A Little Venting about Venting and Other Elements of Thermal Dynamics

Joe Lstiburek
Building Science Corporation
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Vented and Unvented Roof Assemblies

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

presented by www.buildingscience.com
Roof insulation

Insulation wind baffle
2” minimum space

Water protection membrane

Continuous ridge ventilation

Attic ventilation

Continuous soffit vent

Gypsum board with vapor semi-permeable (latex) paint

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

Caulking or sealant

Vinyl or aluminum siding

Rigid insulation (taped or sealed joints)

Gypsum board with permeable (latex) paint

Unfaced cavity insulation, cellulose or low-density spray-applied foam
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
PSYCHROMETRIC CHART
NORMAL TEMPERATURES
SI METRIC UNITS
Barometric Pressure 101.325 kPa
SEA LEVEL
Most of the time the water ends up on the cold spot…Duh…
Relative Humidity
Vapor Pressure
Sorption
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.
Ice Dams
Equation [4]

\[ k_{\text{eff}} = 0.138 - 1.010 \rho + 3.233 \rho^2 \]

\[ R^2 = 0.79 \]
Solar radiation warms cladding

Warm air is trapped by overhang

Cladding warms air
The Myth of the Dew Point
Outside

Exterior sheathing

Dewpoint (50% RH, 70°F)

Location of condensation and frost

Inside

70°F

0°F
Simple linearized energy-temperature relation for water
From Straube & Burnett, 2005
Outside

Condensation and frost accumulating on underside of roof sheathing

Attic

Attic insulation

Inside

Dewpoint
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
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

Insulation/sheathing interface temperature (R-7.5 sheathing, R-13 cavity insulation as shown in adjacent drawing)
Mean monthly outdoor temperature
Dew point temp. at 35% R.H., 70°F
Potential for condensation

Month

Temperature (°F)

0 10 20 30 40 50 60 70 80
APR MAY JUN JUL AUG SEP OCT NOV DEC JAN FEB MAR APR MAY
Figure 8-7. Outside vapour pressure, saturated vapour pressure and inside vapour pressure for Winnipeg.
Cladding

Furring

Rigid Insulation

Air Control Layer (air barrier)

Sheathing

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

Gypsum board
Cladding

Furring

Water Control Layer

Sheathing

Air impermeable insulation
("closed cell" spray polyurethane foam)

Air permeable insulation
(fiberglass batts, netted blown cellulose, netted blown fiberglass, spray applied fiberglass, stone wool / mineral wool batts)

Gypsum board
Map of DOE's Proposed Climate Zones

March 24, 2003
<table>
<thead>
<tr>
<th>Climate Zone</th>
<th>Rigid Board or Air Impermeable Insulation</th>
<th>Total Cavity Insulation</th>
<th>Total Wall Assembly Insulation</th>
<th>Ratio of Rigid Board Insulation or Air Impermeable R-Value to Total Insulation R-Value</th>
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<tbody>
<tr>
<td>4C</td>
<td>R-2.5</td>
<td>R-13</td>
<td>R-15.5</td>
<td>15%</td>
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<tr>
<td></td>
<td>R-3.75</td>
<td>R-20</td>
<td>R-23.75</td>
<td>15%</td>
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<td>5</td>
<td>R-5</td>
<td>R-13</td>
<td>R-18</td>
<td>30%</td>
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<tr>
<td></td>
<td>R-7.5</td>
<td>R-20</td>
<td>R-27.5</td>
<td>30%</td>
</tr>
<tr>
<td>6</td>
<td>R-7.5</td>
<td>R-13</td>
<td>R-20.5</td>
<td>35%</td>
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<tr>
<td></td>
<td>R-11.25</td>
<td>R-20</td>
<td>R-31.25</td>
<td>35%</td>
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<tr>
<td>7</td>
<td>R-10</td>
<td>R-13</td>
<td>R-28</td>
<td>45%</td>
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<tr>
<td></td>
<td>R-15</td>
<td>R-20</td>
<td>R-35</td>
<td>45%</td>
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<tr>
<td>8</td>
<td>R-15</td>
<td>R-13</td>
<td>R-28</td>
<td>50%</td>
</tr>
<tr>
<td></td>
<td>R-20</td>
<td>R-20</td>
<td>R-40</td>
<td>50%</td>
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*Adapted from Table R 702.1 2015 International Residential Code*
Shingles
Roofing paper
Roof Sheathing
Air impermeable insulation ("closed cell" spray polyurethane foam)

Air permeable insulation ("open cell" spray polyurethane foam)
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; housewraps, 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
Building Science Corporation

Metal cap
18" wide membrane strip under parapet folded down over exterior OSB
Coping wedge
OSB
Rubber roofing membrane
OSB sheathing
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
### Insulation for Condensation Control

<table>
<thead>
<tr>
<th>Climate Zone</th>
<th>Rigid Board or Air Impermeable Insulation</th>
<th>Code Required R-Value</th>
<th>Ratio of Rigid Board Insulation or Air Impermeable R-Value to Total Insulation R-Value</th>
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<tbody>
<tr>
<td>1, 2, 3</td>
<td>R-5</td>
<td>R-38</td>
<td>10%</td>
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<td>4C</td>
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<td>R-49</td>
<td>20%</td>
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<tr>
<td>4A, 4B</td>
<td>R-15</td>
<td>R-49</td>
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<td>40%</td>
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<td>50%</td>
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<td>R-49</td>
<td>60%</td>
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<tr>
<td>8</td>
<td>R-35</td>
<td>R-49</td>
<td>70%</td>
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</tbody>
</table>

*Adapted from Table R 806.5 2015 International Residential Code

**Table 1**
Hygric Buoyancy
Dry Air

<table>
<thead>
<tr>
<th>Component</th>
<th>Percentage</th>
<th>Value</th>
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<tbody>
<tr>
<td>Oxygen</td>
<td>(21%)</td>
<td>16</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>(79%)</td>
<td>14</td>
</tr>
<tr>
<td>Component</td>
<td>Percentage</td>
<td>Mass (amu)</td>
</tr>
<tr>
<td>---------------</td>
<td>------------</td>
<td>------------</td>
</tr>
<tr>
<td>Moist Air</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oxygen</td>
<td>(21%)</td>
<td>16</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>(79%)</td>
<td>14</td>
</tr>
<tr>
<td>Water</td>
<td>(tiny)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>less than</td>
<td></td>
</tr>
</tbody>
</table>
Each “Ping” and “Pong” bounces the water molecules up the slope
Shingles
Dense glass gold at ridge
Plywood
Roofing membrane
2x2 framing
Two layers 2” stone wool
Cavity insulation
Zip (OSB) sheathing
Two 2x14 microlams
2x10’s
Plywood
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

- Continuous bead of sealant between OSB and vapor open membrane sheet
- Metal strap nailed over top of vapor open membrane sheet (acting as pressure bar)
- 2x2 furring @ 16" o.c.
Arrhenius Equation
For Every 10 Degree K Rise
Reaction Rate Doubles

\[ k = Ae^{-E_a/(RT)} \]
Damage Functions

Water

Heat

Ultra-violet Radiation
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