

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

# Building Science

## Adventures In Building Science

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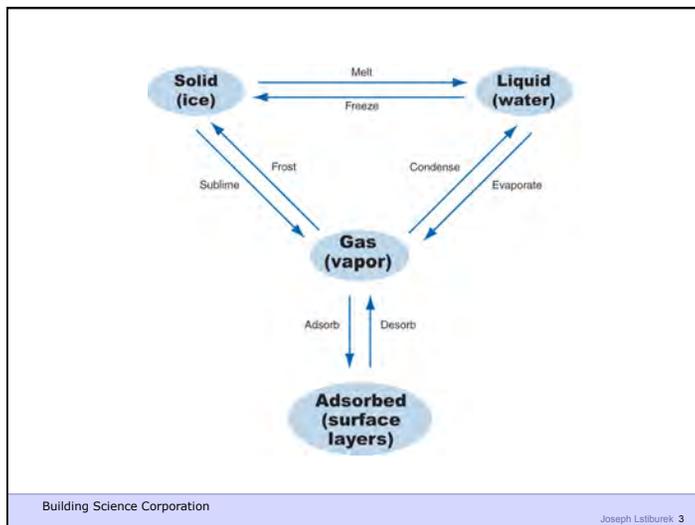
"It isn't what we don't know that gives us trouble, it's what we know that ain't so"

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

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### Moisture transport processes in building materials and components

Transport Process	Phase	Potential (Difference)
Gas diffusion	Vapor	Vapor pressure
Liquid diffusion	Liquid	Concentration
Surface diffusion	Adsorbate	Concentration
Thermal diffusion	Vapor and liquid	Temperature
Capillary flow	Liquid	Suction pressure
Convective flow	Vapor	Air pressure
Gravitational flow	Liquid	Height
Poiseuille flow	Liquid	Liquid pressure

From Kumaran, M. K.; Chapter 1, Moisture in Buildings, ASTM, 1994

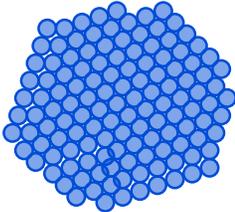
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## Water

- Vapor is a single molecule
- Liquid is molecular clumps, 75 or more

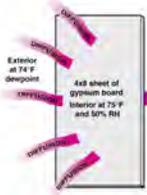


**Vapor**



**Liquid**

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4x8 sheet of gypsum board  
Exterior at 74°F dewpoint  
Interior at 75°F and 50% RH



1 1/2 pints of water

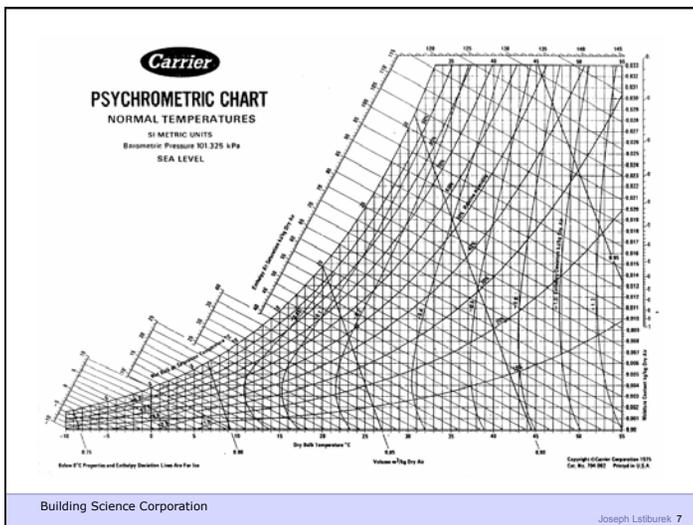


4x8 sheet of gypsum board  
with a 1 sq ft hole  
Exterior at 74°F dewpoint  
Interior at 78°F and 50% RH



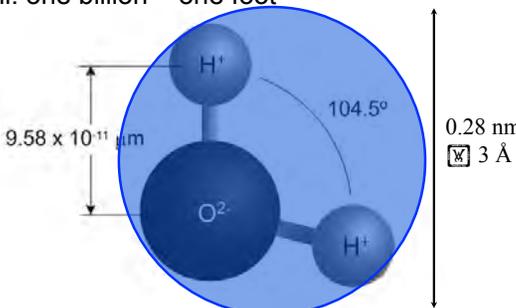
14 pints of water

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## The Water Molecule

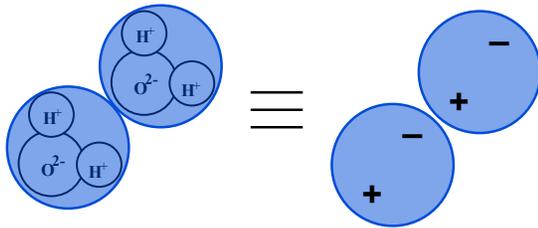
- Asymmetrical = polar
- Small: one billion = one foot



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### The Polar Molecule

- Hydrogen end is “more” positive
- Oxygen end is “more” negative

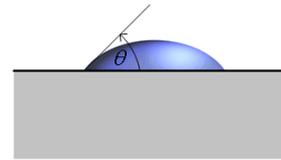


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### Surface Tension: Wettable

**Water attracted to surface more than self**

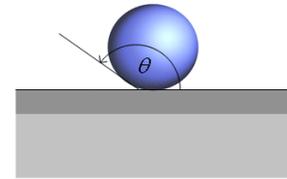
$$\theta < 90^\circ$$



normal material:  
“wetable”

**Water attracted to self more than surface**

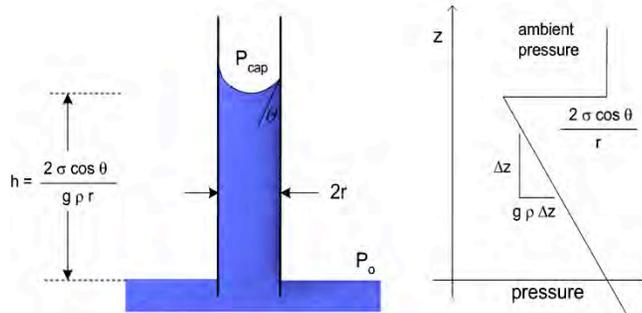
$$\theta > 90^\circ$$



hydrophobically treated:  
“non-wetable”

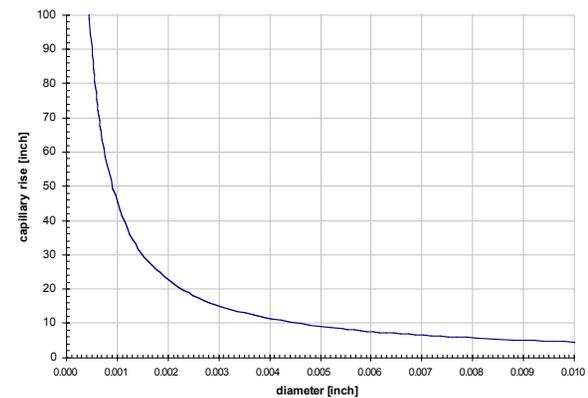
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### Calculating capillary rise

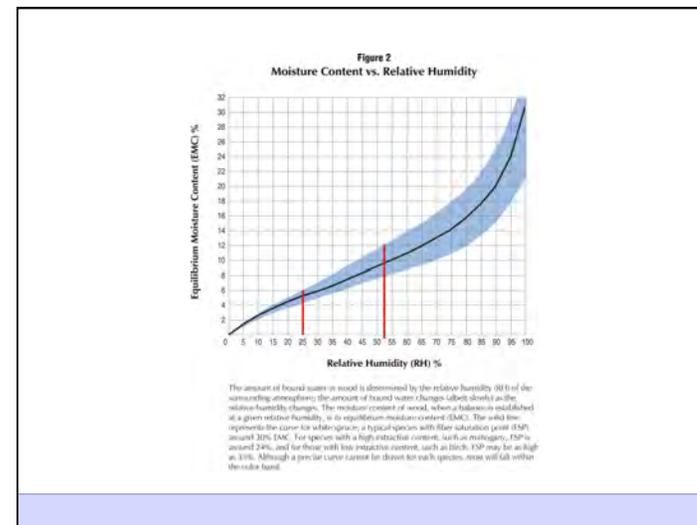
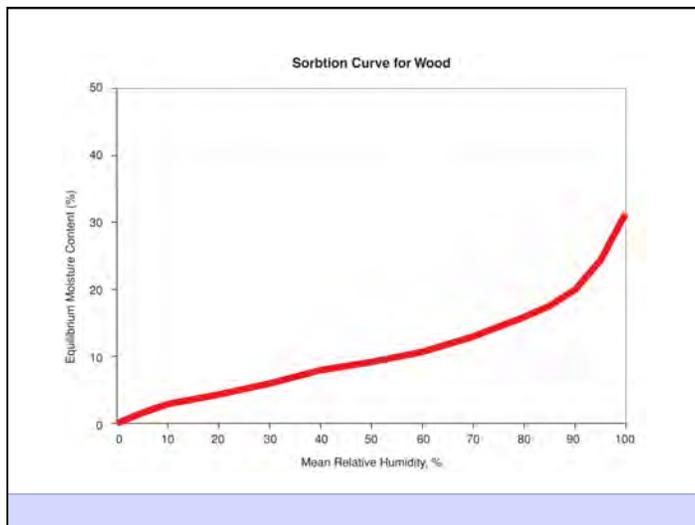
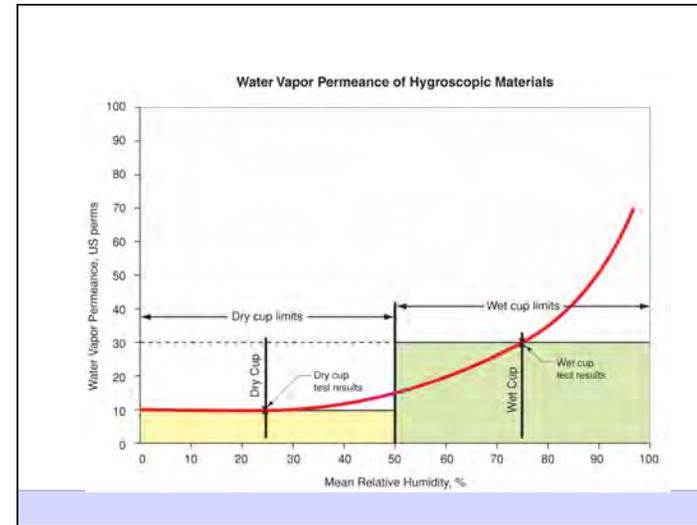


