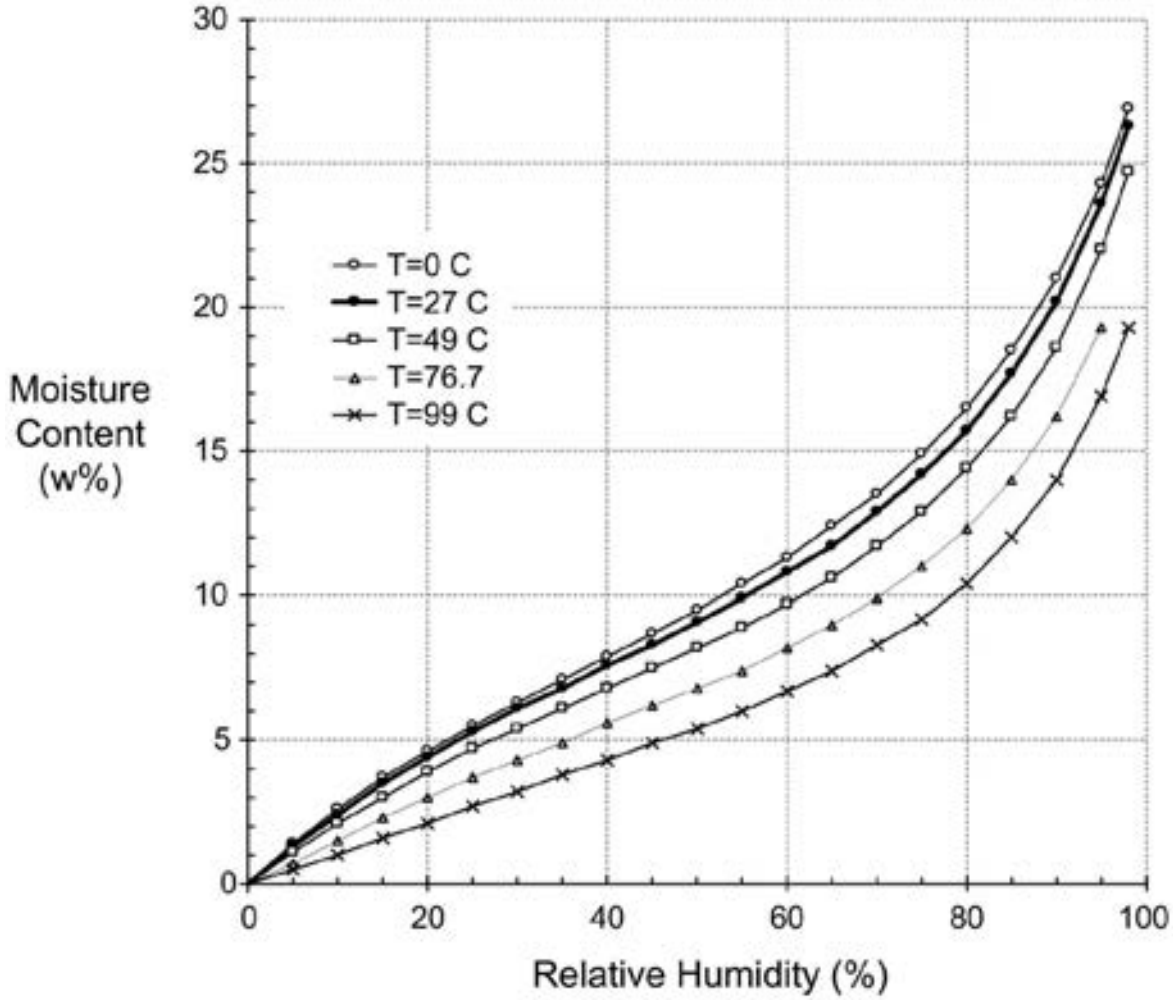


Change in the storage of moisture in a porous building material as the partial pressure of water vapor in the ambient air increases from zero to full saturation value at a given temperature.

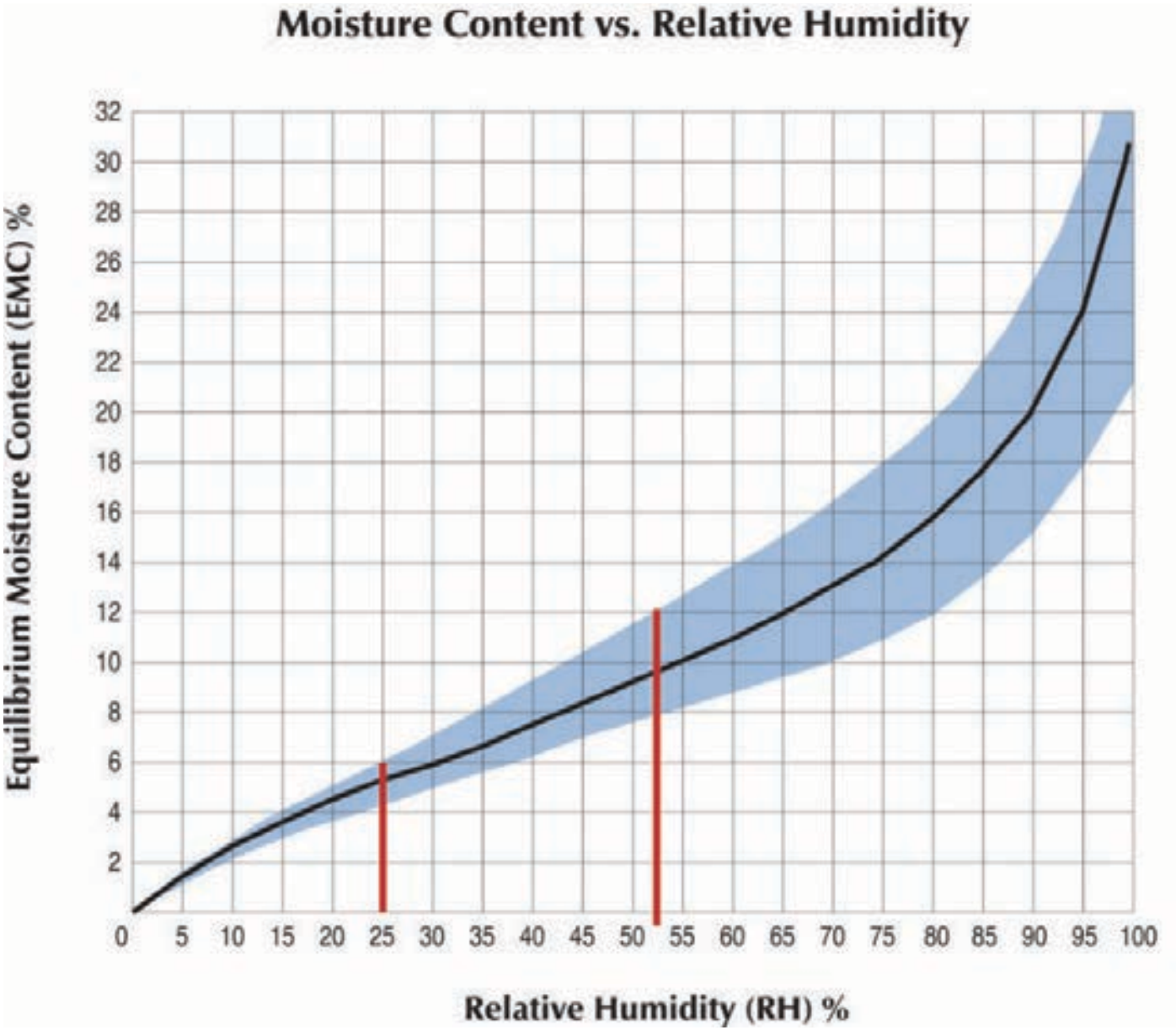
Sorption Curve

From M.K. Kumaran, ASTM MNL 18-2nd Edition, Moisture Control in Buildings, 2009


Spruce
Plywood
Cellulose Insulation
Fiberboard
Stucco
Mortar
Concrete
Red Brick
MC (M%)
RH (%)
0
5
10
15
20
25
0
10
20
30
40
50
60
70
80
90
100



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


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

2nd Law of Thermodynamics

Heat Flow Is From Warm To Cold

Moisture Flow Is From Warm To Cold

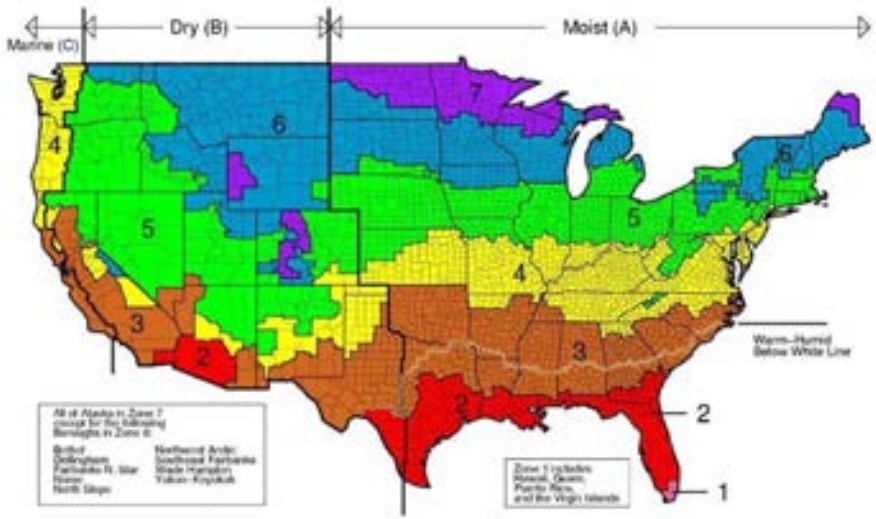
Moisture Flow Is From More To Less

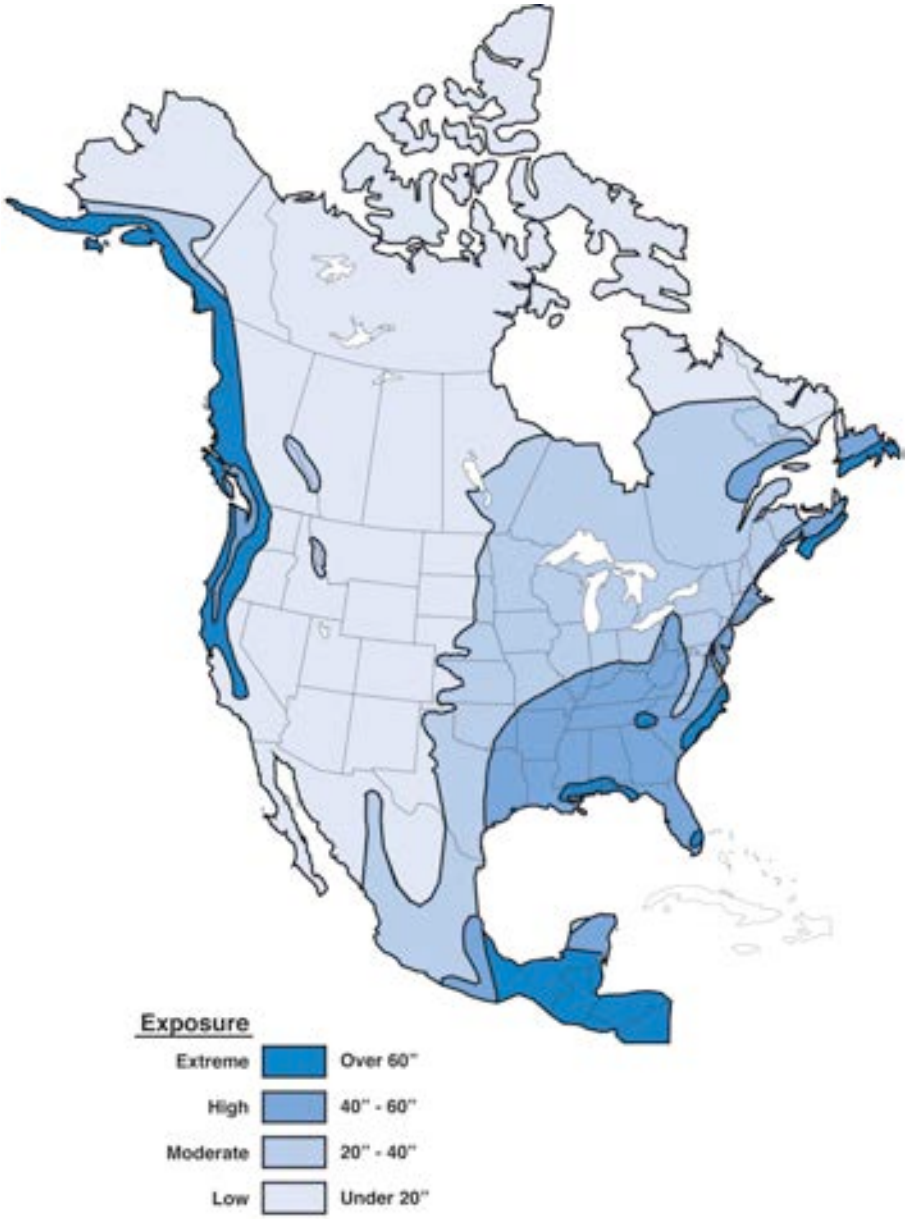
Air Flow Is From A Higher Pressure to a Lower Pressure

Gravity Acts Down

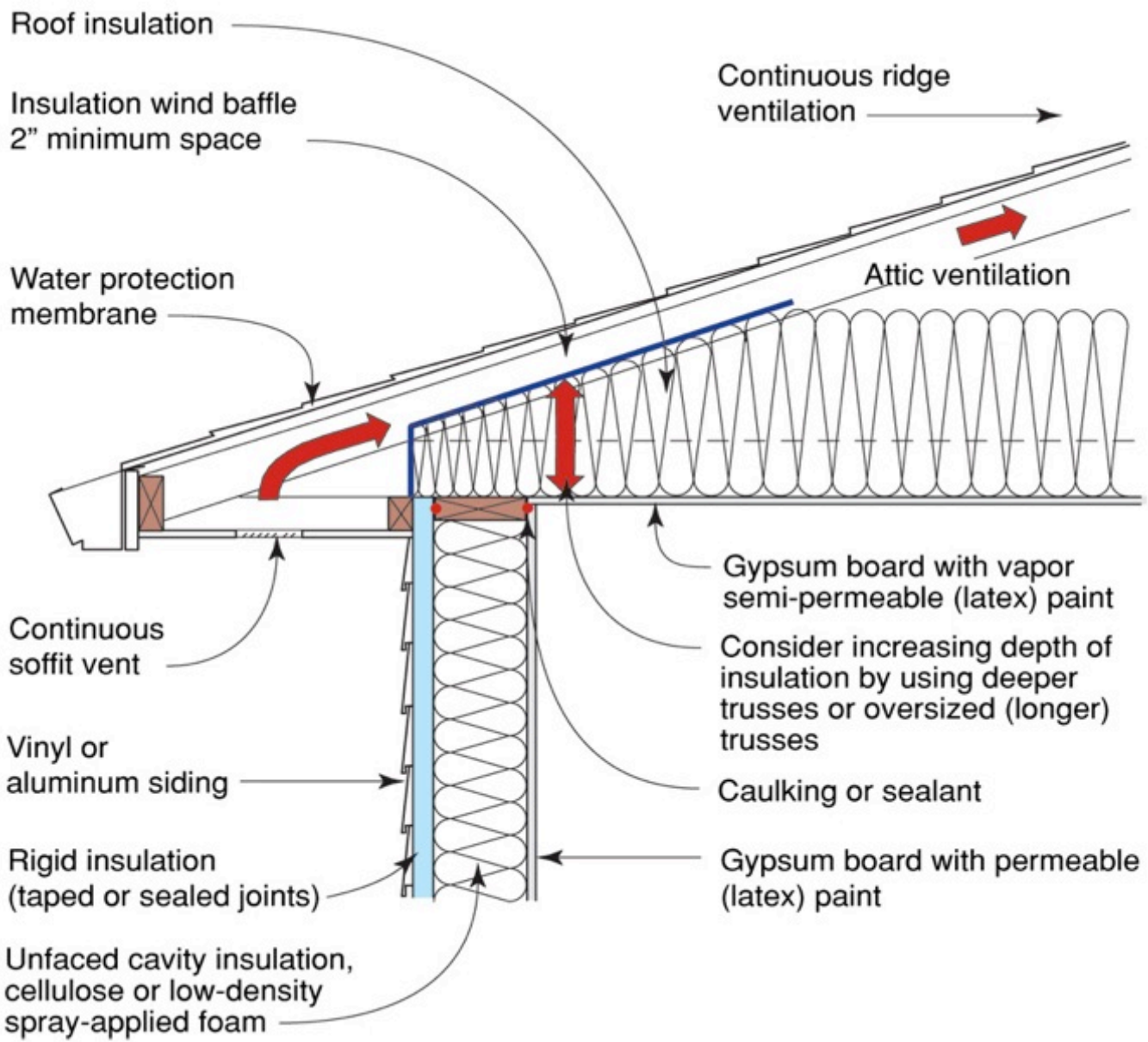

Subarctic/Arctic
Very Cold
Marine
Cold
Mixed-Humid
Mixed-Dry
Hot-Humid
Hot-Dry

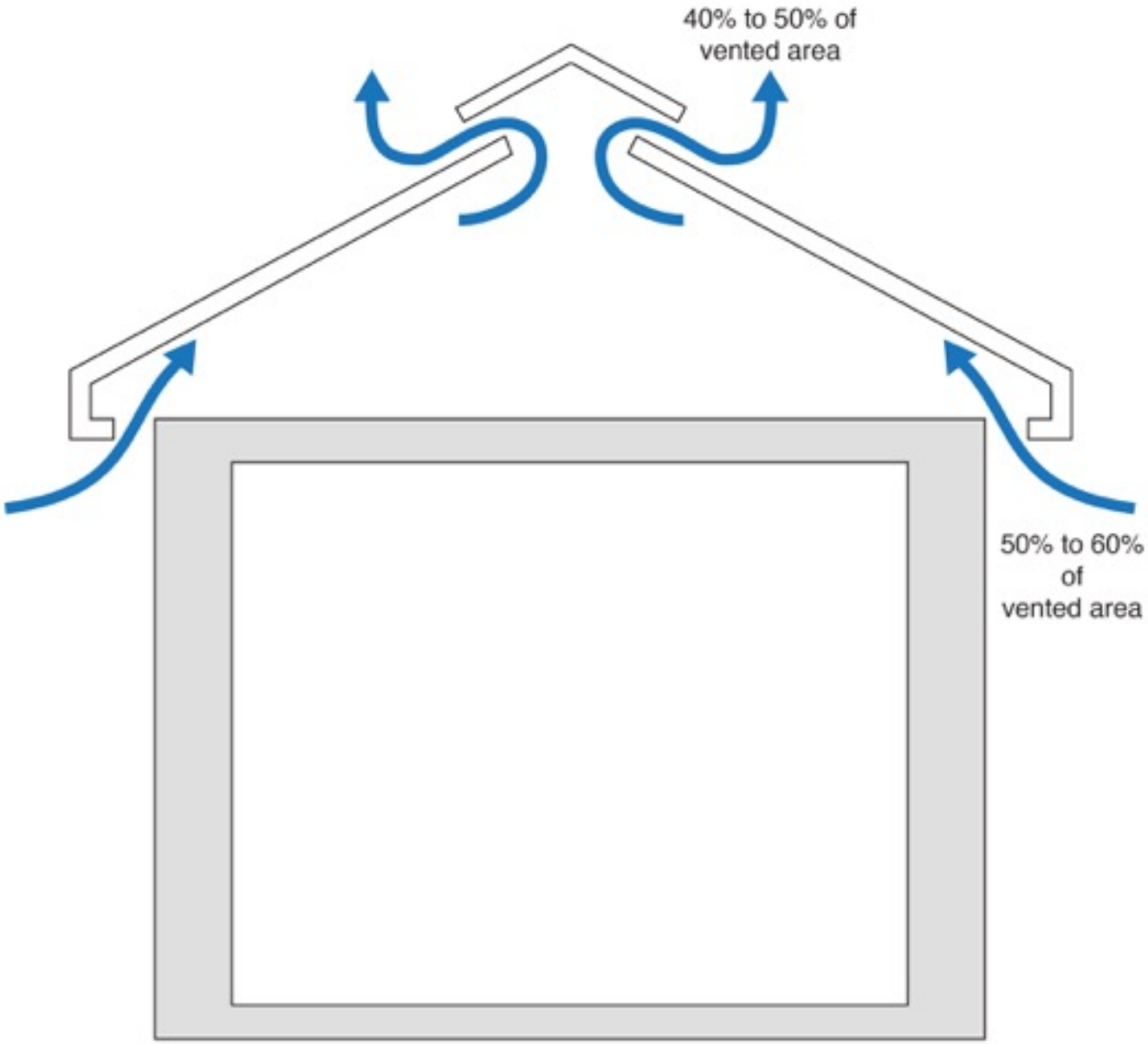

Arctic Bay
Anchorage
Seattle
Minneapolis
Los Angeles
El Paso
Houston
Monterrey
Havana
Belize City
Tropical Wet
Tropical Wet-Dry
Steppe
Desert
Mediterranean
Subtropical humid
Marine West Coast
Continental humid
Subarctic
Tundra
Ice sheet
Highlands

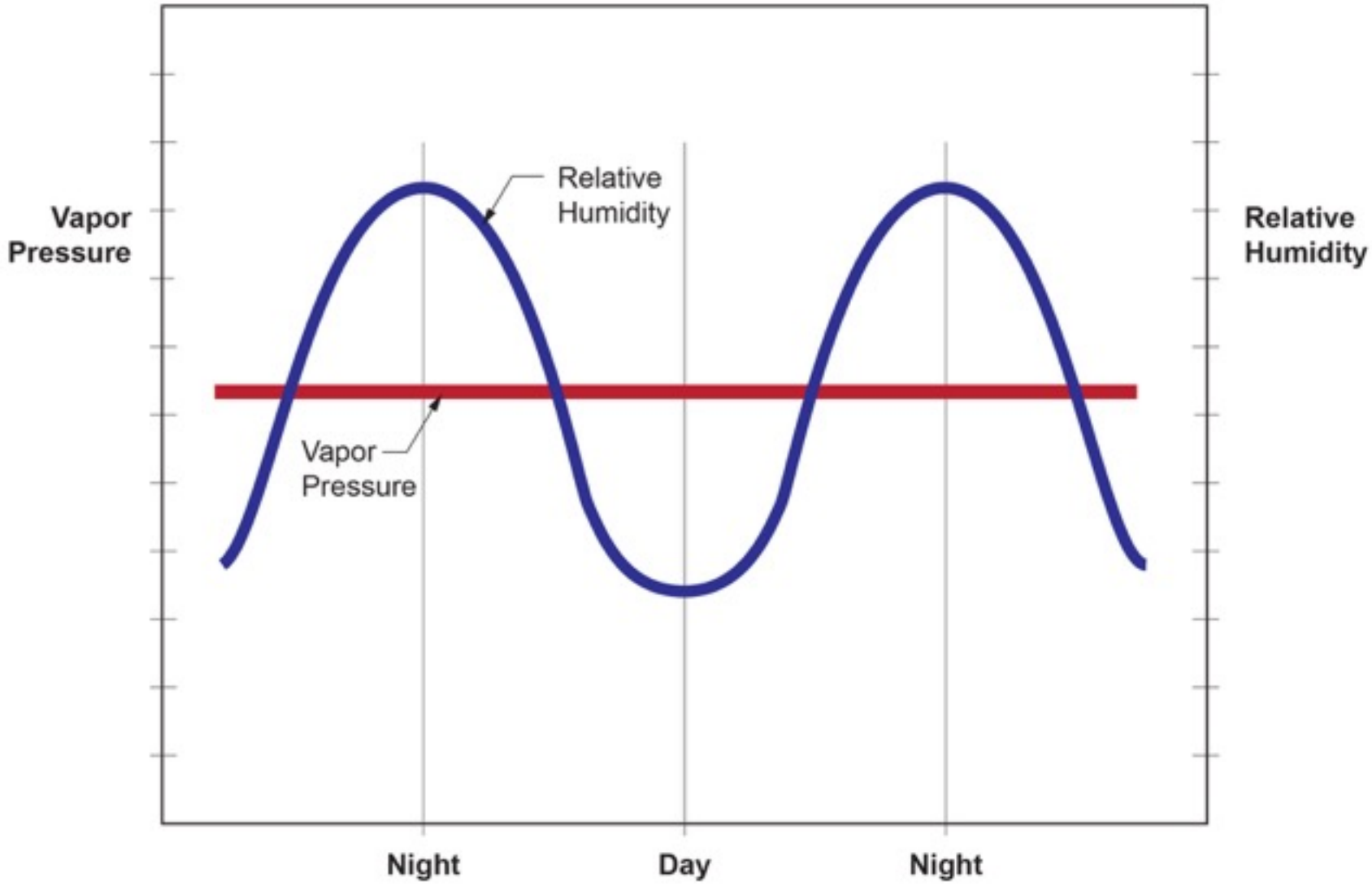

Marine (C)
Dry (B)
Moist (A)
Warm–Humid
Below White Line


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

Vented Attics Are Climate Dependant


Roof insulation
Insulation wind baffle
2" minimum space
Continuous ridge
ventilation
Water protection
membrane
Attic ventilation
Gypsum board with vapor
semi-permeable (latex) paint
Continuous
soffit vent
Consider increasing depth of
insulation by using deeper
trusses or oversized (longer)
trusses
Vinyl or
aluminum siding
Caulking or sealant
Rigid insulation
(taped or sealed joints)
Gypsum board with permeable
(latex) paint
Unfaced cavity insulation,
cellulose or low-density
spray-applied foam

