MNPHA 2018 Conference

Building Science Basics

Major Maintenance and Repair Considerations

Crosier Kilgour & Partners Ltd.

CONSULTING STRUCTURAL ENGINEERS

Part 1: Building Science 101

What is a “Building Envelope”?

- The building envelope provides the environmental separation for the exterior wall and roof systems of a structure.

- Attempt to control Heat, Air, and Moisture from infiltration and exfiltration.

- Requirements are defined under Part 5 for larger buildings and Part 9 for houses and smaller building in the National Building Code.

Why should you care?

Envelope failures due to the uncontrolled movement of heat, air and moisture create numerous problems:

- High energy/operating costs for heating and cooling.
- Structural
- Biological growth/IAQ concerns
- Premature Failure
- Interior occupant discomfort

Uncontrolled Moisture

Poor Drainage

Consequences of Poor Air Barrier

BUILDING ENVELOPE
Design Considerations

- Air barrier
- Vapour barrier
- Water shedding layer(s)
- Insulation options
- Environmental Loads

Three primary wall systems

- **Face-sealed systems**; significant variations in long-term durability.

  Example: Two-coat acrylic stucco wall systems

- **Cavity wall**; provides a path for drainage of moisture.

  Eg. Masonry veneers, siding wall systems.

- **Pressure Equalized Rain Screen (PER)**; superior protection against wind-driven rain.

  Eg. Siding on furring channels c/w Air Stops

The Air Barrier

- Must be able to transfer induced loads to structural back-up, typically due to wind and mechanical effects.
- Material or composite must be rigid enough to transfer loads without excessive deflection.
- Must be continuous throughout exterior of building, foundation to roof.

Vapour Barrier

- Prevents water vapour from migrating through the building envelope.
- Defined in NBC as a material that control water vapour diffusion to less than 60 ng/Pa*S*m^2.
- Continuity and minor penetrations generally do not adversely affect performance of vapour barrier.

Air Barrier vs Vapour Barrier

Q1: What materials are used for an air barrier?

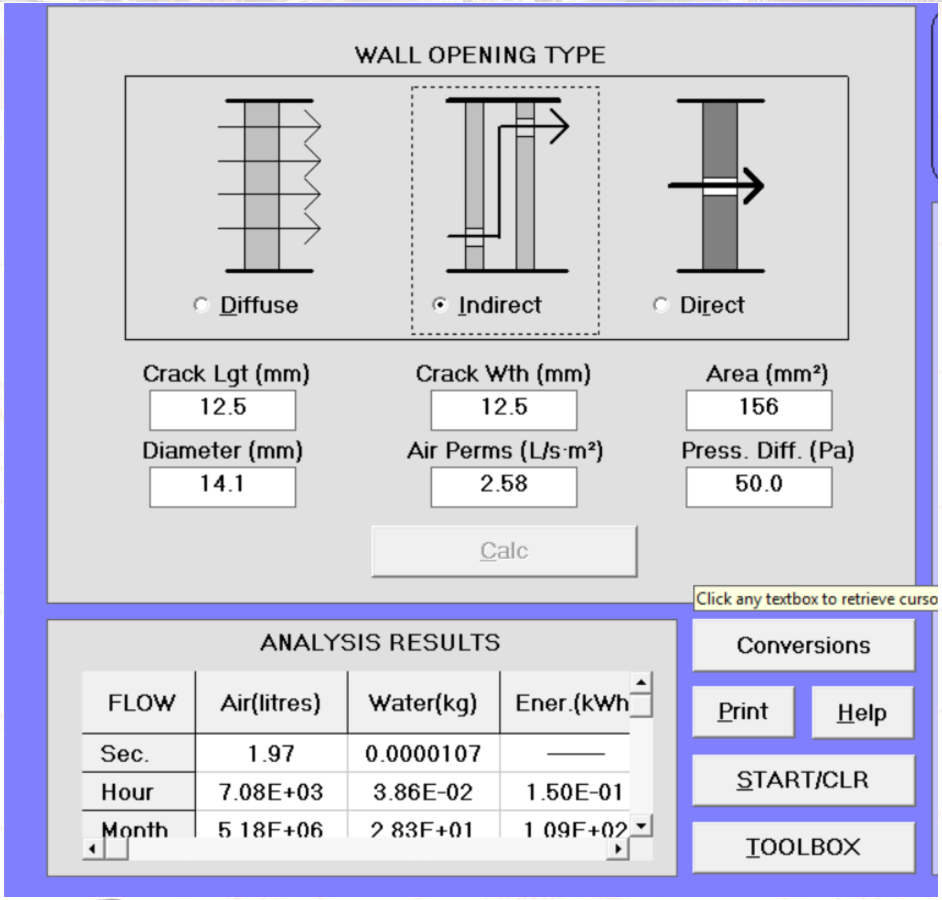
Q2: What materials are typically used for a vapour barrier?

Q3: Which one is more important in the building envelope?

Can sheet poly act as an air barrier?

