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

Building Science

Prioritizing Green

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R2

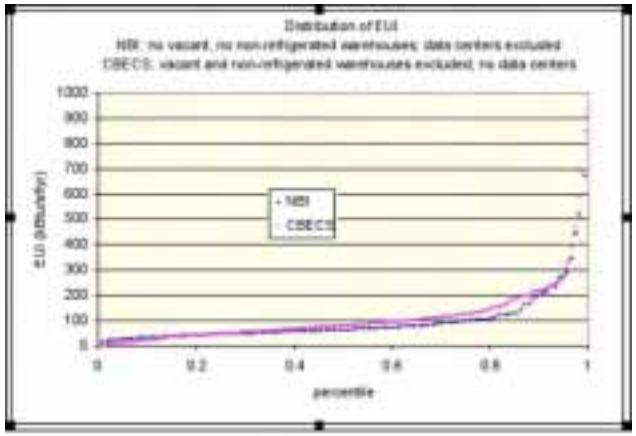
R2

R4

R2

R4

R6



Don’t Do Stupid Things

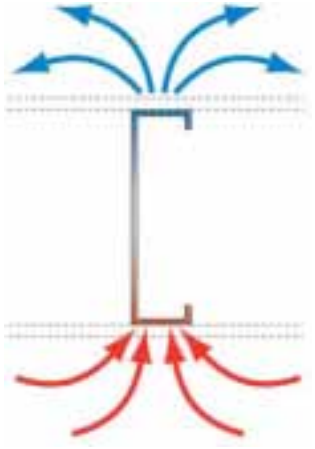
Heat Flow Is From Warm To Cold

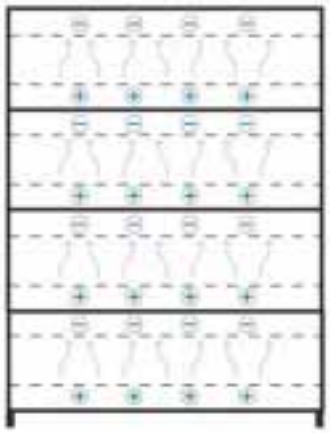
Moisture Flow Is From Warm To Cold

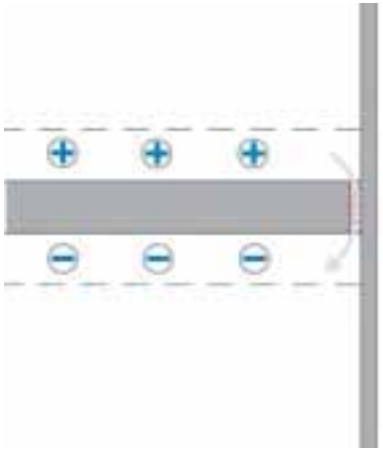
Moisture Flow Is From More To Less

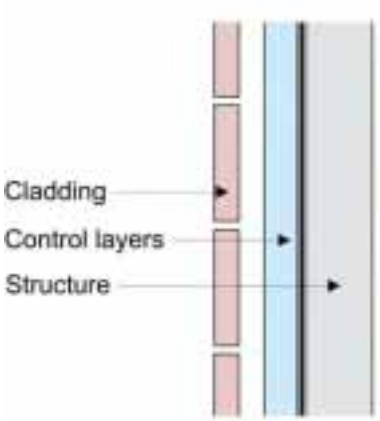
Air Flow Is From A Higher Pressure to a Lower Pressure