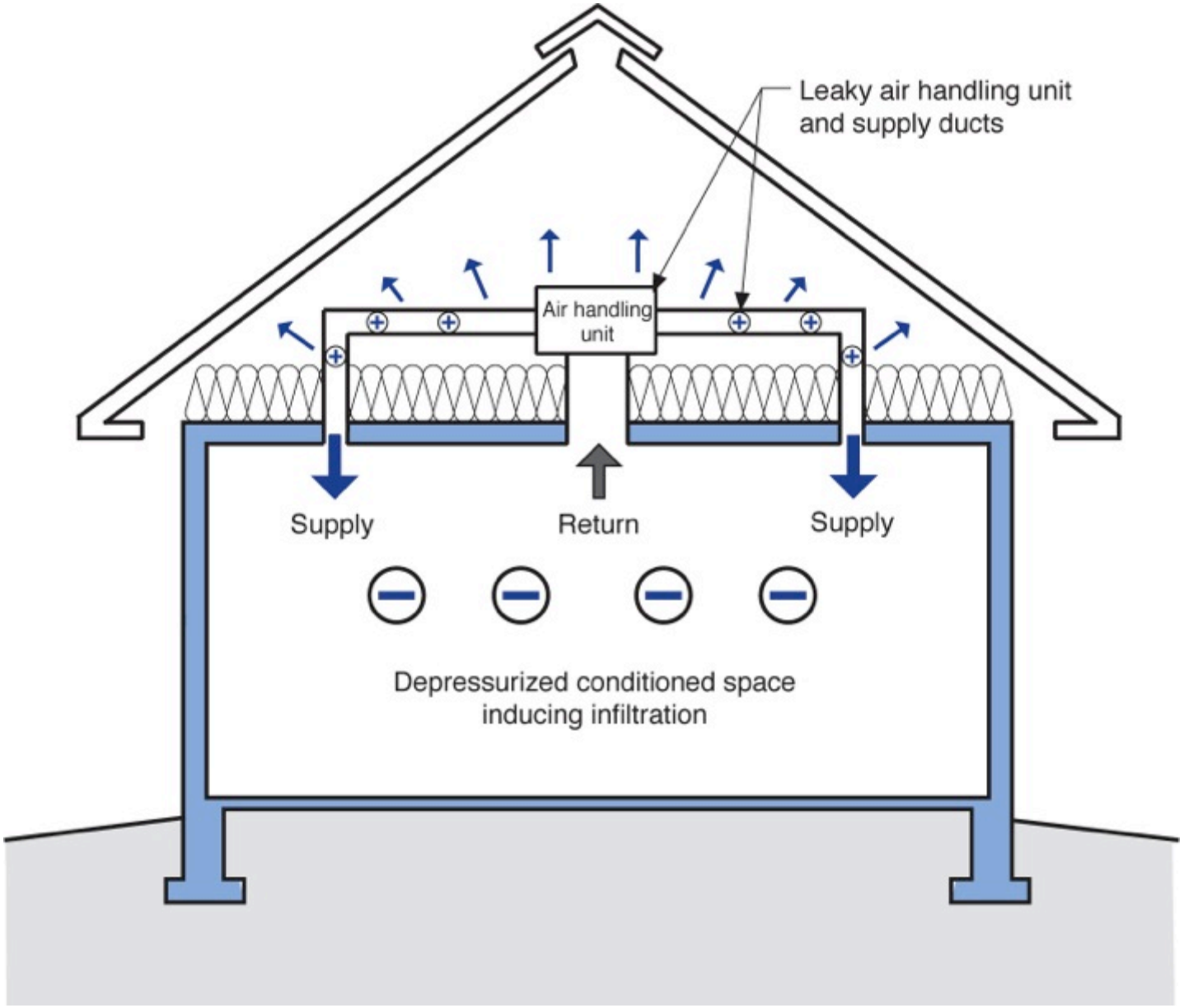

40% to 50% of
vented area
50% to 60%
of
vented area

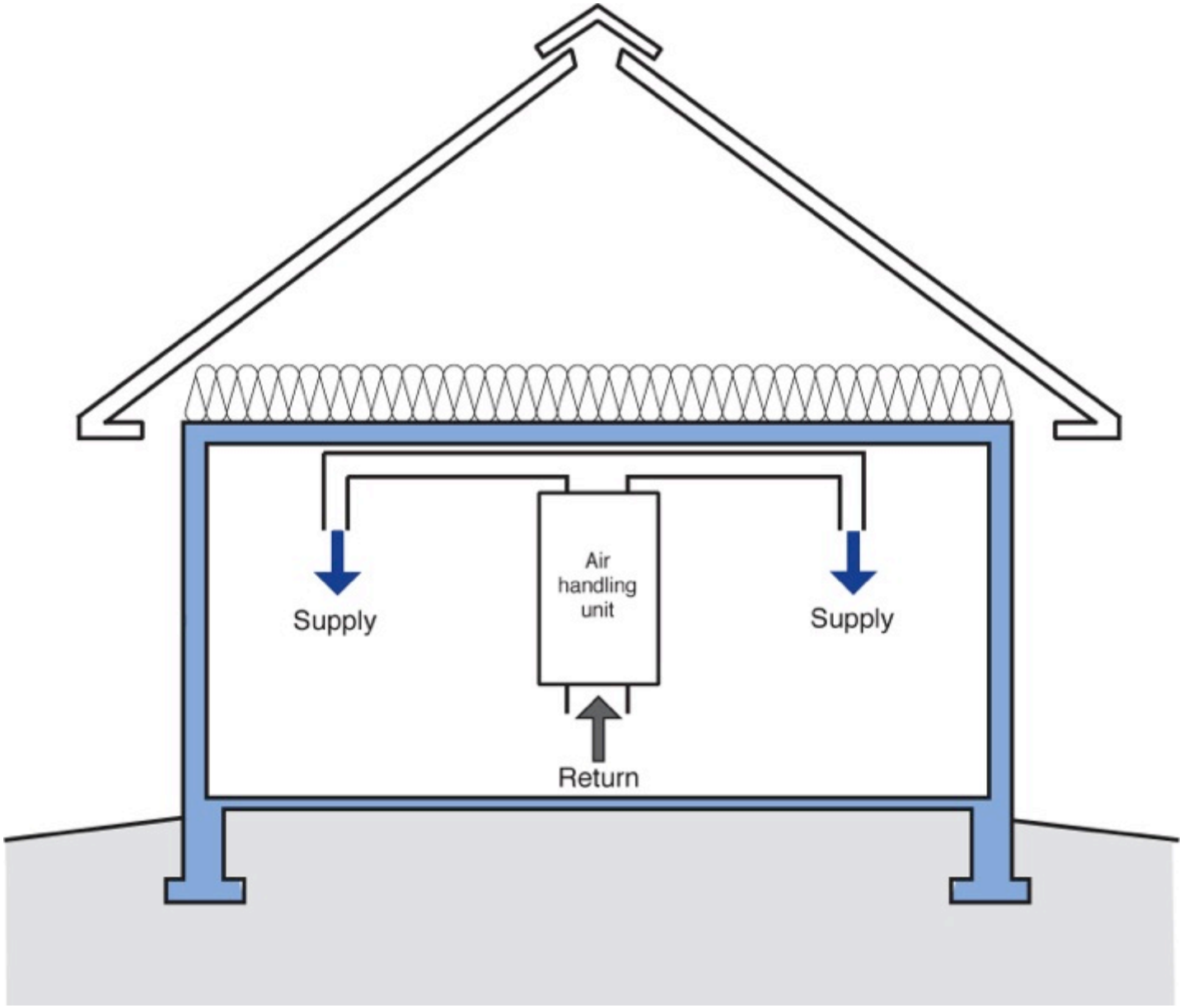

Vapor Pressure
Relative Humidity
Relative Humidity
Vapor Pressure
Night
Day
Night

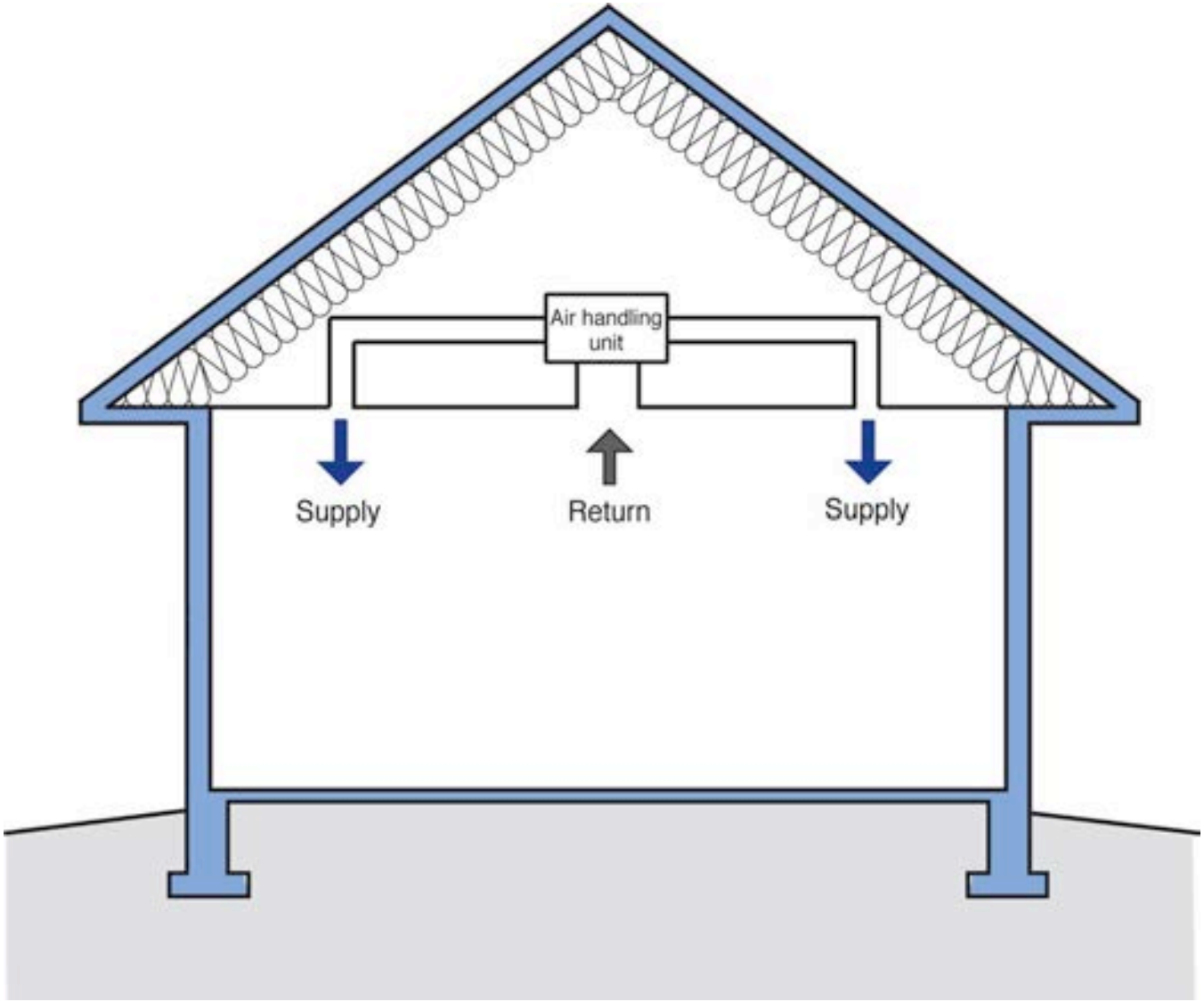
Houses With Vented Attics Suck

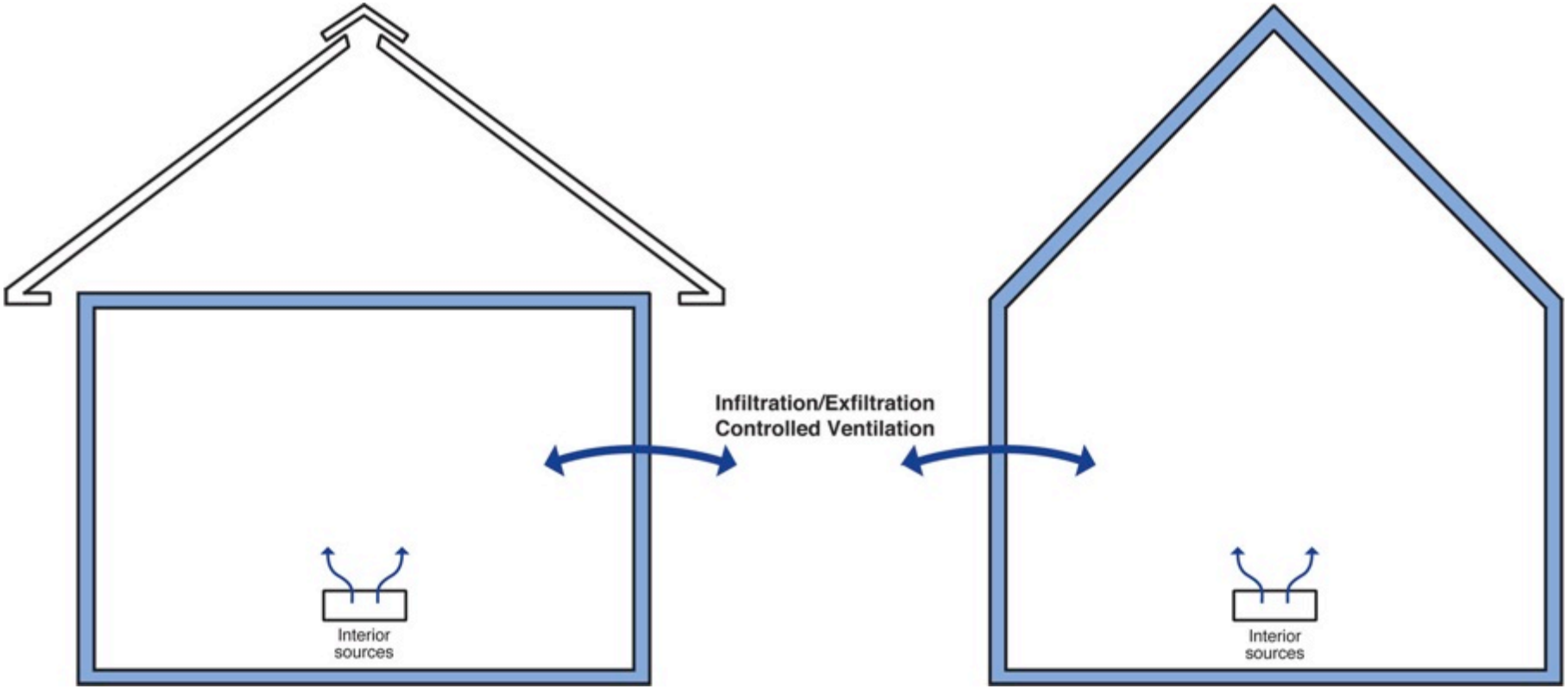
Houses With Vented Attics Suck

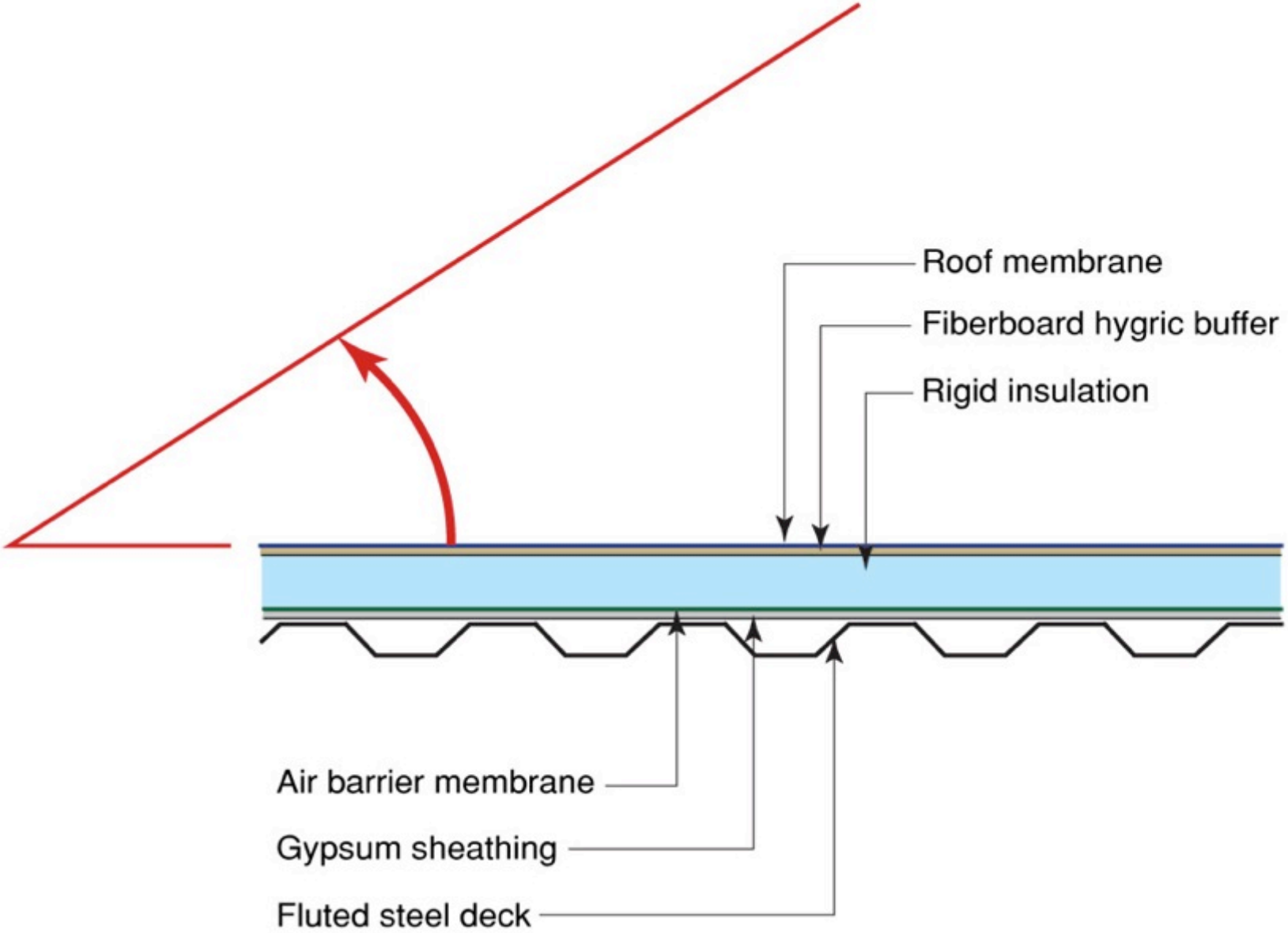
Not all the Time…..but.....

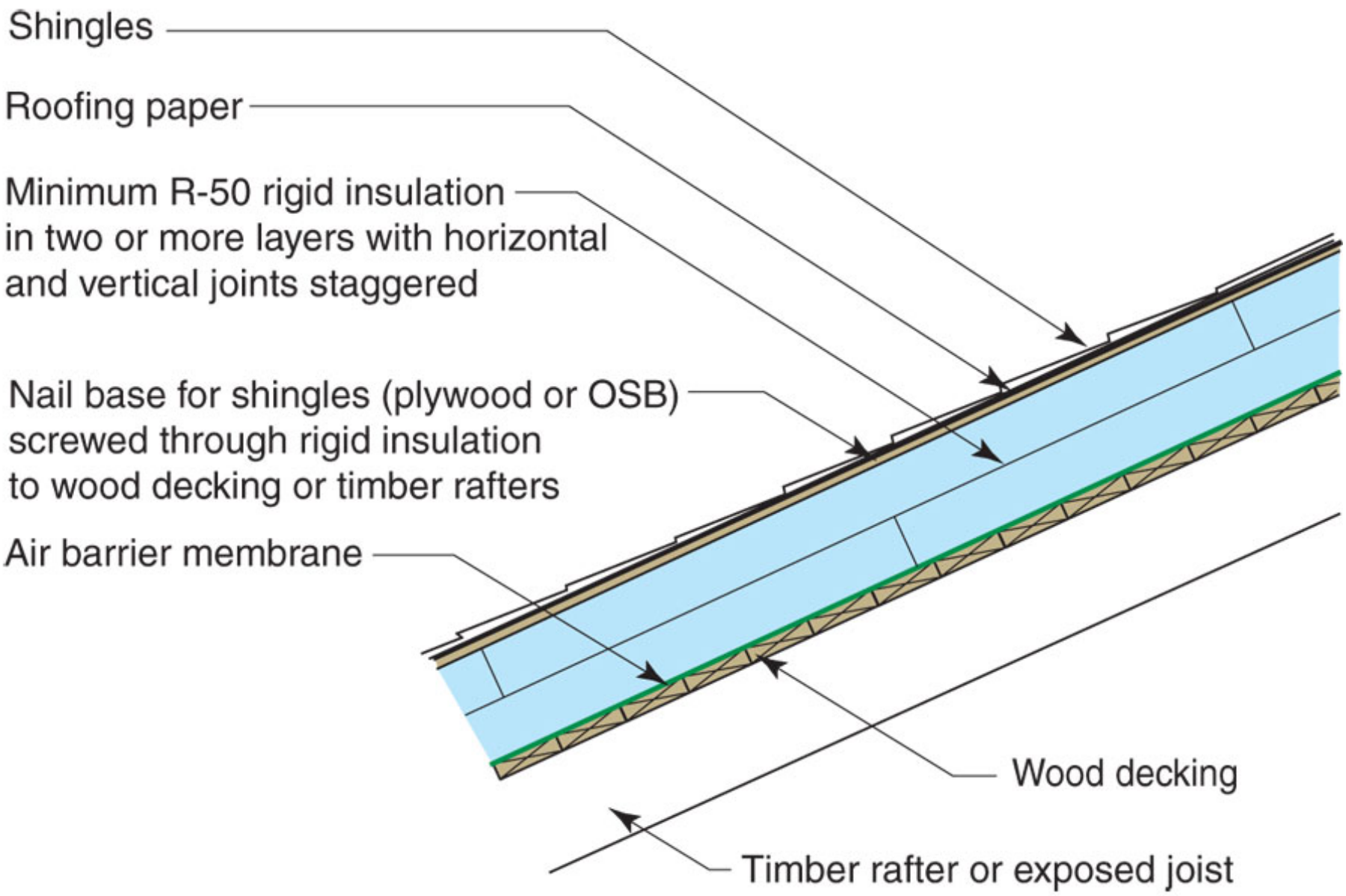

Leaky air handling unit
and supply ducts
Air handling
unit
Supply
Return
Supply
Depressurized conditioned space
inducing infiltration

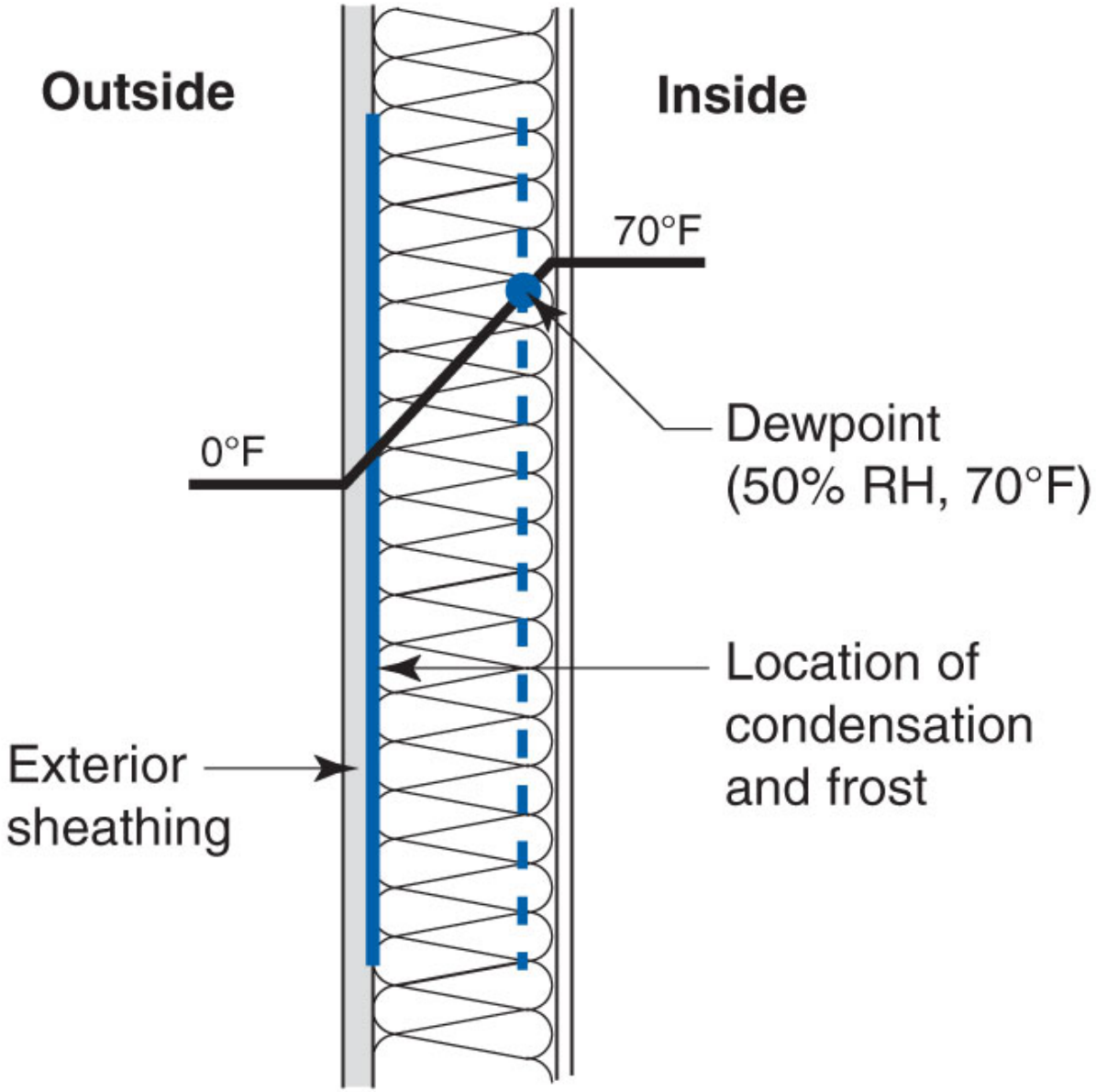

Supply
Air handling unit
Supply
Return

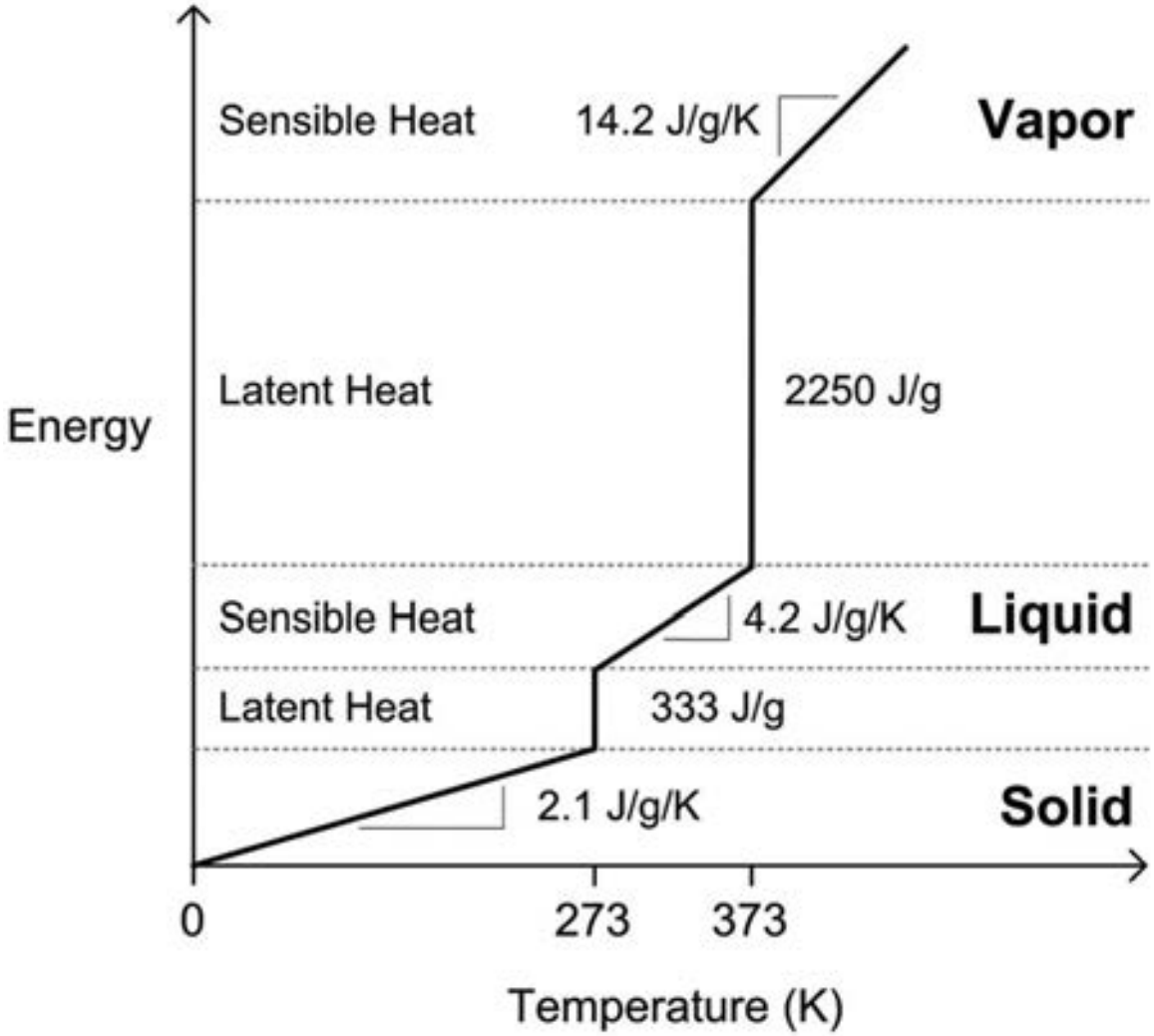

Air handling unit
Supply
Return
Supply


Infiltration/Exfiltration
Controlled Ventilation
Interior sources
Interior sources

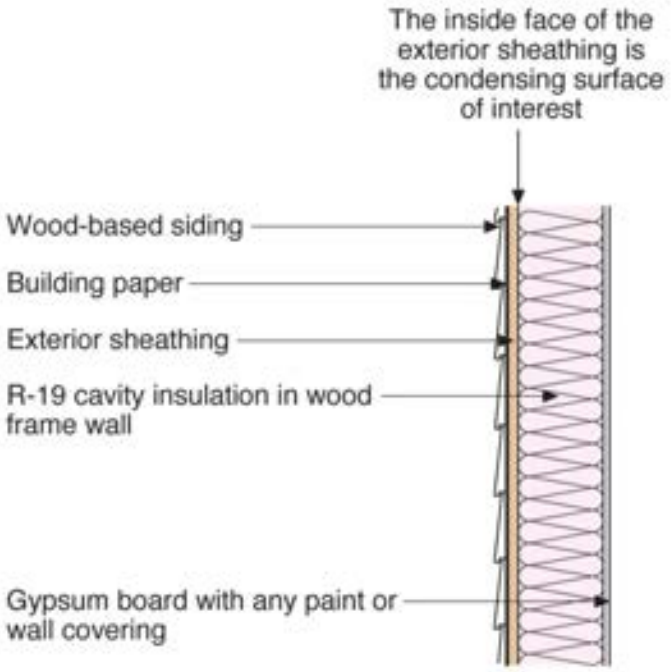

Roof membrane
Fiberboard hygric buffer
Rigid insulation
Air barrier membrane
Gypsum sheathing
Fluted steel deck