- **Wall System:**
  - Metal Siding
  - Furring
  - Foil Faced Polyiso
  - Tyvek
  - Exterior Grade Gypsum
  - 6” Steel Stud c/w R20 Batt
  - Polyethylene
  - Drywall

Power of Air Leakage



- A 0.5" hole in the air barrier under winter design conditions can deposit about 40 grams of water into a wall system every hour or 28 kg a month!
- 0.5" hole creates109 kwh of energy loss per month.

Water Shedding

Poor Detailing and Poor Windows

Poor Design and Execution

Insulation Options

- Minimum levels specified under MBC and MNEC; function of geographic location.
- Note the concept of diminishing returns when adding thick layers of insulation.
- Interaction between mechanical systems, electrical systems and thermal performance on energy consumption.

Insulation Comparison

Insulation Type	Fiberglass	Closed-Cell Urethane	Open-Cell Urethane
Thermal Resistance ('R')	3.4/inch	6/inch	3.7/inch
Density	0.50 lb/cu.ft.	1.7 to 2.0 lb/cu.ft.	0.5 to 0.7 lb/cu.ft.
Vapour Permeance	∞	<60 ng/Pa*S*m^2	>1200 ng/Pa*S*m^2
Air Barrier	No	Yes	Yes
Vapour Retarder	No	Yes	No

R_{gross} versus $R_{effective}$?

- Does 130mm of batt insulation provide R20 in your wall?

- When you account for thermal bridging effects of the studs, the Reffective drops to about R13.

- Reffective is the now the norm.

Thermal bridging from studs.

Building Envelope Retrofit Design Considerations

Building Envelope Components

Consider DSL of components and building.

- **Wall Systems**

  cladding, insulation, water barrier, air barrier.

- **Roof Systems**
- **Windows and Doors**

System Design Considerations

- Durability

  CSA S478 Standard Durable Buildings coming soon to the National Building Code

  Hard to reach and/or expensive components should be designed to meet the Design Service Life.
- Appropriate Solutions
- Cost

