

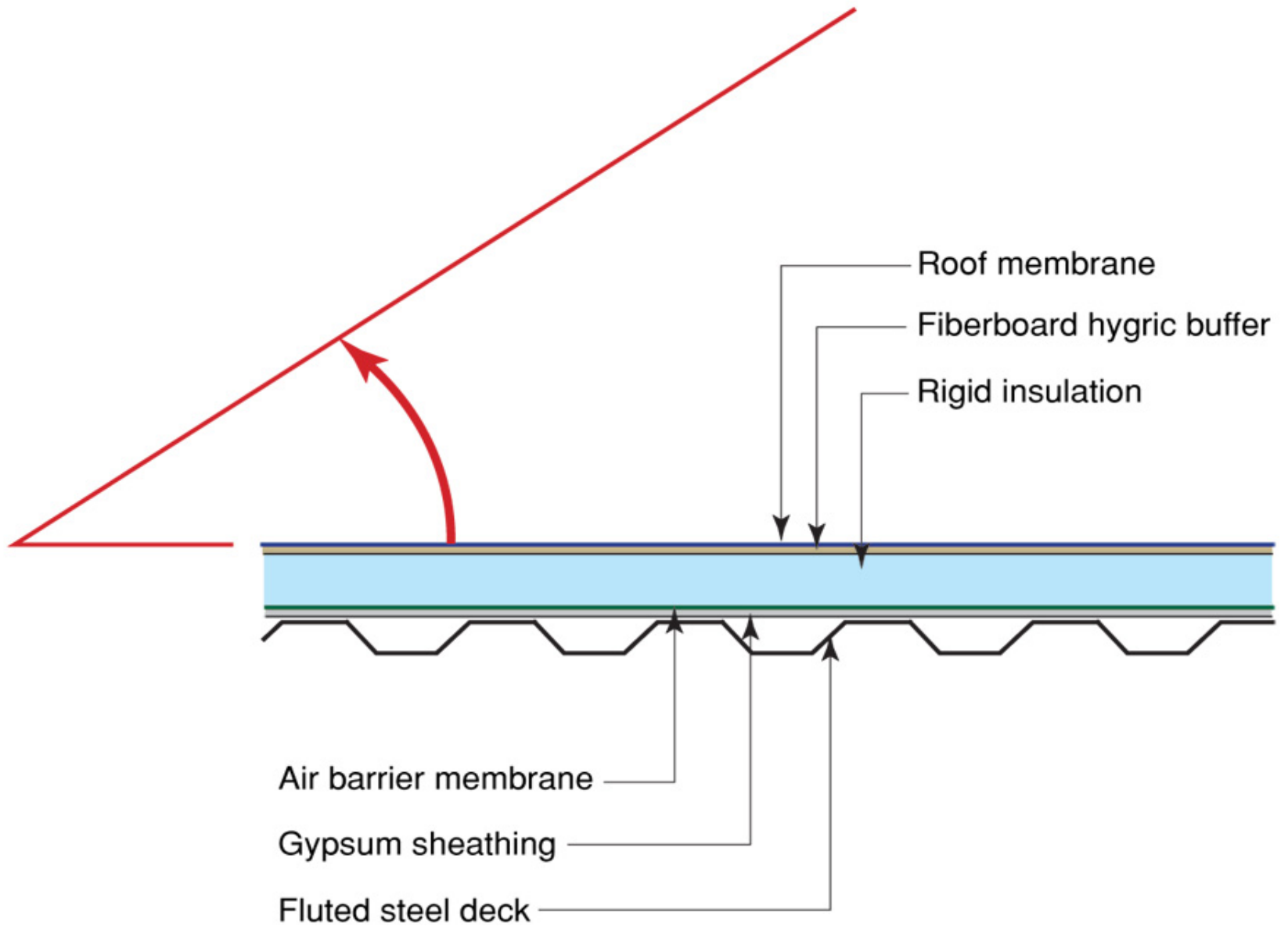
Joseph Lstiburek, Ph.D., P.Eng, ASHRAE Fellow

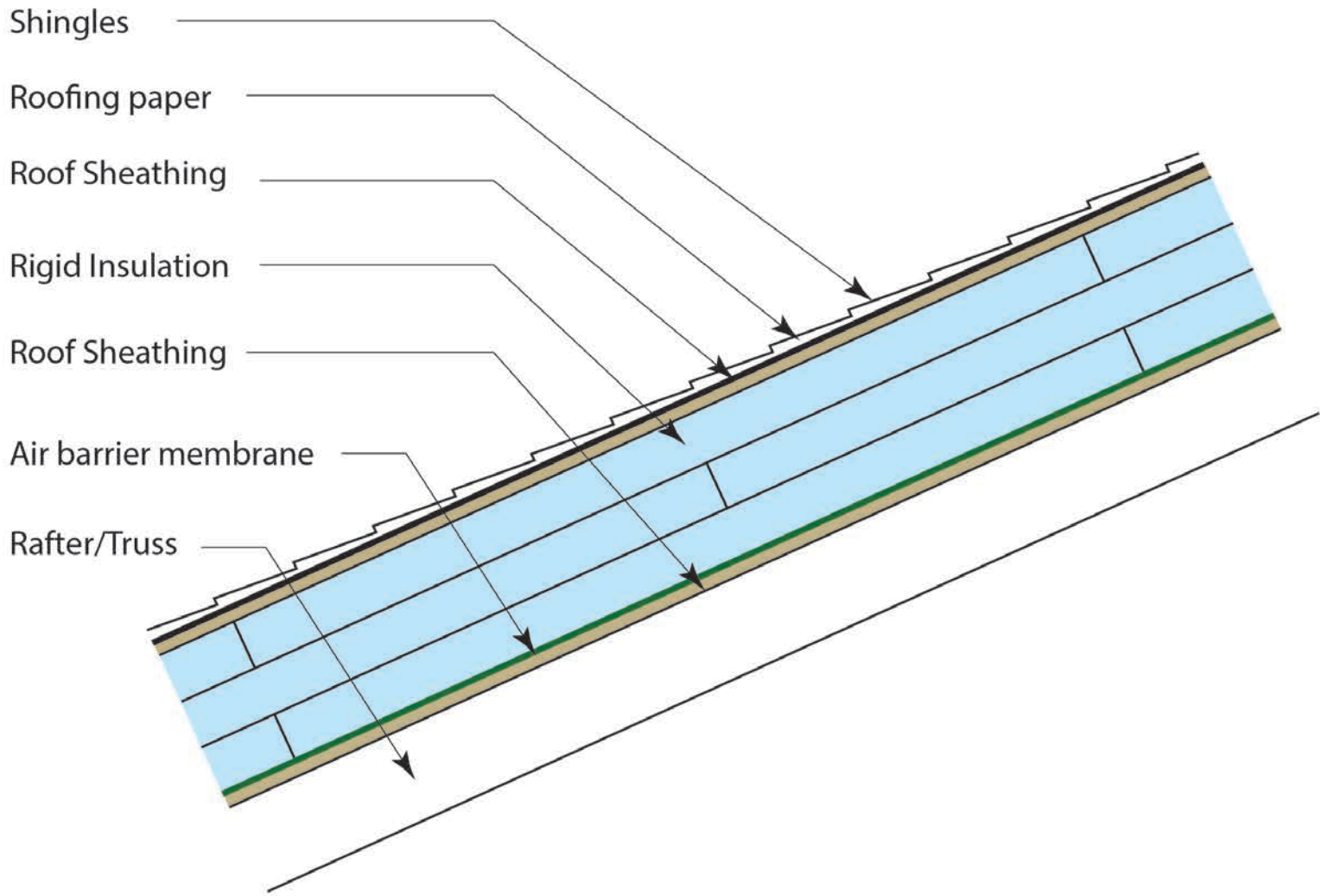
Building Science

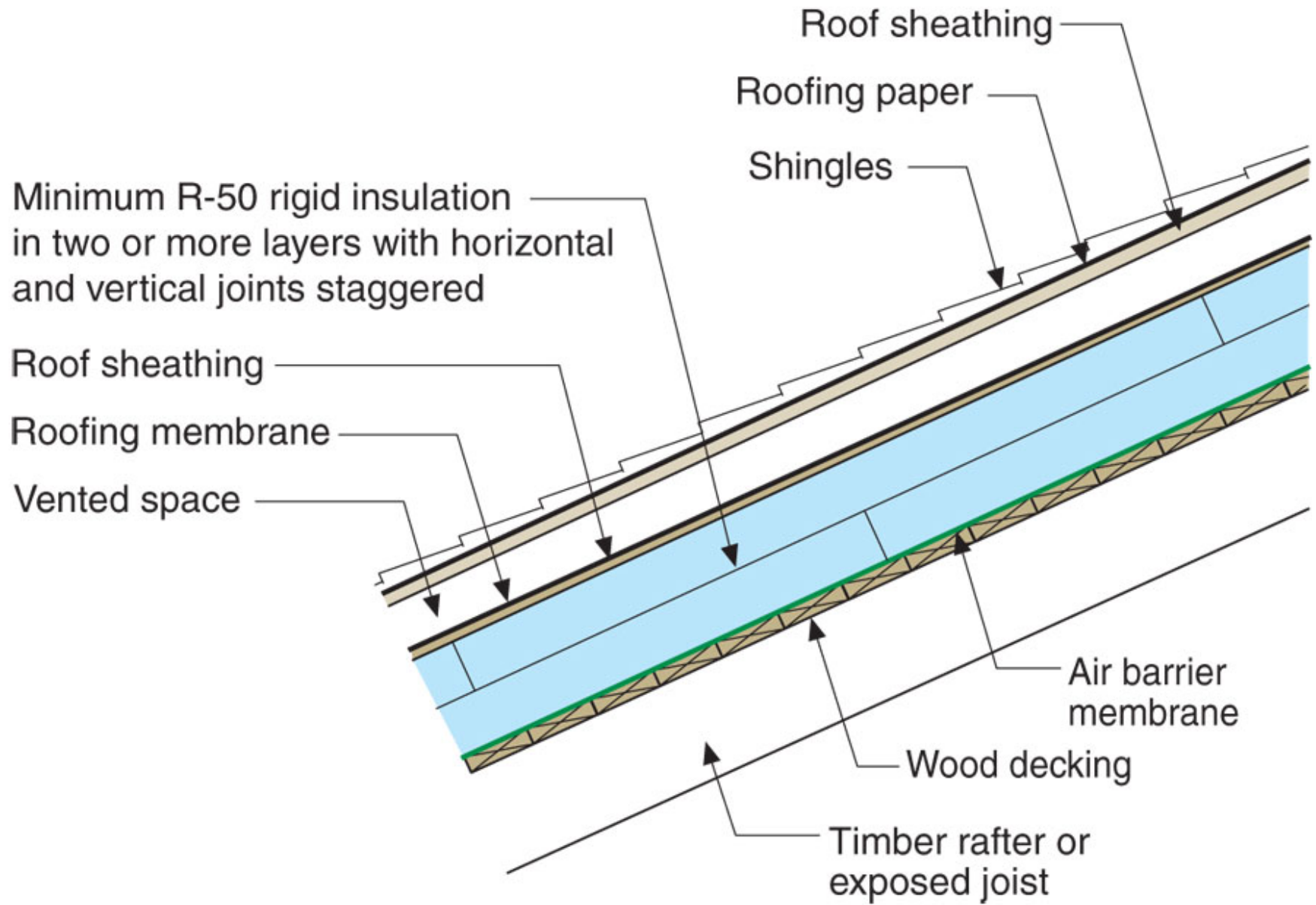
Hybrid Assemblies

presented by www.buildingscience.com

Roofs, Walls and Stuff.....