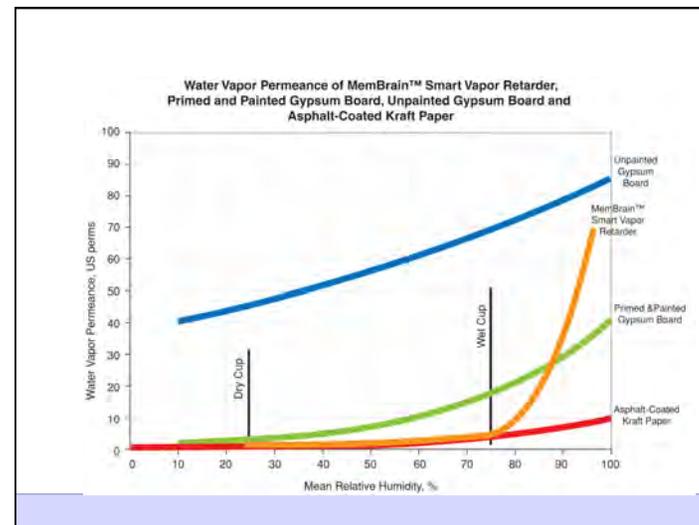
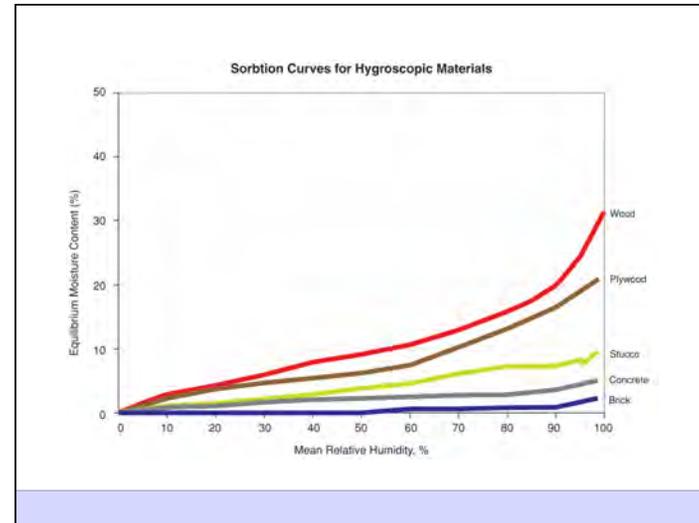
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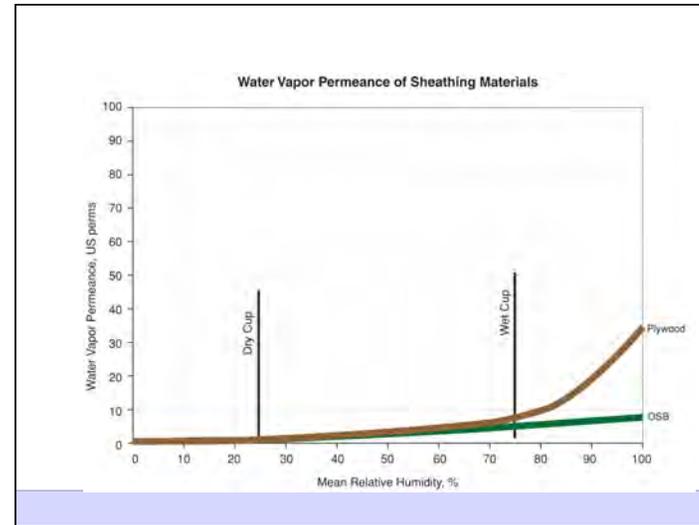
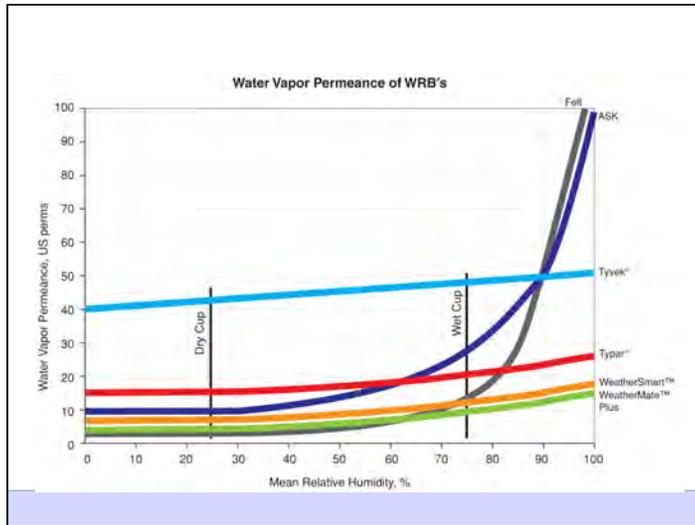
### Capillary rise versus diameter



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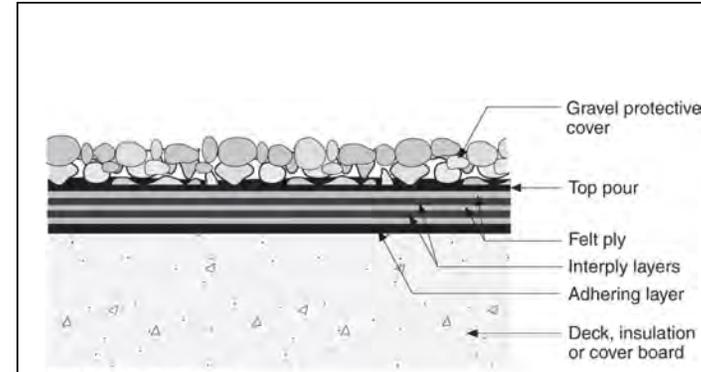






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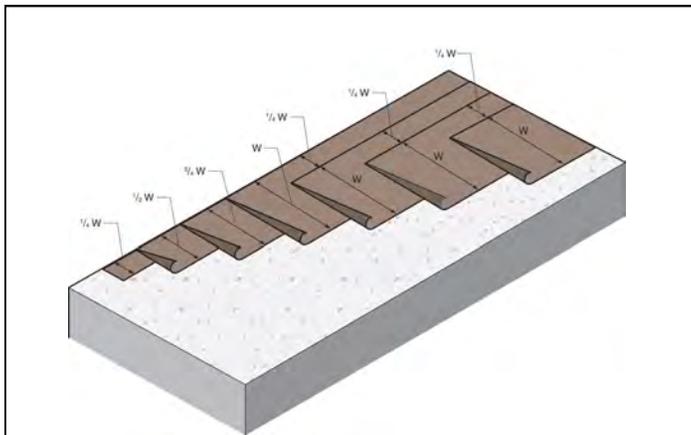
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From Baker, M.: Roofs, 1980