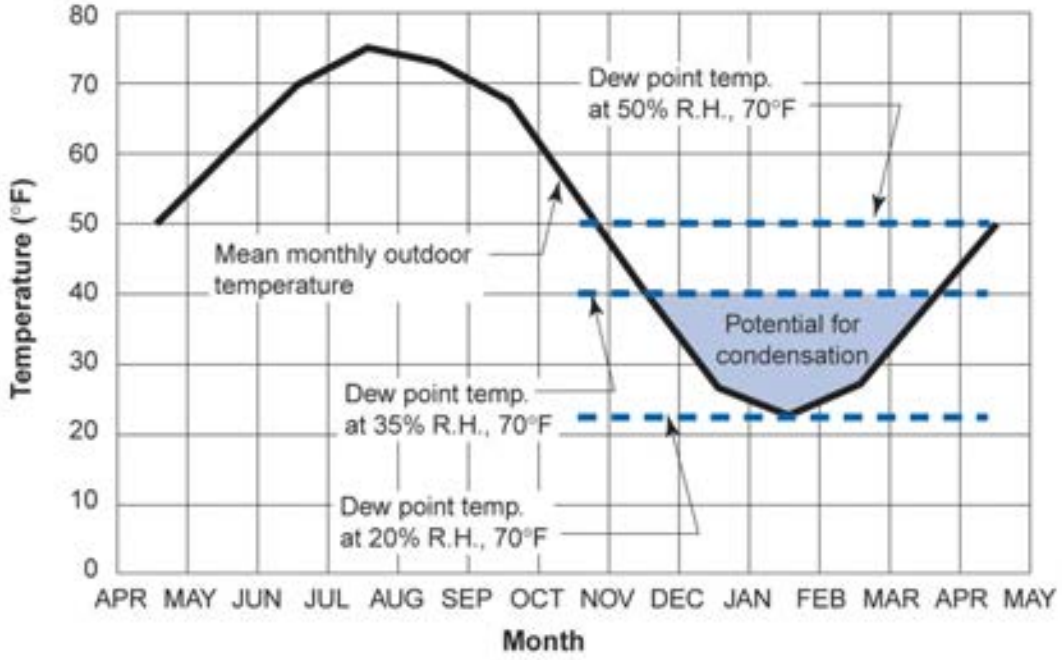

Shingles
Roofing paper
Minimum R-50 rigid insulation
in two or more layers with horizontal
and vertical joints staggered
Nail base for shingles (plywood or OSB)
screwed through rigid insulation
to wood decking or timber rafters
Air barrier membrane
Wood decking
Timber rafter or exposed joist

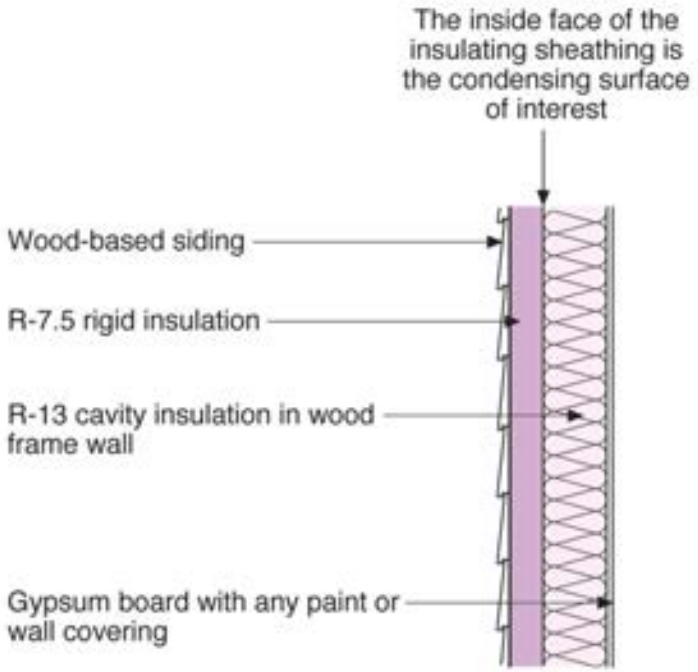

Outside
Inside
70°F
0°F
Dewpoint
(50% RH, 70°F)
Location of
condensation
and frost
Exterior
sheathing

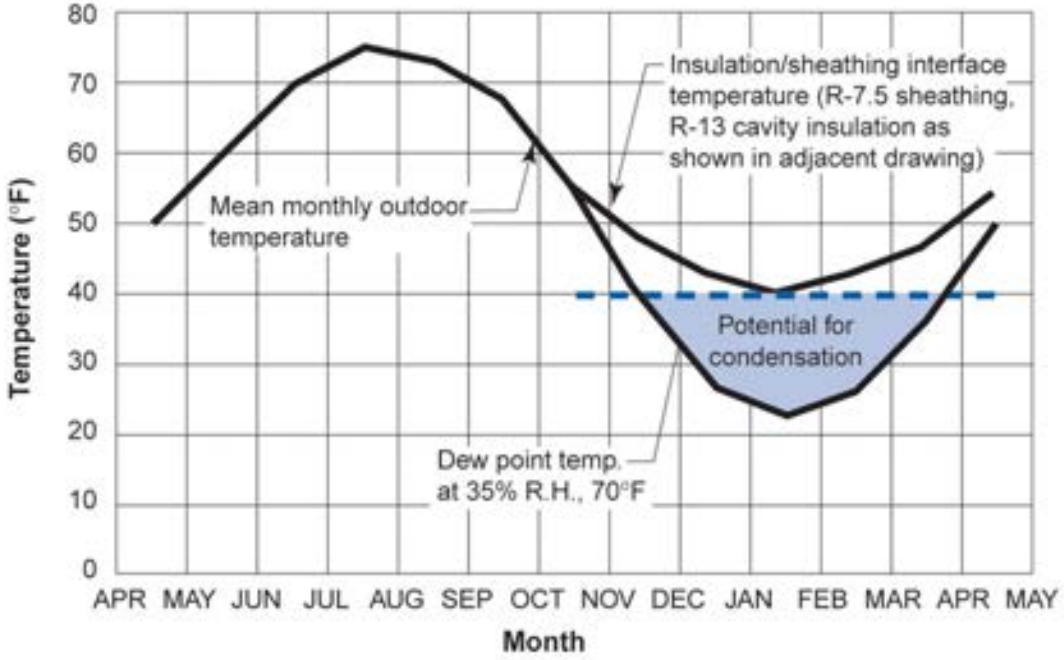


Simple linearized energy-temperature relation for water
From Straube & Burnett, 2005


The inside face of the exterior sheathing is the condensing surface of interest
Wood-based siding
Building paper
Exterior sheathing
R-19 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
Dew point temp. at 50% R.H., 70°F
Mean monthly outdoor temperature
Potential for condensation
Dew point temp. at 35% R.H., 70°F
Dew point temp. at 20% R.H., 70°F


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

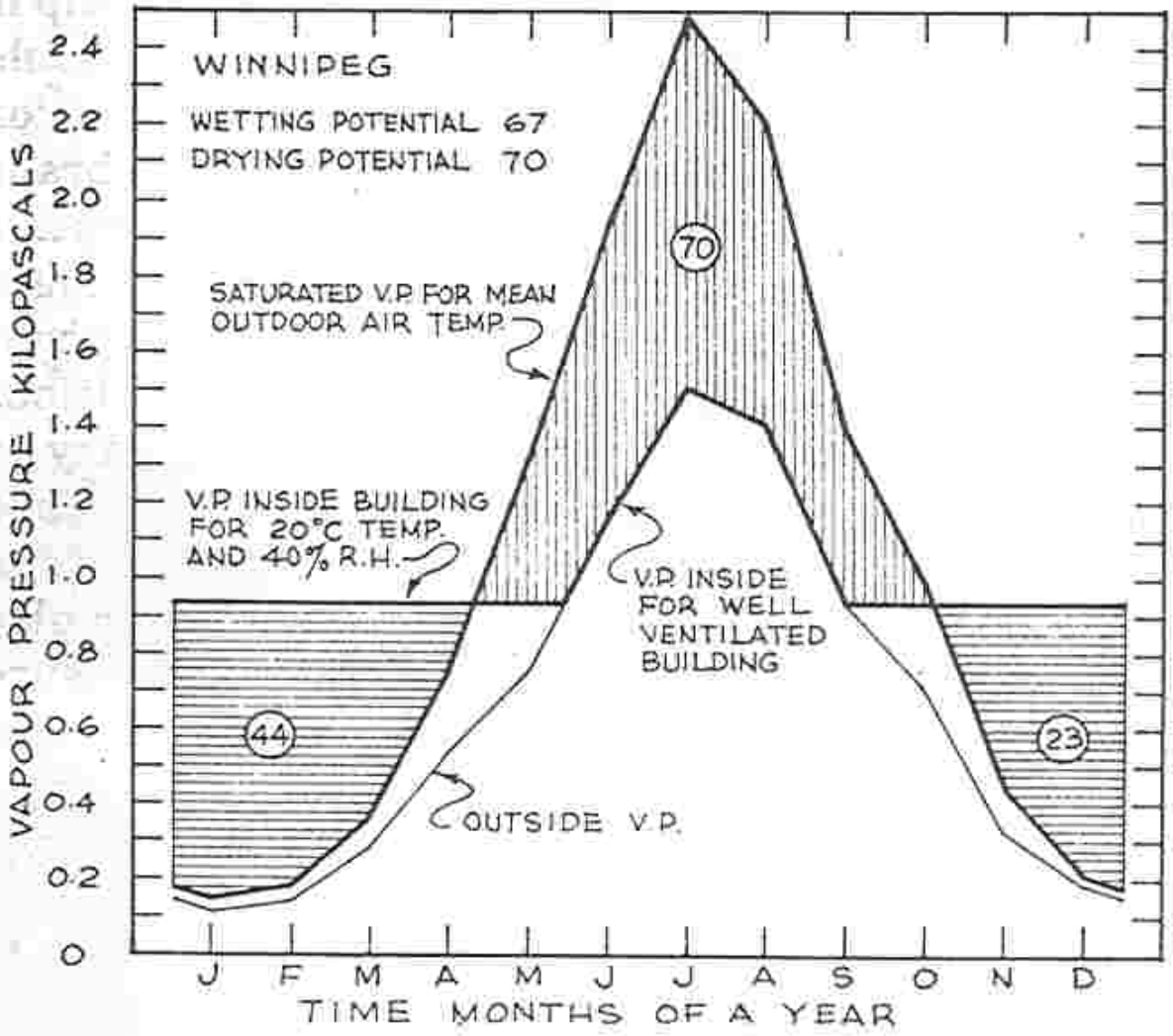
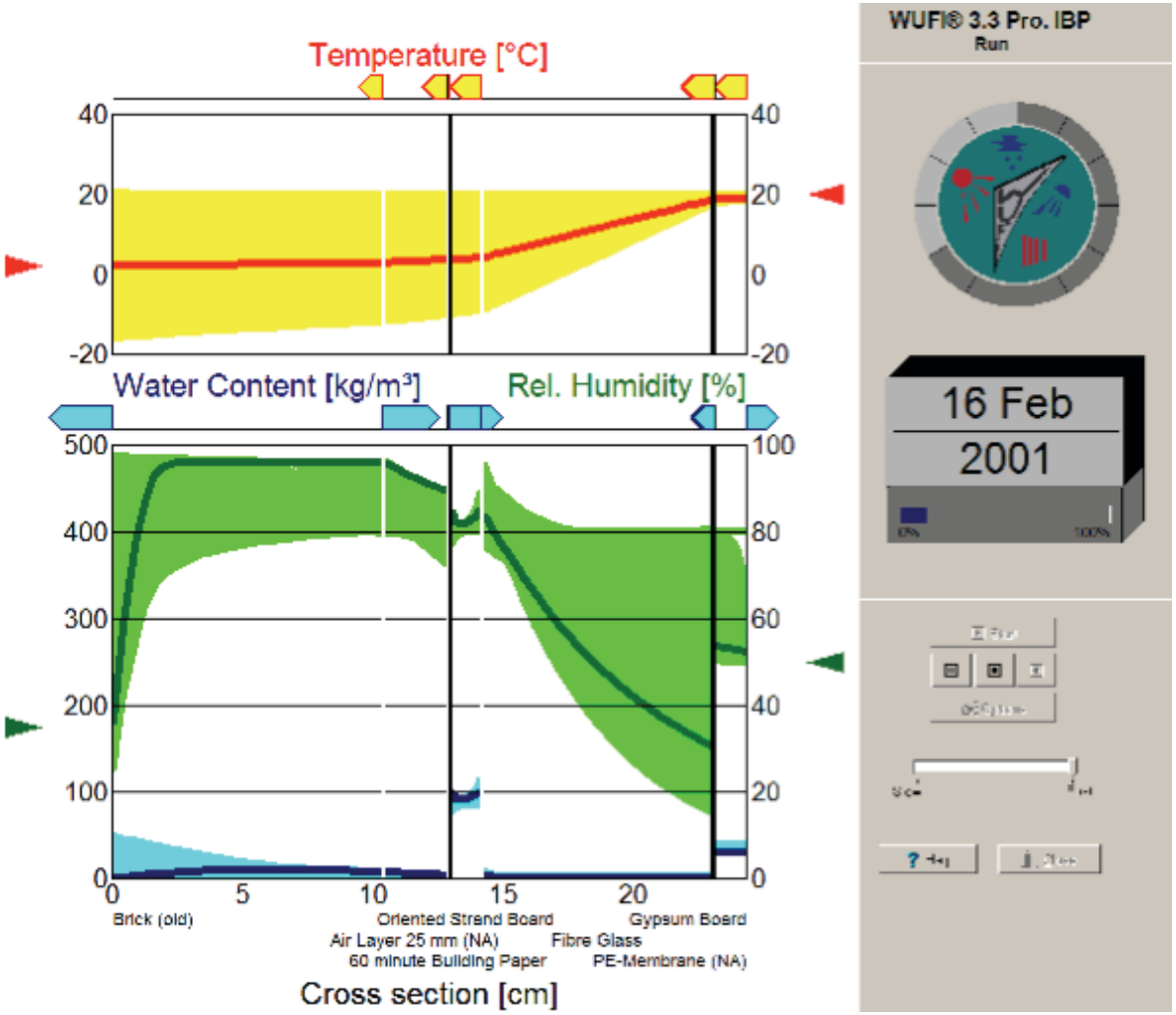
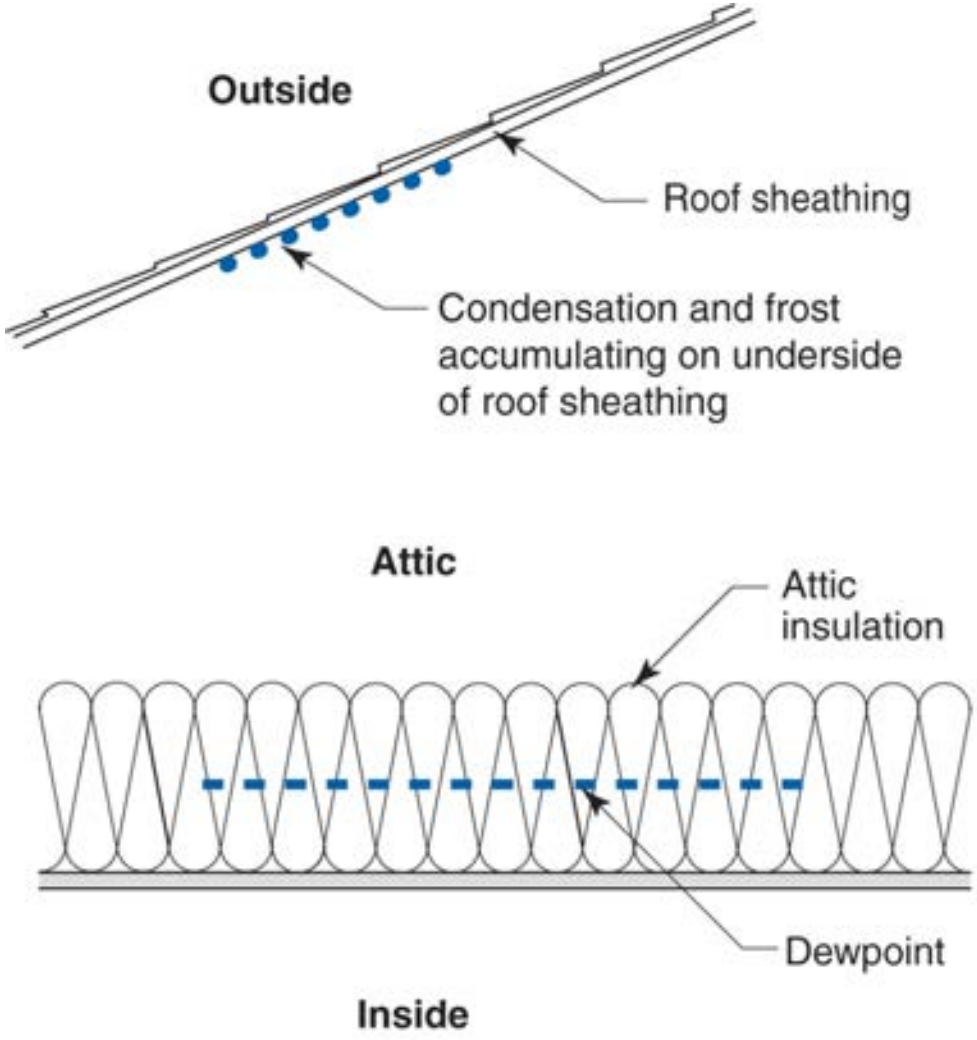
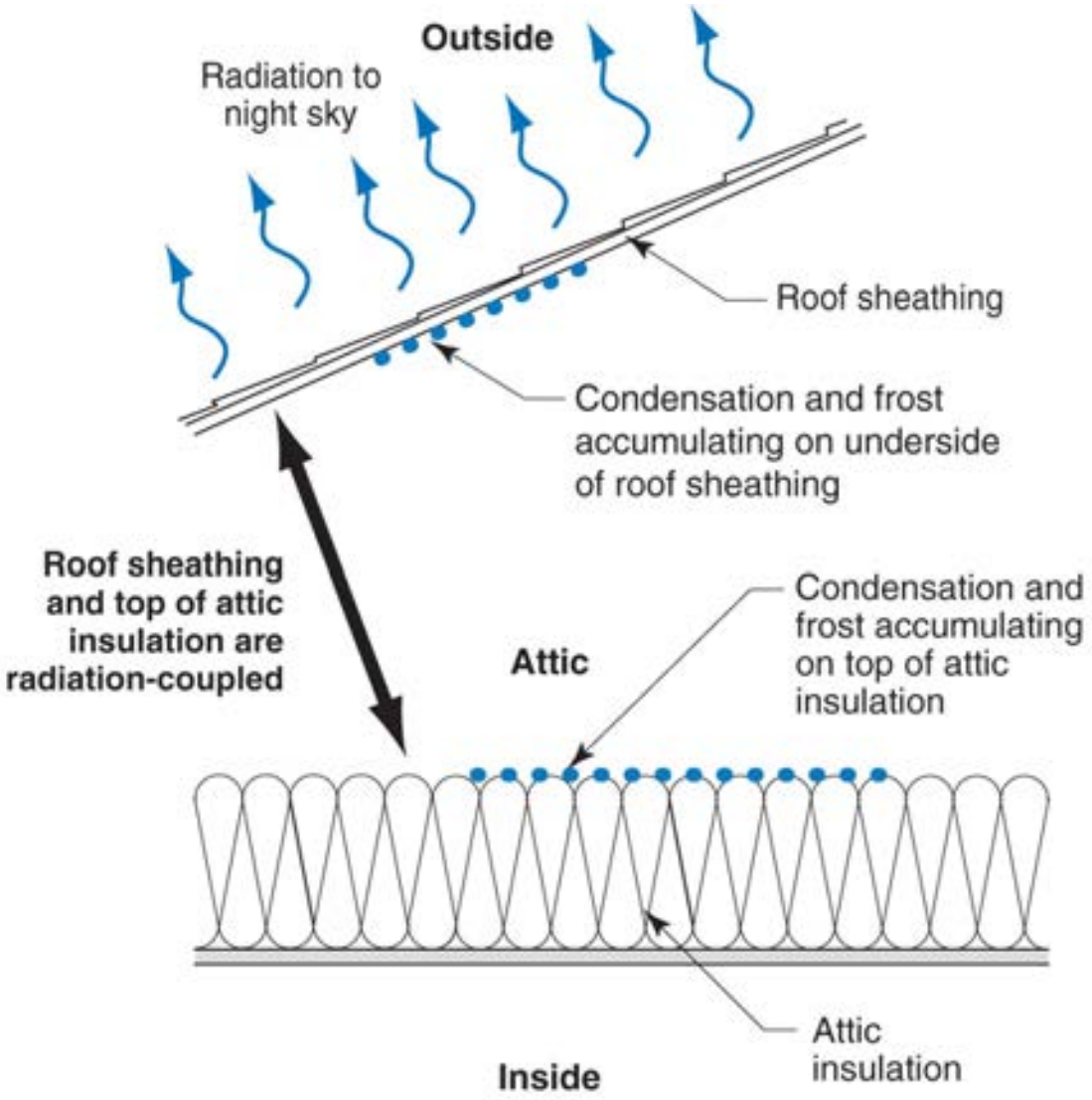
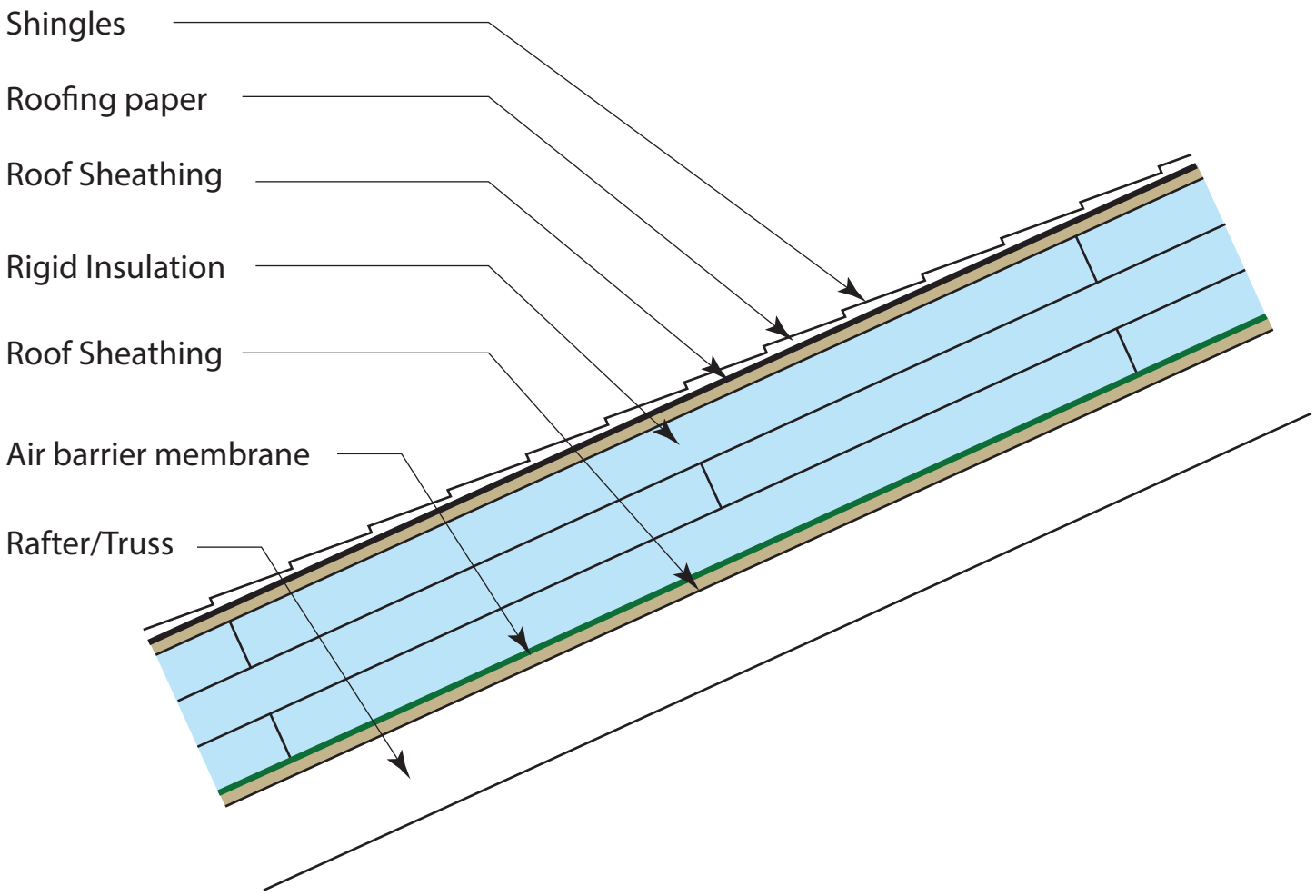


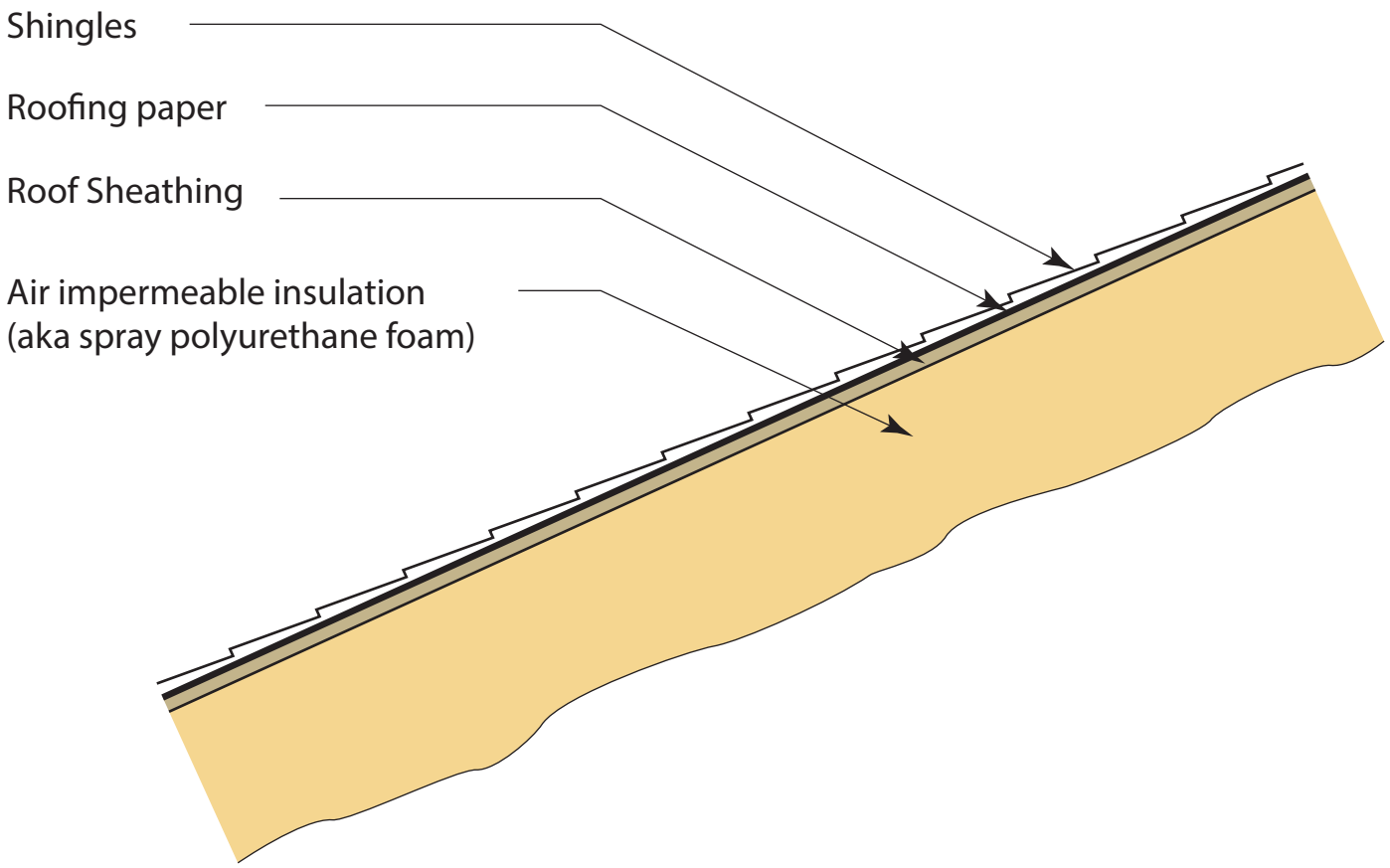
Figure 8-7. Outside vapour pressure, saturated vapour pressure and inside vapour pressure for Winnipeg.