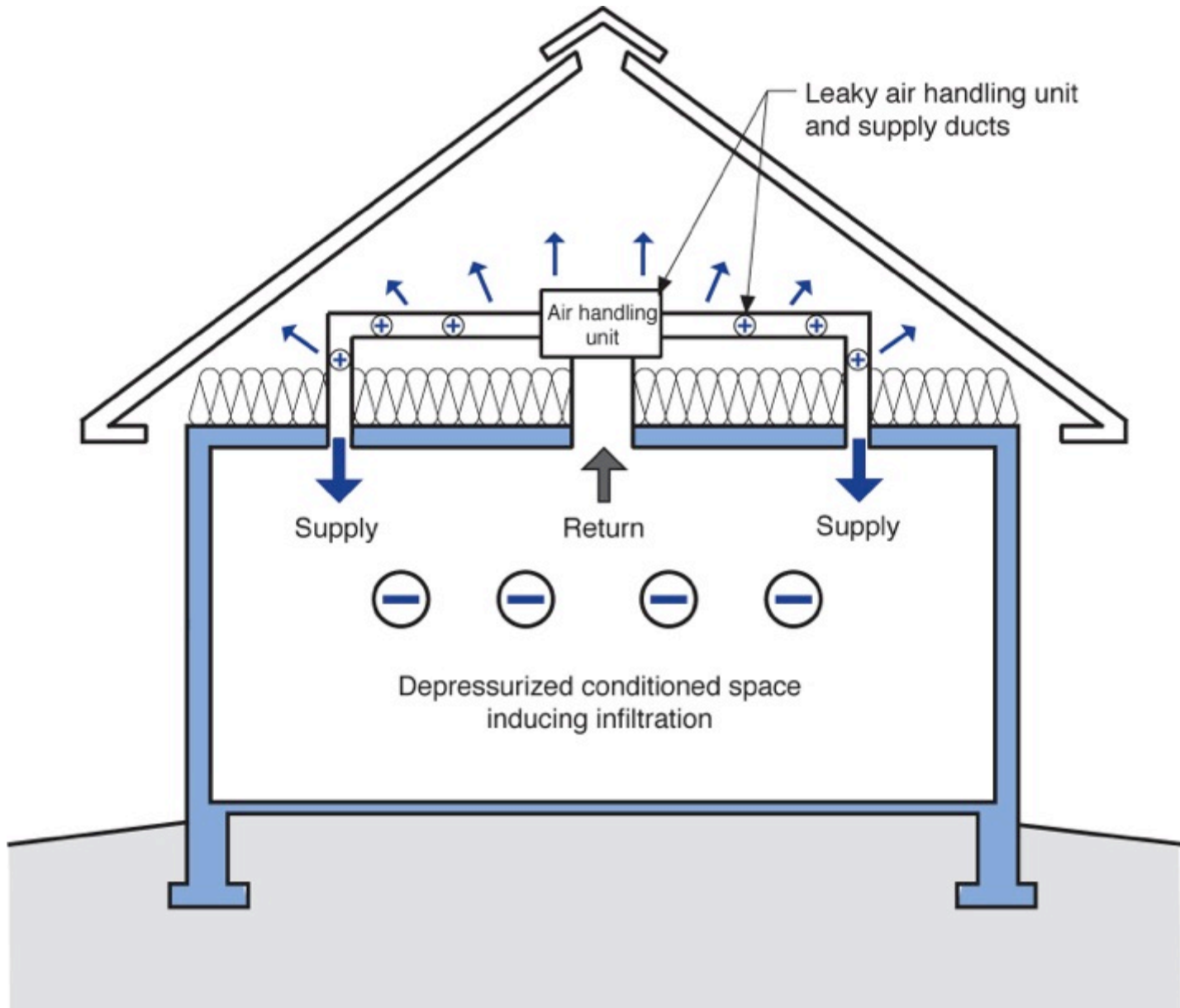


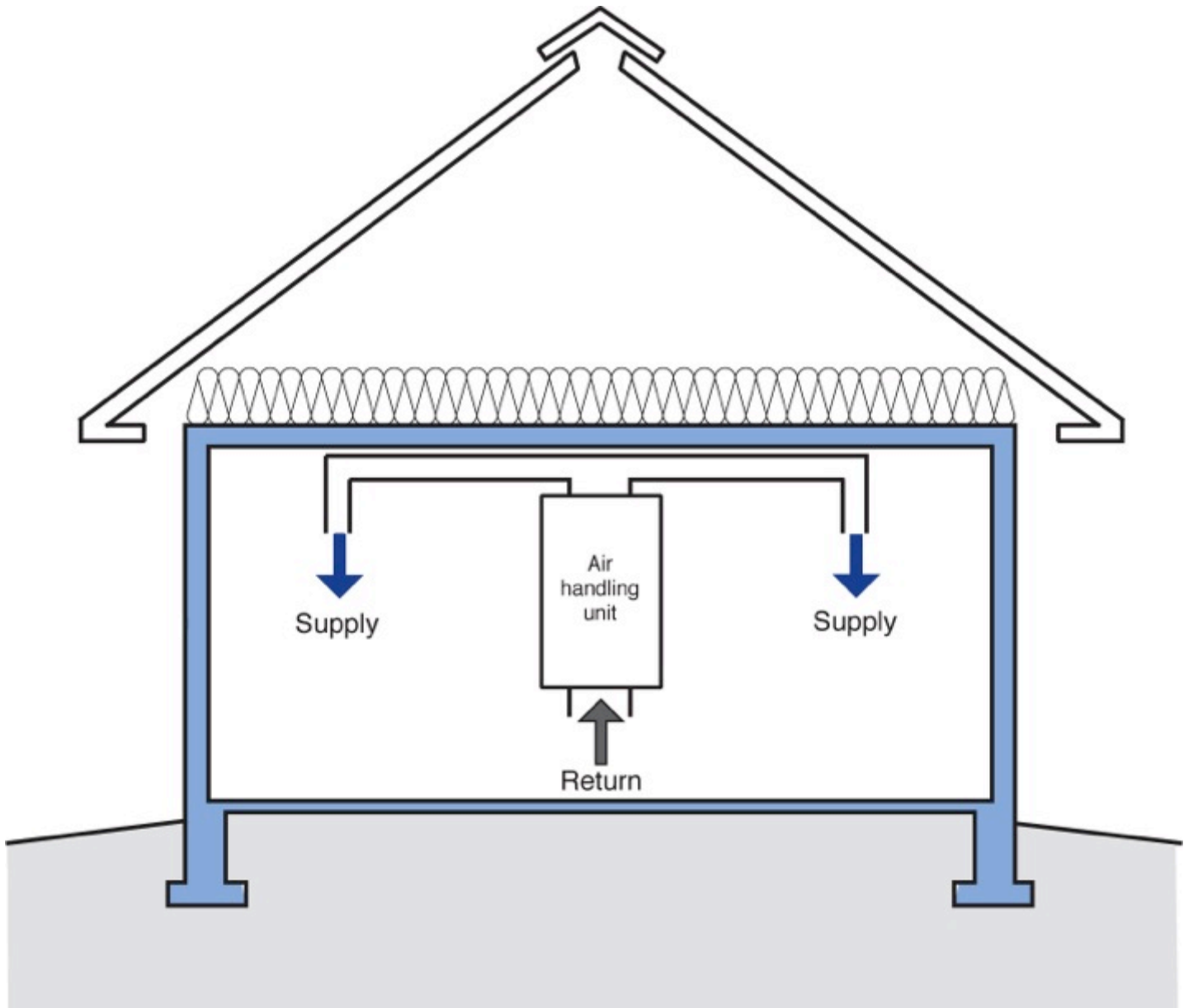


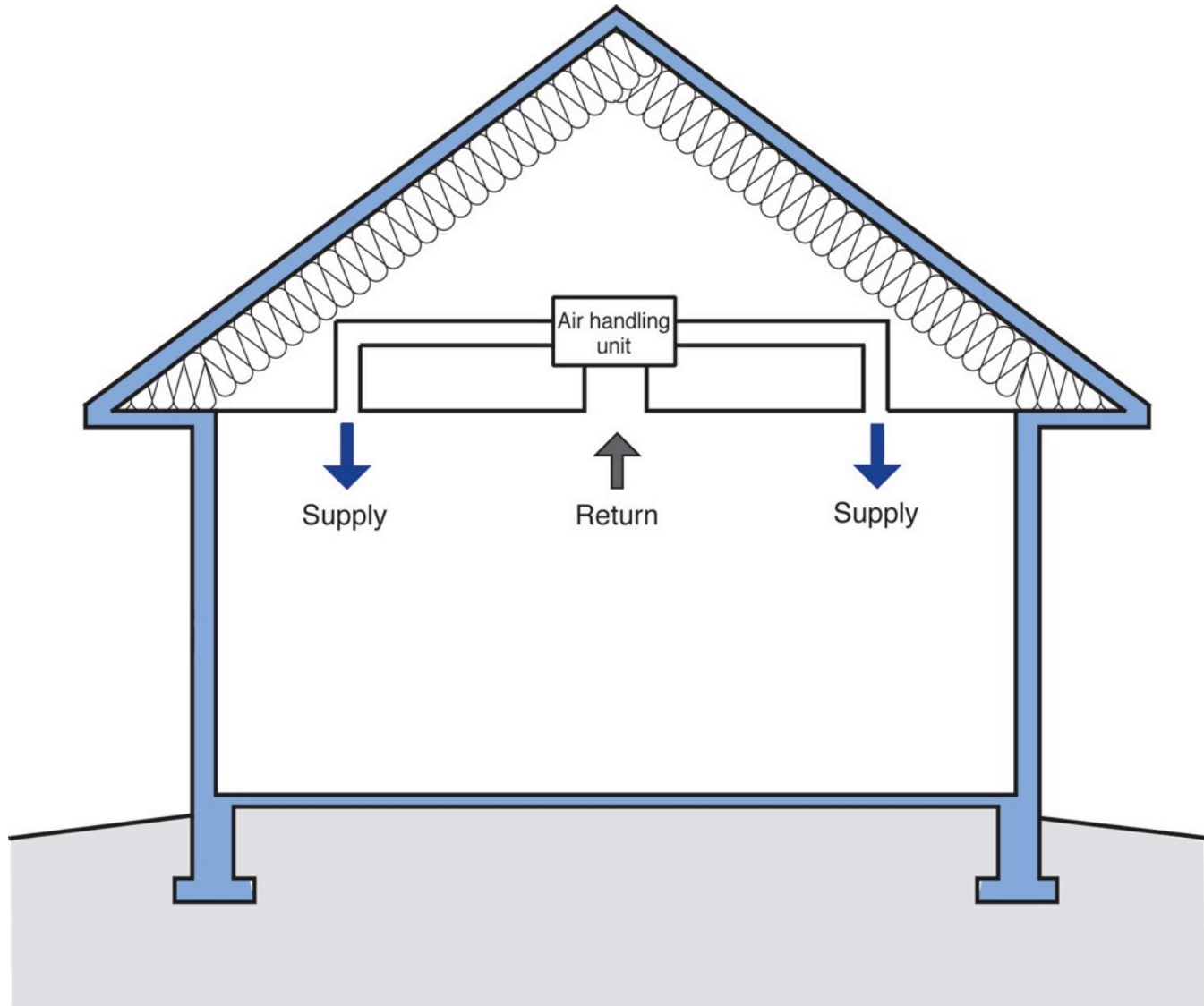


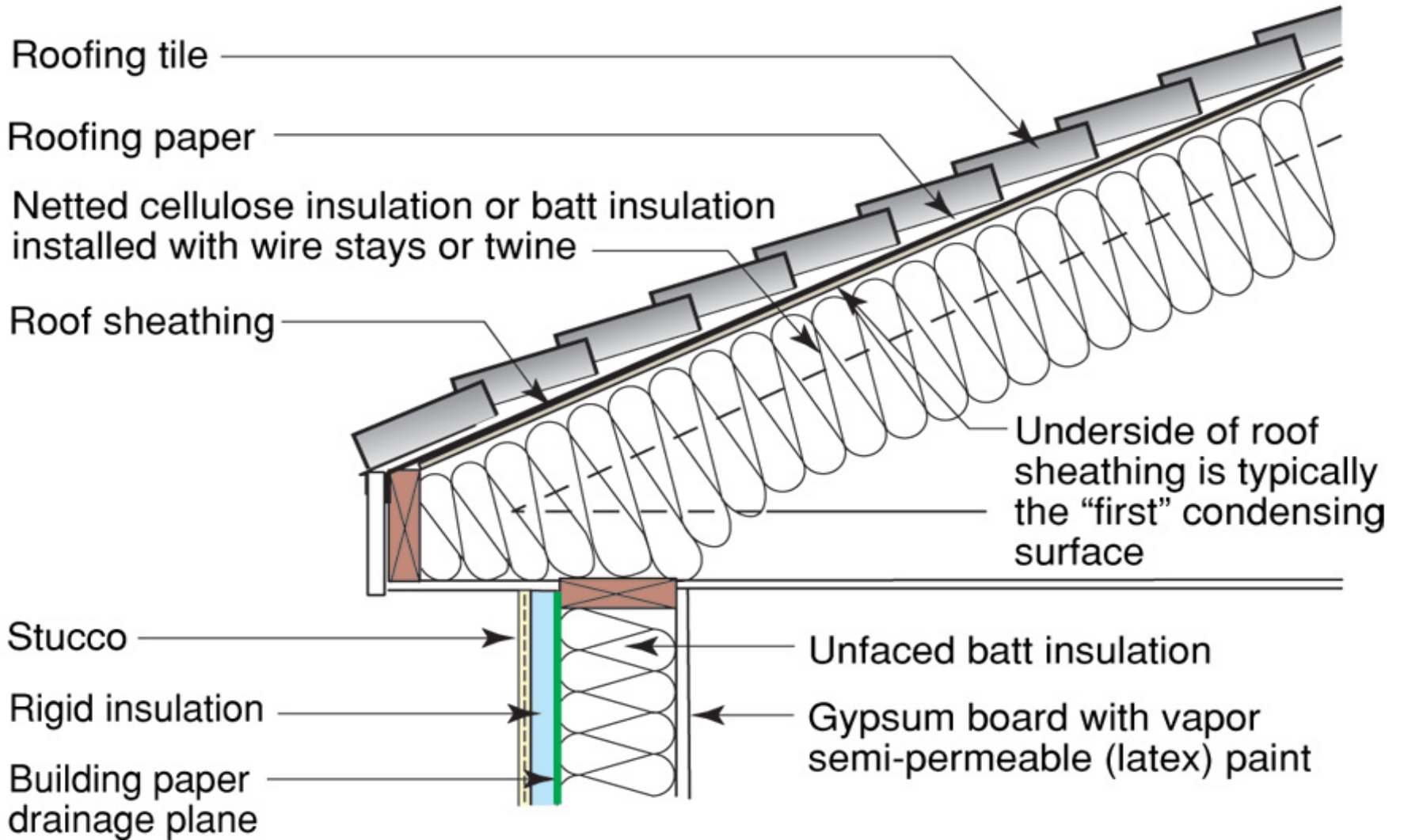






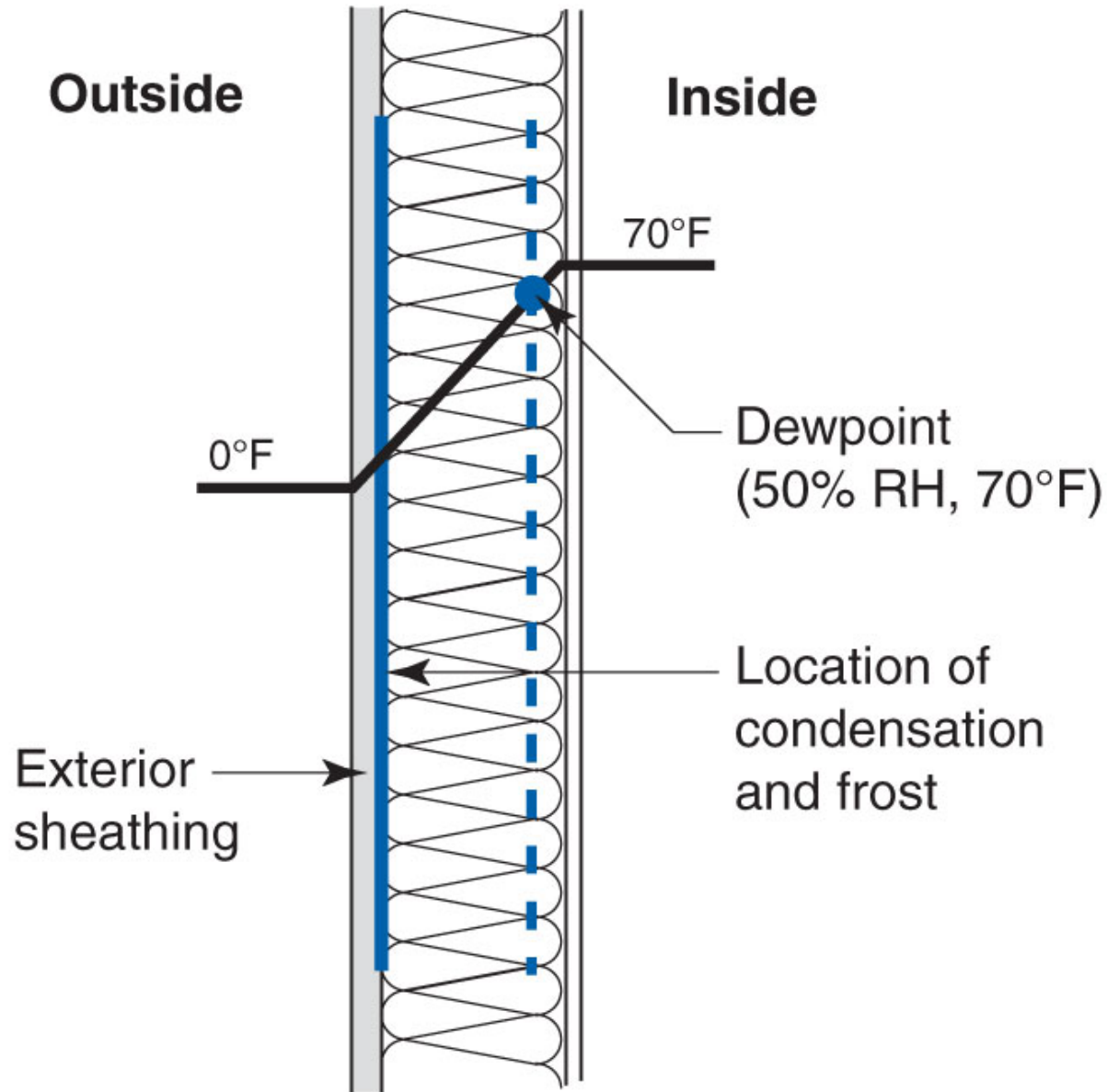




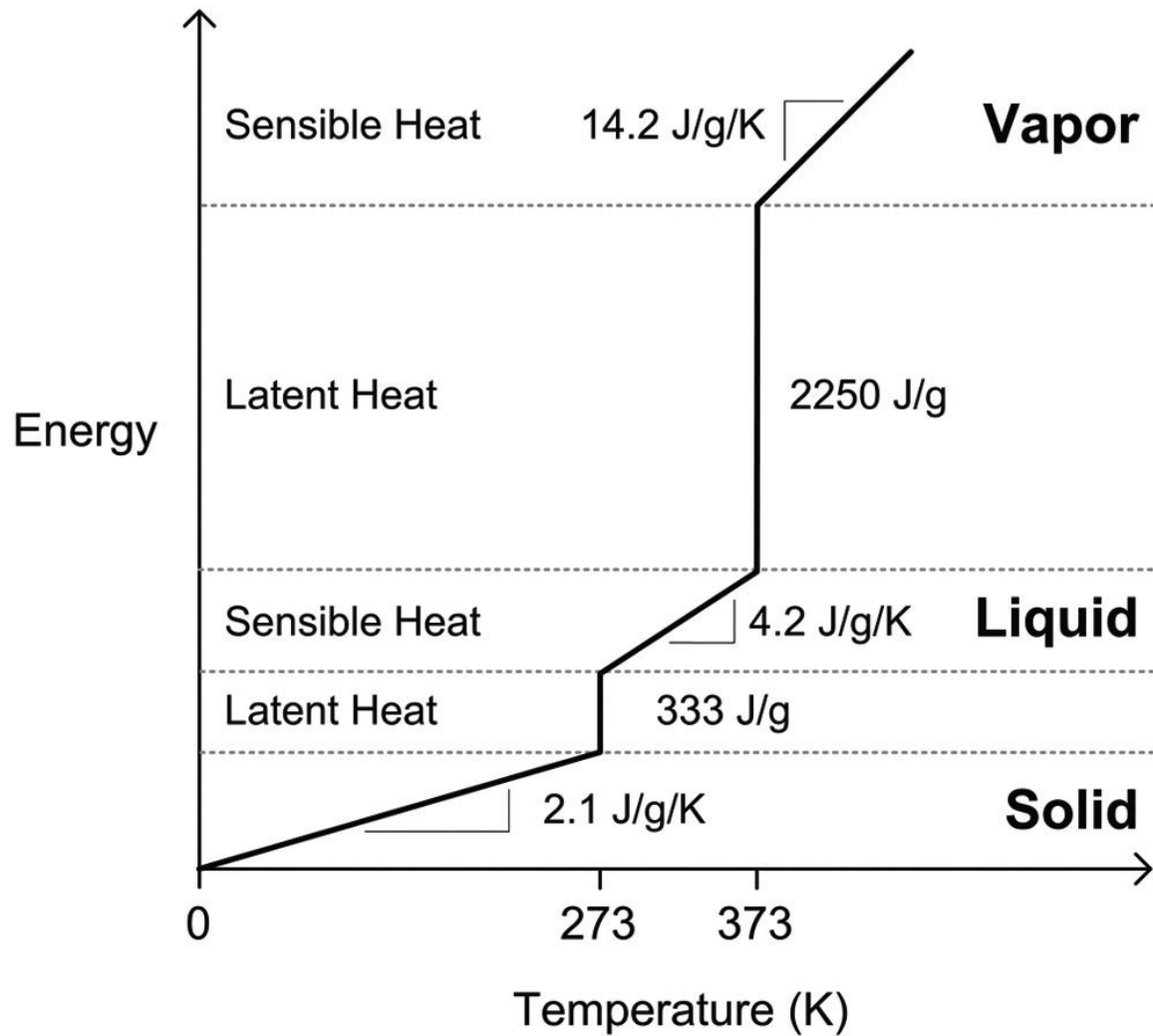










