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

Building Science

There's No Such Thing As A Free Thermodynamic Lunch

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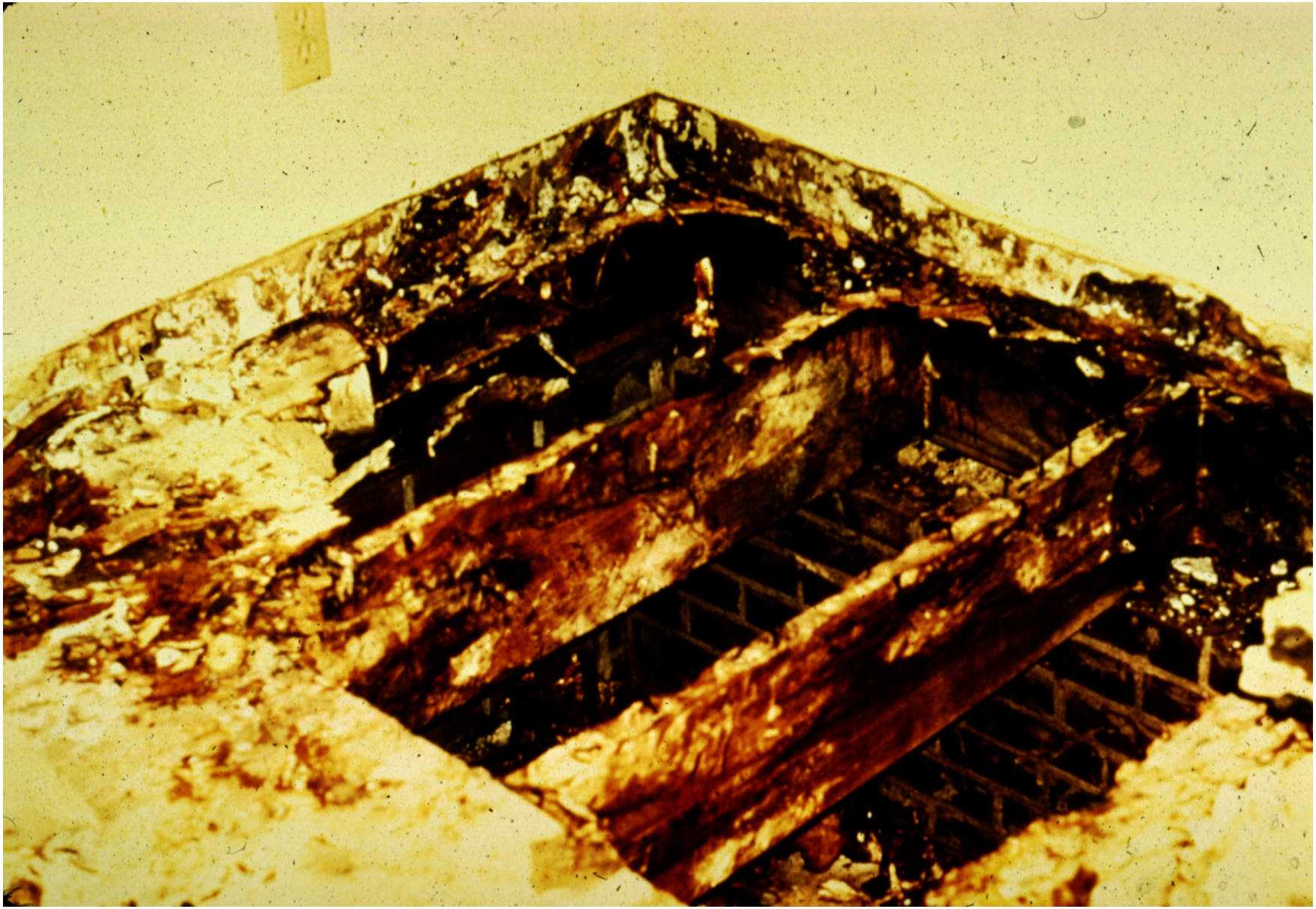
Energy Flow


015


11615


LP TECHSHIELD



Some Physics….

Arrhenius Equation

For Every 10 Degree K Rise
Reaction Rate Doubles

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

Damage Functions

Water

Heat

Ultra-violet Radiation

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

Moisture Flow Is From Warm To Cold

Moisture Flow Is From More To Less

Moisture Flow Is From Warm To Cold

Moisture Flow Is From More To Less

Thermal Gradient – Thermal Diffusion

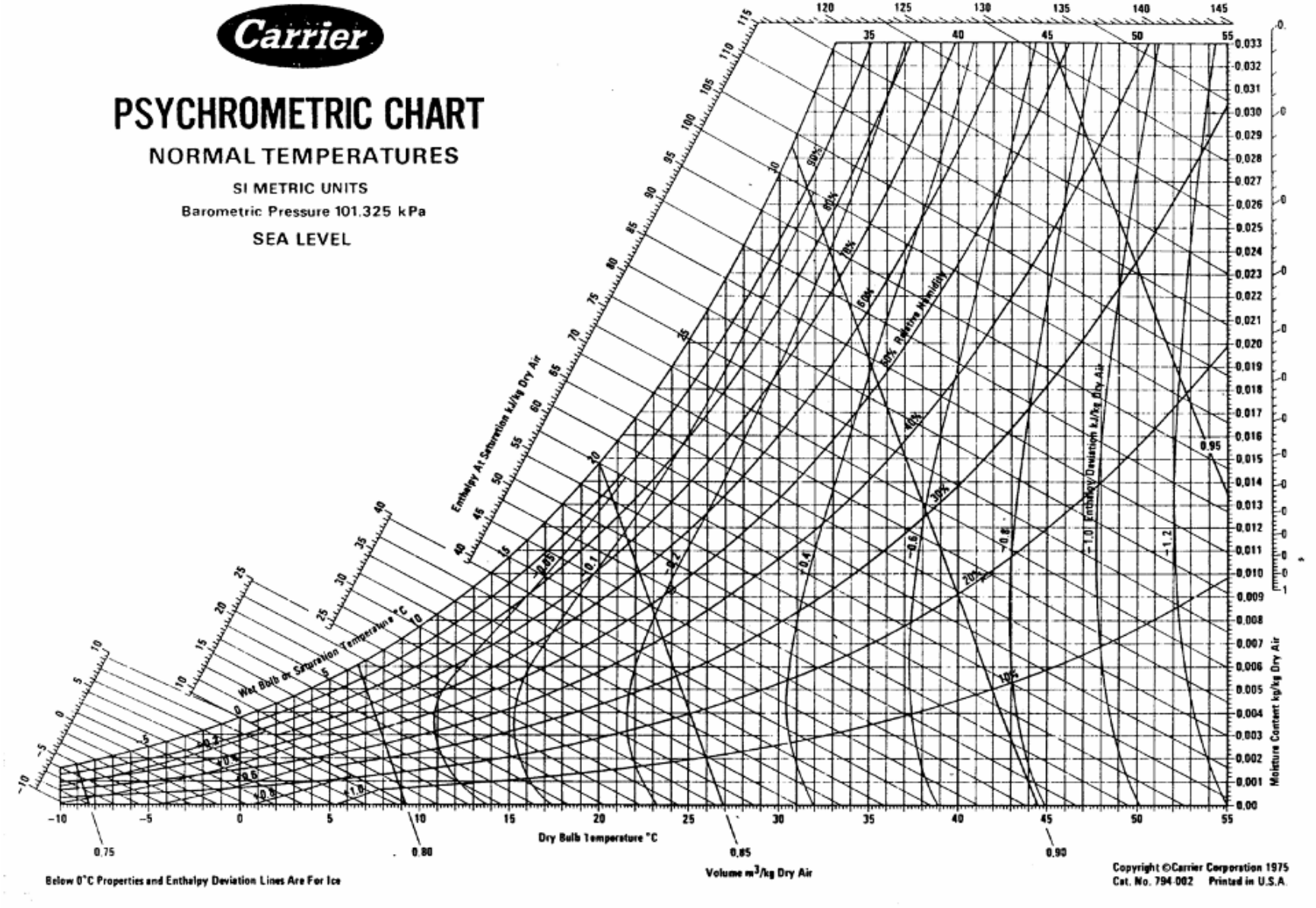
Concentration Gradient – Molecular Diffusion

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


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
50% Relative Humidity
Below 0°C Properties and Enthalpy Deviation Lines Are For Ice
Volume m³/kg Dry Air
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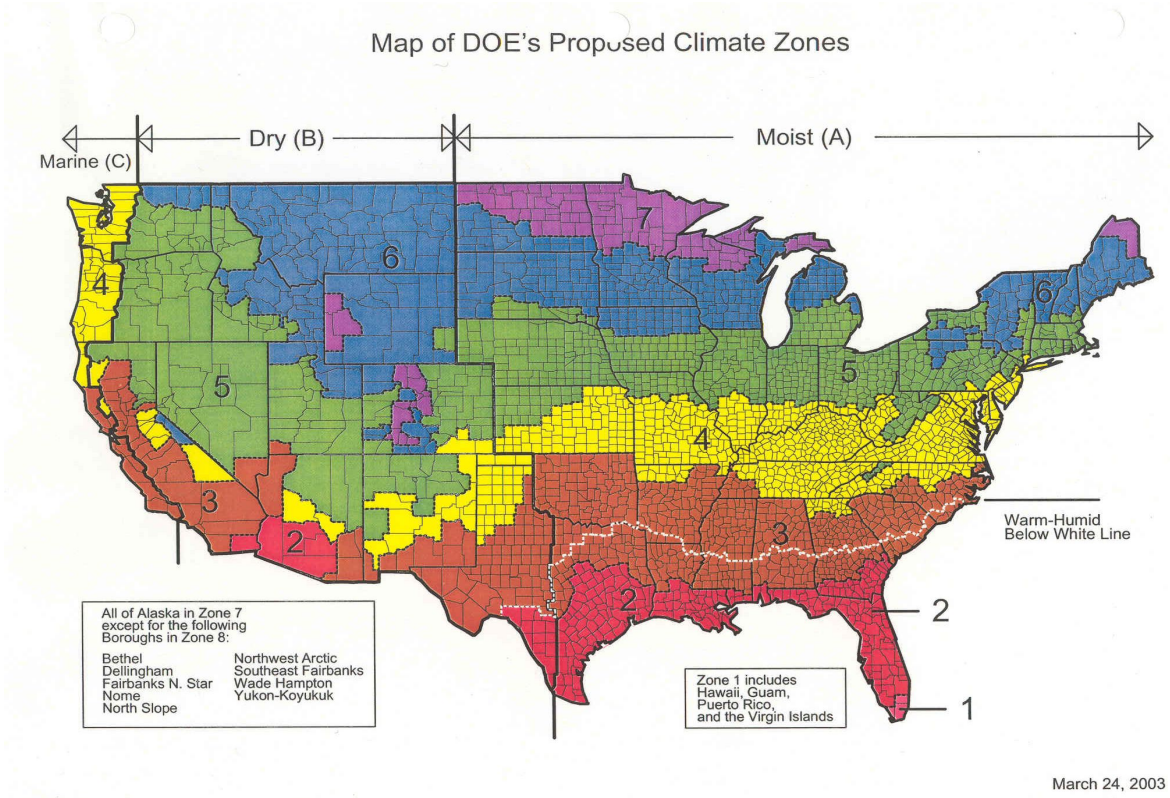
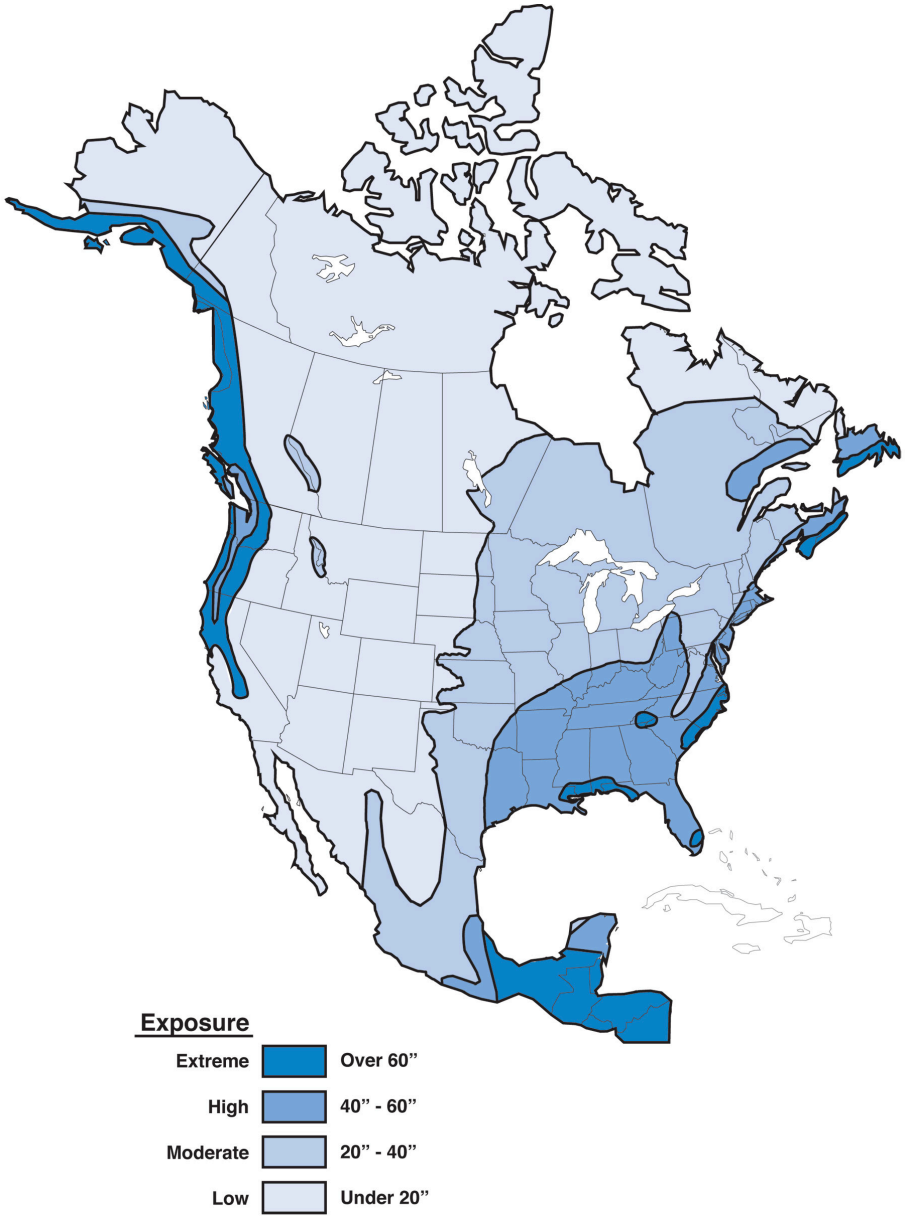
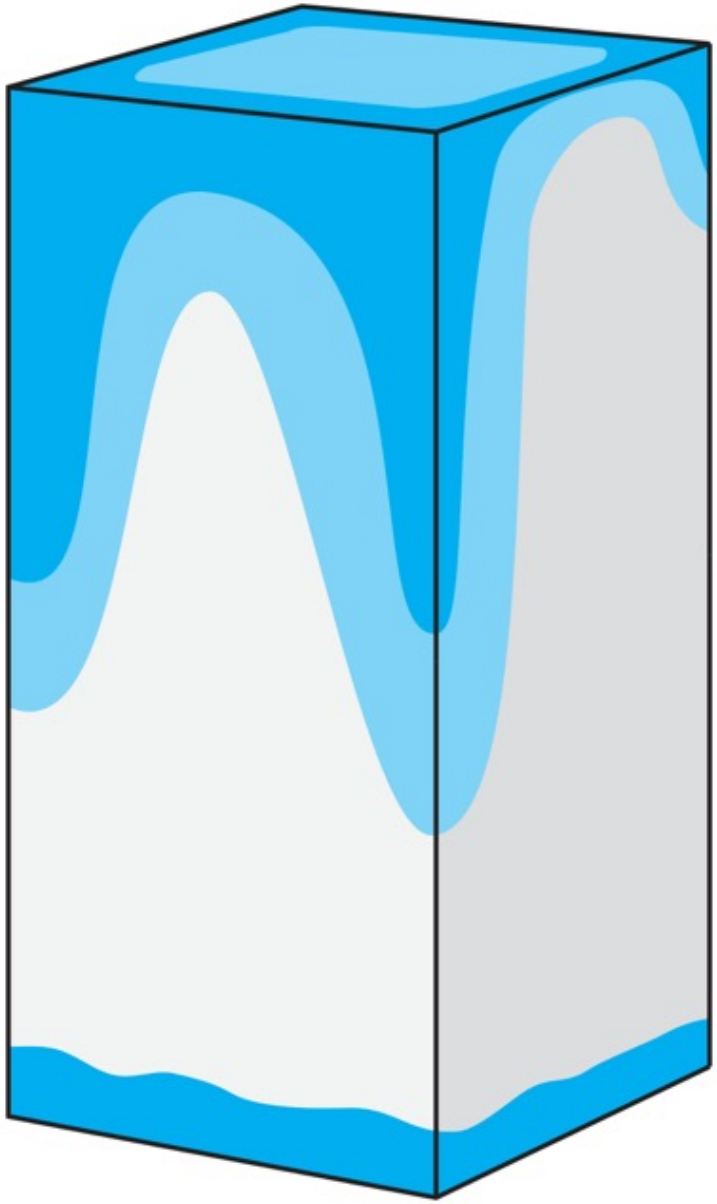
The Effect of Climate

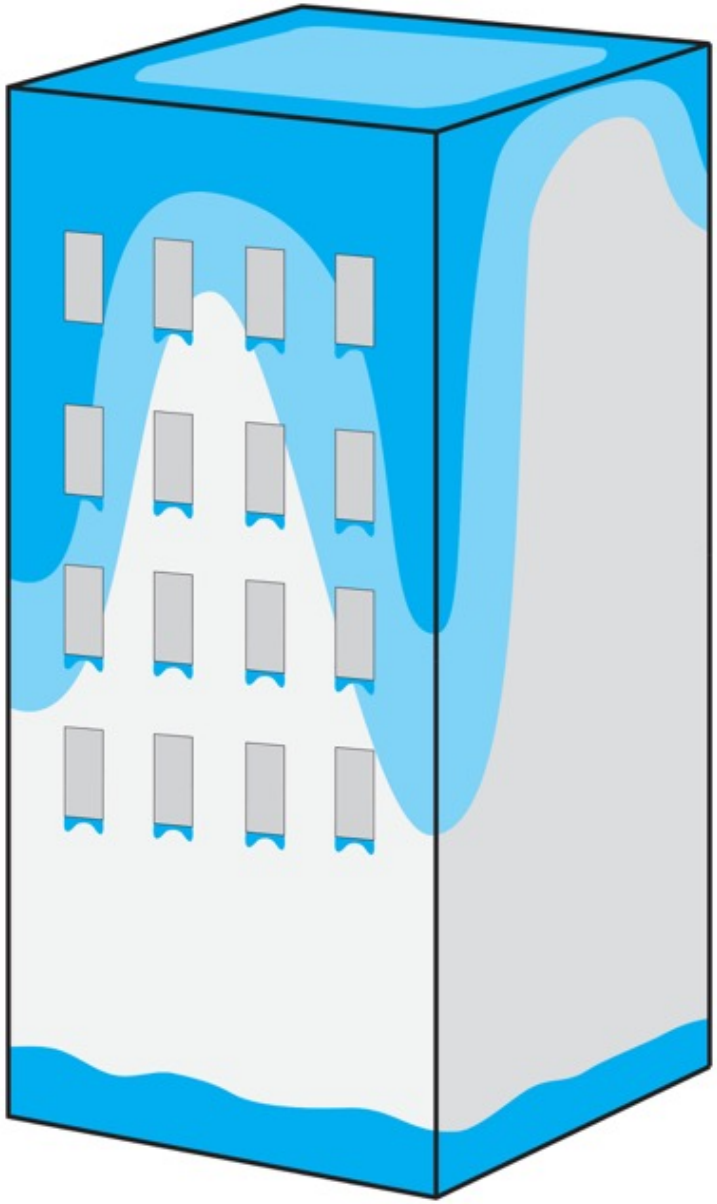

Subarctic/Arctic
Very Cold
Marine
Cold
Mixed-Humid
Mixed-Dry
Hot-Humid
Hot-Dry


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


Map of DOE's Proposed Climate Zones
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
March 24, 2003