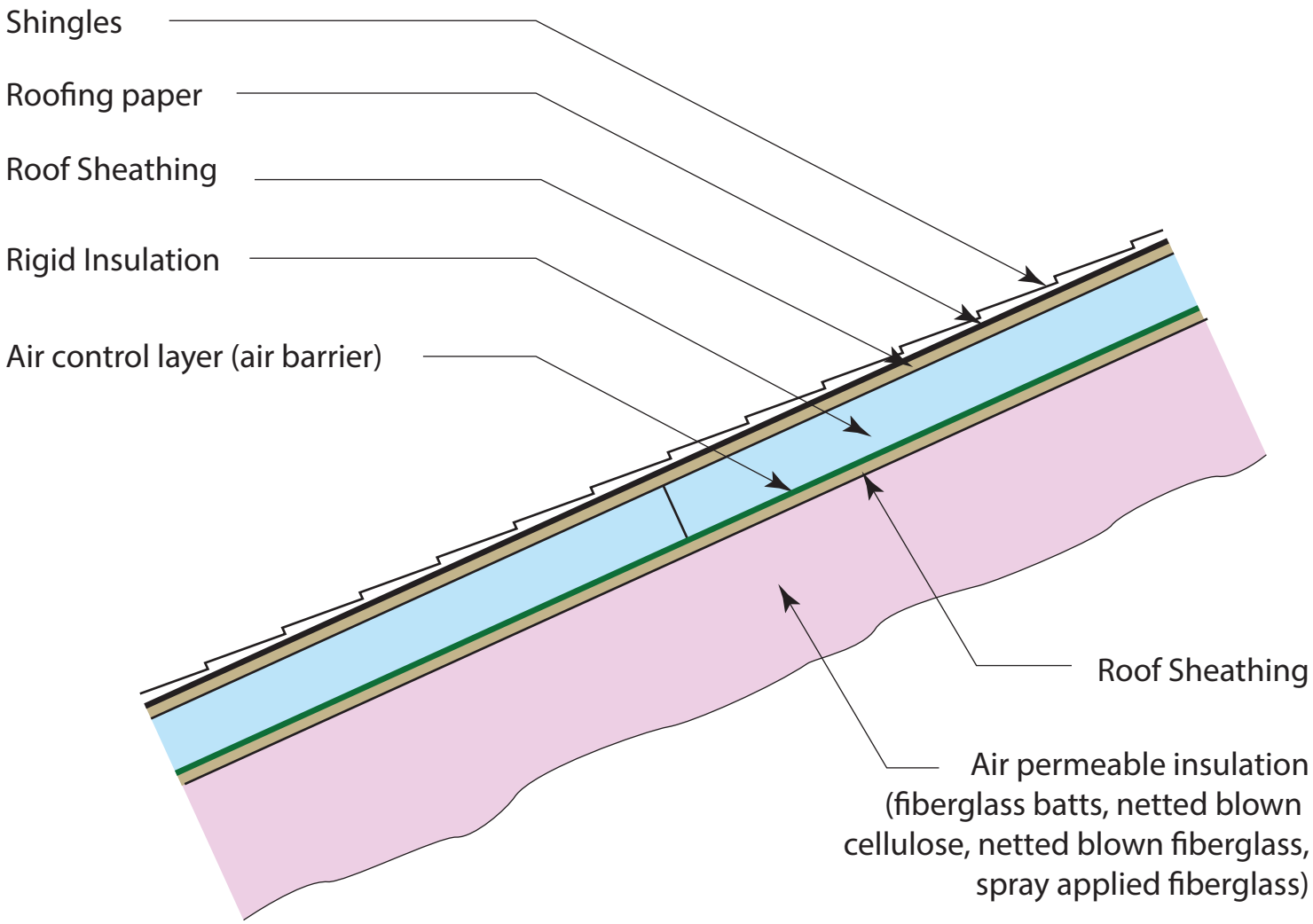

Temperature [°C]
40
20
0
-20
Water Content [kg/m³]
Rel. Humidity [%]
500
400
300
200
100
0
100
80
60
40
20
0
0
5
10
15
20
Brick (old)
Air Layer 25 mm (NA)
60 minute Building Paper
Oriented Strand Board
Fibre Glass
PE-Membrane (NA)
Gypsum Board
Cross section [cm]
WUFI® 3.3 Pro. IBP
Run
16 Feb
2001

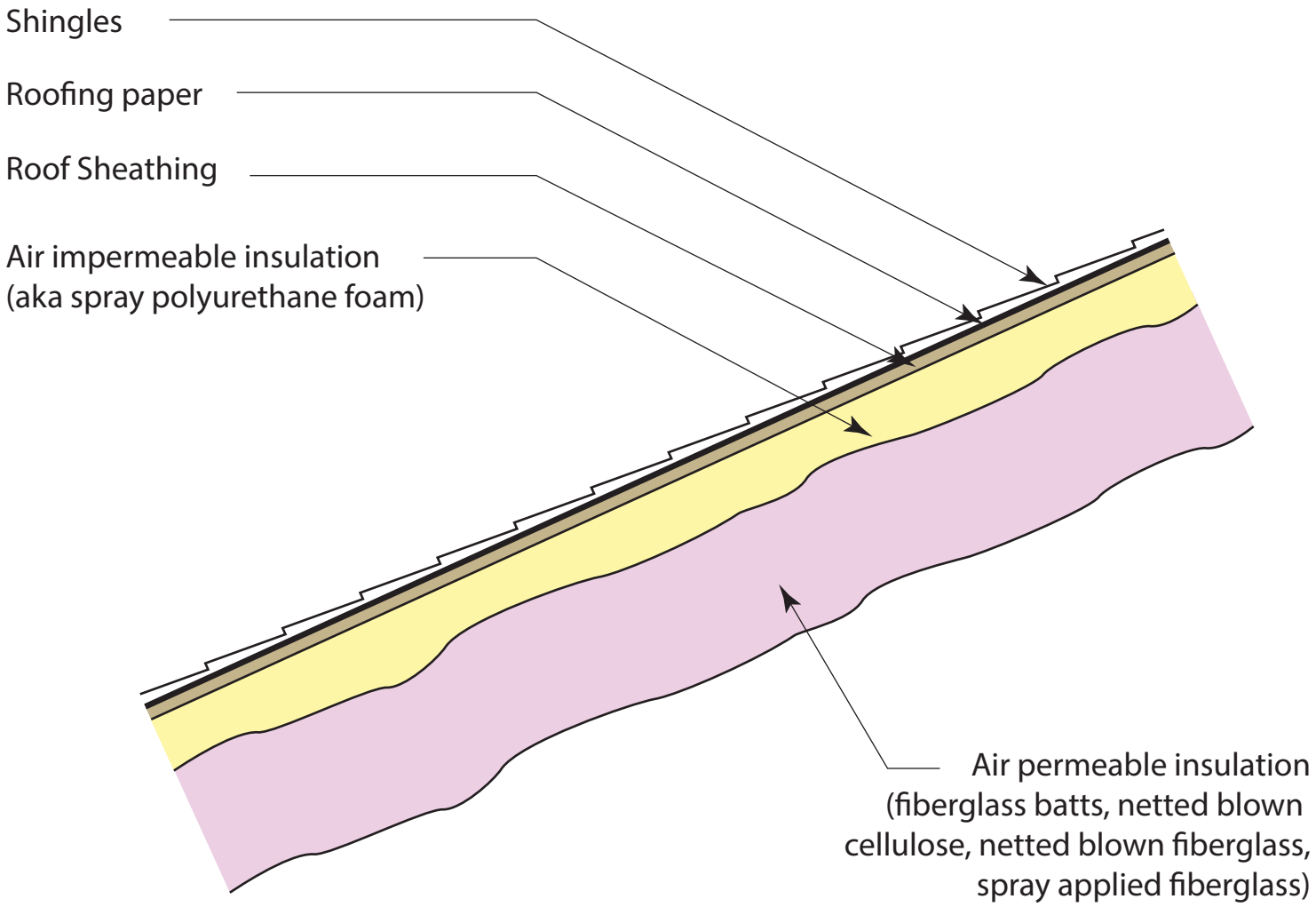

Outside
Roof sheathing
Condensation and frost
accumulating on underside
of roof sheathing
Attic
Attic
insulation
Dewpoint
Inside

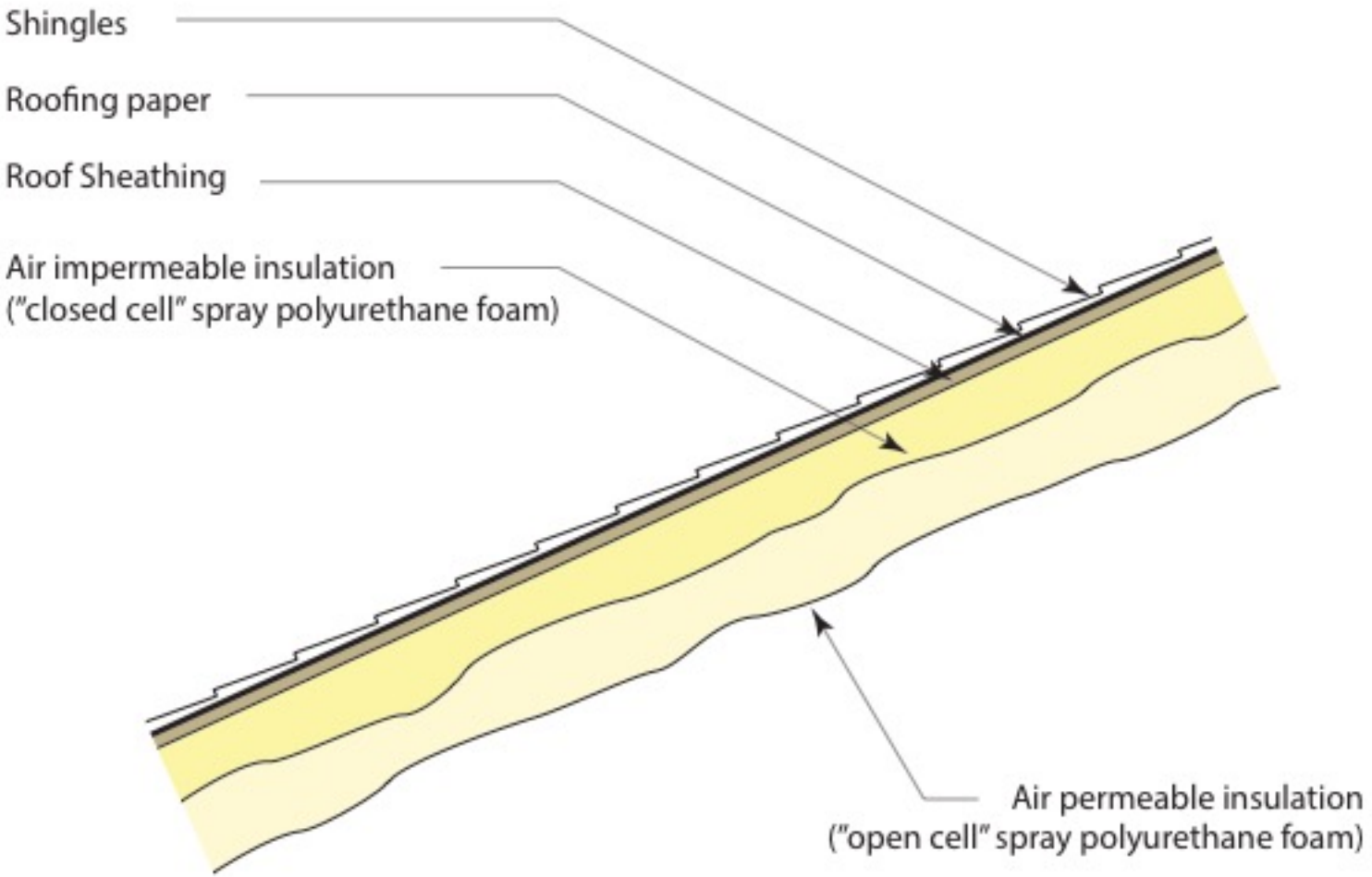

Outside
Radiation to night sky
Roof sheathing
Condensation and frost accumulating on underside of roof sheathing
Roof sheathing and top of attic insulation are radiation-coupled
Attic
Condensation and frost accumulating on top of attic insulation
Attic insulation
Inside


Shingles
Roofing paper
Roof Sheathing
Rigid Insulation
Roof Sheathing
Air barrier membrane
Rafter/Truss


Shingles
Roofing paper
Roof Sheathing
Air impermeable insulation
(aka spray polyurethane foam)


Shingles
Roofing paper
Roof Sheathing
Rigid Insulation
Air control layer (air barrier)
Roof Sheathing
Air permeable insulation
(fiberglass batts, netted blown
cellulose, netted blown fiberglass,
spray applied fiberglass)

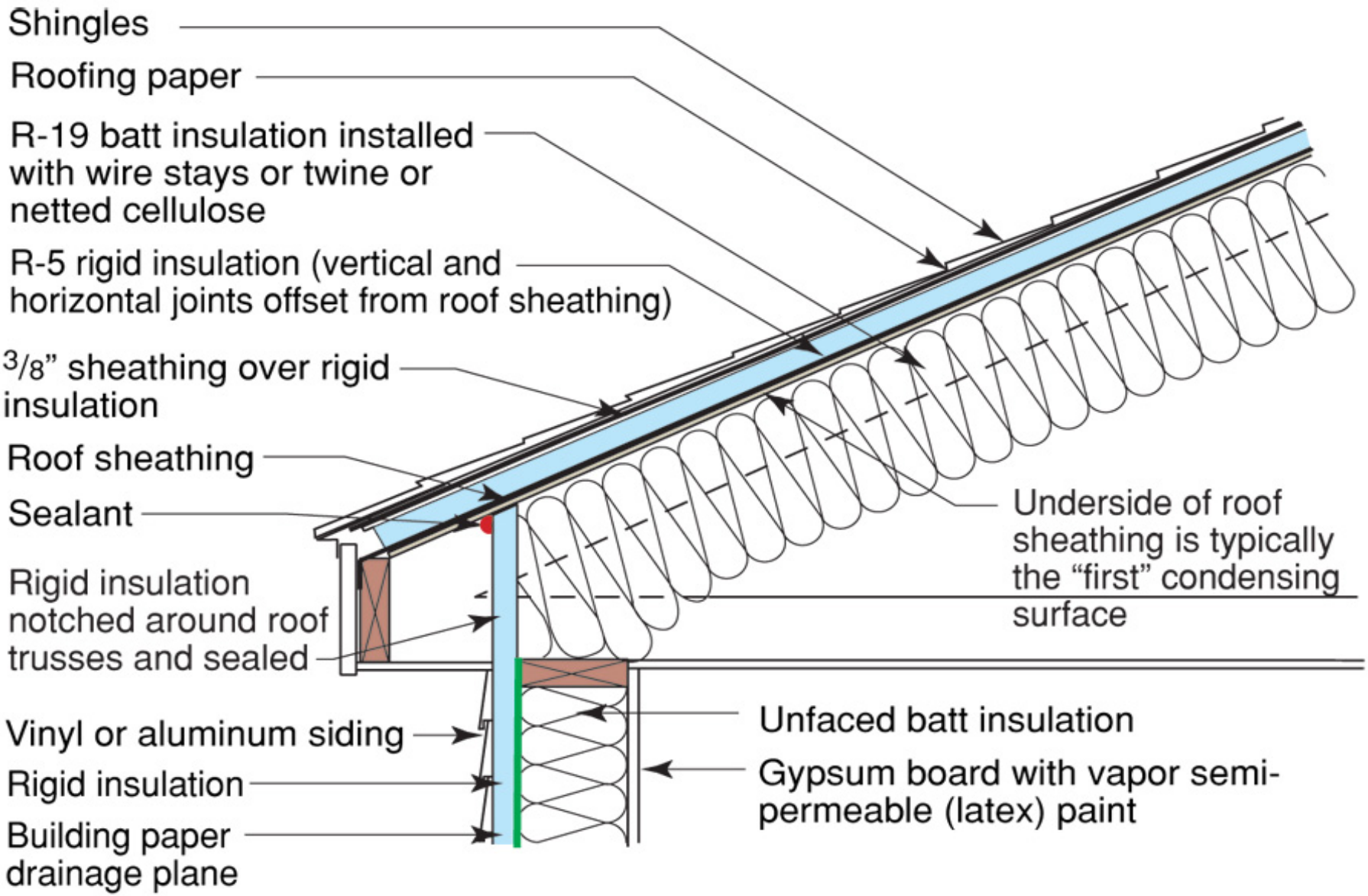

Shingles
Roofing paper
Roof Sheathing
Air impermeable insulation
(aka spray polyurethane foam)
Air permeable insulation
(fiberglass batts, netted blown
cellulose, netted blown fiberglass,
spray applied fiberglass)

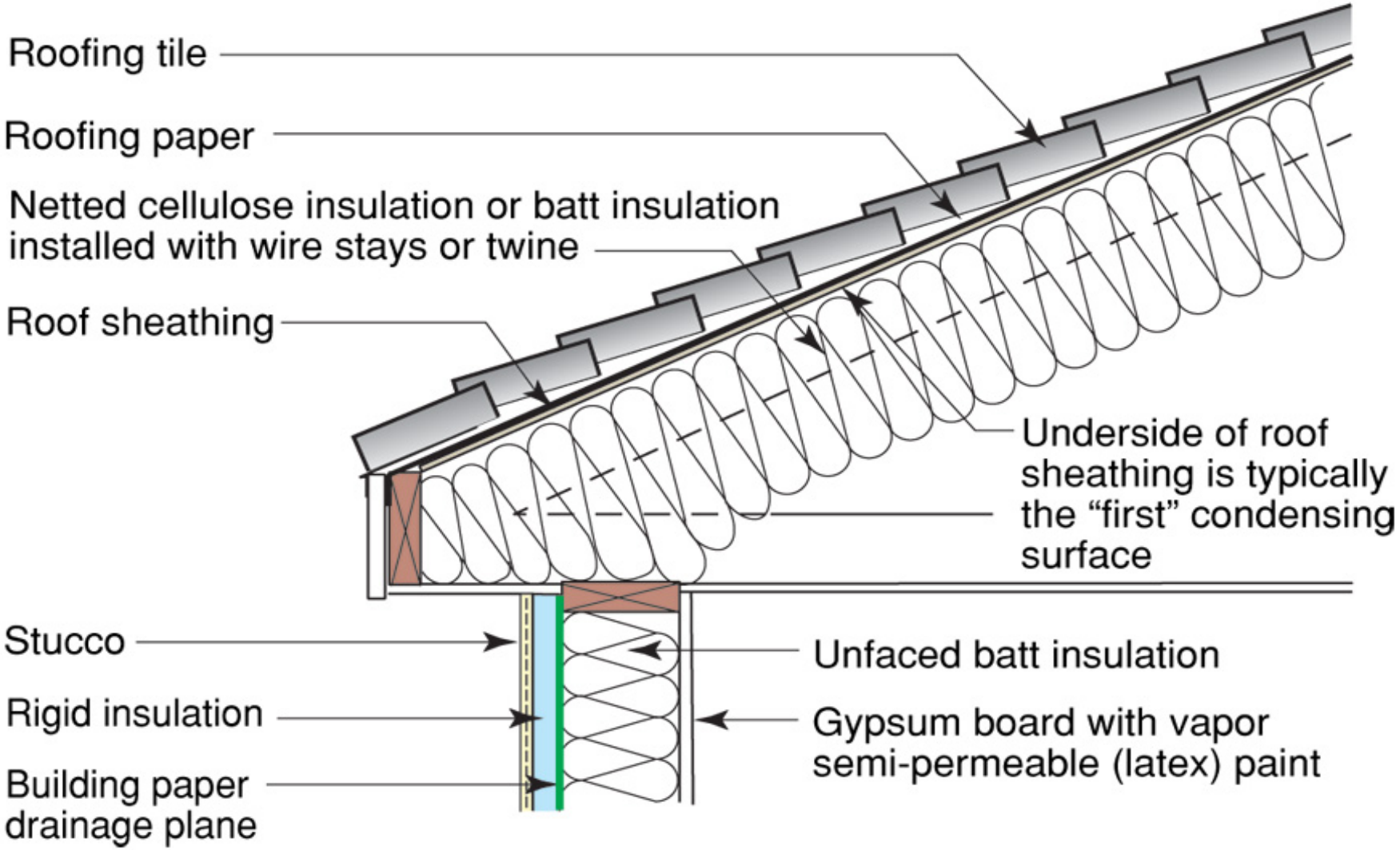

Shingles
Roofing paper
Roof Sheathing
Air impermeable insulation
("closed cell" spray polyurethane foam)
Air permeable insulation
("open cell" spray polyurethane foam)

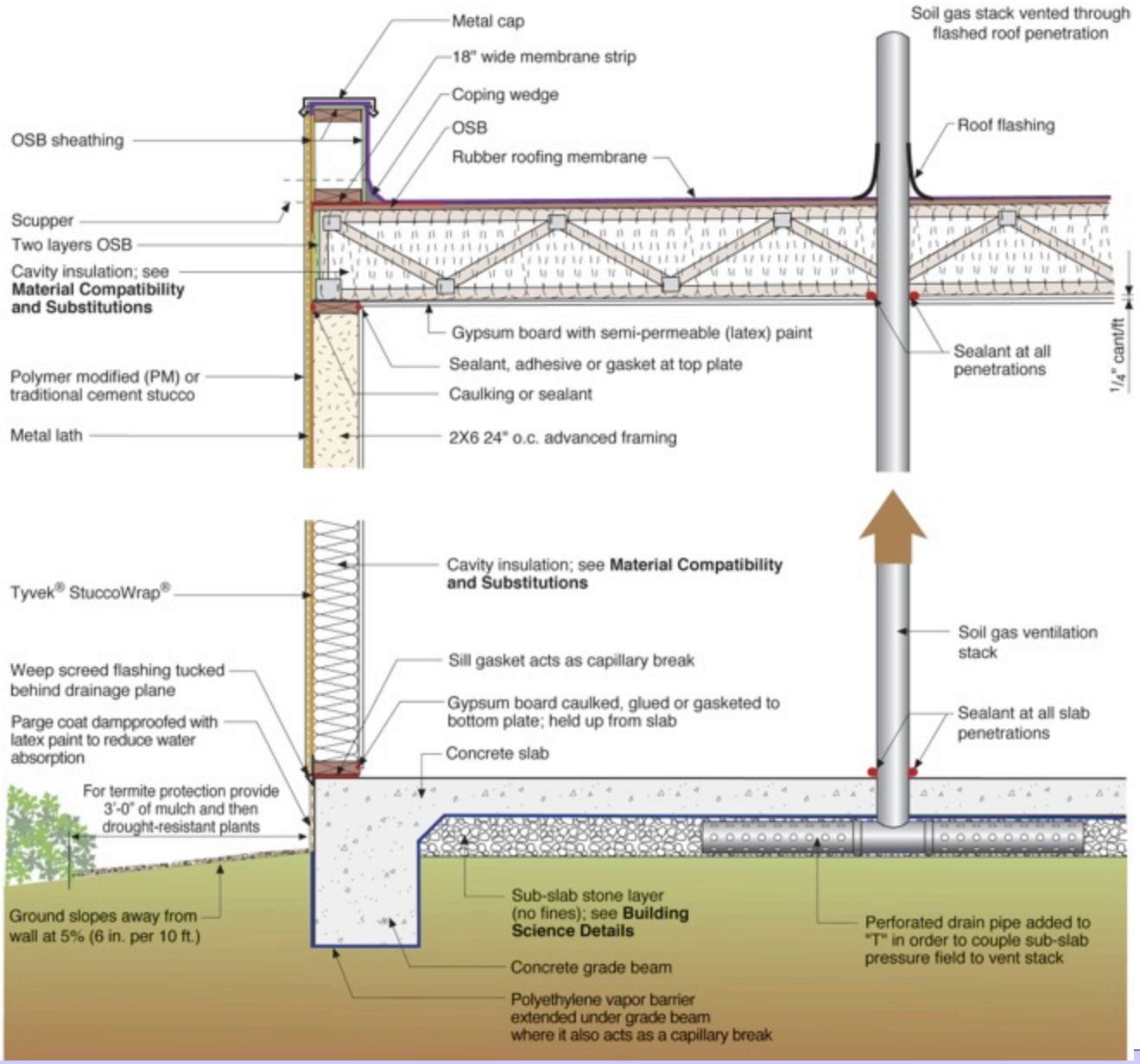
Insulation for Condensation Control*

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

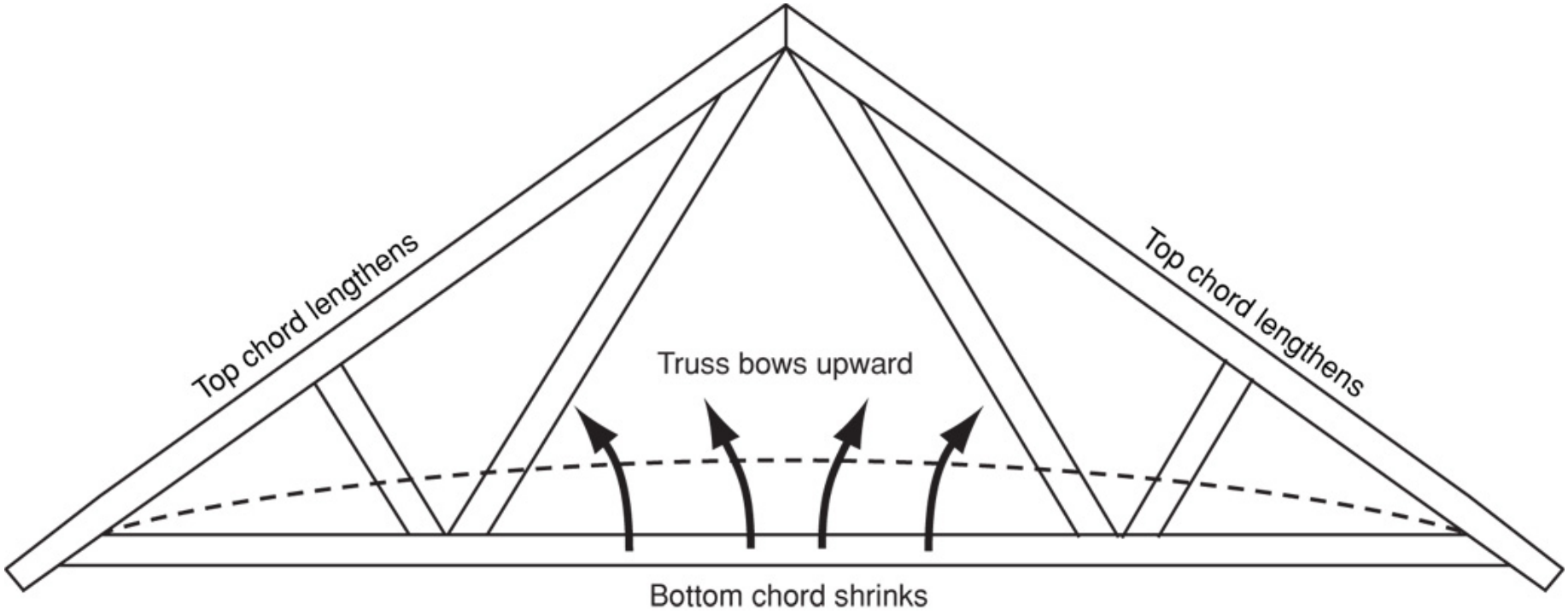

Shingles
Roofing paper
R-19 batt insulation installed with wire stays or twine or netted cellulose
R-5 rigid insulation (vertical and horizontal joints offset from roof sheathing)
3/8" sheathing over rigid insulation
Roof sheathing
Sealant
Rigid insulation notched around roof trusses and sealed
Vinyl or aluminum siding
Rigid insulation
Building paper drainage plane
Underside of roof sheathing is typically the "first" condensing surface
Unfaced batt insulation
Gypsum board with vapor semi-permeable (latex) paint

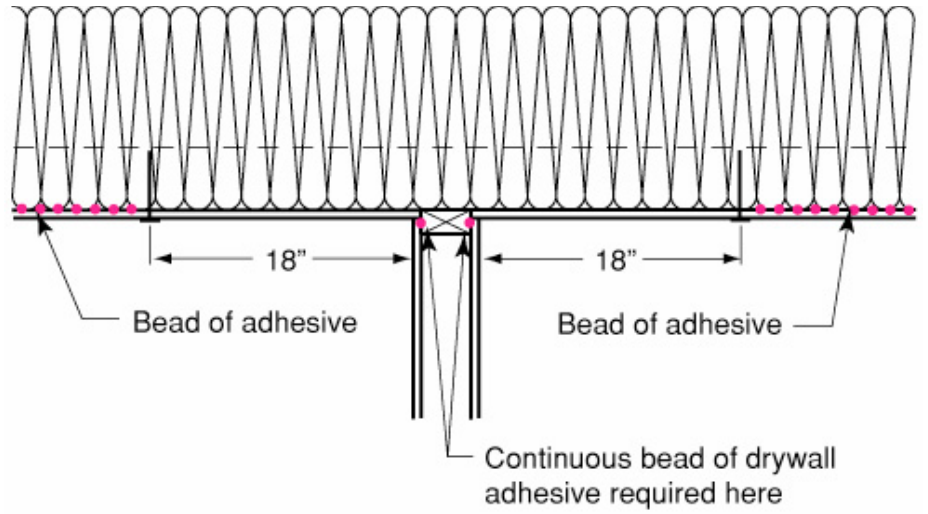

Roofing tile
Roofing paper
Netted cellulose insulation or batt insulation installed with wire stays or twine
Roof sheathing
Underside of roof sheathing is typically the “first” condensing surface
Stucco
Rigid insulation
Building paper drainage plane
Unfaced batt insulation
Gypsum board with vapor semi-permeable (latex) paint