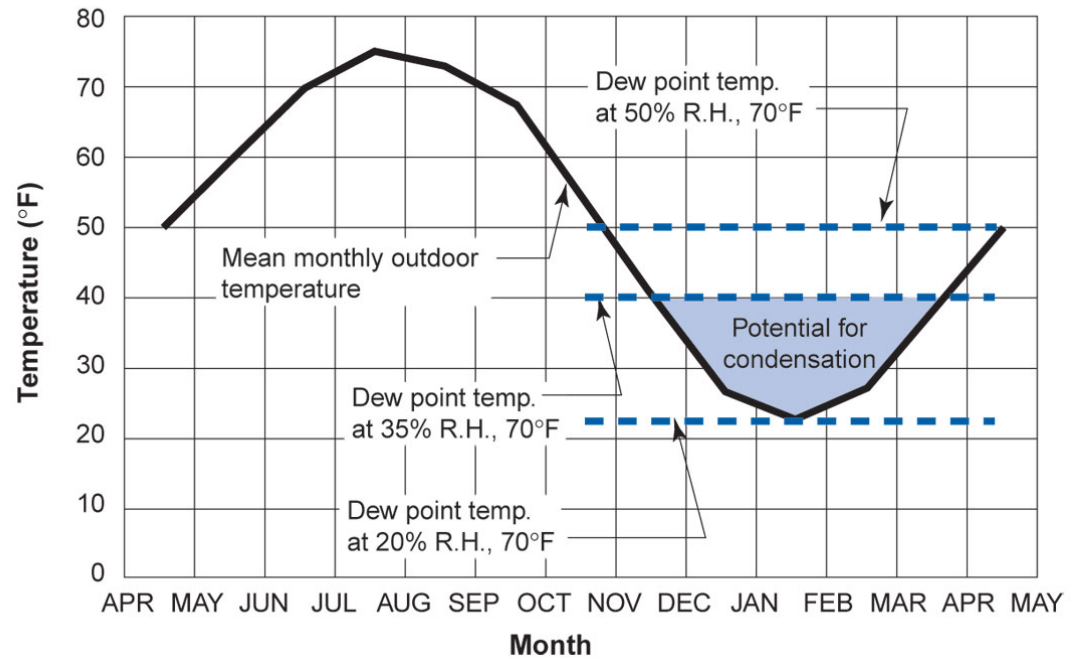
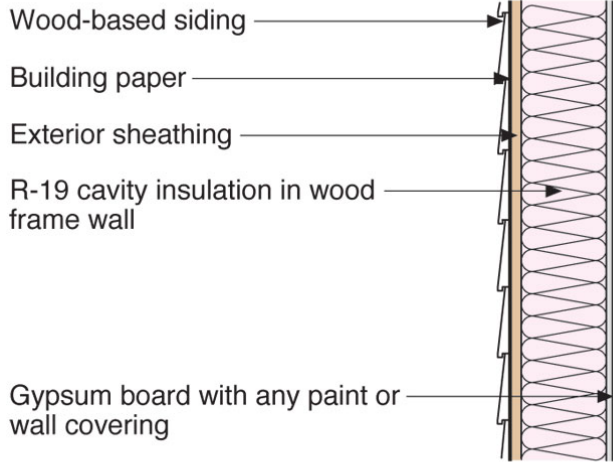


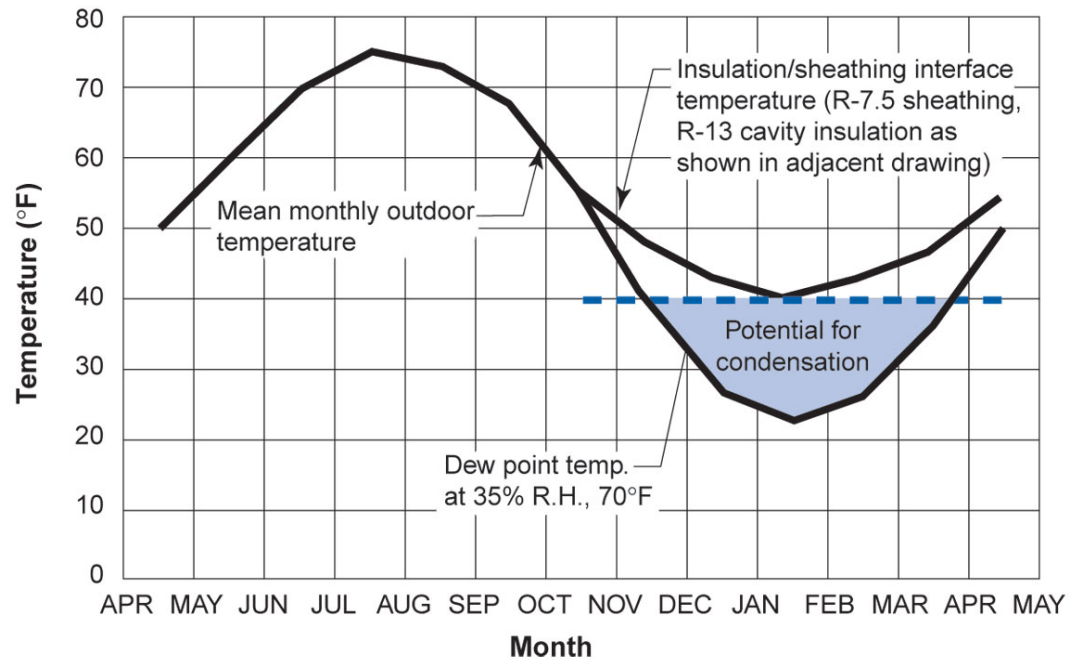
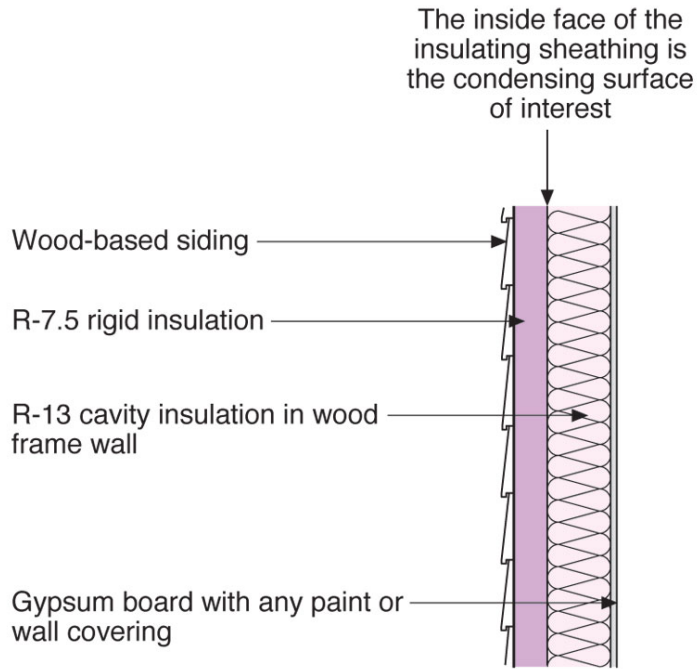
Simple linearized energy-temperature relation for water

