BUILDINGS USE TOO MUCH ENERGY:

THE SOLUTIONS SYMPOSIUM

BEC Charlestown
25 October 2012

Acknowledgements/Credits

Fiona Aldous and Rob Kistler, co-authors and presenters of original presentation at 2012 AIA . National Building Enclosure Council Chairs and past-Chairs

The AIA Committee on Technical Design for Building Performance (TDBP)

with thanks to

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of

National Institute of Building Science (NIBS)

Building Enclosure Technology and Environment Council (BETEC)

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Learning Objectives

1. Understand the impact of ever increasing energy reduction codes, regulations and societal pressures on the building enclosure and how these demands for energy savings can affect the performance of enclosure materials, systems and assemblies.
2. Apply scientific analysis methods to the building enclosure to more accurately predict real-world performance and why design according to old rules-of-thumb are no longer adequate.
3. Learn building science basics behind material and system performance.
4. Investigate new challenges for materials and systems for energy conservation, with a focus on the control of air flow and insulation.
5. Incorporate sophisticated quality assurance and quality control requirements into the design and construction process, including statistically significant sampling, mock-ups, testing, and checklists.

Today's Presentation

- What is "High Performance"
- The Need for High Performance Buildings
- Quality and Building Enclosure Commissioning and how they relate to High Performance Buildings.
- Tools for High Performance Enclosures
- High Performance Design for Energy Savings per Phase

Issues for High Performance Design for Energy Savings

- Climate
- Scientific Analysis Tools
- New Challenges for Materials and Systems
- Durable Design

High Performance Design for Energy Savings per Phase

- Pre-Design
- Schematic Design
- Design Development
- Construction Documents
- Construction Administration

INTRODUCTION

The Need

Increasingly higher performance expectations.

Buildings consume 40% of all energy in the US!

We are the bad guys!

Increasing Performance Criteria

By Code or Regulation:

- Each new version of ASHRAE 90.1 sets lower energy consumption criteria.
- Cities and other governmental agencies are setting lower energy criteria (commonly through LEED but also through the International Green Construction Code).

Increasing Performance Criteria

By Client Demand

- Institutional Users, Universities and Hospitals
- Class A Office space

By Litigation

- Too many buildings fail to perform as designed and/or constructed with resulting claims.

Increasing Performance Criteria

By Governmental Leadership

- GSA requirements for new projects was increased from LEED Silver to LEED Gold in 2010.
- DOD required LEED Silver in 2008.

Fiscal Year	Percentage Reduction
2006	2
2007	4
2008	9
2009	12
2010	15
2011	18
2012	21
2013	24
2014	27
2015	30

Federal Energy Management Program
EISA 2007 ratifies energy reduction goals for Federal facilities, mandating the following energy intensity reductions per fiscal year relative to a 2003 baseline:

Increasing Performance Criteria

By Professional Organization and Societal Pressures:

- AIA 2030 Commitment
- Clinton Climate Initiative

Increasing Performance Criteria

Compounding Increases; while green standards are being increasingly adopted or required, the standards are updated for increased performance.

- Each version of LEED, Energy Star and Green Globes is increasingly more stringent.
- Competing certification systems set requirements more stringent than LEED
  - Passive House
  - Net Zero Energy Buildings
  - Living Building Challenge

Failures Point out Need for Improvement

- Architecture profession under pressure for poor designs.
- Construction industry under pressure for poor quality.
- Claims by USGBC that LEED buildings are more energy efficient have been seriously questioned.
- Some highly touted buildings have turned out to not have performative building enclosures.
- Some jurisdictions have gone as far as to require separate review by building enclosure experts

Focus on Performance

Some green initiatives have over-emphasized less important criteria.

- Operational Energy use of a building over it's lifetime is many times that of the embodied energy.
- Durability is Extremely Important
  - Not included in most Green discussions.
  - Currently required in the Canadian LEED and likely in next versions.
- Performance Verification of the Building Enclosure on the rise.
  - Commissioning of the Building Enclosure
  - The rise of the Building Enclosure Consultant

What is High Performance

- Define High Performance
- What does it mean?
- Independent Ideas

High Performance Buildings Database

http://eere.buildinggreen.com/

Performance

- An implied higher performance building wherein the Owner expects to recoup initial costs over the life cycle of the building
- LEED does not provide parameters for Building Enclosure

Finding definition of HIGH PERFORMANCE DESIGN?

- ASHRAE/IESNA 90.1. Standard 189 & DOE is to achieve a 30 percent reduction in energy cost by 2010
- Green Building Initiative (GBI) is also working toward establishing its Green Globes rating system for commercial buildings

Building Envelope

Appropriate assembly of wall, roof, foundation, and window materials will provide good thermal and moisture control, while supporting reductions in building energy use. A good envelope harnesses natural energy through effective use of passive solar and daylighting techniques.

The New Children's Center
The foster care intake/training facility for the Administration for Children's Services is being retrofitted into a historically significant structure that was built in 1912. For comfort as well as energy savings, the envelope is being upgraded with additional insulation (cellulose) and detailed to prevent thermal bridging. It also utilizes new higher performance windows.
Richard Dattner Architect, P.C.

▸ **Benefits**
Diminished heating, cooling, and lighting loads reduce operating energy costs.
A well-designed envelope can substantially reduce the size and cost of mechanical systems.

❑ **Envelope detailing.** To prevent moisture build-up within the walls, detail the material assembly of the envelope in accordance with best vapor barrier practices. Use monolithic building systems and assemblies as opposed to smaller assembly parts. This will minimize the need for caulking and weather-stripping and will significantly reduce infiltration. Avoid thermal bridging through the exterior walls, roof, and floor details and components.

Building Energy Use

LEVEL 1
❑ **New Buildings.** High performance new buildings shall annually consume a minimum of 30% less energy on a Btu-per-gross-square-foot basis in comparison to what would be consumed if the building were designed for minimum compliance with the NYS Energy Code. Operational cost comparisons should be prepared to ensure that the high performance building will save at least the same percentage in energy costs as it achieves in combined actual energy use reductions.

High Performance Building **Guidelines**
City of New York Department of Design and Construction
April, 1999

High Performance Design

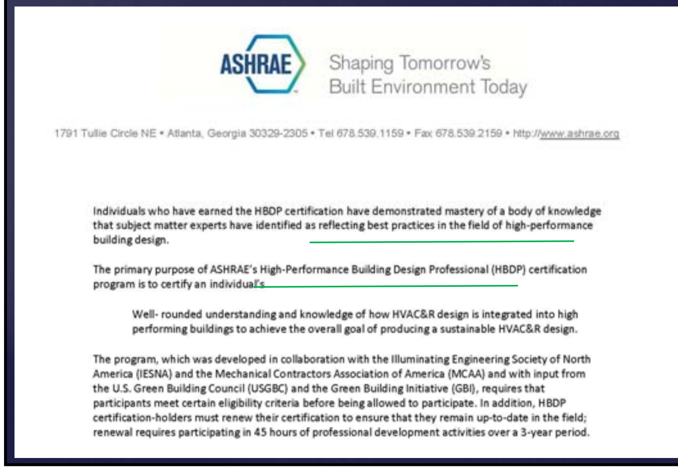
Green building is also known as a sustainable or high performance building.

High Performance Building Council

THE AMERICAN INSTITUTE OF ARCHITECTS

We are now entering into the next era of design and practice, defined by high-performance…
High-performance design is not something most architects understand well.

High Performance Design



ASHRAE Shaping Tomorrow's Built Environment Today

1791 Tullie Circle NE • Atlanta, Georgia 30329-2305 • Tel 678.539.1159 • Fax 678.539.2159 • http://www.ashrae.org

Individuals who have earned the HBDP certification have demonstrated mastery of a body of knowledge that subject matter experts have identified as reflecting best practices in the field of high-performance building design.

The primary purpose of ASHRAE's High-Performance Building Design Professional (HBDP) certification program is to certify an individual's

> Well- rounded understanding and knowledge of how HVAC&R design is integrated into high performing buildings to achieve the overall goal of producing a sustainable HVAC&R design.

The program, which was developed in collaboration with the Illuminating Engineering Society of North America (IESNA) and the Mechanical Contractors Association of America (MCAA) and with input from the U.S. Green Building Council (USGBC) and the Green Building Initiative (GBI), requires that participants meet certain eligibility criteria before being allowed to participate. In addition, HBDP certification-holders must renew their certification to ensure that they remain up-to-date in the field; renewal requires participating in 45 hours of professional development activities over a 3-year period.

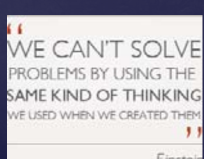
What is High Performance

"I shall not today attempt further to define the kinds of material… but I know it when I see it." Potter Stewart

High Performance Design

High performance involves

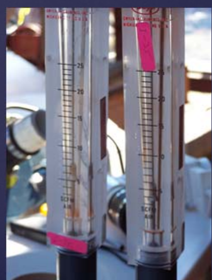
- Thoughtful consideration
- Control of energy across the enclosure
- Occupant comfort and productivity
- Durability of materials and systems
- Resilience



COMMISSIONING FOR HIGH PERFORMANCE BUILDINGS

Commissioning (Cx)

Verify performance of all or (more common) parts of a building.



- Commissioning has previously been thought of for MEP systems but commissioning of the building enclosure is on the rise.
- Focus was formerly concentrated on Construction phase but now generally recognized that some Cx tasks start before design starts
- Previous emphasis on establishing a strong operating and maintenance program.

Building Enclosure Commissioning (BECx)

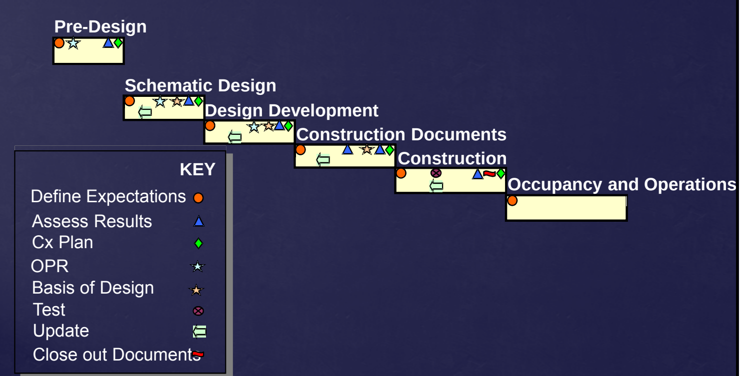
Commissioning an enclosure is different from commissioning a mechanical or electrical system.

- The building enclosure is not adjustable or tunable (with rare exceptions).
- Operative materials will be covered up and essentially impossible to get to for repairs.

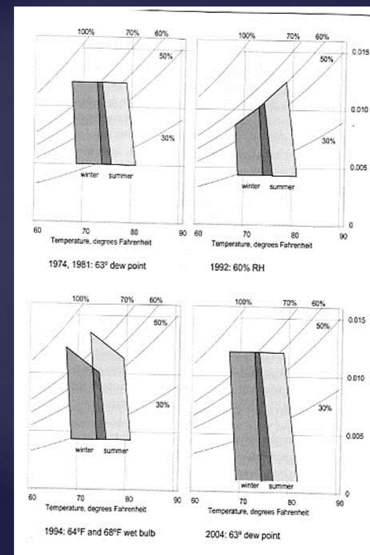
Guideline 3 and ASTM Standard

- Guideline 3 is oriented towards the commissioning process.
- ASTM E 2813, *Standard Practice for Building Enclosure Commissioning* (draft) is developed in concert with GL-3 and includes more definitive requirements for the type and frequency of testing.
- Includes “Fundamental” and “Enhanced” commissioning.
- Includes general qualifications of commissioning authority.

Key Enclosure Commissioning Milestones

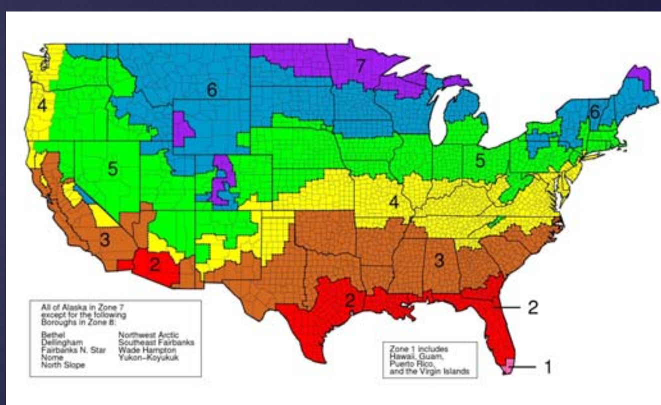


DESIGN WITH CLIMATE FOR ENERGY SAVINGS

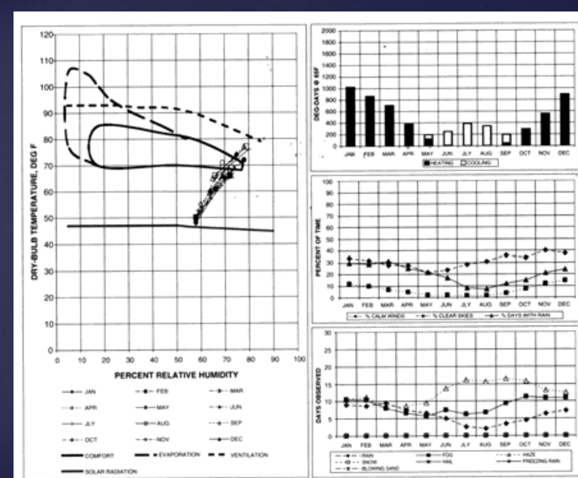


Interior Climate

ASHRAE Climate Zones

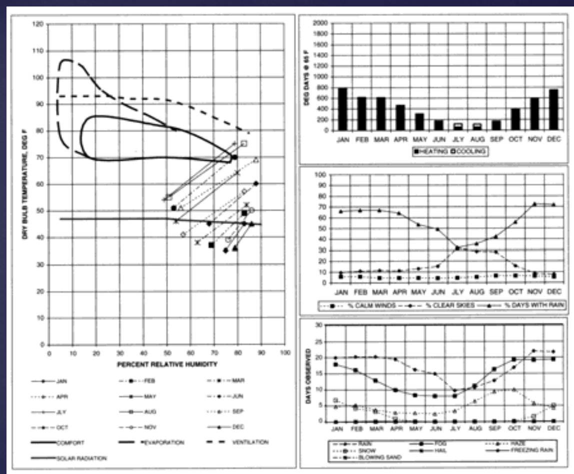


The climate zones were developed based on analysis of the 4775 NOAA weather sites and statistical analysis of regional information. The new climate zones are set by county boundaries. The zones were first adopted by 2004 IECC Supplement model energy code.



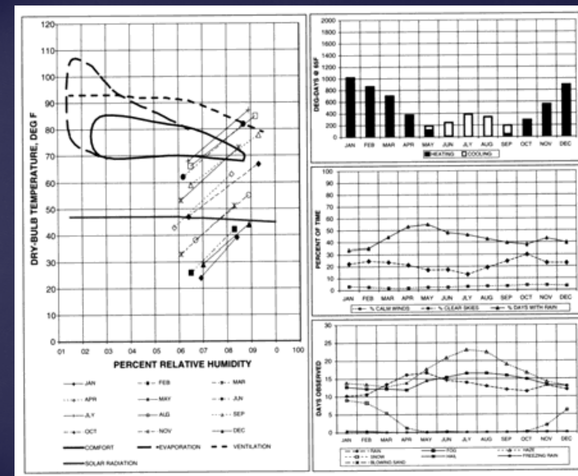
San Diego

From “Integrated Buildings” Leonard R. Bachnan

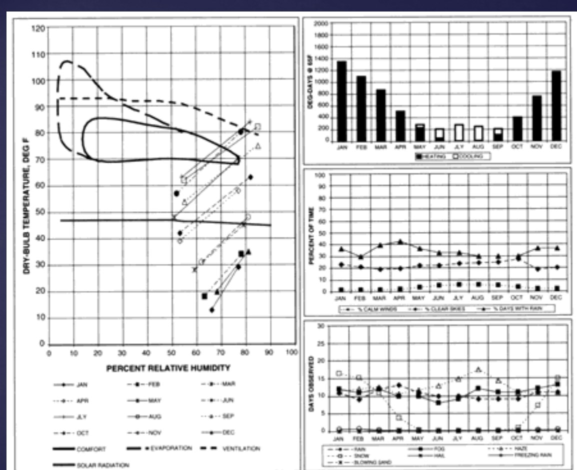


Seattle

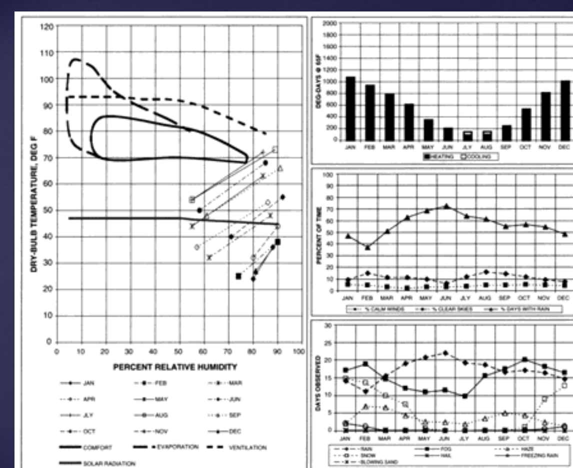
Data Sources, Engineering Weather Data from the
National Climatic Data Center
and the ASHRAE Weather Data Viewer