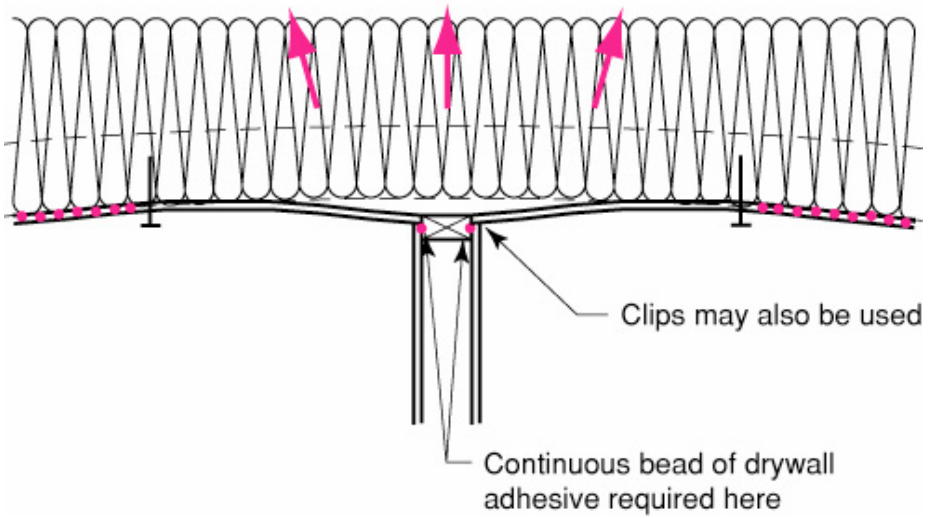

Metal cap
18" wide membrane strip
Coping wedge
OSB
Rubber roofing membrane
Soil gas stack vented through flashed roof penetration
Roof flashing
OSB sheathing
Scupper
Two layers OSB
Cavity insulation; see Material Compatibility and Substitutions
Gypsum board with semi-permeable (latex) paint
Sealant, adhesive or gasket at top plate
Caulking or sealant
2X6 24" o.c. advanced framing
Sealant at all penetrations
1/4" cant/ft
Polymer modified (PM) or traditional cement stucco
Metal lath
Tyvek® StuccoWrap®
Cavity insulation; see Material Compatibility and Substitutions
Soil gas ventilation stack
Weep screed flashing tucked behind drainage plane
Sill gasket acts as capillary break
Gypsum board caulked, glued or gasketed to bottom plate; held up from slab
Sealant at all slab penetrations
Parge coat dampproofed with latex paint to reduce water absorption
Concrete slab
For termite protection provide 3'-0" of mulch and then drought-resistant plants
Ground slopes away from wall at 5% (6 in. per 10 ft.)
Sub-slab stone layer (no fines); see Building Science Details
Perforated drain pipe added to "T" in order to couple sub-slab pressure field to vent stack
Concrete grade beam
Polyethylene vapor barrier extended under grade beam where it also acts as a capillary break

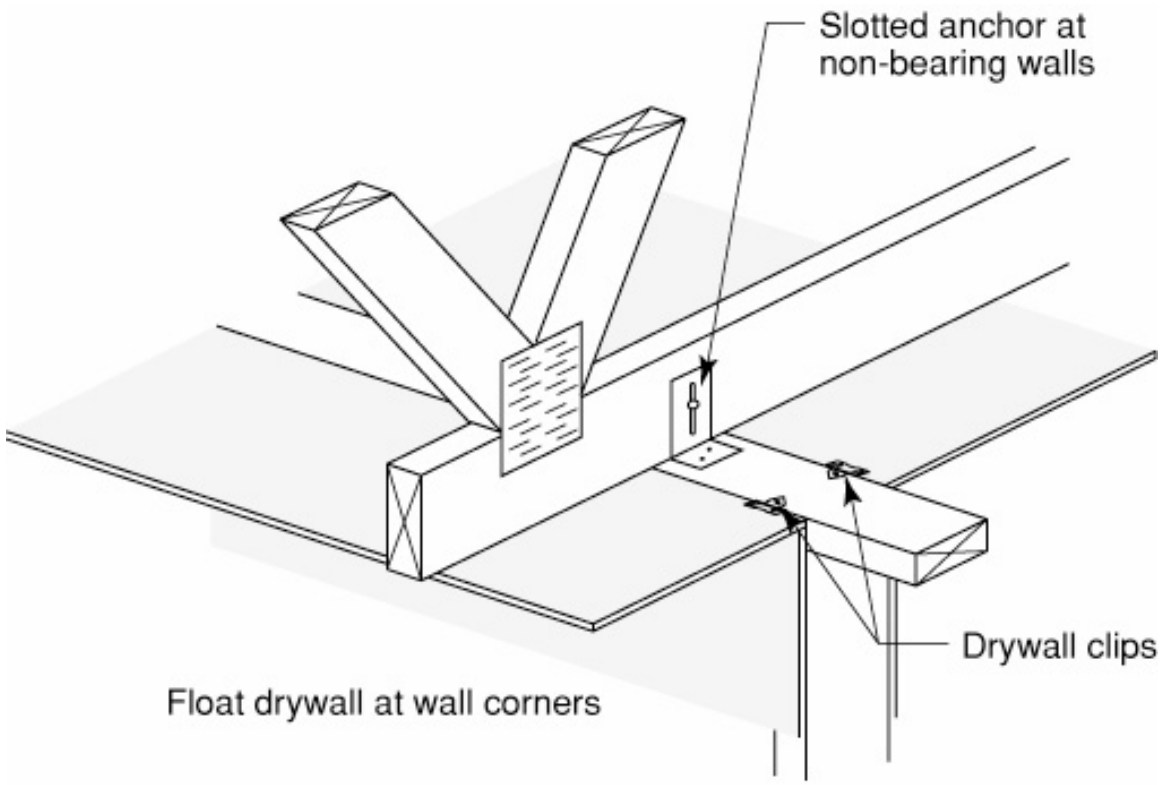
Truss Uplift


6537

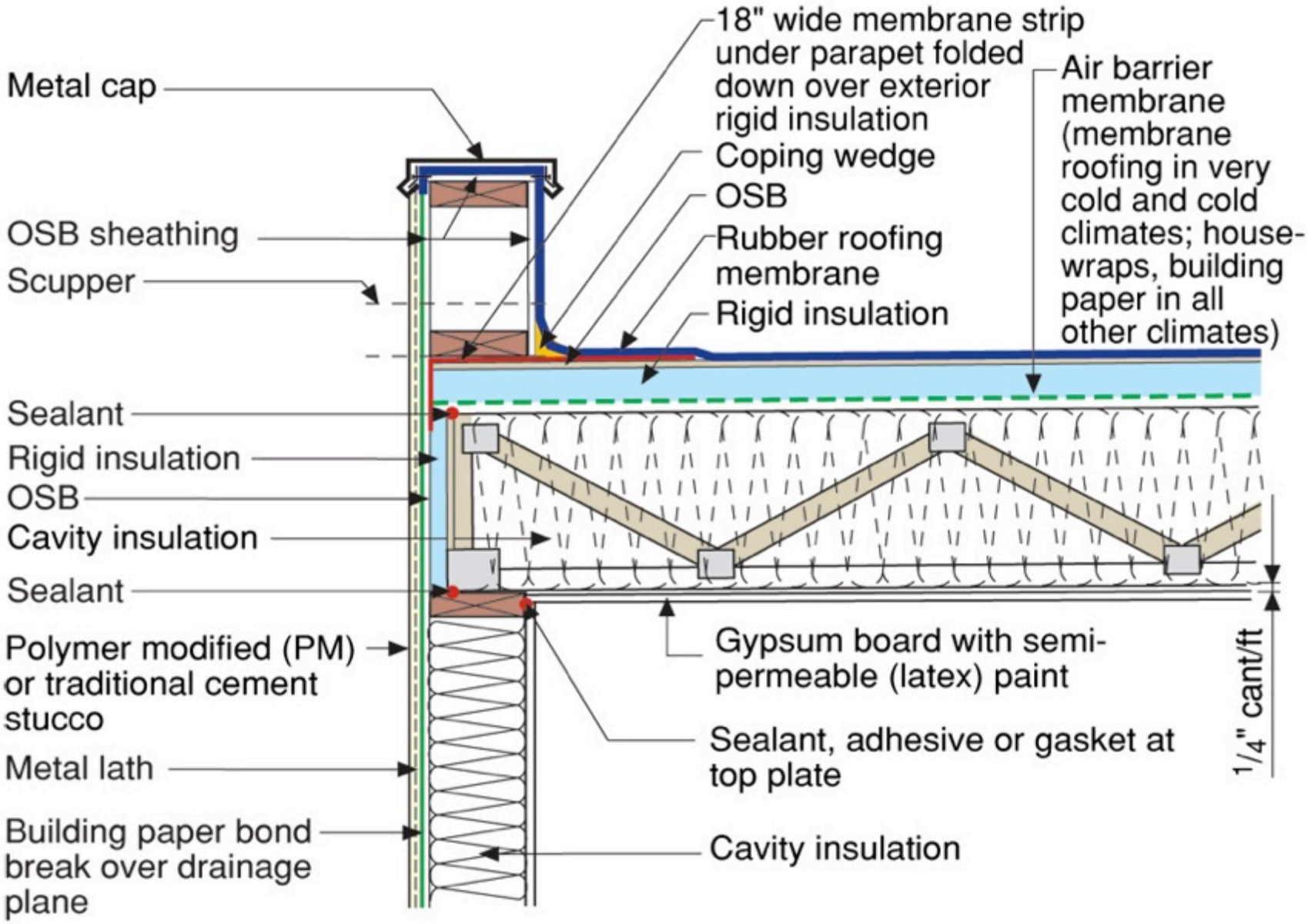

Top chord lengthens
Truss bows upward
Top chord lengthens
Bottom chord shrinks

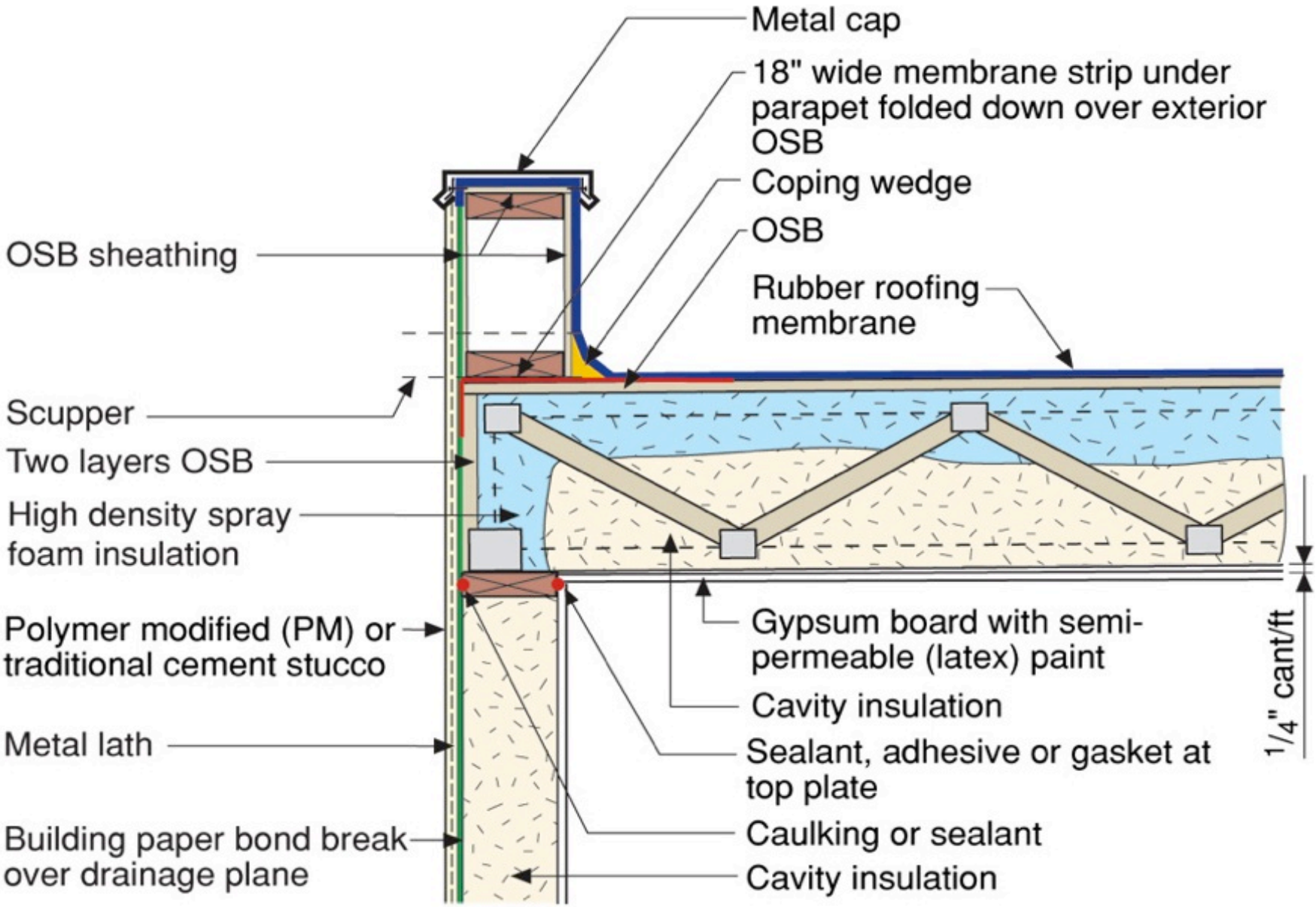

18”
18”
Bead of adhesive
Bead of adhesive
Continuous bead of drywall adhesive required here

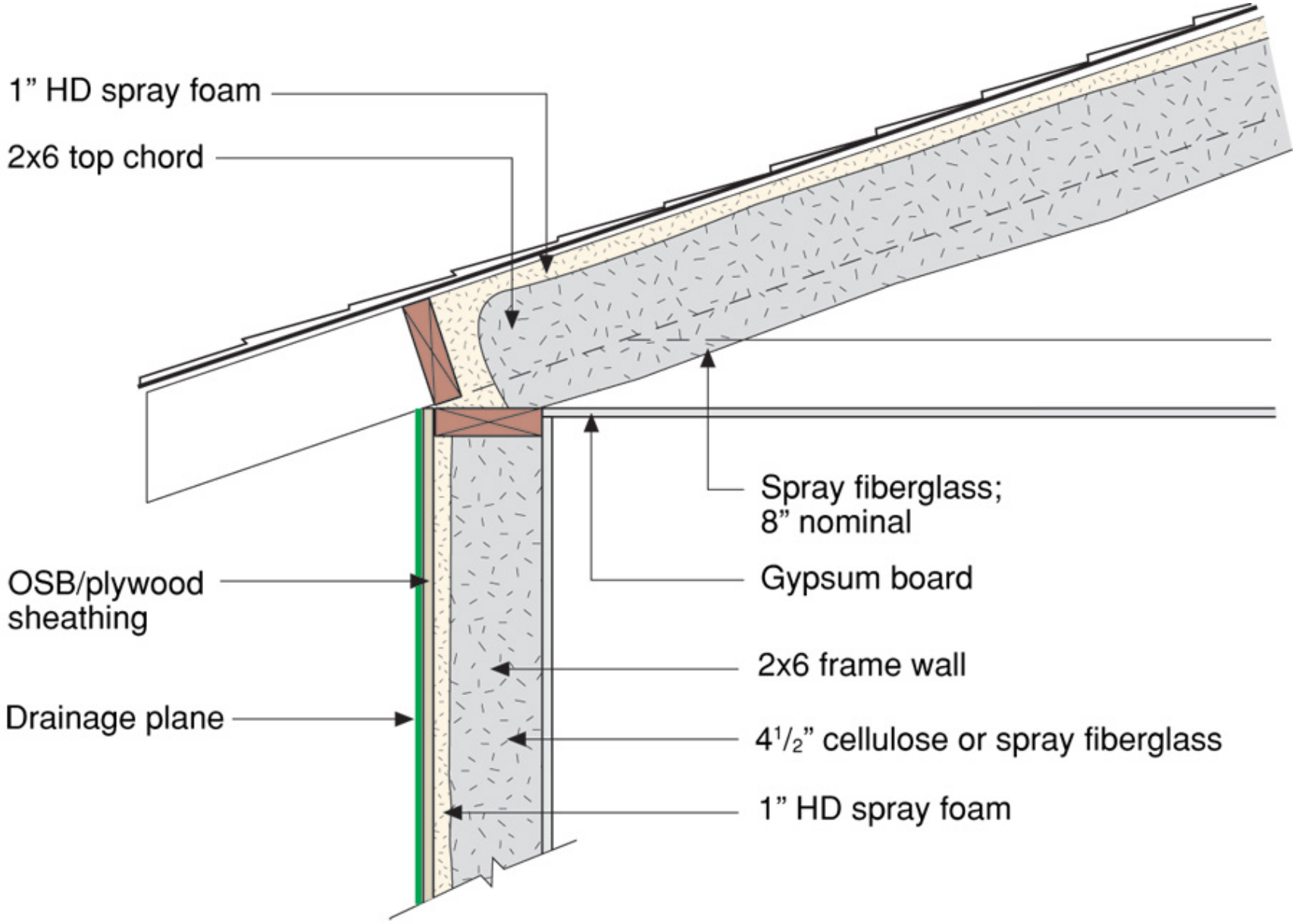

Clips may also be used
Continuous bead of drywall adhesive required here

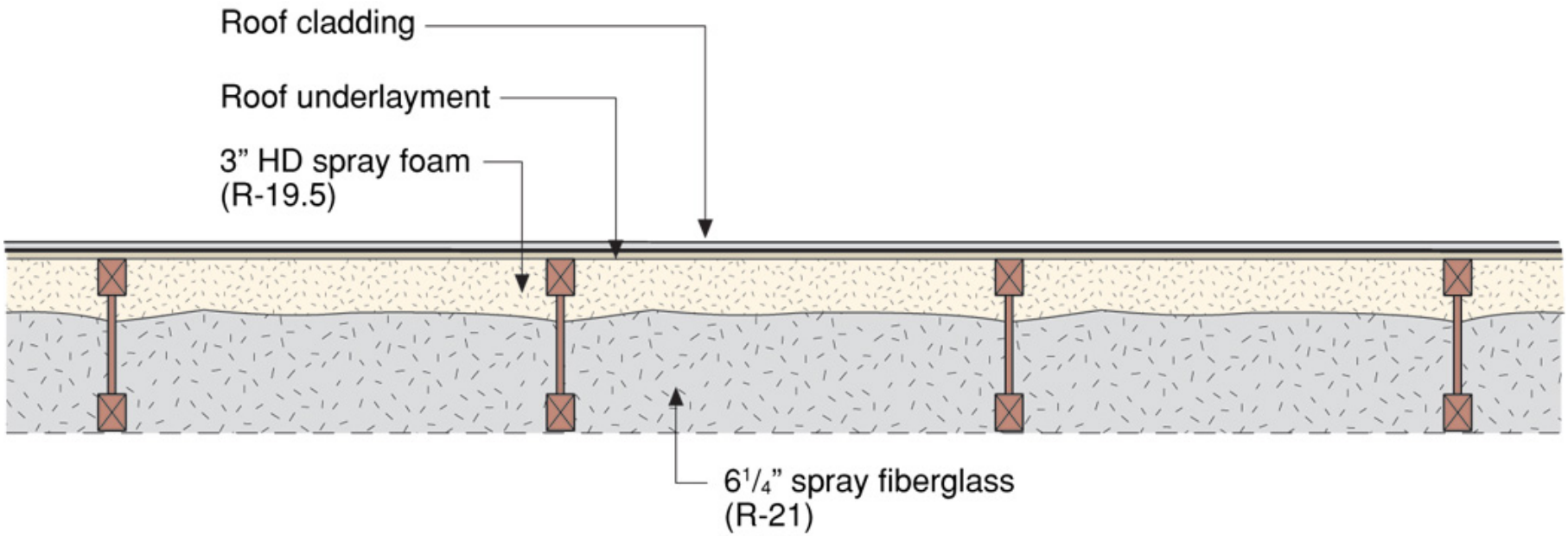

Slotted anchor at
non-bearing walls
Drywall clips
Float drywall at wall corners

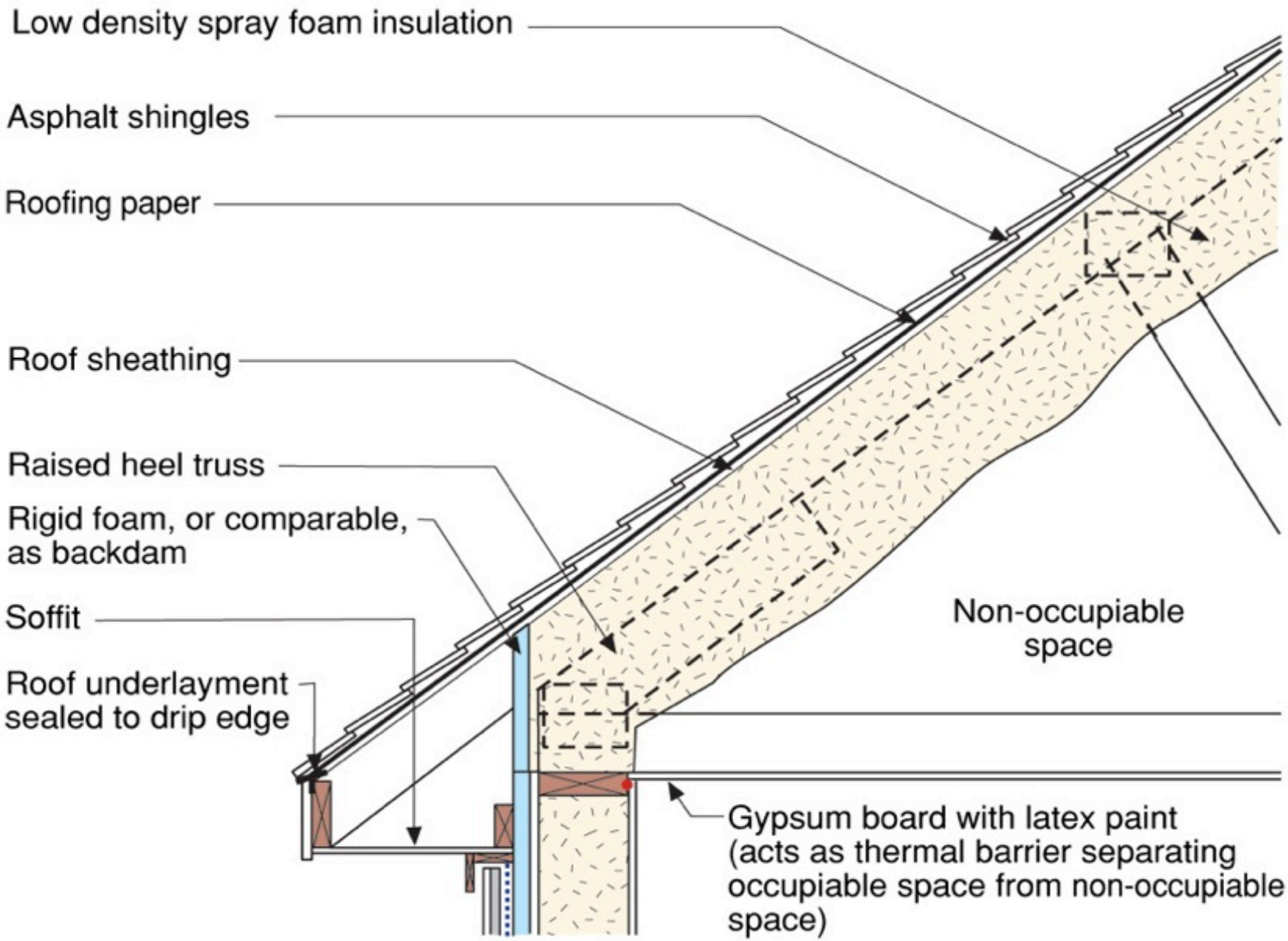

ermo-ply
ermo

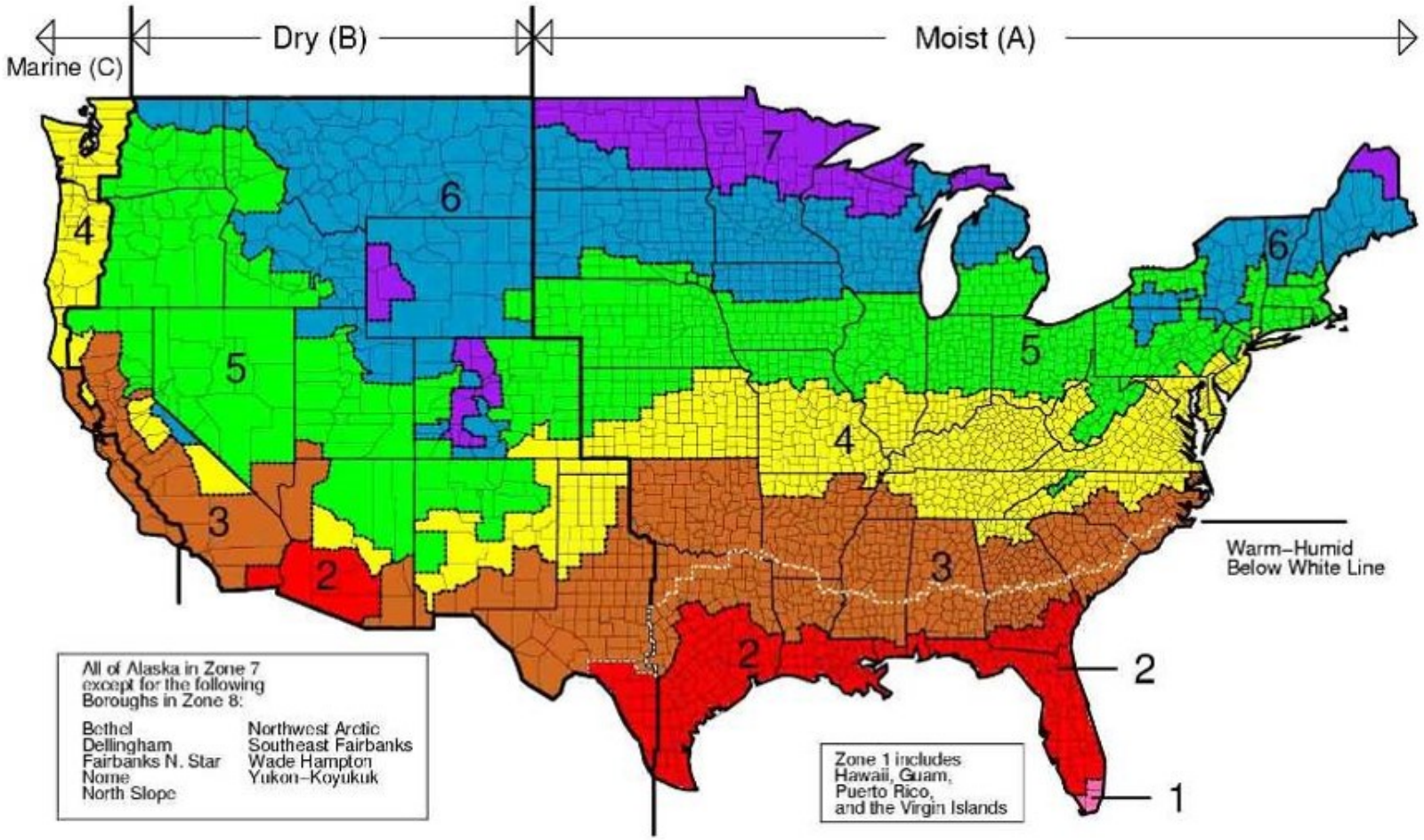

Metal cap
OSB sheathing
Scupper
Sealant
Rigid insulation
OSB
Cavity insulation
Sealant
Polymer modified (PM) or traditional cement stucco
Metal lath
Building paper bond break over drainage plane
18" wide membrane strip under parapet folded down over exterior rigid insulation
Coping wedge
OSB
Rubber roofing membrane
Rigid insulation
Air barrier membrane (membrane roofing in very cold and cold climates; house-wraps, building paper in all other climates)
Gypsum board with semi-permeable (latex) paint
Sealant, adhesive or gasket at top plate
Cavity insulation
1/4" cant/ft