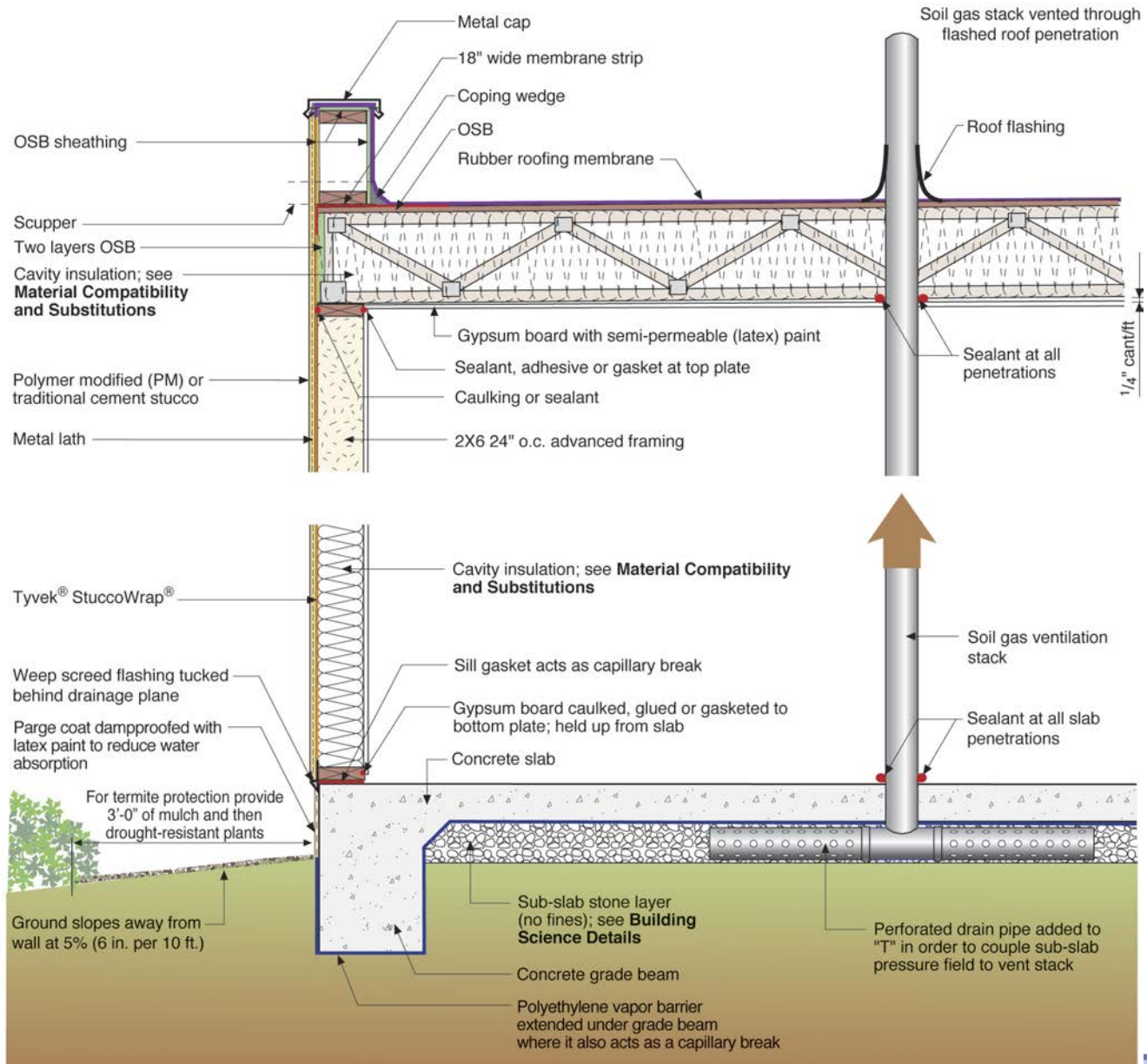
From Straube & Burnett, 2005

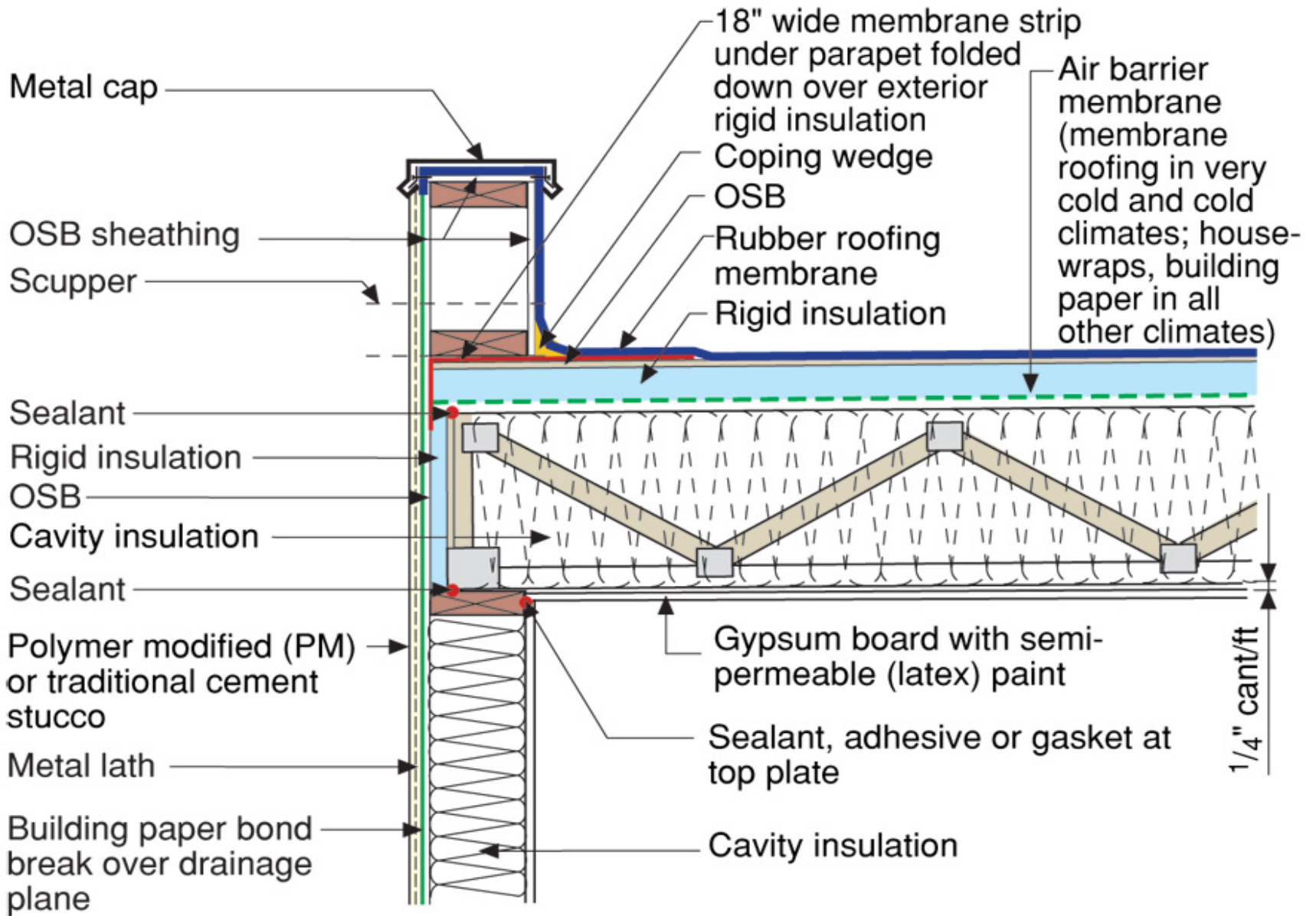


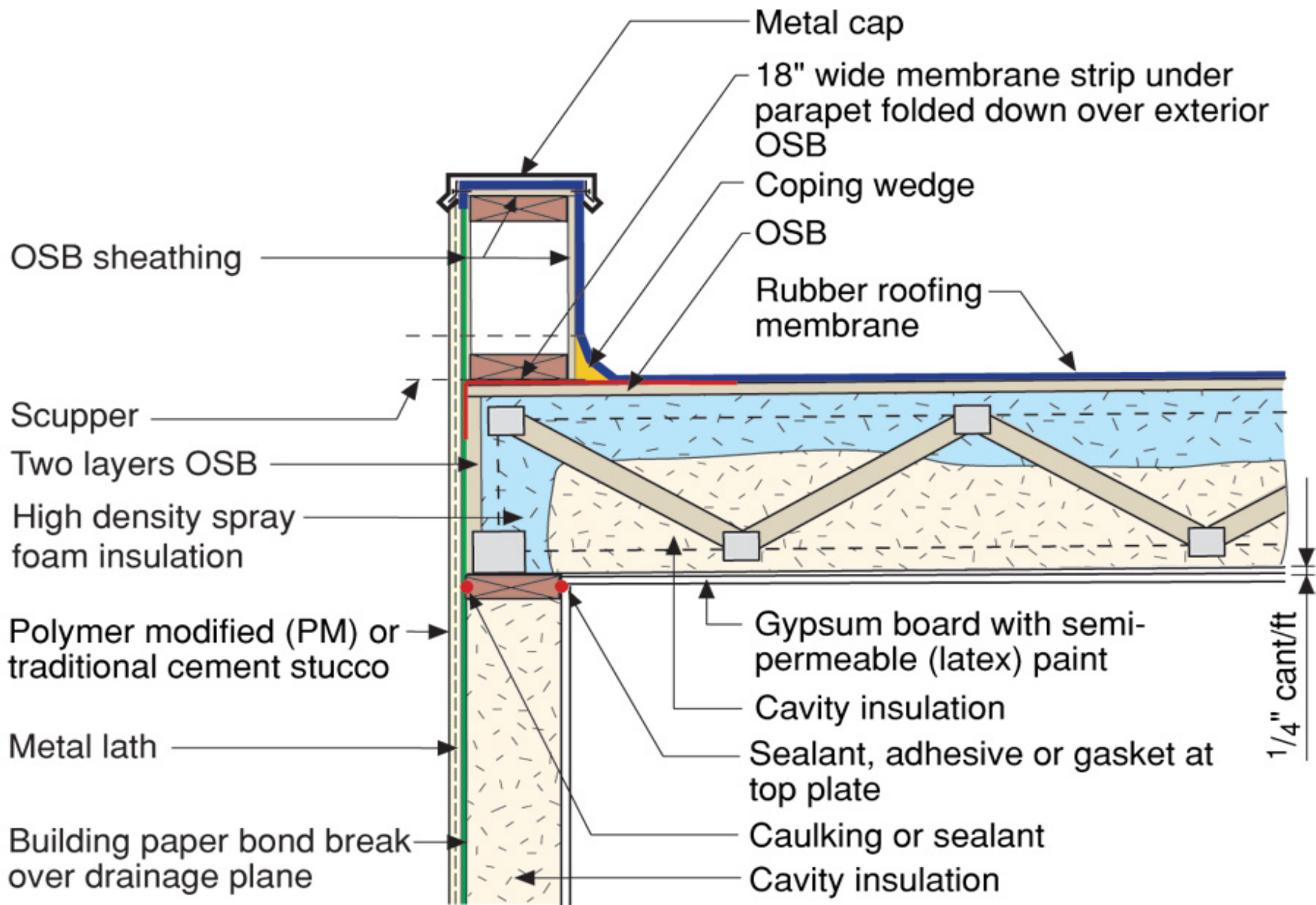
The inside face of the exterior sheathing is the condensing surface of interest