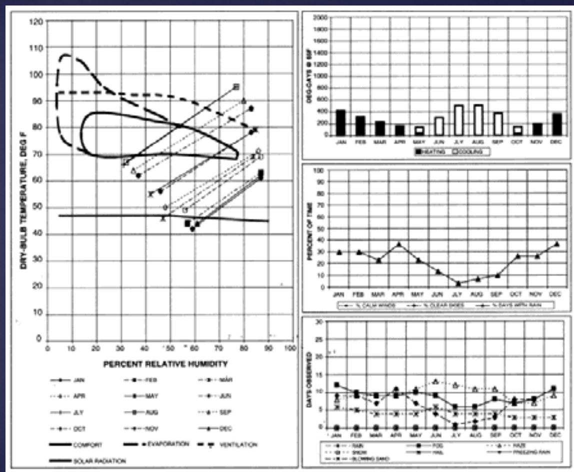
Philadelphia



Chicago



Munich



Seville Spain

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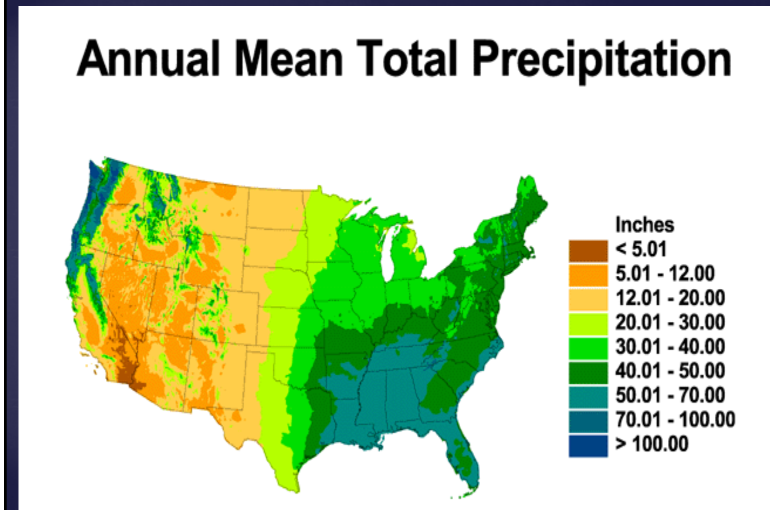
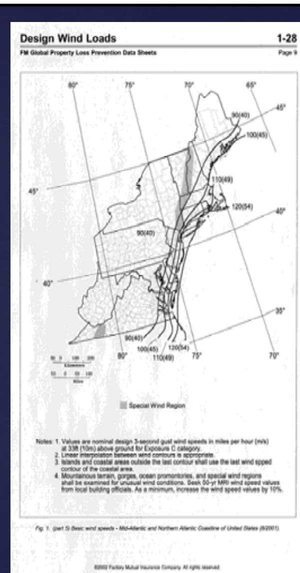


Wind



Design Pressures (DP) / ASCE 7

ASCE 7-05 Minimum Design Loads for Buildings and Other Structures provides requirements for general structural design and the means for determining dead, live, soil, flood, wind, snow, rain, atmospheric ice, and earthquake loads, as well as their combinations, which are suitable for inclusion in building codes and other documents.

THE TOOLS FOR SCIENTIFIC ANALYSIS OF HIGH PERFORMANCE BUILDINGS

Psychometric Chart

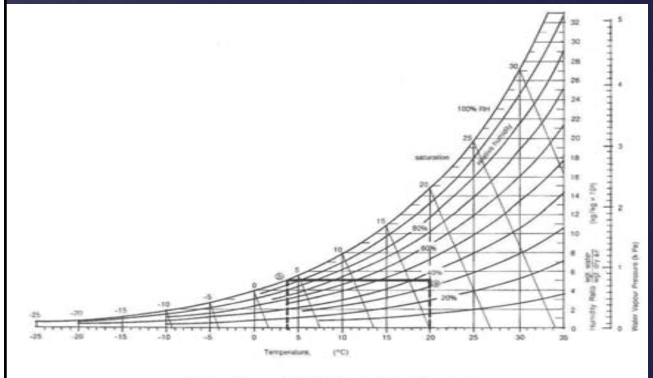
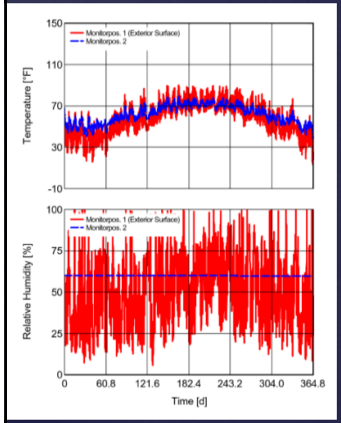


Figure 2.3 Simplified Psychrometric Chart

Transient Hygrothermal Analysis



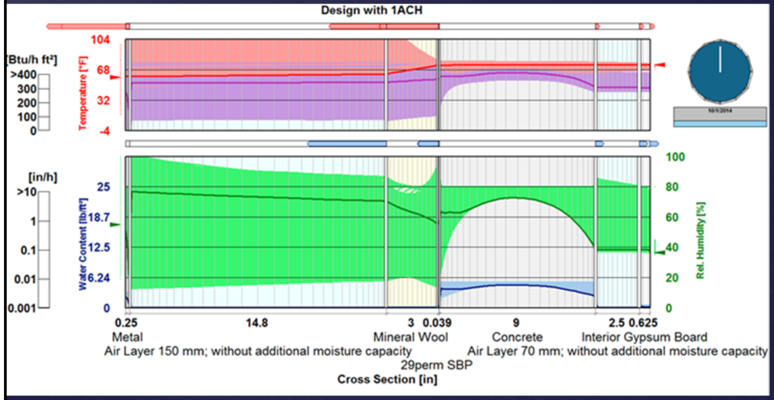
8760 Hour Calculations

WUFI-ORNL/IBP is a menu-driven PC program which allows realistic calculation of the transient coupled one-dimensional heat and moisture transport in multi-layer building components exposed to natural weather. It is based on the newest findings regarding vapor diffusion and liquid transport in building materials and has been validated by detailed comparison with measurements obtained in the laboratory and on outdoor testing fields.

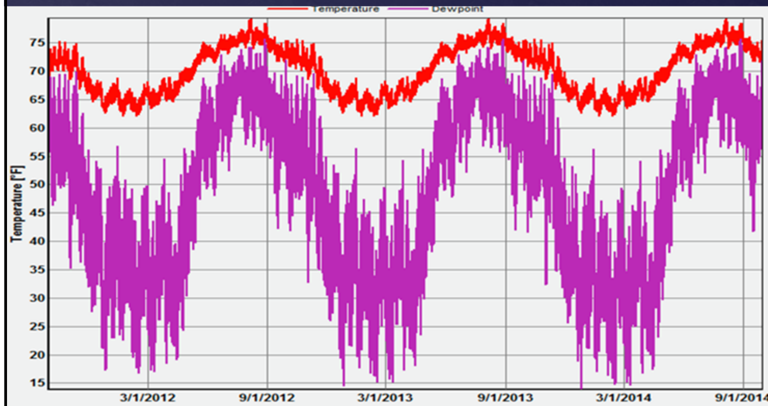
http://www.ornl.gov/sci/btc/apps/moisture/

WUFI Pro 5.0

Hygrothermal Modeling



Hygrothermal Modeling



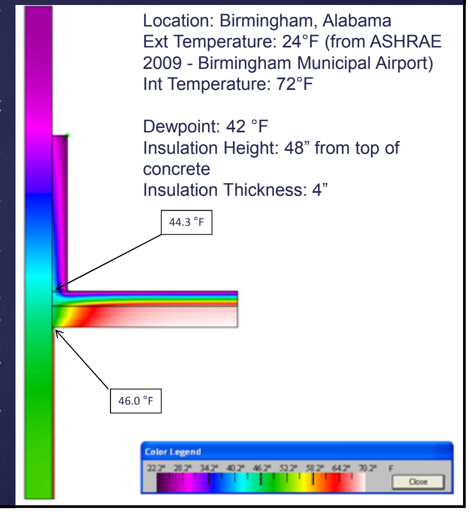
Graph 4: Temperature and Dewpoint vs Time - Exterior face of WRB

Heat Transfer Simulation

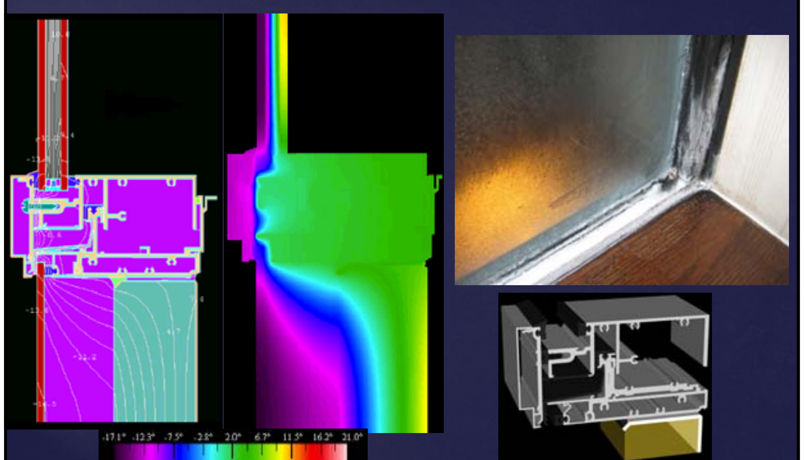
Two-Dimensional Building Heat-Transfer Modeling

THERM is a state-of-the-art, Microsoft Windows™-based computer program developed at Lawrence Berkeley National Laboratory (LBNL) for those interested in heat transfer.

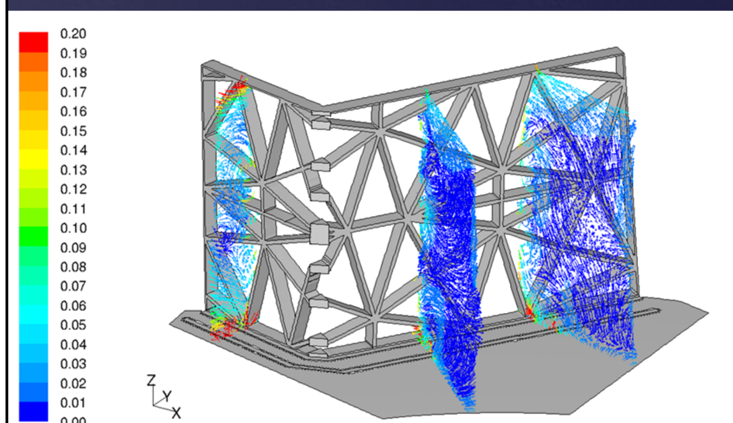
Using THERM, you can model two-dimensional heat-transfer effects in building components such as windows, walls, foundations, roofs, and doors; where thermal bridges are of concern. THERM's heat-transfer analysis allows you to evaluate a product's energy efficiency and local temperature patterns, which may relate directly to problems with condensation, moisture damage, and structural integrity.



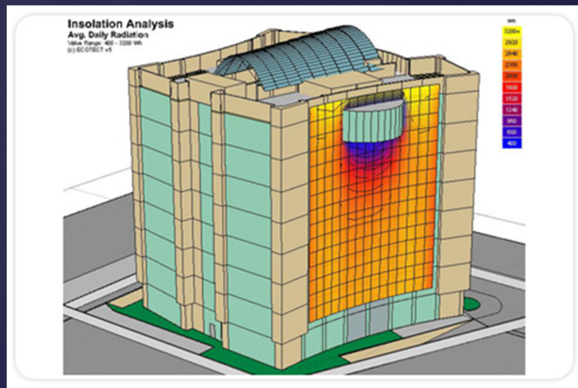
Heat Transfer Simulation



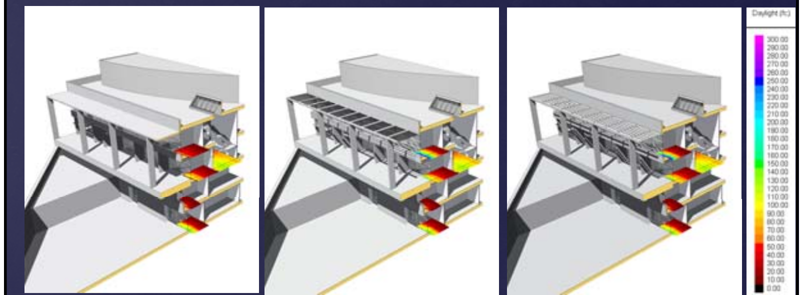
Computation Fluid Dynamics



Solar Insolation



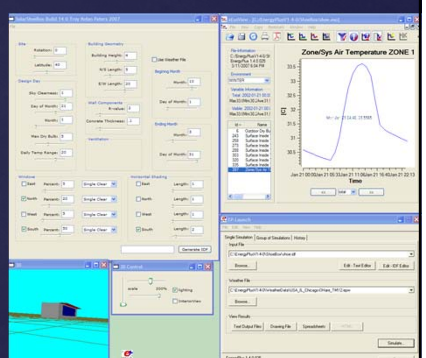
Footcandle mapping, IES VE and Ecotect



Trellis Study 1 Trellis Study 2 Trellis Study 3

Energy Plus Life Cycle Costing

- Replacing lamps
- Replacing fixtures
- Adding lighting controls
- Replacing mechanical plant
- Upgrading mechanical controls
- Adding insulation
- Reducing air infiltration
- Upgrading windows

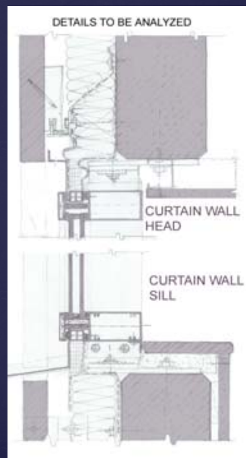


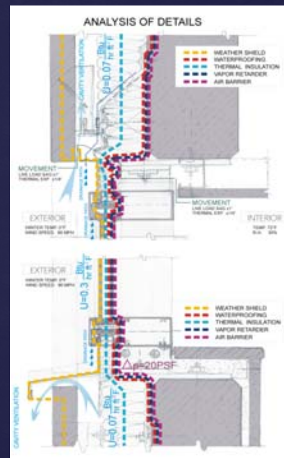
Scientific Analysis

Building science and building physics modeling for many conditions:

- Building Energy Consumption Modeling
- Icing, snow buildup
- Structural analysis
- Movement analysis, deflection
- Rate of curvature
- Panel size optimization

PENCIL TEST: Continuity of barriers





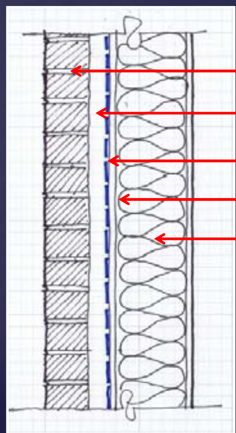
HIGH PERFORMANCE CHALLENGES FOR MATERIALS AND SYSTEMS

New Challenges

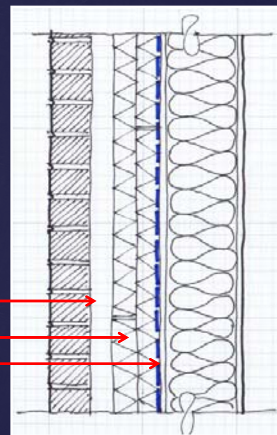
Understand how increased insulation changes the performance of even time proven materials and wall assemblies.

Brick Veneer Changes

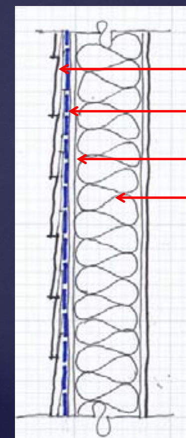
Brick Veneer Changes



BRICK VENEER
DRAINED CAVITY
WRB
GYP SHEATHING
INSULATION IN METAL STUDS
VENTED CAVITY
4” RIGID INSUL
WATERPROOF AIR BARRIER

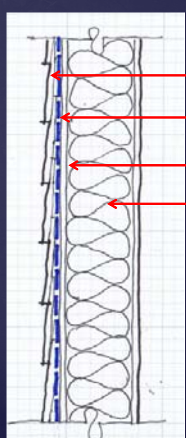


Wood Siding Changes

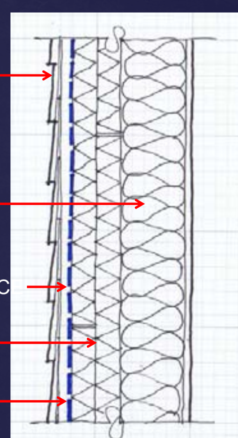


WOOD SIDING
WRB
OSB
BATT INSUL IN WOOD STUDS

Wood Siding Changes



WOOD SIDING
WRB
OSB
BATT INSUL IN WOOD STUDS
FURRED OUT AIR SPAC
4” RIGID INSUL
AIR BARRIER



Building Science

IT?

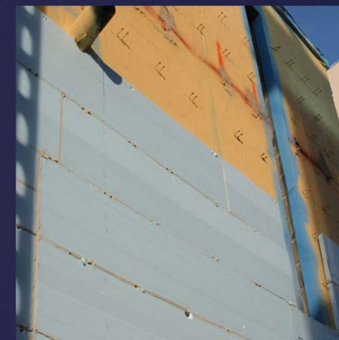
Fine Homebuilding, No 227, Summer 2012
Article by Kevin Ireton

Basics: H.A.M.