Metal cap
18" wide membrane strip under parapet folded down over exterior OSB
Coping wedge
OSB
OSB sheathing
Rubber roofing membrane
Scupper
Two layers OSB
High density spray foam insulation
Polymer modified (PM) or traditional cement stucco
Metal lath
Building paper bond break over drainage plane
Gypsum board with semi-permeable (latex) paint
Cavity insulation
Sealant, adhesive or gasket at top plate
Caulking or sealant
Cavity insulation
1/4" cant/ft


1” HD spray foam
2x6 top chord
Spray fiberglass;
8” nominal
Gypsum board
OSB/plywood
sheathing
2x6 frame wall
Drainage plane
4½” cellulose or spray fiberglass
1” HD spray foam


Roof cladding
Roof underlayment
3” HD spray foam
(R-19.5)
6¼” spray fiberglass
(R-21)

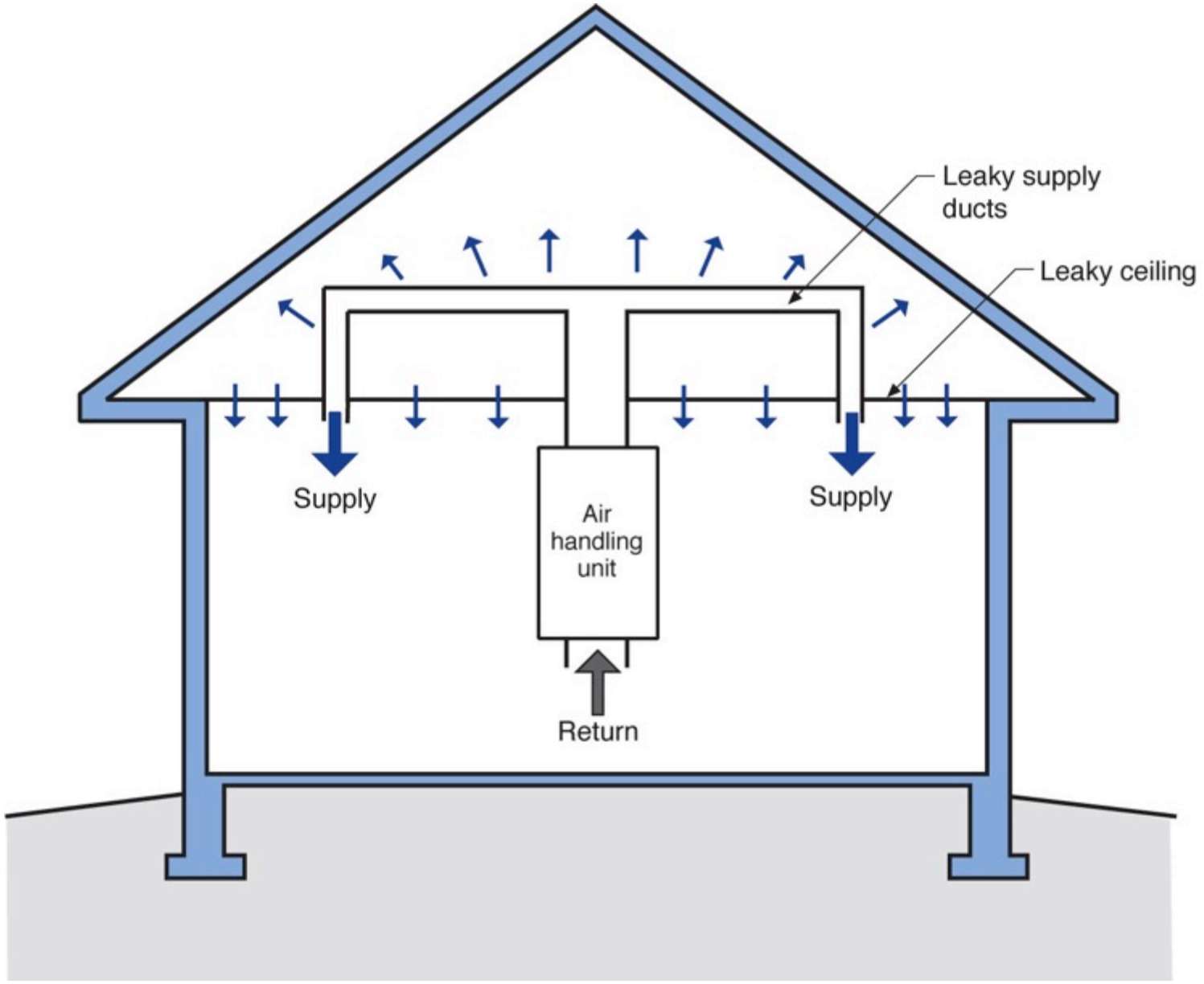

Low density spray foam insulation
Asphalt shingles
Roofing paper
Roof sheathing
Raised heel truss
Rigid foam, or comparable, as backdam
Soffit
Roof underlayment sealed to drip edge
Non-occupiable space
Gypsum board with latex paint (acts as thermal barrier separating occupiable space from non-occupiable space)


Marine (C)
Dry (B)
Moist (A)
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


GRACE
Ice & Water Shield
TRI-FLEX 30
APR 20 2004


APR 20 2004

Conditioned Attics Not Unvented Attics


Leaky supply ducts
Leaky ceiling
Supply
Supply
Air handling unit
Return

Conditioned Attics Not Unvented Attics

Need Supply Air

Conditioned Attics Not Unvented Attics

Need Supply Air

50 cfm/1000 ft2 of Attic

Hygric Buoyancy

Components in Dry Air	Volume Ratio compared to Dry Air	Molecular Mass - *M* *(kg/kmol)*	Molecular Mass in Air
Oxygen	0.2095	32.00	6.704
Nitrogen	0.7809	28.02	21.88
Carbon Dioxide	0.0003	44.01	0.013
Hydrogen	0.0000005	2.02	0
Argon	0.00933	39.94	0.373
Neon	0.000018	20.18	0
Helium	0.000005	4.00	0
Krypton	0.000001	83.8	0
Xenon	$0.09\ 10^{-6}$	131.29	0
Total Molecular Mass of Air			28.97

Components in Dry Air	Volume Ratio compared to Dry Air	Molecular Mass - *M* *(kg/kmol)*	Molecular Mass in Air
Oxygen	0.2095	32.00	6.704
Nitrogen	0.7809	28.02	21.88
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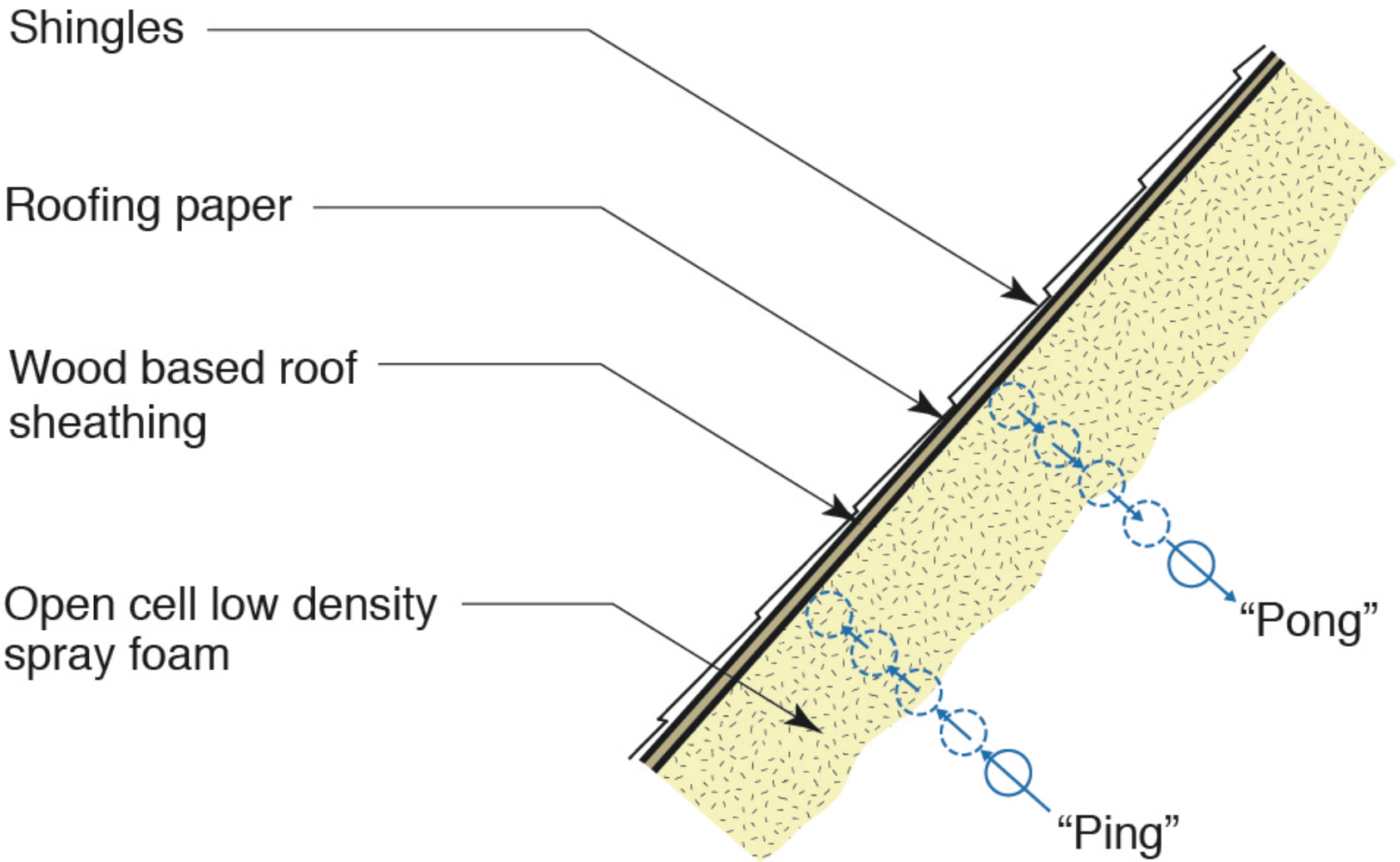
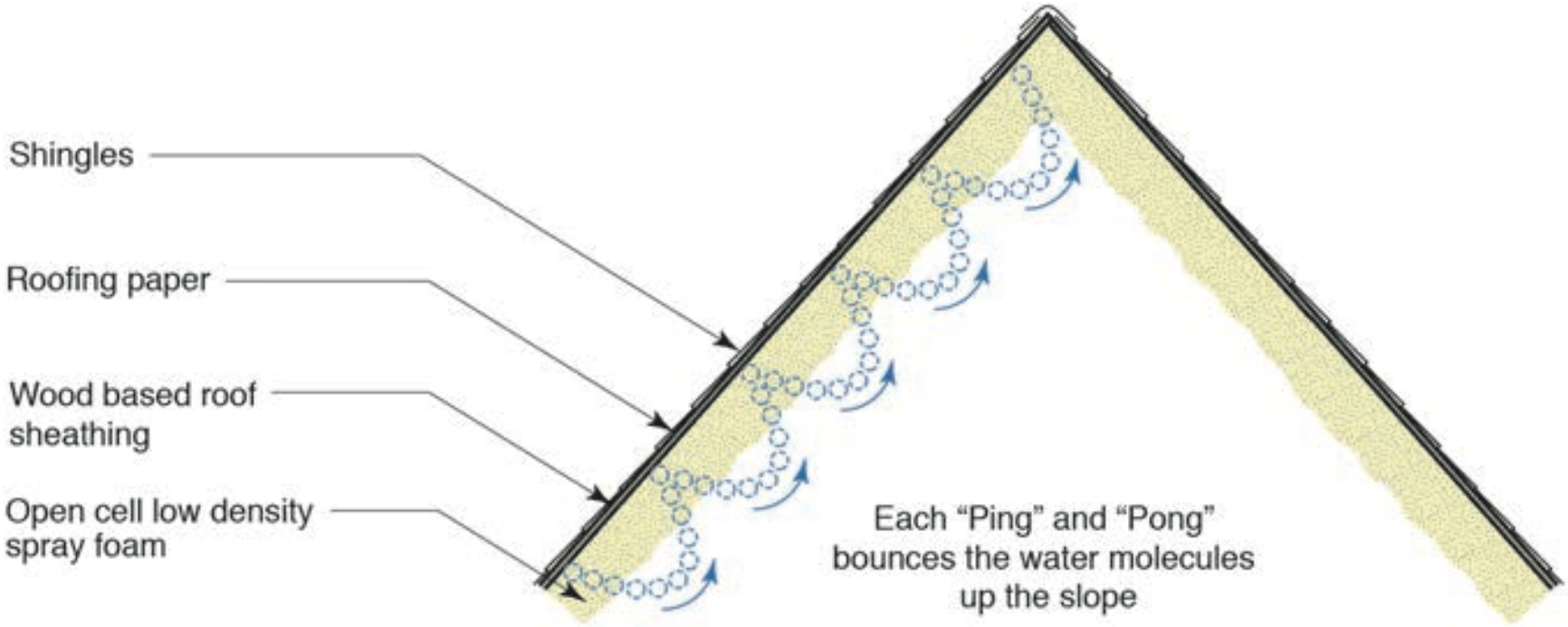
Argon	0.00933	39.94	0.373
Neon	0.000018	20.18	0
Helium	0.000005	4.00	0
Krypton	0.000001	83.8	0
Xenon	$0.09\ 10^{-6}$	131.29	0
Total Molecular Mass of Air			28.97

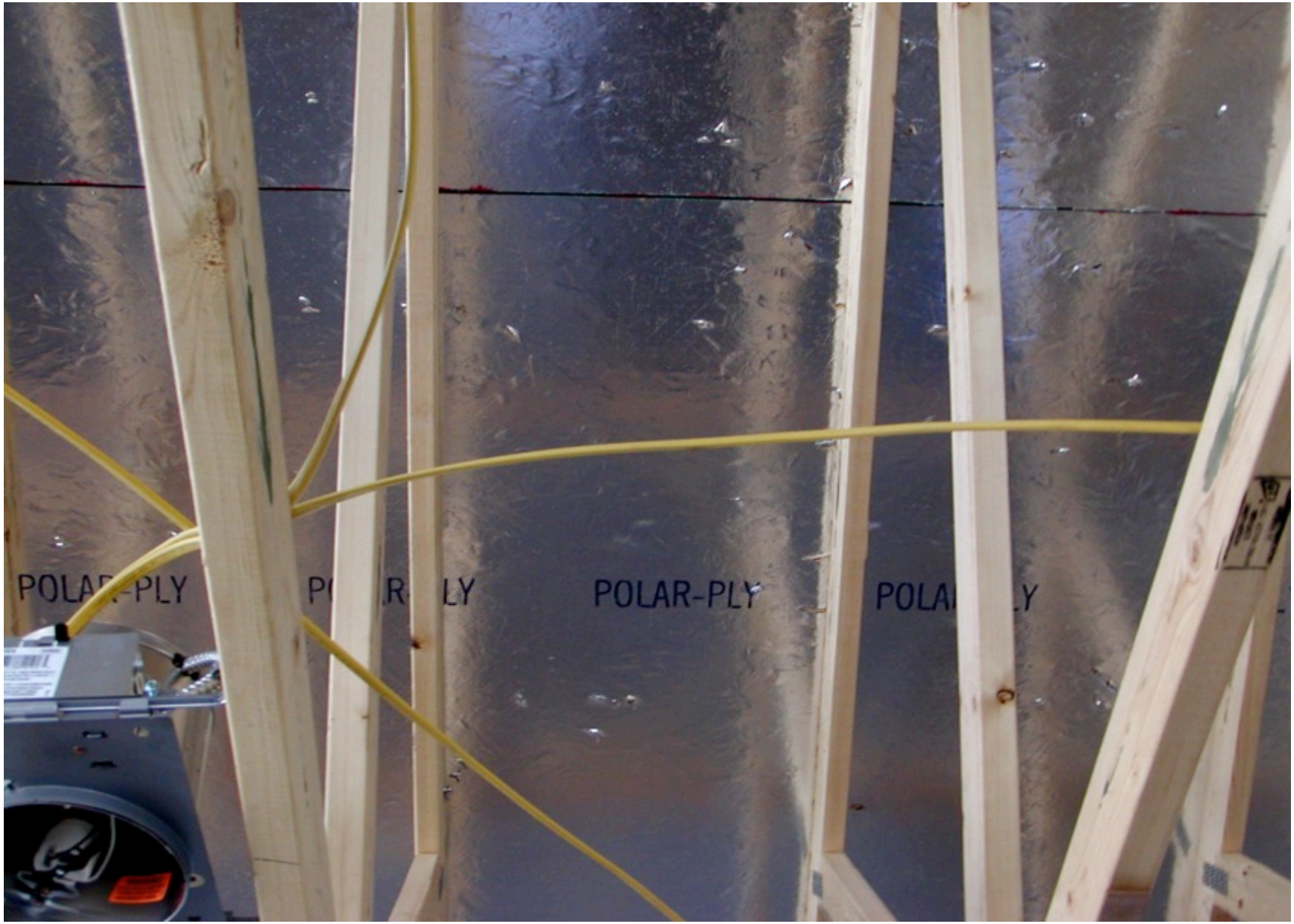
Note Water Vapor (H2O) is 18

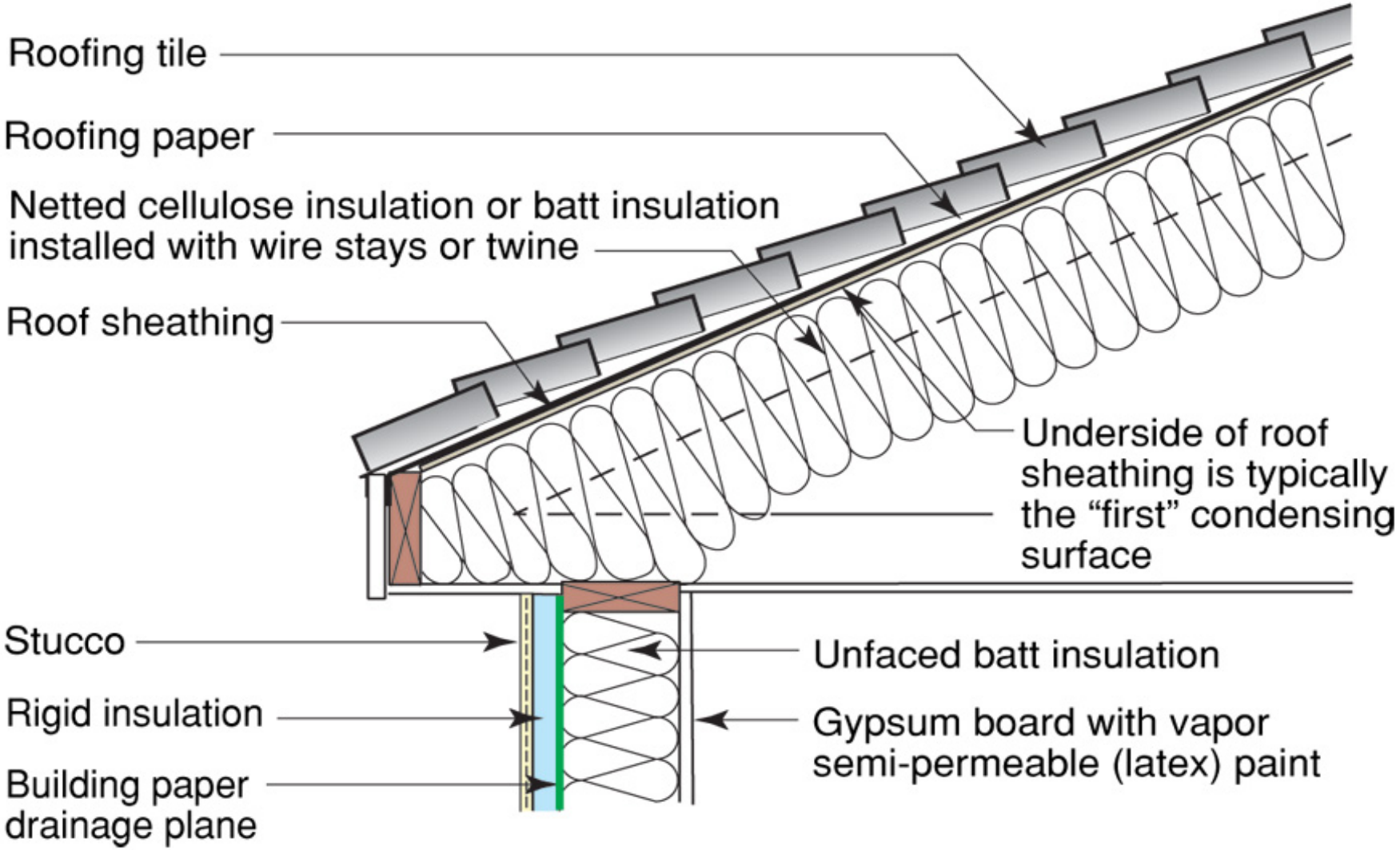
Dry Air is 29

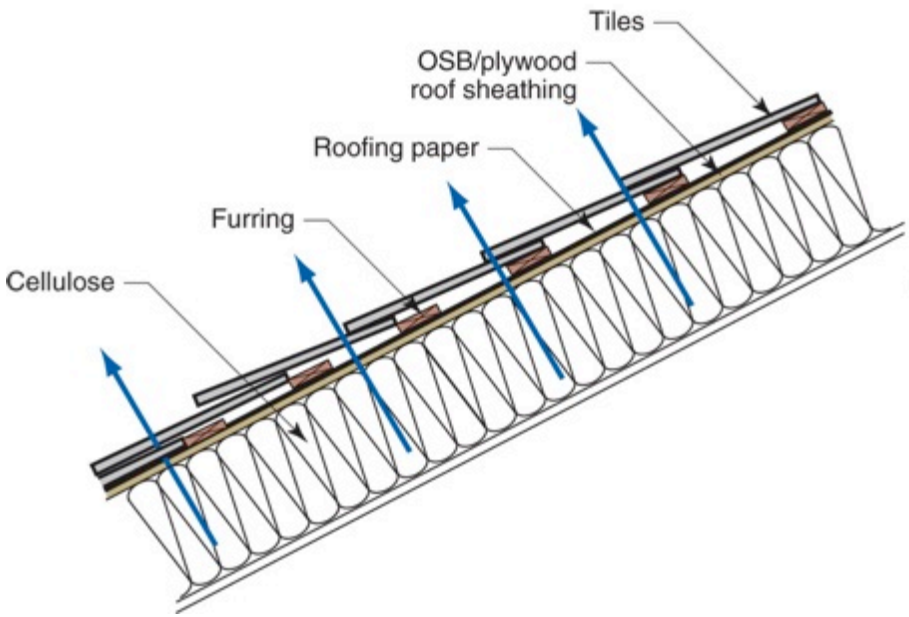

Dual In-Duct
Psychrometer
Fieldpiece
SDP2

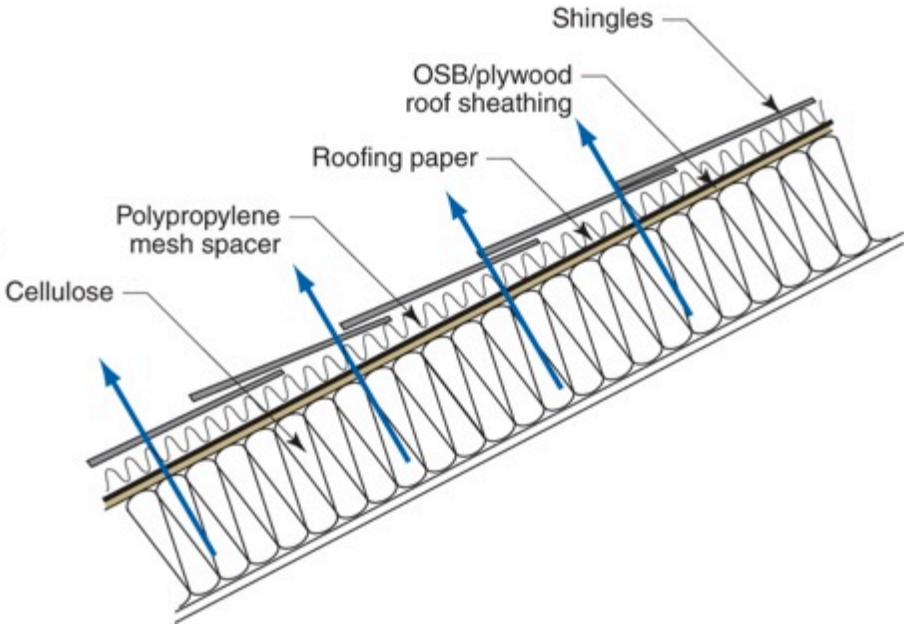

Shingles
Roofing paper
Wood based roof sheathing
Open cell low density spray foam
"Pong"
"Ping"


Shingles
Roofing paper
Wood based roof sheathing
Open cell low density spray foam
Each "Ping" and "Pong" bounces the water molecules up the slope

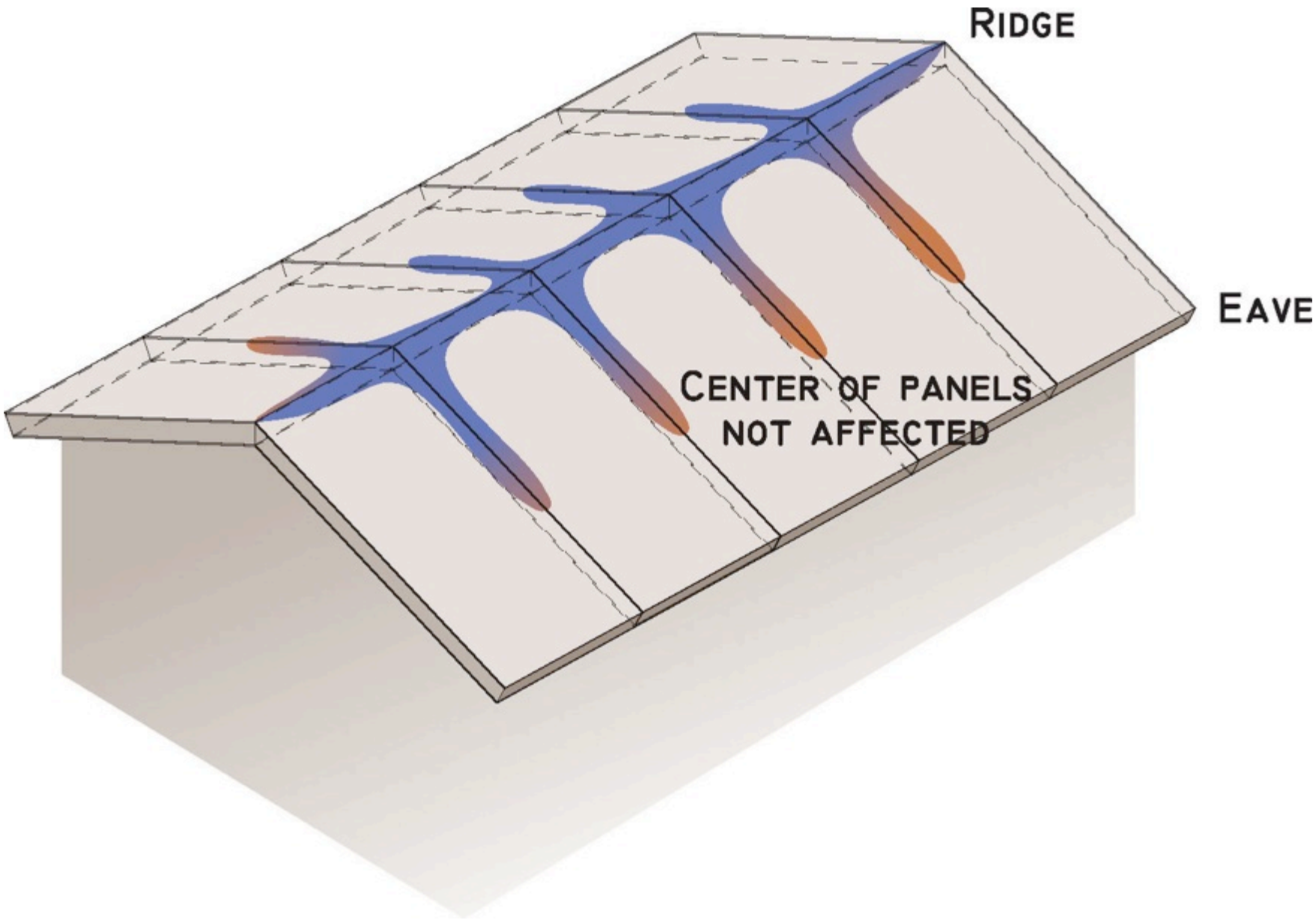

POLAR-PLY
POLAR-PLY


Roofing tile
Roofing paper
Netted cellulose insulation or batt insulation installed with wire stays or twine
Roof sheathing
Underside of roof sheathing is typically the “first” condensing surface
Stucco
Rigid insulation
Building paper drainage plane
Unfaced batt insulation
Gypsum board with vapor semi-permeable (latex) paint