Gravity Acts Down

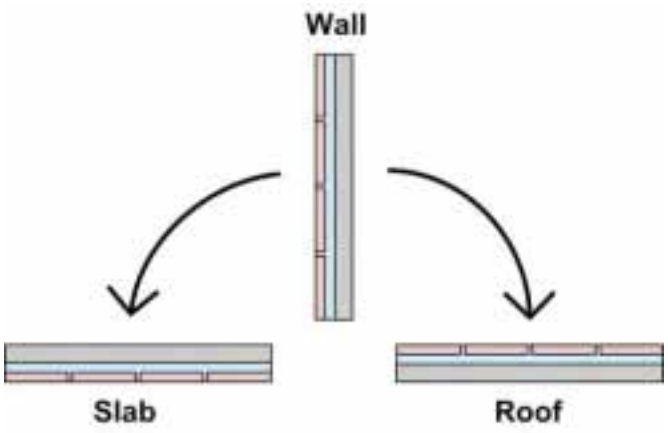


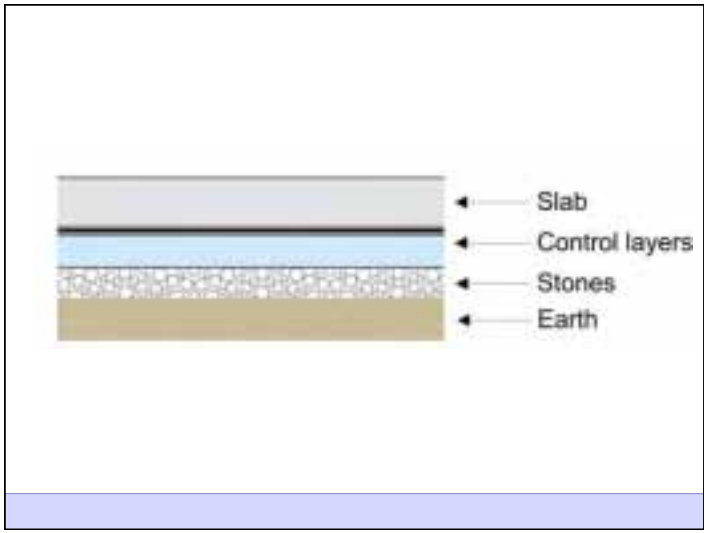


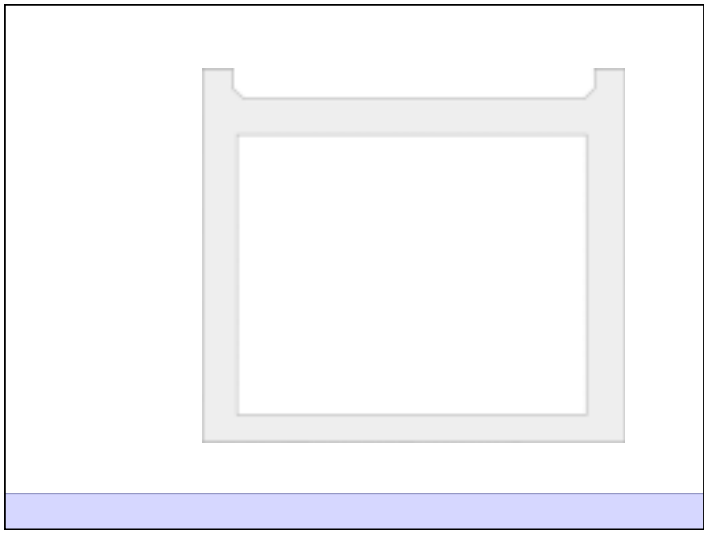


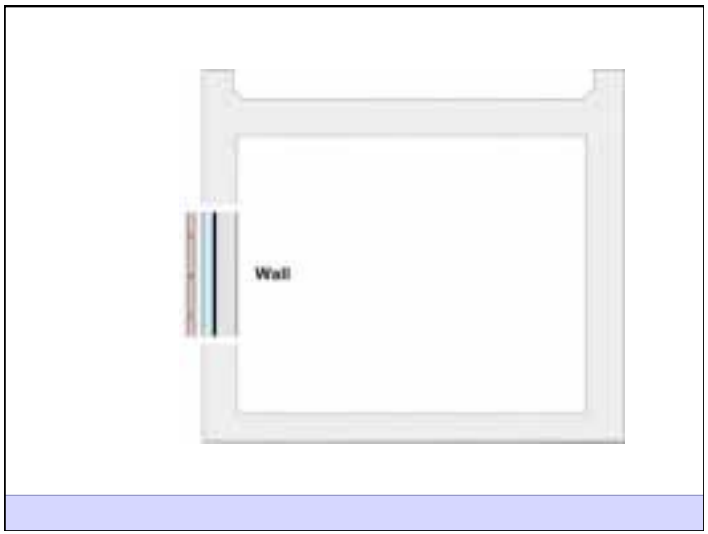


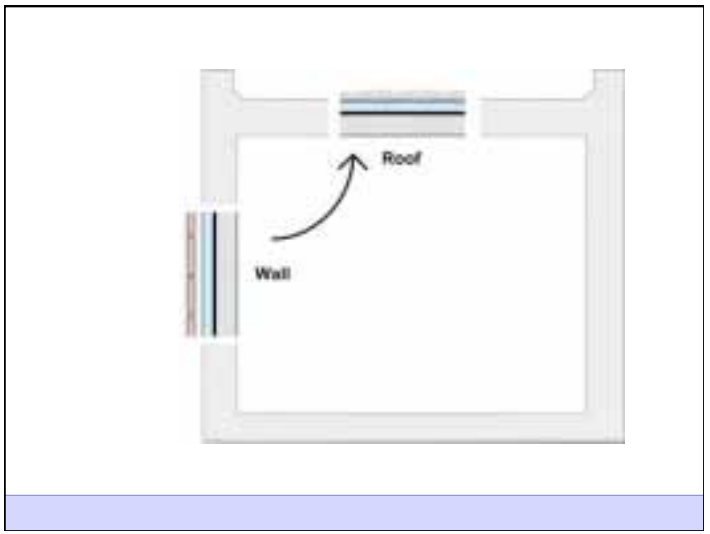
Rain Control Layer
Air Control Layer
Vapor Control Layer
Thermal Control Layer

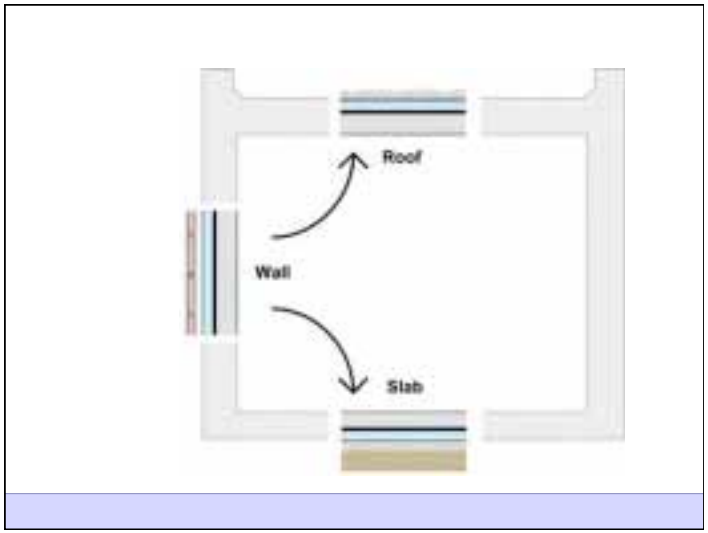


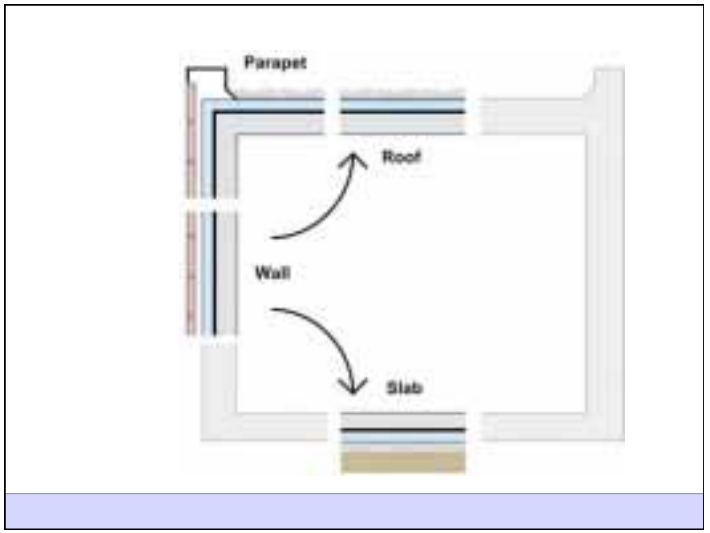


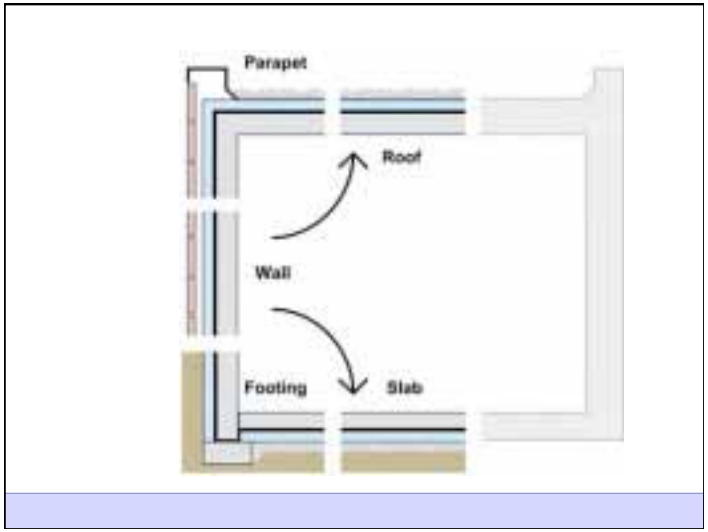


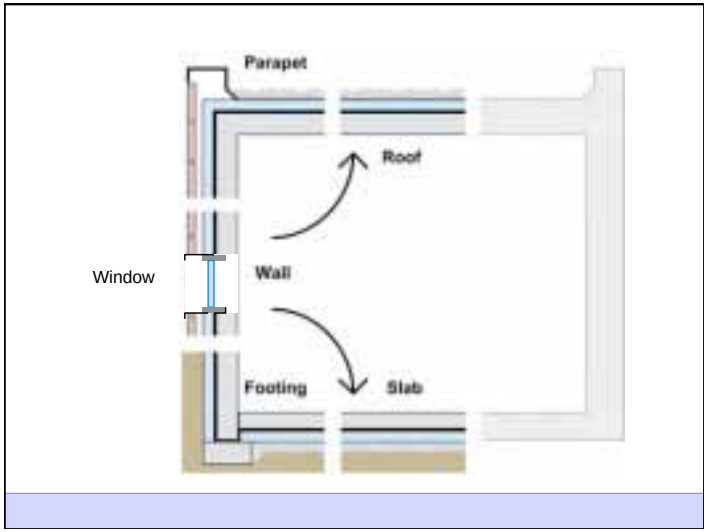










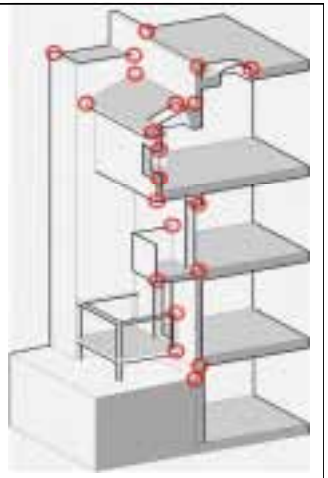


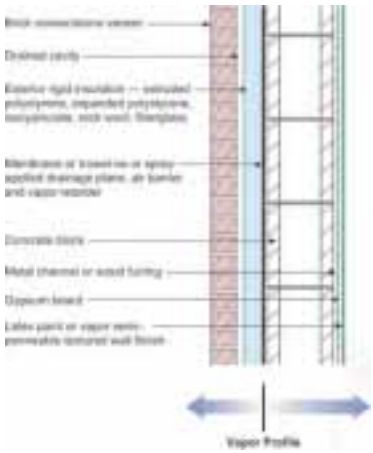
Commercial Enclosure: Simple Layers

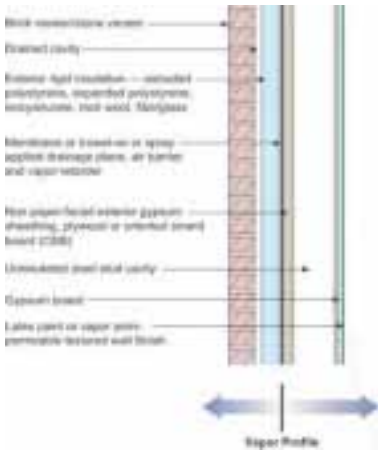
- Structure
- Rain/Air/Vapor
- Insulation
- Finish