HEAT	AIR	MOISTURE
Hot to Cold	**High to Low**	**Control/ Disposal**
Continuous insulation (CI) Thermal bridging effect	Air Barrier system Energy Efficiency	Continuity Permeability

New Challenges

The design and construction industry still has to come to more established understanding of the definitions, applications and combinations of water-resistant barriers, air barriers and vapor retarders as control layers in the enclosure assembly.



New Challenges

The definitions, applications and combinations of water-resistant barriers, air barriers and vapor retarders as control layers in the enclosure assembly.

Control Layers

Air Barriers: Materials or combinations of materials that form a continuous envelope around all sides of the conditioned space to resist the passage of air.

- All joints, seams, transitions, penetrations and gaps shall be sealed.
- Capable of withstanding combined positive and negative wind load, fan and stack pressure without damage or displacement.
- At least as durable as overlying construction.
- Detailed to accommodate anticipated building movement.

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Control Layers

Vapor Barriers and Retarders: Without industry-wide consensus, materials with a perm rating less than 1 are interchangeably called a vapor barrier or vapor retarder (IBC and IEC 2003 use "Vapor Retarder"). More important than the term is to understand basic principles:

- Moisture transport through holes and gaps in a vapor retarder are caused by air flow, not permeation.
- All materials have some greater or lesser degree of resistance to diffusion and their placement in an enclosure assembly, whether intended as a retarder or not, will affect wetting and more importantly drying of an assembly.

Definitions

- IBC 2009: Allows for Class I, II or III in various locations.
  - Class I = Polyethylene or aluminum foil.
  - Class II = Kraft-faced batts or paint with perm rating 0.1 – 1.0
  - Class III = Latex or Enamel Paint

Control Layers

Water-Resistive Barrier: Materials or combinations of materials that form a continuous layer under veneer layers in wall assemblies to resist the penetration of liquid water and direct any water that penetrates to the exterior.

- Defined as ASTM D 226 Type 1, No.15 Asphalt felt with flashing in code.
- No commonly defined performance characteristics.

Air Barriers/Vapor Retarders

Air Barrier

- May or may not be a vapor barrier.
- System to resist the movement of air through an enclosure assembly.
- Must resist structural loading.
- Multiple air barriers allowable
- Located anywhere within the assembly

Vapor Retarder

- Membrane to resist the passage of water vapor, typically designated as less than 1 Perm.
- Typical kraft paper or plastic sheet vapor retarders will not perform adequately as an air barrier.
- VR must be carefully located in assembly based on insulation and relationship to indoor and outdoor climate conditions
- Avoid multiple vapor retarders

Air Barriers/Water-resistive Barriers

Air Barrier
- May or may not be a WRB.
- Must resist structural loading.
- Multiple air barriers allowable
- Located anywhere within the assembly

Water-resistive Barrier
- May or may not be an AB.
- Typically building felts or house wrap
- Usually not a VR
- Only one layer.
- Must be located immediately behind siding or insulation
- Not sufficiently strong or structurally anchored to resist wind loads.

Air Barrier Materials

Common Air Barrier Materials
- Concrete
- Gypsum Drywall
- Plywood
- Ext. Gypsum Sheathing
- Closed cell rigid insulations, extruded polystyrene
- Fully adhered Roofing membranes
- Aluminum and steel
- Sheet Metal Flashing
- Glass
- Some Building Wraps

Common Materials not AB
- CMU
- Brick
- Open cell rigid insulation, expanded polystyrene
- Batt and blanket insulation
- Building Felts
- Some Building Wraps
- Plastic sheets
- Wood fiber board sheathing
- Tongue and Groove sheathing
- Sprayed cellulose insulation
- Asphaltic Dampproofing

Generic Wall Air Barrier Systems

- Airtight Drywall Approach
- Sealed Sheathing
  - Plywood
  - Siliconized Gypsum Sheathing
  - Rigid Insulation
- Building Wraps, taped
- Concrete, Pre-cast Concrete
- Membranes
  - Fluid-applied
  - Peel and Stick
  - Torched
- Sheet Metal Air Barriers
- Spray polyurethane foam

Generic Roof/Ceiling AB Systems

- Airtight Drywall Approach
- Membranes on Structural Deck under shingles or metal panel.
- Vapor Barriers in compact low-slope roofing.
- Low-slope fully-adhered roof membranes.
- Spray polyurethane foam

Generic Below-grade AB Systems

- Concrete slab-on-grade.
- Concrete Foundation Walls
- Foundation Waterproofing membranes

New Challenges

Difficulties of achieving new airtightness criteria for the building enclosure and the impact on indoor air quality.

Air Infiltration & Exfiltration

- Infiltrating air cannot be treated or controlled
- Promotes energy waste, increased condensation & envelope deterioration.
- Can disrupt or overpower HVAC systems.
- Places limitations on control of noise, fire and smoke.
- Is a major cause of rain penetration
- Disrupts ability to control indoor humidity
- Disrupts interior HVAC design pressures (comfort, infection control and IAQ problems)
- Air leakage due to doors and windows only 20%, walls and roofs are 80%.

Airtightness

Definition for Whole Building Airtightness:

- Leaky: 0.60cfm/sf
- Average: 0.30cfm/sf
- Tight: 0.10cfm/sf

Per ASHRAE Fundamentals 2005

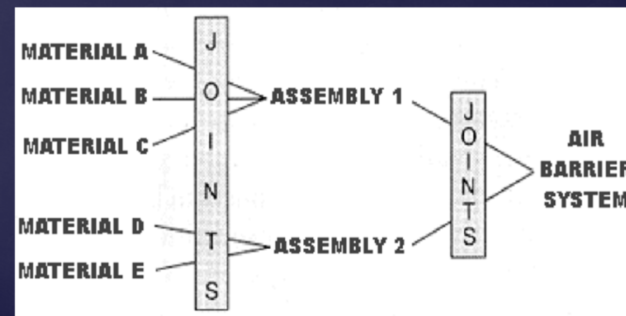
Measured at 75 pascals, 1.56psf, 25mph wind

Air Tightness

- ASHRAE 189
- ASHRAE 90.1/GSA = 0.4 cfm/ ft2 (2.0 L/s/m2) at a pressure differential of 0.3" w.g.(75 Pa)
- Army Corp of Engineers (USACE) = 0.25 cfm/ ft2 (2.0 L/s/m2) at a pressure differential of 0.3" w.g.(75 Pa)
- Green building Code IBC

Airtightness Requirements, ASHRAE 90.1

- MATERIALS: ASTM E 2178 **0.004** cfm/sf @ 0.3" w.g.
- ASSEMBLY: ASTM E 1677 : **0.04** cfm/sf @ 0.3" w.g.
- WHOLE BUILDING: ASTM E 799 : **0.4** cfm/sf @ 0.3" w.g.



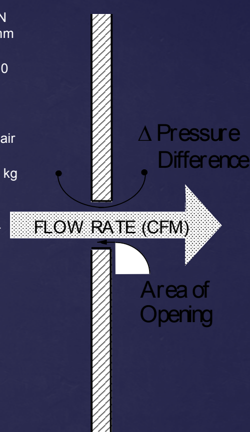
Air Flow

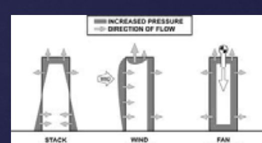
IF AN ELECTRIC OUTLET HAS AN AIR LEAKAGE AREA OF 625 sq.mm (1 sq. in.)

- ∆ P = 10 Pa (0.2 lb. /s.f. or 10 mph wind) sustained for one month:

  $Q = 780 \times A \times \Delta P^{0.5}$
- 2600 cu m. (91818 cu ft.) of air = 3000 kg air (6614 lb)
- 3000 x .0046 (kg/kg air) = 14 kg water (31 lb)
- If 10% were to remain in the wall, 1.4 kg (3.1 lb) or 49.6 / . 211 = 233

233 times more water accumulates from air leakage than accumulates than by diffusion (Quirouette, 1985)





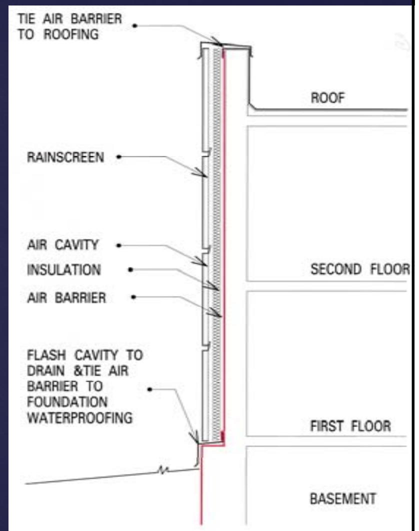
Air Flow Rate is Determined by:

- Hole or Pathway Area
- Pressure Difference Between Both Sides

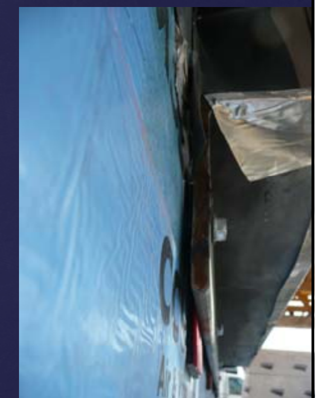
Common Air Barrier defects

- Open splice joints
- Gaps at perimeter of windows
- Gaps at floor slabs
- Gaps at the underside of steel deck or other floor structures
- Gaps behind spandrel beams
- Voids at outlets or other penetrations

Air Barrier Continuity



Air Barrier Continuity



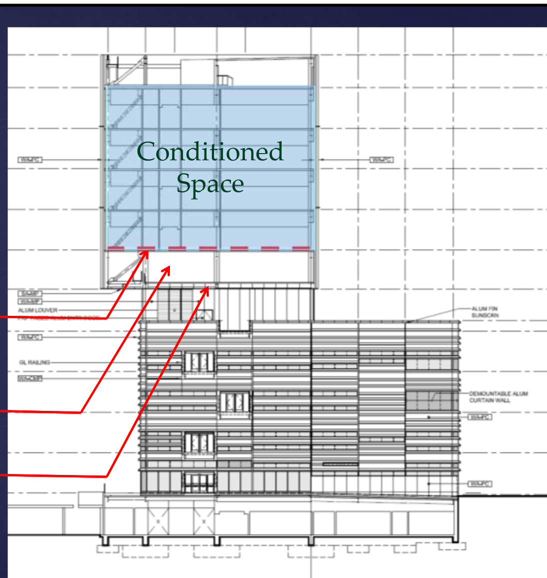
Air Barrier Continuity

Think about all surfaces

Air Barrier at Floor Line

Ventilated Mechanical Room

Exterior Soffit



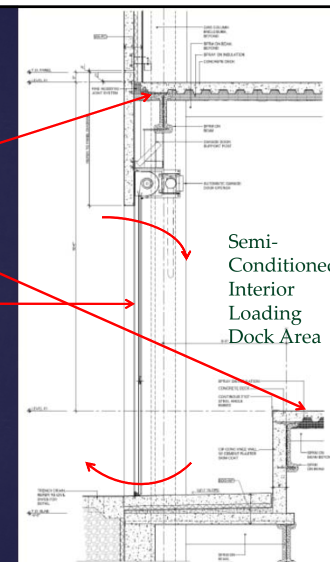
Air Barrier Continuity

Move air barrier line to limits of truck dock

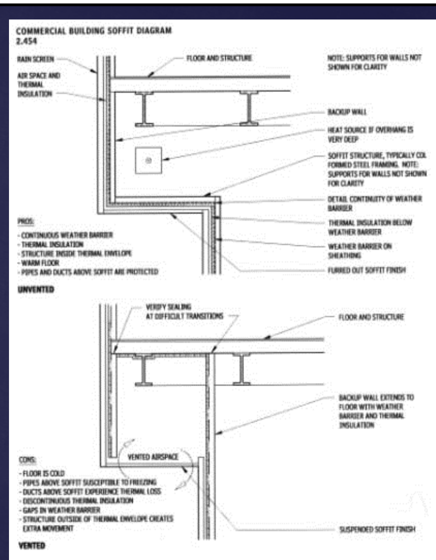
Open Door

Air Leaks

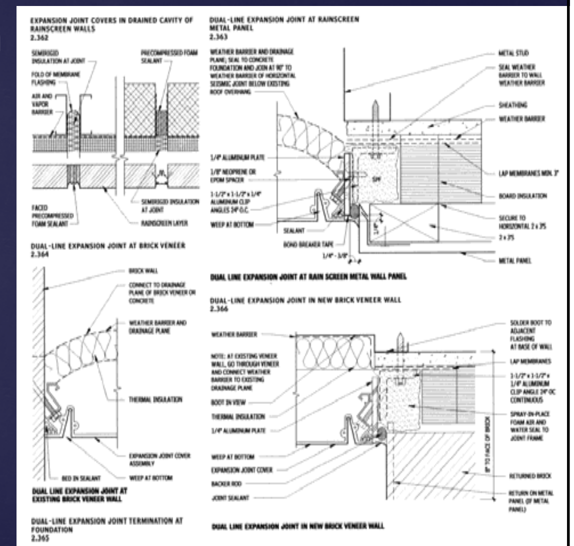
Think about areas where it is difficult to control air leakage.



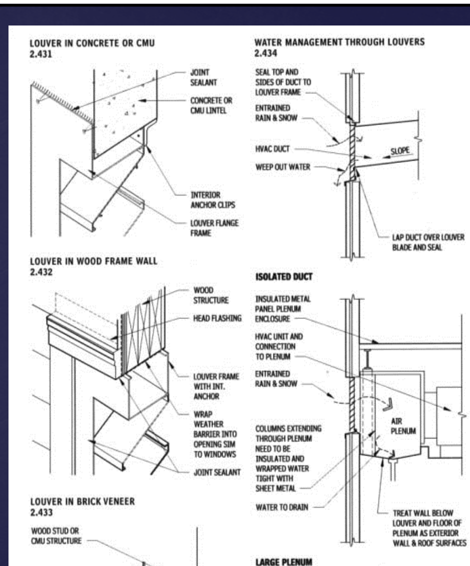
Soffits



Expansion Joints



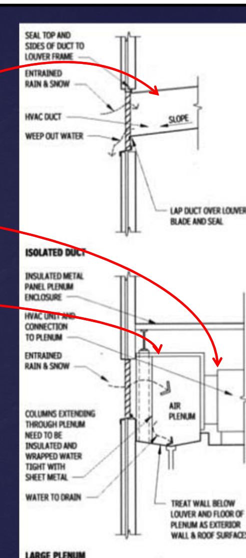
Louvers



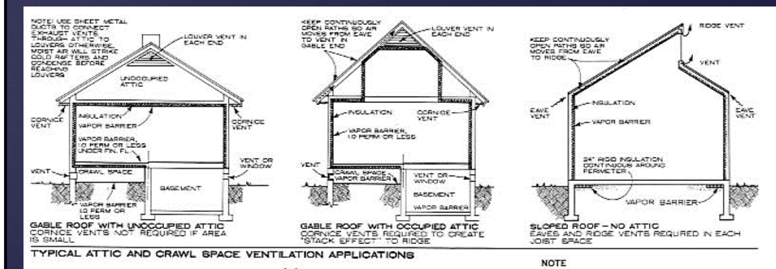
Louvers

Make ducts air tight back to air handler.

Make plenum behind louvers air and watertight.

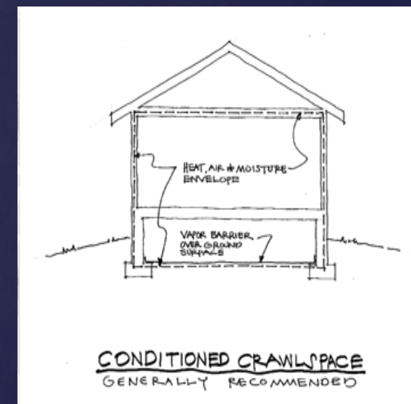


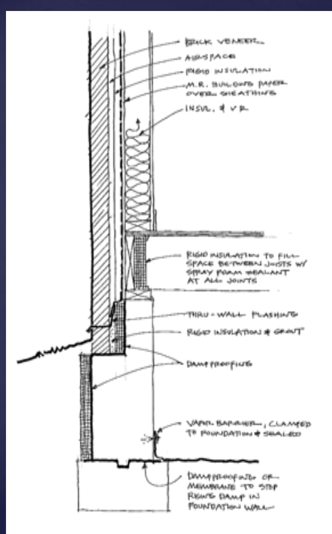
Attic Ventilation

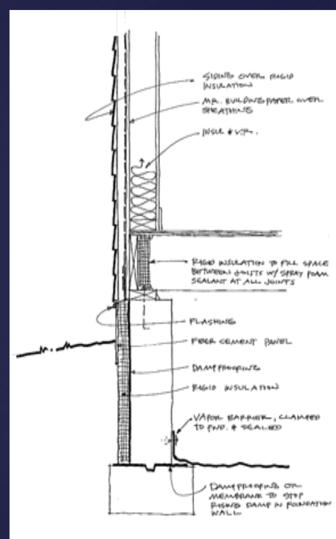


Crawlspace Ventilation

Crawlspace part of the conditioned interior environment







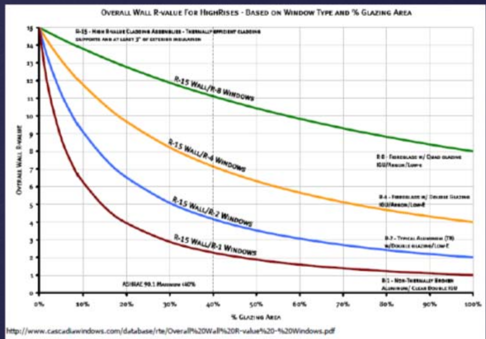
Attention to New Details

Attention to New Details

Attention to New Details

New Challenges

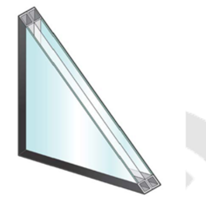
Highly insulating windows at approximately 40% wall/window ratio can deliver a net energy gain



High Performance Windows

Glazing and window frames have changed substantially in 40 years.