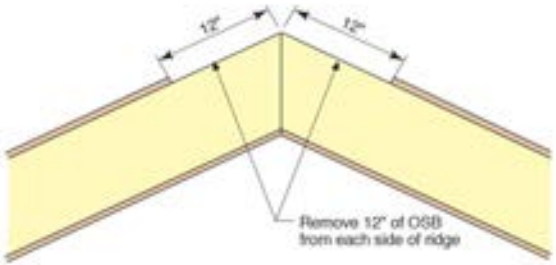

Tiles
OSB/plywood
roof sheathing
Roofing paper
Furring
Cellulose


Shingles
OSB/plywood
roof sheathing
Roofing paper
Polypropylene
mesh spacer
Cellulose

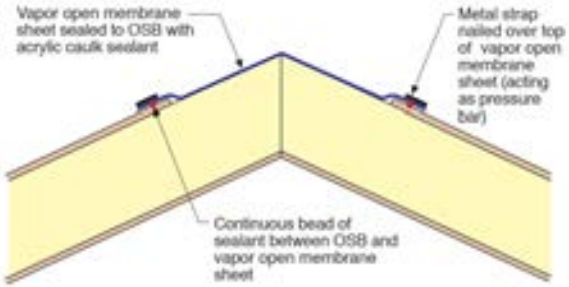

8/22/01 09:32


RIDGE
EAVE
CENTER OF PANELS
NOT AFFECTED

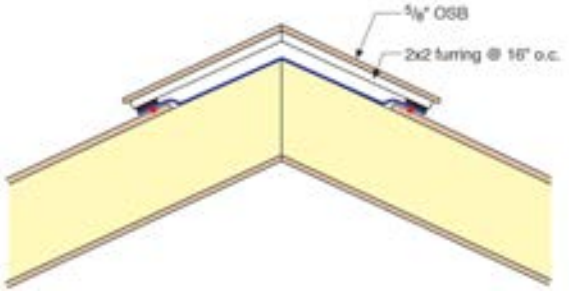
Step 1
- Remove strip of OSB from each side of ridge



Step 2
- Create air seal with strip of vapor open membrane (tape seams)
- Vapor open membrane sheet sealed to OSB with acrylic caulk sealant
- Hold vapor open membrane sheet in place with metal strapping



Step 3
- Construct wood ridge vent with 2x2 furring



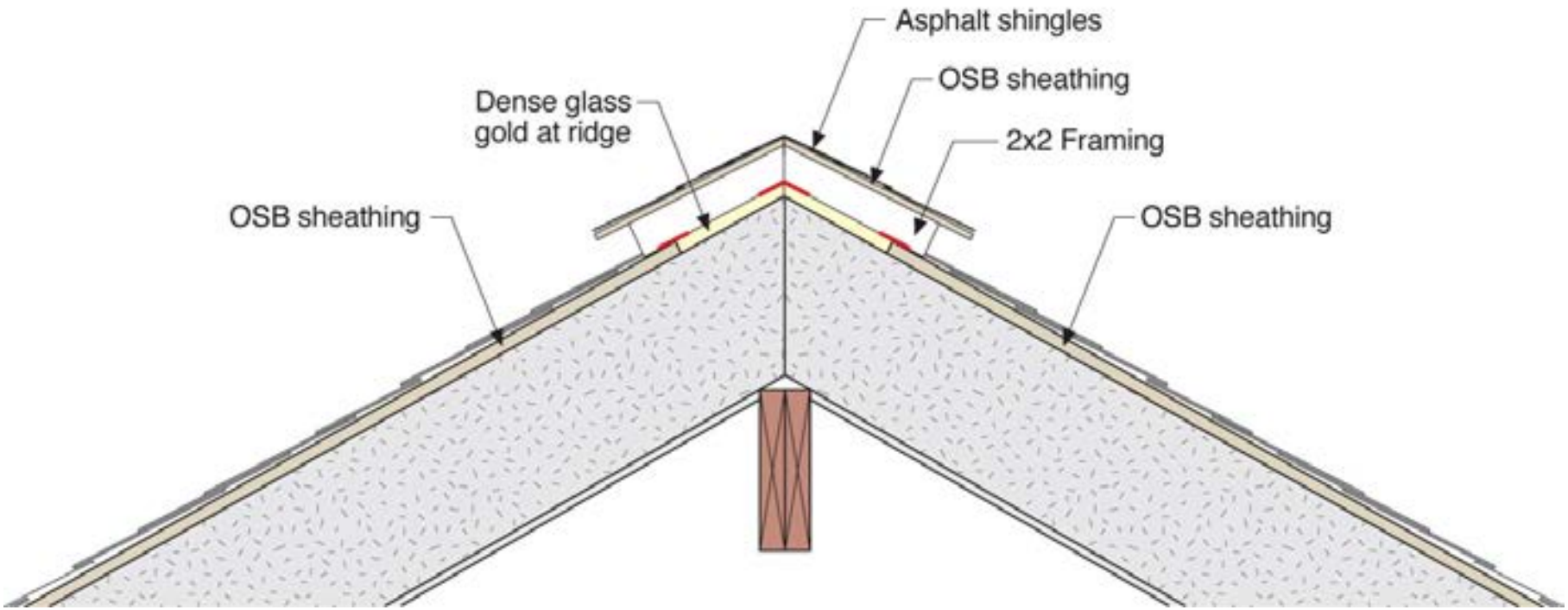

GRACE
Ice & Water Shield
Tyvek
Attic Wrap
DuPont

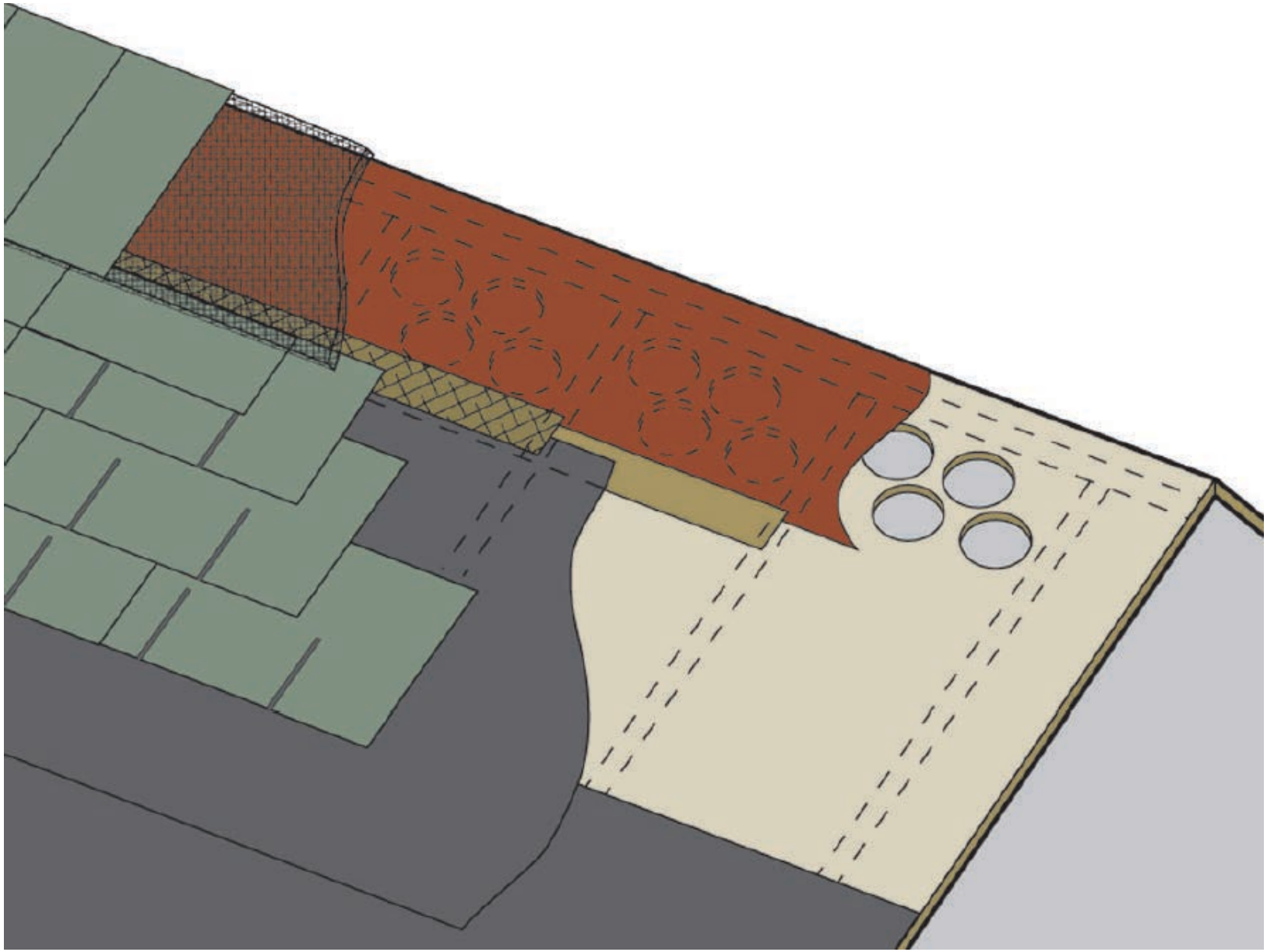

Tyvek
AtticWrap

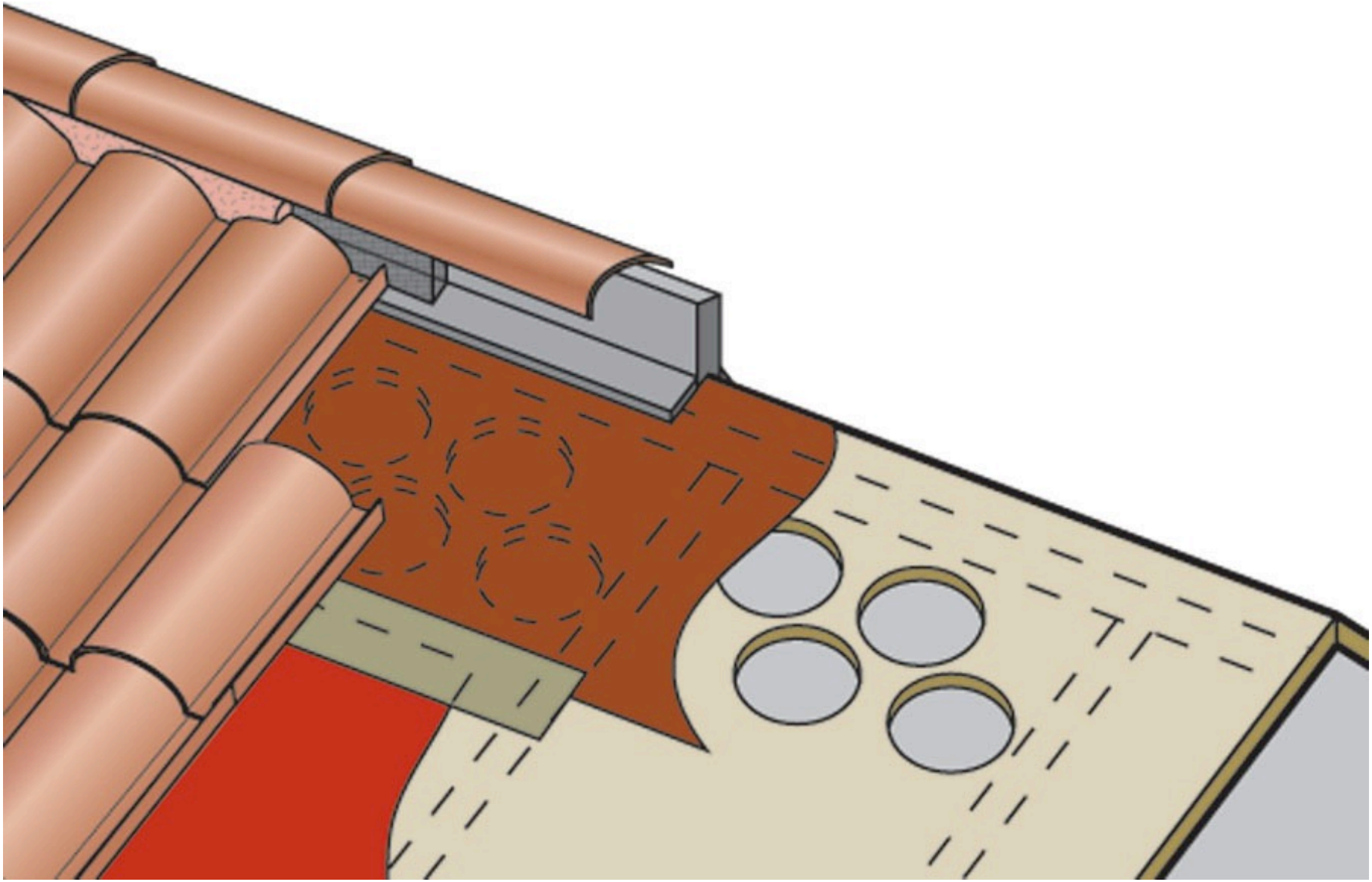

Tyvek

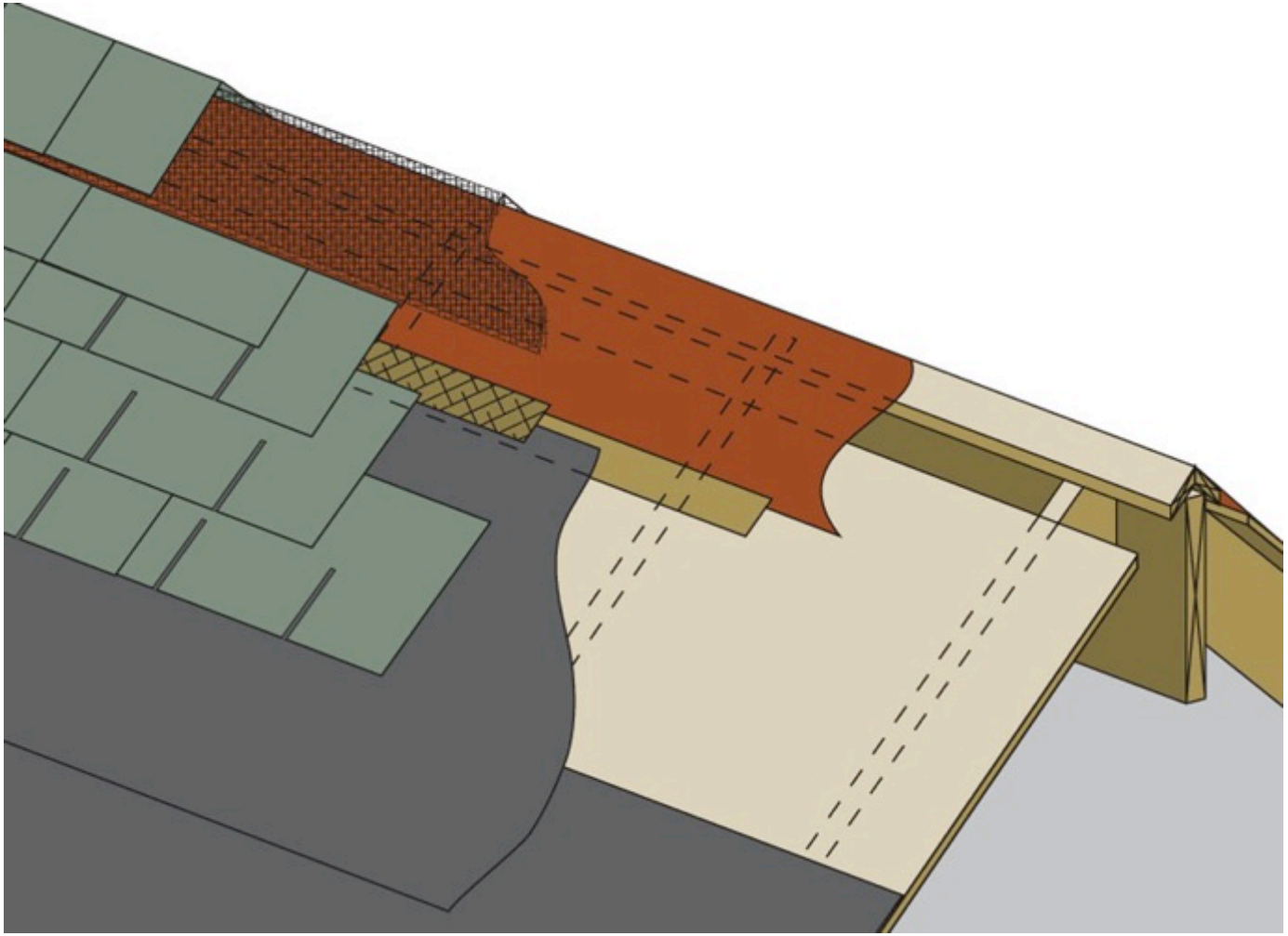

GRACE
Ice & Water Shield®

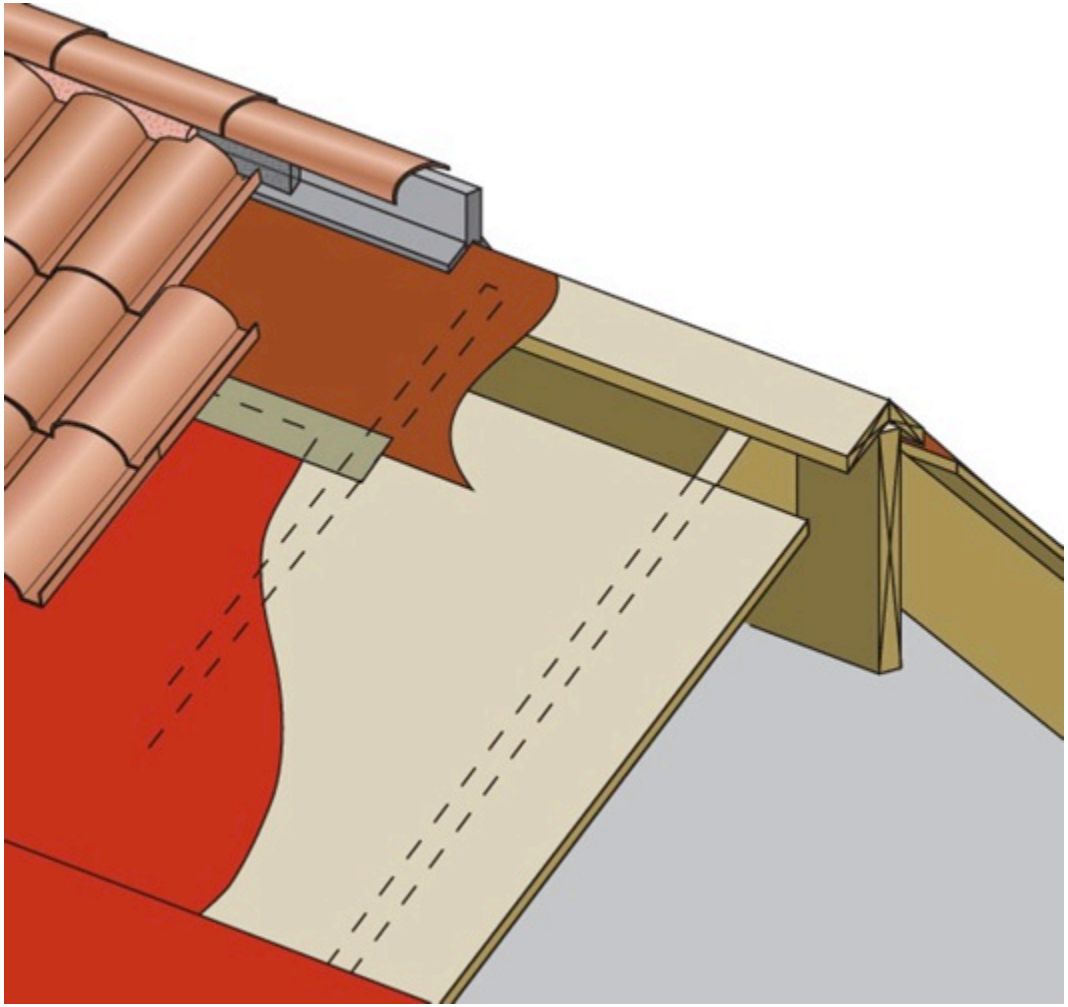

JUL 9 2006


Asphalt shingles
OSB sheathing
Dense glass
gold at ridge
2x2 Framing
OSB sheathing
OSB sheathing










3M


DELTA
DELTA
DELTA


R-30
PROPINK
High Performance
Attic System
OWENS CORNING
R-30
PROPINK
High Performance
Attic System
R-30
PROPINK
High Performance
Attic System