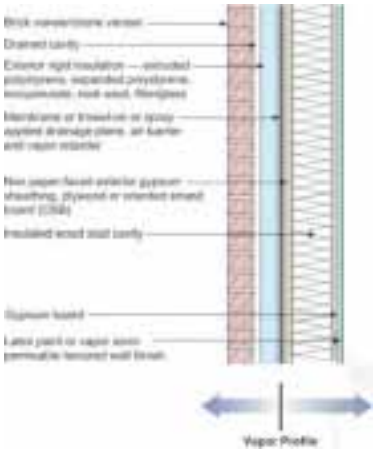
Enclosure Design: Details

- Details demand the same approach as the enclosure.
- Scaled drawings required at

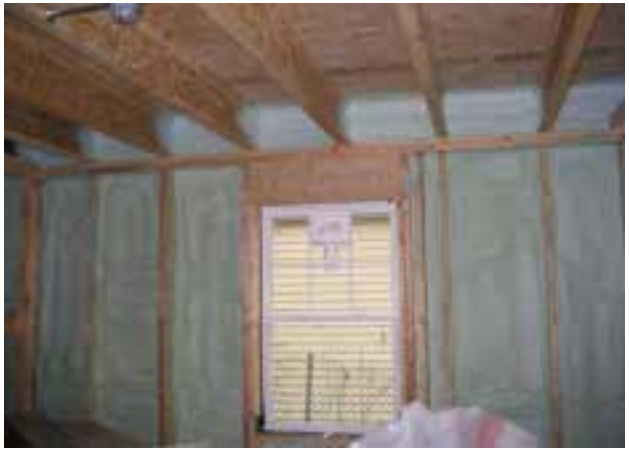


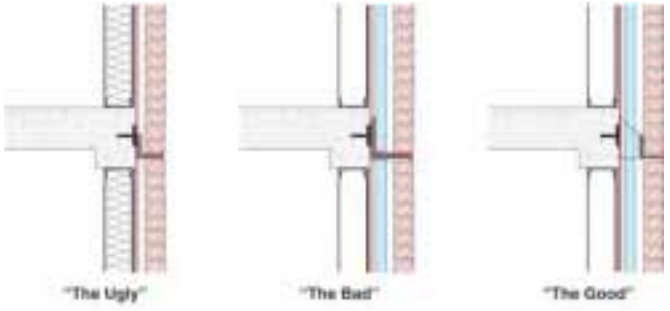


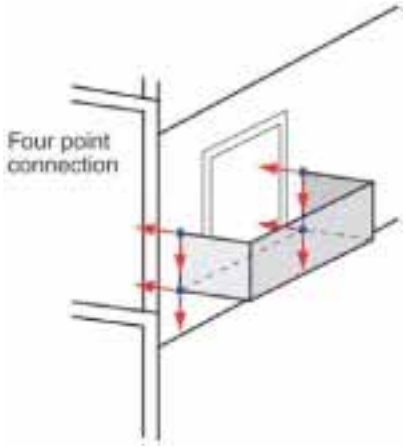


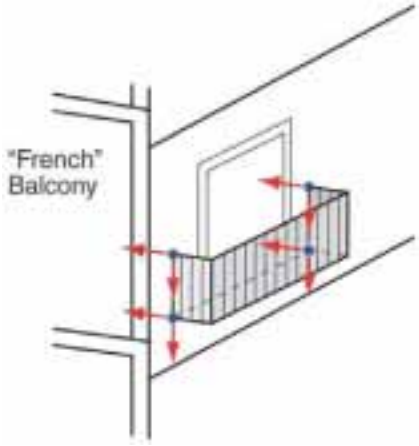

Vapor Profile

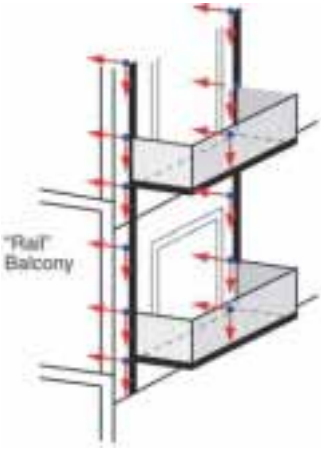
Don’t Do Stupid Things

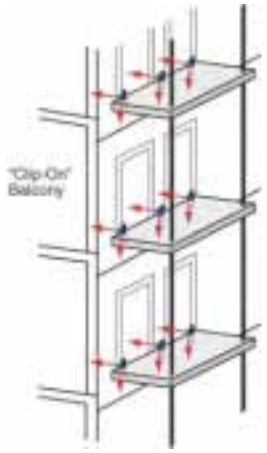




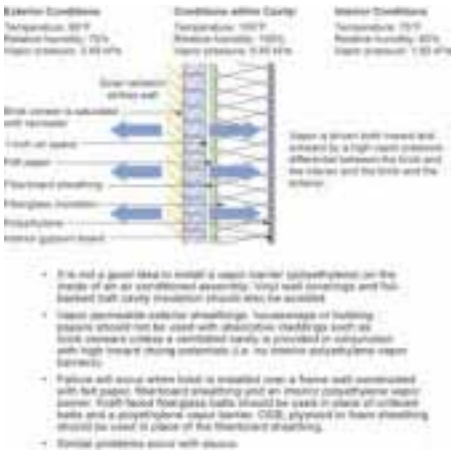

Four point
connection

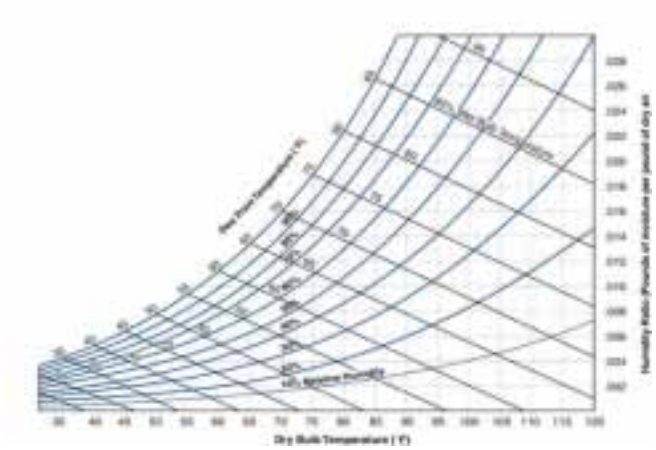

"French"
Balcony


"Rail"
Balcony


"Clip On"
Balcony

Confusion About Diffusion





Aluminium Pressure Vessel Filled With A Cryogenic Liquid On a Beach In Florida In July

Carbon Fibre Nano Tube Kevlar Tang
Composite and Micro Porous Polymer
Modified Ionised Coating

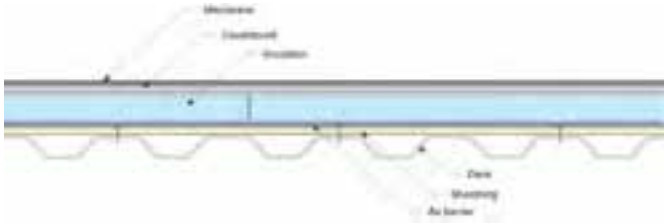
"the NASA repair"

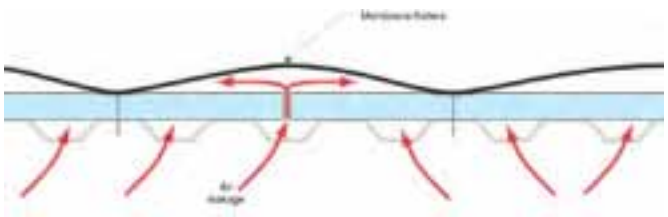
Chicken Wire and Epoxy Paint

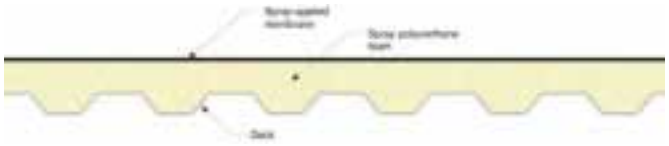
"the Home Depot repair"