- Circa 1962 windows, 6 inches deep
- R-value: 1.75, SHGC: 0.50, VT: 0.47
- 1662 windows, 60,000 sqft total

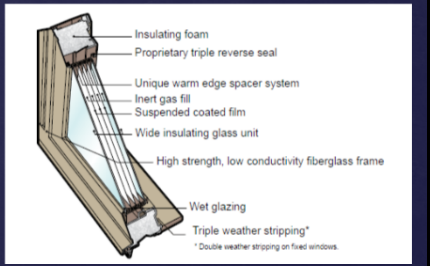


SCF IGU Package

- SG 8 3/16_SB60
- R-value: 7.7, SHGC: 0.34, VT: 0.63
- Interior Glazing retrofit, $4/sqft labor
- Product cost in volume, $7.21/sqft

High Performance Windows

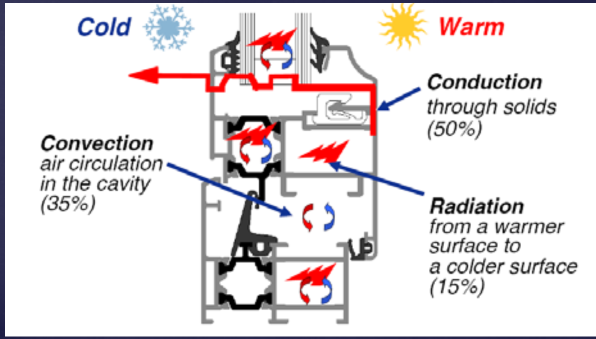
- Multiple air spaces between glass/film layers
- Multiple low-e coatings
- Thermally isolated frames
- Highly gasketed
- Warm edge spacers
- Inert gas filling



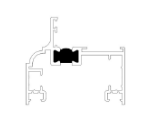
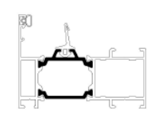
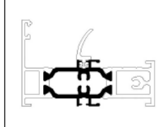
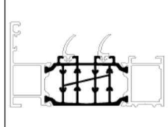
Serious 1125 window illustrated

Thermal Breaks

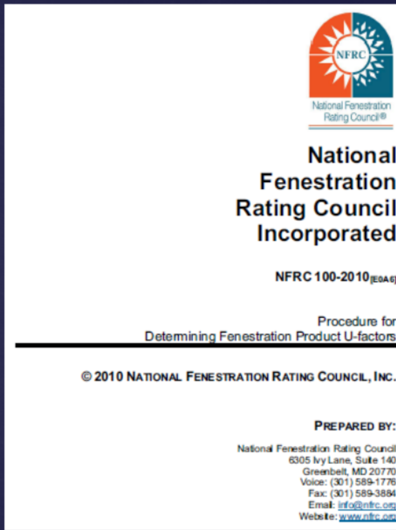
Need to control modes of heat transfer



Thermal Breaks - Evolution

Before 2002	2002-2006	2006-2010	2010
Polyurethane thermal break common	Standard polyamide strips 20 to 30mm	Multi-function polymide strips >30mm	Custom polyamide strips > 40mm
.63 Btu/hr-ft²-F	.39 Btu/hr-ft²-F	.37 Btu/hr-ft²-F	.32 Btu/hr-ft²-F
			

High Performance Window Rating


National Fenestration Rating Council®

National Fenestration Rating Council Incorporated

NFRC 100-2010[E0A6]

Procedure for Determining Fenestration Product U-factors

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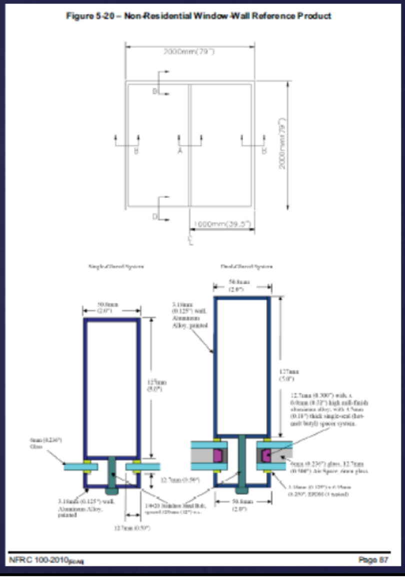
High Performance Window Rating

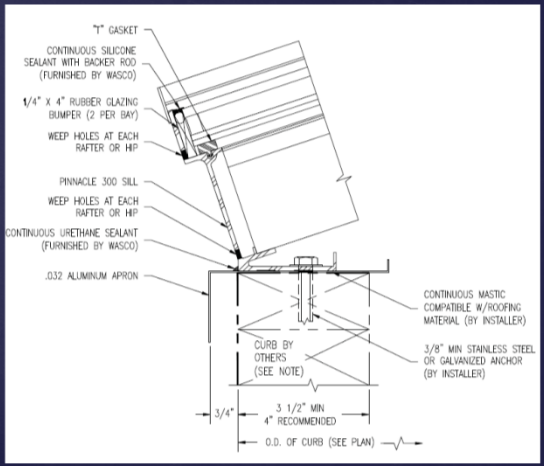


New Challenges, Curtain Wall

Aluminum and Glass Curtain Wall will not likely deliver a highly insulating wall, no matter what you do to the spandrel area.

- No matter how well the spandrel is insulated the wall performance is horrible.
  - Assume 100' long by 12' high typical office building wall with 7' of R-3 glass and 5' of R-20 spandrel insulation.
  - (100 x 7 x.33) + (100 x 5 x .05)/1200 = .21 or **R 4.8**
- The aluminum mullions are inherent heat sinks, lowers true R even more.
- If you cover the aluminum mullions with insulation then the condensation resistance is likely compromised.

New Challenges, Skylights



New Challenges, Skylights

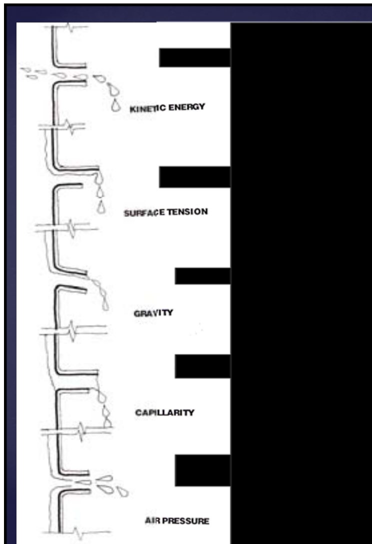
Aluminum and Glass Skylights are just as bad insulators as curtain wall, but in a location where even more R-value is needed.

- Leak Air by Design
- Difficult to keep waterproof.
- Create cold convection loops affecting occupant comfort.
- Condensation is always an issue.
- Glare and overheating.

New Challenges, Rainscreens

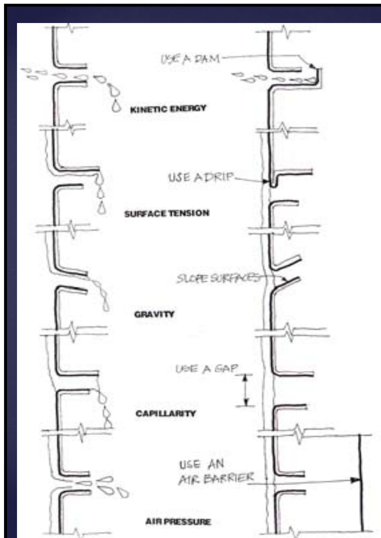
The false panacea of "rainscreen" walls.

- "Rainscreen" was (at least initially) the shortened version of "Pressure-equalized rainscreen"
- PE-Rainscreen systems counteracted all forces driving water through a wall AT THE EXTERIOR FACE.
- Simple, square open joints, or just partially open materials do not stop water at exterior face and simply force the waterproofing function to an inner layer.

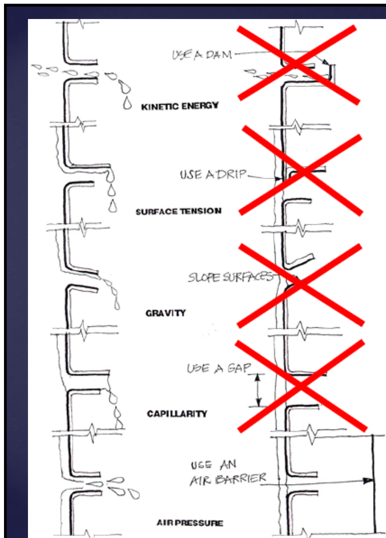


Forces Driving water Through the Wall

Graphic Courtesy of Richard Keleher



Forces Driving water Through the Wall
And
The Methods to Counteract them



Open joint systems fail to address one or more of the methods to stop water penetration.

Rainscreen Misconceptions

New Challenges

The New Wonder Materials, maybe ………. maybe not

Spray Foam Insulation

- Can be very good for thermal control.
- Unsure as air barrier and WRB.
- Understand proper use of open cell, closed cell and the various densities available.
- Understand the chemistry and verify how long that exact chemistry has been on the market.
- Does it really stick to everything with little or no surface prep? Gyp Sheathing, Plywood and OSB, probably. Metal studs, maybe not.
- Many onsite quality control issues, doing sensitive chemistry in a mud hole?
- Extremely sensitive to temperature and the ability of substrates to absorb heat.
- See Journal of Light Construction, March 2012, "Trouble Shooting Spray Foam"

New Challenges

The New Wonder Materials, maybe ………. maybe not

Radiant Barriers

- Only work in hot climates, if at all.
- Cannot stop conduction! There is no R-value for a paper thin shiny film. There is no science for "equivalent R-value.
- Must have an air space.
- What happens when they get dusty?

New Challenges

Equivalent, Effective, or Mass-enhanced R-Value…..No Such Thing

R = ratio of the temperature difference across an insulator and the heat transfer per unit area.

Claims for products with large R-values but not based on any actual science

- Radiant Barriers.
- Continuous Insulation.
- Green Roofs
- Log Homes
- Insulating concrete forms
- Insulated CMU

New Challenges

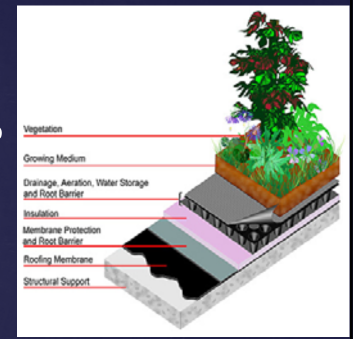
The New Wonder Materials, maybe ………. maybe not

- Taped together WRB or back-up wall assemblies
  - Tape is not shingled for flow of water.
  - How long will tape last inside the wall.
  - Are the products as marketed subject to any realistic quality control from the manufacturer?
  - Is the system still affordable if it undergoes rigorous QA/QC.

Green Roofs?

Dirt is a bad insulator!!!!!!

- Main energy benefits appear to come from evapotranspiration.
- Highest energy savings in hot and rainy climates.
- High maintenance and high first cost.
- Be very careful about the waterproofing, pay attention to physics.
- Effective at run-off control, but an expensive solution.
- Irrigation and fertilization may compromise other sustainable benefits



Green Roofs?

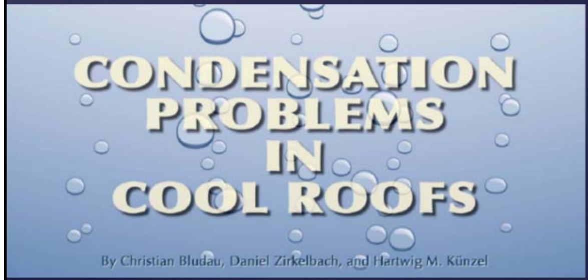
Great aesthetics and visual comfort for people who look down on a green roof.

http://www.wbdg.org/resources/greenroofs.php?r=envelope

Cool Roofs?

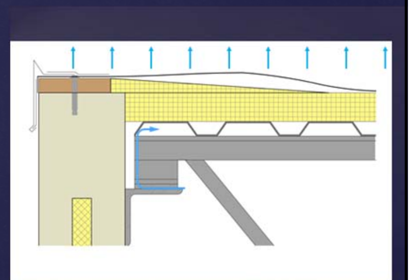
Great energy saving benefit for cooling driven buildings.

- Better for hot climates.
- In cooler climates may lead to moisture accumulation due to reduced drying potential.
- Presence of vapor barrier may exacerbate problem.



Cool Roofs?

- Pillowing of mechanically attached roof membranes pump interior air into the assembly.



New Challenges

Why double facades are rarely a good solution.

Double Facades

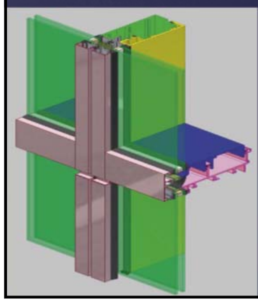
- Challenges:
- Expensive, $200psf and up.
- Very Low-R value, -R-10 versus R-30+
- More glass than necessary for daylighting.
- Successful precedent frequently used in a milder climate, with natural ventilation and narrow floorplates.
- Requires very sophisticated analysis.

Double Facades

Re-skins can be a potential use for double facades:

New Challenges

Improved detailing for air, thermal and moisture control.



Short Circuits and Leaks

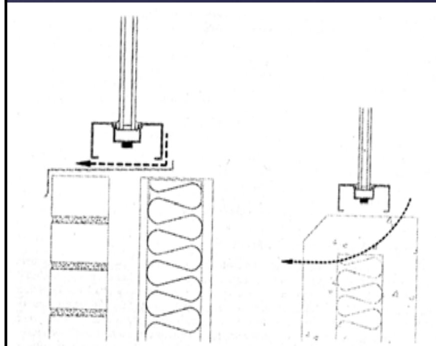


FIG. 2 – Break-metal and non-thermally broken flashing pans.

FIG. 3—Insulated precast or tilt-up concrete panels.

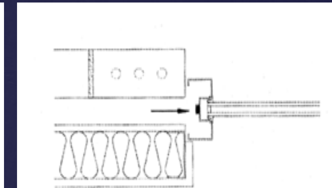
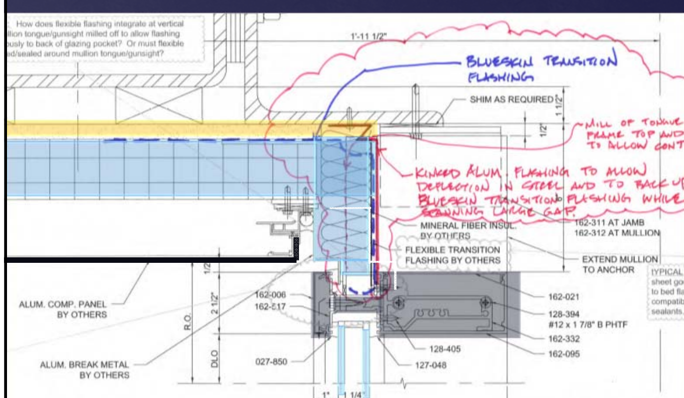
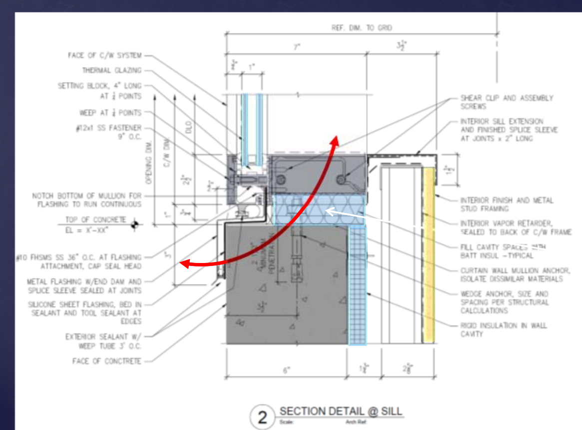


FIG. 1—Cold cavity air.