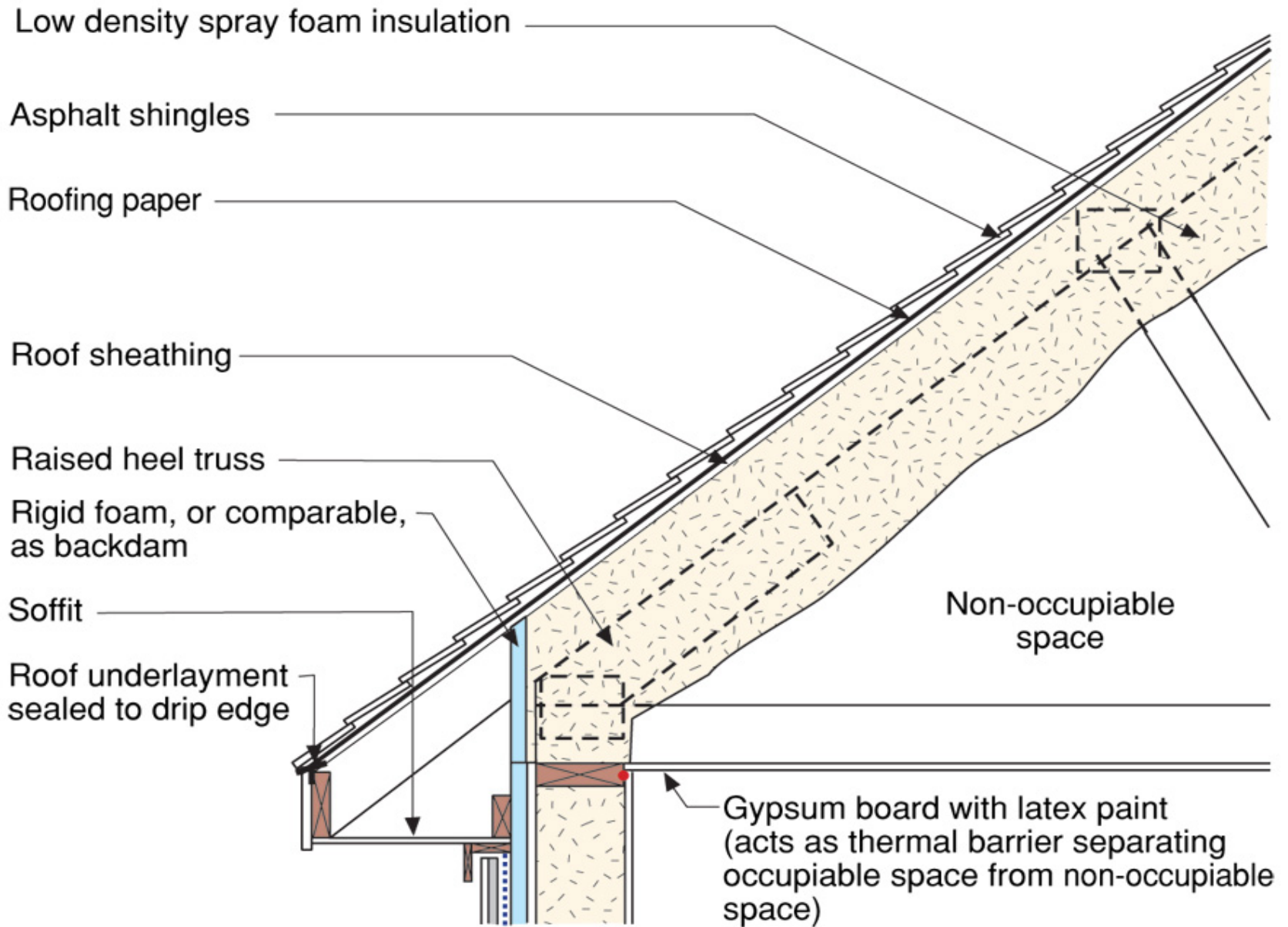








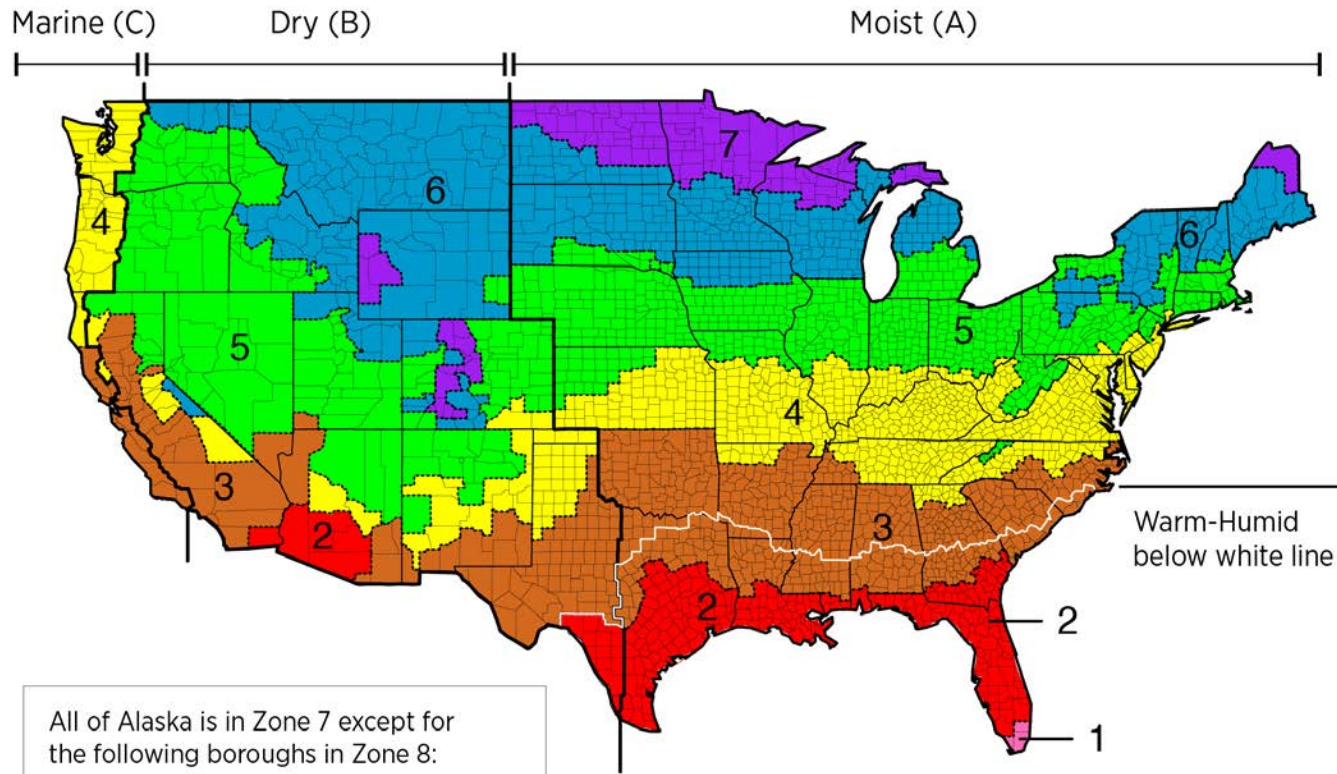












All of Alaska is in Zone 7 except for the following boroughs in Zone 8:
 Bethel, Northwest Arctic, Dellingham, Southeast Fairbanks, Fairbanks N. Star, Wade Hampton, Nome, Yukon-Koyukuk, North Slope

Zone 1 includes Hawaii, Guam, Puerto Rico, and the Virgin Islands

Insulation for Condensation Control*

Climate Zone	Rigid Board or Air Impermeable Insulation	Code Required R-Value	Ratio of Rigid Board Insulation or Air Impermeable R-Value to Total Insulation R-Value
1,2,3	R-5	R-38	10%
4C	R-10	R-49	20%
4A, 4B	R-15	R-49	30%
5	R-20	R-49	40%
6	R-25	R-49	50%
7	R-30	R-49	60%
8	R-35	R-49	70%