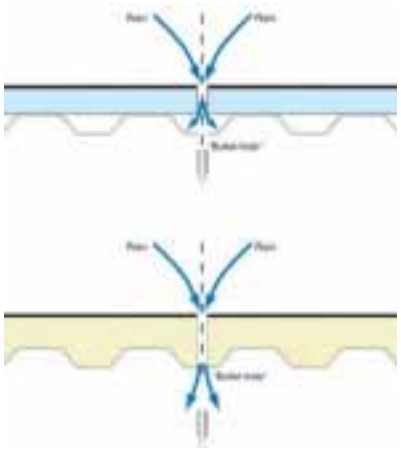
Early Shuttle Fights Had Aluminum Paint Over External Tank Foam - Note White Color On Tank - Aluminum Paint Removed To Save Weight

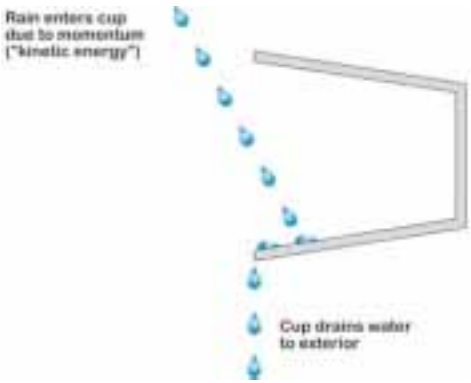
"value engineering"

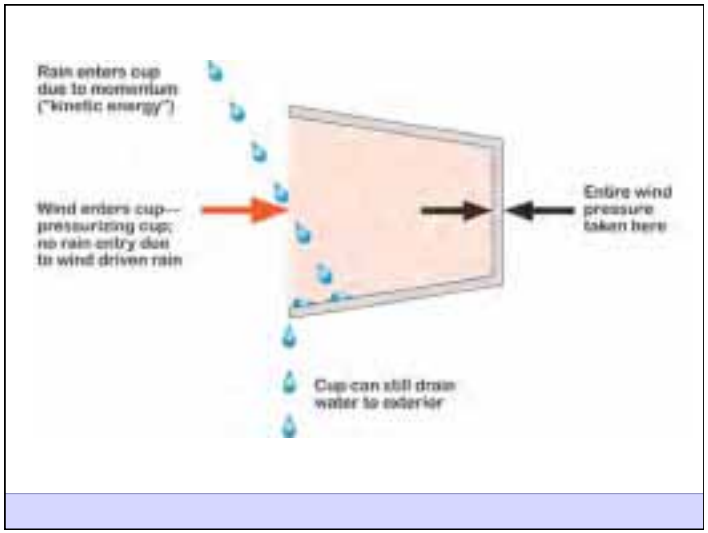


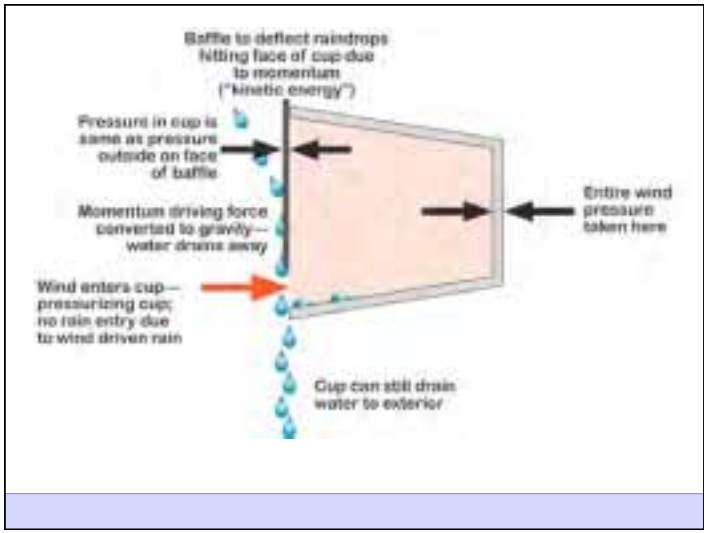


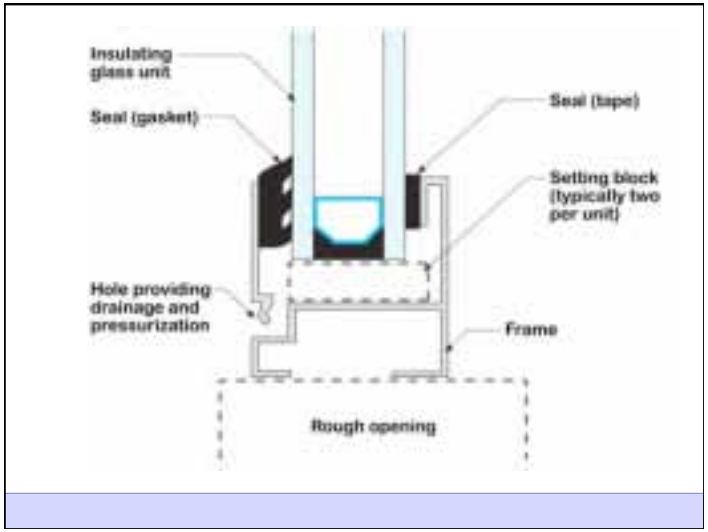


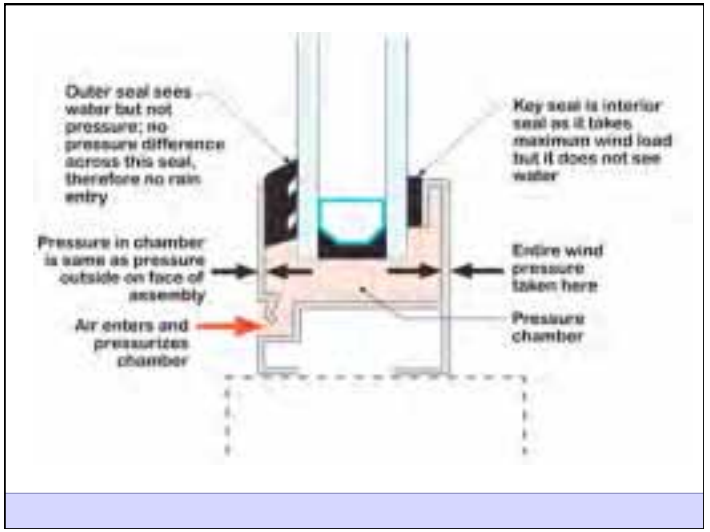


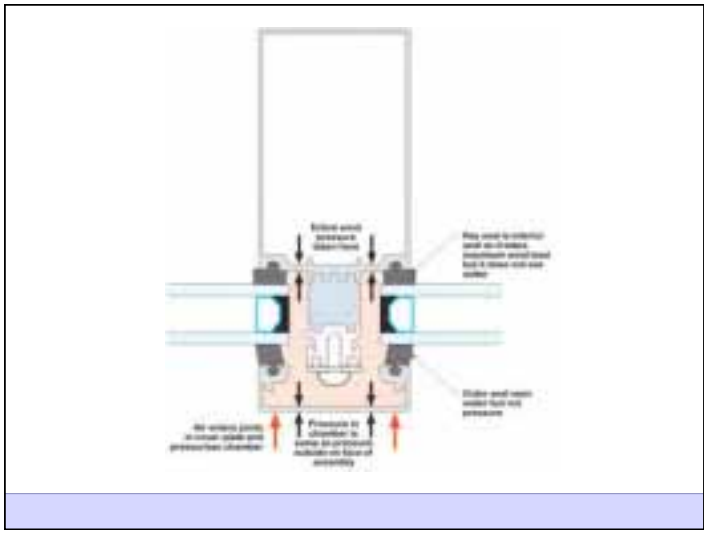


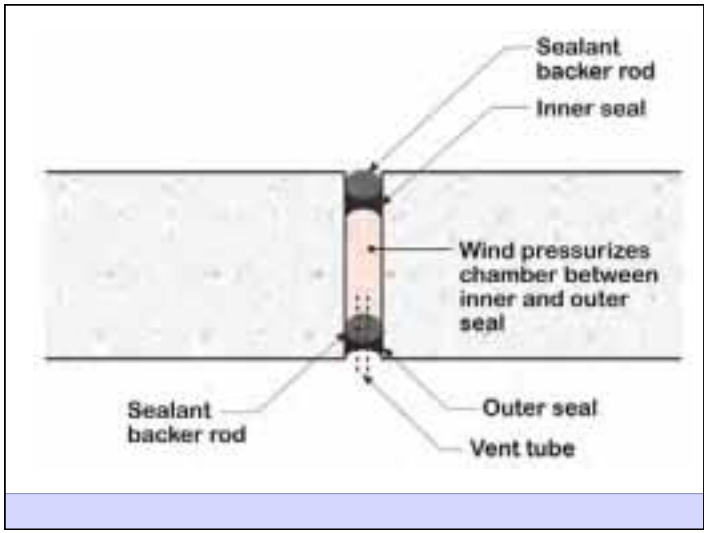

Rain enters cup due to momentum ("kinetic energy")
Wind enters cup—pressurizing cup; no rain entry due to wind driven rain
Entire wind pressure taken here
Cup can still drain water to exterior