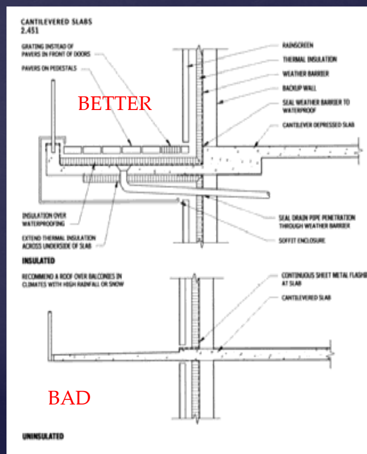
Detailing

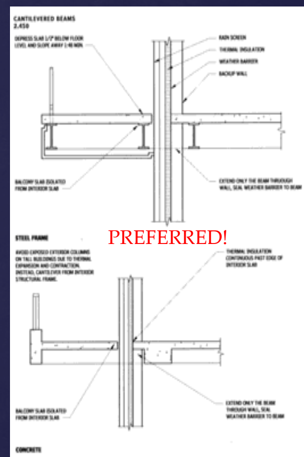


Detailing

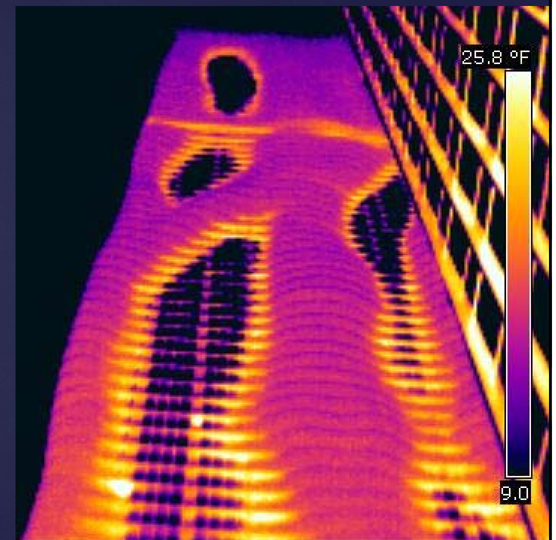


Balconies

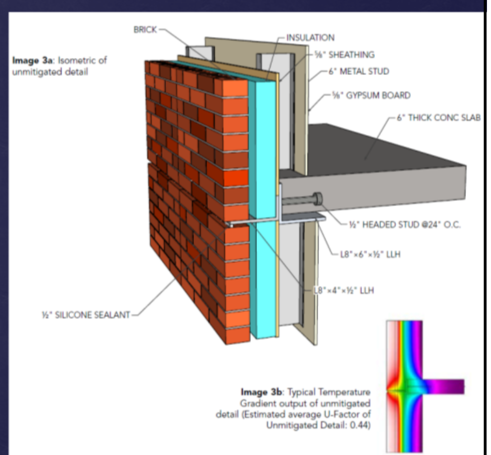




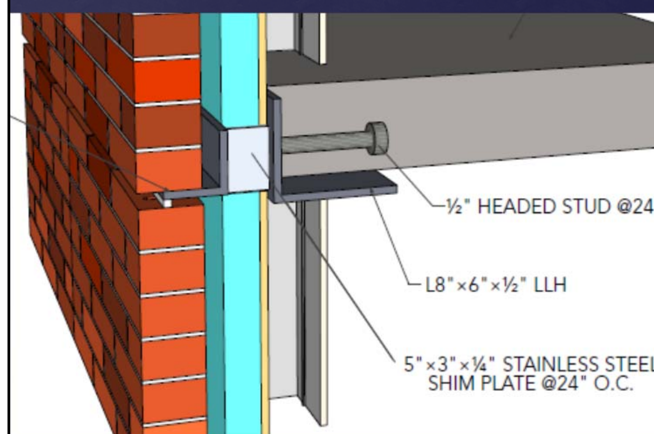
Balconies



Shelf Angles



Shelf Angles



Shelf Angles

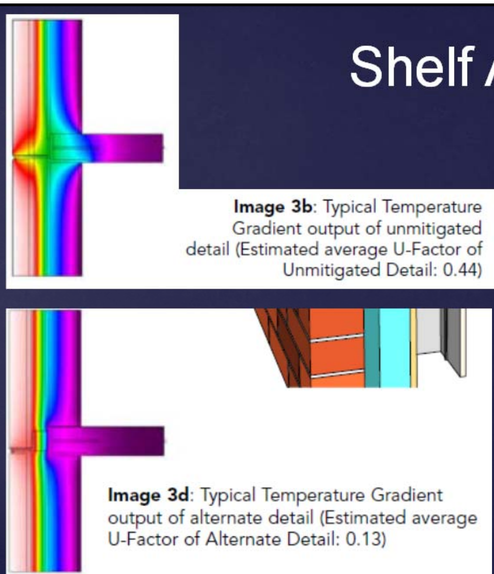
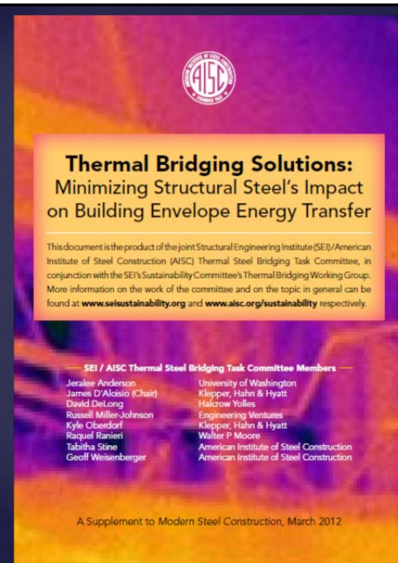


Image 3b: Typical Temperature Gradient output of unmitigated detail (Estimated average U-Factor of Unmitigated Detail: 0.44)

Image 3d: Typical Temperature Gradient output of alternate detail (Estimated average U-Factor of Alternate Detail: 0.13)

Steel Detailing



Thermal Bridging Solutions:
Minimizing Structural Steel's Impact on Building Envelope Energy Transfer

This document is the product of the joint Structural Engineering Institute (SEI)/American Institute of Steel Construction (AISC) Thermal Steel Bridging Task Committee, in conjunction with the SEI's Sustainability Committee's Thermal Bridging Working Group. More information on the work of the committee and on the topic in general can be found at **www.seisustainability.org** and **www.aisc.org/sustainability** respectively.

SEI / AISC Thermal Steel Bridging Task Committee Members

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David DeLong	Halcrow Yolles
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Raquel Ranieri	Walter P Moore
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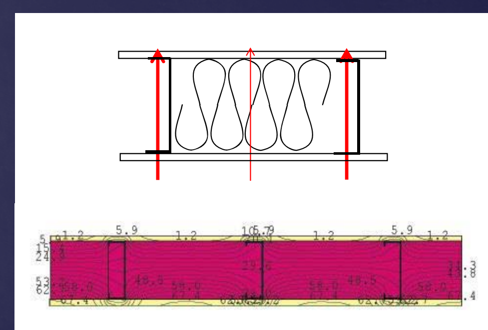
Geoff Weisenberger	American Institute of Steel Construction

A Supplement to *Modern Steel Construction*, March 2012

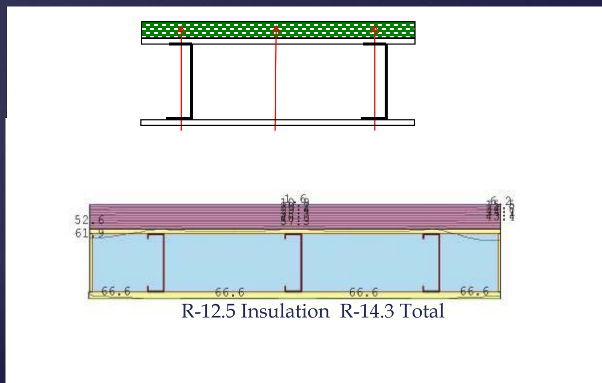
Continuous Insulation

Insulation in the Stud Space

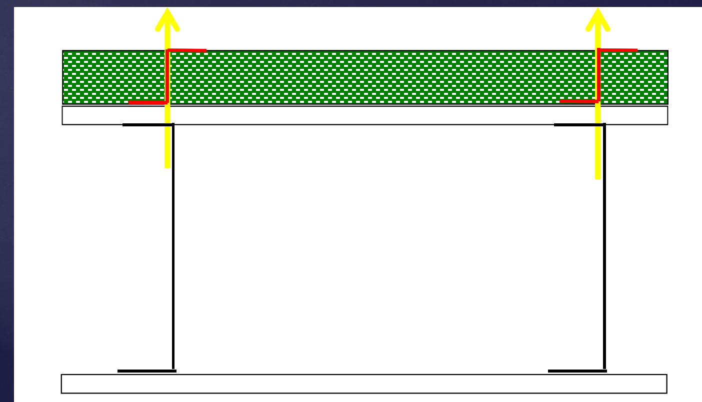


R-19 Batts, R-7 Total

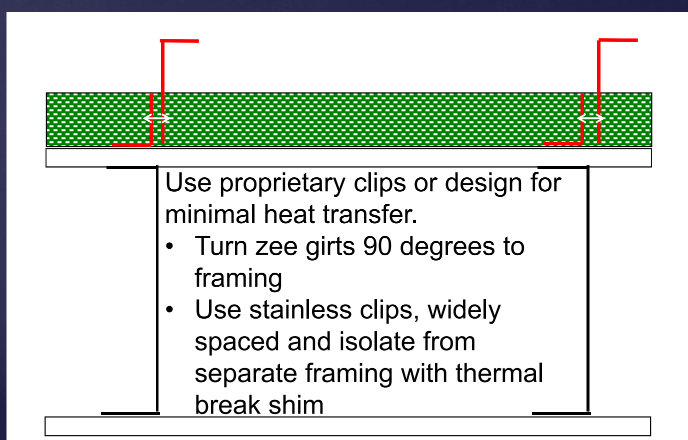
Continuous Insulation, the Solution?



If it is not Continuous Insulation, it is NOT the Solution



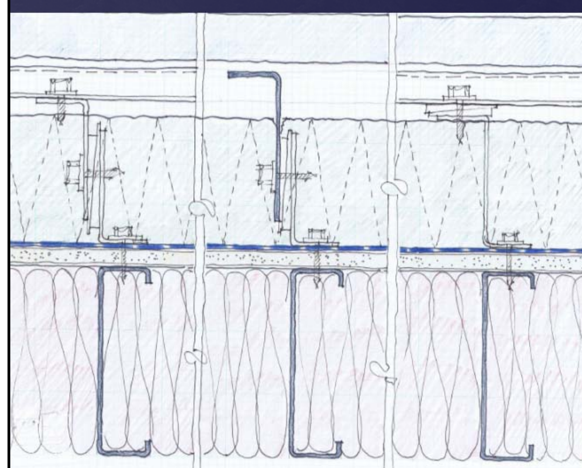
Nearly Continuous Insulation, is the Solution



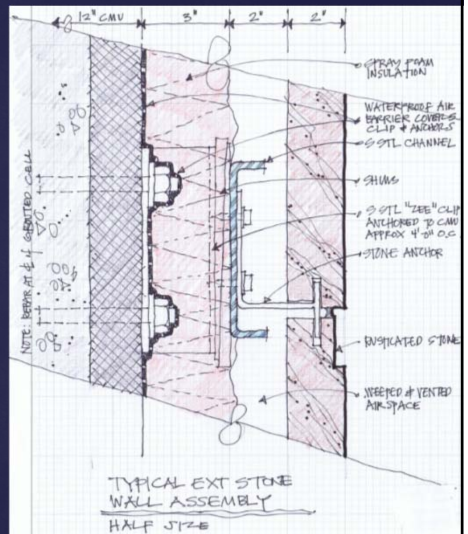
Use proprietary clips or design for minimal heat transfer.

- Turn zee girts 90 degrees to framing
- Use stainless clips, widely spaced and isolate from separate framing with thermal break shim

Nearly Continuous Insulation, is the Solution



Nearly Continuous Insulation, is the Solution



Thermal Detailing


REPORT

Thermal Performance of Building Envelope Details for Mid- and High-Rise Buildings (1365-RP)

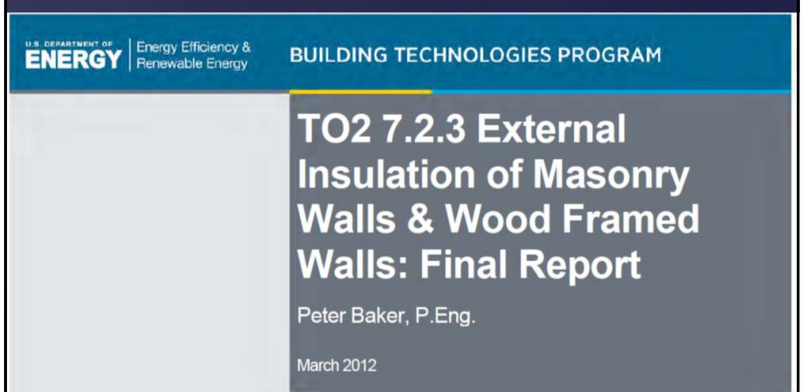
Presented to:

Technical Committee 4.4
Building Materials and Building Envelope Performance

ASHRAE Inc.
1791 Tullie Circle, NE
Atlanta, Georgia 30329

Report No. 5085243.01 July 6, 2011

Thermal Detailing


U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

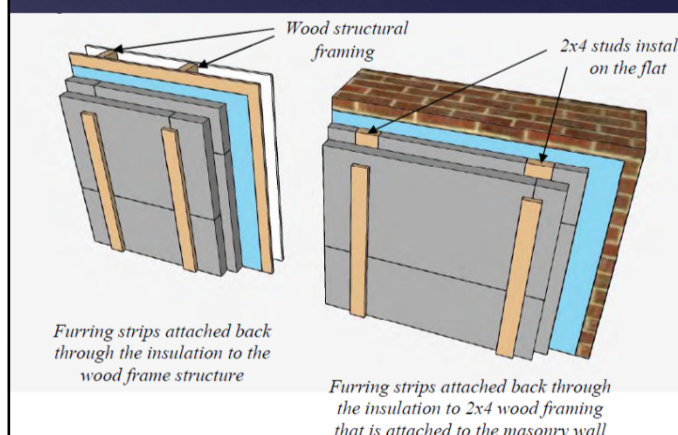
BUILDING TECHNOLOGIES PROGRAM

TO2 7.2.3 External Insulation of Masonry Walls & Wood Framed Walls: Final Report

Peter Baker, P.Eng.

March 2012

Continuous Insulation



Continuous Insulation

The impact of large amounts of insulation in the wall assembly.

- Changes to wetting/drying cycles (old solutions may no longer work)
- Changes to detailing.
- Changes to combustibility. - NFPA 285
- Eliminates/reduces thermal bridges
- Move condensation potential outside of framed wall area
- Increases building cost through increased structural needs, perhaps offset by reduced HVAC system.

Continuous Insulation

What types of continuous insulation, pros and cons

- Extruded polystyrene (XPS)
- Expanded polystyrene (EPS)
- Polyisocyanurate
- Foam-in-Place Insulation
  - Spray Polyurethane Foam, Open and Closed cell
  - Icynene
- Semi-rigid Mineral Wool

Continuous Insulation

Wall systems with continuous insulation

- Barrier Wall Assemblies - EIFS
- Drainage Plane Wall Assemblies
  - EIFS
  - Stucco
- Drained Cavity Walls
- Pressure-Equalized Walls

Continuous Insulation

Air Infiltration Interrelationship

- The importance of control of air movement.
- Energy code increased requirements
- Pending building air infiltration testing
- Air washing of insulation

NFPA 285

History of the test

NFPA 285, 2009 and older IBC

NFPA 285, 2012 IBC

NFPA 285

Requirements of a “systems” test versus component requirements.

- Why not a component approach as code allows for use foam plastic insulation in non-combustible roof assemblies?
- The choice of every layer of wall, and especially the WRB/air barrier will be substantially reduced.
- Cost of testing will be borne by owners.

NFPA 285

Window penetration detailing.

NFPA 285

NFPA 285

- The application of 285 to EIFS versus cavity walls.
- How do fully-sprinklered buildings change the requirements?

NFPA 285, How is the public protected

- The balance between energy efficiency and life safety.
  - Foam Plastic provided the highest R-value per inch.
  - Increasing cavity size for low-R insulation increases cost more.
- Why is foam plastic allowed on the inside face of exterior walls without a 285 test?
- What are the risks?
  - Loss history?
  - Construction phase versus full occupancy.
- Follow the money
  - Proprietary systems versus commodity products.
  - Extra cost to owners for materials and extra testing.
  - How are the codes influenced by manufacturers?

New Challenges for Systems Integration

The HVAC systems must change along with the enclosure.

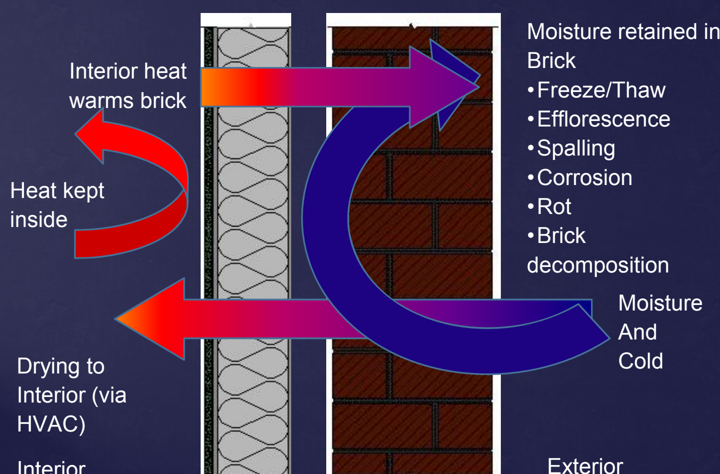
- Indoor Air Quality
- Downsize AC to control humidity?
- Separate dehumidification?
- Requires careful and controlled ventilation with heat recovery.
- Integrate daylighting

New Challenges for Existing Buildings

Investigate the special challenges to updating the stock of existing buildings for improved enclosure performance.

Hygrothermal Changes

Moisture migration affected by adding insulation . . .



Failure

Failure

Trapping moisture leads to . . .

2. Rot

Failure

Trapping moisture leads to . . .

3. Sub-florescence

Failure

Trapping moisture leads to . . .

