Water Control Layer
Air Control Layer
Vapor Control Layer
Thermal Control Layer
Cladding

Control layers

Structure
Hours of a winter day

Temperature (°C)

Temperature (°F)

Membrane

Outside air

From Baker, M.; Roofs, 1980
Insulation moved because of poor adhesion to deck and between layers

Top four courses of brick and wood blocking pulled inward by contracting membrane

Adapted from Baker, M.; Roofs, 1980; Courtesy National Research Council of Canada
Ballast (rock, pavers, earth)

Filter fabric

Extruded polystyrene insulation

Sloped concrete topping; slope minimum 2% to drains

Concrete structural deck

Drainage gap, i.e., drainage mat or grooved insulation

Fully-adhered roof membrane
Really Heavy Pink Stuff

Liquid Waterproofing over Concrete Deck
Wind across the corner of a roof produces a vortex spreading along edges from the windward corner.

Adapted from Baker, M., Roofs, 1980; Courtesy National Research Council of Canada.
Wind

No parapet

Low parapet

High parapet

Adapted from Leutheusser, H.J.; 1964; Courtesy University of Toronto
Exterior - Cold

Water-shedding rain screen roof

Roof Space - Cold

Thermal control layer

Interior - Warm

Air control layer

*From Baker, M.; Roofs, 1980*
Roof insulation

Insulation wind baffle
2” minimum space

Water protection membrane

Continuous ridge ventilation

Attic ventilation

Continuous soffit vent

Vinyl or aluminum siding

Rigid insulation (taped or sealed joints)

Unfaced cavity insulation, cellulose or low-density spray-applied foam

Gypsum board with vapor semi-permeable (latex) paint

Consider increasing depth of insulation by using deeper trusses or oversized (longer) trusses

Caulking or sealant

Gypsum board with permeable (latex) paint
Note: Colored shading depicts the building’s thermal barrier and pressure boundary. The thermal barrier and pressure boundary enclose the conditioned space.
Note: Colored shading depicts the building's thermal barrier and pressure boundary. The thermal barrier and pressure boundary enclose the conditioned space.
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
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

- Roof sheathing
- Roofing paper
- Shingles
- structural insulated panel
- area prone to moisture damage
- movement of air and moisture in panel joint towards roof peak
- open joint
Sealant at this location would not have prevented failure.

Continuous sealant at this location, or at a location closer to the interior, would have prevented failure.

Continuous sealant at this location would have prevented failure.
Legend

- Green arrows: Upper level air flows
- Blue arrows: Lower level air flows
- Orange arrows: Air flow at panel joints
New roofing system

Fully adhered membrane

Roof sheathing

Two layers of rigid insulation (joints staggered and offset)

Fully adhered membrane air barrier

Gypsum sheathing

Fluted metal deck
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)

\( \frac{3}{8} \)” sheathing over rigid insulation
Roof sheathing
Sealant
Rigid insulation notched around roof trusses and sealed

Underside of roof sheathing is typically the “first” condensing surface

Unfaced batt insulation
Gypsum board with vapor semi-permeable (latex) paint

Vinyl or aluminum siding
Rigid insulation
Building paper drainage plane
Dew point temperature at 50% R.H., 70°F

Dew point temperature at 40% R.H., 70°F

Mean monthly outdoor temperature

First condensing surface temperature (underside of roof sheathing) if R-5 rigid insulation is installed over roof deck
The inside face of the roof sheathing forming the cavity is the first condensing surface.

OSB or plywood nail base for shingles

R-30 unfaced batt ceiling insulation compressed to fit within 2x8 rafters or damp spray cellulose or “netted” dry blown cellulose or fiberglass

R-5 rigid insulation (vertical and horizontal joints offset from roof sheathing)

OSB or plywood roof sheathing

Gypsum board ceiling with semi-vapor permeable (latex) paint

Caulking or sealant

Gypsum board with semi-vapor permeable (latex) paint

Rigid insulation notched around roof rafters and sealed

Vinyl or aluminum siding

Rigid insulation (taped, shiplapped or sealed joints)

Unfaced batt insulation

Sealant
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

Unfaced batt insulation

Rigid insulation

Gypsum board with vapor semi-permeable (latex) paint

Building paper 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; housewraps, building paper in all other climates)

Gypsum board with semi-permeable (latex) paint
Sealant, adhesive or gasket at top plate

Cavity insulation

Polymer modified (PM) or traditional cement stucco
Metal lath
Building paper bond break over drainage plane

Metal cap
OSB sheathing
Scupper
Sealant
Rigid insulation
OSB
Cavity insulation
Sealant
Map of DOE's Proposed Climate Zones

March 24, 2003

Building Science Corporation
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

Gypsum board with latex paint (acts as thermal barrier separating occupiable space from non-occupiable space)