*Adapted from Table R 806.5 2015 International Residential Code

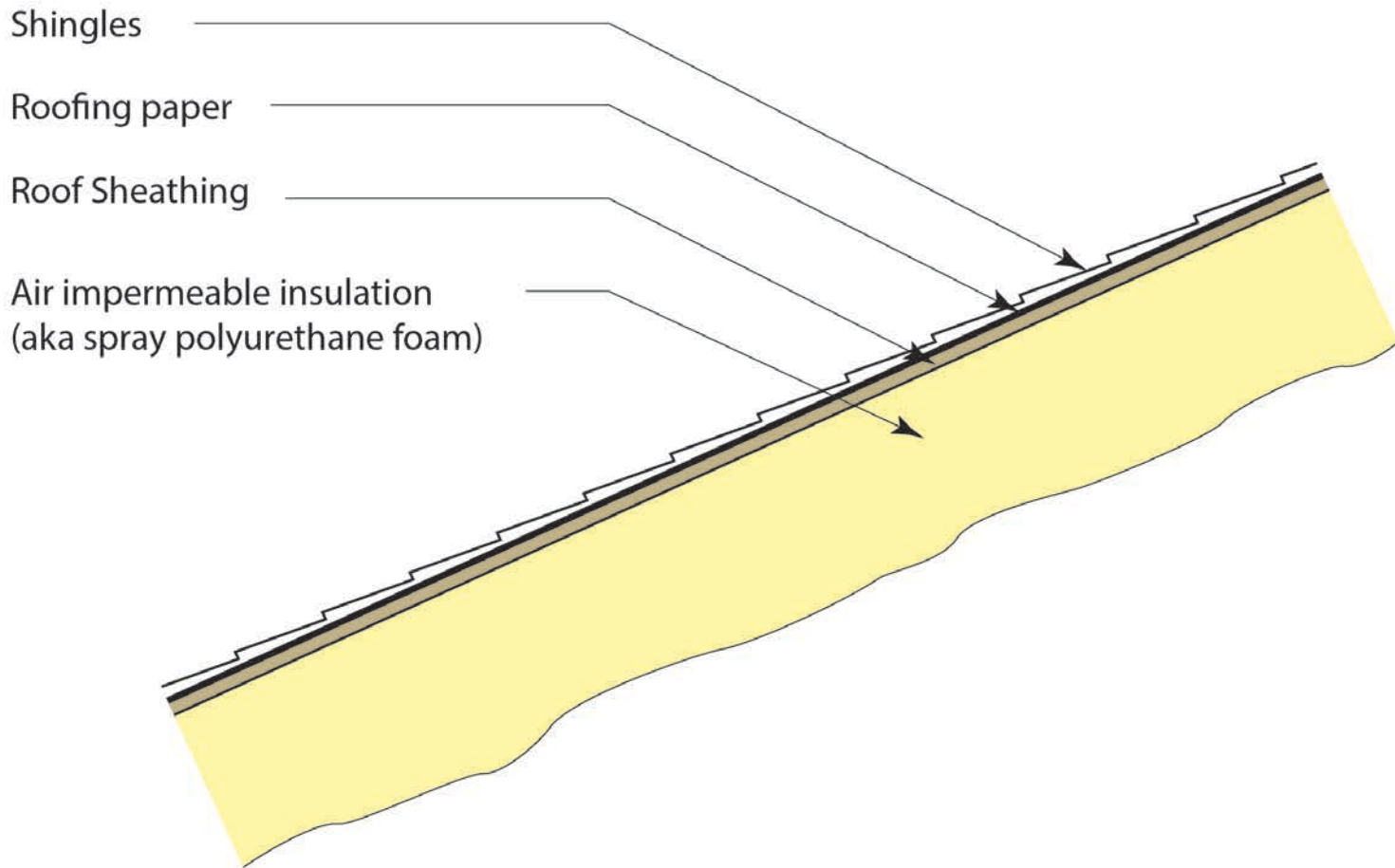
Table 1

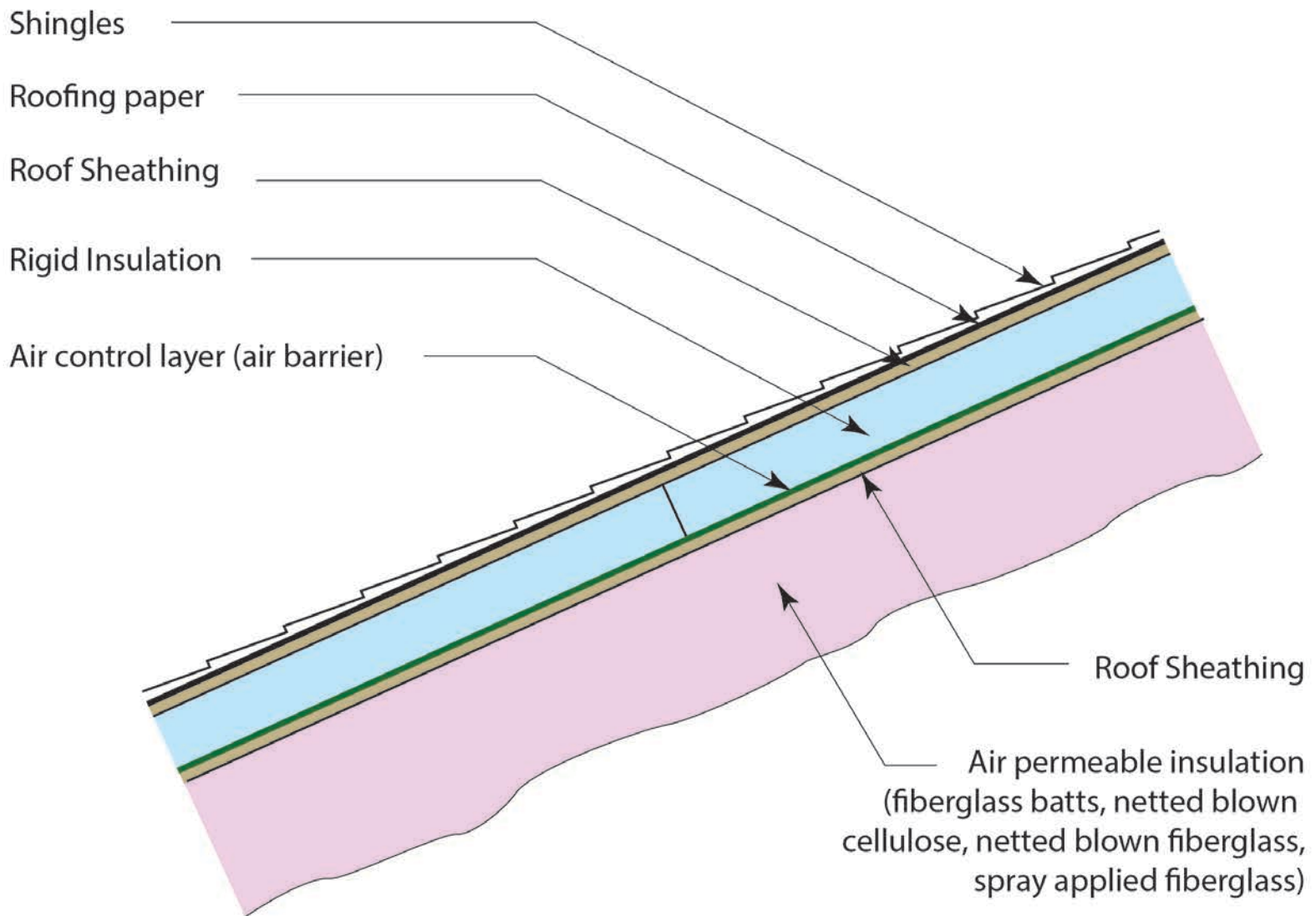
Insulation for Condensation Control*

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

Table 2



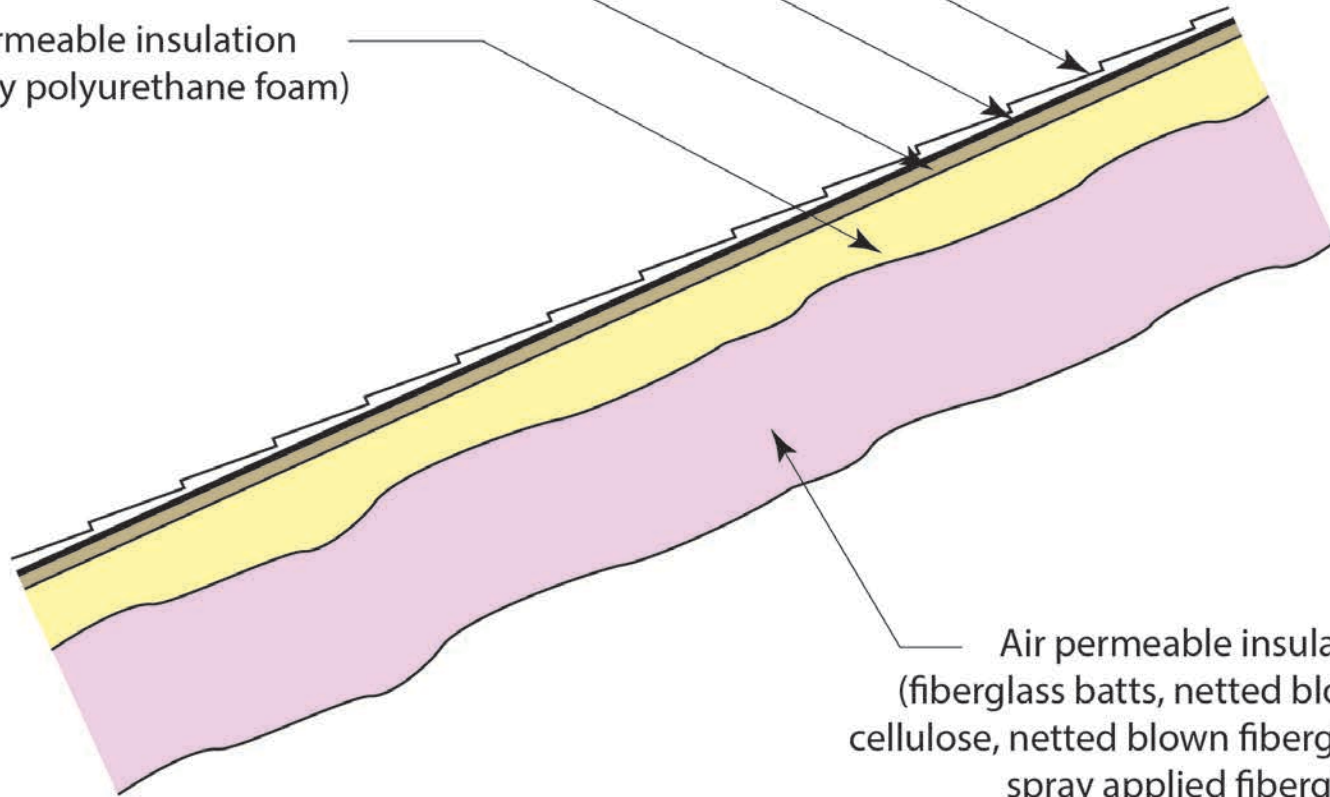


Shingles

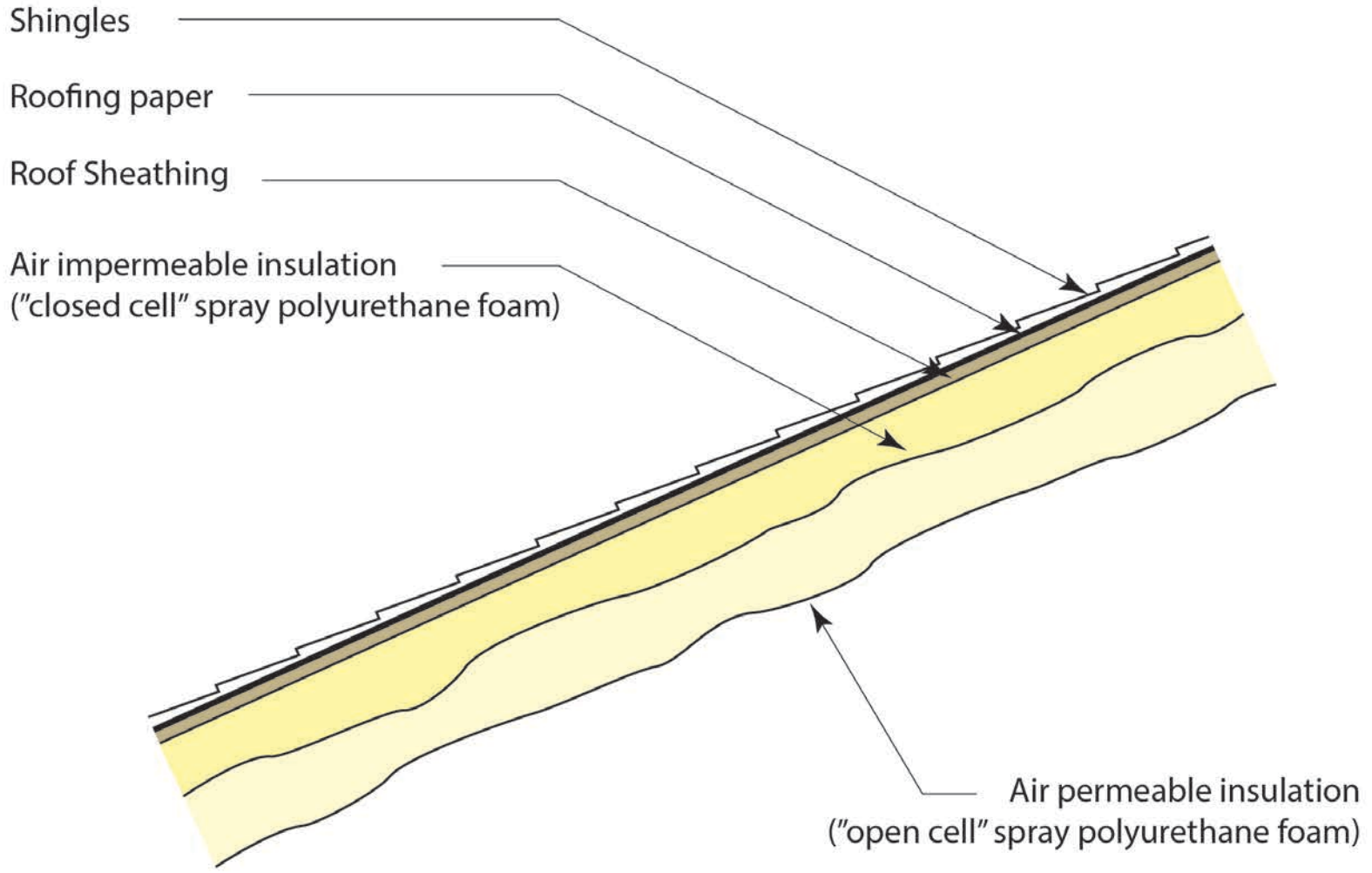
Roofing paper

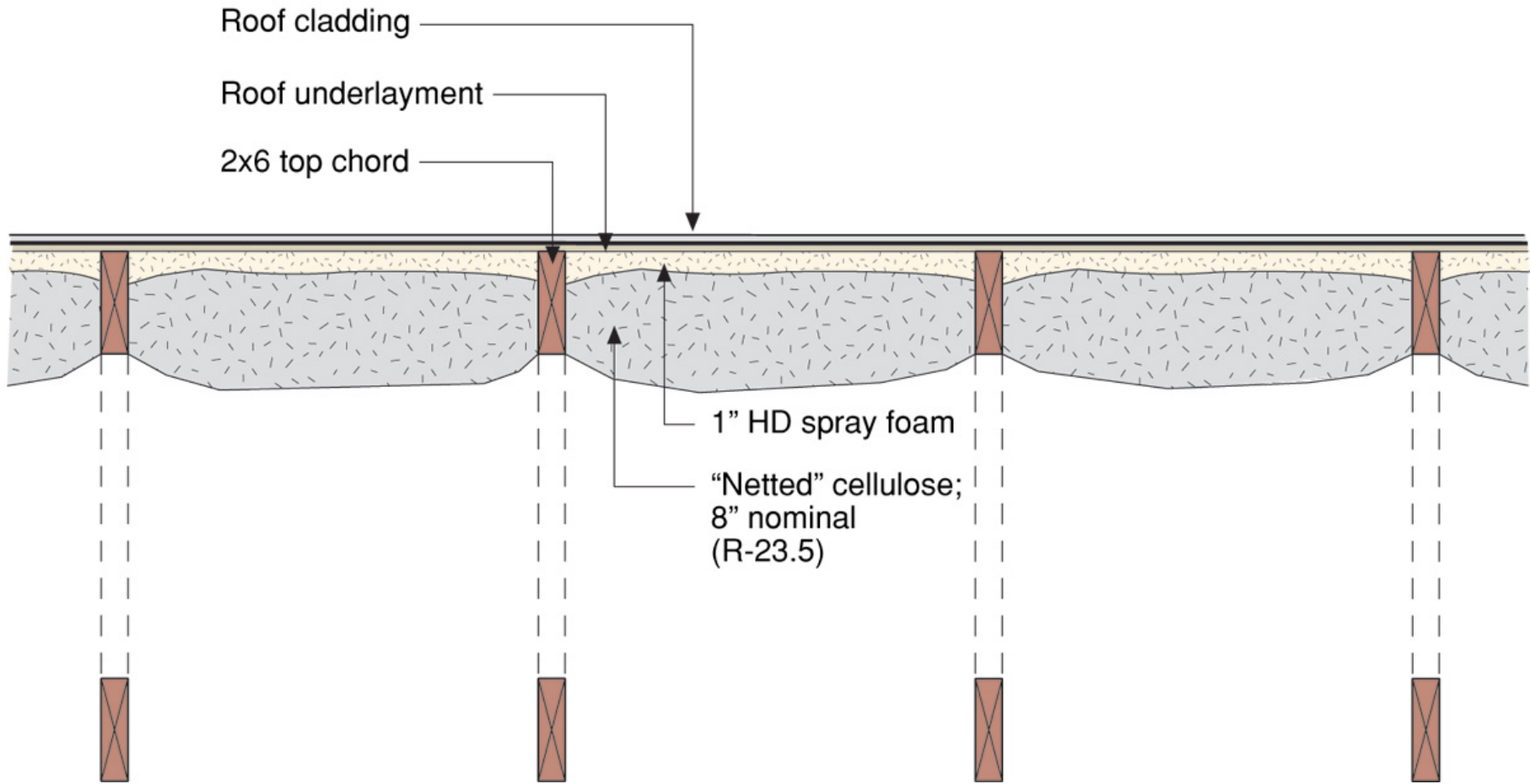
Roof Sheathing

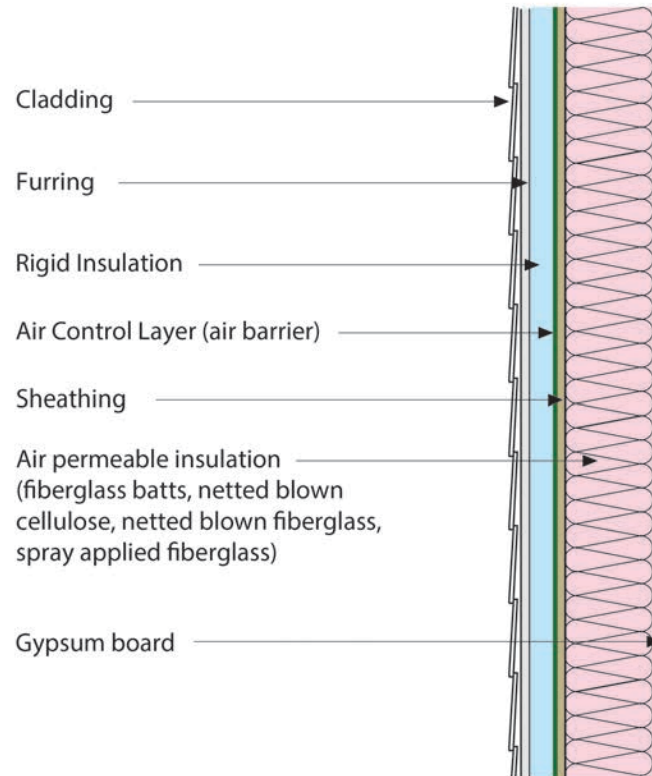
Air impermeable insulation
(aka spray polyurethane foam)

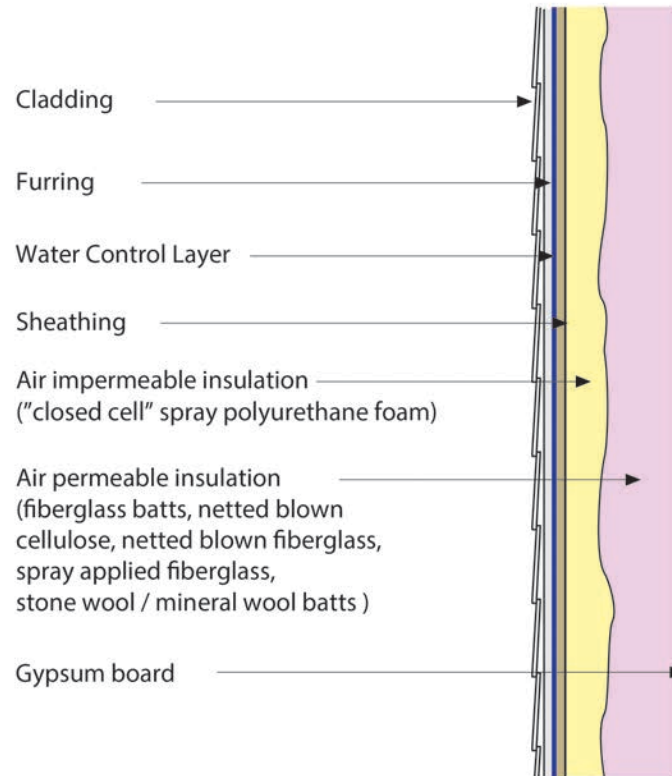


Air permeable insulation
(fiberglass batts, netted blown
cellulose, netted blown fiberglass,
spray applied fiberglass)

