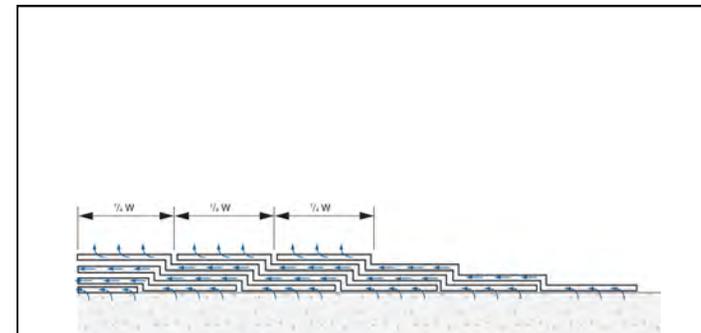
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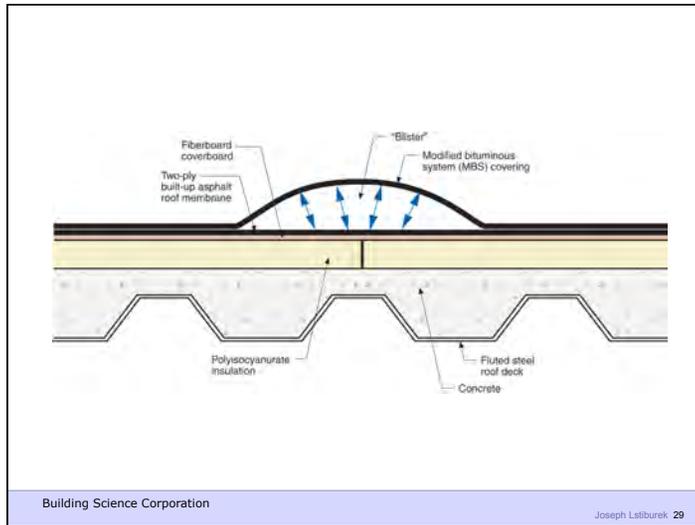
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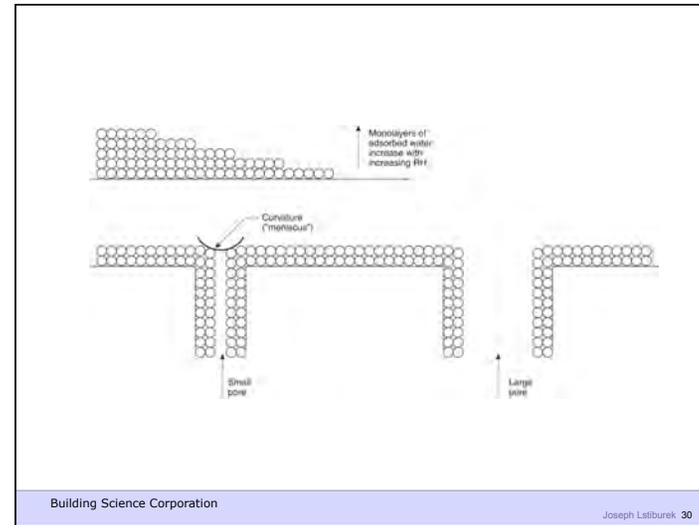
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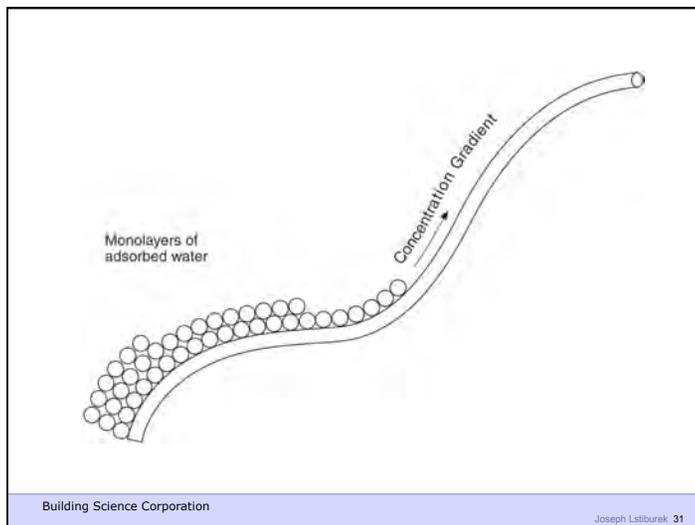
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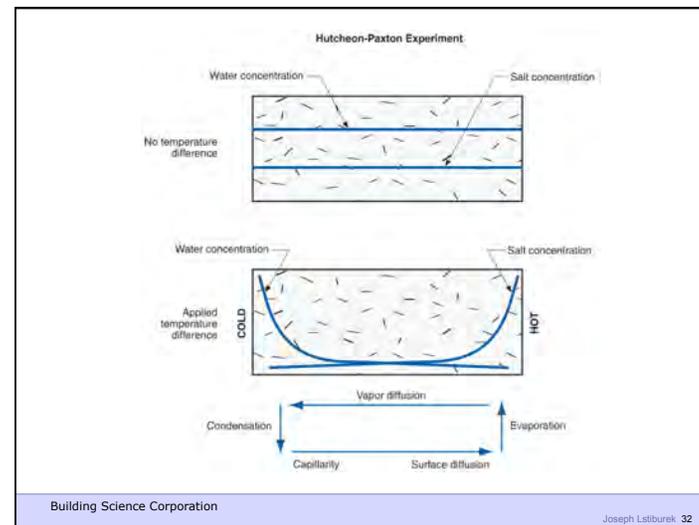
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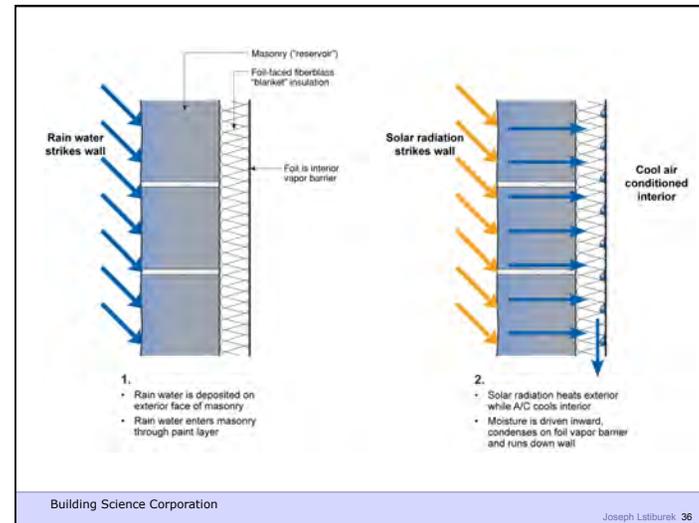
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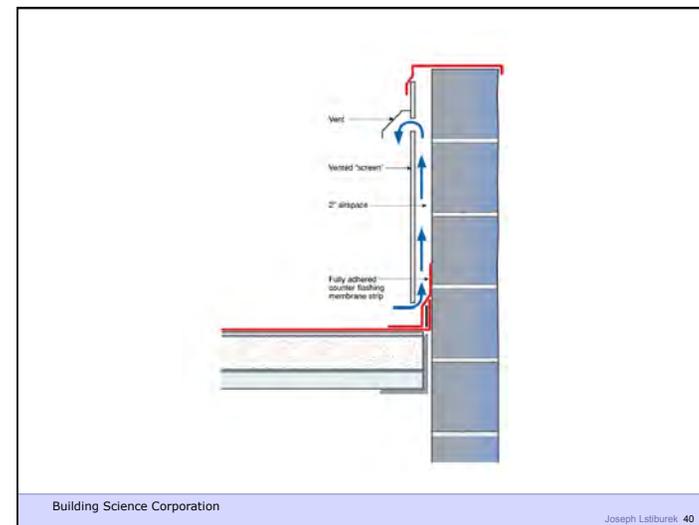
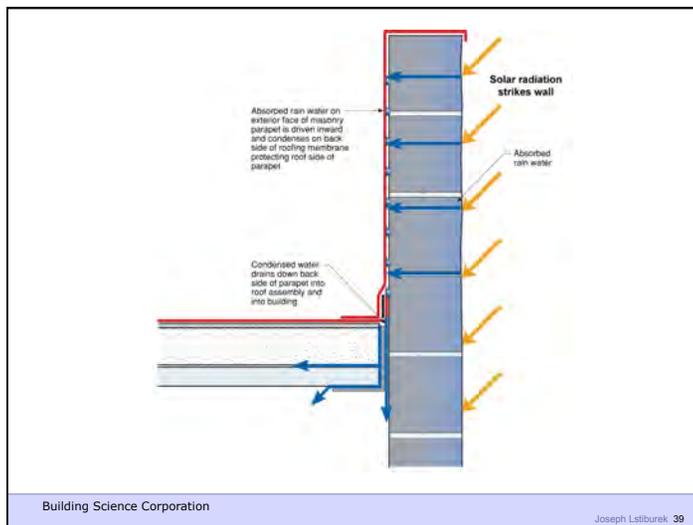
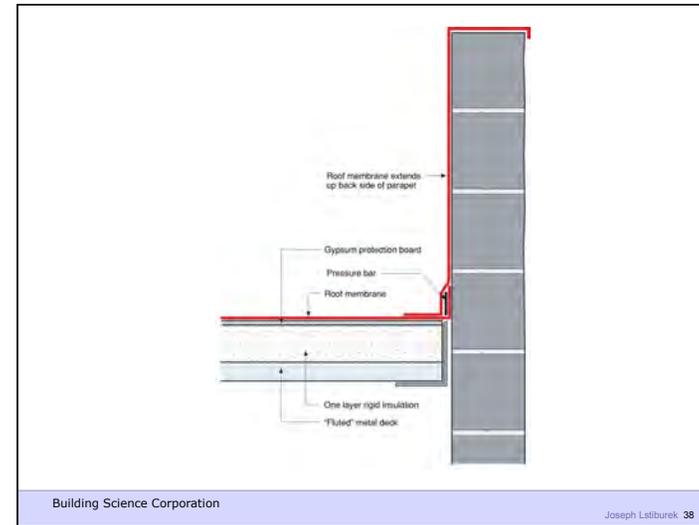
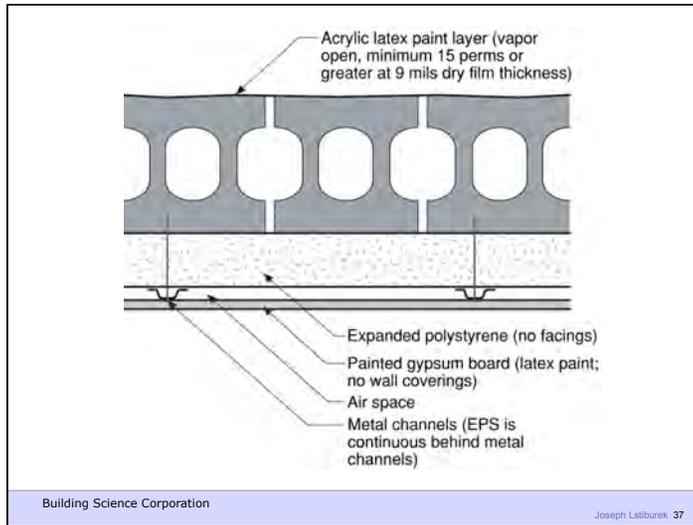
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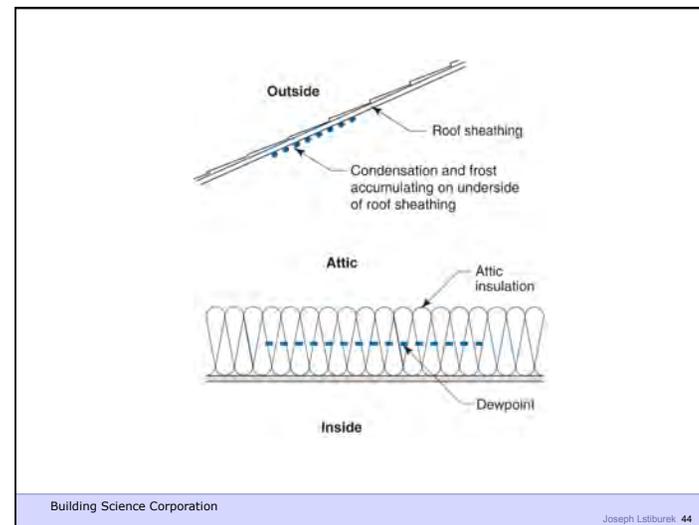
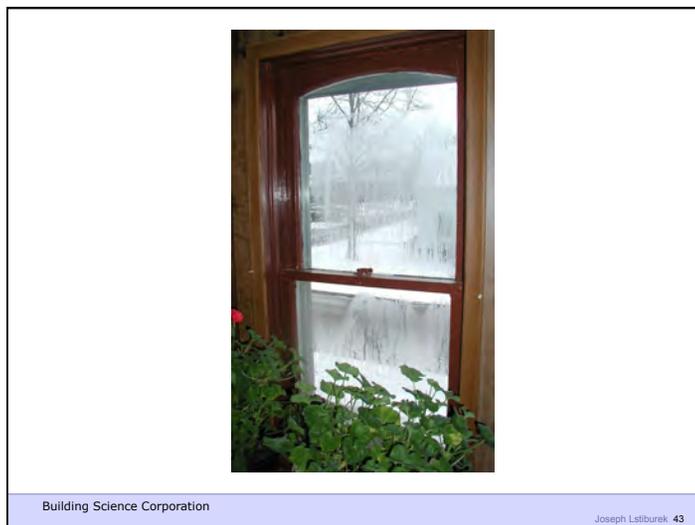
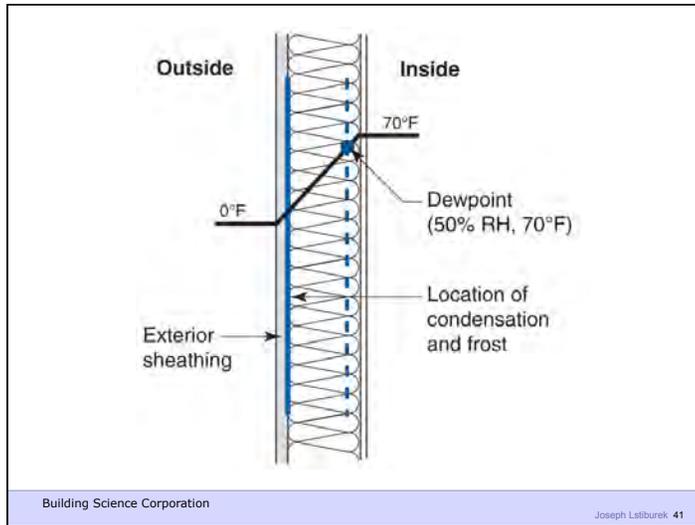