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





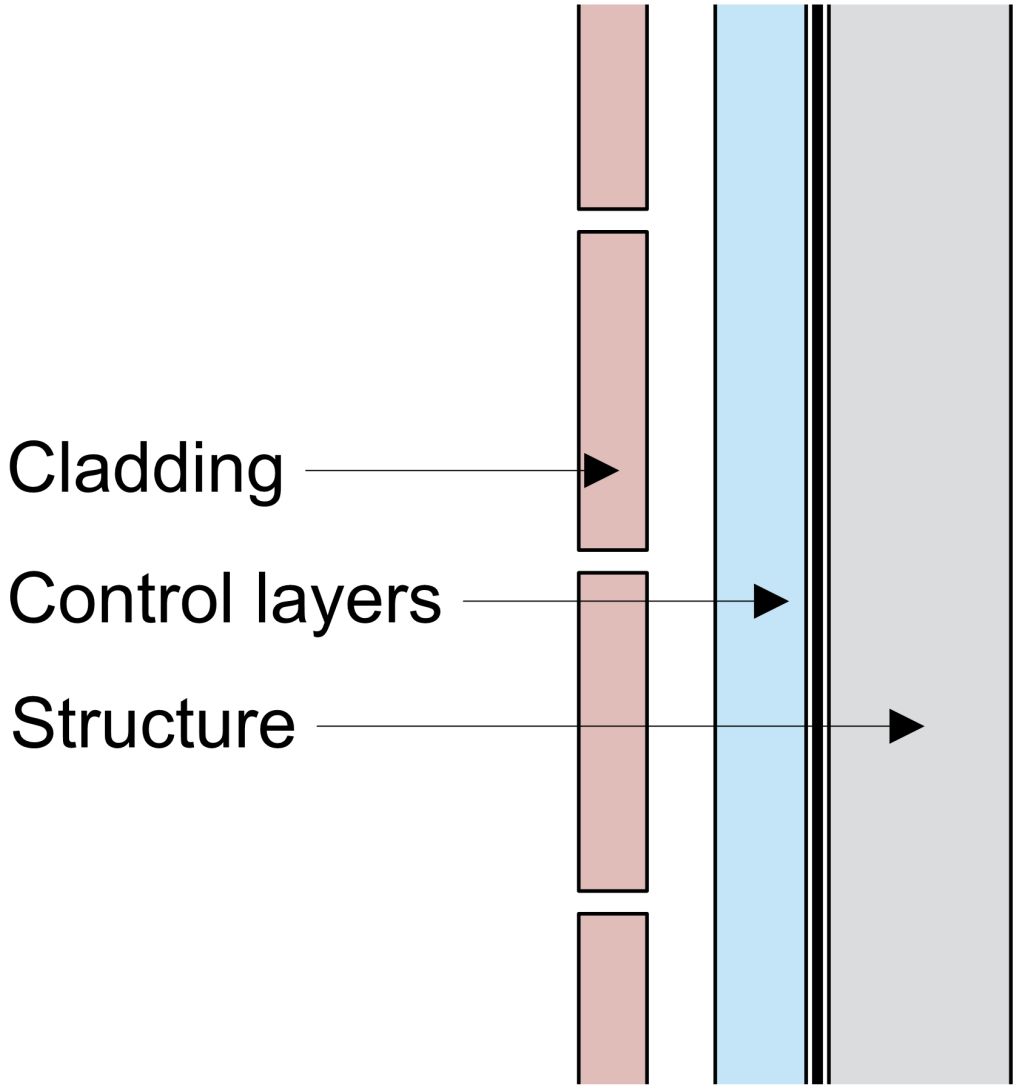
The Perfect Wall

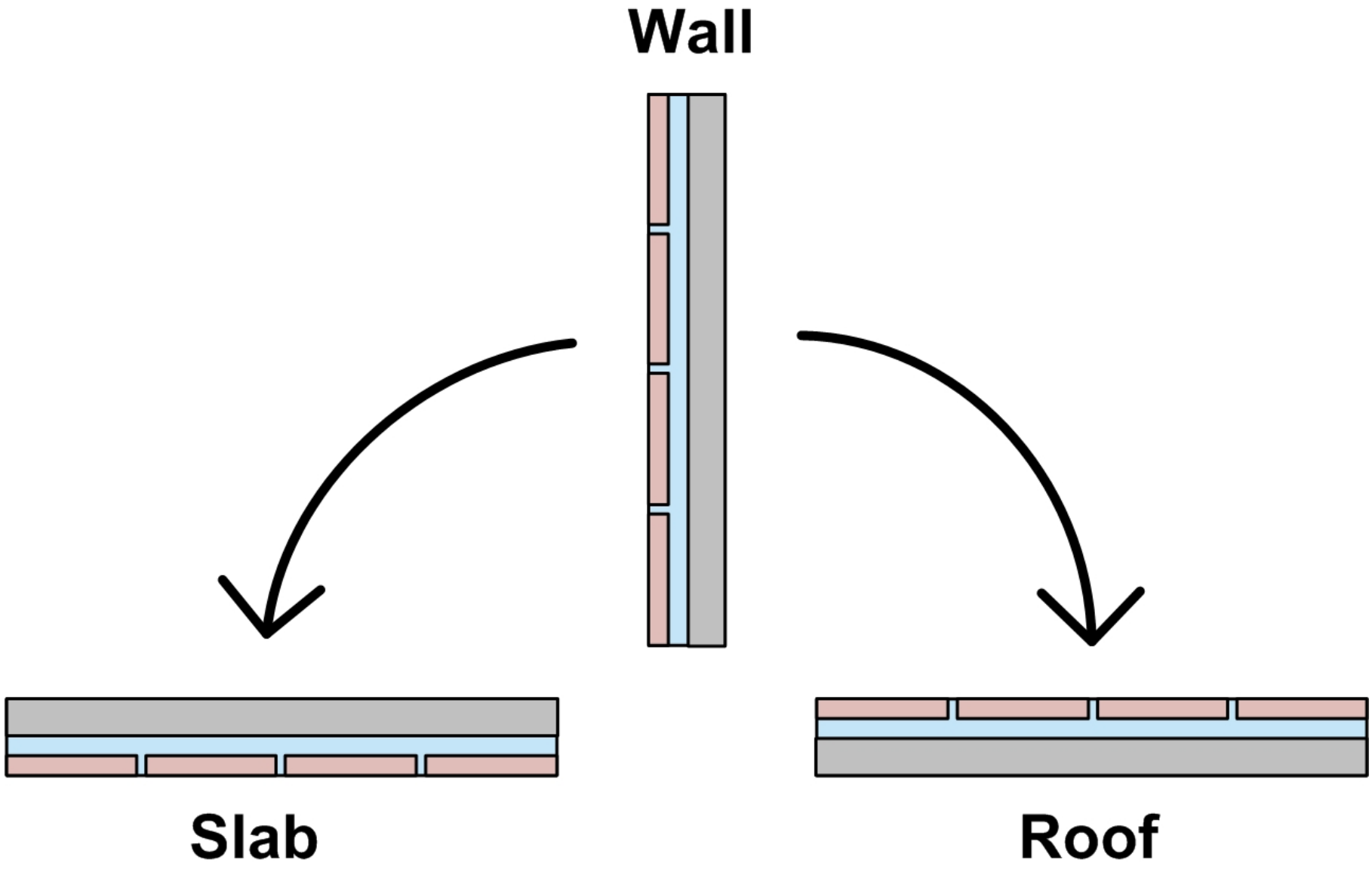
Water Control Layer

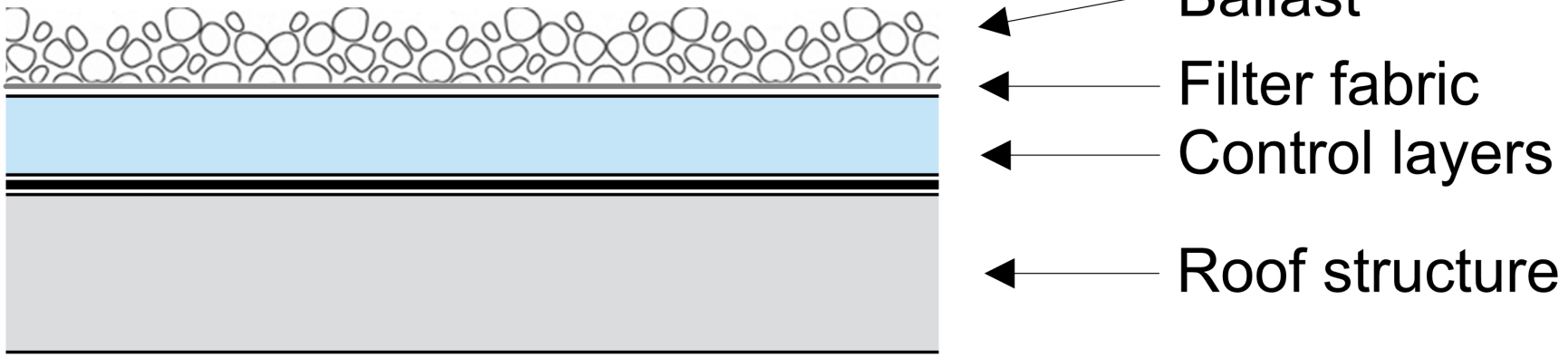
Air Control Layer

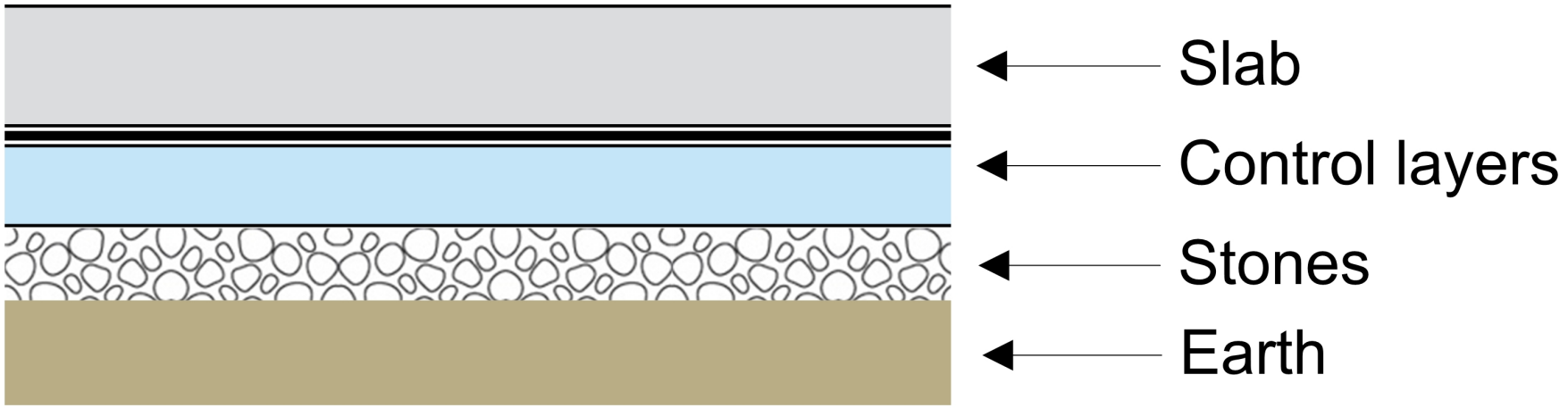
Vapor Control Layer

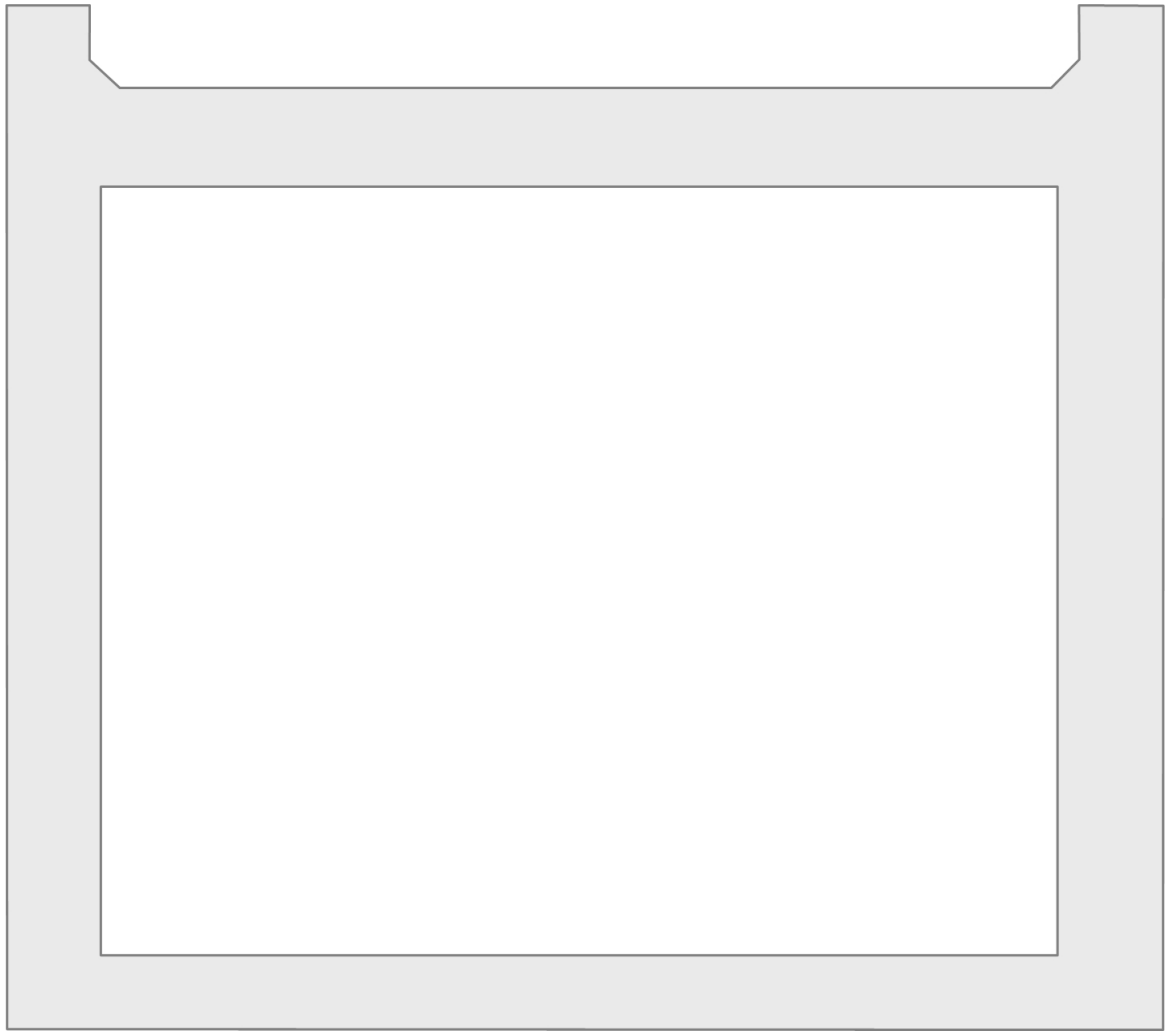
Thermal Control Layer

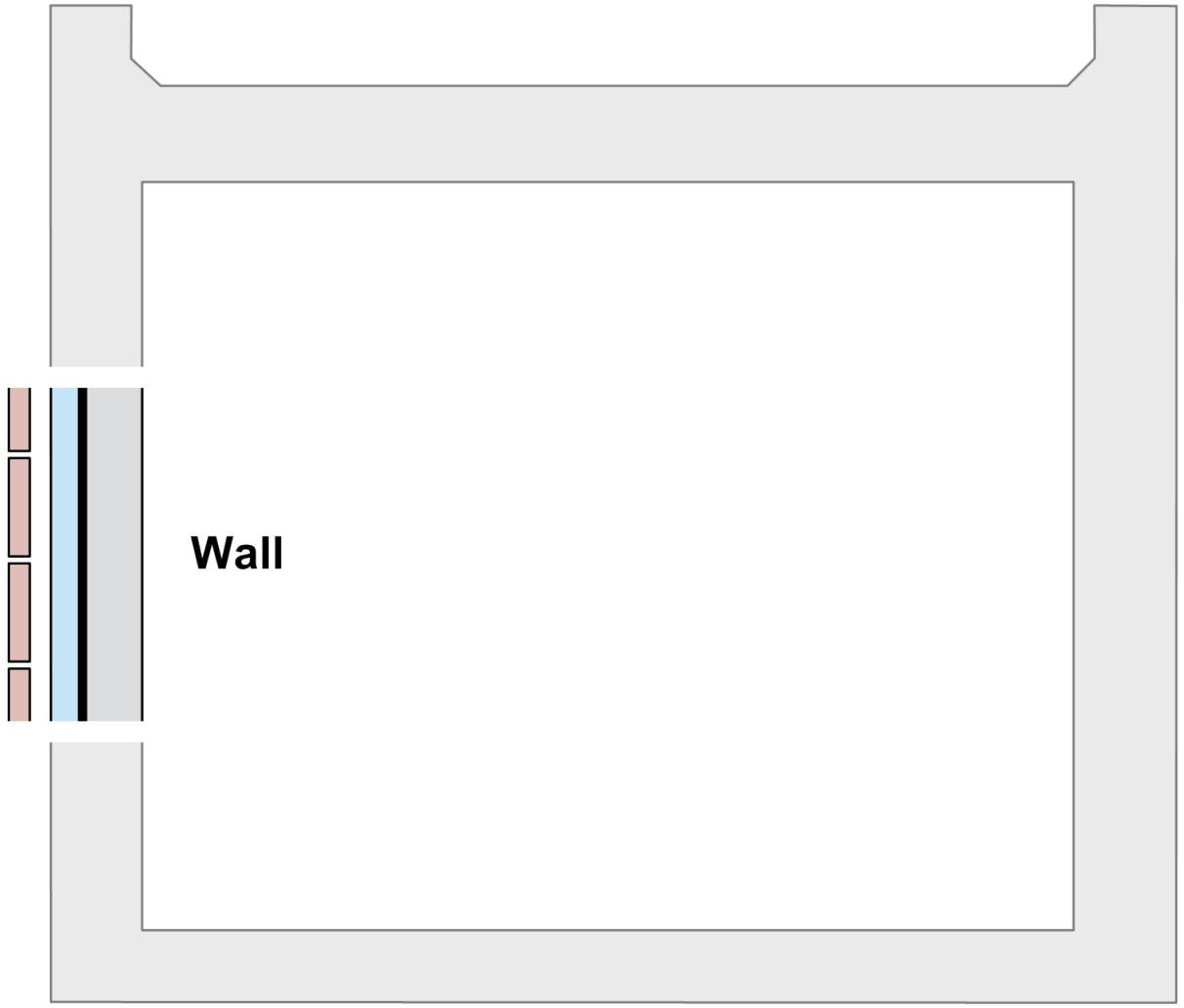

Cladding
Control layers
Structure

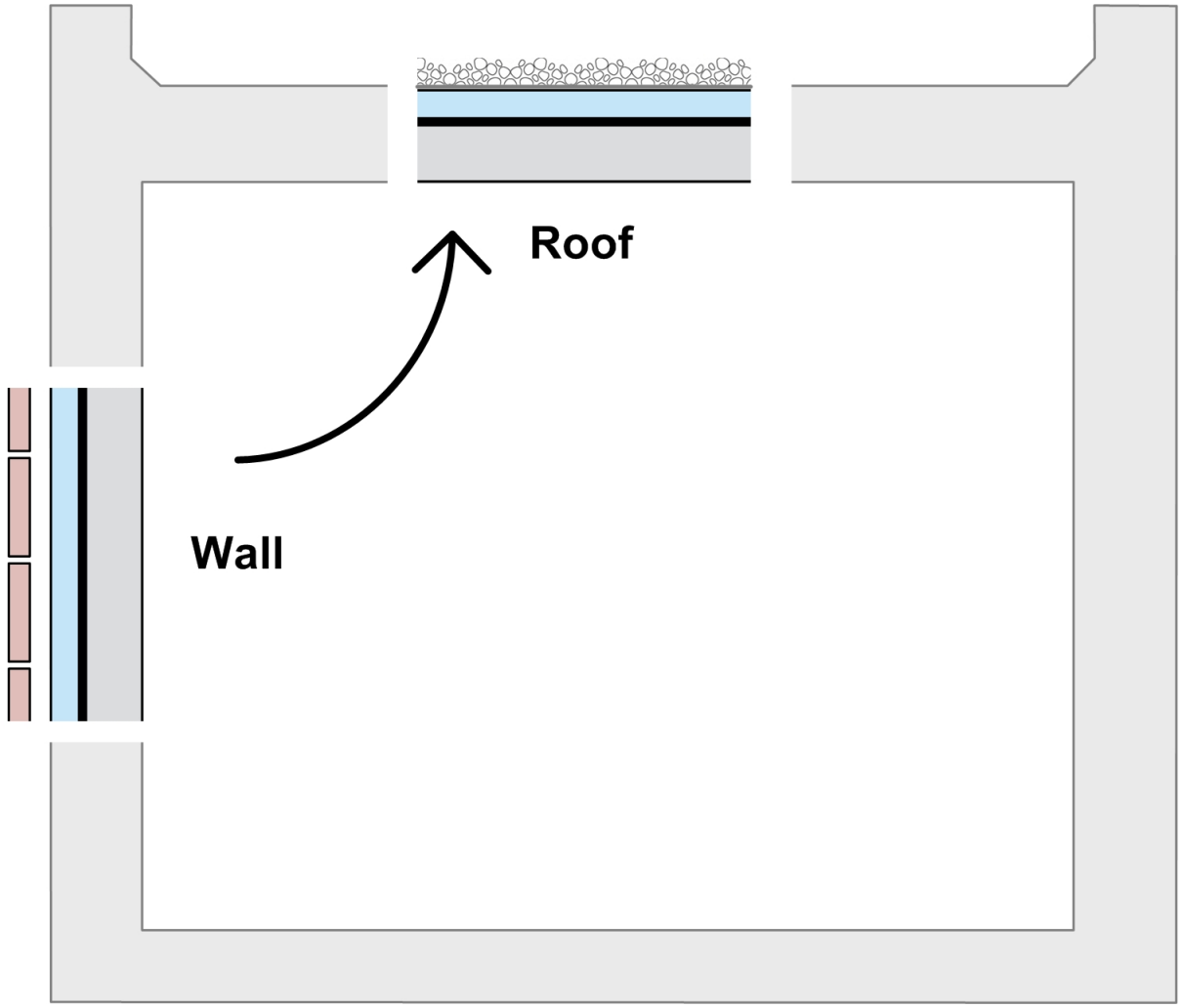

Wall
Slab
Roof

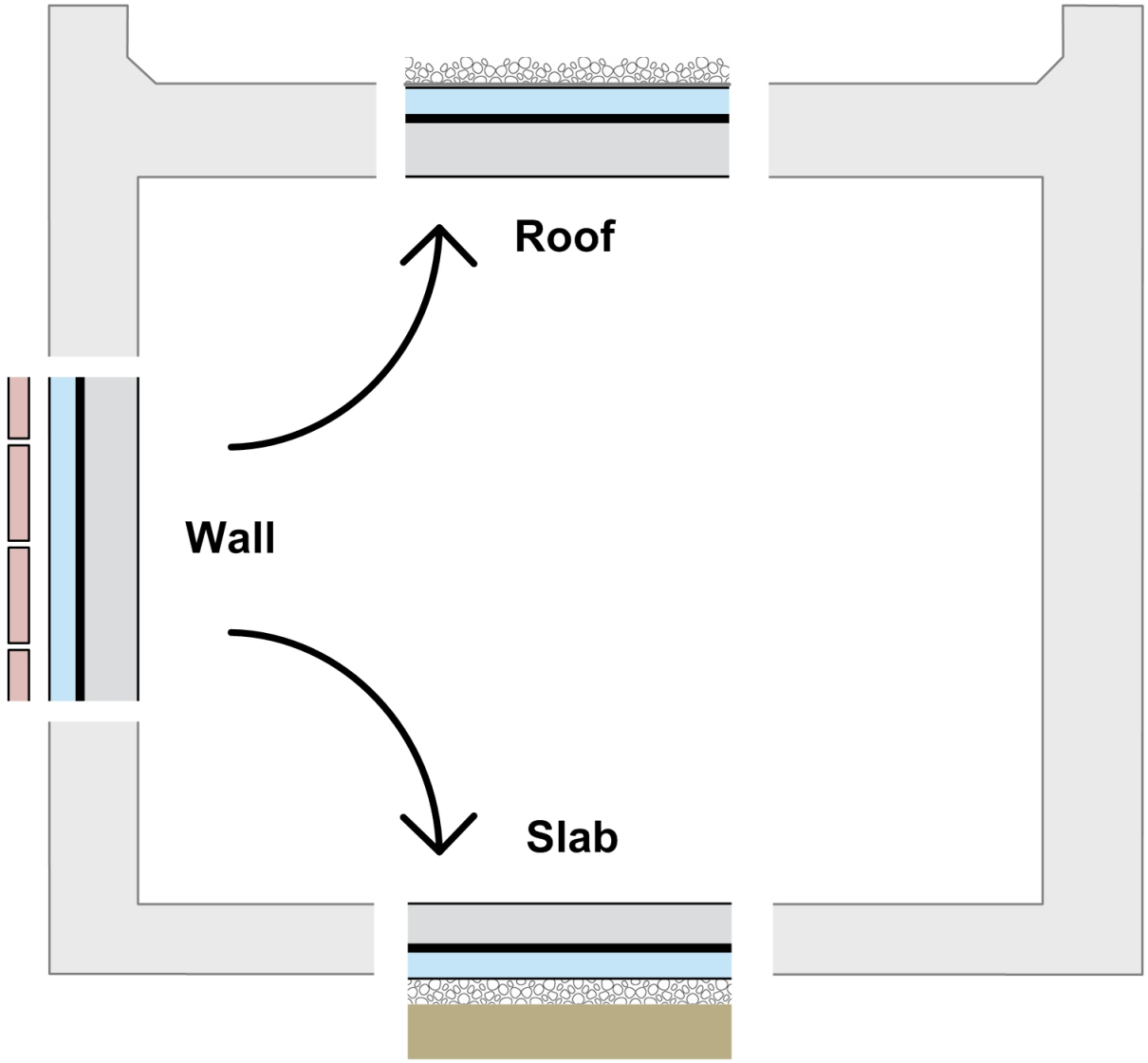

Ballast
Filter fabric
Control layers
Roof structure

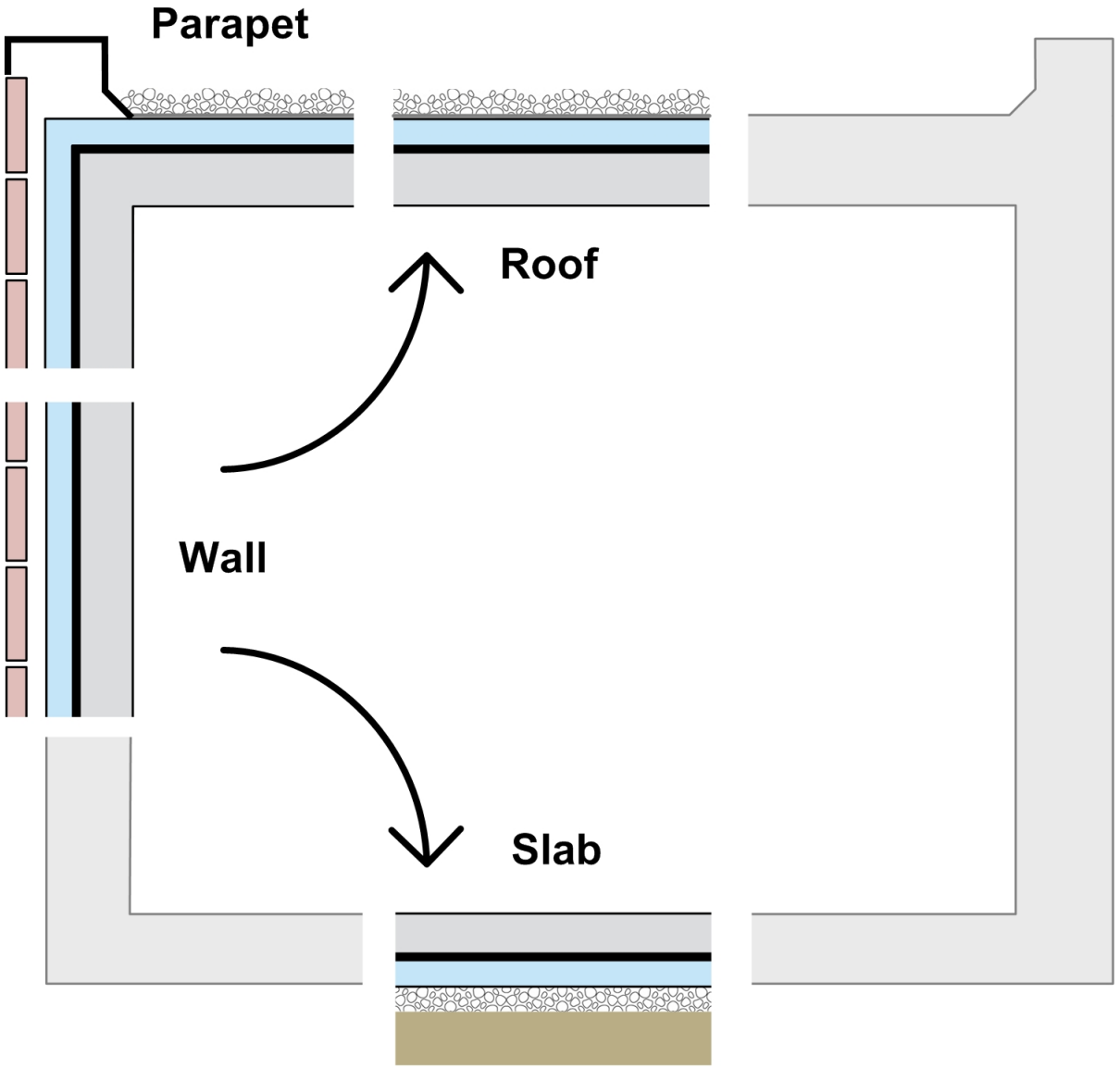

Slab
Control layers
Stones
Earth

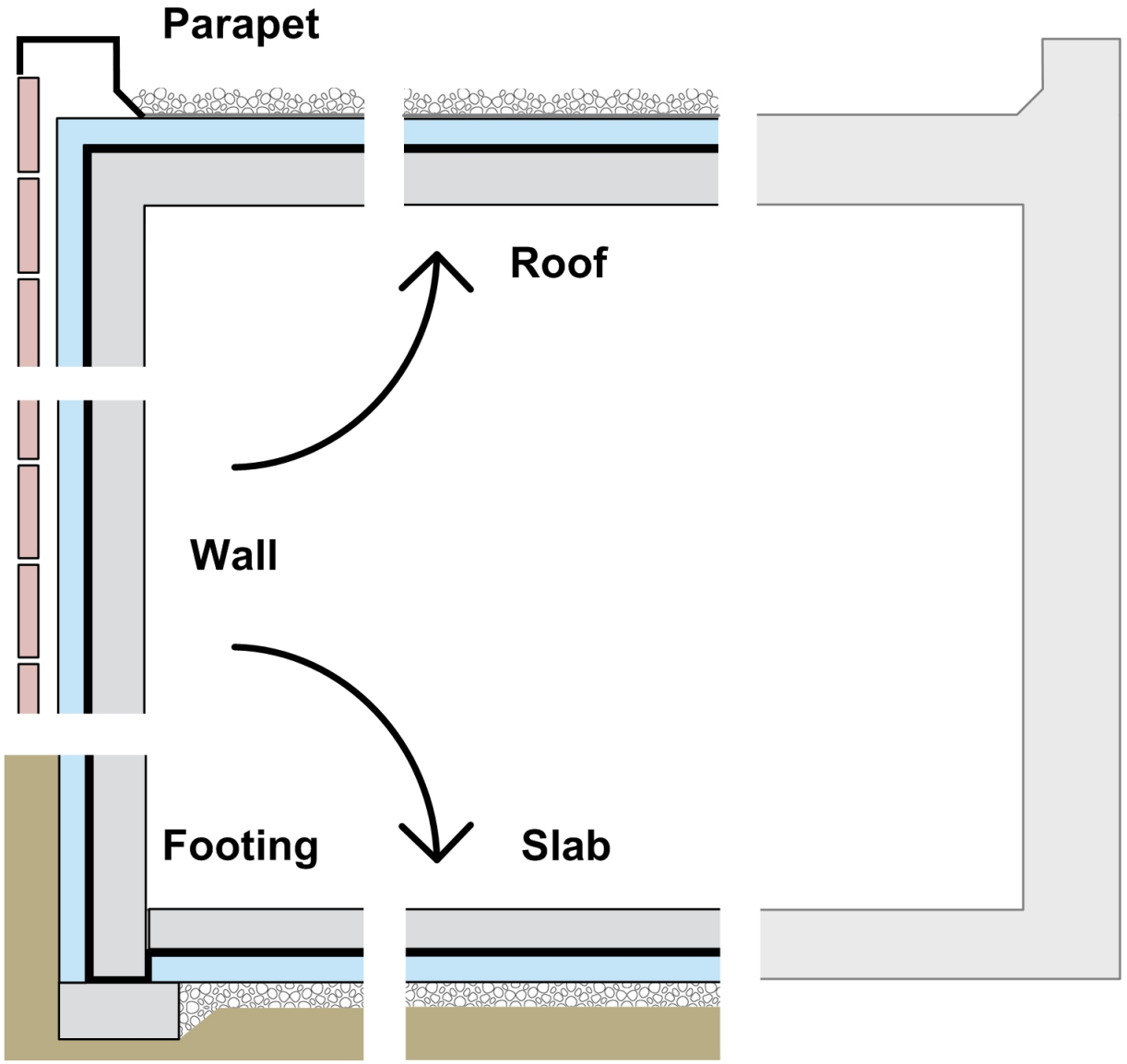


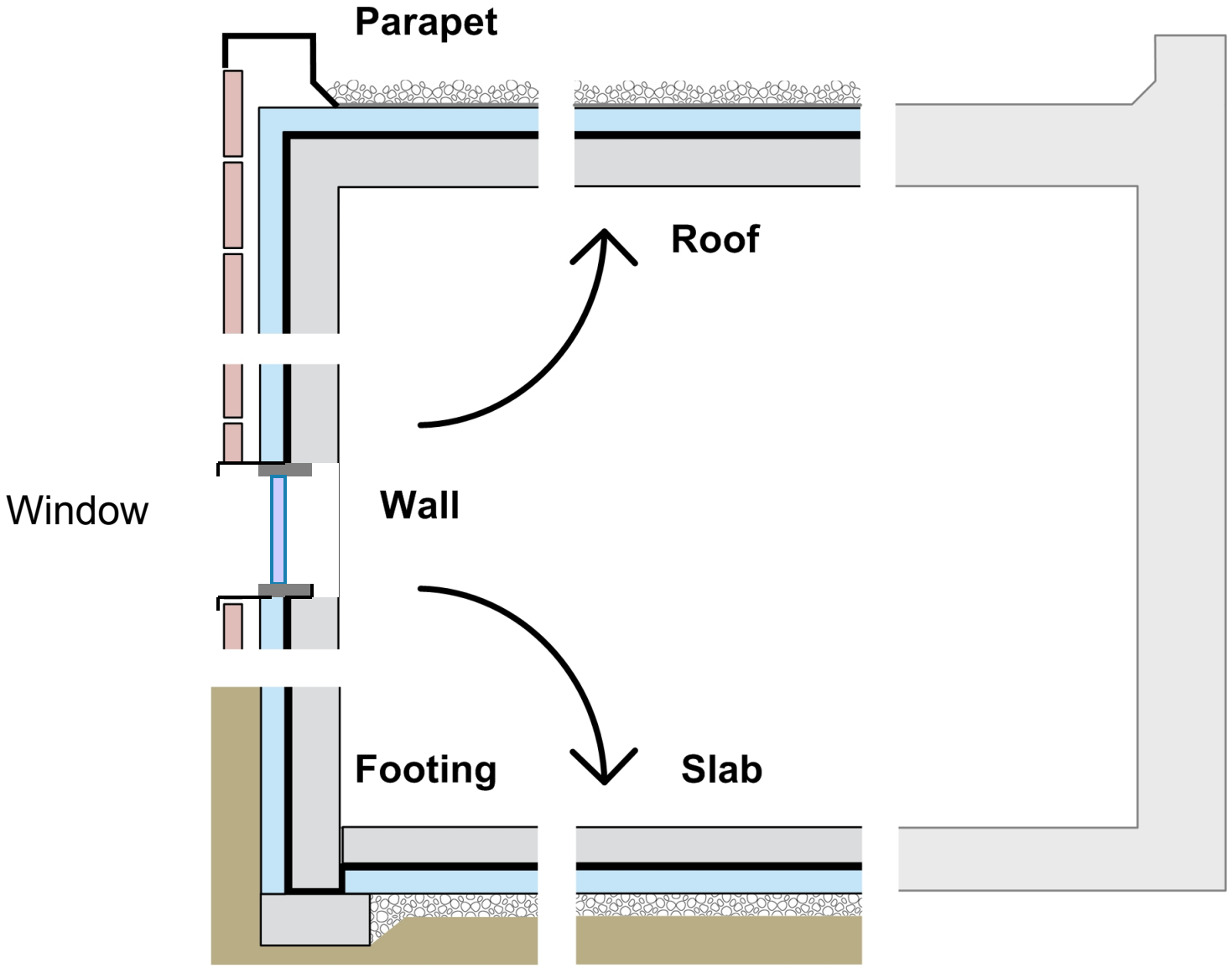

Wall

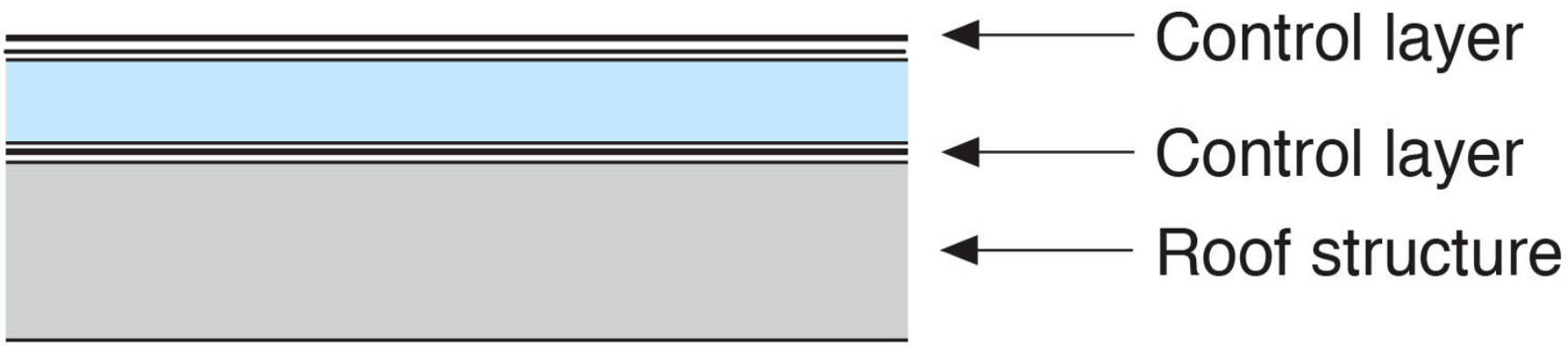