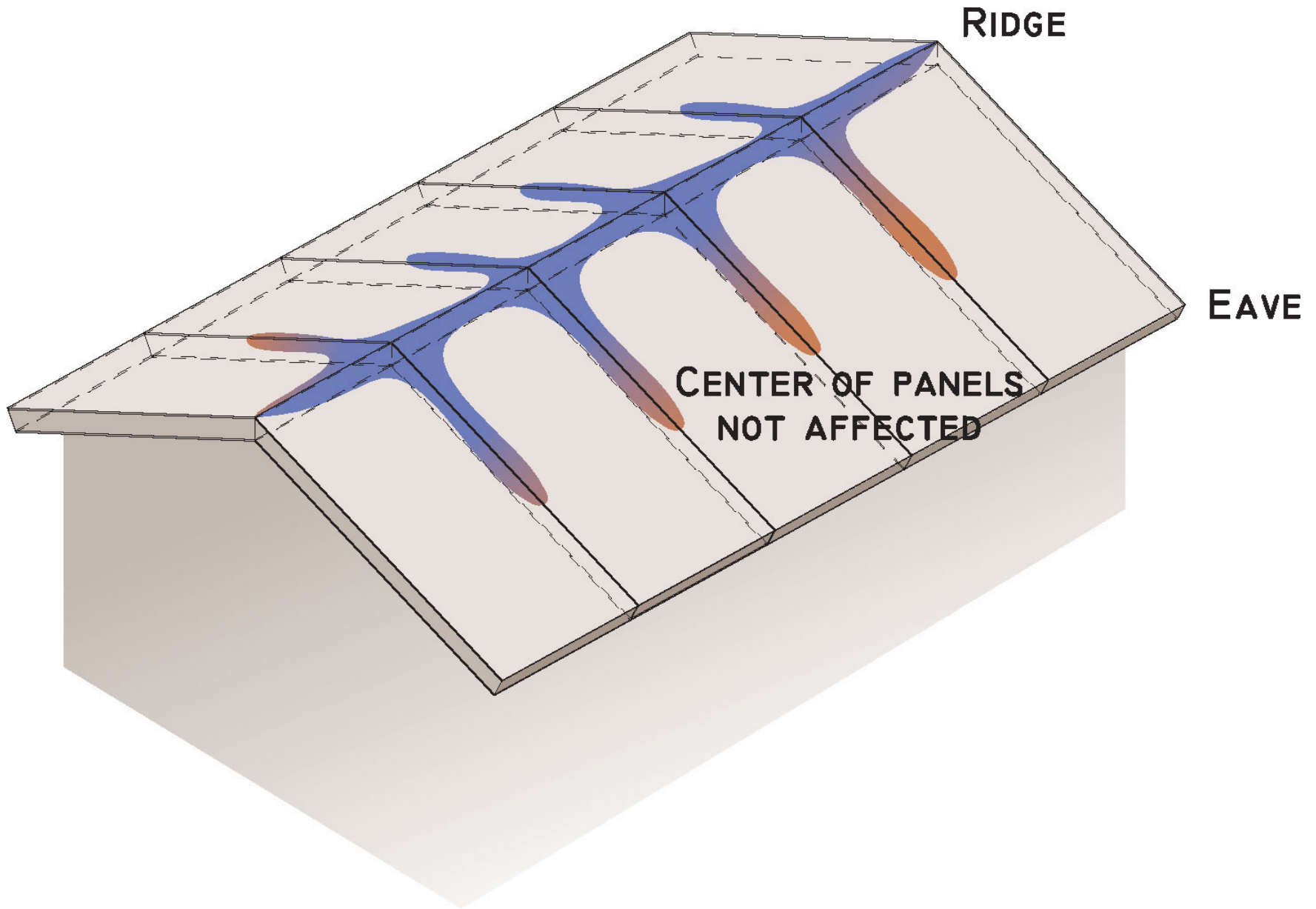
























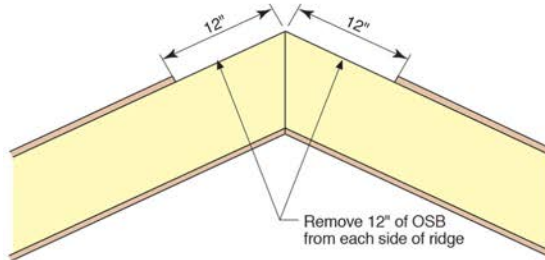






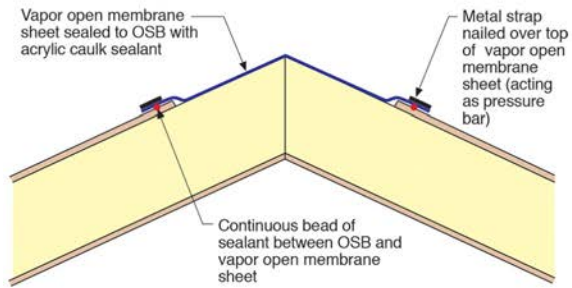
Step 1

- Remove strip of OSB from each side of ridge



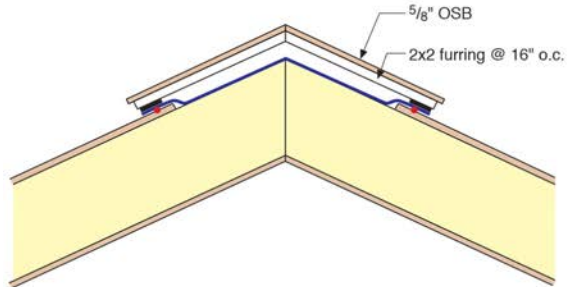
Step 2

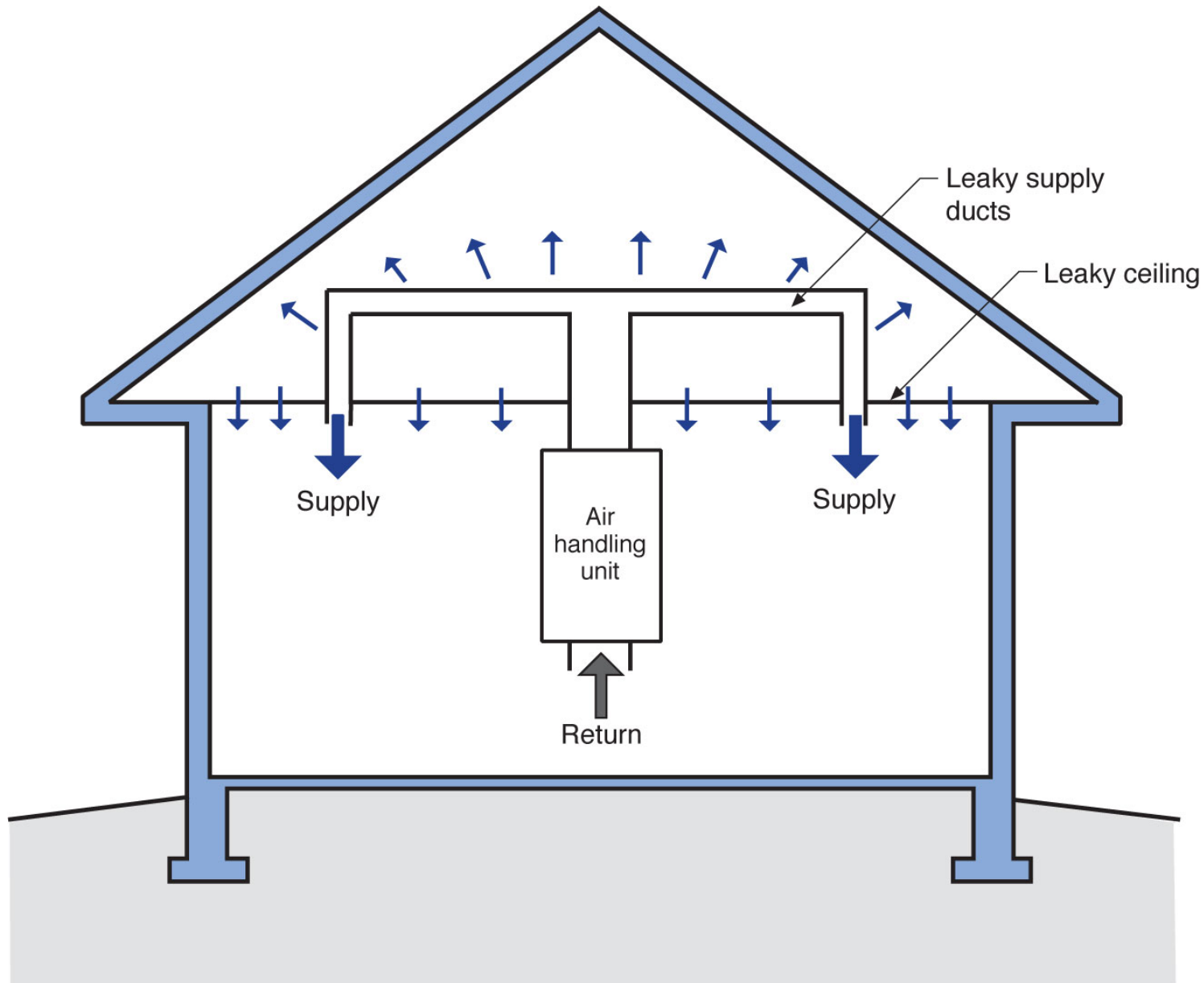
- Create air seal with strip of vapor open membrane (tape seams)
- Vapor open membrane sheet sealed to OSB with acrylic caulk sealant
- Hold vapor open membrane sheet in place with metal strapping



Step 3

- Construct wood ridge vent with 2x2 furring





Hygric Buoyancy

Periodic Table

Group →	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
Period ↓	1																		2
	1 H												5 B	6 C	7 N	8 O	9 F		10 Ne
	2 3 Li	4 Be											13 Al	14 Si	15 P	16 S	17 Cl		18 Ar
	3 11 Na	12 Mg										30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br		36 Kr
	4 19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br		36 Kr
	5 37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I		54 Xe
	6 55 Cs	56 Ba	57 La *	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At		86 Rn
	7 87 Fr	88 Ra	89 Ac *	104 Rf *	105 Db *	106 Sg *	107 Bh *	108 Hs *	109 Mt *	110 Ds *	111 Rg *	112 Cn *	113 Nh *	114 Fl *	115 Mc *	116 Lv *	117 Ts *		118 Og *
				* 58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu		
				* 90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr		

Nitrogen 14

Oxygen 16

Nitrogen	14	N2	28
Oxygen	16	O2	32
		H2O	18

Nitrogen	14	N ₂	28
Oxygen	16	O ₂	32
		H ₂ O	18
		Air	21% O ₂
			79% N ₂
Molecular Weight of Dry Air			29