Sweating Ducts

Sweating Ducts

Light Colored Roofs

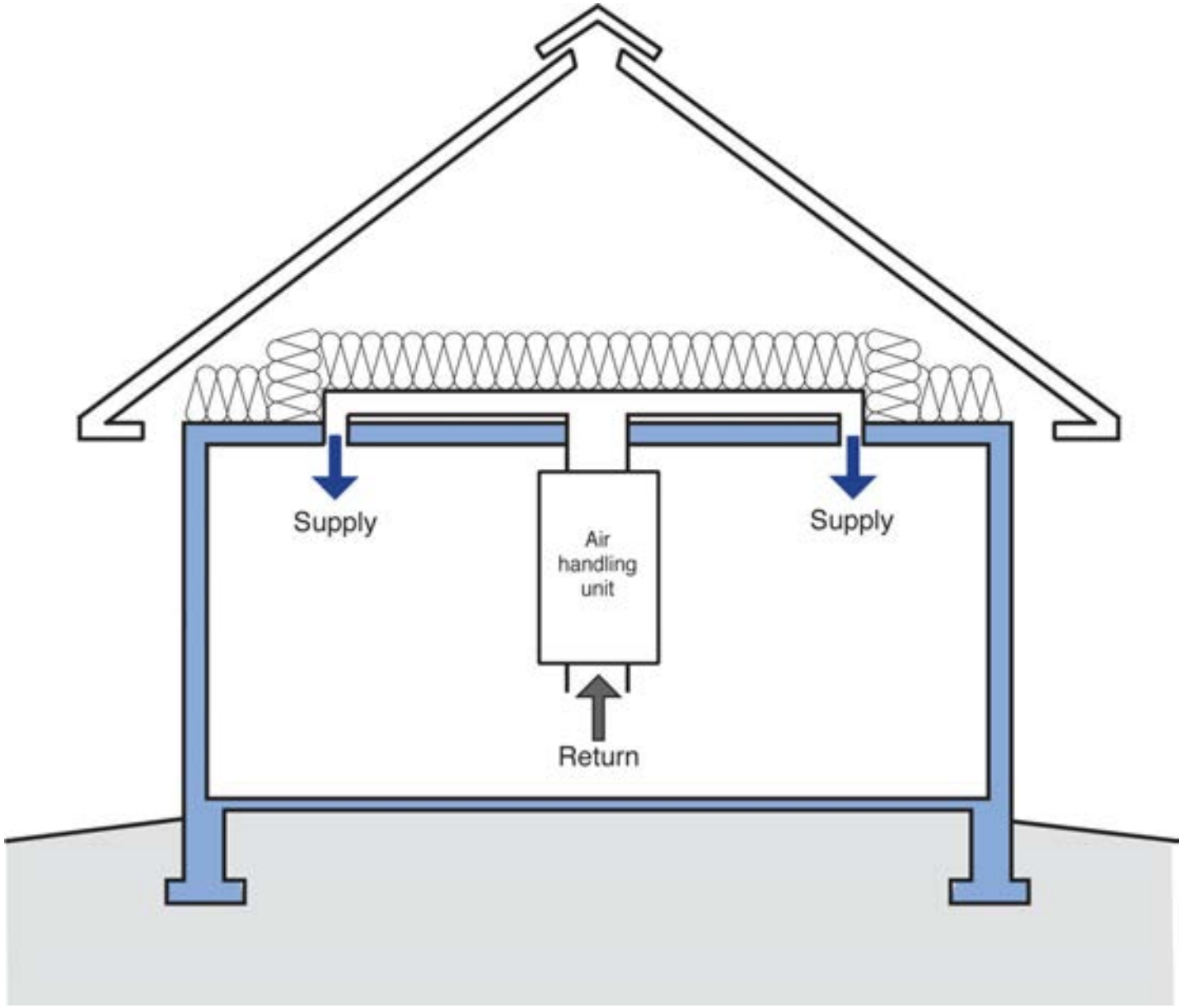
Cool Roofs

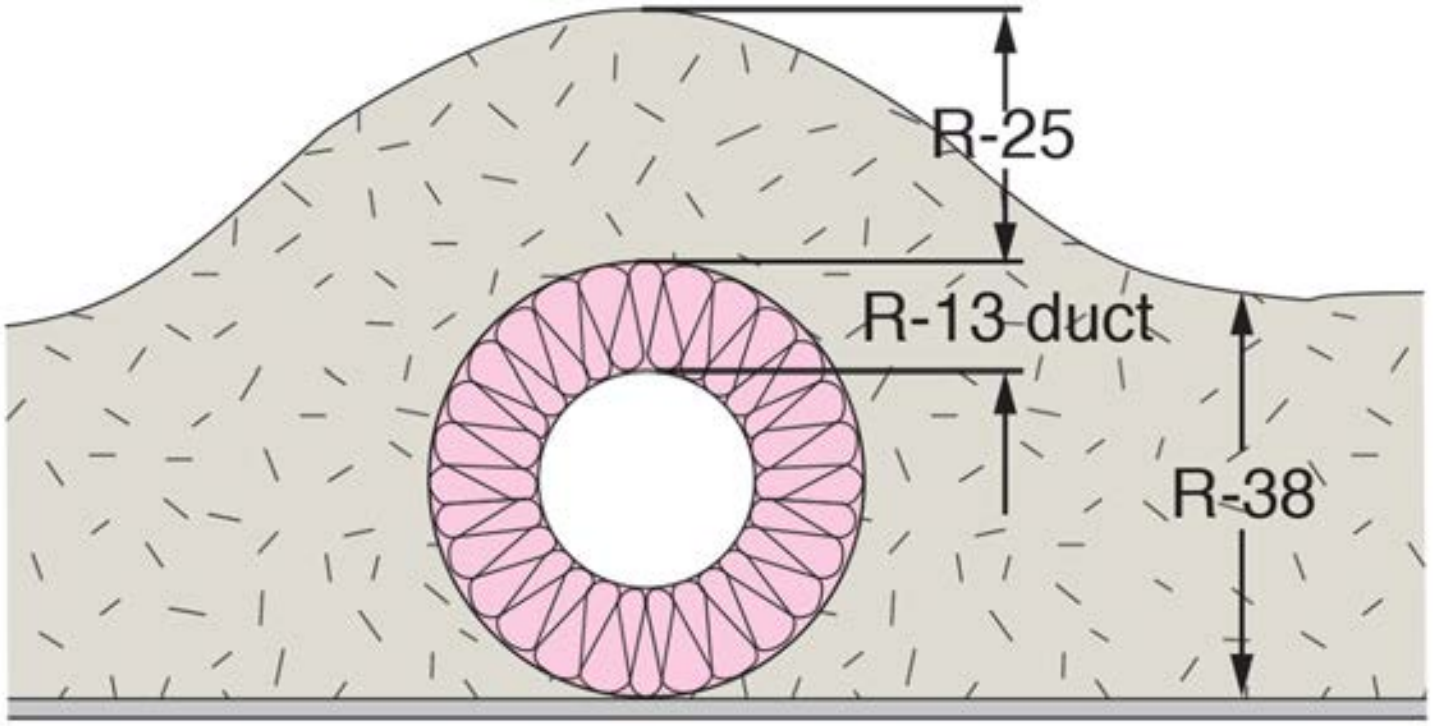
Radiant Barriers

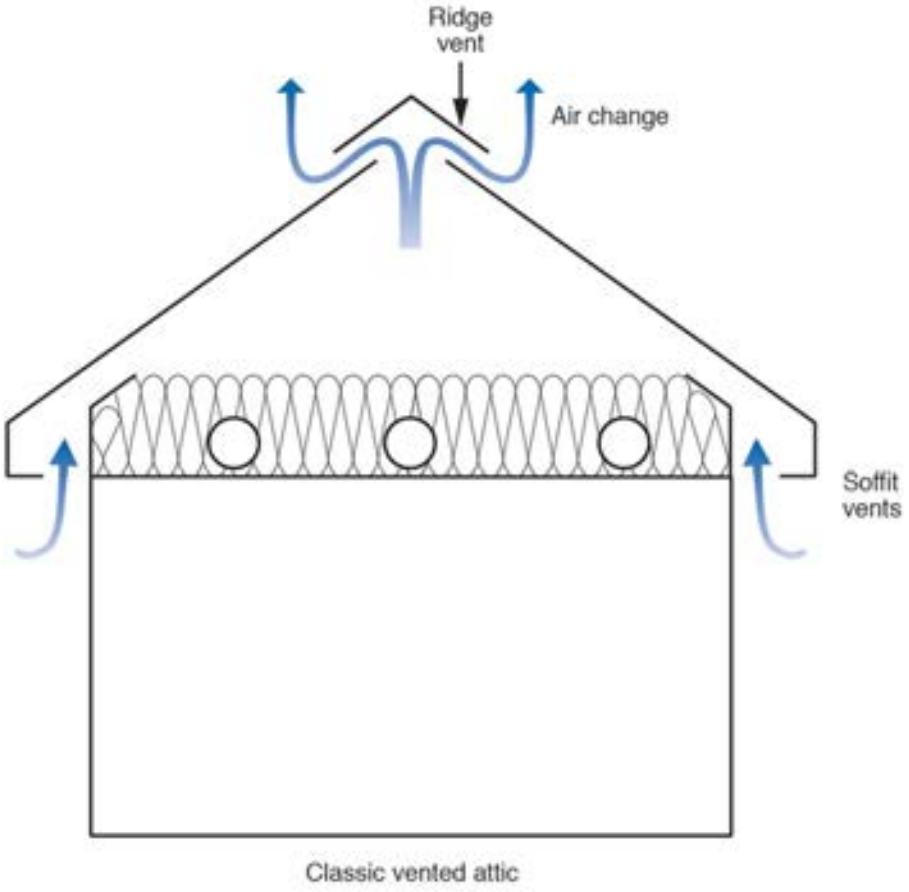
ACCA Manual J, S and D

Ductwork Attic Dehumidification System

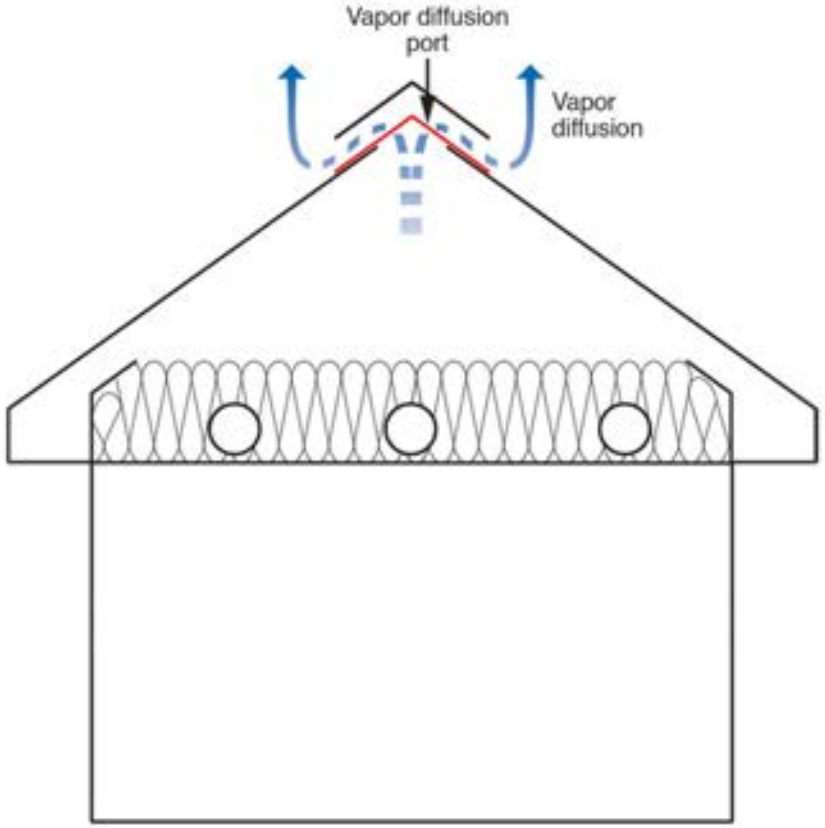
Burying Ducts


Supply
Air handling unit
Supply
Return


R-25
R-13 duct
R-38

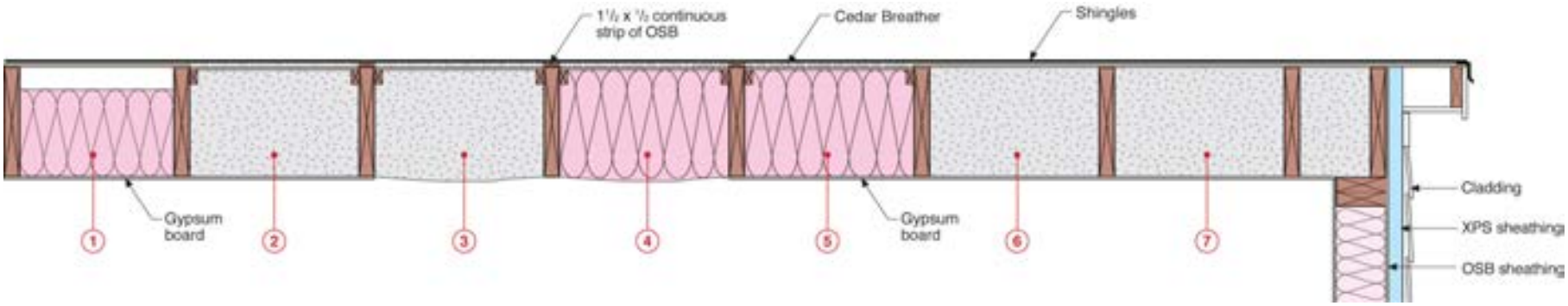


Classic vented attic



Unvented attic with vapor diffusion port

Cold Climates

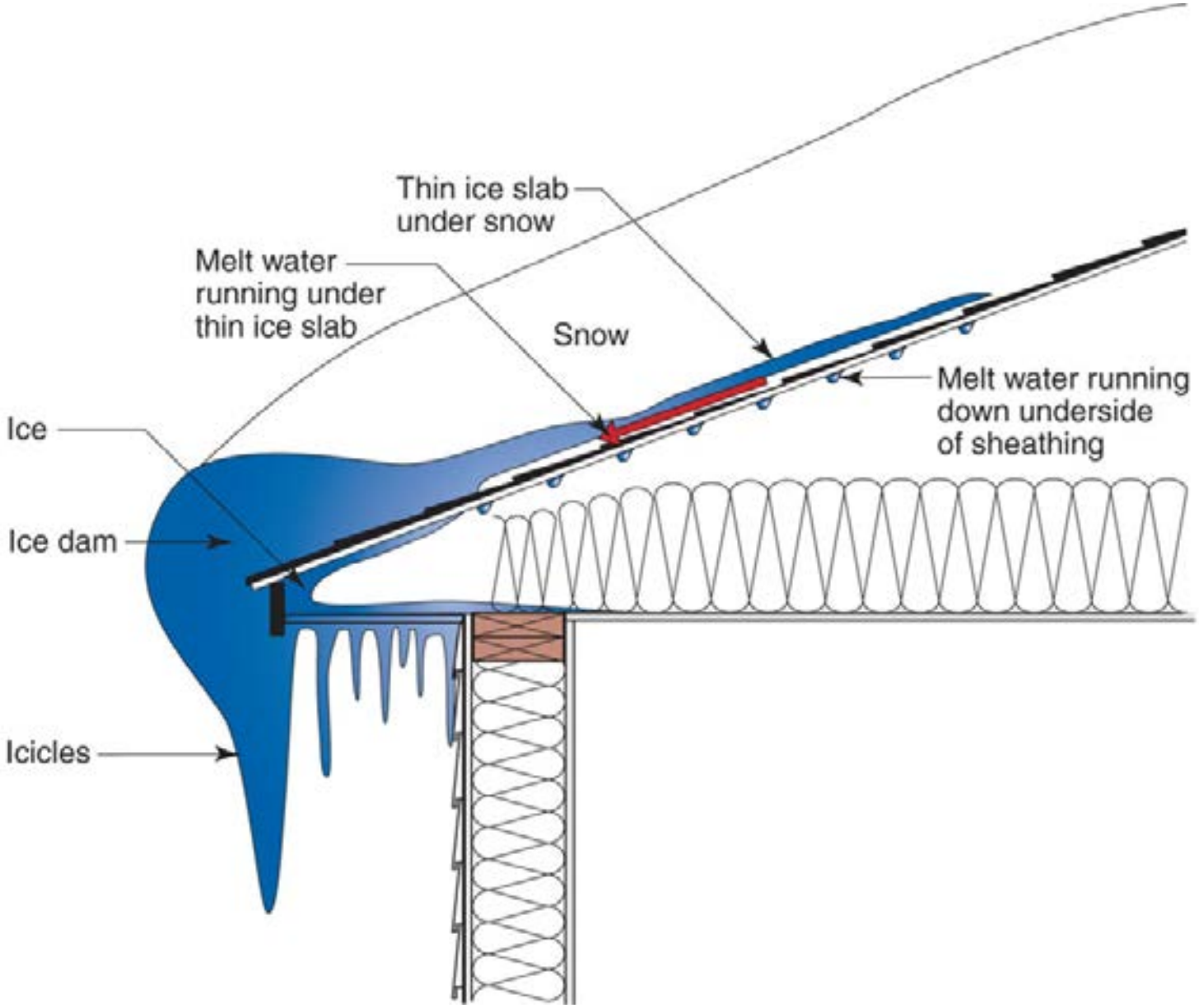

1 ½ x ½ continuous strip of OSB
Cedar Breather
Shingles
Gypsum board
Gypsum board
Cladding
XPS sheathing
OSB sheathing
1
2
3
4
5
6
7


FlexWrap

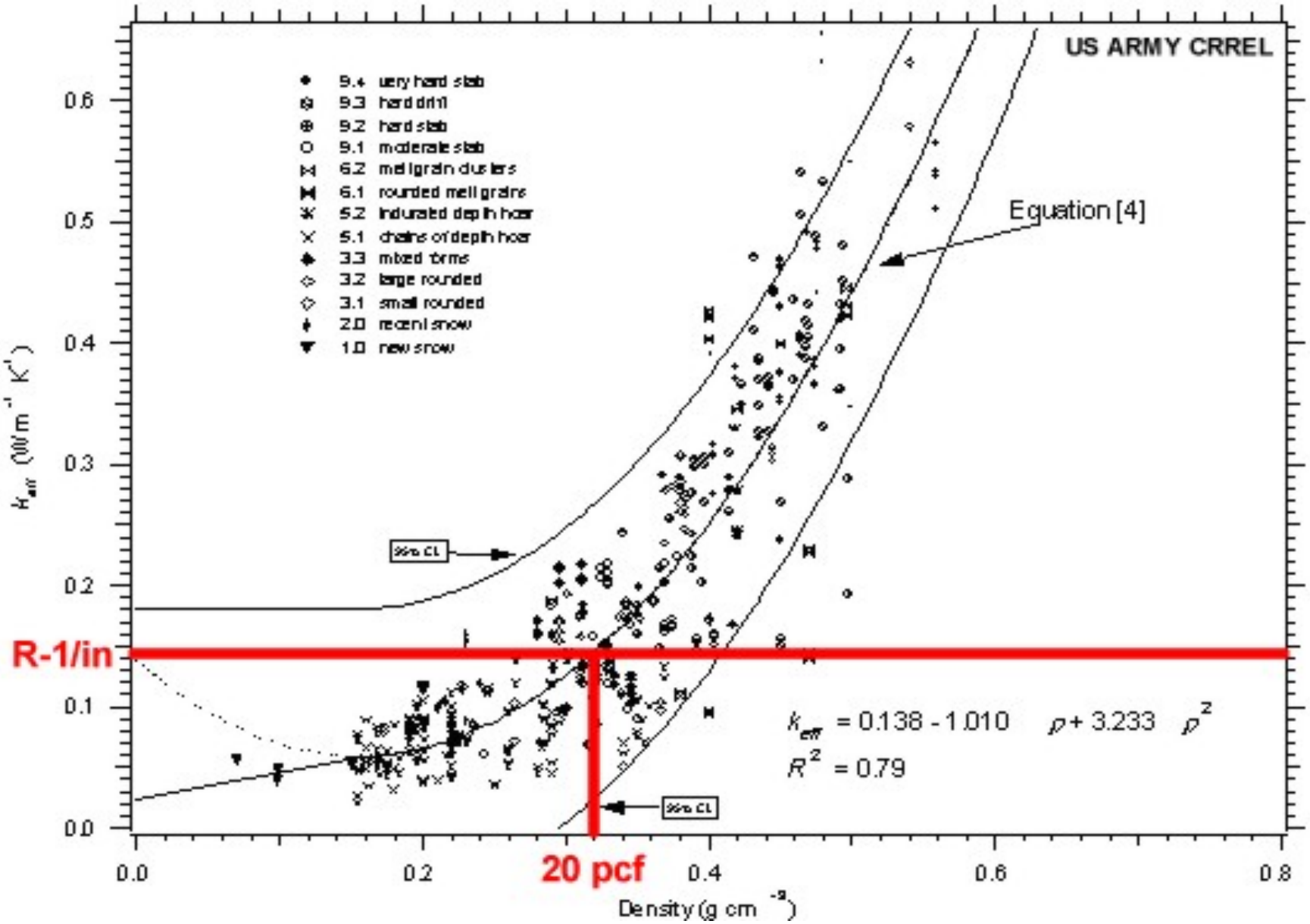

AVAILABLE

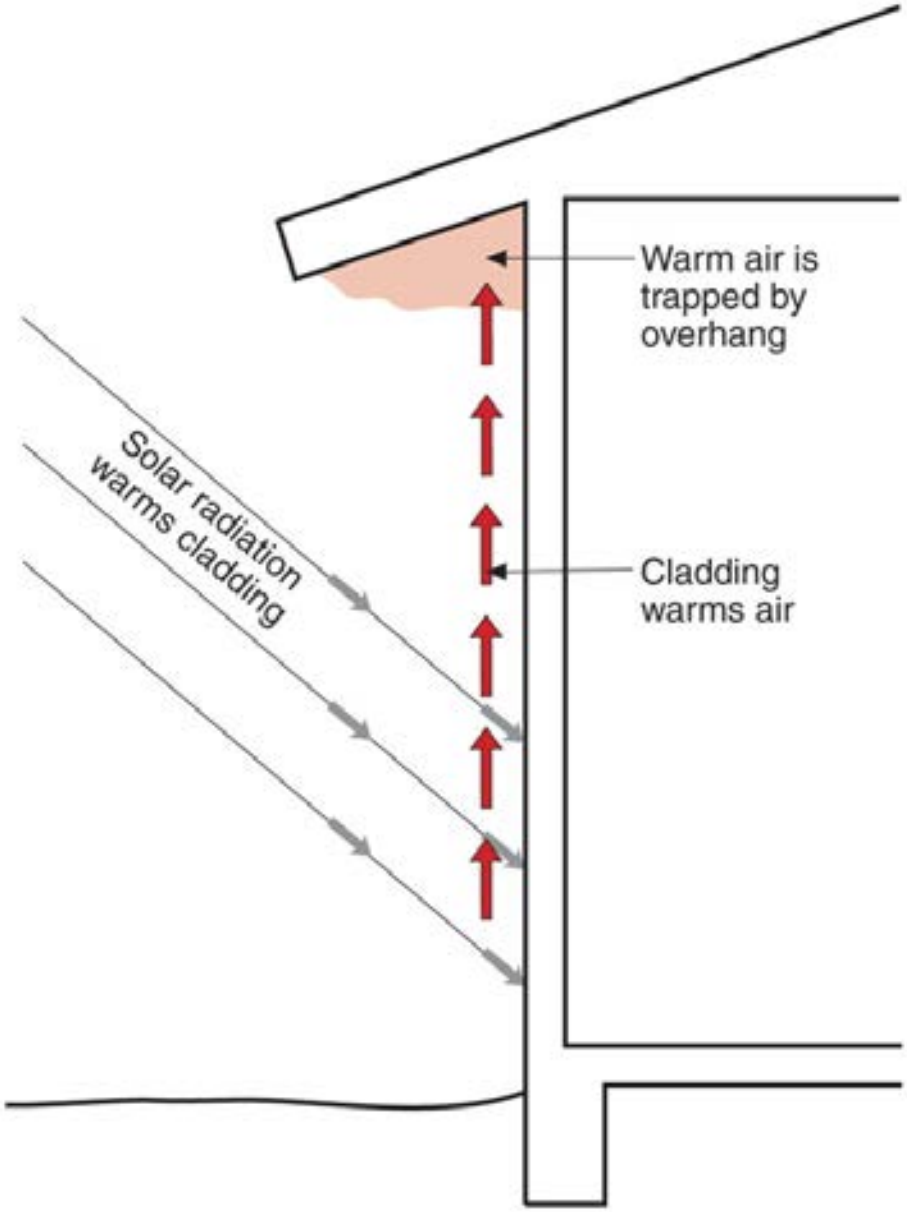

R-30
R-30


R-30

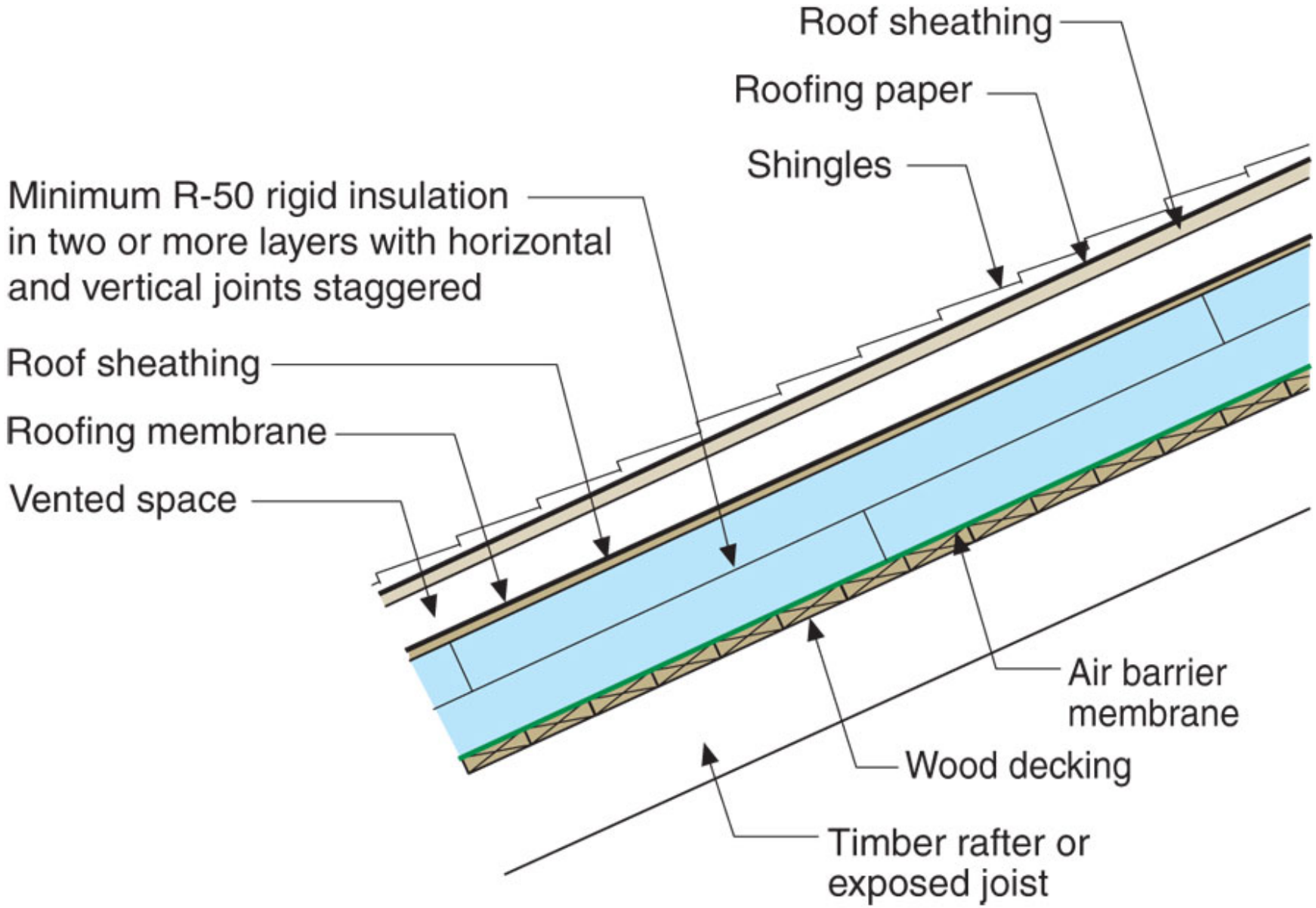

Thin ice slab
under snow
Melt water
running under
thin ice slab
Snow
Melt water running
down underside
of sheathing
Ice
Ice dam
Icicles

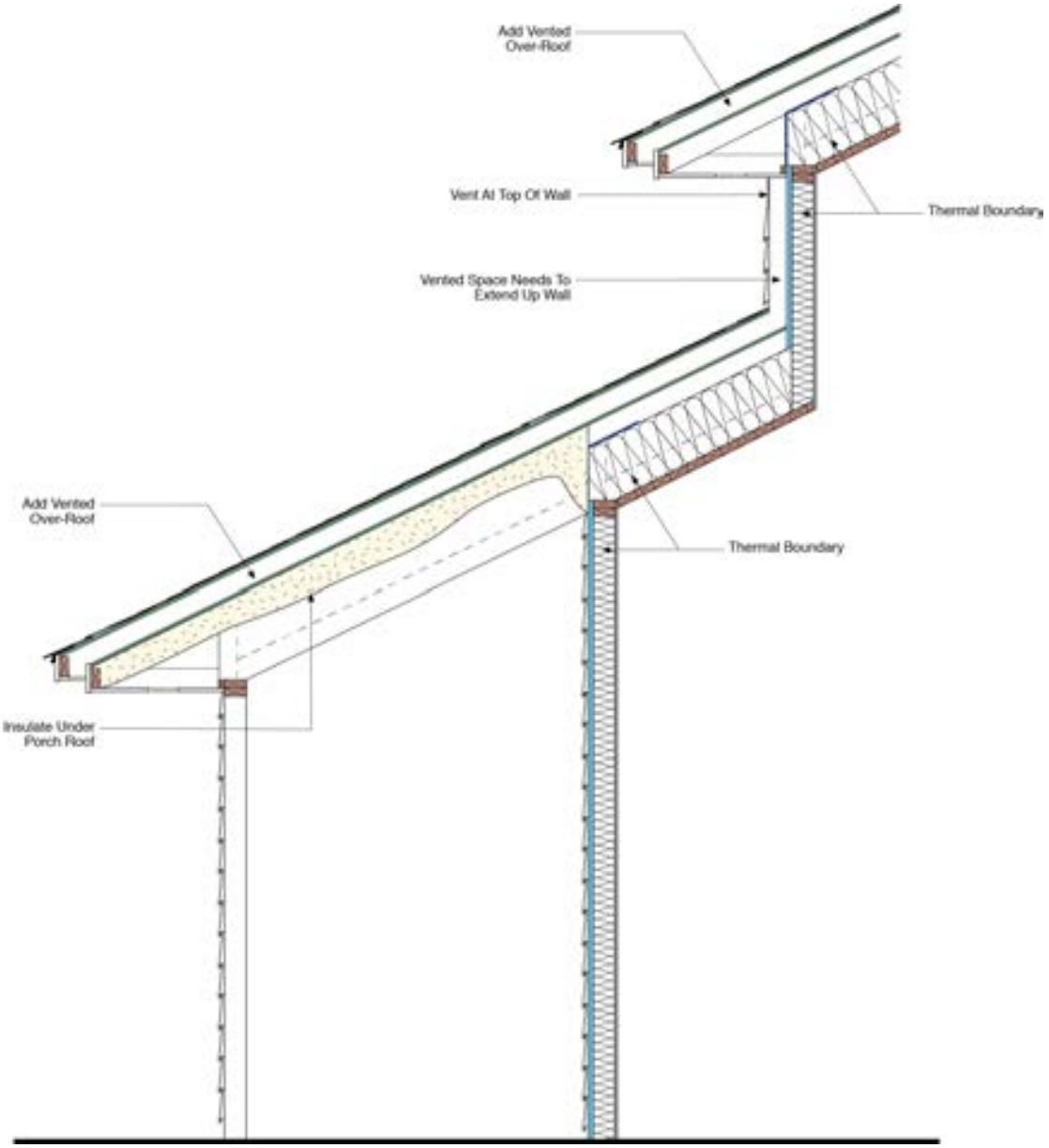

WESTFORD REAL ESTATE

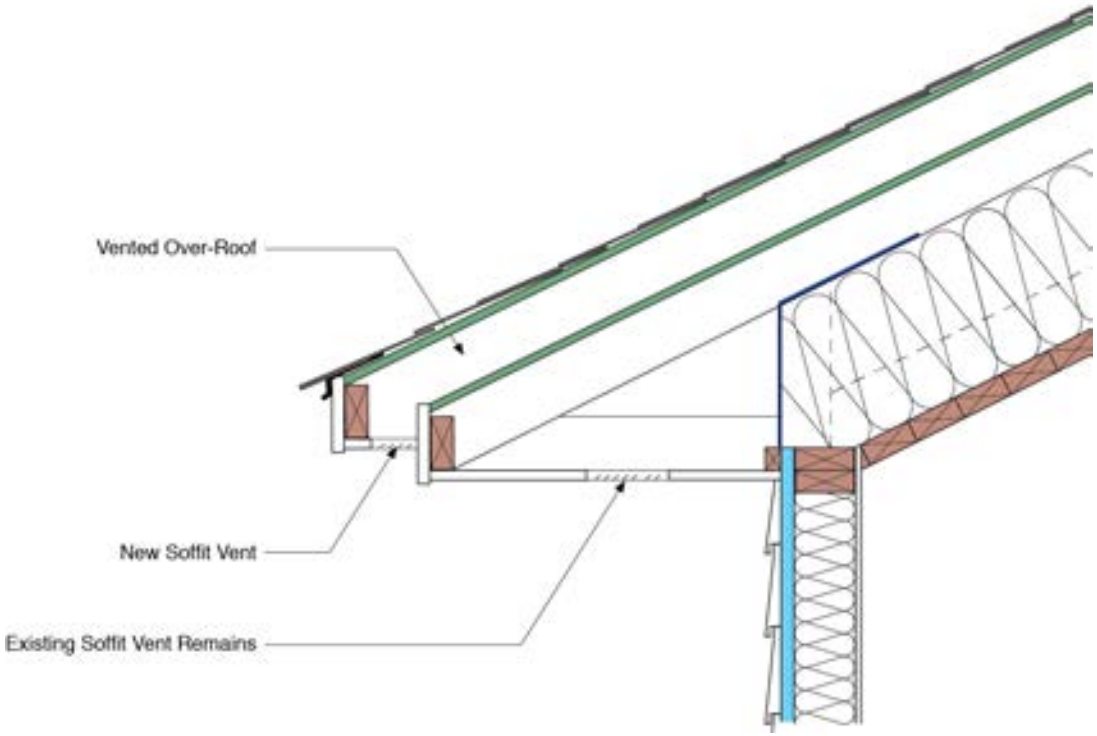

US ARMY CRREL
9.4 very hard slab
9.3 hard drift
9.2 hard slab
9.1 moderate slab
6.2 melt grain clusters
6.1 rounded melt grains
5.2 indurated depth hoar
5.1 chains of depth hoar
3.3 mixed forms
3.2 large rounded
3.1 small rounded
2.0 recent snow
1.0 new snow
Eguation [4]
95% CL
95% CL
R-1/in
20 pcf
k_{eff} = 0.138 - 1.010 ρ + 3.233 ρ^2
R^2 = 0.79
k_{eff} (W m^{-1} K^{-1})
Density (g cm^{-3})
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.0
0.2
0.4
0.6
0.8


Warm air is trapped by overhang
Solar radiation warms cladding
Cladding warms air


KEEP OUT


Roof sheathing
Roofing paper
Shingles
Minimum R-50 rigid insulation
in two or more layers with horizontal
and vertical joints staggered
Roof sheathing
Roofing membrane
Vented space
Air barrier
membrane
Wood decking
Timber rafter or
exposed joist


Add Vented
Over-Roof
Vent At Top Of Wall
Thermal Boundary
Vented Space Needs To
Extend Up Wall
Add Vented
Over-Roof
Thermal Boundary
Insulate Under
Porch Roof


Vented Over-Roof
New Soffit Vent
Existing Soffit Vent Remains