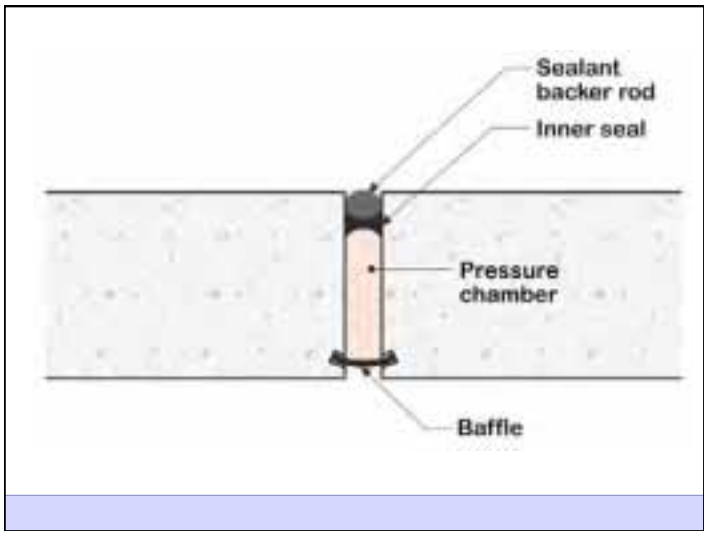

Baffle to deflect raindrops hitting face of cup due to momentum ("kinetic energy")
Pressure in cup is same as pressure outside on face of baffle
Momentum driving force converted to gravity—water drains away
Wind enters cup—pressurizing cup; no rain entry due to wind driven rain
Entire wind pressure taken here
Cup can still drain water to exterior

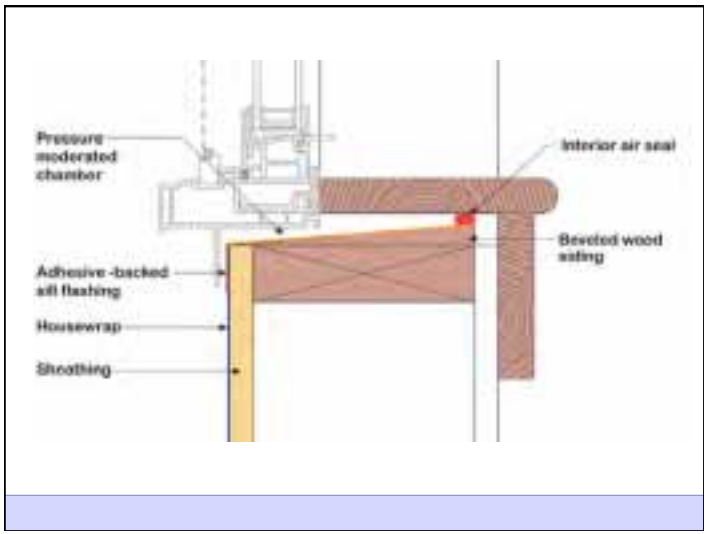

Insulating glass unit
Seal (gasket)
Seal (tape)
Setting block (typically two per unit)
Hole providing drainage and pressurization
Frame
Rough opening


Outer seal sees water but not pressure; no pressure difference across this seal, therefore no rain entry
Key seal is interior seal as it takes maximum wind load but it does not see water
Pressure in chamber is same as pressure outside on face of assembly
Entire wind pressure taken here
Air enters and pressurizes chamber
Pressure chamber