Roof
Wall

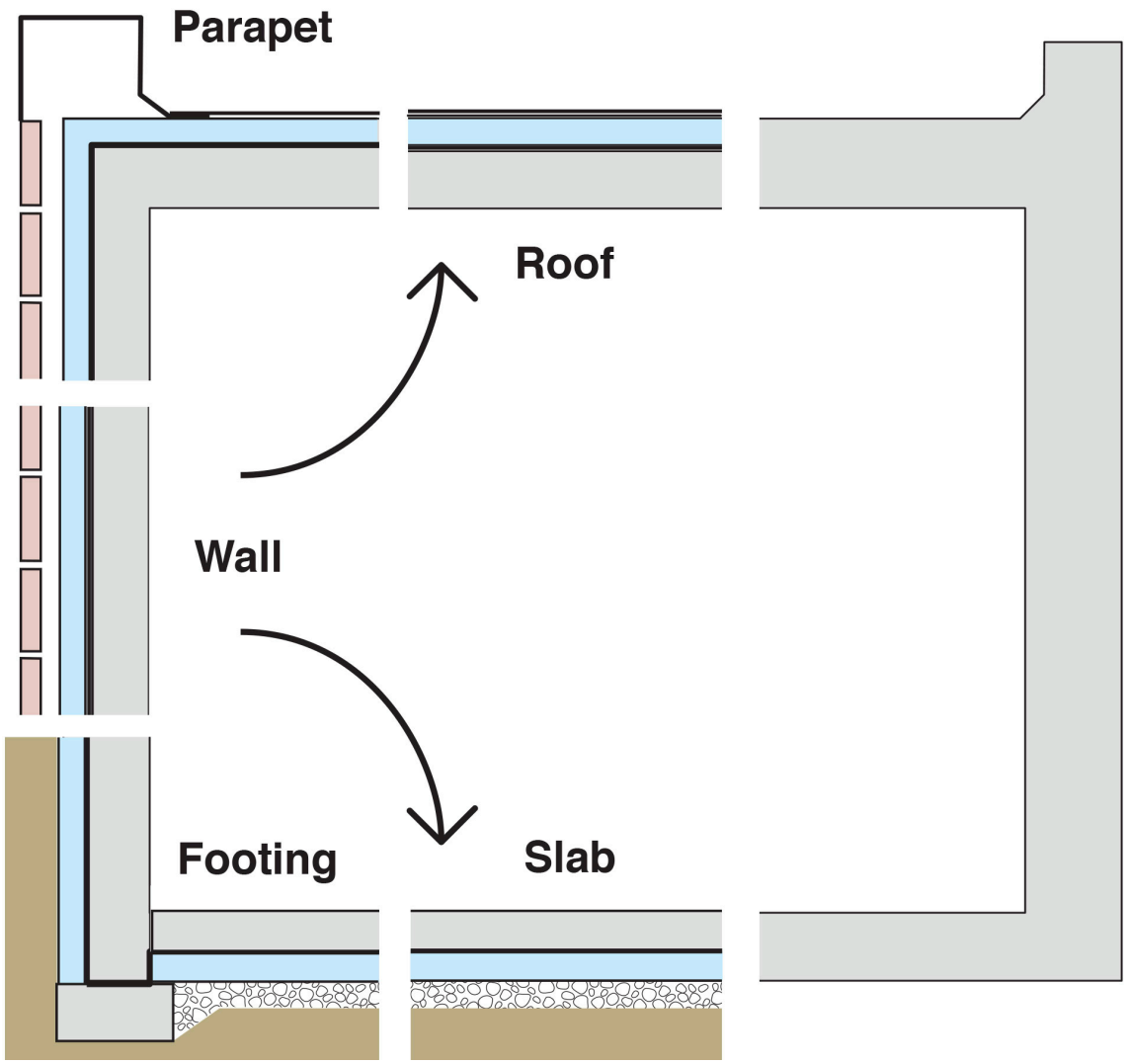

Roof
Wall
Slab

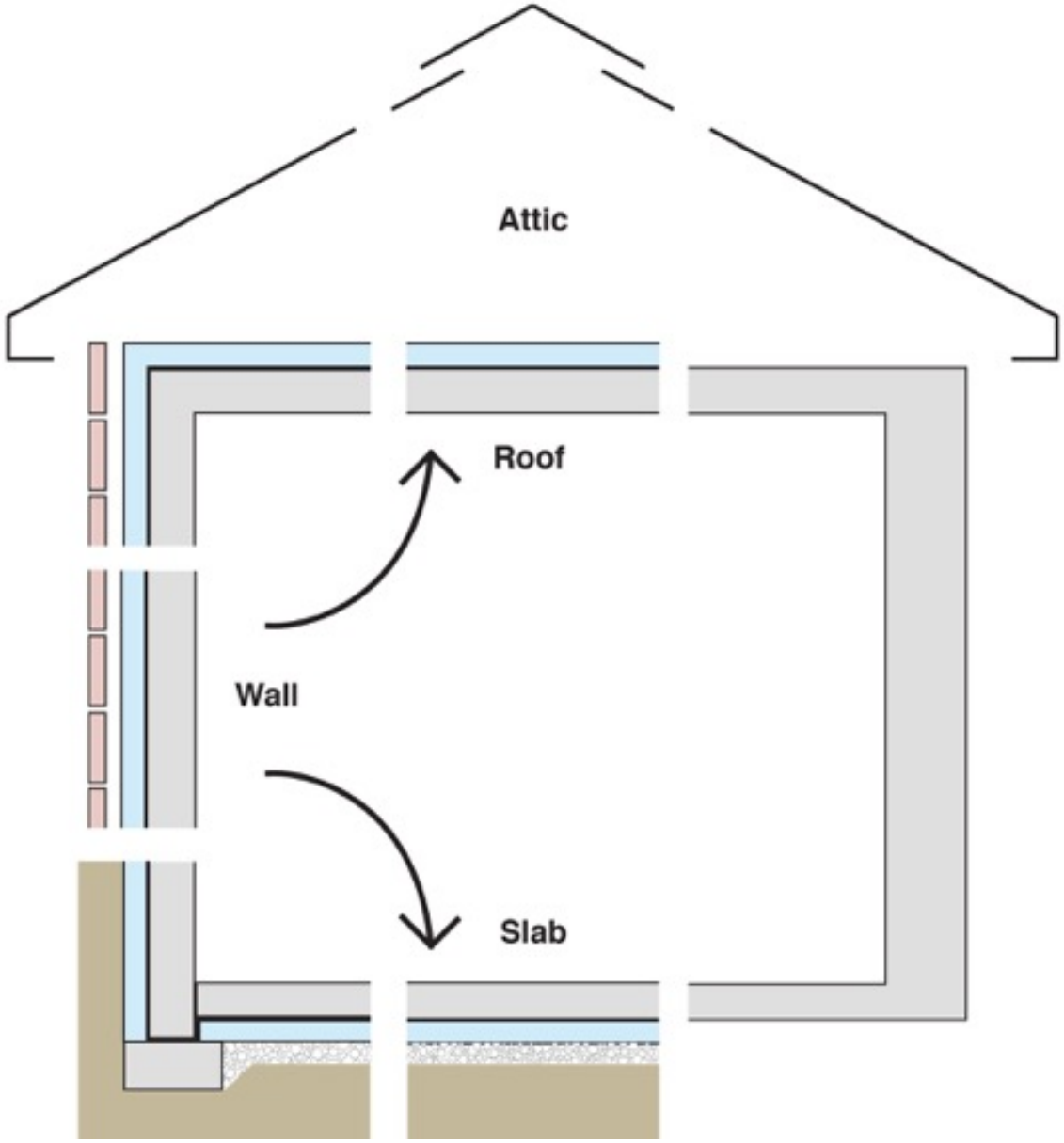

Parapet
Roof
Wall
Slab

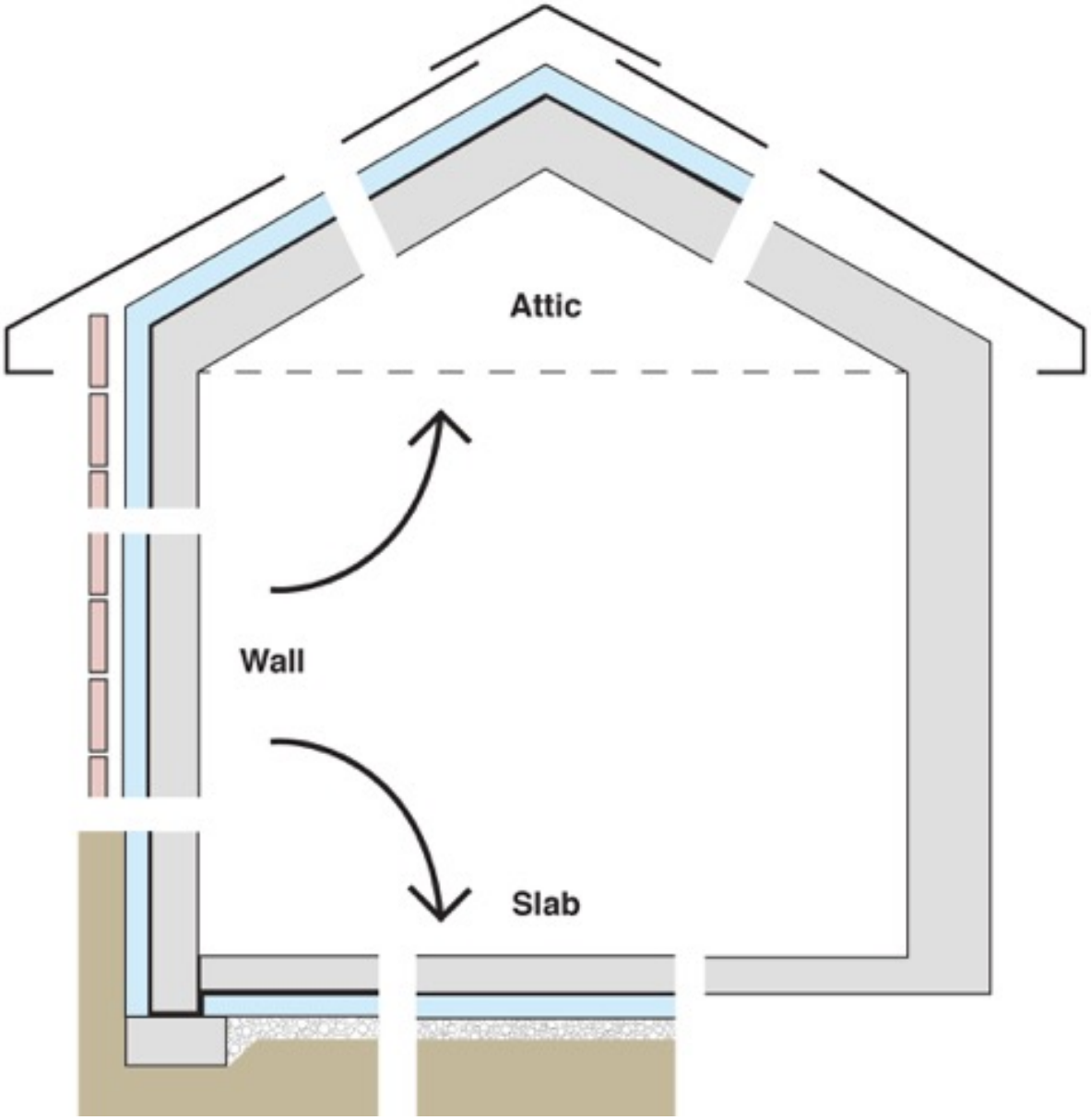

Parapet
Roof
Wall
Footing
Slab

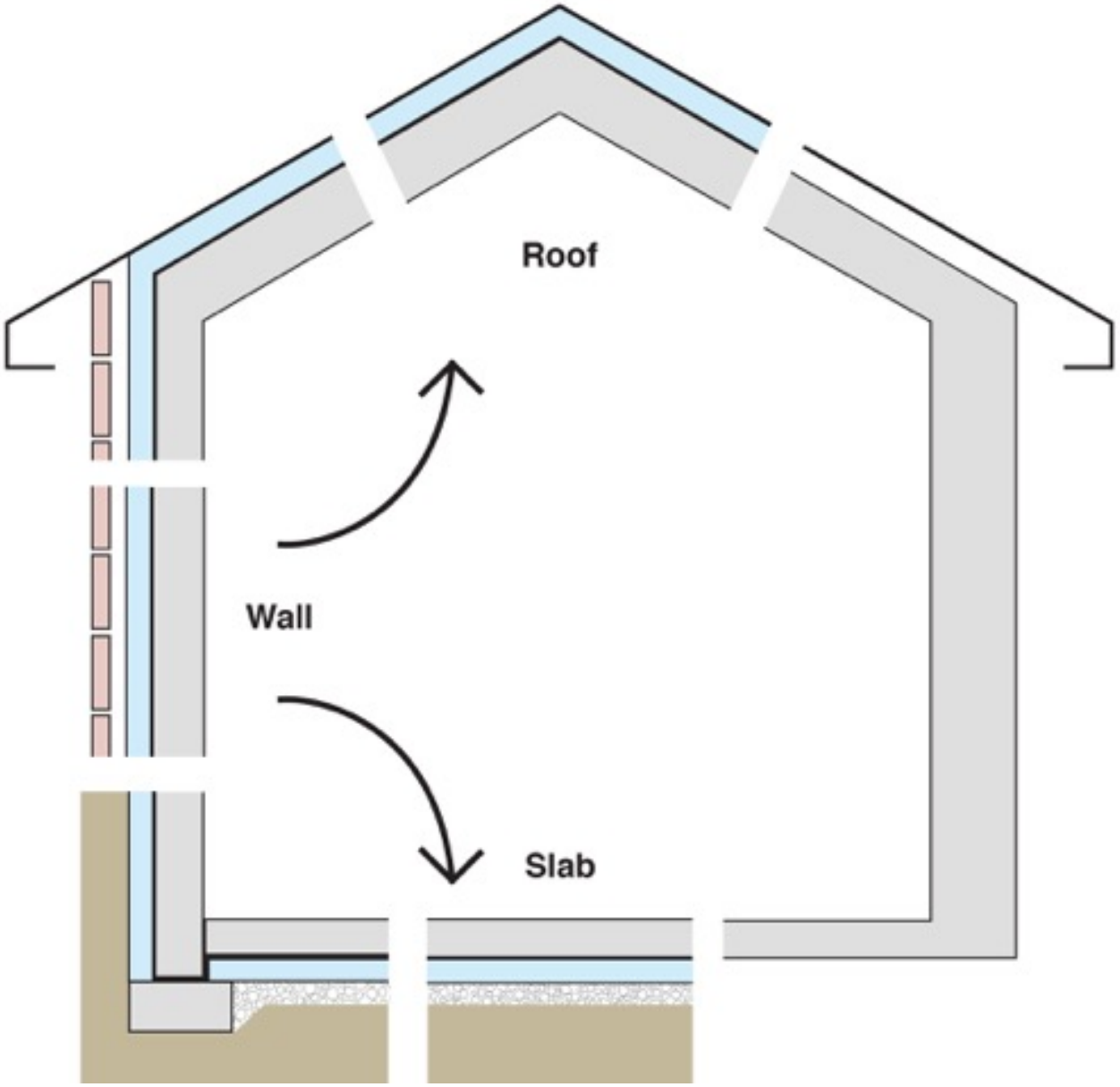

Parapet
Roof
Window
Wall
Footing
Slab


Control layer
Control layer
Roof structure

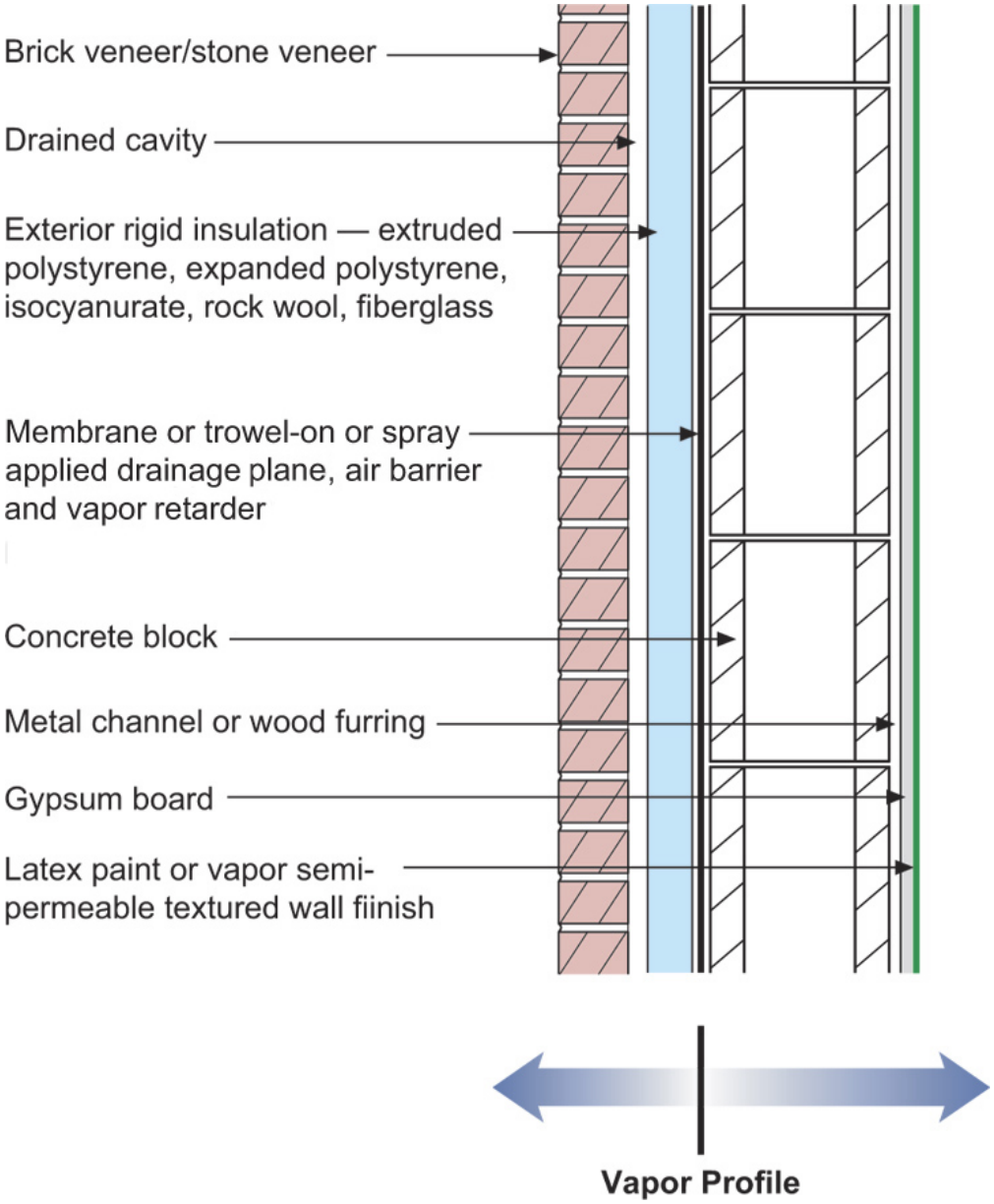

Parapet
Roof
Wall
Footing
Slab

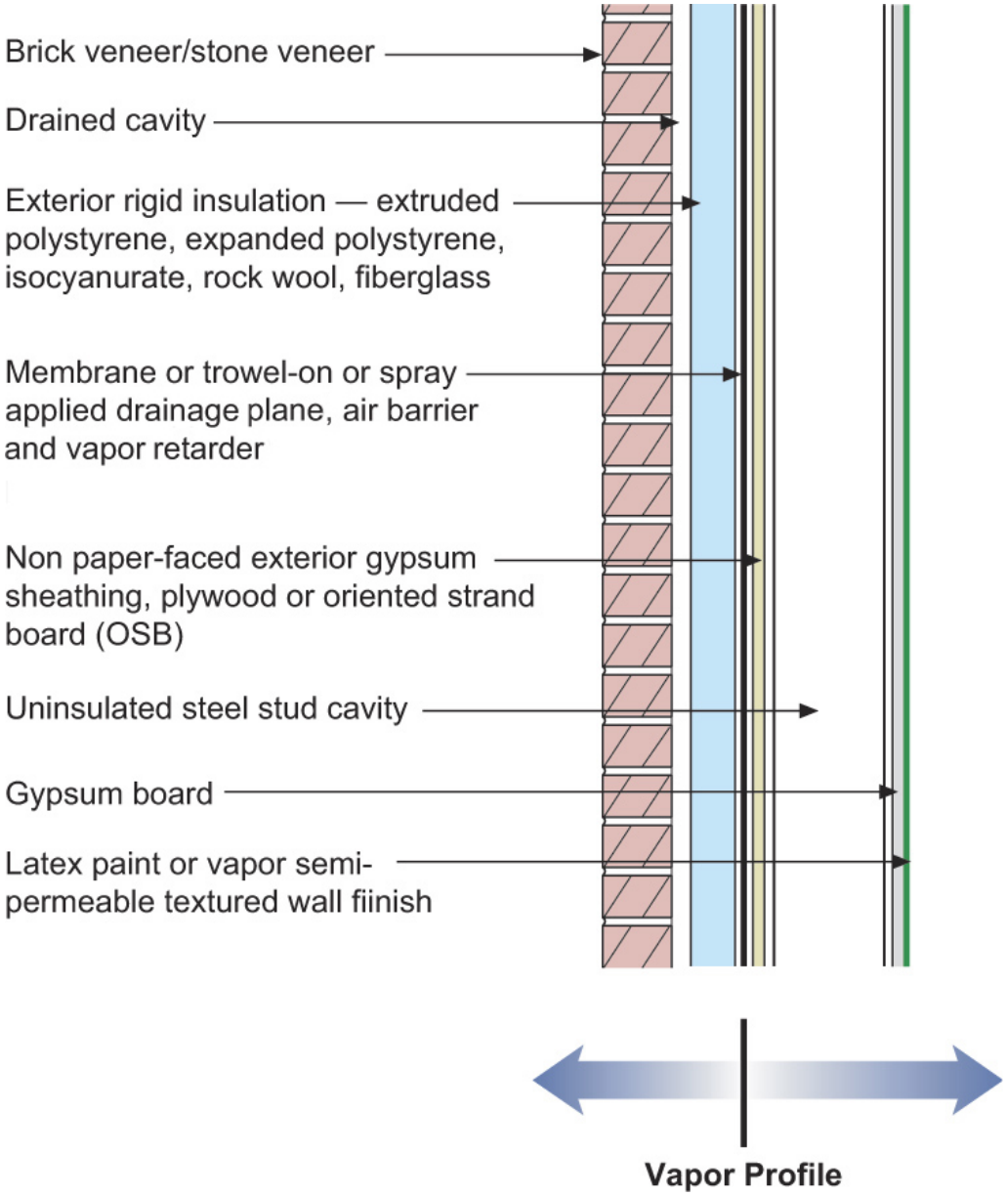

Attic
Roof
Wall
Slab

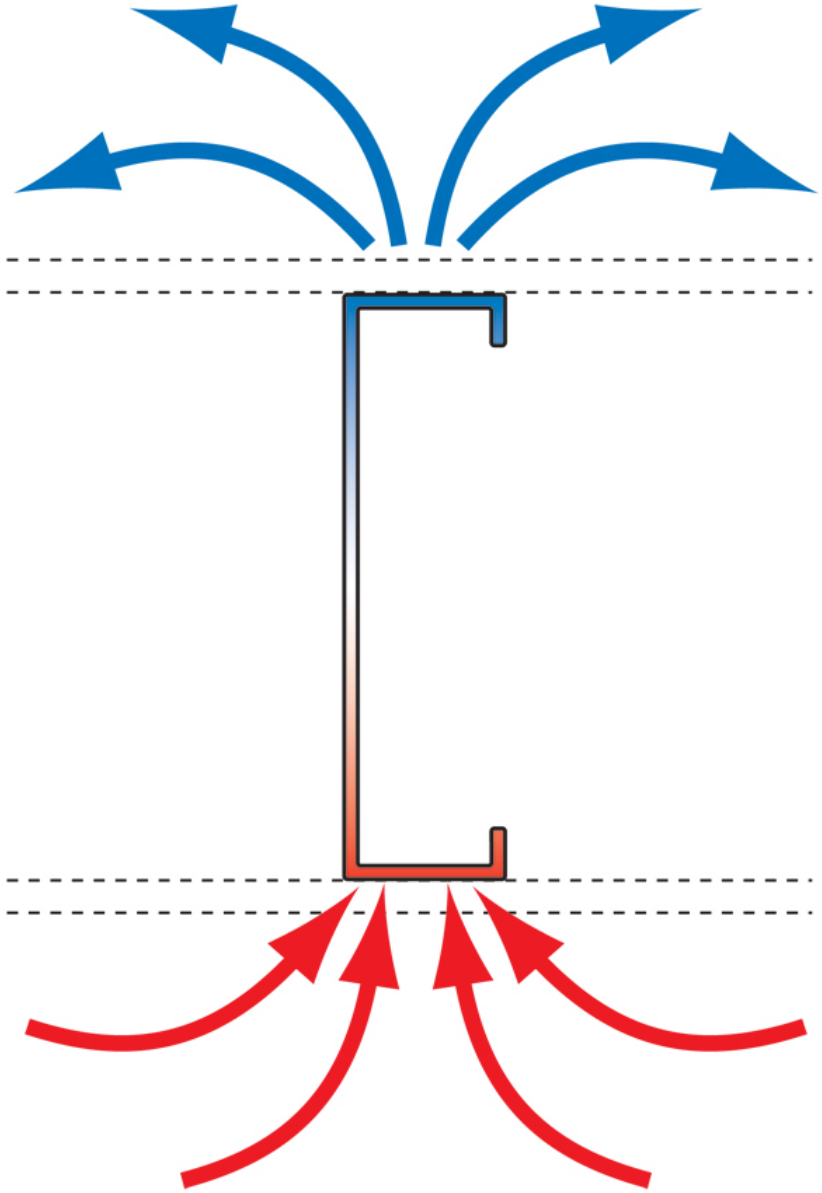

Attic
Wall
Slab

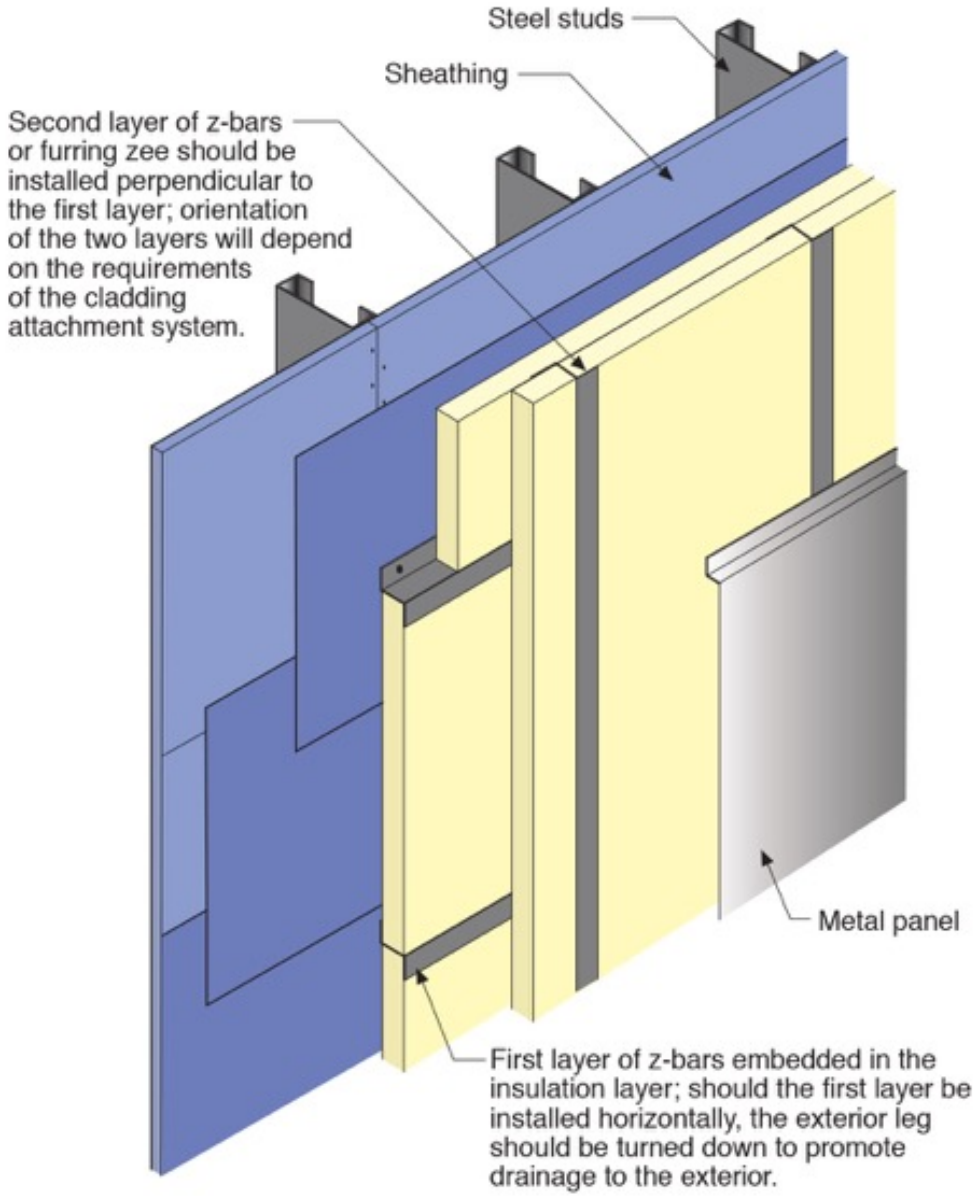

Roof
Wall
Slab

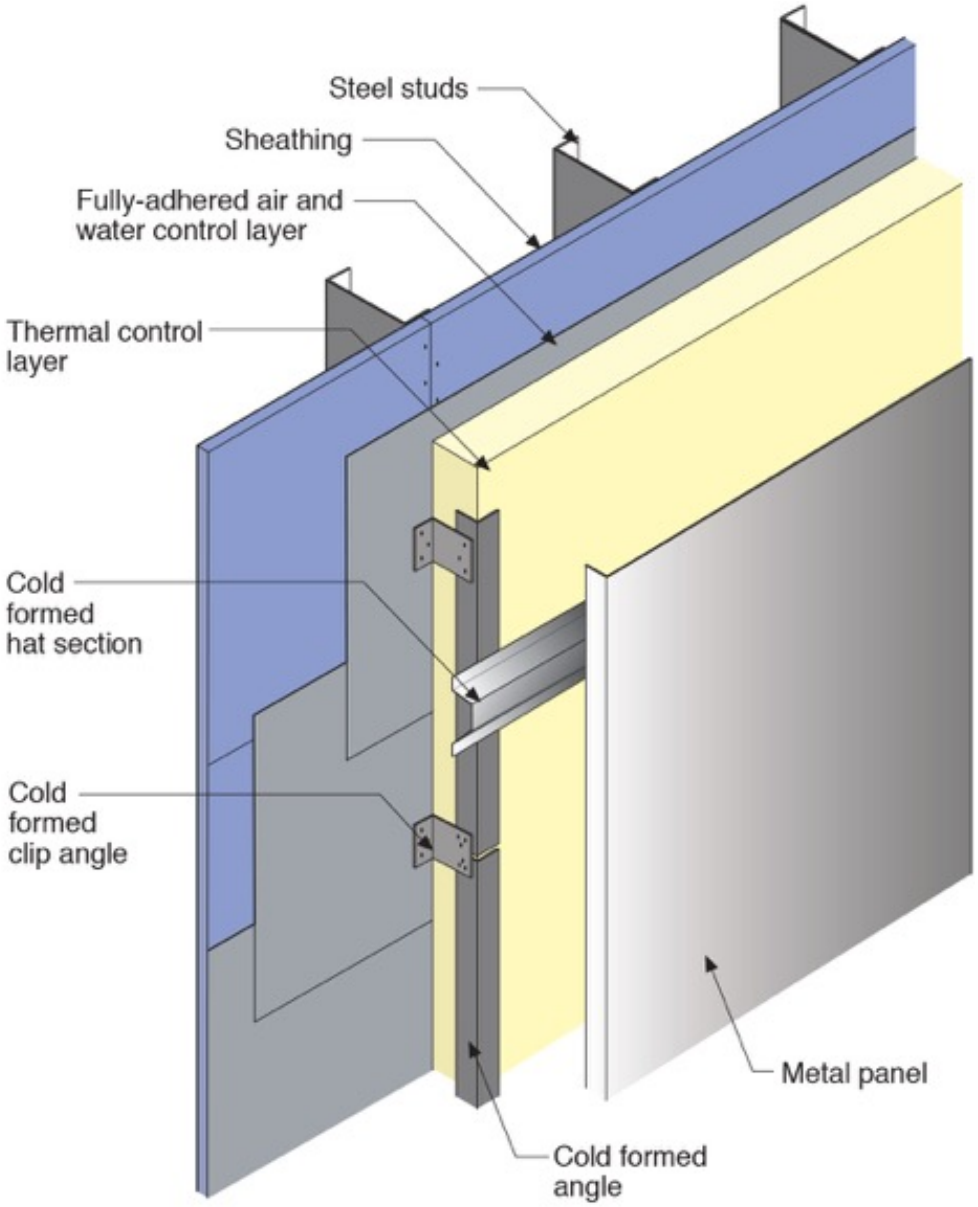
Configurations of the Perfect Wall

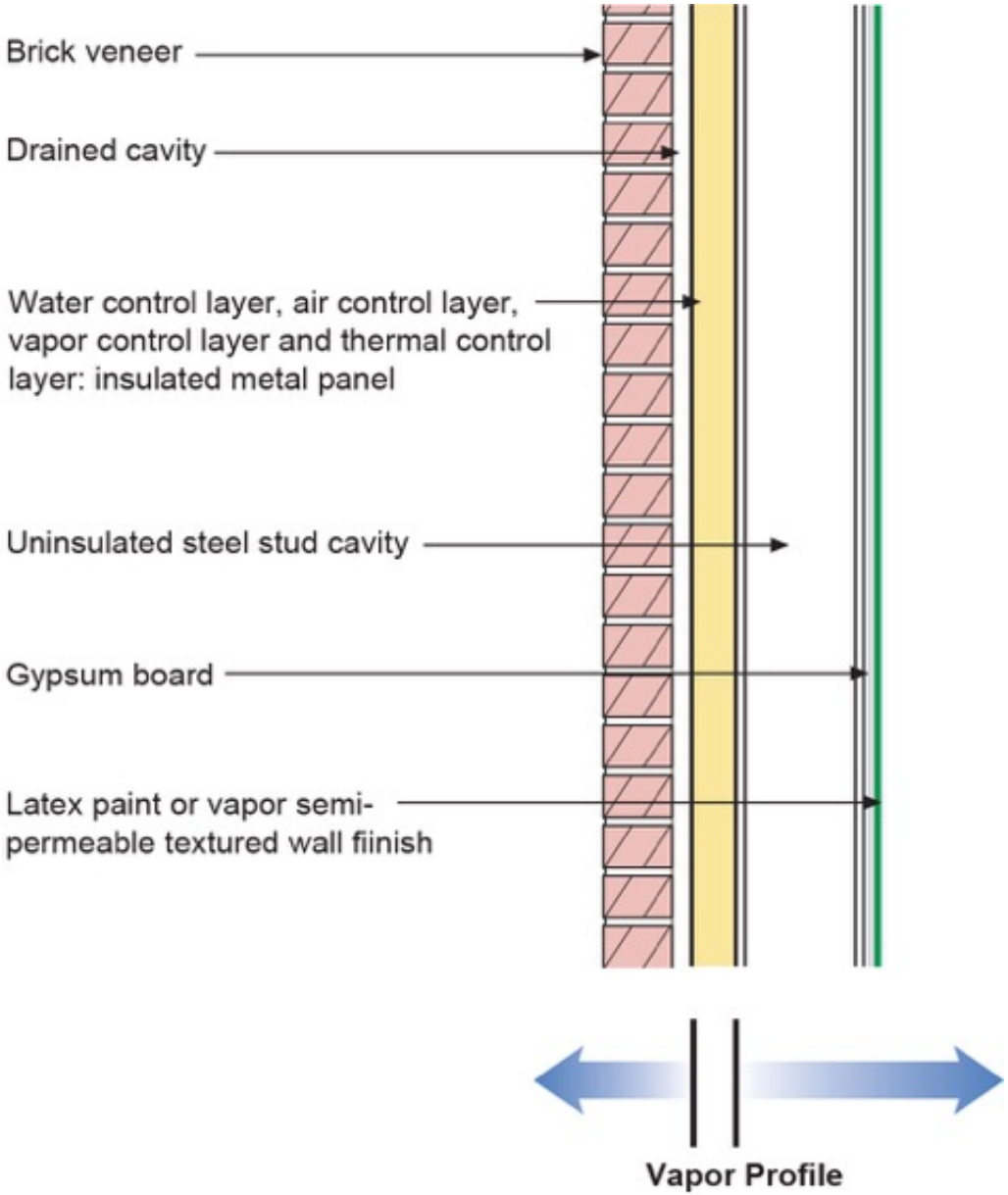

Brick veneer/stone veneer
Drained cavity