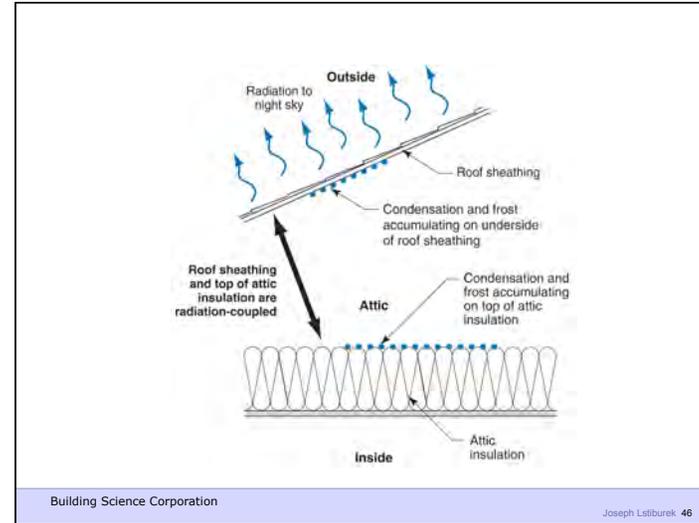
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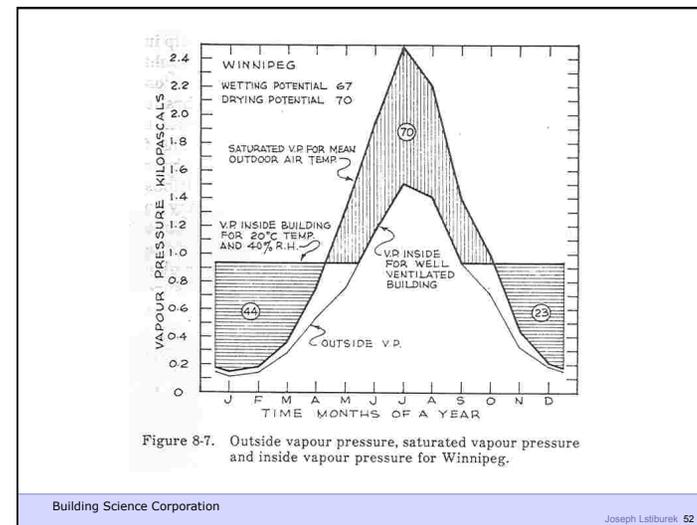
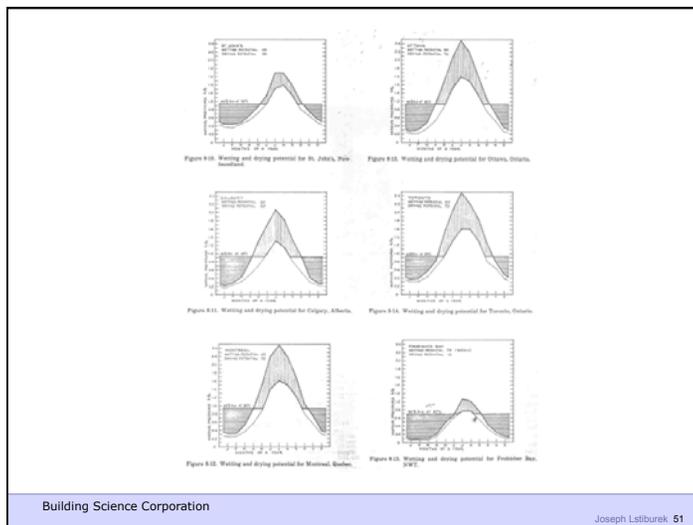
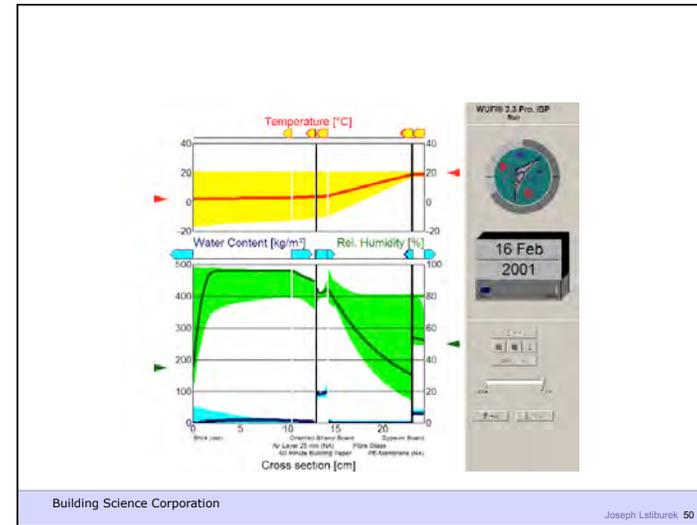
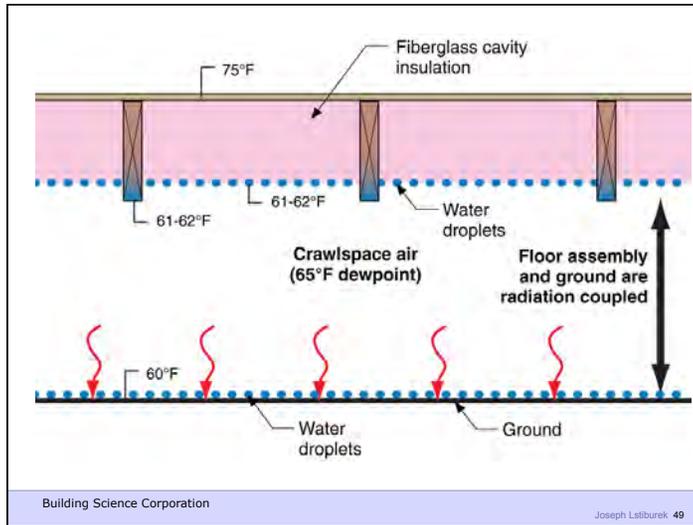
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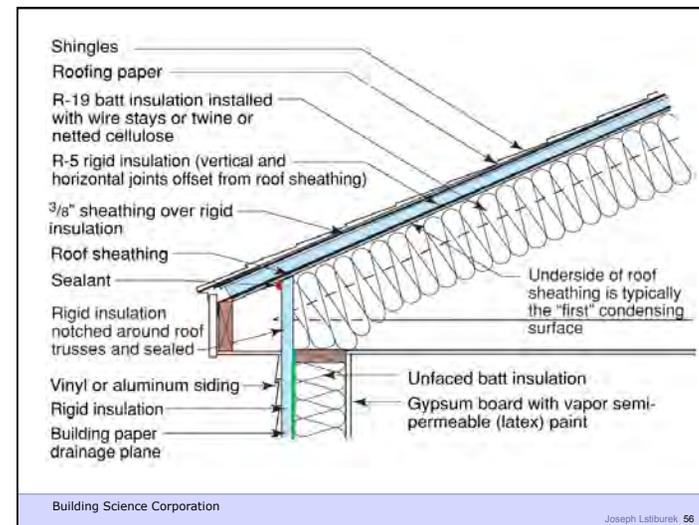
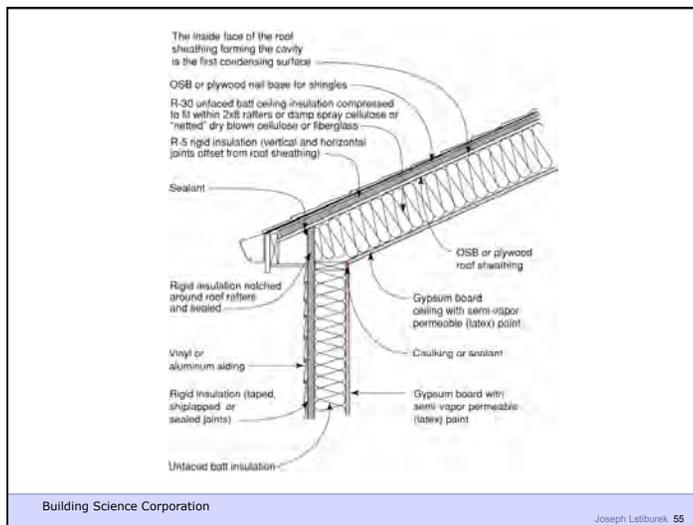
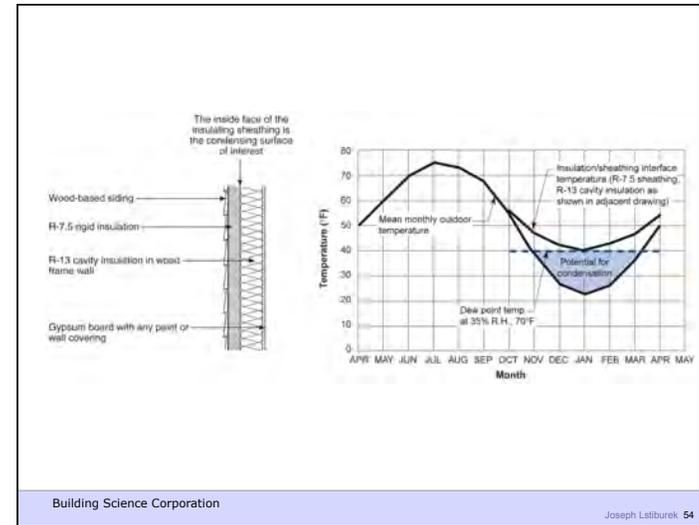
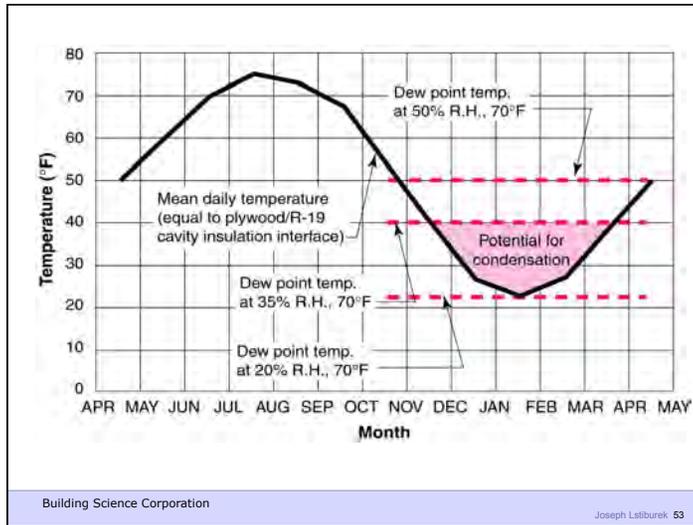


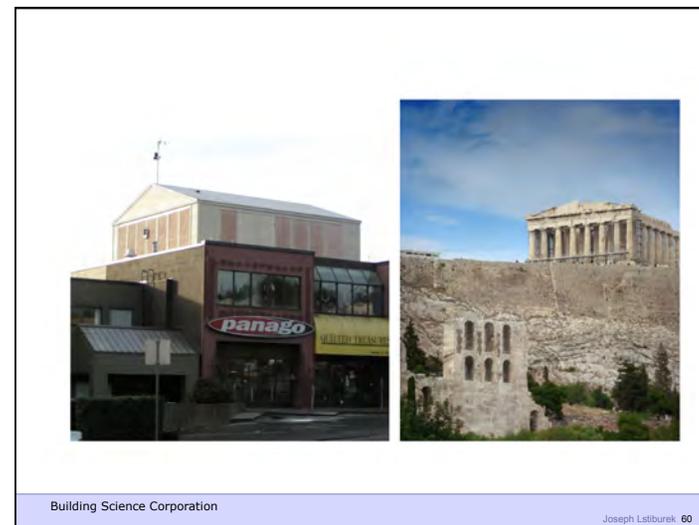
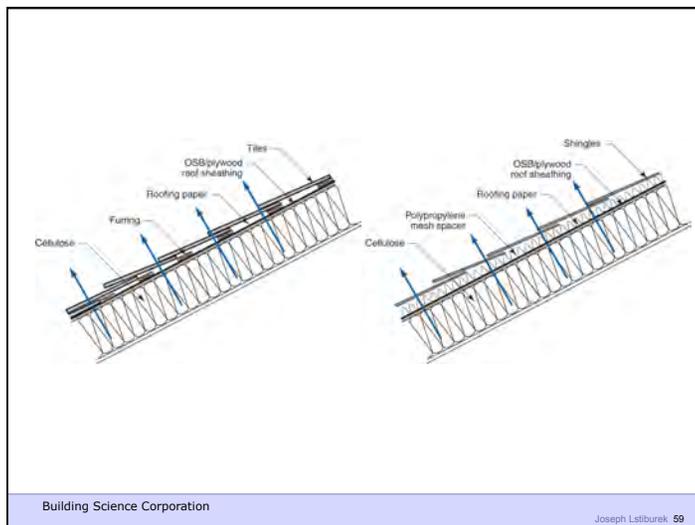
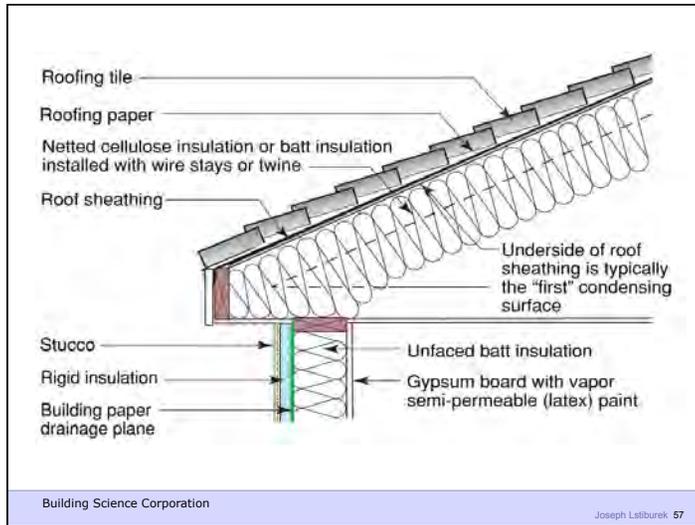