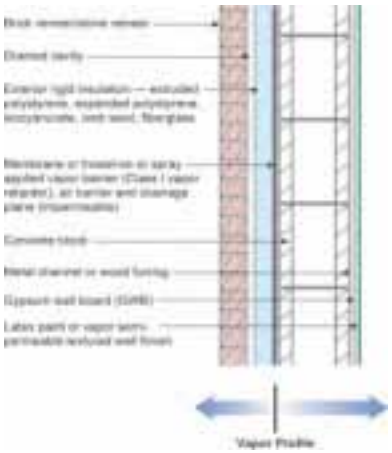


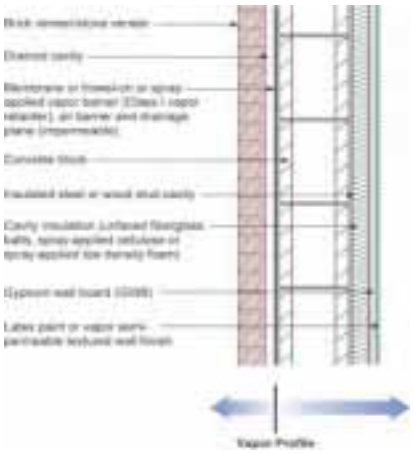


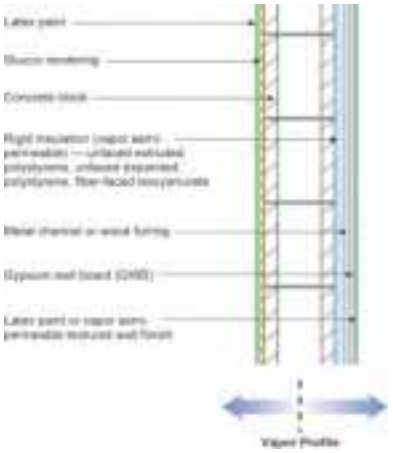


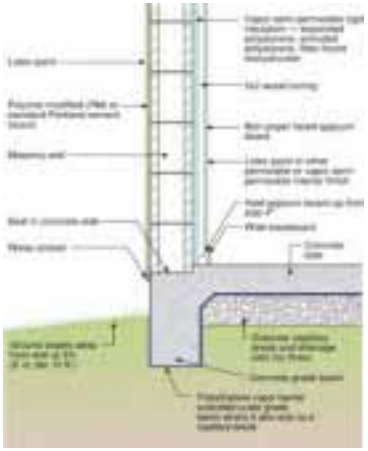


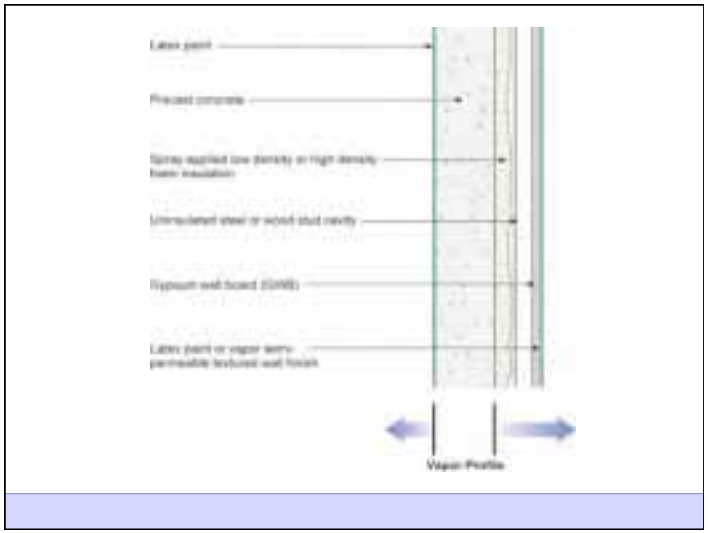

Subarctic/Arctic
Very Cold
Marine
Cold

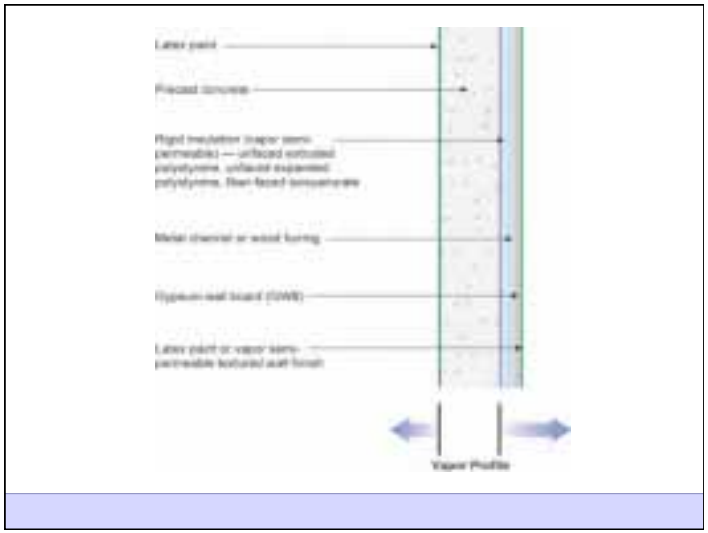

Vapor Profile

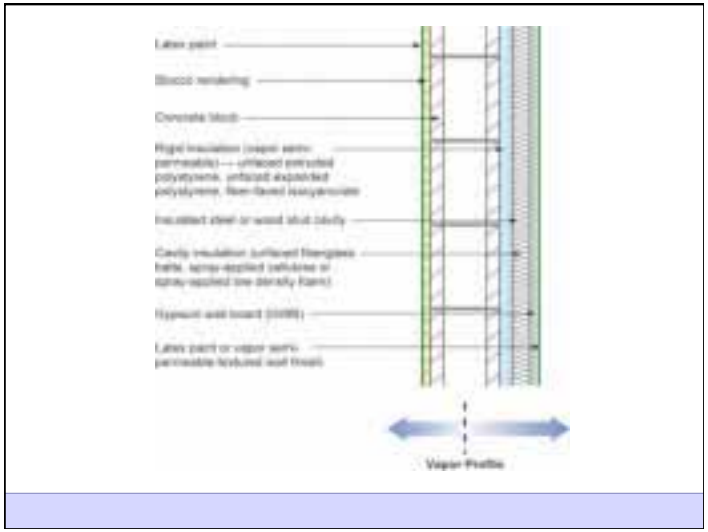

Vapor Profile

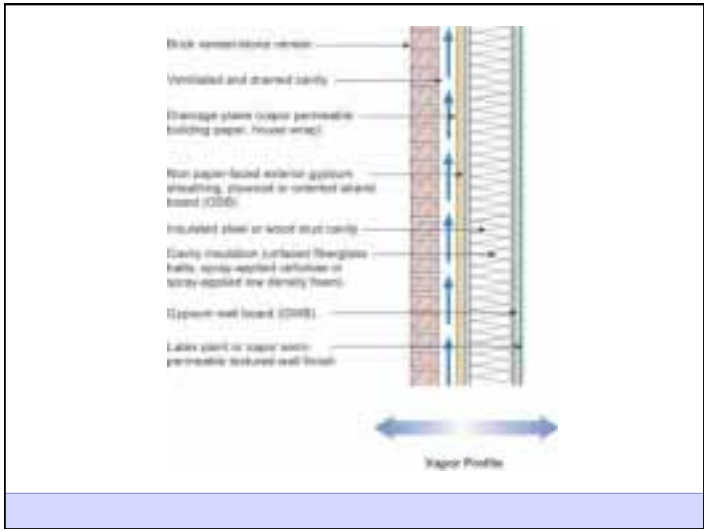

Latex paint
Stucco rendering
Concrete block
Rigid insulation (vapor semi-permeable) — unfaced extruded polystyrene, unfaced expanded polystyrene, fiber-faced isocyanurate
Metal channel or wood furring
Gypsum wall board (GWB)
Latex paint or vapor semi-permeable textured wall finish
Vapor Profile