Exterior rigid insulation — extruded polystyrene, expanded polystyrene, isocyanurate, rock wool, fiberglass
Membrane or trowel-on or spray applied drainage plane, air barrier and vapor retarder
Concrete block
Metal channel or wood furring
Gypsum board
Latex paint or vapor semi-permeable textured wall fiinish
Vapor Profile

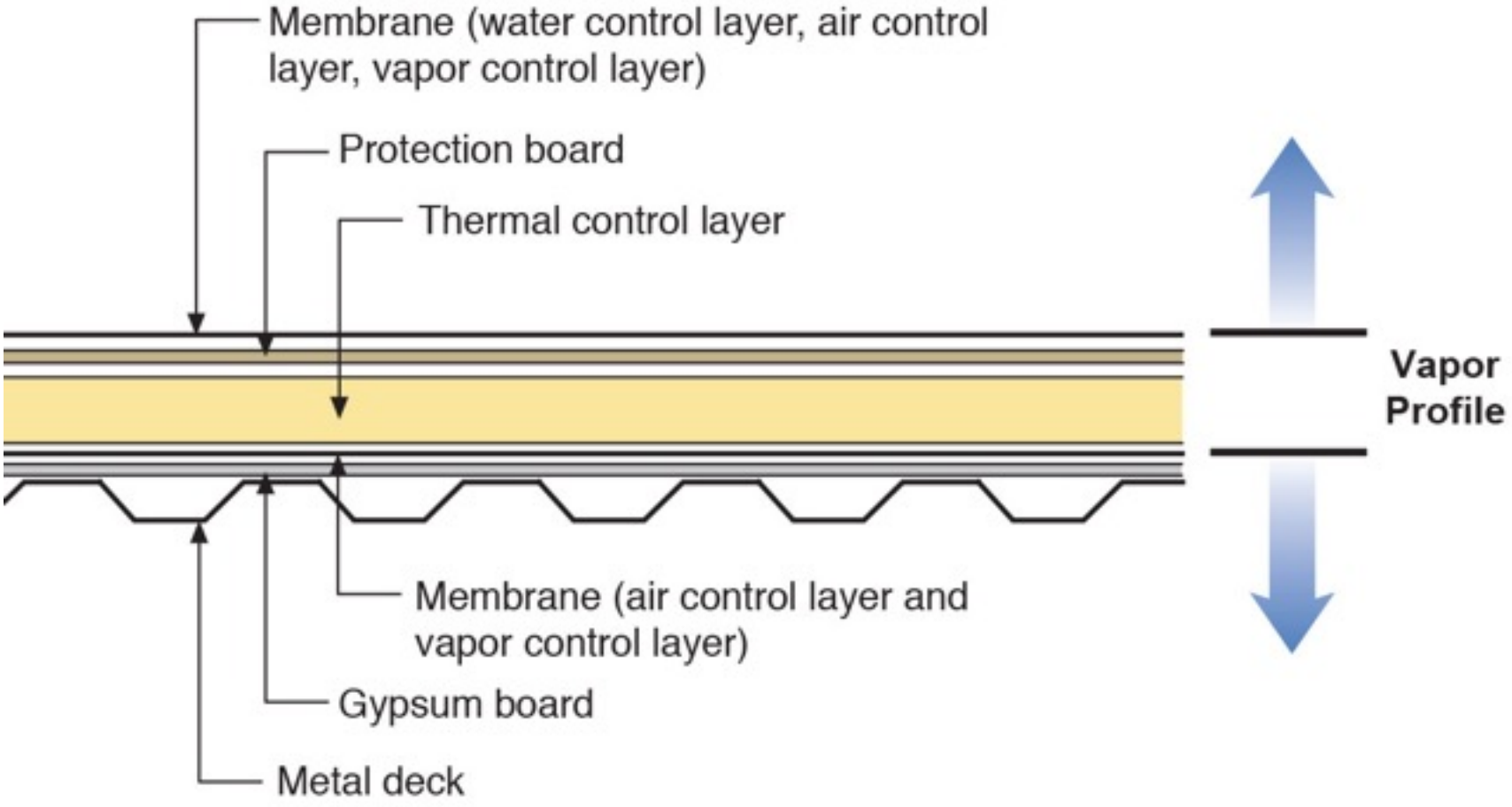

Brick veneer/stone veneer
Drained cavity
Exterior rigid insulation — extruded polystyrene, expanded polystyrene, isocyanurate, rock wool, fiberglass
Membrane or trowel-on or spray applied drainage plane, air barrier and vapor retarder
Non paper-faced exterior gypsum sheathing, plywood or oriented strand board (OSB)
Uninsulated steel stud cavity
Gypsum board
Latex paint or vapor semi-permeable textured wall fiinish
Vapor Profile