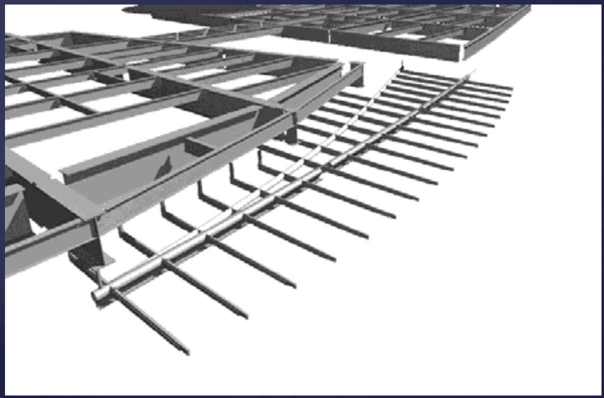
4. Freeze / thaw spalling

New Challenges: BIM

BIM

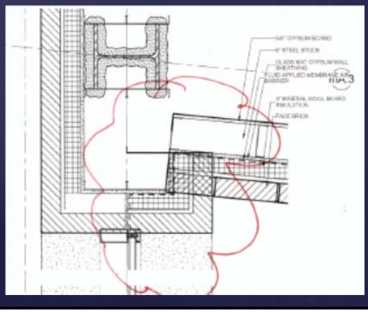
- Some models can be extracted into analysis tools for conceptual energy modeling and solar insolation studies.
- Some advanced BIM and parametric modeling can be useful to study difficult material intersections.

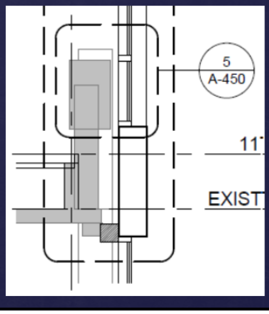
BIM provides for detailed study of complex geometries



Shortfalls of BIM

- Over reliance on the computer model.
- Too difficult to model details.





BIM

Future of BIM

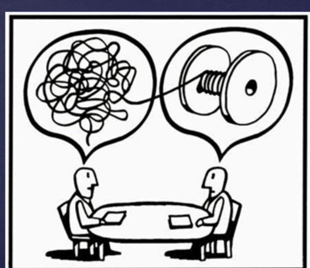
- Energy consumption impact may be instantaneous with changes to model.
- Rapid prototyping and mass-customization may help deliver enclosure materials and systems highly tuned for their use.

HIGH PERFORMANCE DESIGN PER PHASE

HIGH PERFORMANCE DESIGN PER PHASE

- PRE DESIGN

Communication Between Owner and Team

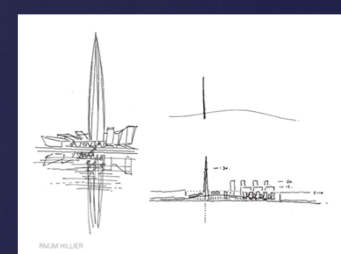


Build a Relationship over Time

- Managing the Owner
- Working through quality, scope, cost and schedule issues takes time.
- Initial “wants” will be challenged by budget to determine ultimate “needs”.
- Criteria is frequently mutually exclusive. Find the right balance.
- Criteria for performance will evolve over time.

Predesign

- Owner’s expectations, program.
- Site, geotechnical, and environmental, analysis
- Interior Environment Tolerances
- Corporate, institutional, and social goals.



Owner Project Requirements

The OPR produces a list documenting the requirements against which the Pre-Design, Design and Construction phases are executed.

The indispensible first step to getting the things you want out of life is this: decide what you want.

Eleanor Roosevelt

Predesign

The Owner's Project Requirements

- Local climate; heating/cooling degree days, rainfall, snow, freeze/thaw, wind, sunlight, etc.
- Interior Uses and Conditions
- Ground Water, soil conditions, topography, run-off control.
- Energy Savings targets; U-value for assemblies, glazing performance, heat island mitigation,
- Fire-resistance, combustibility
- Lifespan and Durability
- Limits/Preferences on Materials; aesthetics, availability.
- Structural loading
- Fenestration Test Pressures
- Special Performance Attributes; acoustic, blast, seismic, security,
- Tolerance for Water and Moisture infiltration
- Owner's ability to operate and maintain building

HIGH PERFORMANCE DESIGN PER PHASE

- PRE DESIGN
- SCHEMATICS

Schematic Design

- Develop massing/orientation schemes and test for energy
- Develop alternative enclosure schemes and test for energy
- Perform moisture analyses
- Interaction with structure, HVAC, lighting
- Energy code analysis COMcheck EZ or DOE 2 whole building analysis.
- Impact of Cx on schedule and budget.

Schematic Design

- Select enclosure systems
- QA review typical enclosure details and outline specs
- Update OPR and Cx Plan
- Document, Basis of Design (BOD)

Schematic Design

Basis of Design

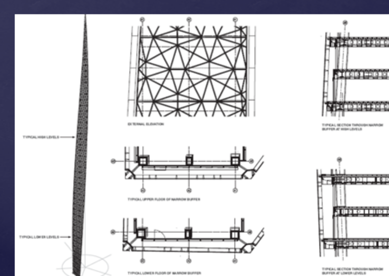
- Narrative descriptions of building exterior enclosure systems (e.g., roof, exterior walls, floors, windows, skylights, atria, thermal mass, etc.).
- A general description of the intent for each enclosure system with a statement of intent on how to meet the OPR. Concepts of integration of other building systems with the enclosure systems should be outlined.
- Descriptions of the schemes considered and the reasoning behind selection.
- The assumptions made in developing a design solution that fulfill the criteria in the Owner's Project Requirements document.
- Statements of how schematic design and the OPR balance scope, budget and installed performance of wall assemblies .
- For projects with specialized performance criteria (e.g. blast resistance or extremely high energy savings) more detailed descriptions of how the design addresses these criteria should be provided.

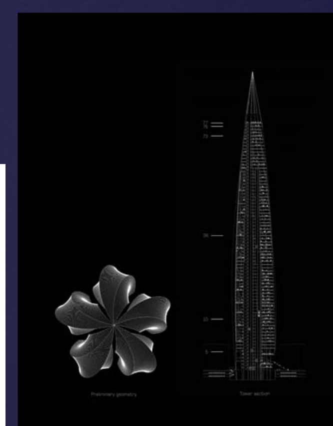
HIGH PERFORMANCE DESIGN PER PHASE

- PRE DESIGN
- SCHEMATICS
- DESIGN DEVELOPMENT

Design Development

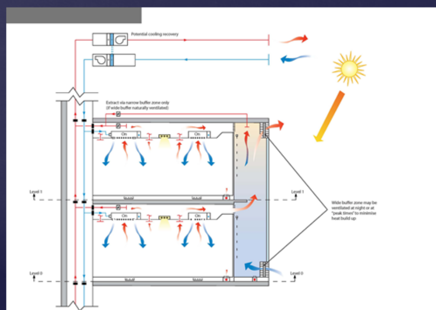
Complete analysis and design of enclosure systems

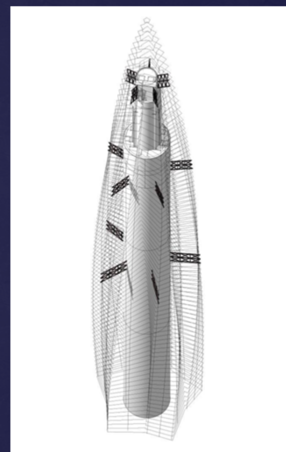




Design Development

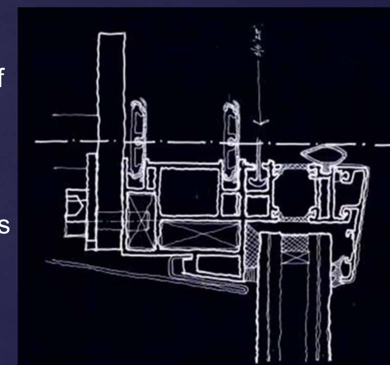
Review interactions between systems





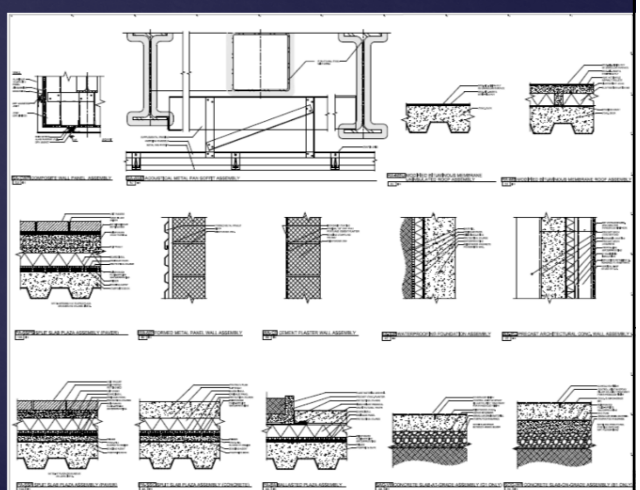
Design Development

- Develop typical details for enclosure systems
  - Full or half size details of the most typical conditions.
  - Start early in DDs
- Perform moisture analyses
- Refine energy code analysis



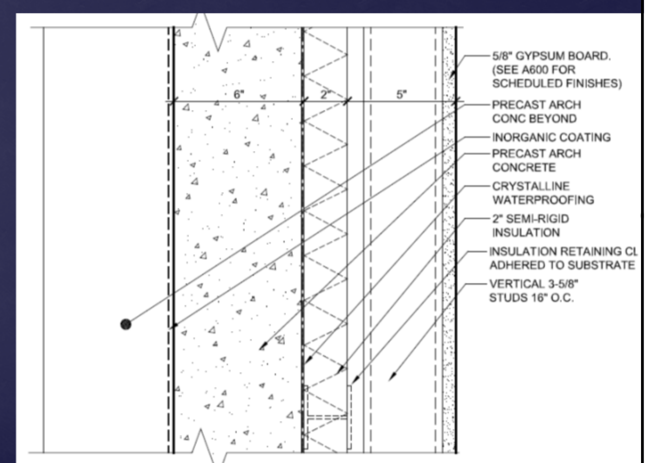
Design Development

Assembly Systems



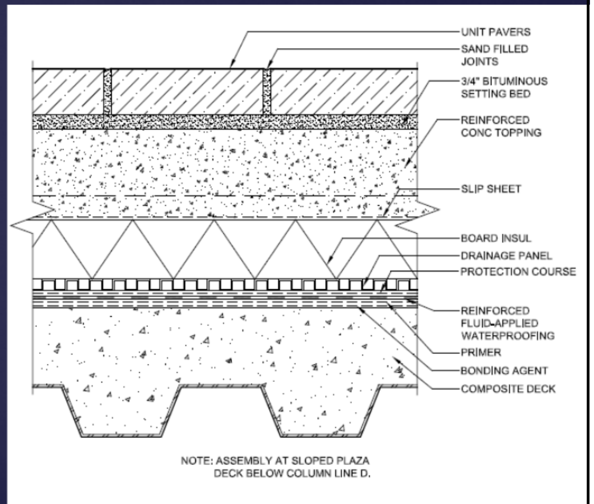
Design Development

Assembly Systems



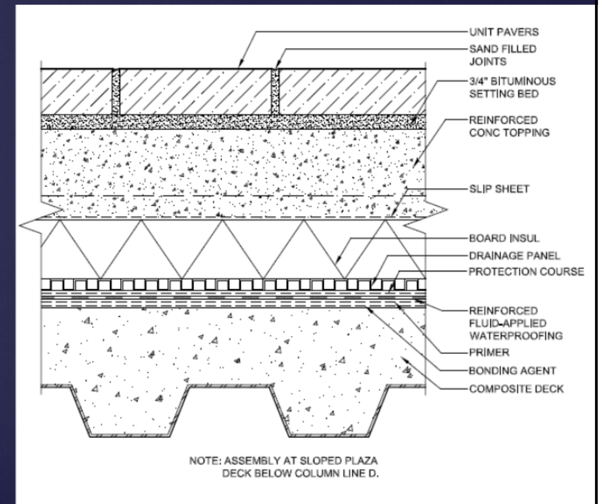
Design Development

Assembly Systems



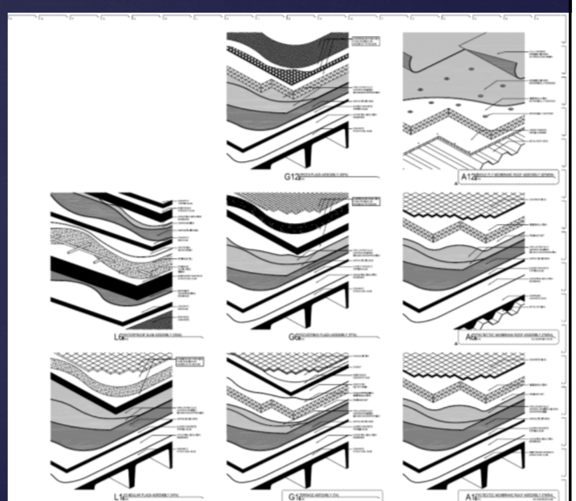
Design Development

Assembly Systems

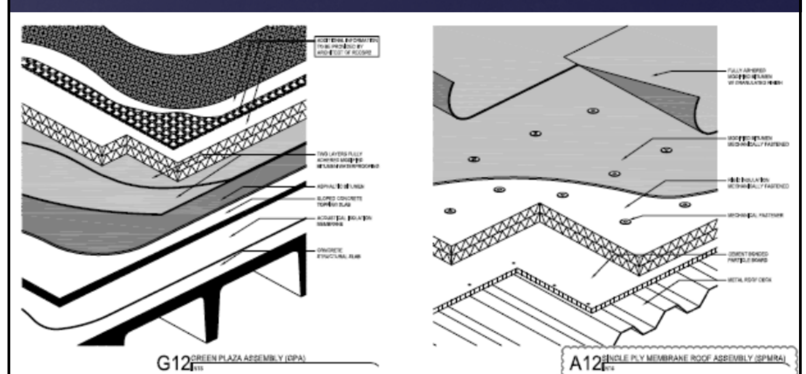


Design Development

Assembly Systems

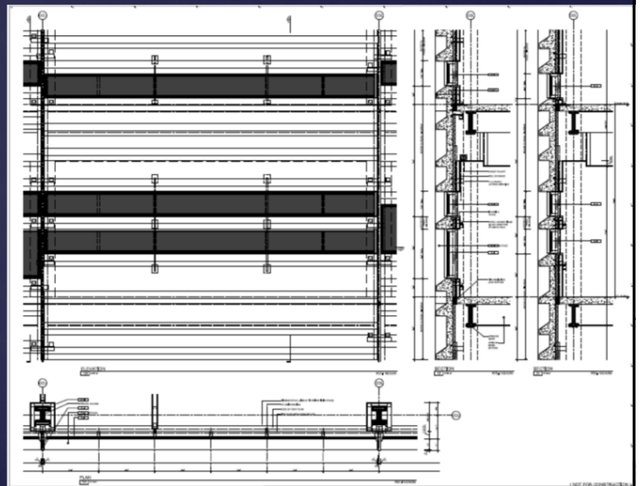


Design Development



Design Development

Typical Bay Drawings



Design Development

- Outline Mockups, testing and other CA phase quality management activities
- Peer Review enclosure details and specifications
- Review estimate and budget for testing.
- Update Cx Plan, OPR and BOD

Performance Tests

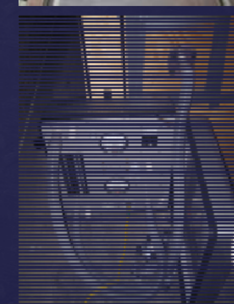
- project specific & comprehensive
- demonstrate that each Building Enclosure system, and system to system interfaces meet or exceed the performance requirements of the OPR, Contract Documents and the Building Enclosure Design Intent
- random selection
- early in construction

Performance Criteria

Defining Air Tightness Performance:

Curtain wall and skylights have an allowable air leakage 0.06 cfm ft² at 6.24psf in accordance with **ASTM E283** *Standard Test Method for Determining Rate of Air Leakage Through Exterior Windows, Curtain Walls, and Doors Under Specified Pressure Differences Across the Specimen*.

The industry standard organization, AAMA typically allows for an increase in air leakage allowance of 150% of design conditions. This equates to an installed air leakage allowance of 0.09 cfm ft² at 6.24psf. Field Testing shall be performed in accordance with **ASTM E783** *Standard Test Method for Field Measurement of Air Leakage Through Installed Exterior Windows and Doors*



Performance Criteria

Defining water leakage:

- Definition of water leakage per AAMA and ASTM, allows water leakage that enters the interior, but does not penetrate beyond the inner most plane of the framing to be considered a “pass”.
- AAMA 502-08 Voluntary Specification for Field Testing of Newly Installed Fenestration Products, parallels ASTM E1105’s definition of water leakage.
- AAMA 503 -08 Voluntary Specification for Field Testing of Newly Installed Storefronts, Curtain Walls and Sloped Glazing Systems allows for up to ½ oz of water to collect on top of an interior frame surface and does not spill over to be considered a “pass” .