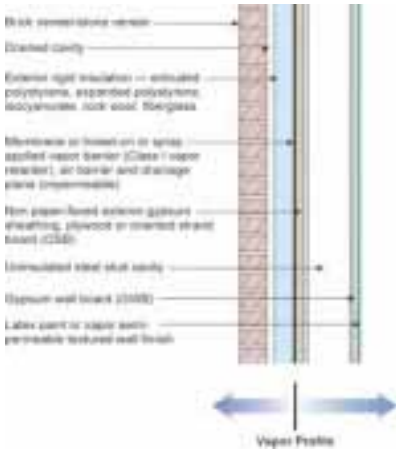








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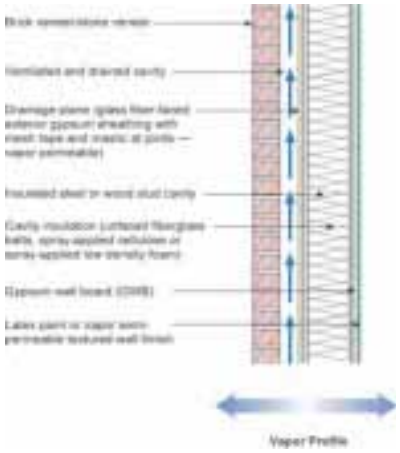
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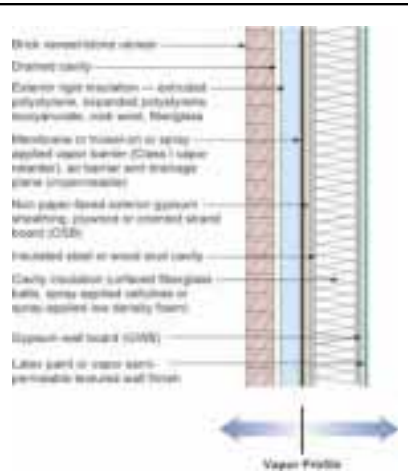
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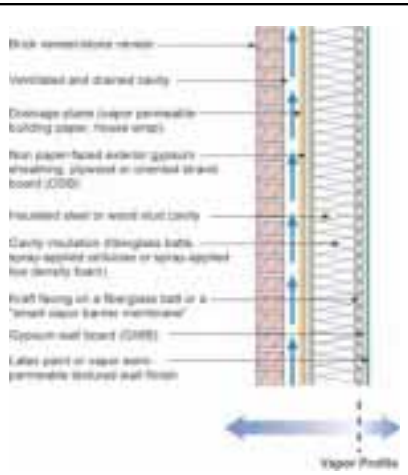
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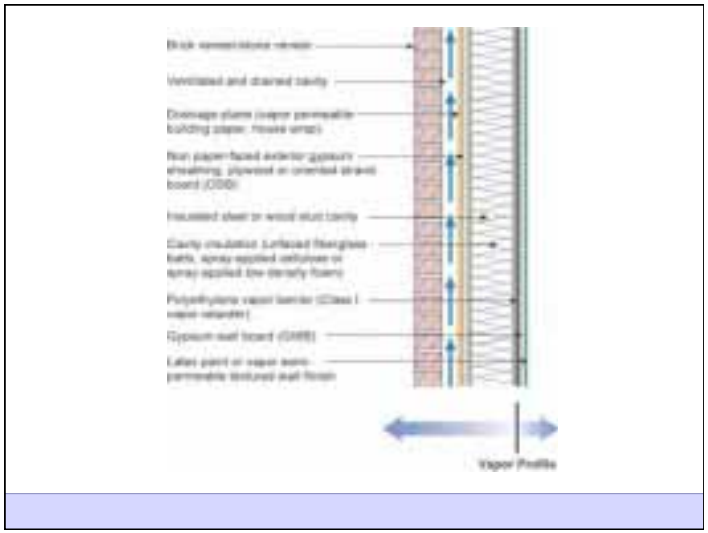
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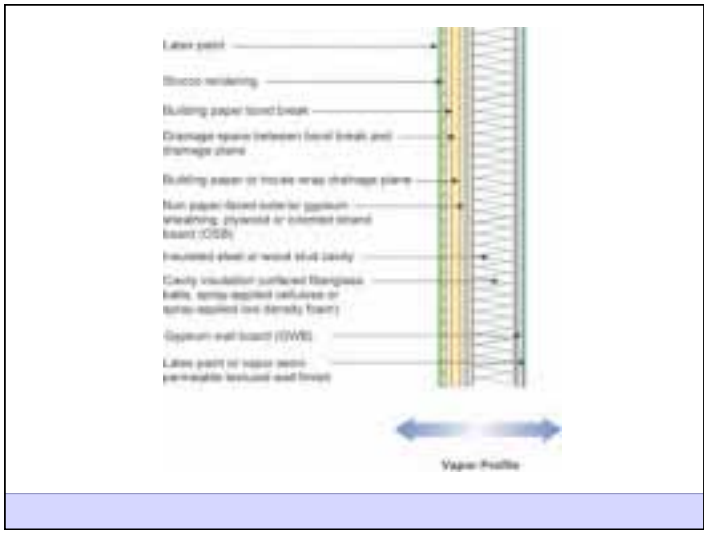
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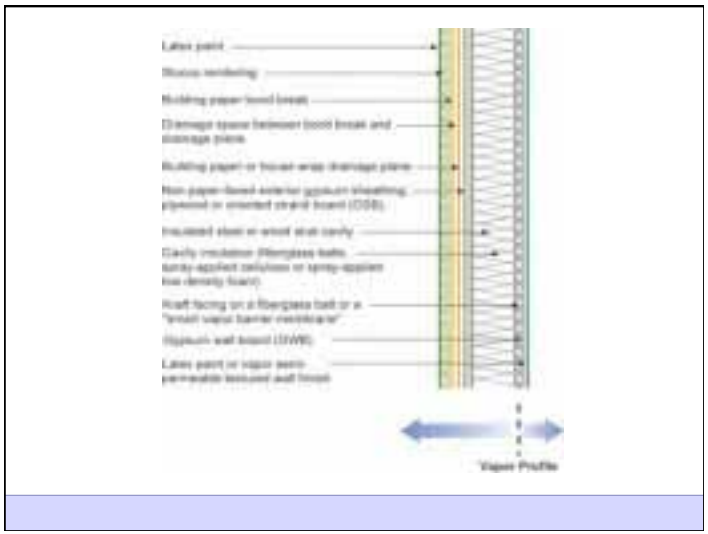
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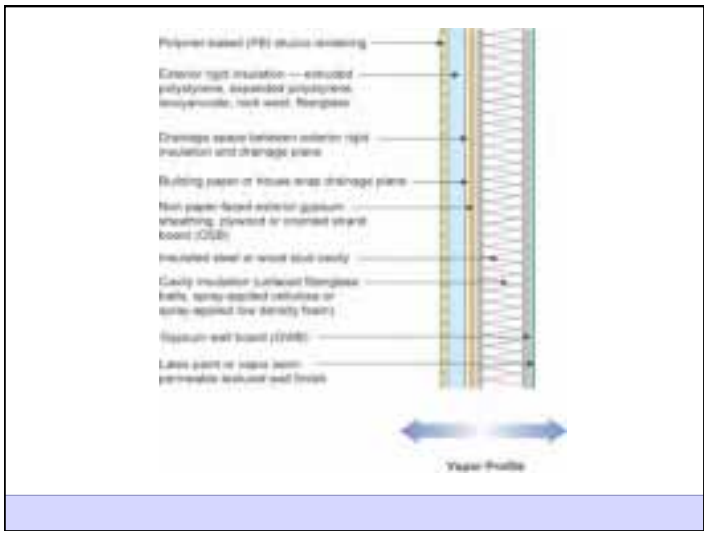
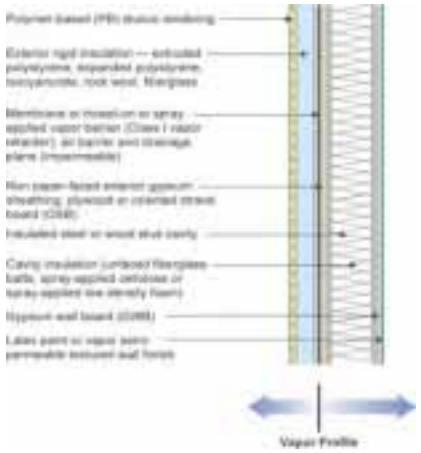
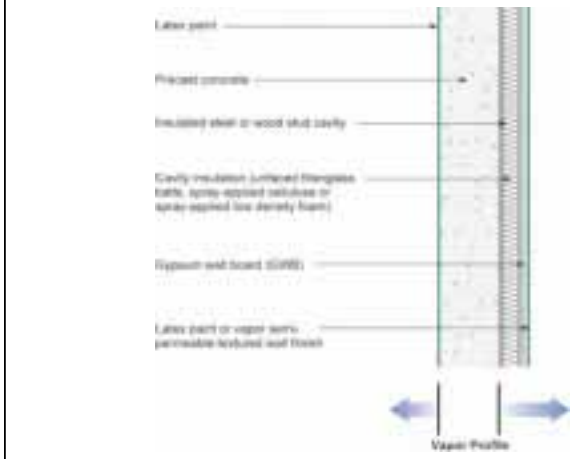
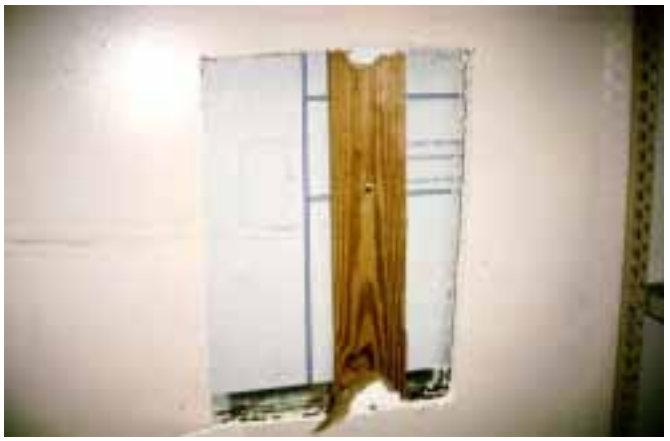
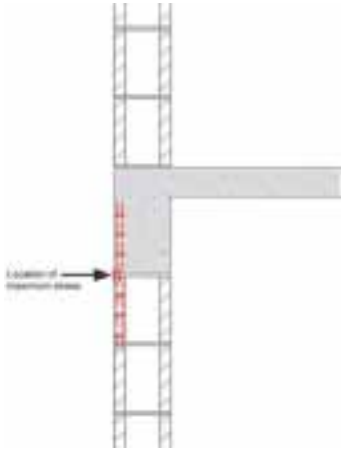
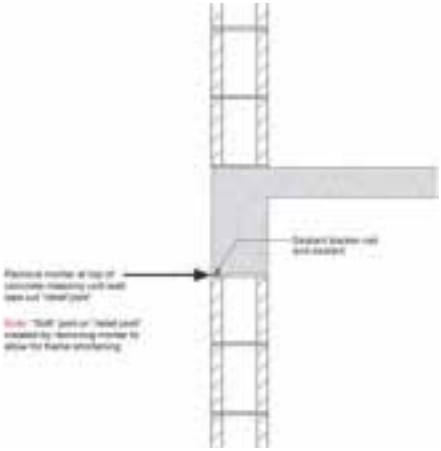

Vapor Profile

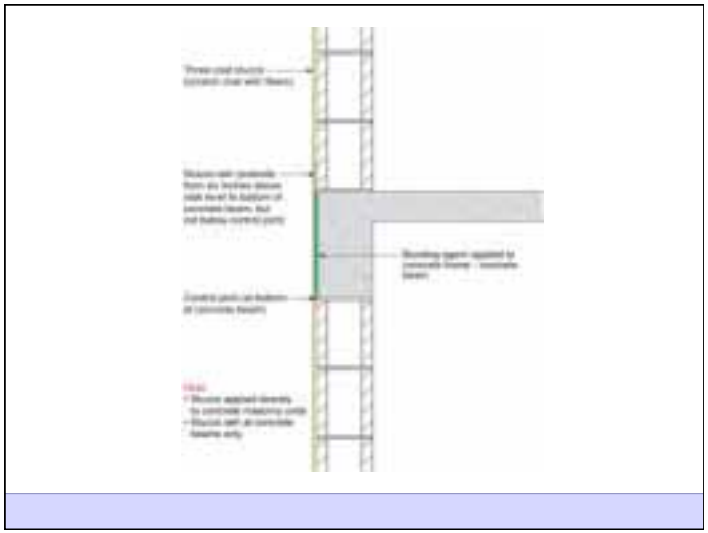

Polymer based (PB) stucco sheathing
Exterior rigid insulation — extruded polystyrene, expanded polystyrene, isocyanurate, rock wool, fiberglass
Membrane or mineral-ion or spray applied vapor barrier (Class I vapor retarder), air barrier and drainage plane (impermeable)
Non-paper-faced exterior gypsum sheathing, plywood or oriented strand board (OSB)
Insulated steel or wood stud cavity
Cavity insulation (unfaced fiberglass batts, spray-applied cellulose or spray-applied low density foam)
Gypsum wall board (GWB)
Latex paint or vapor semi-permeable textured wall finish
Vapor Profile