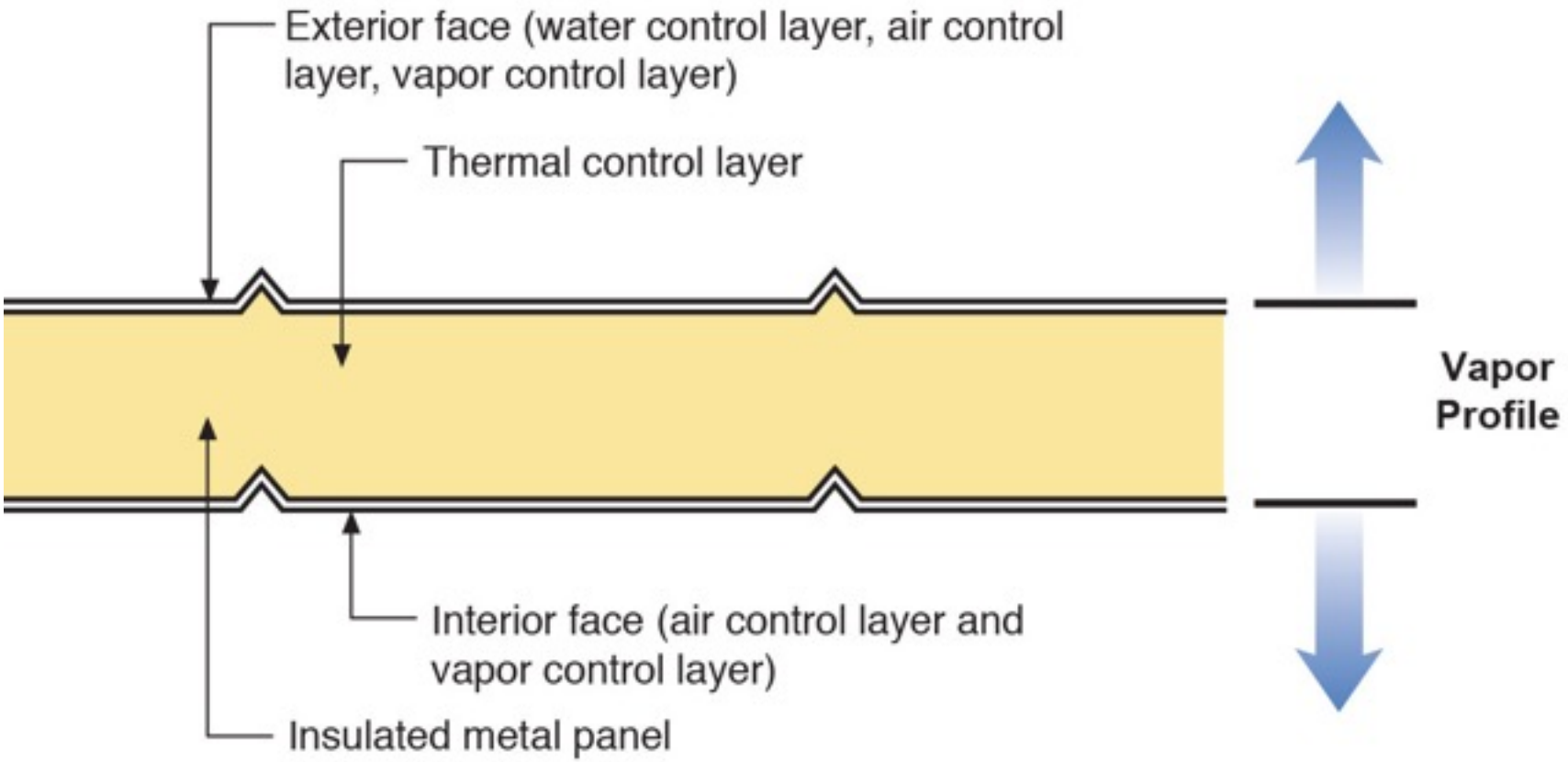


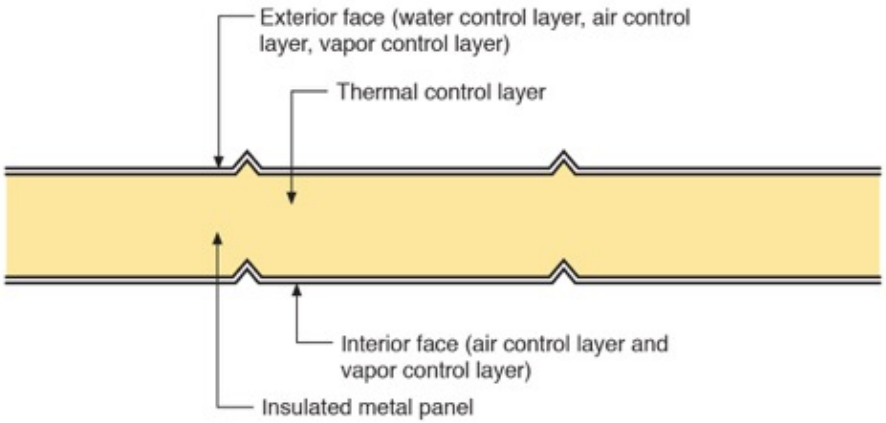

Steel studs
Sheathing
Second layer of z-bars or furring zee should be installed perpendicular to the first layer; orientation of the two layers will depend on the requirements of the cladding attachment system.
Metal panel
First layer of z-bars embedded in the insulation layer; should the first layer be installed horizontally, the exterior leg should be turned down to promote drainage to the exterior.


Steel studs
Sheathing
Fully-adhered air and water control layer
Thermal control layer
Cold formed hat section
Cold formed clip angle
Metal panel
Cold formed angle

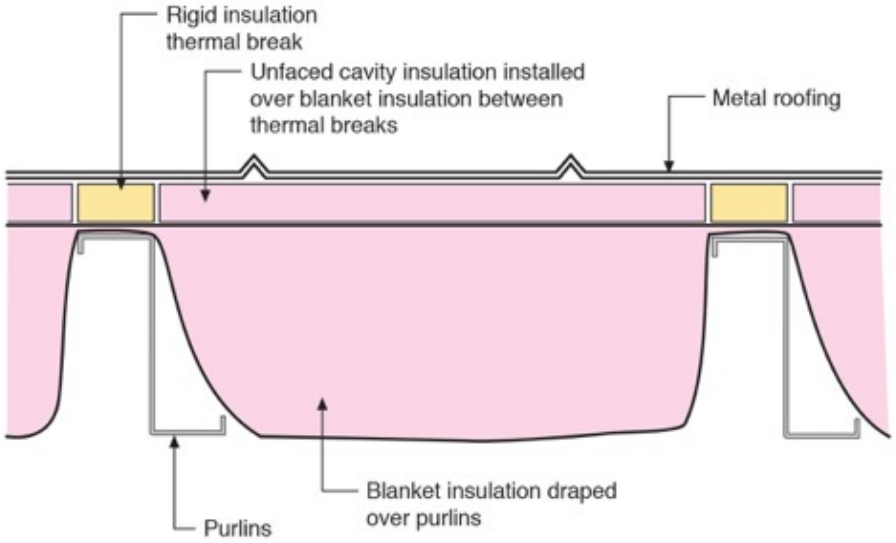

Brick veneer
Drained cavity
Water control layer, air control layer, vapor control layer and thermal control layer: insulated metal panel
Uninsulated steel stud cavity
Gypsum board
Latex paint or vapor semi-permeable textured wall fiinish
Vapor Profile


Membrane (water control layer, air control layer, vapor control layer)
Protection board
Thermal control layer
Vapor Profile
Membrane (air control layer and vapor control layer)
Gypsum board
Metal deck

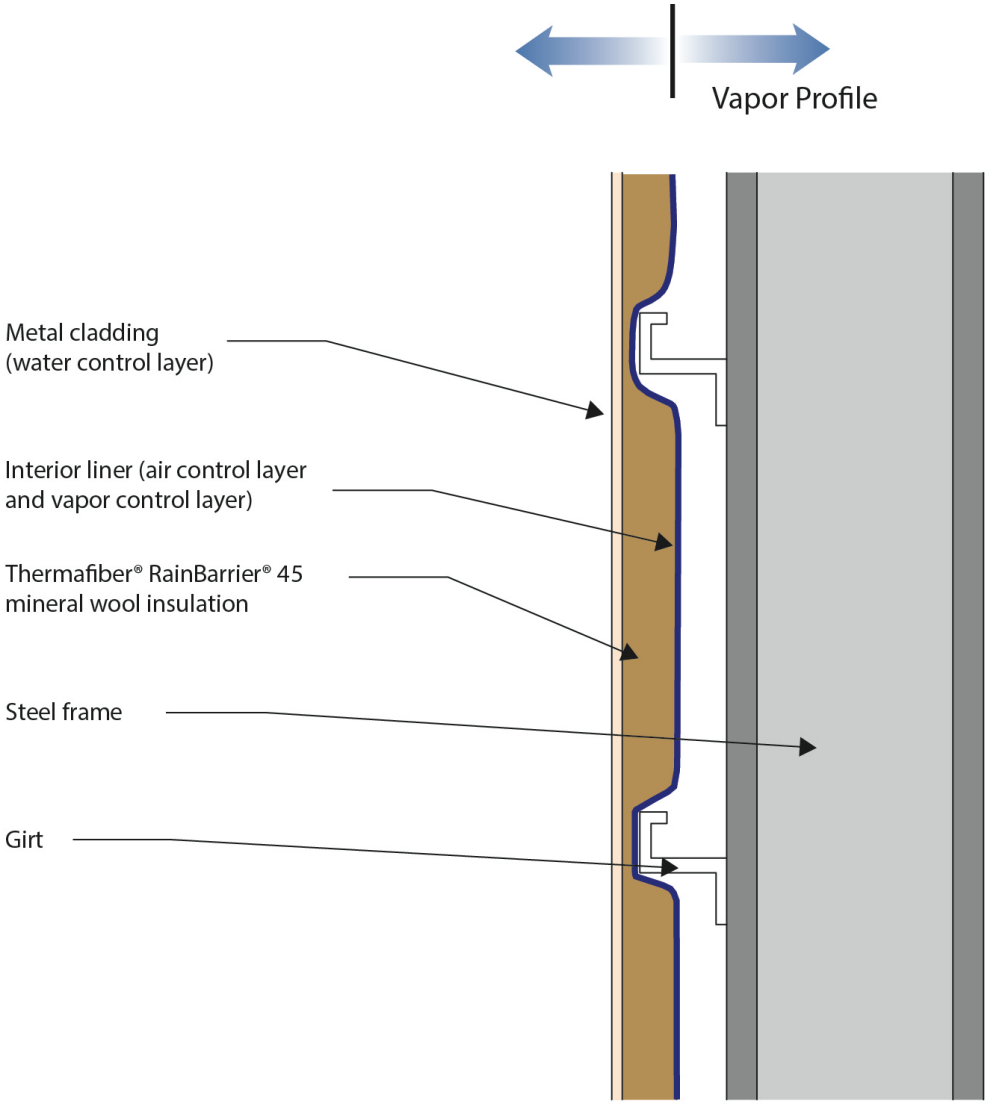

Exterior face (water control layer, air control layer, vapor control layer)
Thermal control layer
Vapor Profile
Interior face (air control layer and vapor control layer)
Insulated metal panel

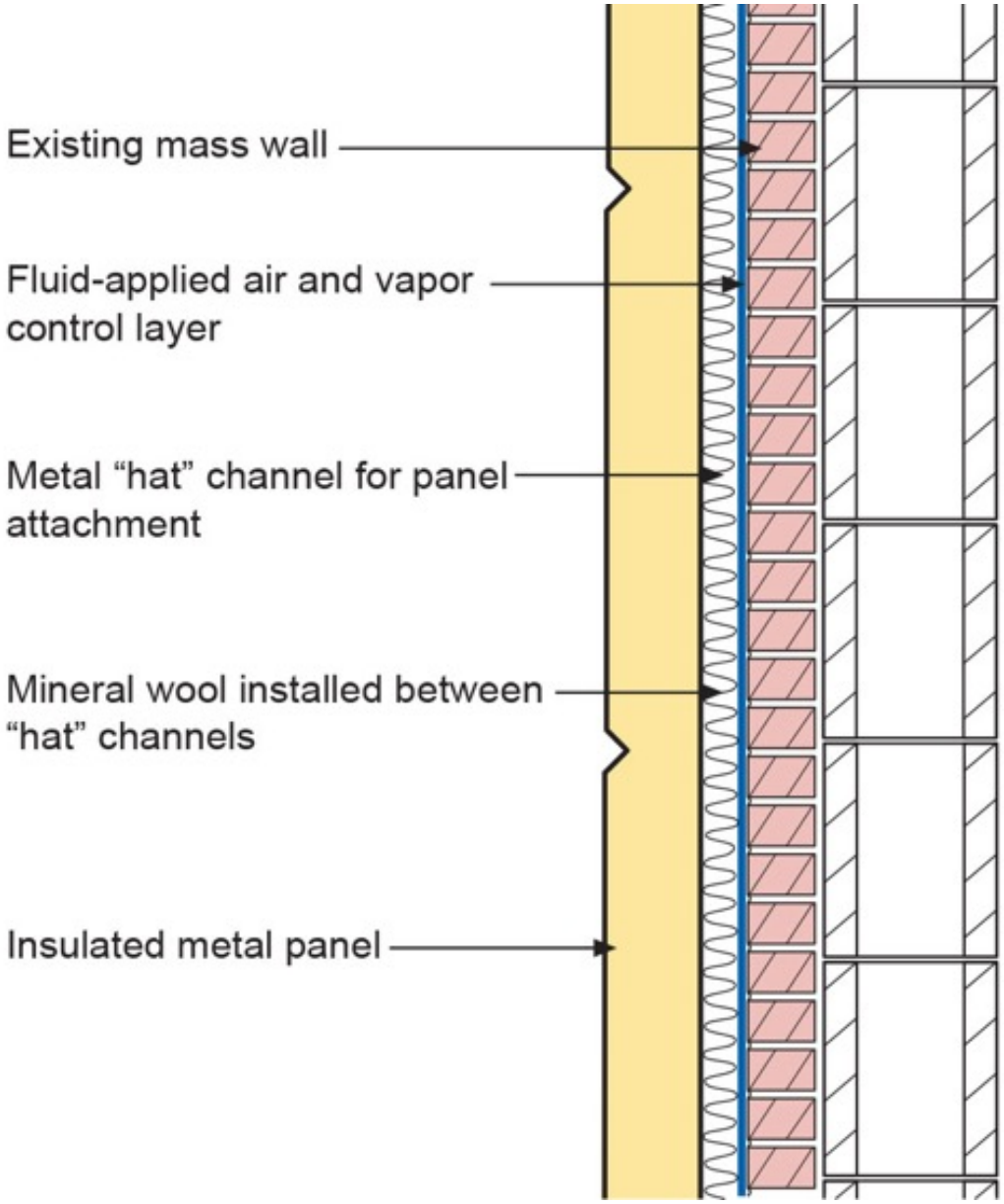


Insulated Metal Panel Roof System

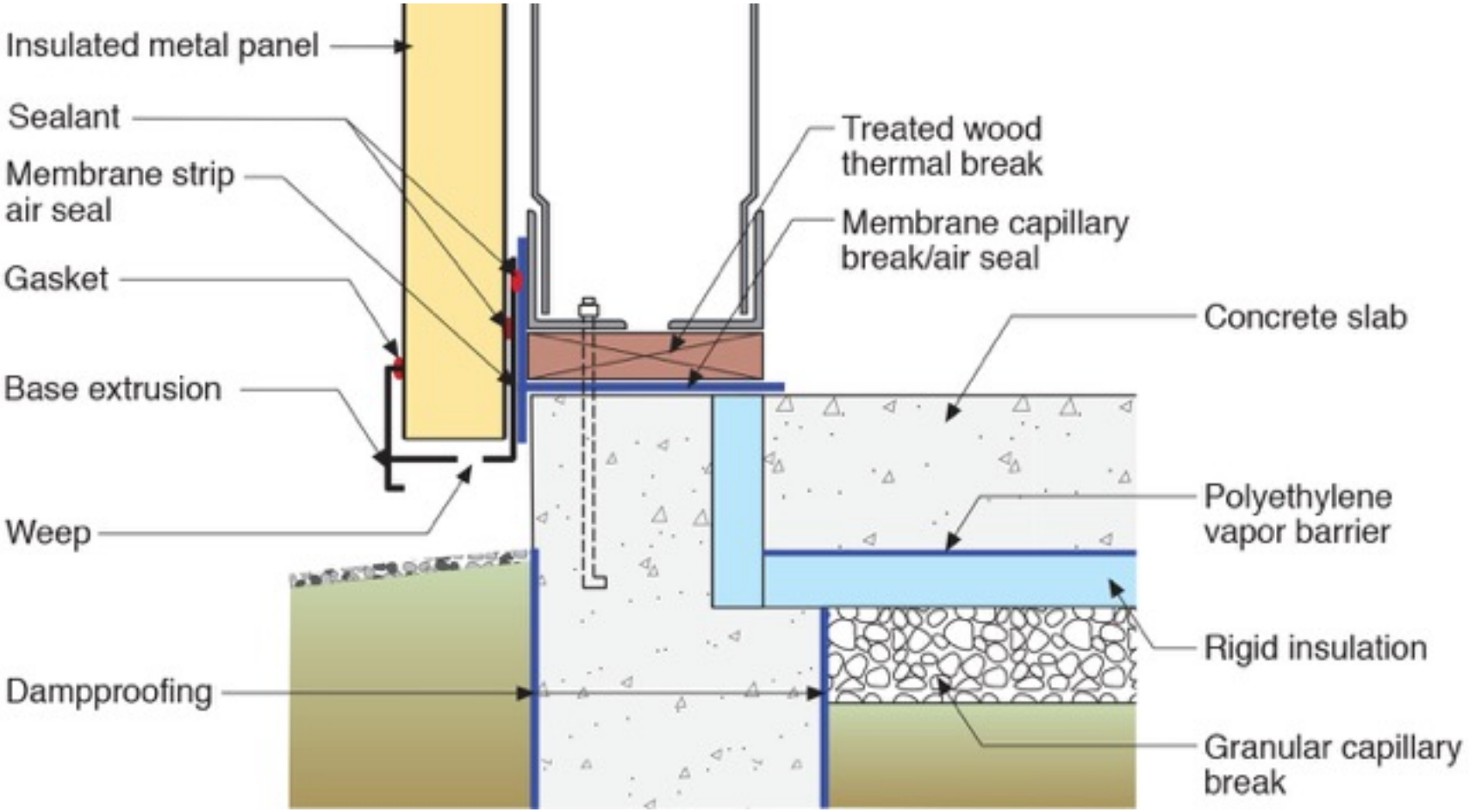


Blanket Insulation Purlin Roof System

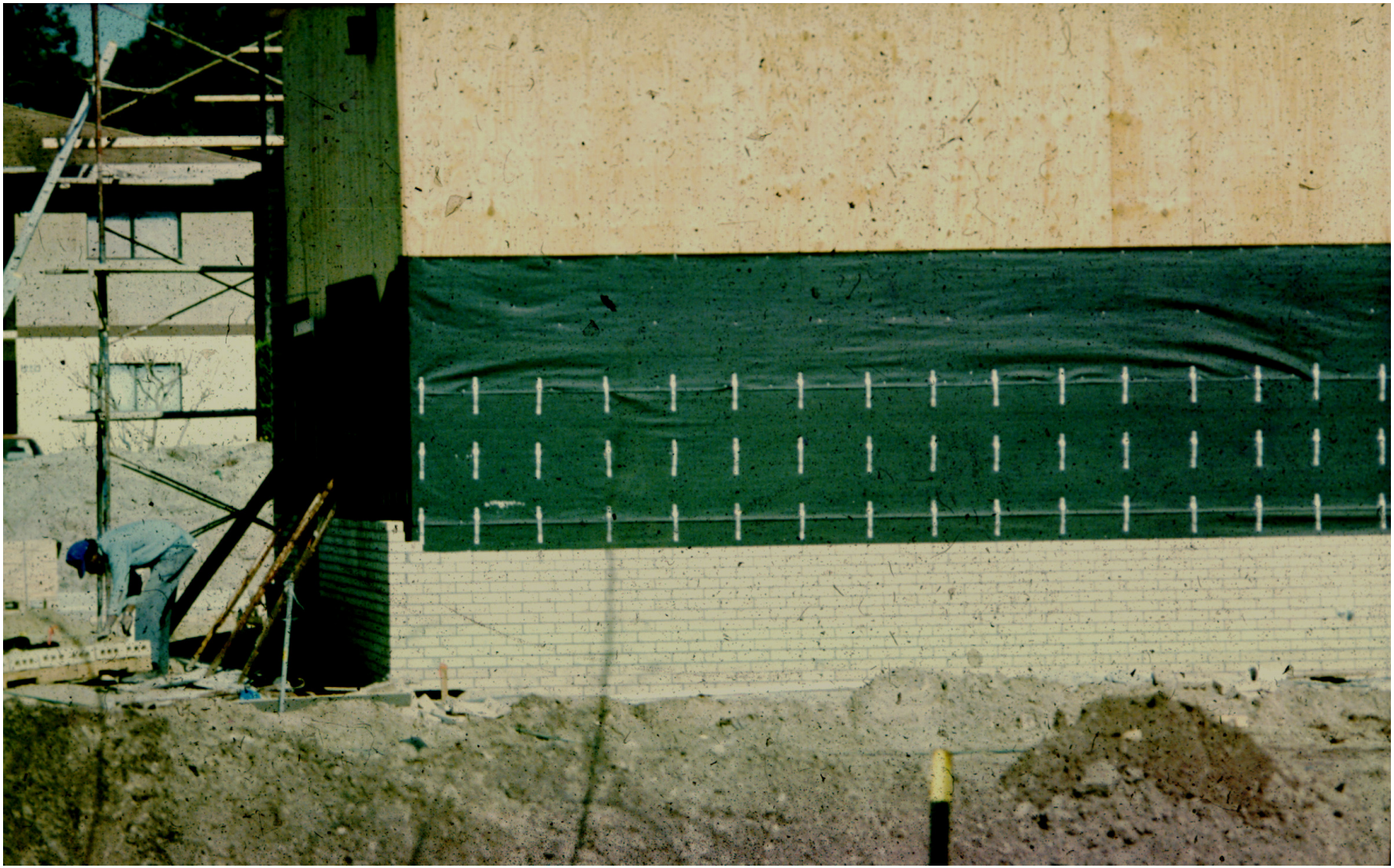

Vapor Profile
Metal cladding
(water control layer)
Interior liner (air control layer
and vapor control layer)
Thermafiber® RainBarrier® 45
mineral wool insulation
Steel frame
Girt