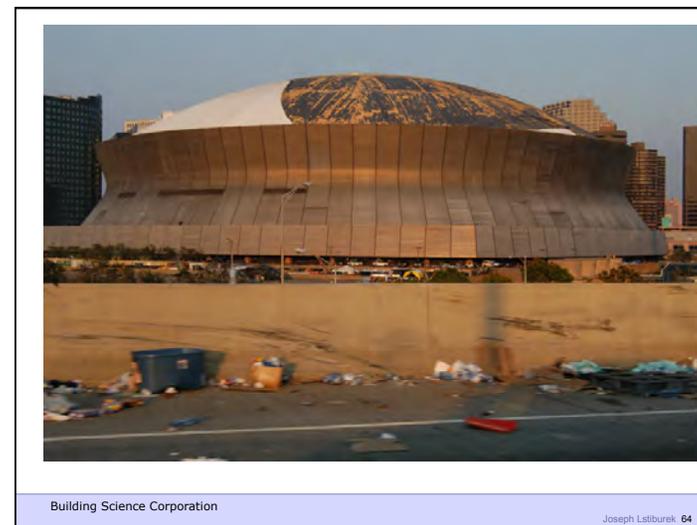
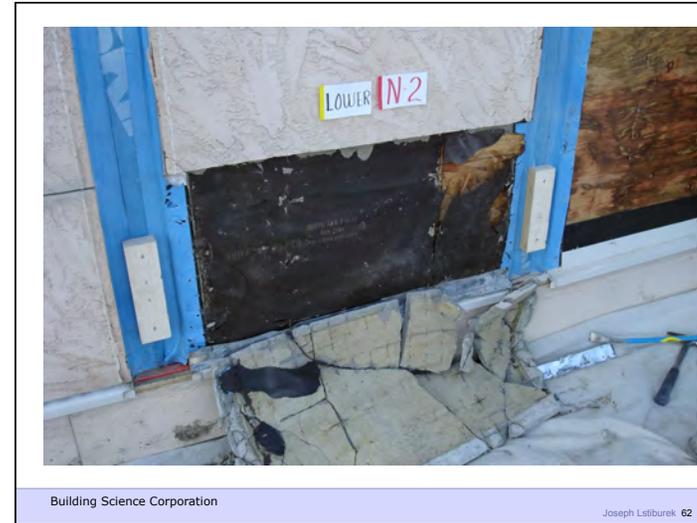
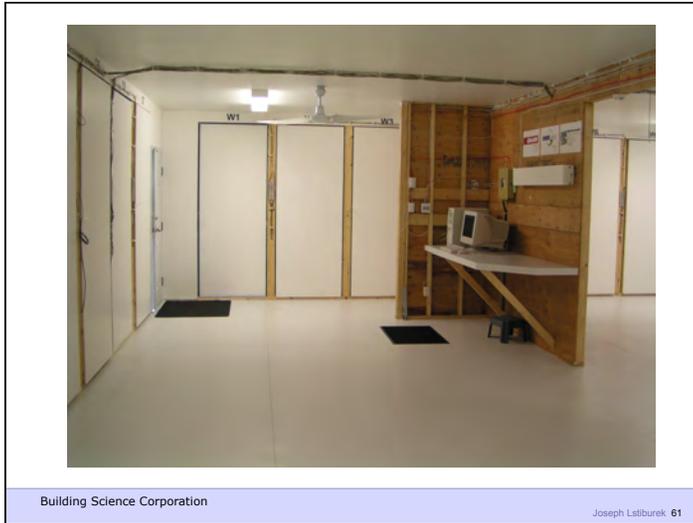


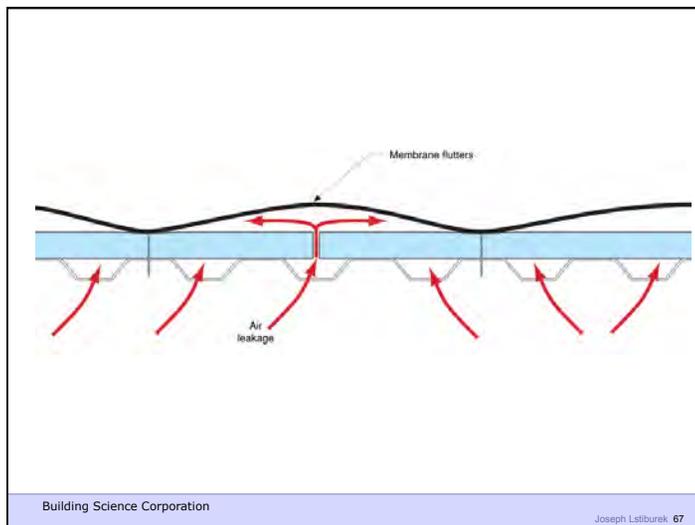
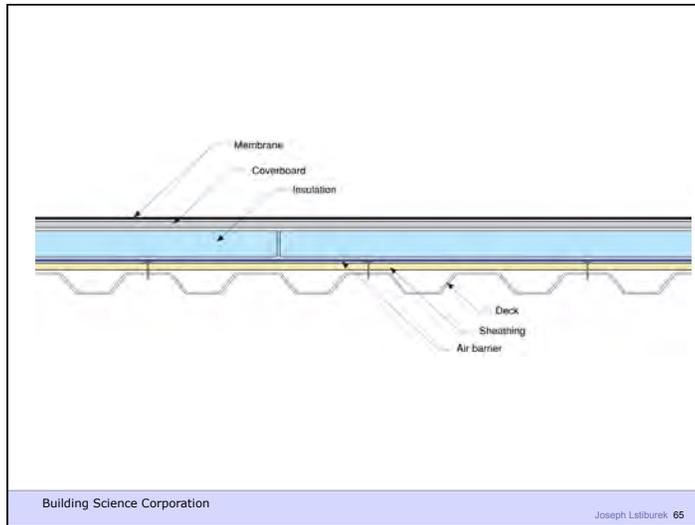


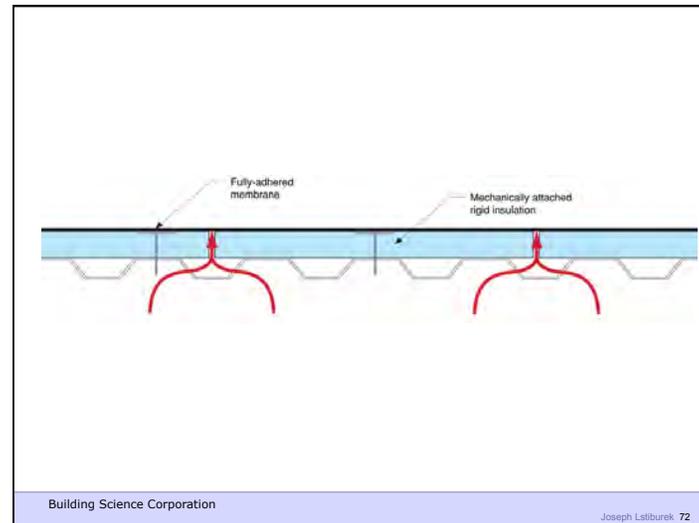
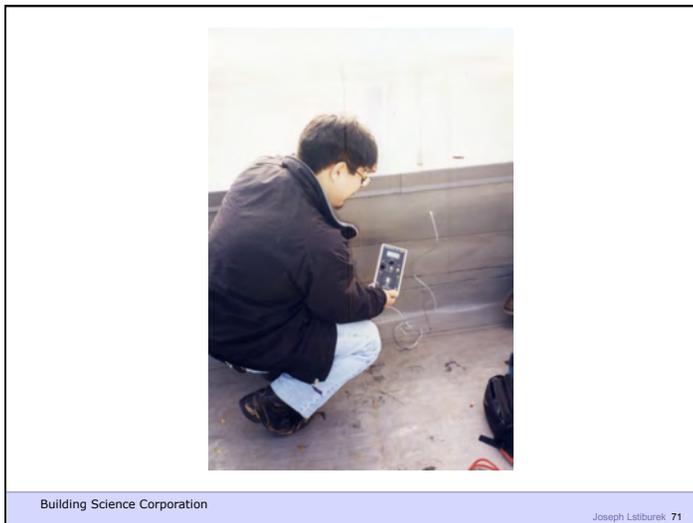
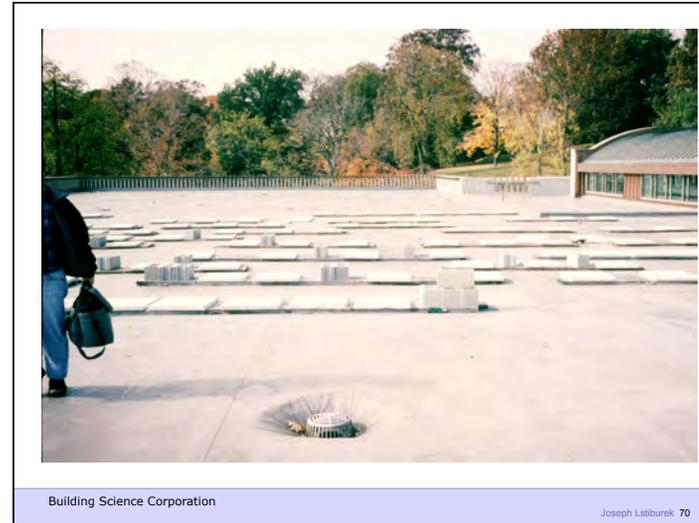


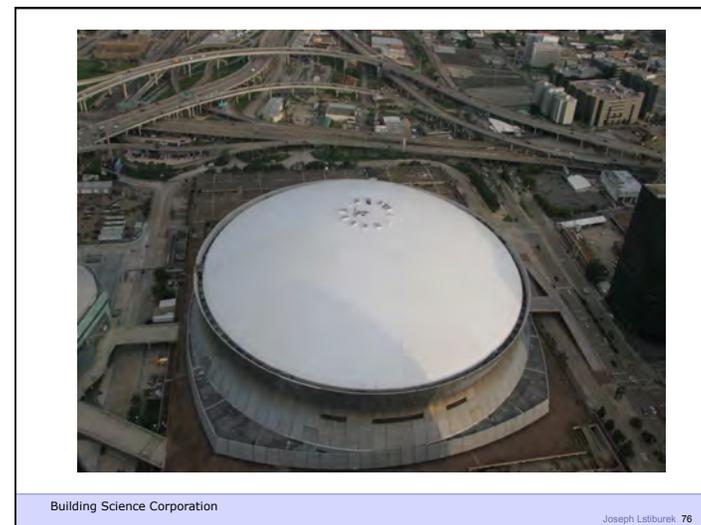
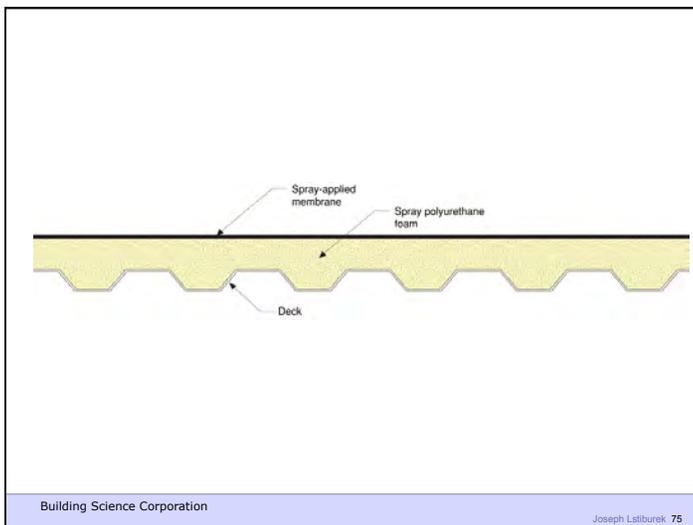
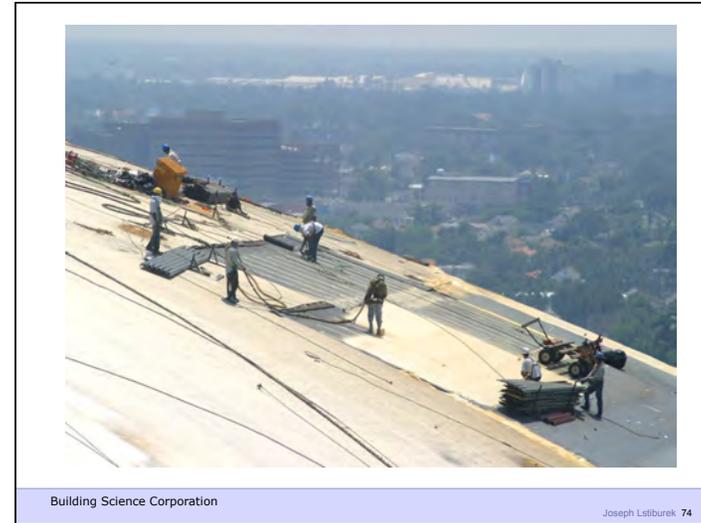
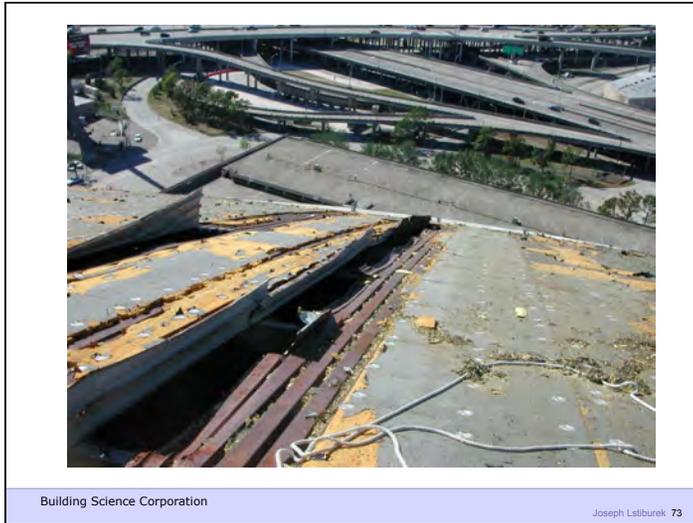