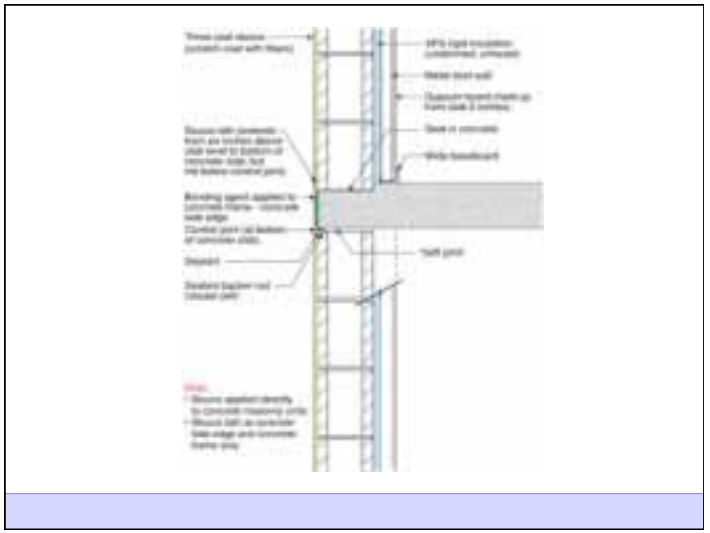

Latex paint
Precast concrete
Insulated steel or wood stud cavity
Cavity insulation (unfaced fiberglass batts, spray-applied cellulose or spray-applied low density foam)
Gypsum wall board (GWB)
Latex paint or vapor semi-permeable textured wall finish
Vapor Profile

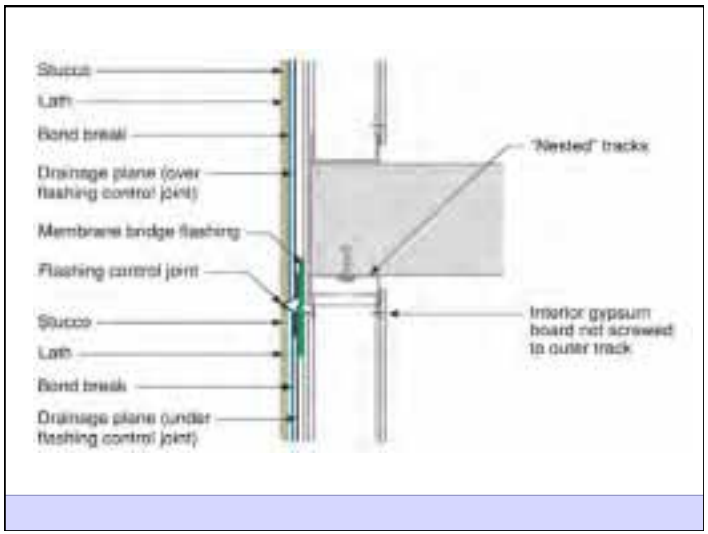


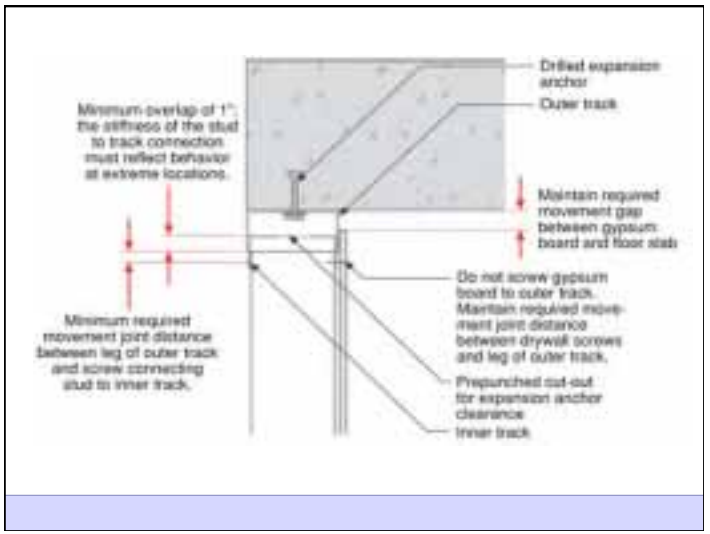












What Is A Building?

It is an environmental separator

At the most basic level a building provides shelter - shelter from the elements as well as from other dangers. Its' function is to separate the inside from the outside as required by the local environment and the wishes of its occupants. A building creates an interior environment that is different from the exterior environment – it is an environmental separator. This interior environment should be controllable by the occupants in a manner that meets their needs.

- 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

Focus of Building Science

Not all performance objectives are equal. All are important, but some are more important than others. Control of heat, air and moisture stand above the rest.

Damage Functions

Four things destroy most buildings:
Water, Heat, Ultra-Violet Radiation and Ozone

Of these four, control of water is the most important, followed by heat and finally followed by sunlight. Water and heat cause the vast majority of building durability problems.

A great deal of water can be transported by air. And water is often referred to as “moisture”.

The Rules

Control of heat, air and water deals with over 80 percent of the problems faced by the construction industry.

Heat, air and water control are the key to building science

The Rules

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 Always Acts Down

Building Science

Climate Dependence of Moisture Control

Buildings should be suited to their environment. It is not desirable to construct the same manner of building in Montreal, Memphis, Mojave and Miami. It's cold in Montreal, it's humid in Memphis, it's hot and dry in Mojave and it's hot and wet in Miami. And that's just the outside environment. It is also not desirable to construct the same manner of building to enclose a warehouse, house, school, office, health club with a swimming pool, hospital or museum. The interior environment also clearly matters.

Building Science

Environmental Loads

Hygro-thermal regions
Rain exposure zones
Interior climate classes

Used to design building envelopes and mechanical systems.

Building Science

Hygro-Thermal Regions

- Severe Cold
- Cold
- Mixed-Humid
- Hot-Dry/Mixed Dry
- Hot-Humid

Rain Exposure Zones

- Extreme (above 60 inches annual precipitation)
- High (40 to 60 inches annual precipitation)
- Moderate (20 to 40 inches annual precipitation)
- Low (less than 20 inches annual precipitation)

Building Science

Interior Climate Classes

I – Temperature moderated
Vapor pressure uncontrolled
Air pressure uncontrolled (warehouses, garages, storage rooms)

II – Temperature controlled
Vapor pressure moderated
Air pressure moderated (houses, apartments, offices, schools, commercial and retail spaces)

III – Temperature controlled
Vapor pressure controlled
Air Pressure controlled (hospitals, museums, swimming pool enclosures and computer facilities)

Building Science

Heat

The best understood.
Easiest to understand

- Convection
- Conduction
- Radiation

Building Science

Air

Easy to understand
“Before you can control air you must enclose air”
Concept of building enclosures – no big holes
Air barriers
Air sealing

Building Science

Moisture

- Most difficult to understand
- Can be easy to understand
  - "Moisture goes from warm to cold"
  - "Moisture goes from more to less"
- Vapor barriers vs. vapor retarders
- Venting vs. non –venting of roofs, crawl spaces and walls
- Positive or negative pressures

Building Science

Moisture Balance

Building assemblies get wet from the outside, get wet from the inside and start out wet. We must control wetting from the outside, control wetting from the inside, and let assemblies dry to the inside, or to the outside, or to both sides.

Building Science

Moisture Control

Various strategies can be implemented to minimize the risk of moisture damage.

The strategies fall into following three groups:

- Control of moisture entry
- Control of moisture accumulation
- Removal of moisture

Building Science

The Big Four of Moisture Control

- Controlling rain entry
- Controlling ground water
- Controlling water vapor via air transport
- Controlling water vapor via vapor diffusion