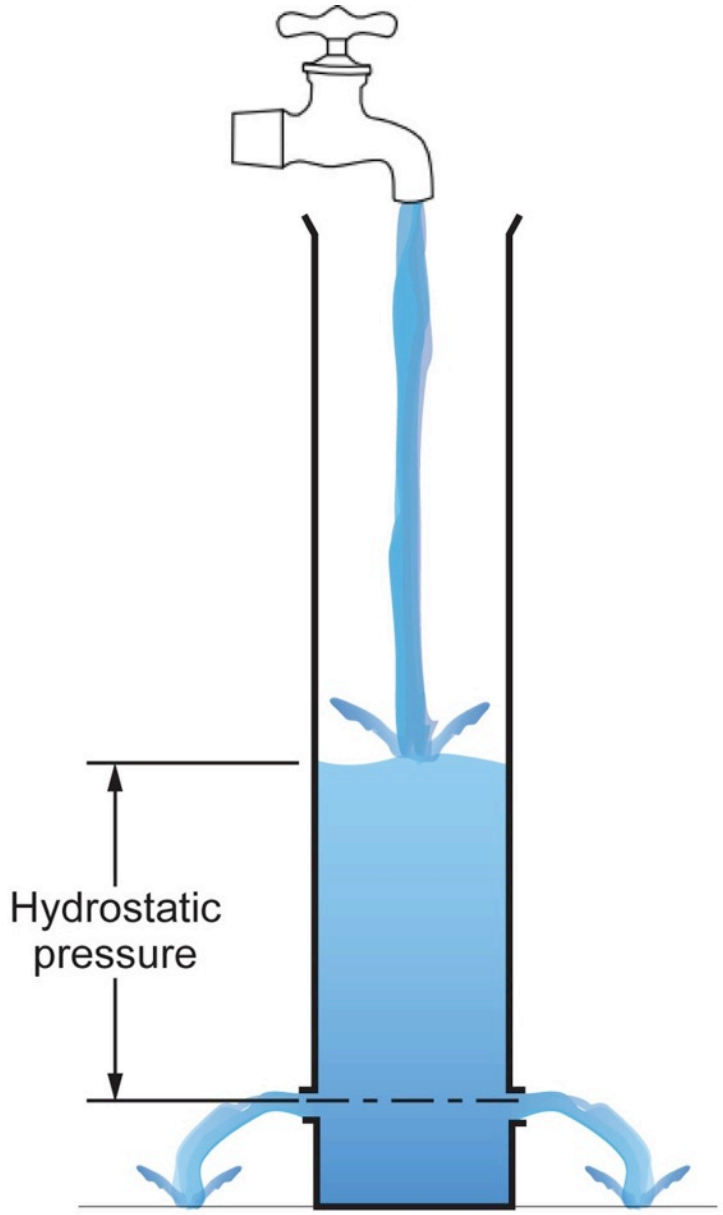

Existing mass wall
Fluid-applied air and vapor control layer
Metal “hat” channel for panel attachment
Mineral wool installed between “hat” channels
Insulated metal panel

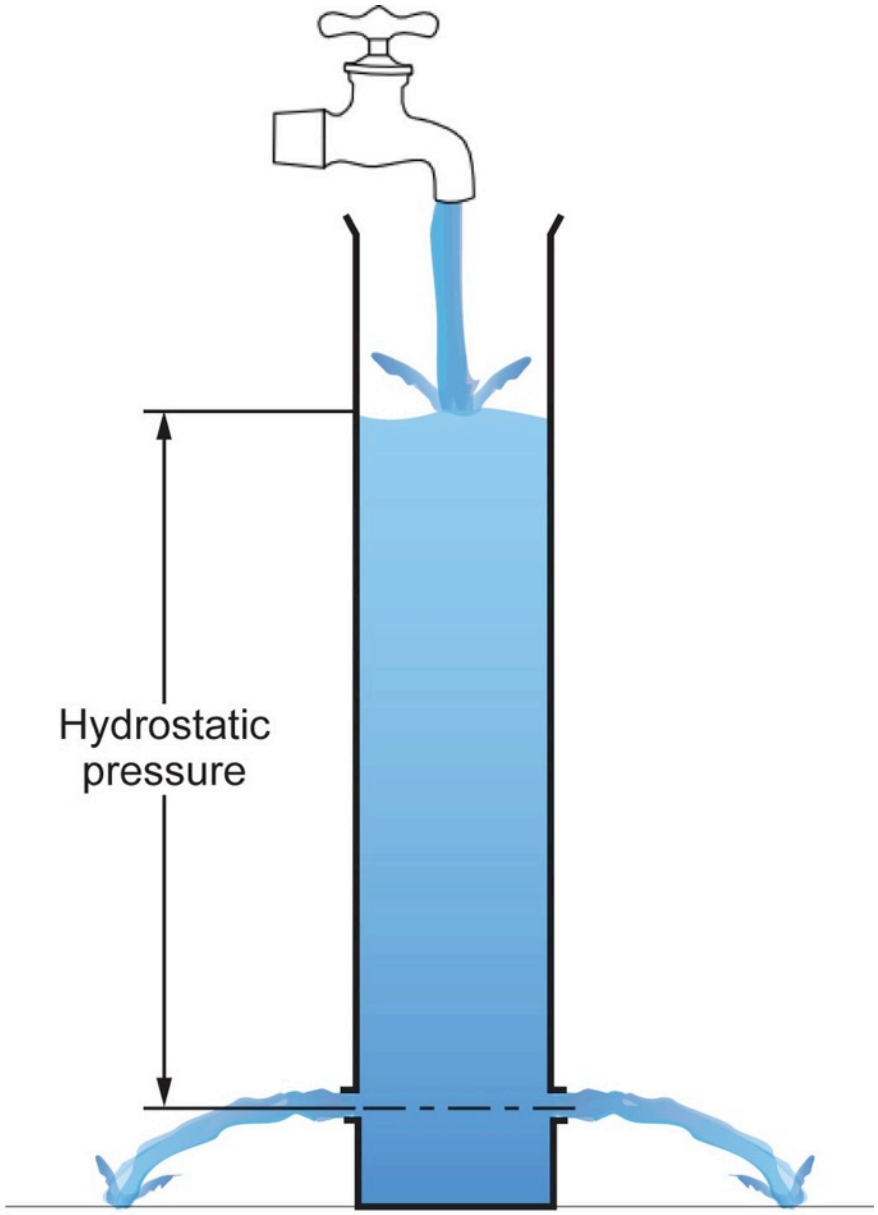

GP
Sheathing


Insulated metal panel
Sealant
Membrane strip air seal
Gasket
Base extrusion
Weep
Dampproofing
Treated wood thermal break
Membrane capillary break/air seal
Concrete slab
Polyethylene vapor barrier
Rigid insulation
Granular capillary break

Rain




Hydrostatic
pressure


Hydrostatic
pressure


yvek
omeWrap
Tyve
HomeWrap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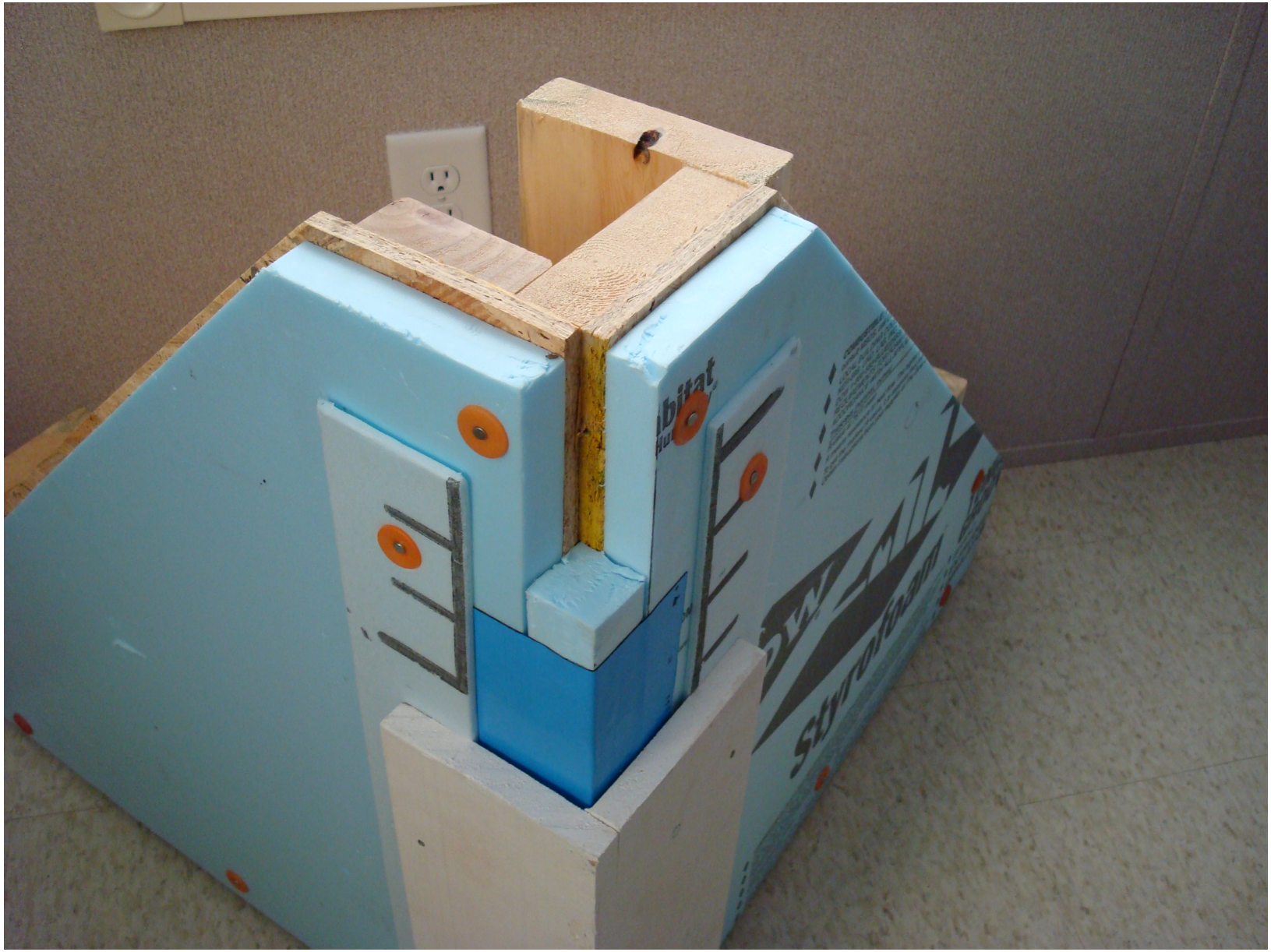
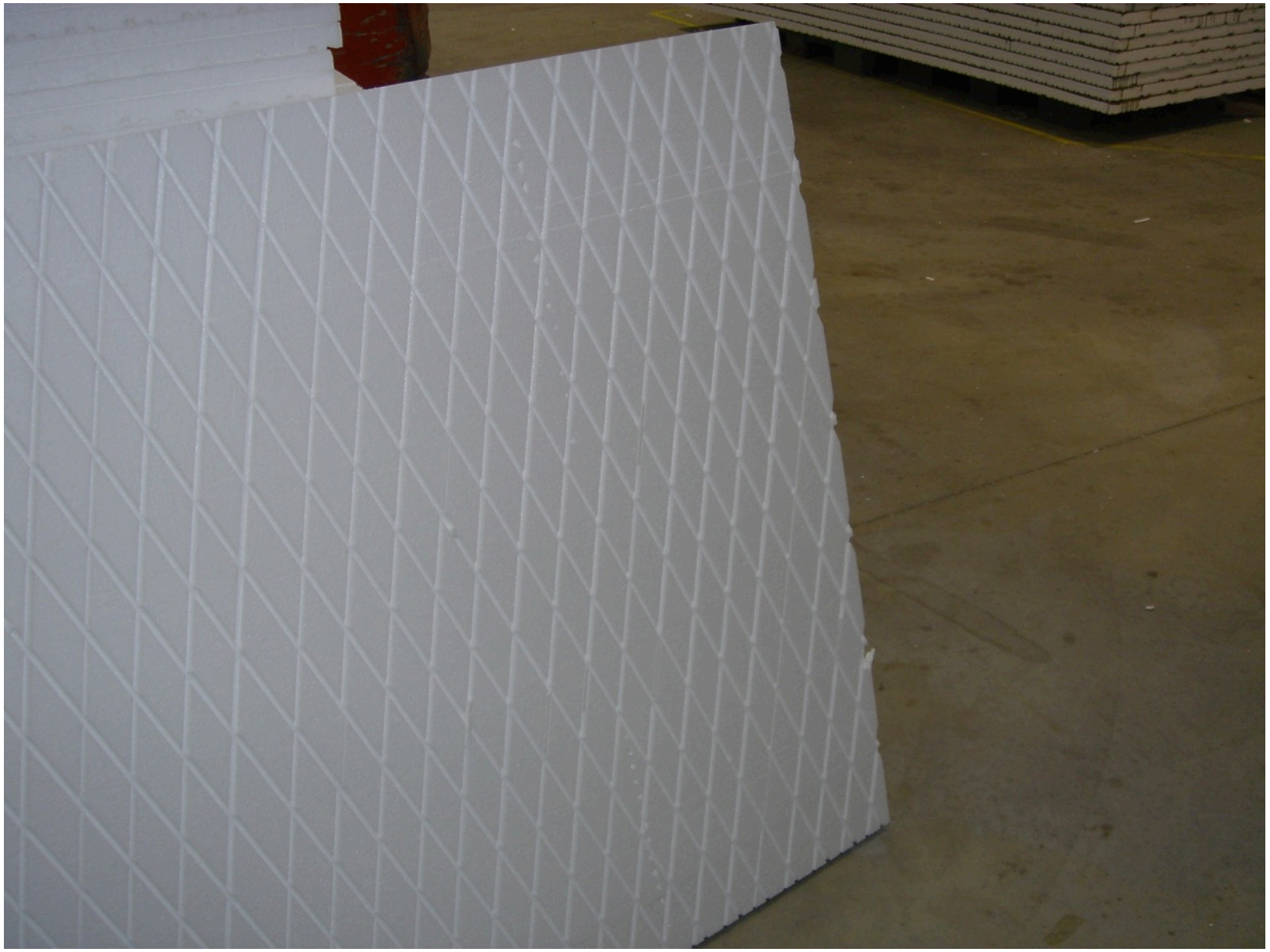
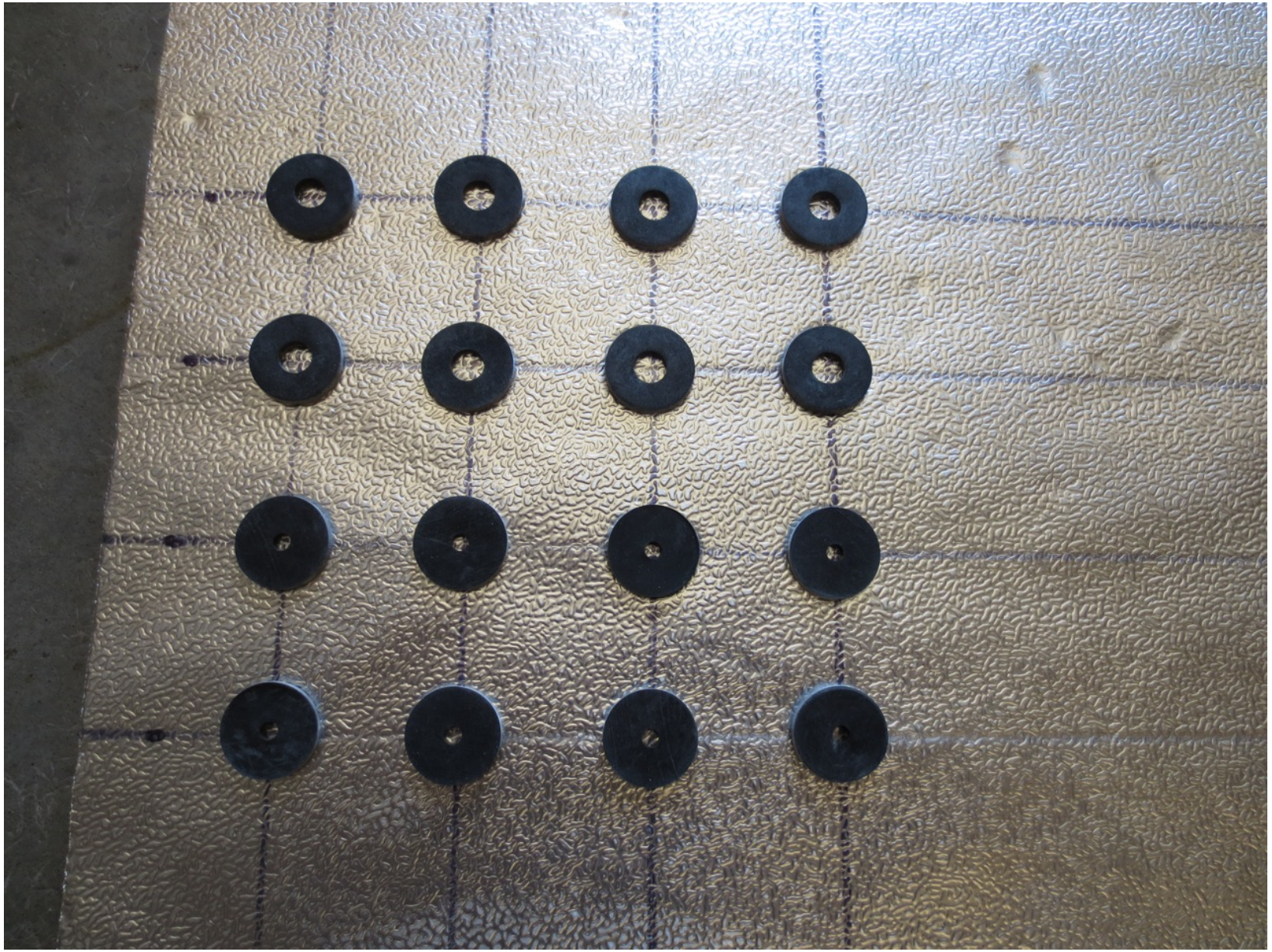
WWW.TYVEK.COM


Styrofoam

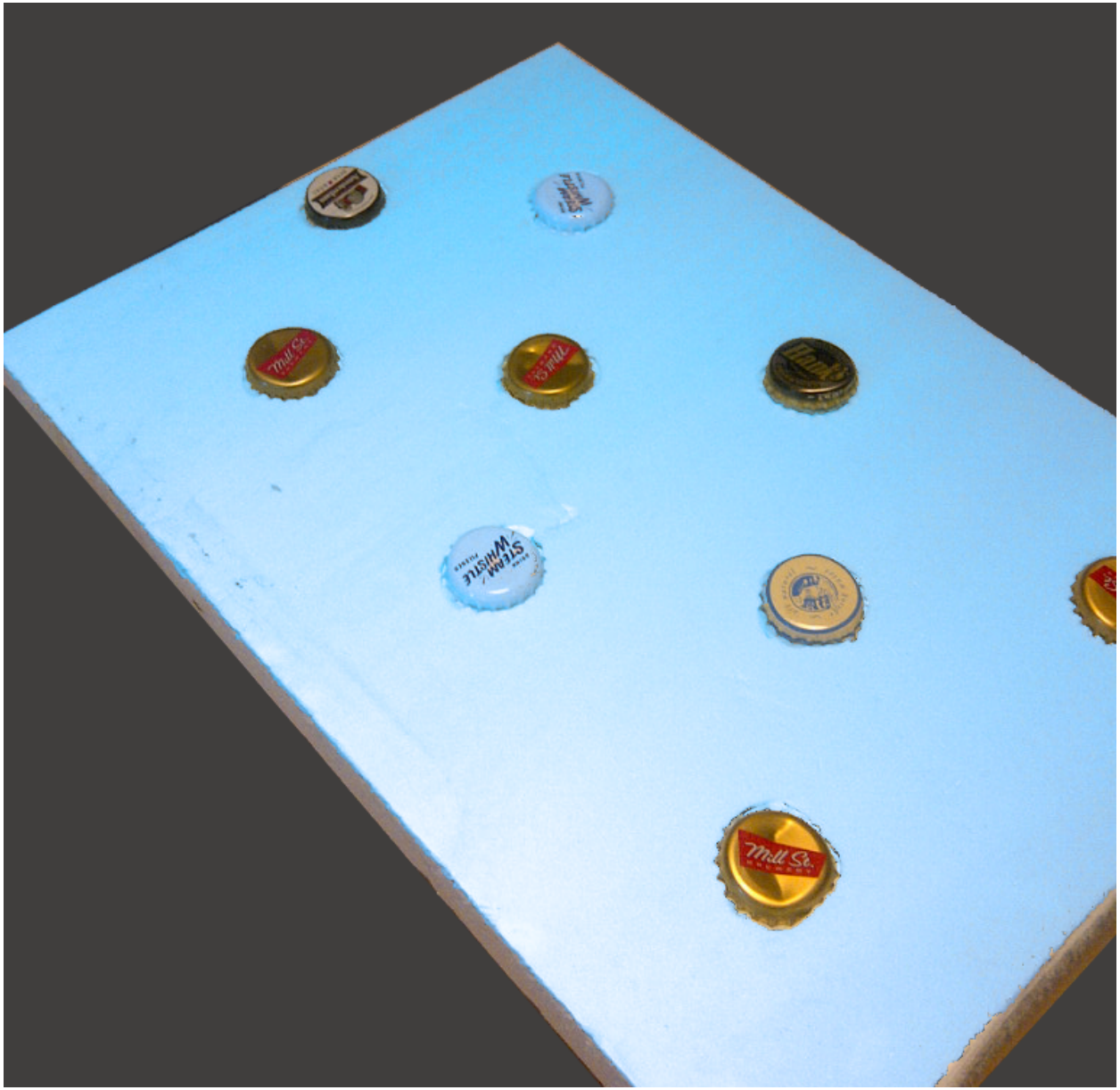

DuPont
Tyvek
Tape
DuPont
Tyvek
Tape



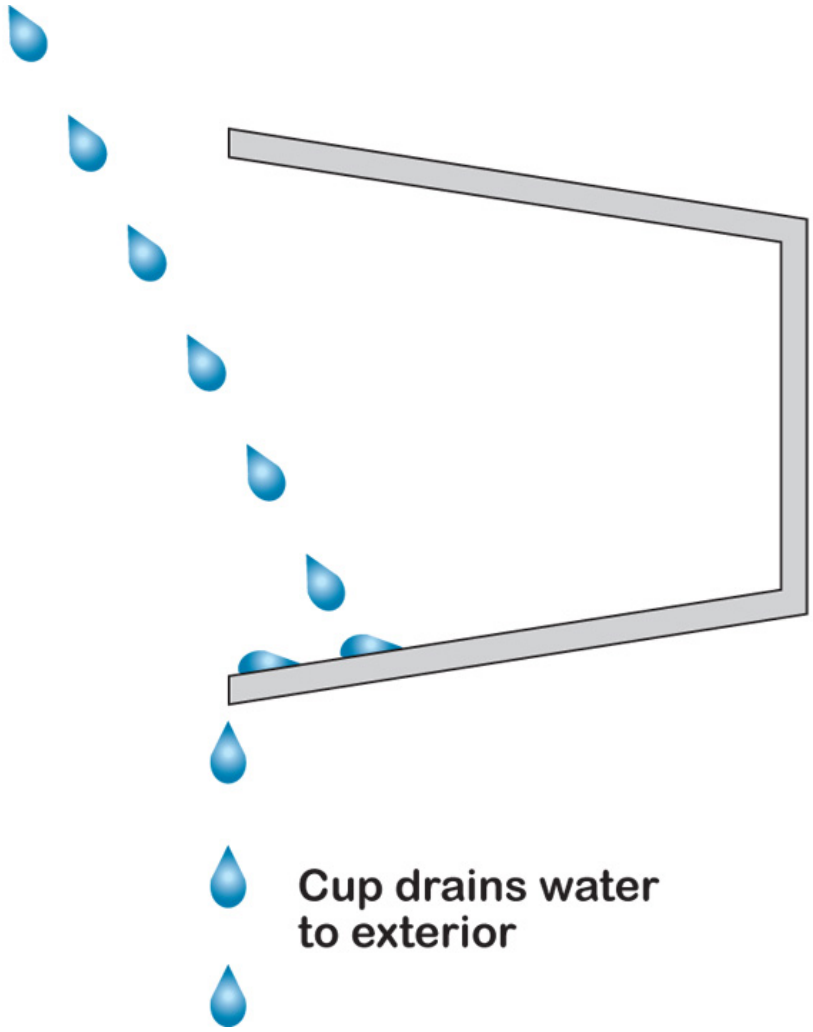
Rain Screen



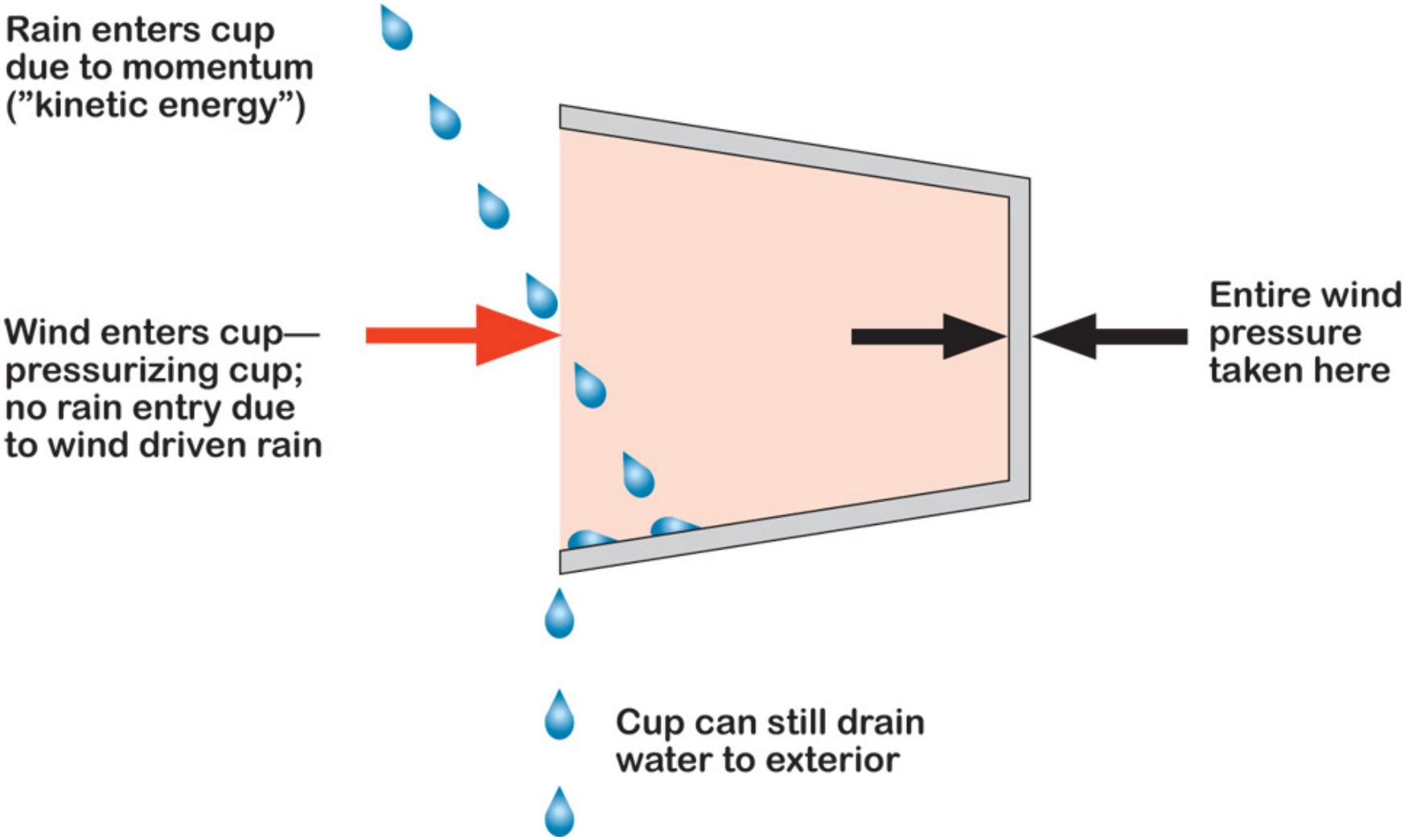
Beer Screen?