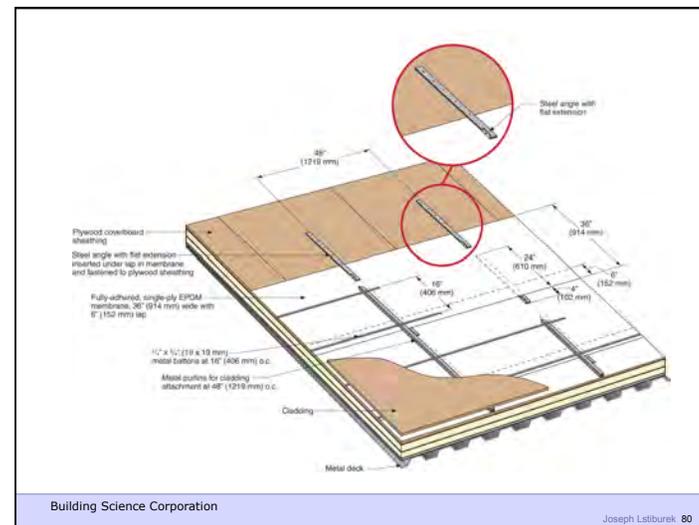
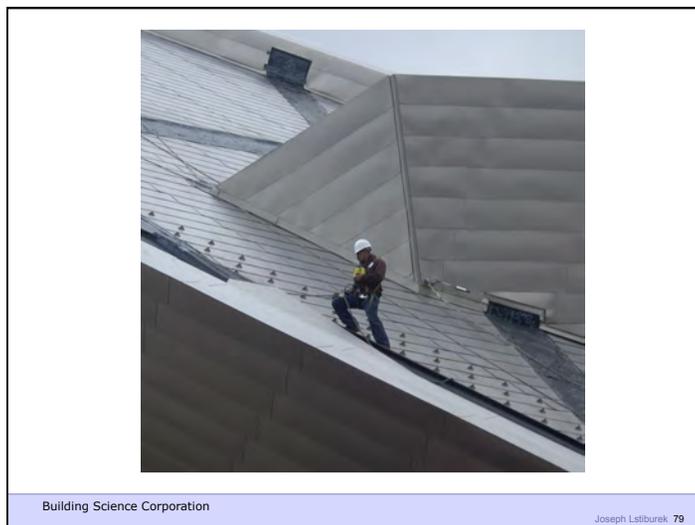
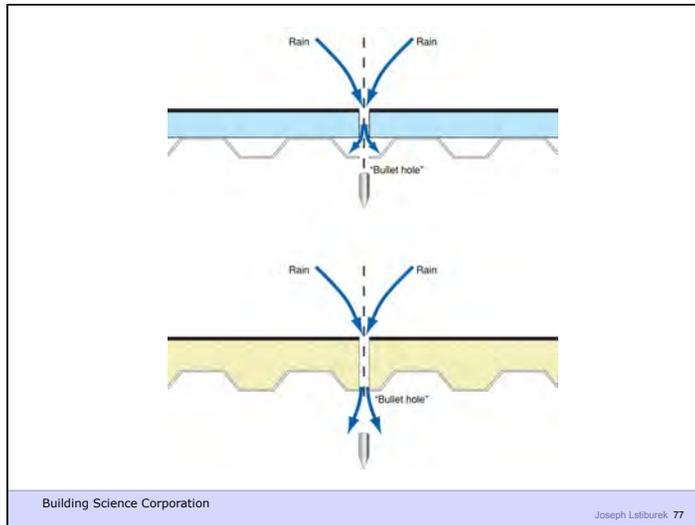


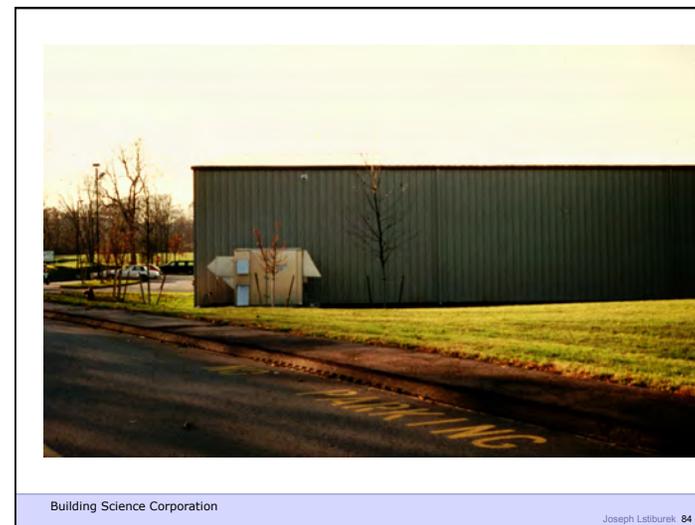
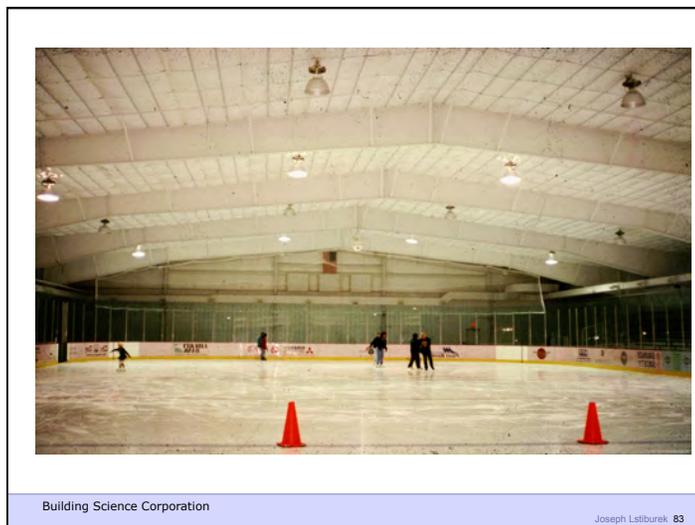
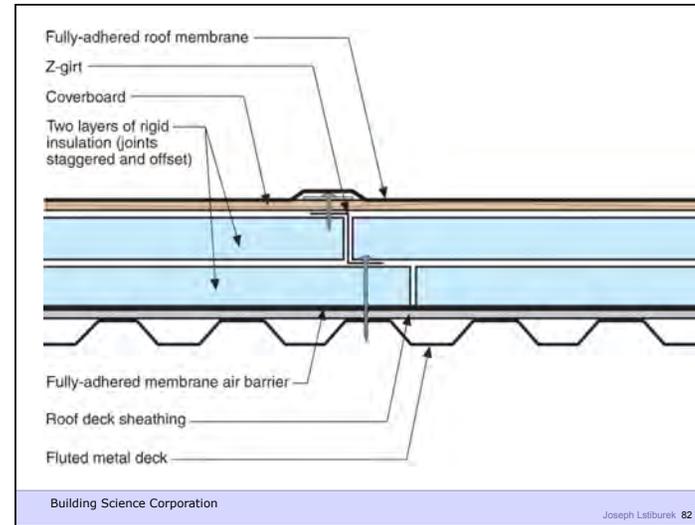
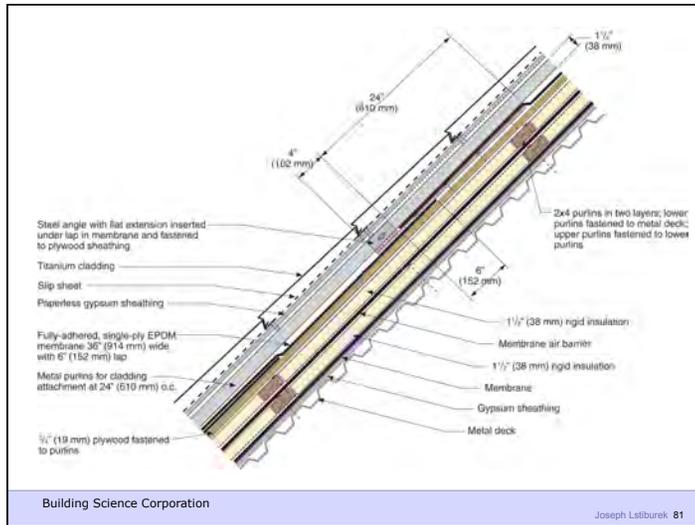


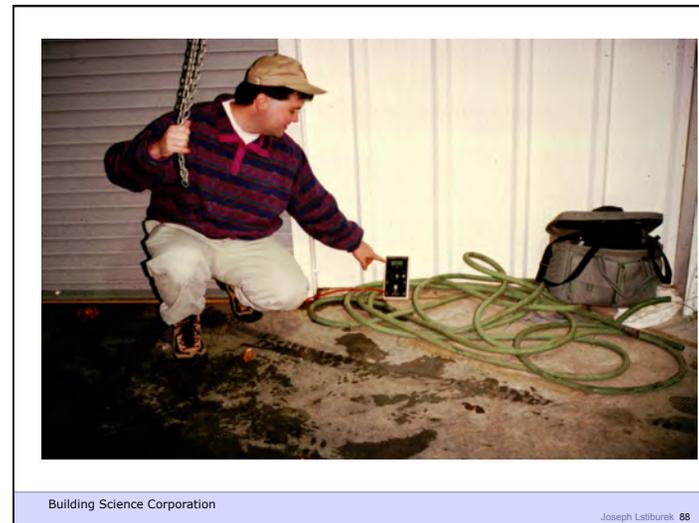
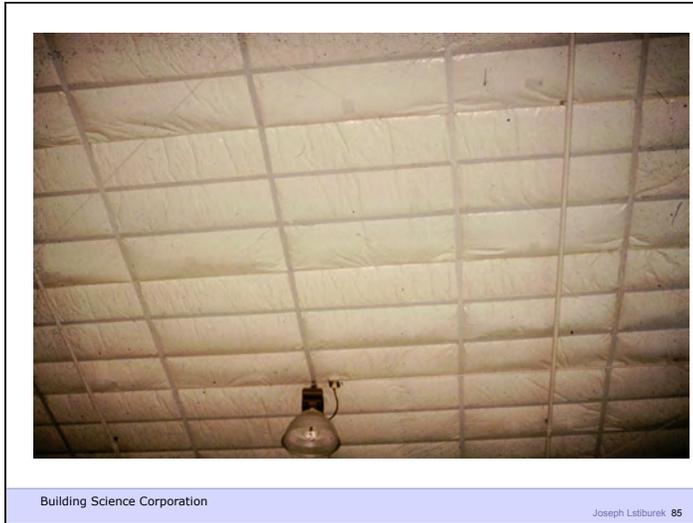




