“It isn’t what we don’t know that gives us trouble, it’s what we know that ain’t so”

Will Rogers

“There are known knowns. These are things we know. There are known unknowns. There are things that we know we don’t know. But there are also unknown unknowns. There are things we don’t know we don’t know.”

Donald Rumsfeld

Order of Magnitude

1 to 10
10 to 100
100 to 1000
1000 to 10000
First Order Effects, Second Order Effects….
What is a Building?

A Building is an Environmental Separator

- Control heat flow
- Control airflow
- Control water vapor flow
- Control rain
- Control ground water
- Control light and solar radiation
- Control noise and vibrations
- Control contaminants, environmental hazards and odors
- Control insects, rodents and vermin
- Control fire
- Provide strength and rigidity
- Be durable
- Be aesthetically pleasing
- Be economical

Zeroth Law – Equal Systems
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

Thermodynamic Potential

Vapor Diffusion
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

Heat
Air
Moisture

HAM

Hygrothermal Analysis
Hygrothermal Analysis

**Moisture Transport in Porous Media**

<table>
<thead>
<tr>
<th>Phase</th>
<th>Transport Process</th>
<th>Driving Potential</th>
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<tbody>
<tr>
<td>Vapor</td>
<td>Diffusion</td>
<td>Vapor Concentration</td>
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<tr>
<td></td>
<td>Convective Flow</td>
<td>Air Pressure</td>
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<td>Adsorbate</td>
<td>Surface Diffusion</td>
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<td>Liquid</td>
<td>Capillary Flow</td>
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<td>Surface Tension</td>
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<tr>
<td></td>
<td>Momentum</td>
<td>Kinetic Energy</td>
</tr>
<tr>
<td></td>
<td>Convective Flow</td>
<td>Air Pressure</td>
</tr>
</tbody>
</table>

**Moisture Transport in Assemblies**

- Capillary suction draws water into porous material and tiny cracks
- Cavity acts as capillary break and receptor for capillary water interrupting flow

Building Science Corporation

Joseph Lstiburek
Surface Energy

- Water (20 C) 73 dynes/cm
- Water (100 C) 59 dynes/cm
- Epoxy 46 dynes/cm
- Polyethylene 31 dynes/cm
- Soapy water 30 dynes/cm
- Paraffin wax 25 dynes/cm
- Silicone 24 dynes/cm
- Teflon 18 dynes/cm

Calculating capillary rise

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

Capillary rise versus diameter

![Graph showing capillary rise versus diameter.](image)
\begin{align*}
J_B &= -k \cdot \text{grad} \Phi_B \\
J_{Bx} &= -k_x \cdot \left( \frac{d}{dx} \right) \Phi_{Bx} \\
k_x &= k_y = k_z
\end{align*}

\begin{align*}
J_V &= -\mu \cdot \text{grad} \, p \\
J_{Vx} &= -\mu_x \frac{dp}{dx} \\
W &= \mu A \Theta \frac{(P_1 - P_2)}{l}
\end{align*}

\begin{align*}
W &= \mu A \Theta \frac{(P_1 - P_2)}{l} \\
&= MA \Theta (P_1 - P_2)
\end{align*}

\begin{align*}
M &= \frac{\bar{\mu}}{l} \\
W &= MA \Theta (P_1 - P_2)
\end{align*}
\[ J_c = -D_c \cdot \text{grad } c \]
Rain Screen

Beer Screen?
Don’t Do Stupid Things
- It is not a good idea to install a vapor barrier (polyethylene) at the inside of an air conditioned assembly. Vinyl wall coverings and foamed-in-place urethane insulation should also be avoided.

- Vapor permeable exterior sheathing. You can trowel-on building paper to cover the sheathing or apply a single-ply foil-backed asphaltic built-up roofing with self-adhered membrane. Roofing felt or roofing mineral-surfaced felt should be used to cover the sheathing. A mineral-surfaced felt placed under the exterior sheathing is a good practice.

- Failure will occur when brick is installed over a thermal wall constructed with felt, fibrous aluminum foil and an exterior polyethylene vapor barrier. Kraft faced fiberglass batts should be used in place of ventilated sheathing to prevent condensation in the wall. If the exterior sheathing is not in place, an air leak will occur at the exterior sheathing.

- To effectively insulate a brick veneer from a wall system by using wall insulation, the insulating layer must also be a vapor barrier. However, if the brick veneer is 4 inches thick, it is very difficult to install a vapor barrier between the brick veneer and the insulation. Alternately, the rigid insulation can be supported on the brick and the brick veneer can be installed directly on top of the insulation. Alternately, the rigid insulation can be supported on the brick and the brick veneer can be installed directly on top of the insulation.

- To effectively insulate a brick veneer from a wall system by using wall insulation, the insulating layer must also be a vapor barrier. However, if the brick veneer is 4 inches thick, it is very difficult to install a vapor barrier between the brick veneer and the insulation. Alternately, the rigid insulation can be supported on the brick and the brick veneer can be installed directly on top of the insulation. Alternately, the rigid insulation can be supported on the brick and the brick veneer can be installed directly on top of the insulation.
Intent of sealant is to limit this lateral flow of water between sheathing and building wrap.

Flash tape
Sealant “bedding” joint

Building wrap “wrapped” into opening