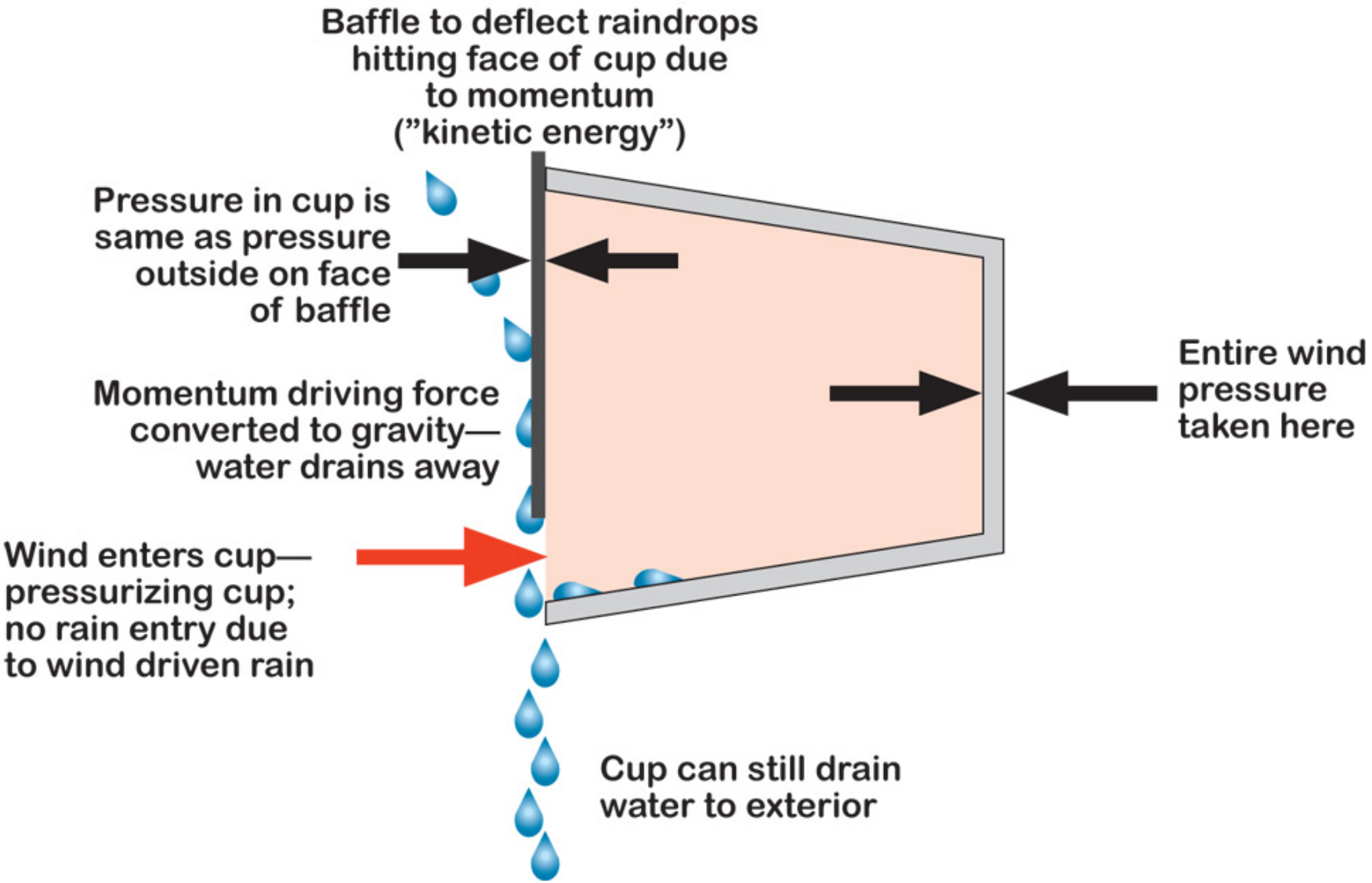

Mill St.
Steam Whistle
Mill St.

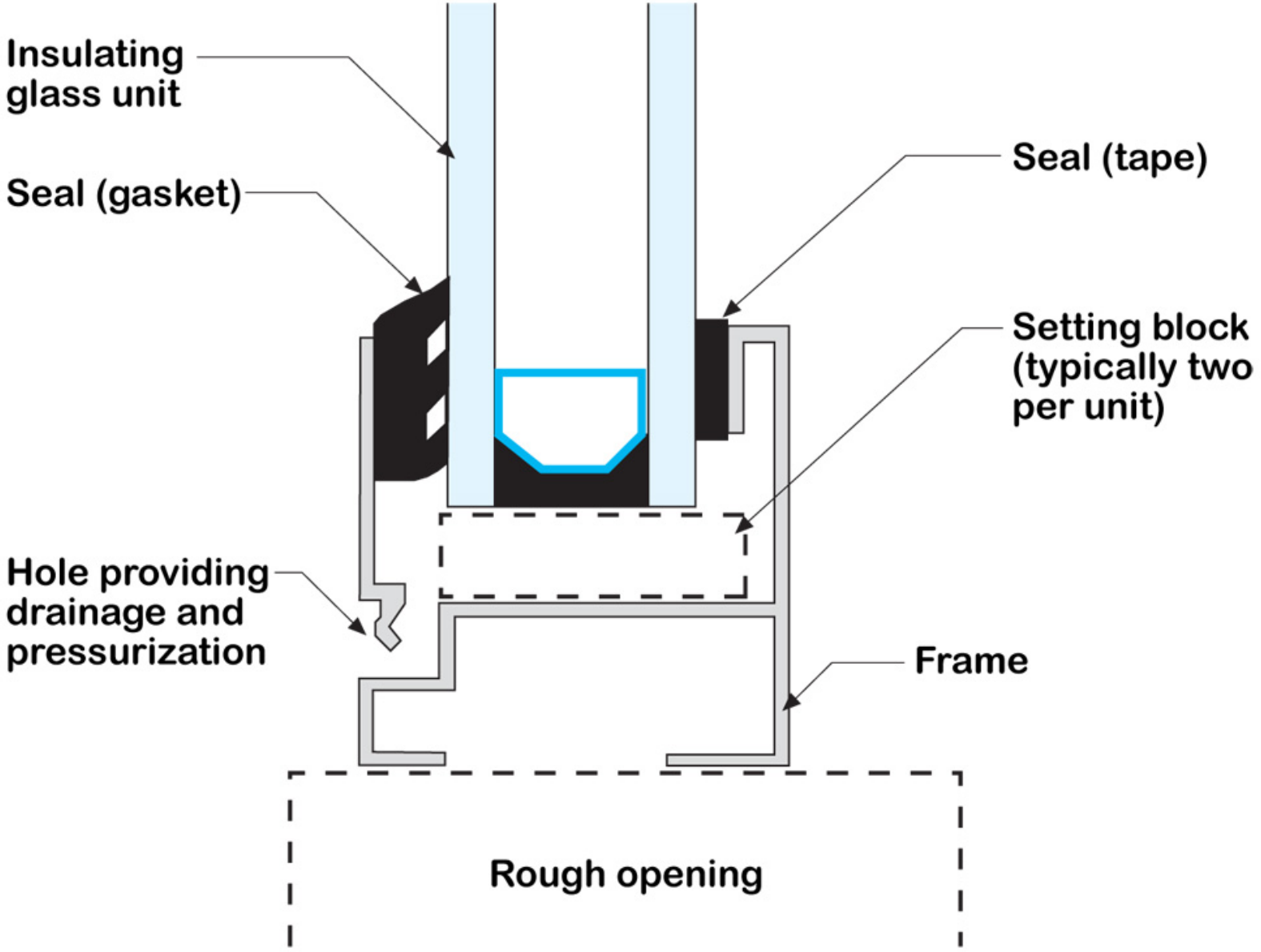
Rain enters cup due to momentum ("kinetic energy")

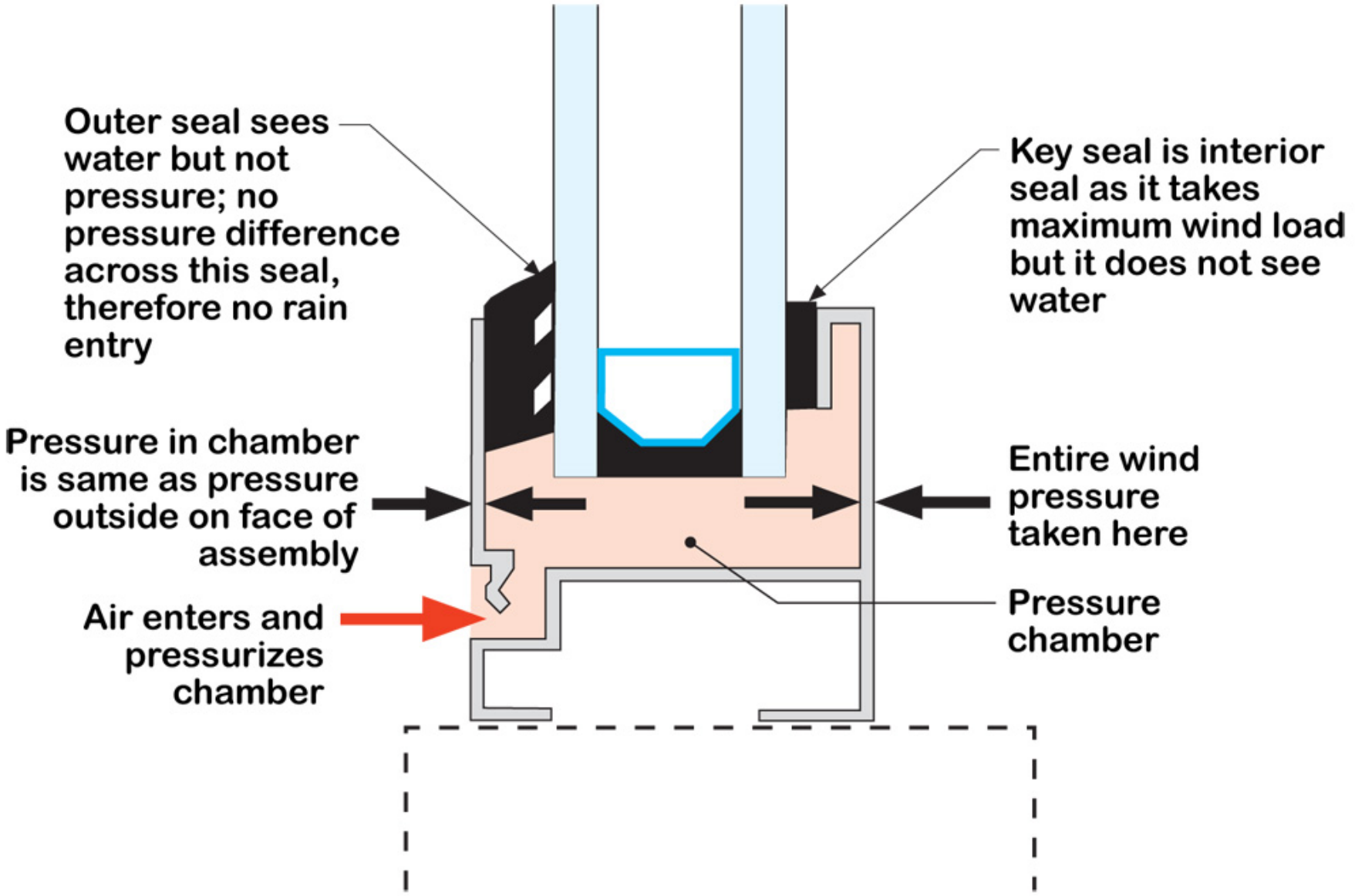


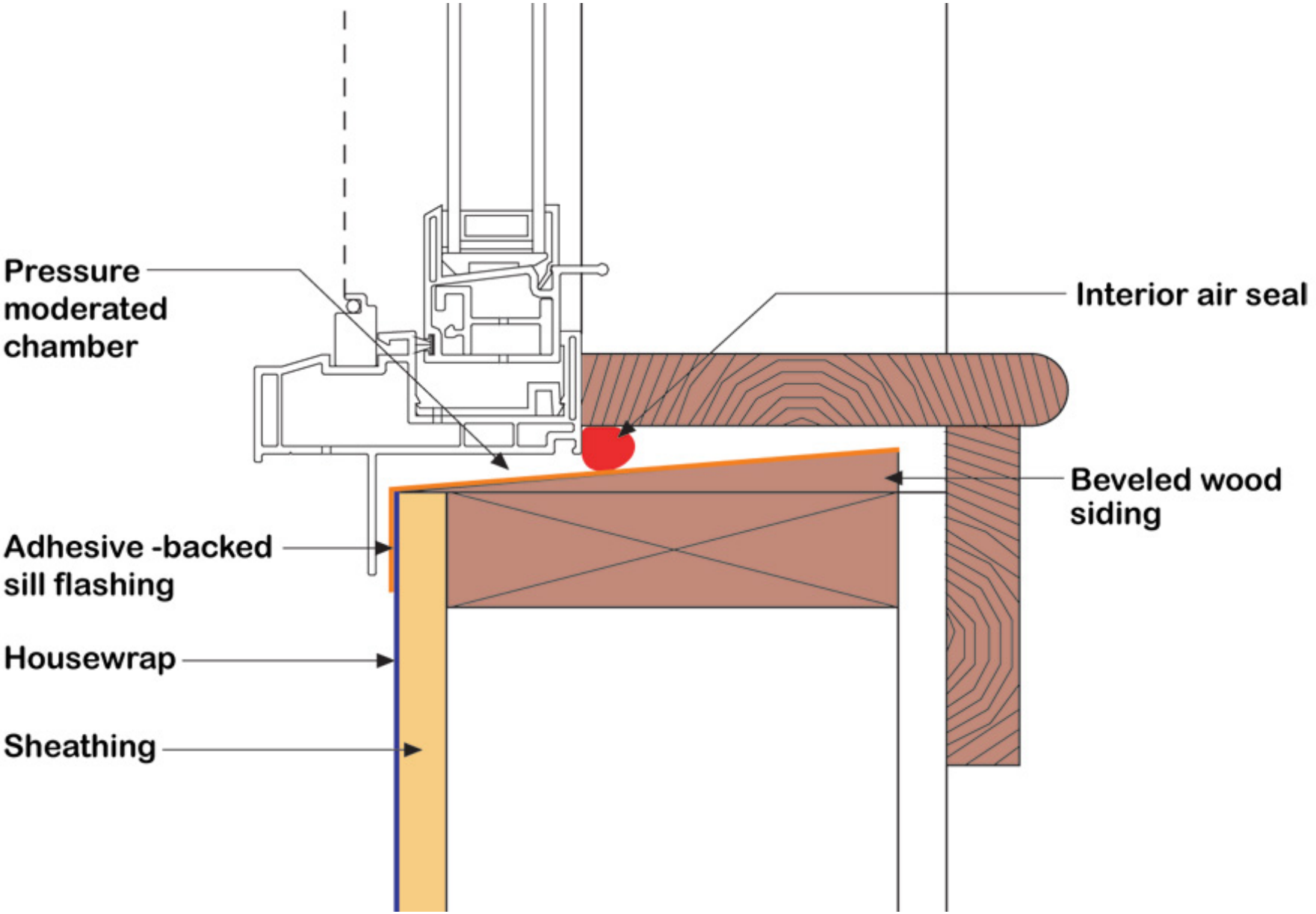
Cup drains water to exterior


Rain enters cup due to momentum ("kinetic energy")
Wind enters cup— pressurizing cup; no rain entry due to wind driven rain
Entire wind pressure taken here
Cup can still drain water to exterior

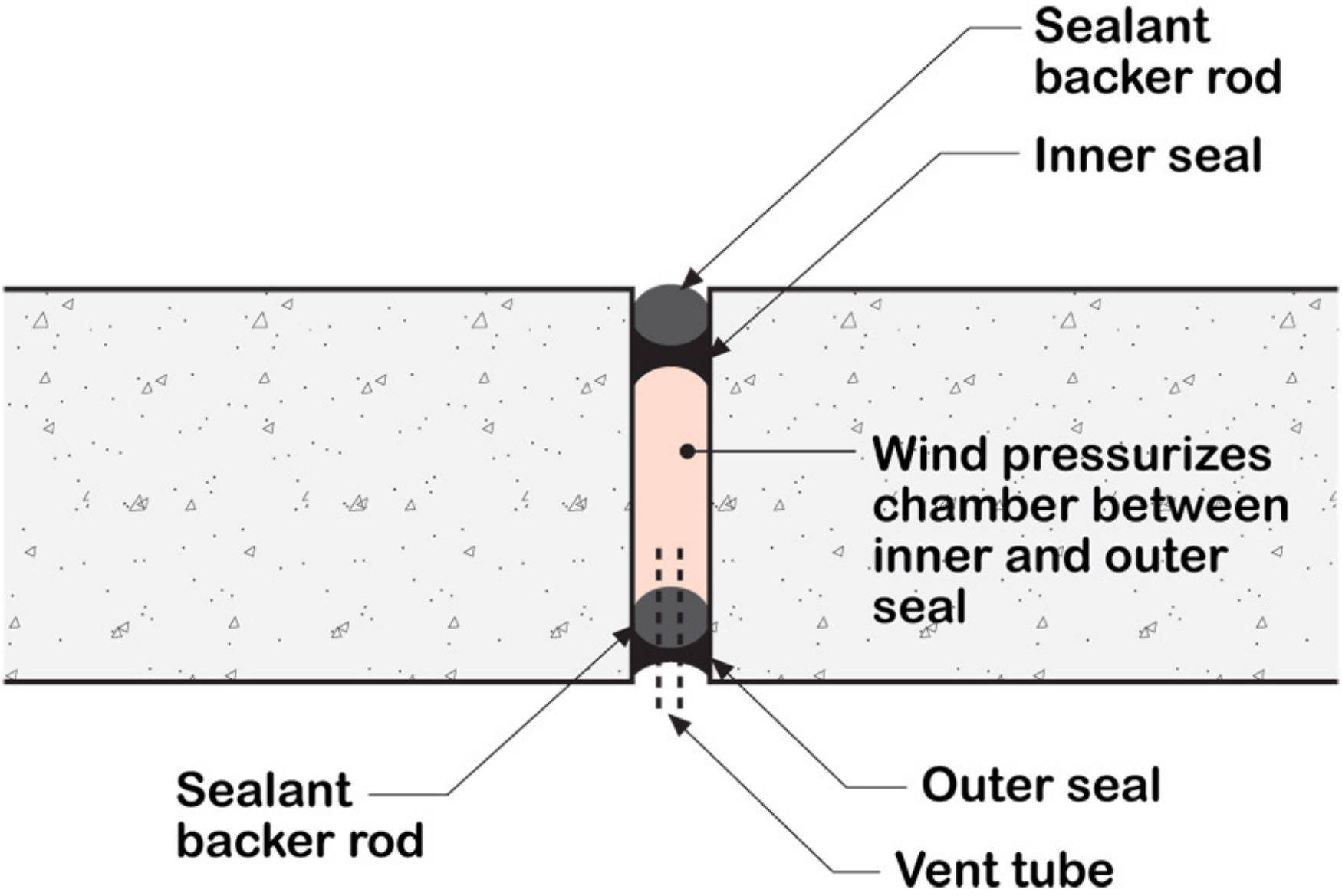

Baffle to deflect raindrops hitting face of cup due to momentum ("kinetic energy")
Pressure in cup is same as pressure outside on face of baffle
Momentum driving force converted to gravity— water drains away
Wind enters cup— pressurizing cup; no rain entry due to wind driven rain
Entire wind pressure taken here
Cup can still drain water to exterior

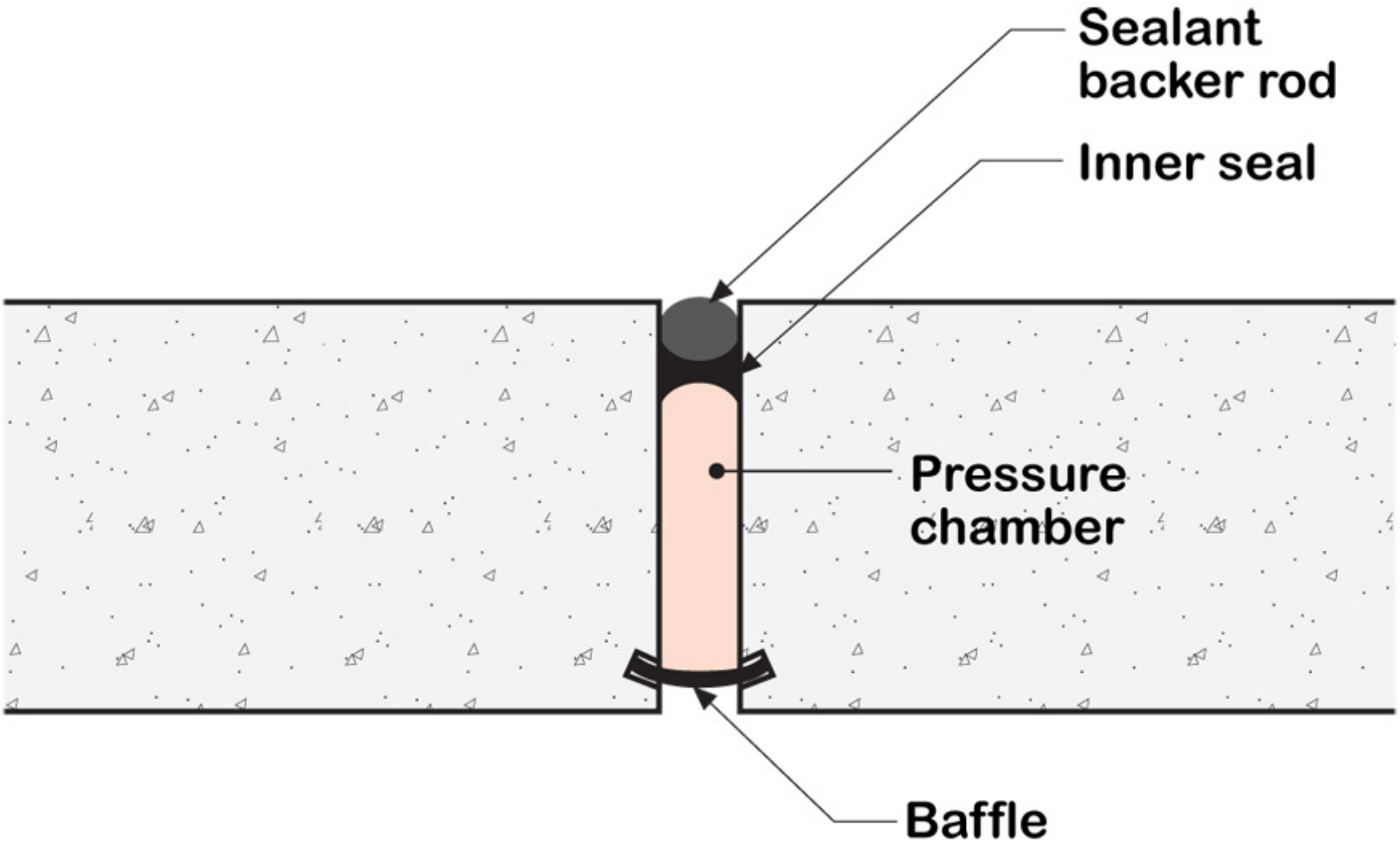

Insulating glass unit
Seal (gasket)
Seal (tape)
Setting block (typically two per unit)
Hole providing drainage and pressurization
Frame
Rough opening