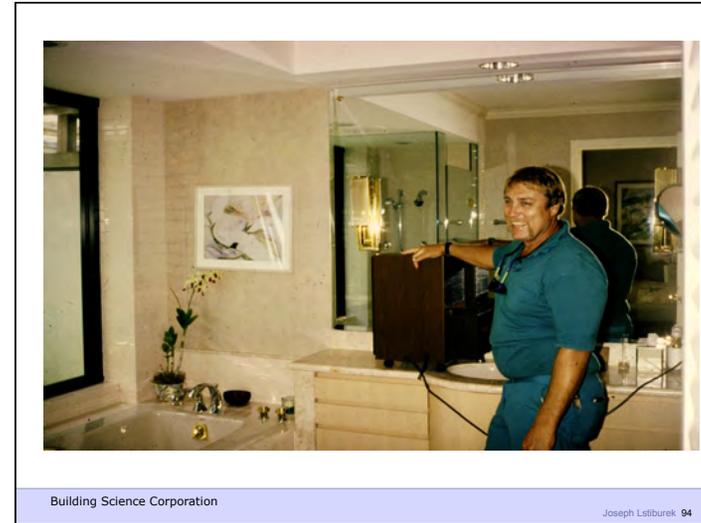


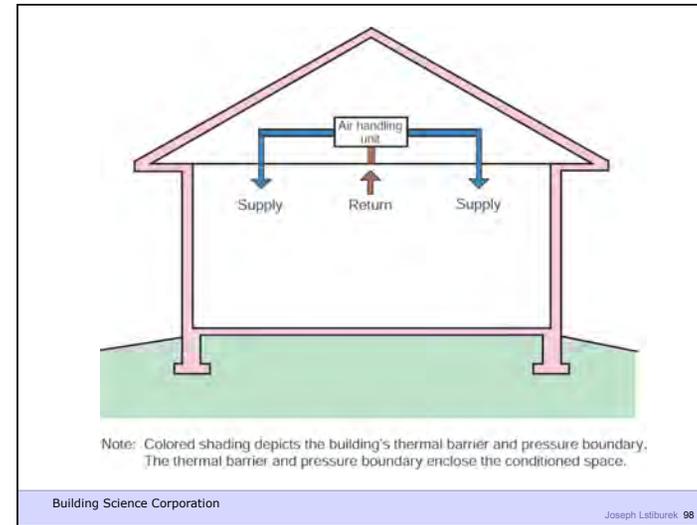
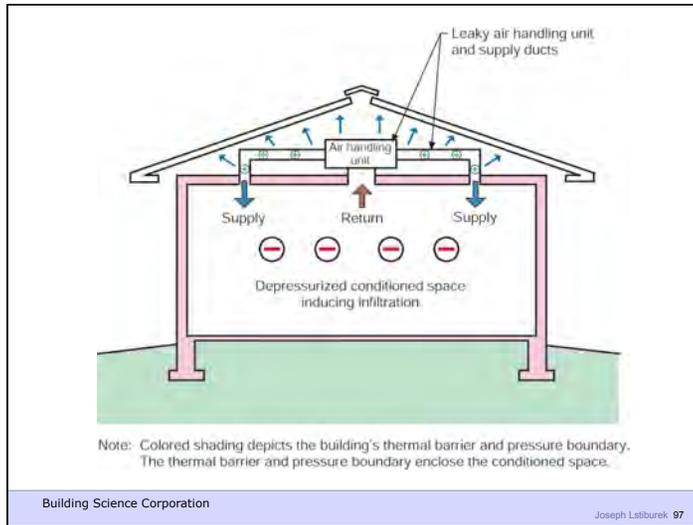


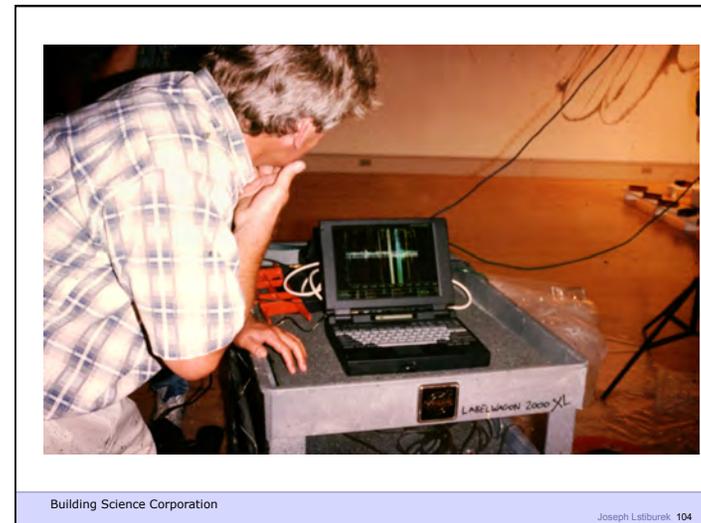
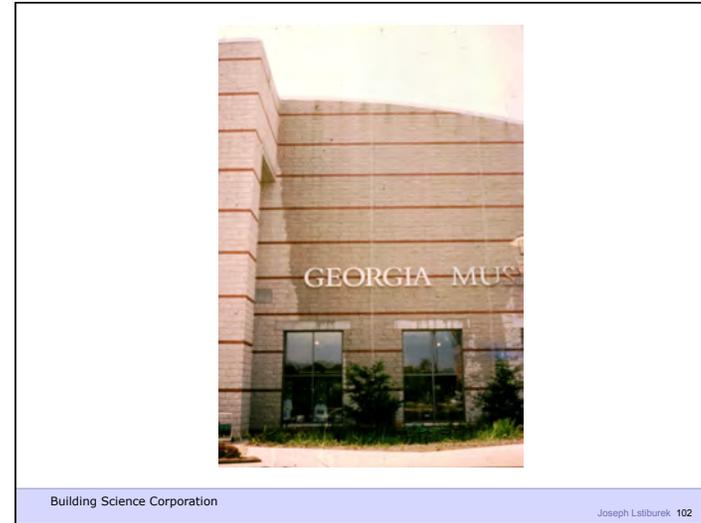


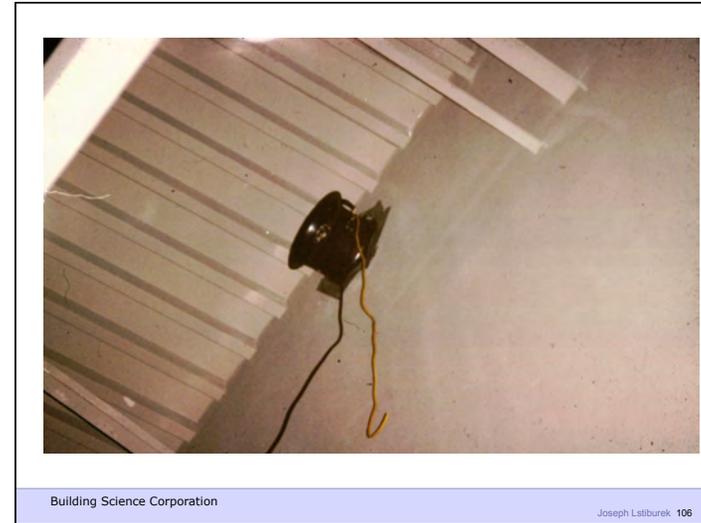
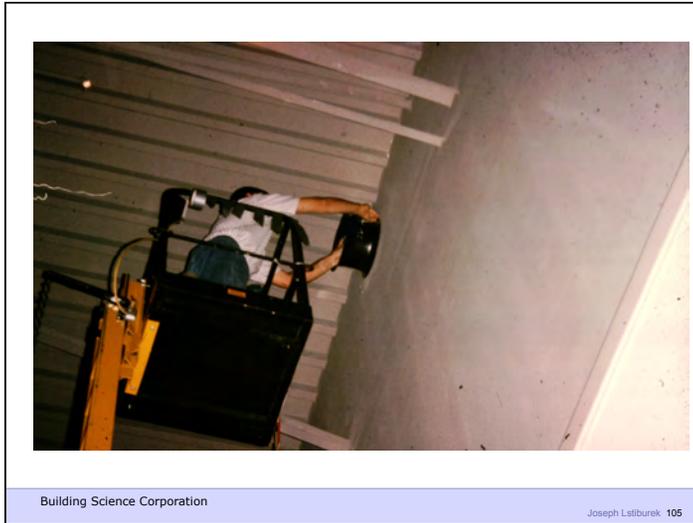


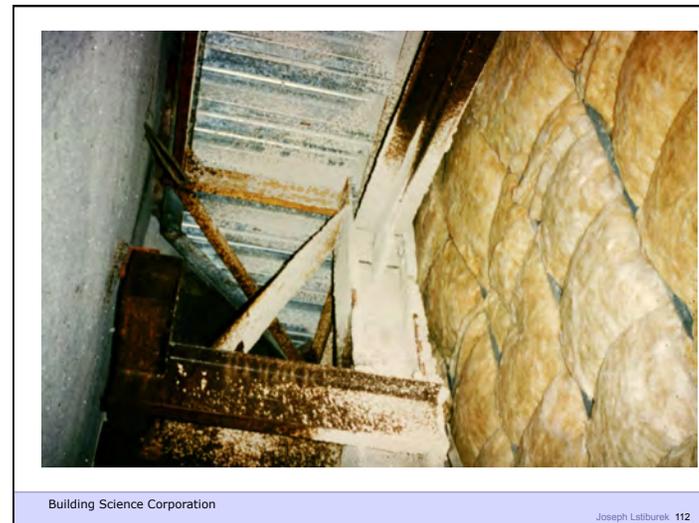
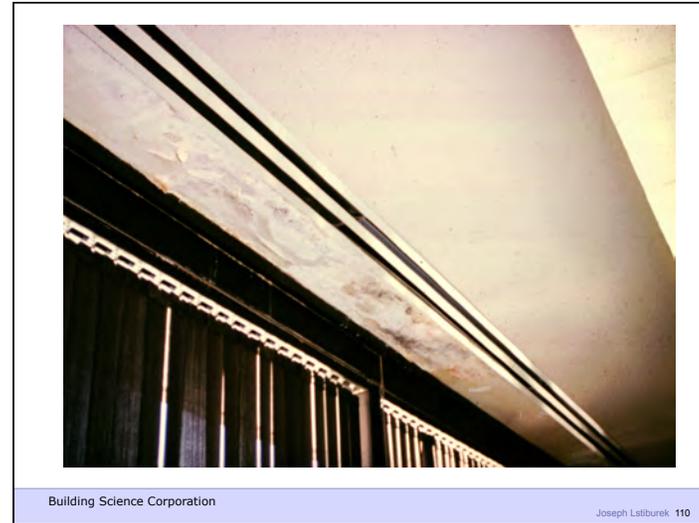


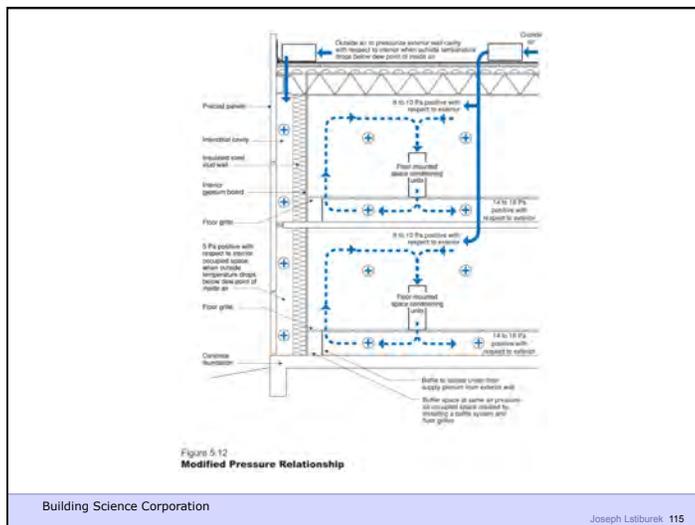
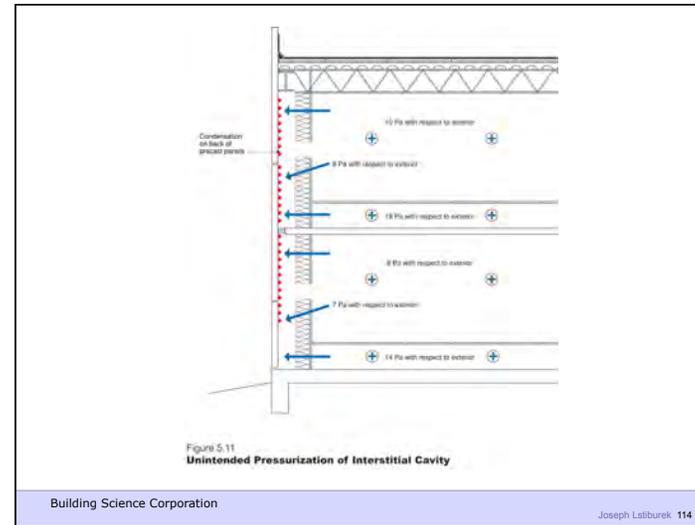
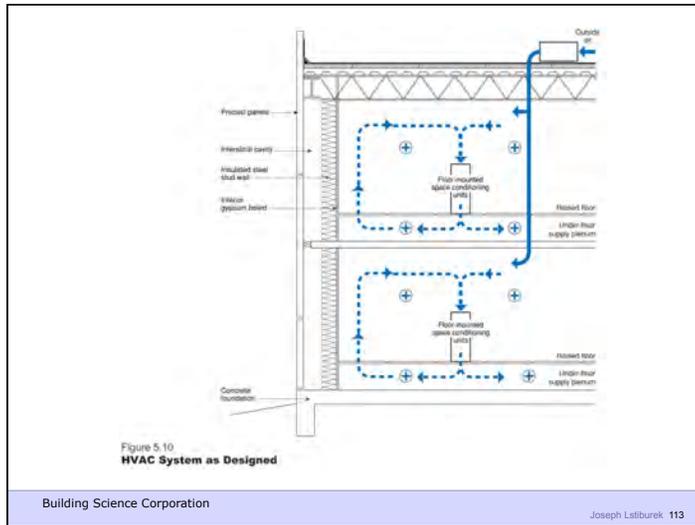


