Arrhenius Equation
For Every 10 Degree K Rise
Activation Energy Doubles

\[ k = A e^{-E_a/(RT)} \]

Damage Functions
Damage Functions
Water
Heat
Ultra Violet Radiation

Oxidization (Ozone)
Fatigue (Creep)
The Three Biggest Problems In Buildings Are Water, Water and Water…

80 Percent of all Construction Problems are Related to Water
Laws of Thermodynamics

Zeroth Law – A=B and B=C therefore A=C
First Law - Conservation of Energy
Second Law - Entropy
Third Law – Absolute Zero
2nd Law of Thermodynamics

In an isolated system, a process can occur only if it increases the total entropy of the system

Rudolf Clausius
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

Vapor Diffusion
Thermodynamic Potential
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
  - 1½T RH = 75%
Example: Air leakage wetting of sheathing
Interior: 21°C/40% RH
Exterior: -10°C/85% RH
RSL 2.11 batt in stud space
RSL 1.40 insulated sheathing

Cooling and condensation
From Straube & Burnet, 2005

Sorption Isotherms
Change in 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**

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

Moisture Content vs. Relative Humidity

Equilibrium Moisture Content (EMC) %

Relative Humidity (RH) %
Quick Aside - Vented Attics
Vapor Diffusion Vapor Concentration
Convective Flow Air Pressure
Adsorbate Surface Diffusion Concentration
Monolayers of adsorbed water increase with increasing RH.

Monolayers flow along surface following concentration gradient.
Gravel protective cover
Top pour
Felt ply
Interply layers
Adhering layer
Deck, insulation or cover board

Vapor  Diffusion  Vapor Concentration
Convective Flow  Air Pressure

Adsorbate  Surface Diffusion  Concentration

Liquid  Capillary Flow  Suction Pressure

---

**Calculating capillary rise**

\[ h = \frac{2 \sigma \cos \theta}{g \rho f} \]

**Diagram:**
- Ambient pressure
- Pressure gradient
- Capillary pressure \( P_{cap} \)
- Height \( h \)
- Contact angle \( \theta \)
- Capillary radius \( r \)
Capillary rise versus diameter

![Graph showing capillary rise versus diameter](image)

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Surface area vs. particle size
From Blaas & Turrell, 2000

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Joseph Lstiburek 56
Heat
Air
Moisture
HAM

Hygrothermal Analysis
Wind Speed (mph) vs. Stagnation Pressure (Pa)

<table>
<thead>
<tr>
<th>Pascals (Pa)</th>
<th>mph</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>29</td>
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<tr>
<td>100</td>
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<tr>
<td>500</td>
<td>65</td>
</tr>
<tr>
<td>1,000</td>
<td>99</td>
</tr>
</tbody>
</table>
Rain Screen
Beer Screen?
Rockwool

1x3 furring @ 24” o.c.
#10 screws @ 16” o.c. vertically
Result: 20 psf cladding weight
with < 2/100” deflection

Myth of the Dew Point
Outside

70°F

Dewpoint (50% RH, 70°F)

Location of condensation and frost

Inside

0°F

Exterior sheathing

May 10, 2016
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

The graph shows:
- Mean monthly outdoor temperature
- Potential dew point temperature
- Insulation/sheathing interface temperature (R-13 cavity insulation as shown in adjacent drawing)
- Dew point temp. at 35% R.H., 70°F
- Dew point temp. at 50% R.H., 70°F
- Dew point temp. at 65% R.H., 70°F

Graph labels:
- Month
- Temperature (°F)

- April
- May
- June
- July
- August
- September
- October
- November
- December
- January
- February
- March
- April

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May 10, 2016

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GVHBA

Heat, Air and Moisture
Figure 8.7. Outside vapour pressure, saturated vapour pressure and inside vapour pressure for Winnipeg.