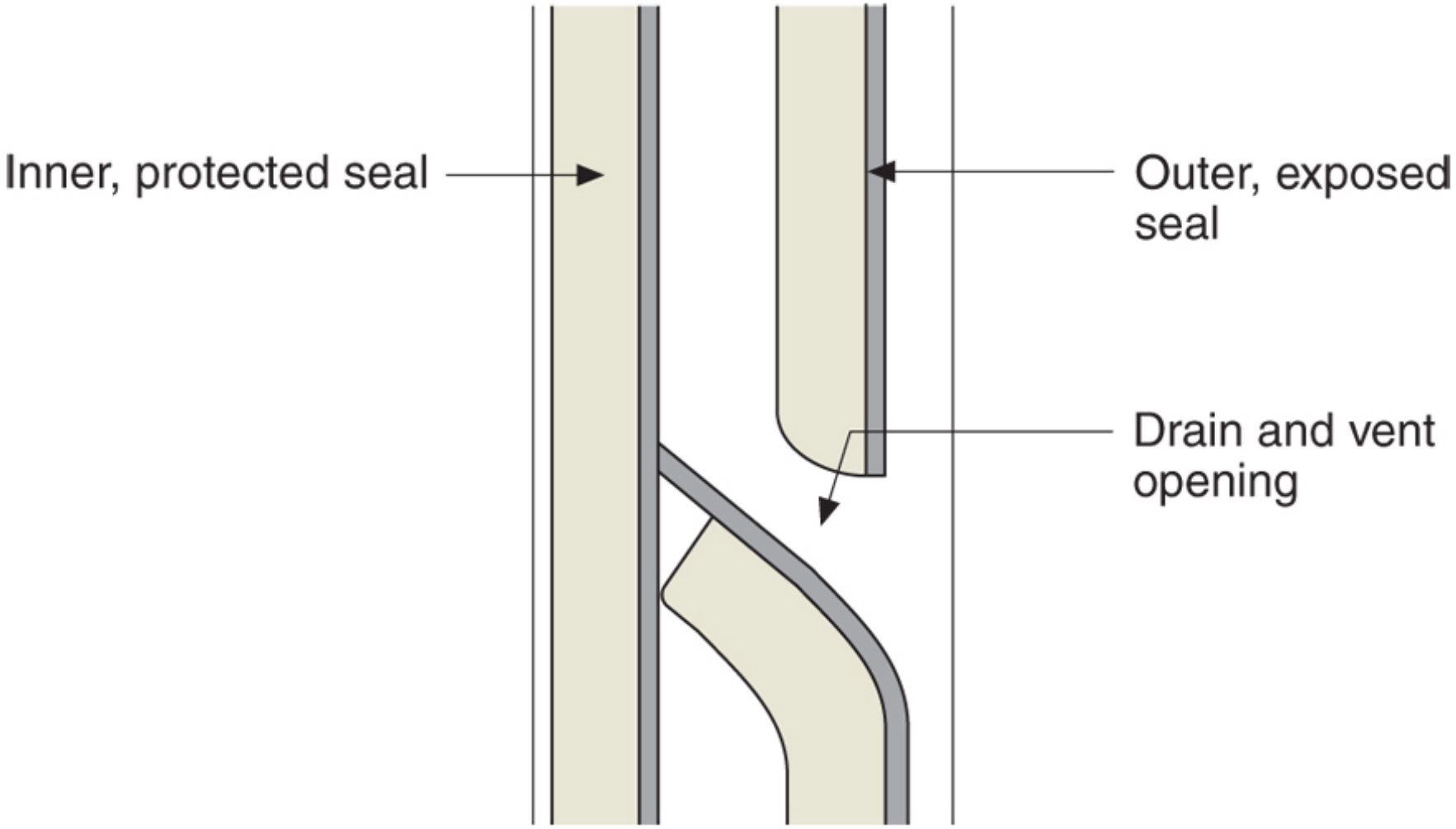

Outer seal sees water but not pressure; no pressure difference across this seal, therefore no rain entry
Key seal is interior seal as it takes maximum wind load but it does not see water
Pressure in chamber is same as pressure outside on face of assembly
Entire wind pressure taken here
Air enters and pressurizes chamber
Pressure chamber

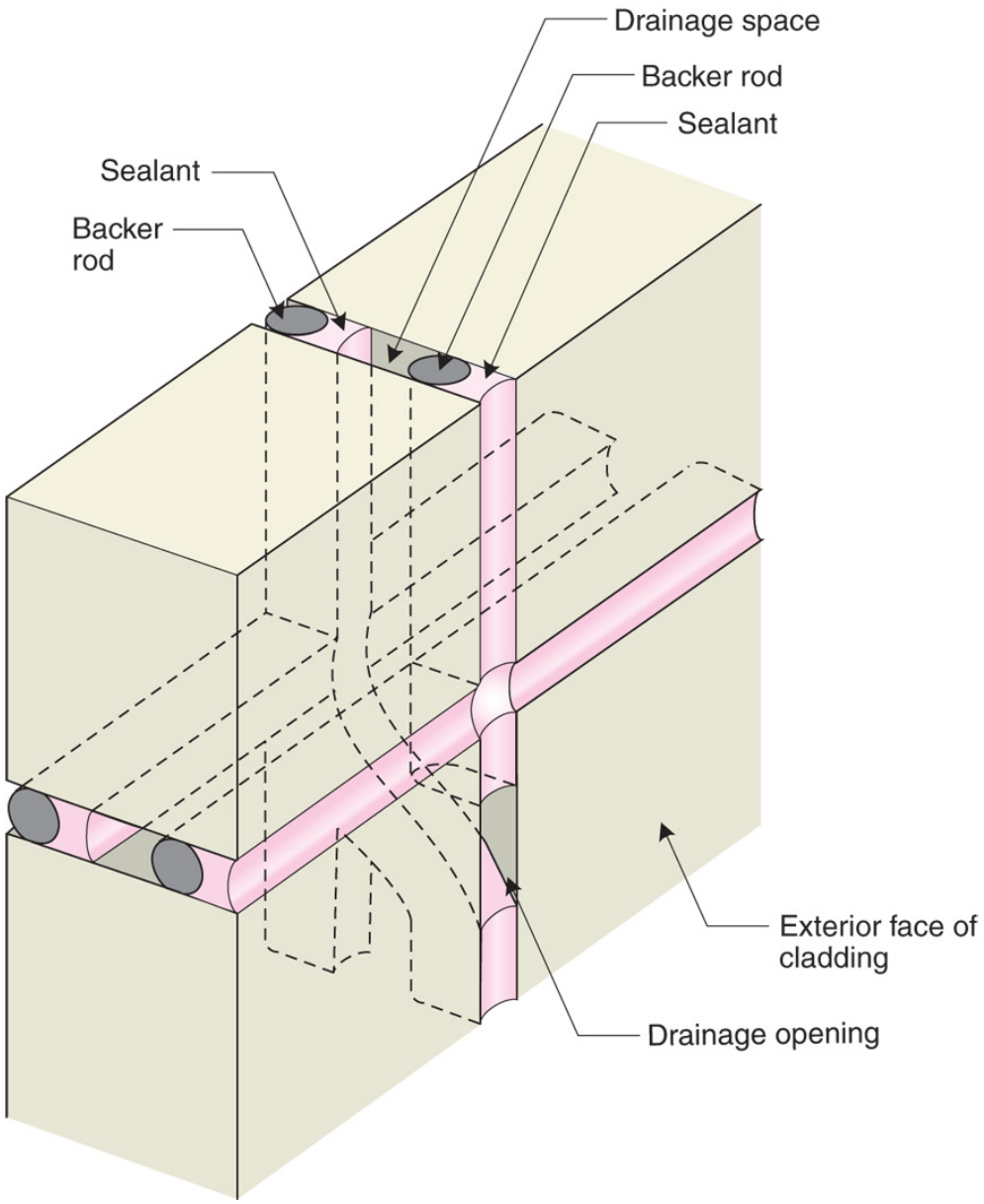

Pressure moderated chamber
Interior air seal
Beveled wood siding
Adhesive -backed sill flashing
Housewrap
Sheathing

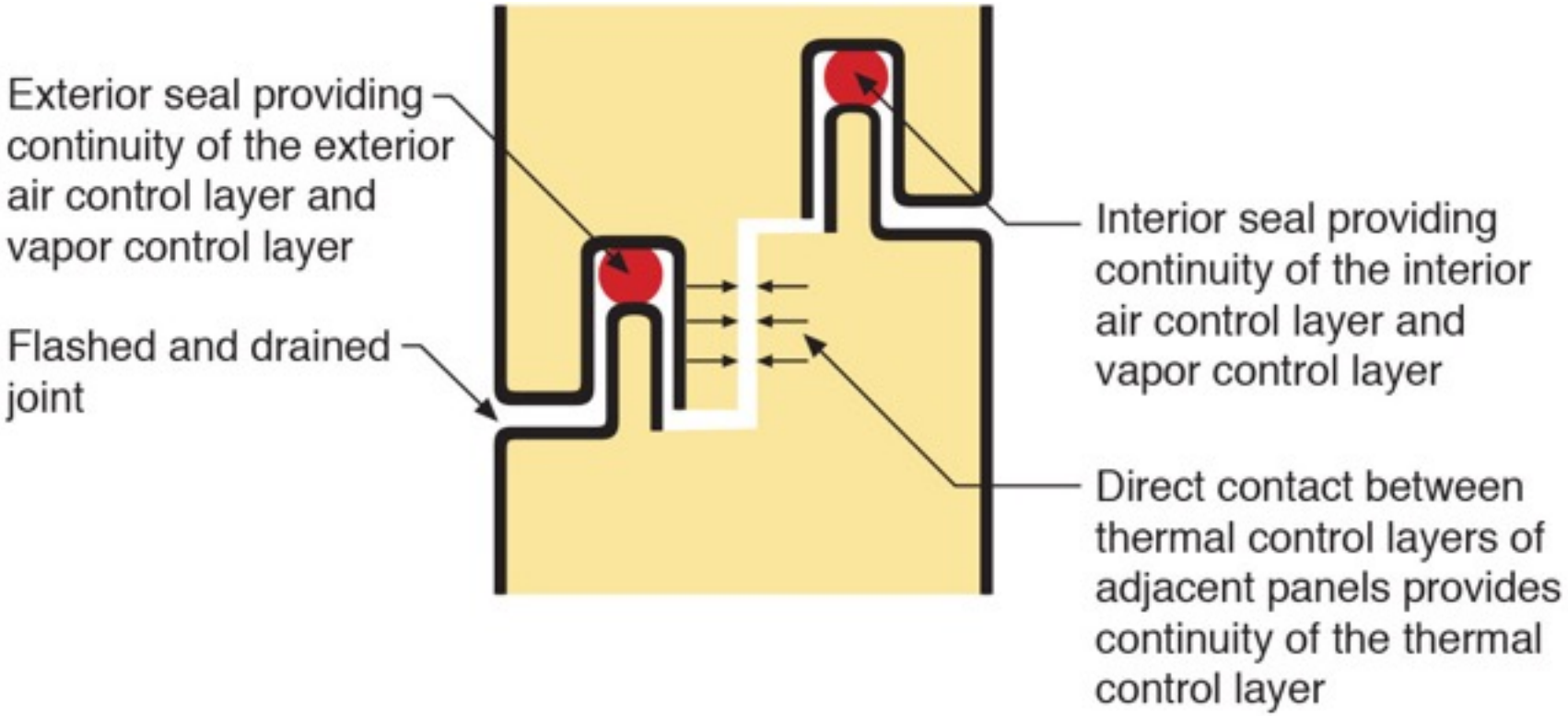

DOW
Styrofoam

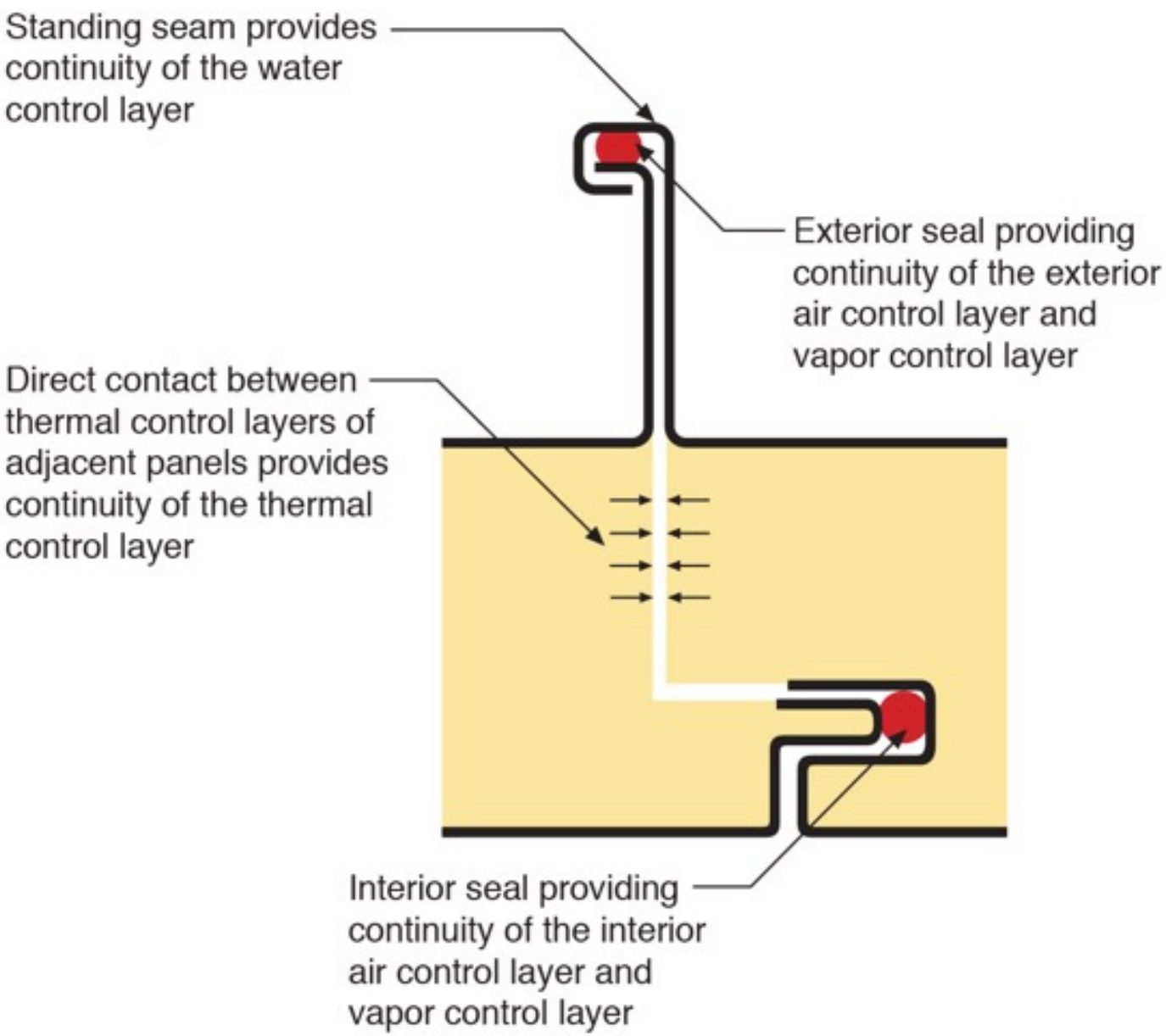

Sealant backer rod
Inner seal
Wind pressurizes chamber between inner and outer seal
Sealant backer rod
Outer seal
Vent tube

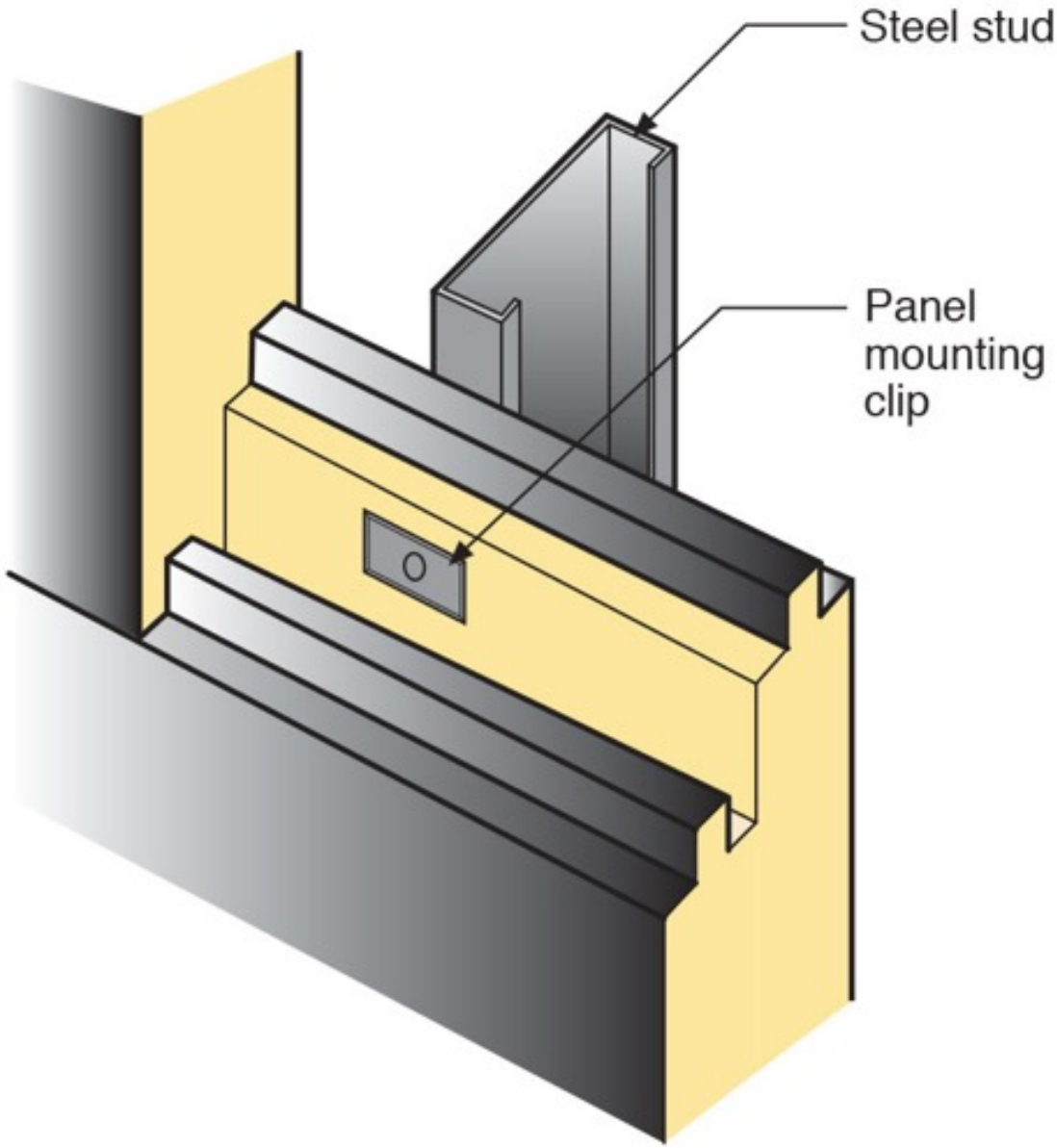

Sealant
backer rod
Inner seal
Pressure
chamber
Baffle

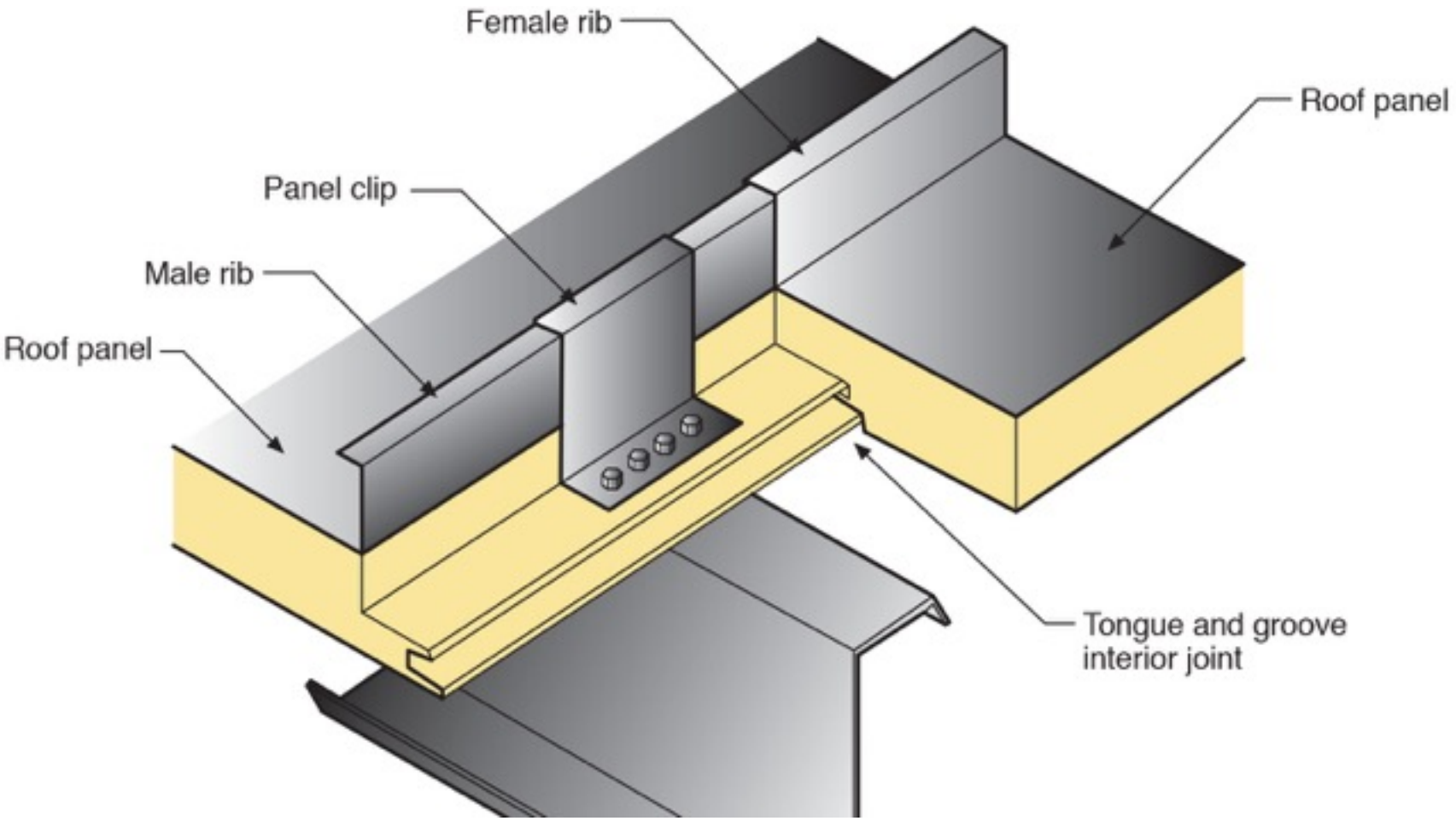

Inner, protected seal
Outer, exposed seal
Drain and vent opening


Drainage space
Backer rod
Sealant
Sealant
Backer rod
Exterior face of cladding
Drainage opening


Exterior seal providing continuity of the exterior air control layer and vapor control layer
Flashed and drained joint
Interior seal providing continuity of the interior air control layer and vapor control layer
Direct contact between thermal control layers of adjacent panels provides continuity of the thermal control layer


Standing seam provides continuity of the water control layer
Exterior seal providing continuity of the exterior air control layer and vapor control layer
Direct contact between thermal control layers of adjacent panels provides continuity of the thermal control layer
Interior seal providing continuity of the interior air control layer and vapor control layer


Steel stud
Panel
mounting
clip


Female rib
Roof panel
Panel clip
Male rib
Roof panel
Tongue and groove
interior joint