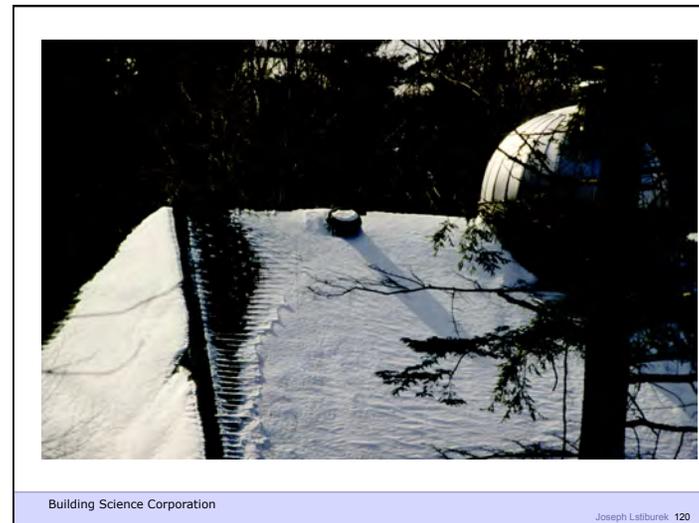
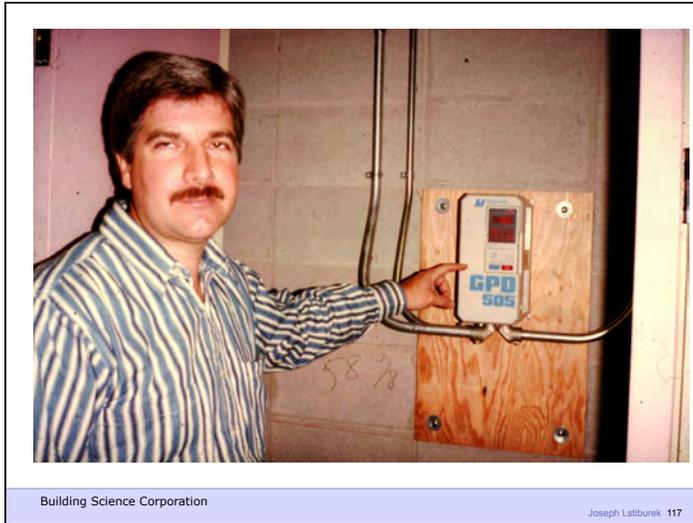


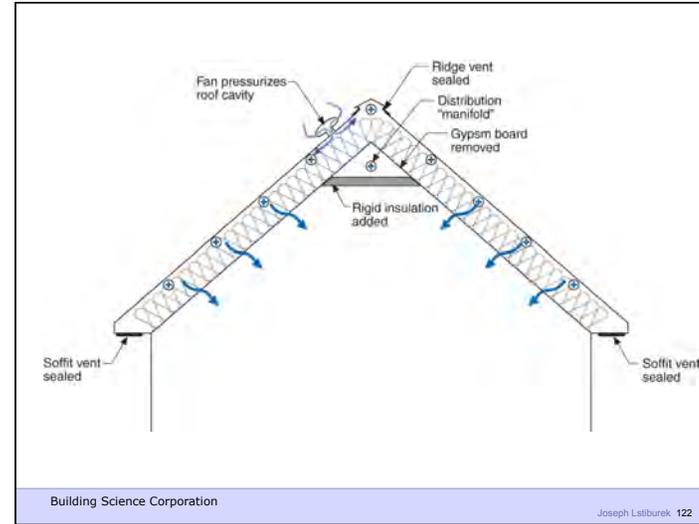
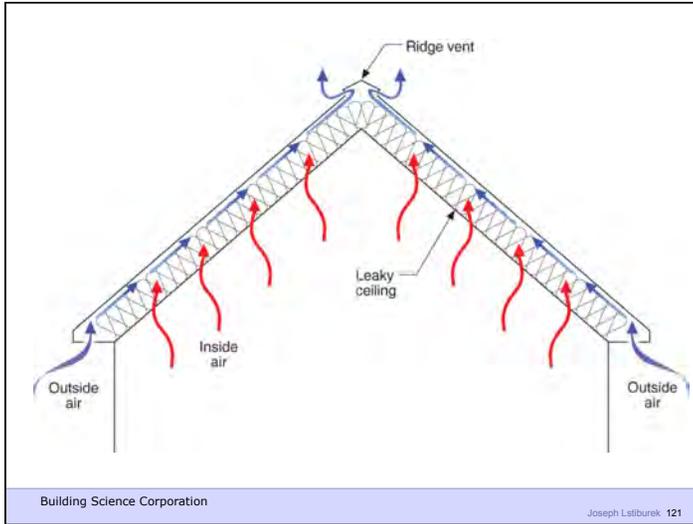


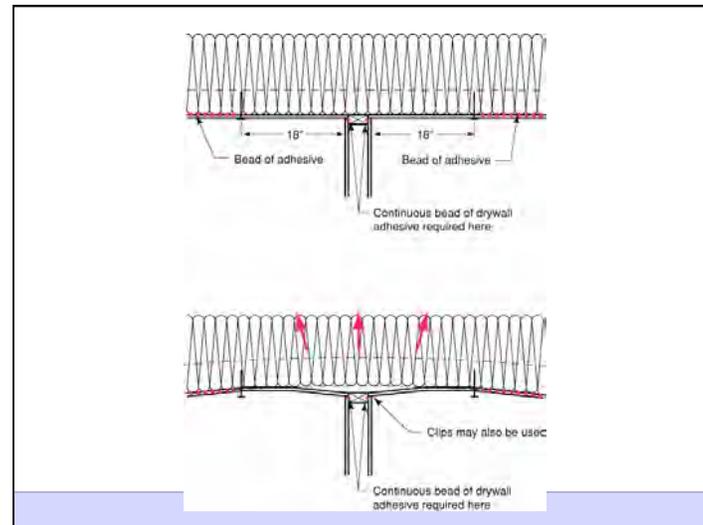


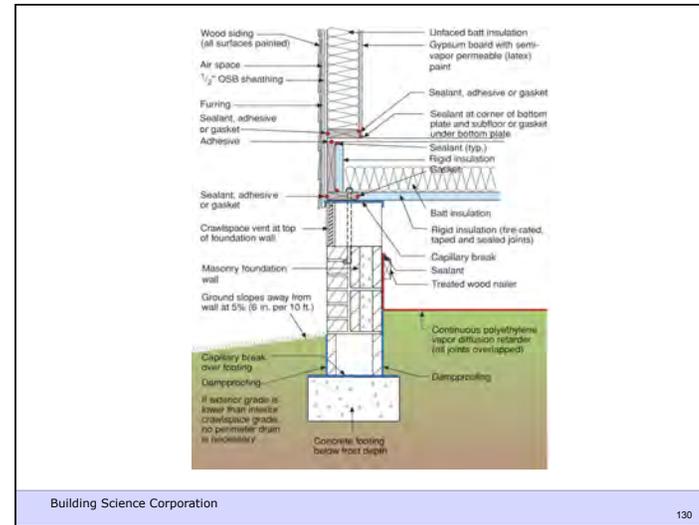
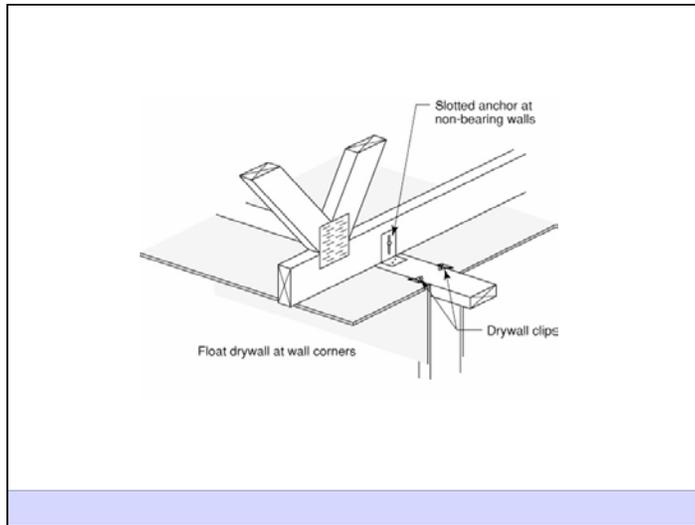




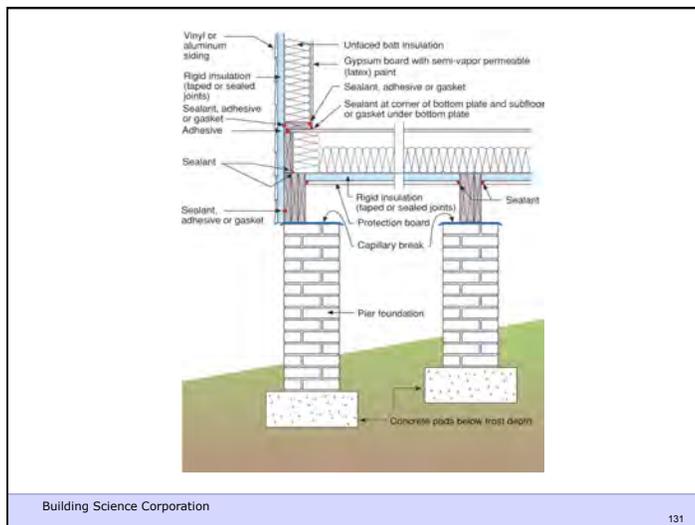




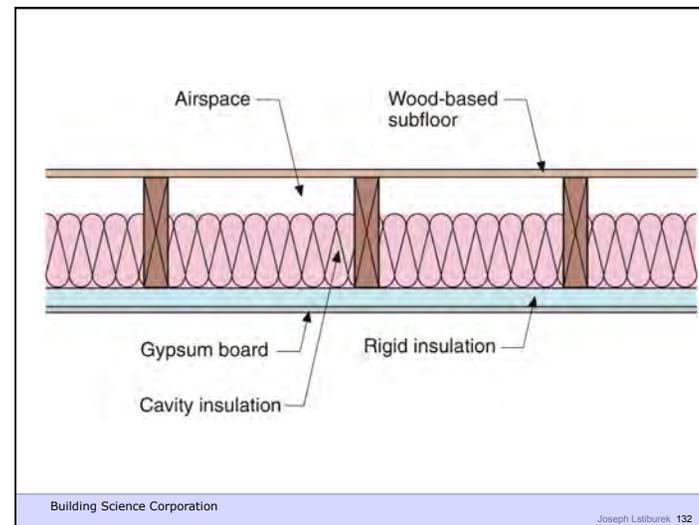




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