*** Define leakage in accordance with your own assessment of the risk and long term durability. Is any water to the interior side of the framing system acceptable?*

Performance Criteria

Defining Pressure Differential:

Penetration resistance determined per ASTM E1105 / AAMA 503-08 states:

4.3.1 **Water penetration resistance tests shall be conducted at a static pressure of 2/3 (0.667) of the specified project water penetration test pressure but not less than 4.18psf. (approx. 40mph wind)**

AAMA 502-08

4.3. **Water penetration resistance tests shall be conducted at a static pressure of 2/3 (0.667) of the specified project water penetration test pressure but not less than 1.19psf. (approx. 28mph wind)**

Example: A product rated as C-50 shall be field tested at a pressure differential of (.15)(50)=7.50 psf x 0.667=5.00 psf

The issue of the “Two-Thirds rule”:

- AAMA allows a reduction from the lab test pressure to the field.
- AAMA outlines this as “reasonable adjustment for differences between a laboratory test environment and a field test environment”.
- AAMA 502-08 and 503-08 allow the architect to waive this requirement in favor of field testing at the static/cyclic full design pressure differential specified under Performance Requirements of the appropriate specification section.

***Clearly identify in the specifications the design pressure and field test criteria to avoid confusion.*

Performance Criteria

Defining Condensation Criteria:

AAMA 501 : Methods of Tests for Exterior Walls (Optional Test AAMA 501.5 – Thermal Cycling)

AAMA 1503:Voluntary Test Method for Thermal Transmittance and Condensation Resistance of Windows, Doors and Glazed Wall Sections

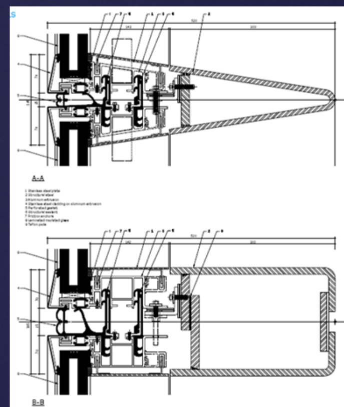
***Is some condensation acceptable, and if so, for how many hours per year?.*

HIGH PERFORMANCE DESIGN PER PHASE

- PRE DESIGN
- SCHEMATICS
- DESIGN DEVELOPMENT
- **CONSTRUCTION DOCUMENTS**

Construction Documents

- Develop final details for enclosure systems and specifications
- Define site and lab mockups and finalize testing and QA protocols
- Refine envelope energy code compliance

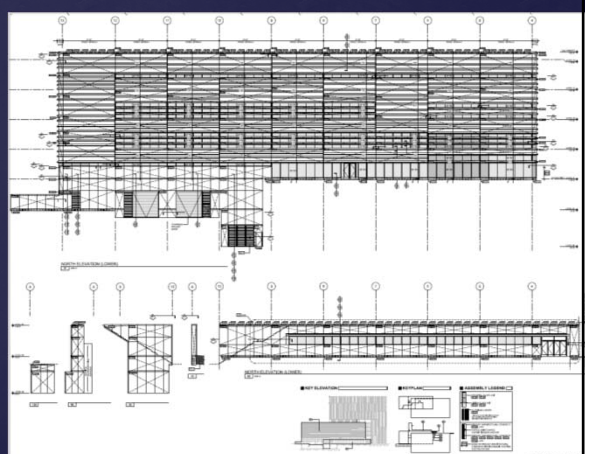


Construction Documents

Mock-up Drawing

Construction Documents

Developed Elevations

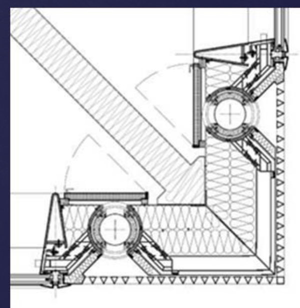


Construction Documents

Develop final details for enclosure systems and specifications

Construction Documents

- Perform peer review checking at 50% and 90%
- Complete Construction/Contract Documents
- Review estimate and budget
- Update Cx Plan, OPR and BOD

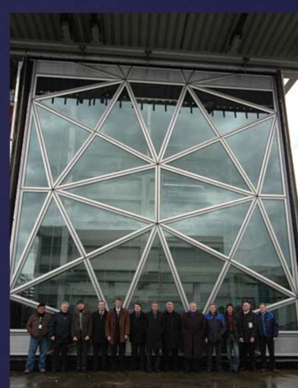


HIGH PERFORMANCE DESIGN PER PHASE

- PRE DESIGN
- SCHEMATICS
- DESIGN DEVELOPMENT
- CONSTRUCTION DOCUMENTS
- **CONSTRUCTION ADMINISTRATION**

Construction Administration

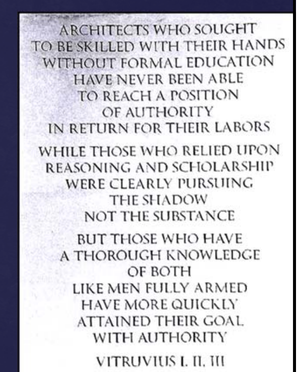
- Enforce Coordination requirements of contract.
- Administer field and lab mockups and testing.
- Review Submittals
- Pre-Installation meetings
- “First-Installation” kick-off meetings
- Periodic Observations
- Deficiencies Log



Communication Between Builders and Designers

Respect Mutual Roles

- Support the roles of other parties without challenging or taking responsibility.
- Be constructive.
- Ask for help with your own issues.
- Understand the limitation of the other side.
- The designers need to include exactly what they expect in the Construction Documents.
- Contractors need to deliver what is required in the Construction Documents



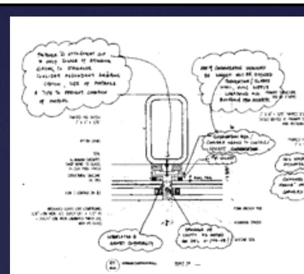
Submittal Reviews

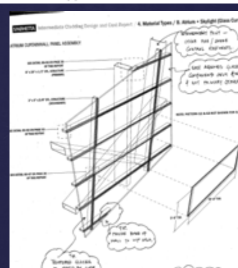
Technically-focused review of the building enclosure submittals

Meet performance objective?

Interface between design and construction team

- Performance and constructability of details
- Impacts to schedule and cost
- Durability
- Compatibility / Adhesion
- Coordination between submittals





Exterior Enclosure Coordination Meeting

All sub-contractors involved with the Enclosure along with CM,GC, Arch, Eng, and owner

Goal is to clarify design and encourage Sub-Contractor Coordination

- Hold BEFORE preparation of shop drawings
- Review overall schedule / durations
- Discuss potential options for sequence of installation
- Review Testing and Inspection requirements
- Review details

Moisture Management Plan

Construction generated moisture is not typically addressed and can contribute to premature failure:

- A 4" thick concrete slab in an enclosed building can generate 1 ton of water per 1000sf
- Propane heaters for temp heat can produce 30 gallons of water per 200# tank
- Plaster & drywall trades generate contribute to high interior moisture

Moisture Control Plan

The University of Texas Southwestern Medical Center at Dallas

University Hospital & MMB
Dallas, Texas

Date: 3 October 2011
OFPC Project No: 303-366

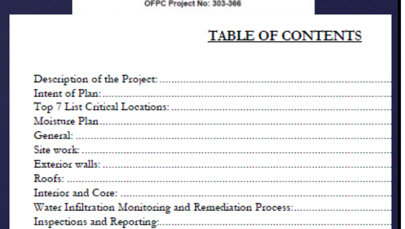


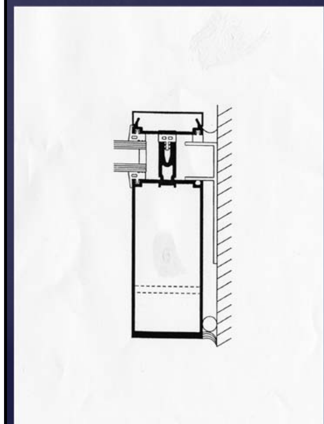
TABLE OF CONTENTS

Test, Test, Test

Most new buildings are essentially a prototype, the collection of materials is completely new and used in a completely new configuration.

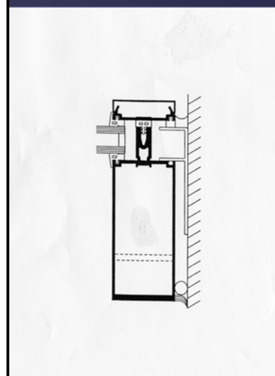
- Prove the system works as designed.
- Prove the system works at initial installation.
- Testing during installation helps enforce quality.
- Failure when testing is far more prevalent than success at initial stage.

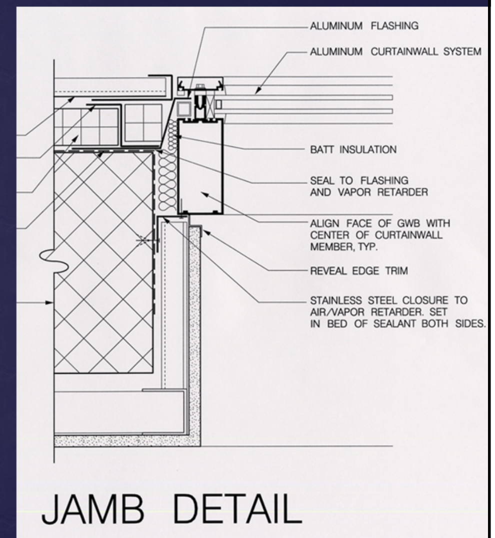
Why test a system that has already been tested?



Typical Manufacturers information for window to wall interface and basis for reported test results.

Actual conditions are quite different





Comprehensive Building Enclosure Test Program

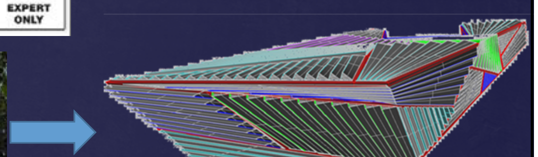
Design: Complex / unique forms; building height

Enclosure Assembly: Barrier; drainage/rainscreen; combination of assemblies

Building Function and IAQ Requirements: Performance critical facility; multi-family high-rise; high performance

Location: coastal/high wind zone, defined by ASCE -7; contaminated ground

Field Test Program



Laboratory Test Program
Field Test Program

Types of Testing?

- Lab Testing/Field Testing
- Air Infiltration
- Water Infiltration
- Water Absorption
- Structural Load
- Seismic Racking
- Thermal Performance
- Acoustics
- Accelerated Aging
- Membrane Adhesion
- Sealant Adhesion
- Anchor Pull-out
- Infrared Thermography
- Whole Building Air Tightness

Pre-Construction Phase

Laboratory Performance Mock-Up

Allows for evaluation of the design prior to wide spread construction

Pre-Construction Phase

Laboratory Performance Mock-Up

Mock-Up Process -

Visits to Fabrication Plant

Complete laboratory testing in accordance with ASTM E2099. Susceptible details can be reviewed and tested for structural, seismic, air leakage, water penetration and thermal resistance.

Mock-up Performance Testing

Tests for water, air and structure per ASTM E 2099-00(2007) Standard Practice for the Specification and Evaluation of Pre-Construction Laboratory Mockups of Exterior Wall Systems, performed by qualified independent test lab.

Typical test sequence:

- Static Air Infiltration Test (ASTM E283)
- Static Water Test (ASTM E331)
- Dynamic Water Test (AAMA 501.1-83)
- Uniform Load Test (ASTM E330)
- Static Water Test (ASTM E331)
- Interstory Drift / Lateral and Vertical Movement (AAMA 501.4-200)
- Static Water Test (ASTM E331)
- Thermal Cycle (AAMA 501.5)
- Dynamic Water Test (AAMA 501.1-83)
- Structural Overload Test
- Thermal Resistance Test (AAMA 1503)

Testing for air infiltration

ASTM E283: Standard Test Method for Determining Rate of Air Leakage Through Exterior Windows, Curtain Walls, and Doors Under Specified Pressure Differences Across the Specimen

4.1 "The test consists of sealing a test specimen into or against one face of an air chamber, supplying air to or exhausting air from the chamber at the rate required to maintain the specified test pressure difference across the specimen, and measuring the resultant air flow through the specimen."

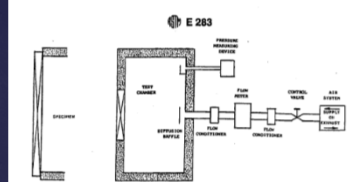


FIG. 1 General Arrangement of the Air Leakage Apparatus

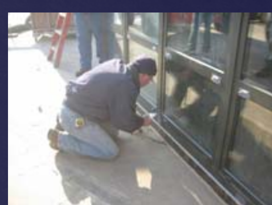

Tear bag

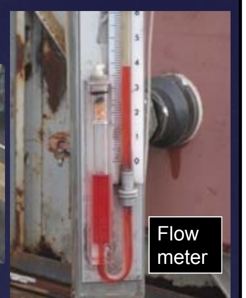
Testing for air infiltration

Air infiltration is determined by a calibrated high precision mass flow meter. The specimen is subjected to a constant air pressure differential.

The difference in air leakage amounts detected after considering barometric pressure and air temperature provides the total air infiltration.

Test results determine a Pass/Fail rating based upon pre-determined criteria.

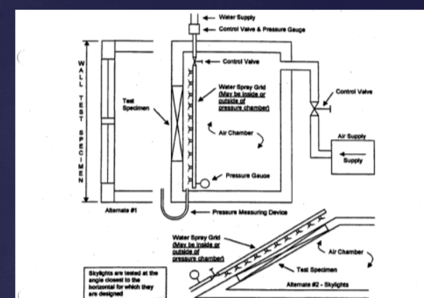

Smoke bottle tests for air leak locations combined with pressurizing chamber


Flow meter

Testing for water leakage

ASTM E331: Standard Test Method for Water penetration of Exterior Windows, Skylights, Doors, and Curtain Walls by Uniform Static Air Pressure Difference

4.1 "This test method consists of sealing the test specimen into or against one face of an air chamber, supplying air to or exhausting air from the chamber at the rate required to maintain the specified test pressure difference across the specimen, while spraying water onto the outdoor face of the specimen at the required rate and observing any water penetration."



NOTE 1—For a negative pressure system, the water-spray grid would be located outside the chamber and the air supply would be replaced by an air-exhaust system.

FIG. 1 General Arrangement of the Water Leakage Apparatus Positive Chamber System

Comparison of Water Test Pressure with Wind Speed

Pa	kph	psf	in.H2O	mph
75 Pa	40 kph	1.57 psf	0.30" H2O	25 mph
137 Pa	54 kph	2.86 psf	0.55" H2O	34 mph
144 Pa	56 kph	3.00 psf	0.58" H2O	35 mph
150 Pa	57 kph	3.13 psf	0.60" H2O	35 mph
180 Pa	62 kph	3.75 psf	0.72" H2O	39 mph
200 Pa	66 kph	4.17 psf	0.80" H2O	41 mph
216 Pa	68 kph	4.50 psf	0.87" H2O	42 mph
252 Pa	74 kph	5.25 psf	1.01" H2O	46 mph
288 Pa	79 kph	6.00 psf	1.15" H2O	49 mph
299 Pa	80 kph	6.24 psf	1.20" H2O	50 mph
300 Pa	80 kph	6.26 psf	1.20" H2O	50 mph
324 Pa	85 kph	6.75 psf	1.30" H2O	52 mph
360 Pa	88 kph	7.50 psf	1.44" H2O	55 mph
383 Pa	90 kph	8.00 psf	1.53" H2O	56 mph
384 Pa	91 kph	8.00 psf	1.54" H2O	56 mph
396 Pa	92 kph	8.25 psf	1.59" H2O	57 mph
400 Pa	93 kph	8.34 psf	1.61" H2O	58 mph
431 Pa	96 kph	9.00 psf	1.73" H2O	60 mph
467 Pa	100 kph	9.75 psf	1.88" H2O	62 mph
500 Pa	104 kph	10.43 psf	2.01" H2O	64 mph
503 Pa	104 kph	10.50 psf	2.02" H2O	65 mph
539 Pa	108 kph	11.25 psf	2.17" H2O	67 mph
575 Pa	111 kph	12.00 psf	2.31" H2O	69 mph
600 Pa	114 kph	12.53 psf	2.41" H2O	71 mph
700 Pa	123 kph	14.60 psf	2.81" H2O	76 mph
750 Pa	127 kph	15.64 psf	3.01" H2O	79 mph

Testing for water leakage

Water resistance tests are performed on specimens to check for water penetration under cyclic and static air pressure. The air pressure is intended to simulate actual natural weather characteristics such as normal and extreme rainstorm with wind events.

The spray rack is calibrated to deliver water application against the exterior surface of the specimen at a rate of 3.4L/m2min (5.0 U.S. gal/sf/hr) at the required cycle and pressure conditions.

Predetermined criteria for water penetration determines the pass/fail result.

AAMA 501.1-05 Standard Test Method for Exterior Windows, Curtain Walls, and Doors for Water Penetration Using Dynamic Pressure

Calibrated spray rack

Observe for leaks at interior of chamber

WIND VELOCITY		STATIC P. H_2O		STATIC PRESSURE	
MPH	KPH	INCH	MM	PSF	Pa
25	40	.300	7.62	1.56	75
50	80	1.20	30.5	6.24	300
63	100	1.92	48.8	10	480
70	112	2.30	58.2	12	575
77	125	2.89	73.4	15	720
118	189	6.72	170.7	35	1676
142	229	9.62	244	50	2394
167	267	13.4	340	70	3352
200	322	19.2	487.7	100	4788
224	358	24.0	609.9	125	5985
283	453	38.4	975.4	200	9576

PSF = .002496 $(MPH)^2$
INCH H_2O = .192 X PSF
1 PSF = 47.88 Pa [N/m^2]
1 CFM = .588 m^3/hr.
GLASS WT: 13lb/ft^2/inch

AAMA 501.1-05 Standard Test Method for Exterior Windows, Curtain Walls, and Doors for Water Penetration Using Dynamic Pressure

Structural Performance Test

ASTM E330: Standard Test method for Structural performance of Exterior Windows, Curtain walls, and Doors by Uniform Static Air pressure Difference

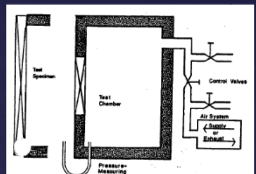


FIG. 1 General Arrangement of Testing Apparatus

4.1 "This test method consists of sealing the test specimen into or against one face of an air chamber, supplying air to or exhausting air from the chamber according to a specific test loading program, at the rate required to maintain the test pressure difference across the specimen, and observing, measuring, and recording the deflection, deformations, and nature of any distress or failures of the specimen."