Nitrogen 14 N2 28

Oxygen 16 O2 32

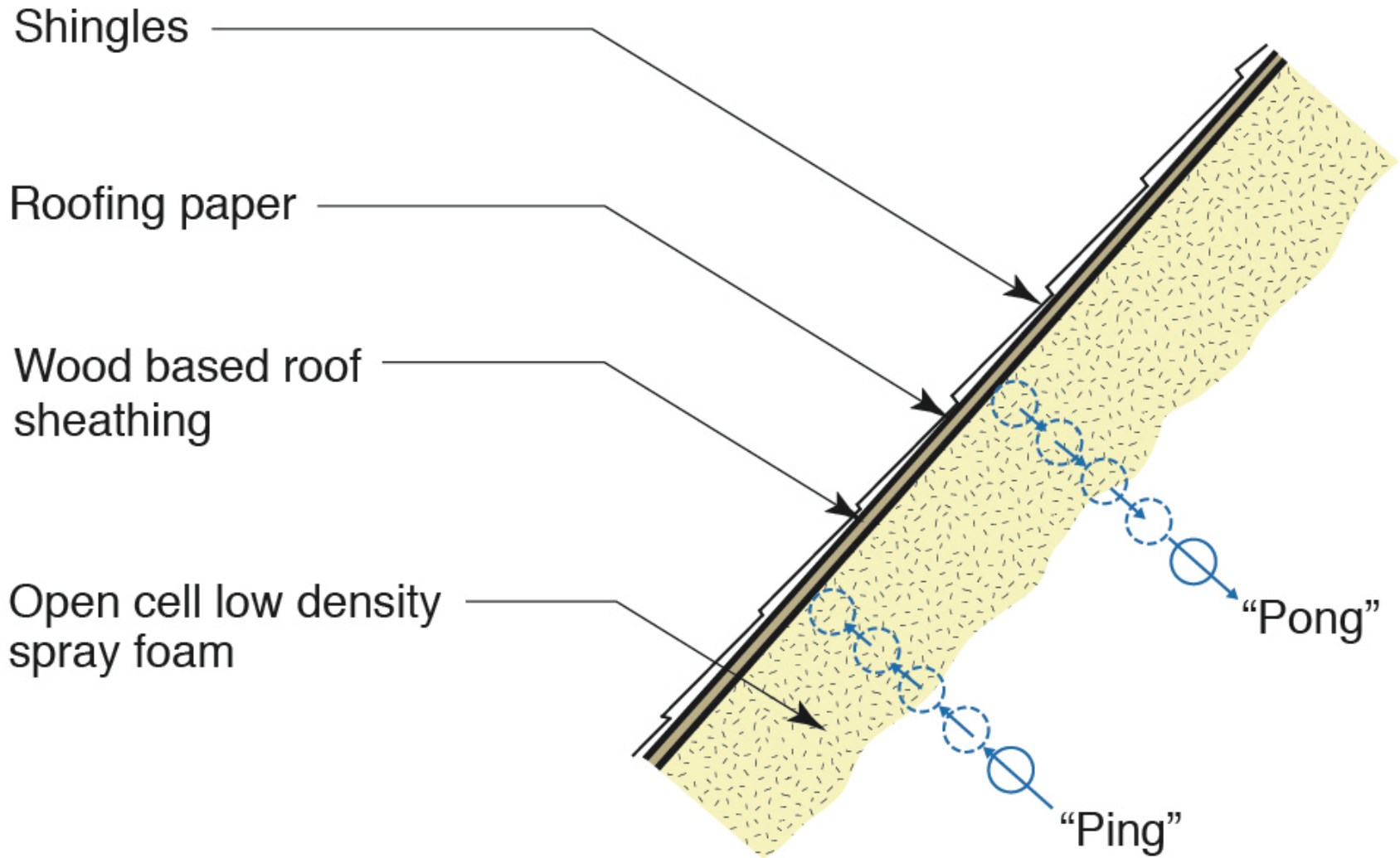
H2O 18

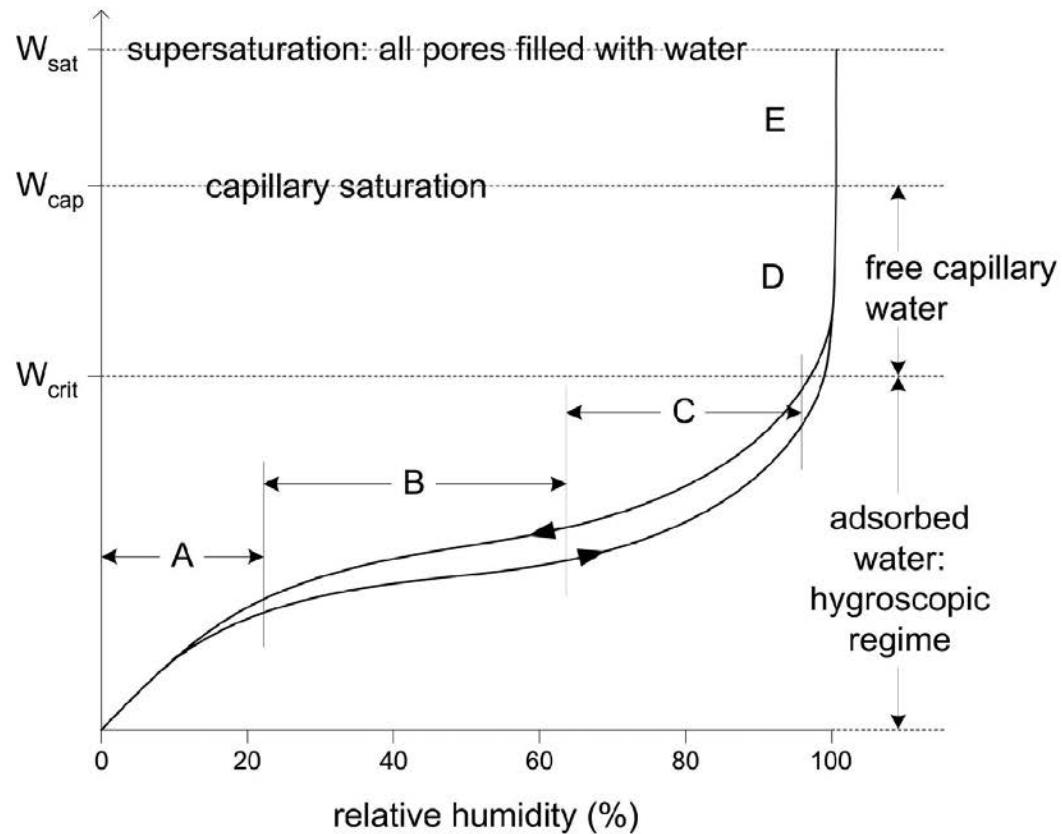
Air 21% O2

79% N2

Molecular Weight of Dry Air 29

Adding Water Vapor Lowers It.....





- A: Single-layer of adsorbed molecules
- B: Multiple layers of adsorbed molecules
- C: Interconnected layers (internal capillary condensation)
- D: Free water in Pores, capillary suction
- E: Supersaturated Regime

Regimes of moisture storage in a hygroscopic porous material

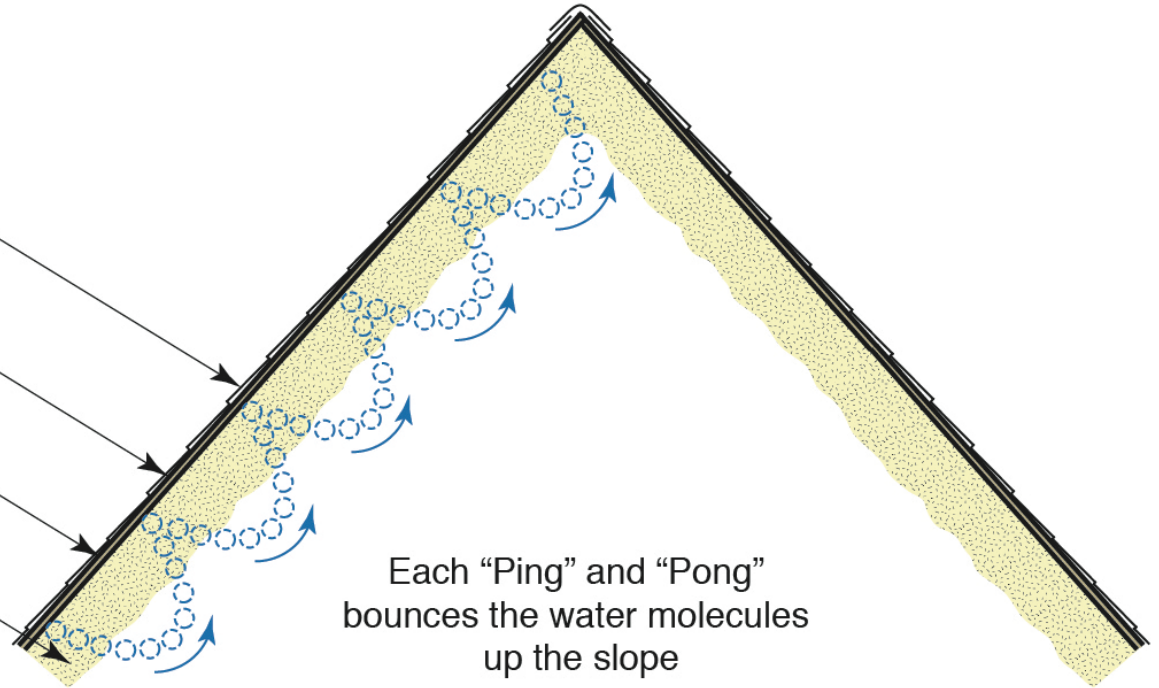
From Straube & Burnett, 2005

Shingles

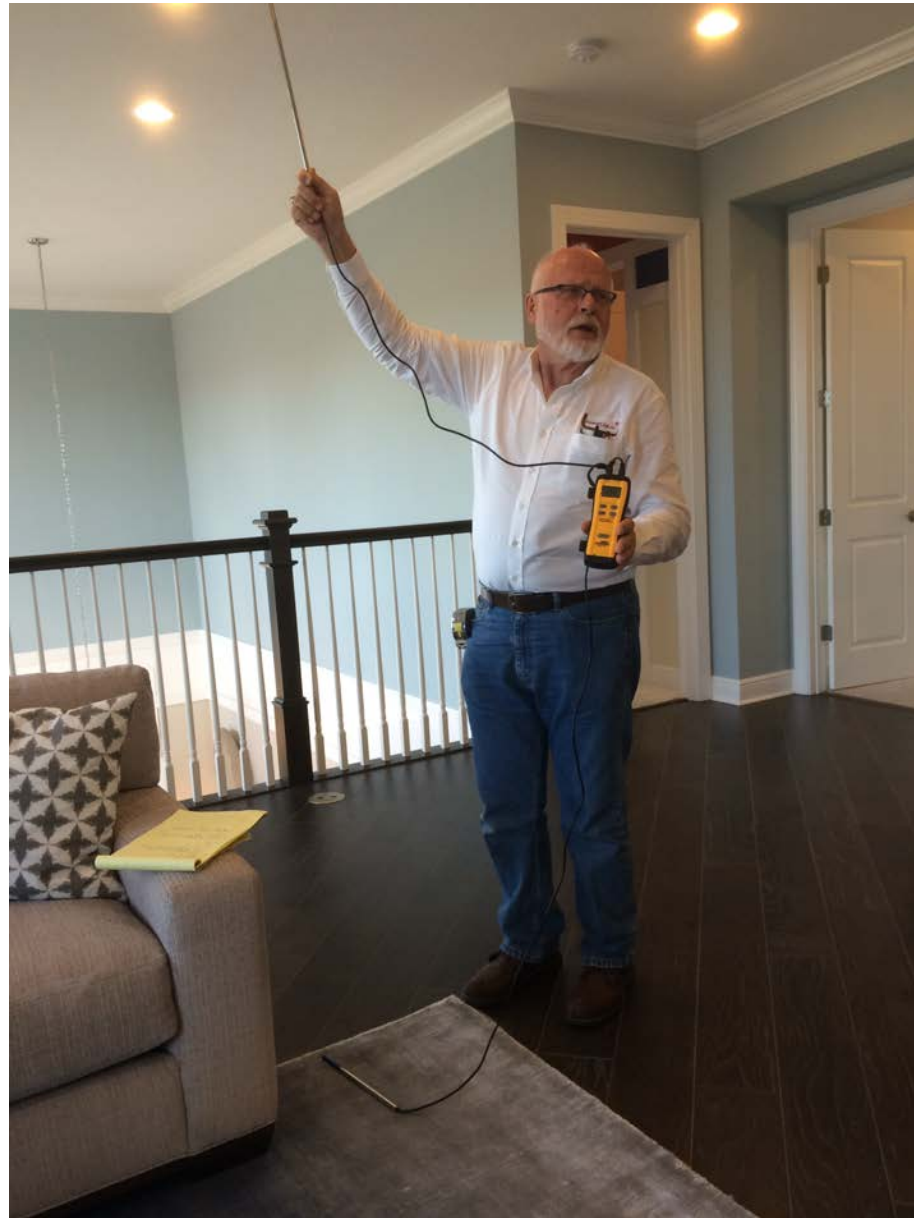
Roofing paper

Wood based roof sheathing

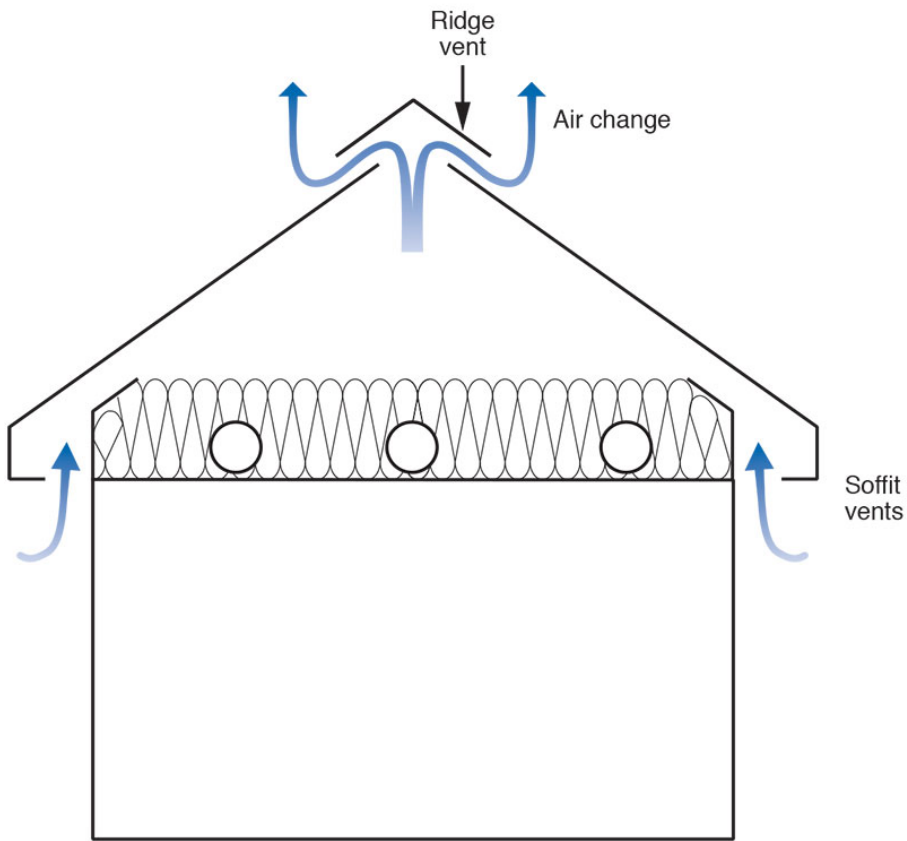
Open cell low density spray foam



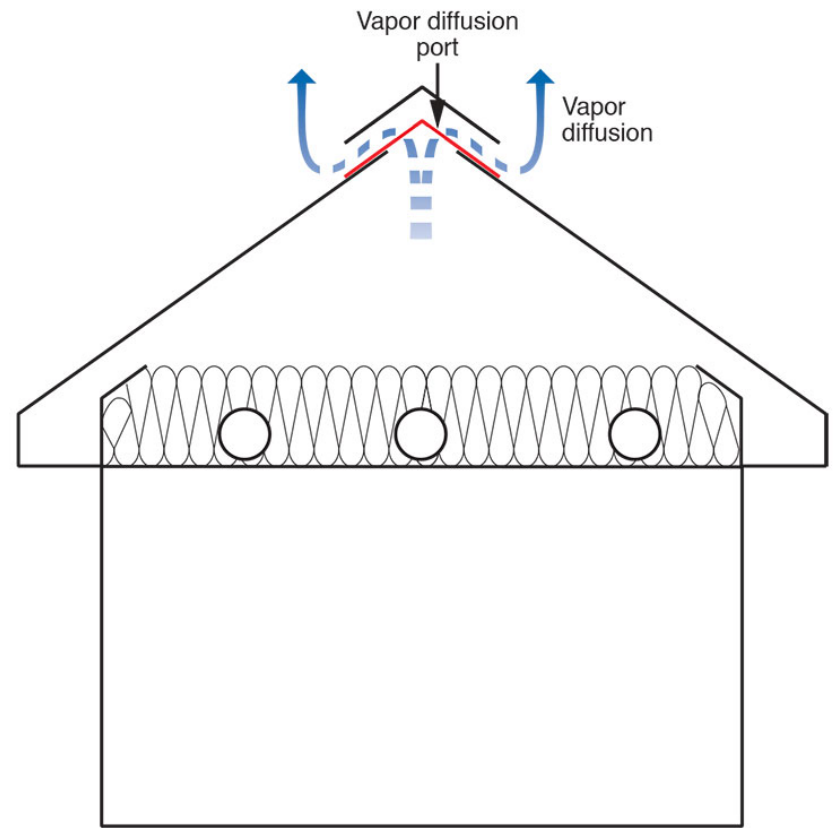
Each "Ping" and "Pong"
bounces the water molecules
up the slope







Classic vented attic



Unvented attic with vapor diffusion port



