Exterior view of chamber under seismic loading of 1.4" lateral

Structural Performance Test

A uniform load structural test determines the specimen's strength under positive and negative air-pressure loads.

The results are determined by using gauges, occasionally digital instrumentation, which measures permanent set and deflection readings under ratios established by the standard and/or Professional Engineer.

Structural load resistance tests may also include blast, impact test, and seismic or other depending on Owner Project Requirements

Gauges measure movement of the specimen

Hydraulic jacks create movement of the chamber structure to induce load

Window washing tie back test

Large Missile Impact Test

Thermal testing

AAMA 501 : Methods of Tests for Exterior Walls (Optional Test AAMA 501.5 – Thermal Cycling)

Thermal cycling test temperatures shall be selected to meet the expected job conditions, but if these are not known, the standard test conditions shall be utilized. Three thermal cycles are performed.

Typically, this test is a part of the ASTM E2099 test sequence, followed by air and water infiltration resistance testing in accordance with ASTM E283 (optional) and ASTM E331 (at a minimum) respectively.

AAMA 1503:Voluntary Test Method for Thermal Transmittance and Condensation Resistance of Windows, Doors and Glazed Wall Sections

The AAMA 1503 test method is based on ASTM methodology. The U-factor is determined under winter, night-time conditions which simulate different temperatures on the interior and exterior sides of the sample. (interior: 70 degrees F, exterior: 0 degrees F). An exterior surface coefficient is established which is based on a 15 mph wind. Readings using thermocouples are taken at various locations on glazing and framing.

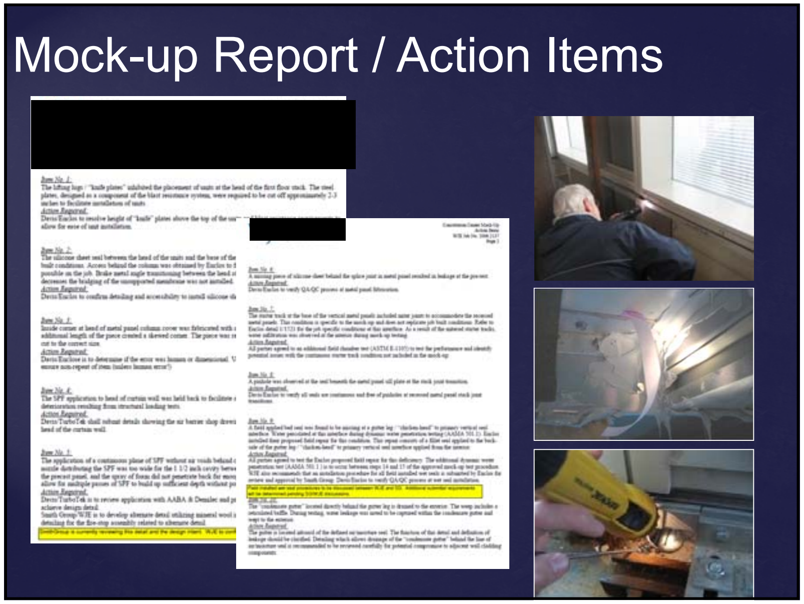
Typically this test is performed on individual products of a standard size for comparison of CRF.

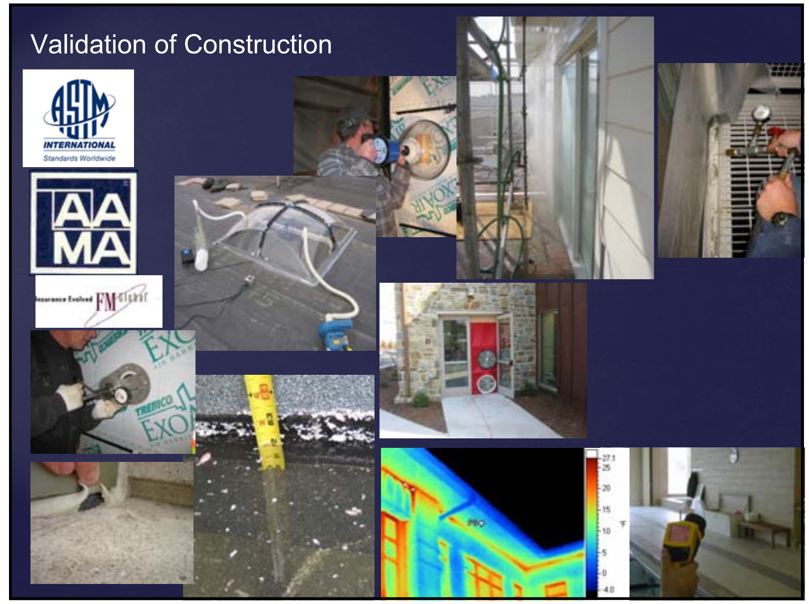
Fenestration: Condensation Resistance

Specified Condensation Resistance Requirements:

Condensation resistance (AAMA 1503-985) at winter design conditions:
0 degrees F exterior and 15mph wind velocity, 68 degrees F interior temperature and 30% Relative Humidity. No condensation or surface temperatures at or below the dew point.

Material Properties Testing


Mock-up Report / Action Items


Validation of Construction
INTERNATIONAL
Standards Worldwide
AAMA


Differential Pressure Tests
MAGNEHELIC


Field Air Tests – Glazed assemblies & Interfaces
ASTM E783 Standard Test Method for Field Measurement of Air Leakage Through Installed Exterior Windows and Doors

Field Water Tests – Glazed assemblies & Interfaces

ASTM E-1105-00(2008) Standard Test Method for Field Determination of Water Penetration of Installed Exterior Windows, Curtain Walls, and Doors by Uniform or Cyclic Static Air Pressure Differential.

Field Water Tests – Glazed assemblies & Interfaces

AAMA 501.2 Standard Test Method for Field Determination of Water Penetration of Installed Exterior Windows, Curtain Walls, and Doors by Uniform or Cyclic Static Air Pressure Differential.

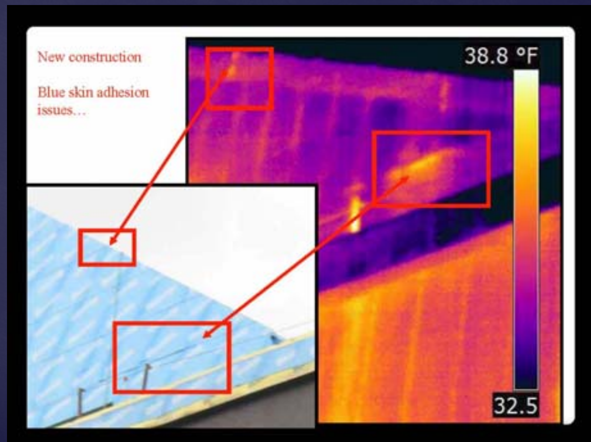
Field Water Tests – Glazed assemblies & Interfaces

AAMA 501.1-05 Standard Test Method for Exterior Windows, Curtain Walls, and Doors for Water Penetration Using Dynamic Pressure – Modified for Field Use

Field Air Tests – Air Barrier

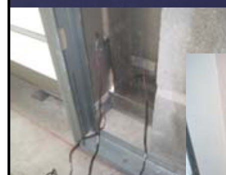
ASTM E1186 – (2009) *Standard Practices for Air Leakage Site Detection in Building Envelopes and Air Barrier Systems*

Air Leakage Testing

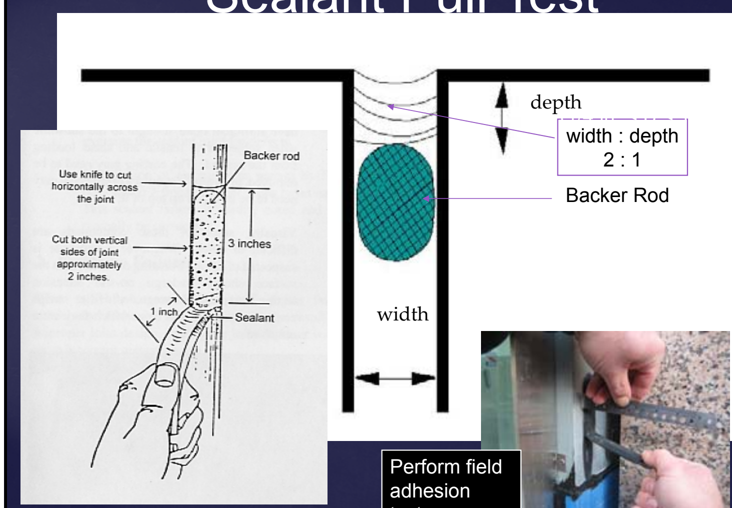


Field Thermal Tests – Glazed Assemblies/Transition to Air barr

AAMA 1503-09 Voluntary Test Method for Thermal Transmittance and Condensation Resistance of Windows, Doors and Glazed Wall Assemblies.



Sealant Pull Test

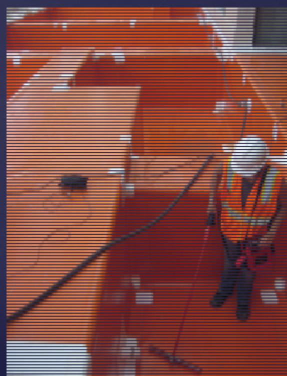


Perform field adhesion tests

Field Air Tests – Roof

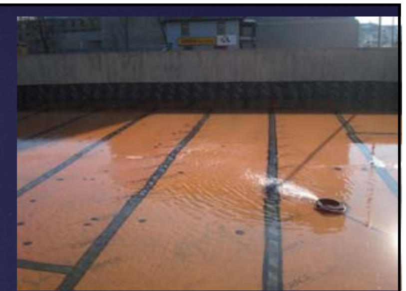
ASTM E1186 Standard Practices for Air Leakage Site Detection in Building Envelopes and Air Barrier Systems

Field High Voltage Electronic Leak detection – Roofing and Planter waterproofing



Field Water Tests – Water proofing

ASTM D-5957-98(2005): Standard Guide for Flood Testing Horizontal Waterproofing Installations



Project Specific Tests

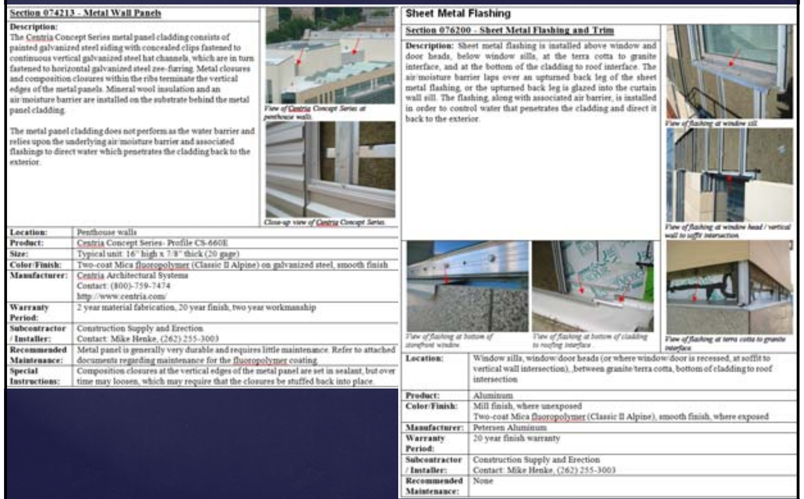
ASTM D4541 - 09 Standard Test Method for Pull-Off Strength of Coatings Using Portable Adhesion Testers

ASTM C1521 - 09e1 Standard Practice for Evaluating Adhesion of Installed Weatherproofing Sealant Joints.

Construction Close-out

- Ensure Completion of all items on Deficiencies Log
- Final Site Observation
- Punchlist process
- Owner’s Maintenance Manual

Close Out Report



Sheet Metal Flashing

Section 074213 - Metal Wall Panels	
Description: The Centria Concept Series metal panel cladding consists of painted galvanized steel siding with concealed clips fastened to continuous vertical galvanized steel hat channels, which are in turn fastened to horizontal galvanized steel zee-furring. Metal closures and composition closures within the ribs terminate the vertical edges of the metal panels. Mineral wool insulation and an air/moisture barrier are installed on the substrate behind the metal panel cladding. The metal panel cladding does not perform as the water barrier and relies upon the underlying air/moisture barrier and associated flashings to direct water which penetrates the cladding back to the exterior.	
Location:	Penthouse walls
Product:	Centria Concept Series- Profile CS-660E
Size:	Typical unit: 16" high x 7/8" thick (20 gage)
Color/Finish:	Two-coat Mica fluoropolymer (Classic II Alpine) on galvanized steel, smooth finish
Manufacturer:	Centria Architectural Systems Contact: (800)-759-7474 http://www.centria.com/
Warranty Period:	2 year material fabrication, 20 year finish, two year workmanship
Subcontractor / Installer:	Construction Supply and Erection Contact: Mike Henke, (262) 255-3003
Recommended Maintenance:	Metal panel is generally very durable and requires little maintenance. Refer to attached documents regarding maintenance for the fluoropolymer coating.
Special Instructions:	Composition closures at the vertical edges of the metal panel are set in sealant, but over time may loosen, which may require that the closures be stuffed back into place.

View of Centria Concept Series at penthouse walls.

Close-up view of Centria Concept Series.

Section 076200 - Sheet Metal Flashing and Trim	
Description: Sheet metal flashing is installed above window and door heads, below window sills, at the terra cotta to granite interface, and at the bottom of the cladding to roof interface. The air/moisture barrier laps over an upturned back leg of the sheet metal flashing, or the upturned back leg is glazed into the curtain wall sill. The flashing, along with associated air barrier, is installed in order to control water that penetrates the cladding and direct it back to the exterior.	
Location:	Window sills, window/door heads (or where window/door is recessed, at soffit to vertical wall intersection), between granite/terra cotta, bottom of cladding to roof intersection
Product:	Aluminum
Color/Finish:	Mill finish, where unexposed Two-coat Mica fluoropolymer (Classic II Alpine), smooth finish, where exposed
Manufacturer:	Petersen Aluminum
Warranty Period:	20 year finish warranty
Subcontractor / Installer:	Construction Supply and Erection Contact: Mike Henke, (262) 255-3003
Recommended Maintenance:	None

View of flashing at window sill

View of flashing at window head / vertical wall to soffit intersection

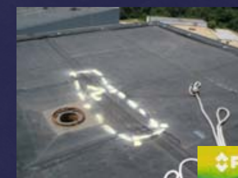
View of flashing at bottom of storefront window.

View of flashing at bottom of cladding to roofing interface.

View of flashing at terra cotta to granite interface

Post Construction testing

Although useful to diagnose issues and perform qualitative reviews, testing after the building enclosure is complete is not useful in the overall schedule and mission to achieve the OPR.



Adapt tests to validate performance and undertake early in the construction process.

Post-Construction Building Enclosure – Air Tightness

ASTM E1827 *Standard Test Methods for Determining Airtightness of Buildings Using an Orifice Blower Door*

<u>Result: (</u>Enclosure, including basement)
<u>0.12 cfm/ ft² at a pressure differential of 0.3" w.g.(75 Pa)</u>

<u>Result: (</u>Enclosure, without basement)
<u>0.2 cfm/ ft² at a pressure differential of 0.3" w.g.(75 Pa)</u>

Testing undertaken as part of ASHRAE 1478TRP "Measuring Air-Tightness of Mid and High Rise Non-Residential Buildings". Results courtesy of Gary Nelson & Collin Olsen. Much thanks to entire WID team, Terry Brennan & Wagdy Anis.

Evolving Knowledge

If knowledge can create problems, it is not through ignorance that we can solve them.

Isaac Asimov

Useful links to develop building enclosure knowledge:

www.wbdg.org/
Whole Building Design Guide (WBDG): A comprehensive guide for exterior envelope design and construction for institutional / office buildings.

http://www.nibs.org/
National Institute of Building Sciences (NIBS): This site is the building community's connection to the authoritative national source of knowledge and advice on matters of building regulation, science and technology.

http://www.bec-national.org/
Building Envelope Councils (BEC): The BECs are charged with providing a forum for the construction industry on the crucial area of building enclosures. Washington DC AIA/BEC …… next meeting **28th May at 4.00pm**, @ Gensler offices, 2020 K St, 2nd Floor.

Reference Materials

- Designing the Exterior Wall, An Architectural Guide to the Vertical Envelope by Linda Brock
- Water in Buildings, An Architect's Guide to Moisture and Mold by William B. Rose
- Moisture Control Handbook: Principles and Practices for Residential and Small Commercial Buildings by Joseph W. Lstiburek and John Carmody www.buildingscience.com
- The Whole Building Design Guide and the Exterior Envelope Design Guide www.wbdg.org

Thank You

- Questions