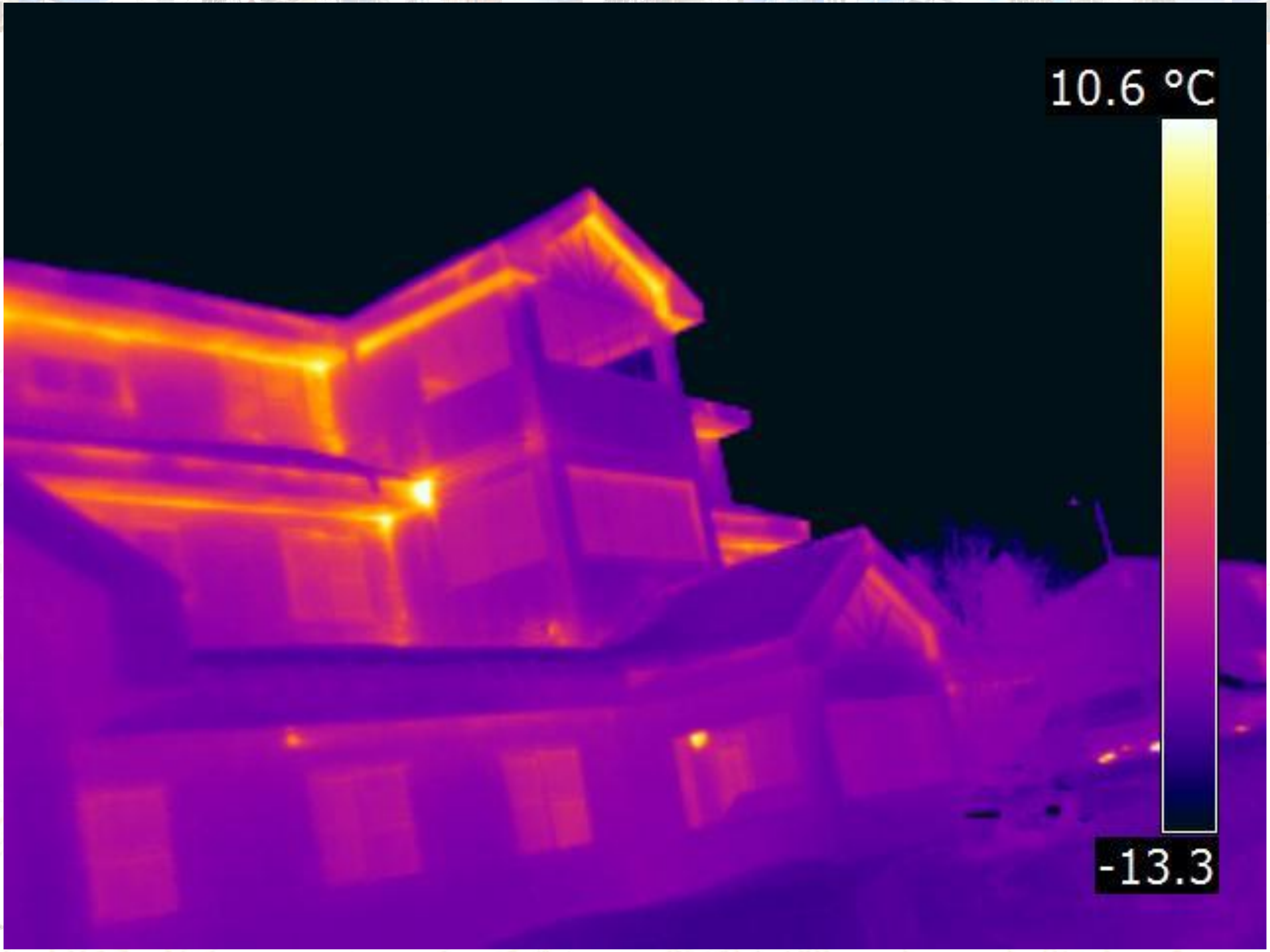
Design for Durability

Durability of the building envelope dependent upon:

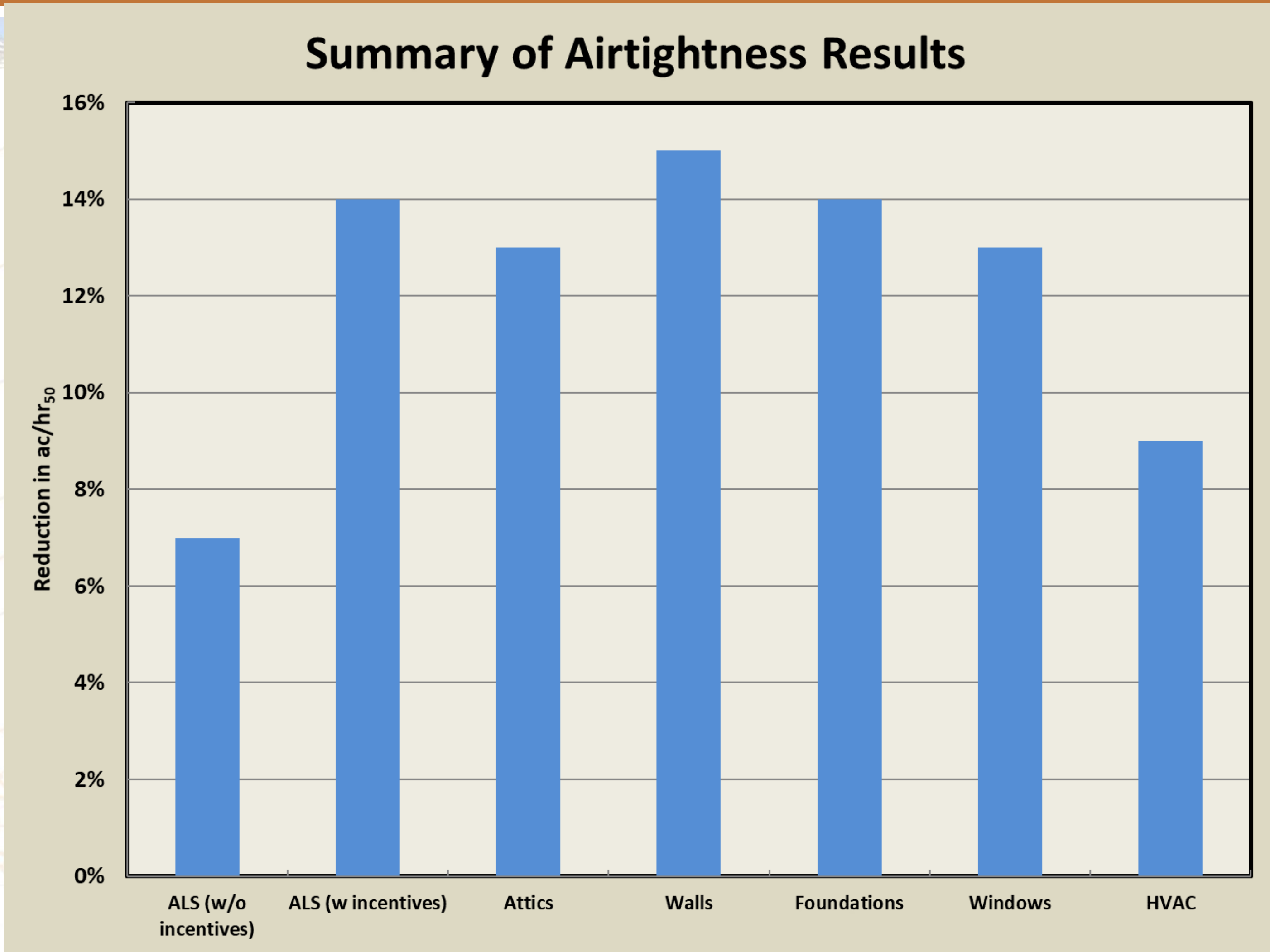
1. Exposure conditions
2. Convection control (air leakage)
3. Precipitation control.
4. Conduction (thermal bridging)
5. Radiation (solar heat gain)

Material and system choices must accommodate these variables.

Failed Remediation



Target Retrofit Priorities



Source: Proskiw, et al

Penetrations

Fastener penetrations are ***not*** self-sealing

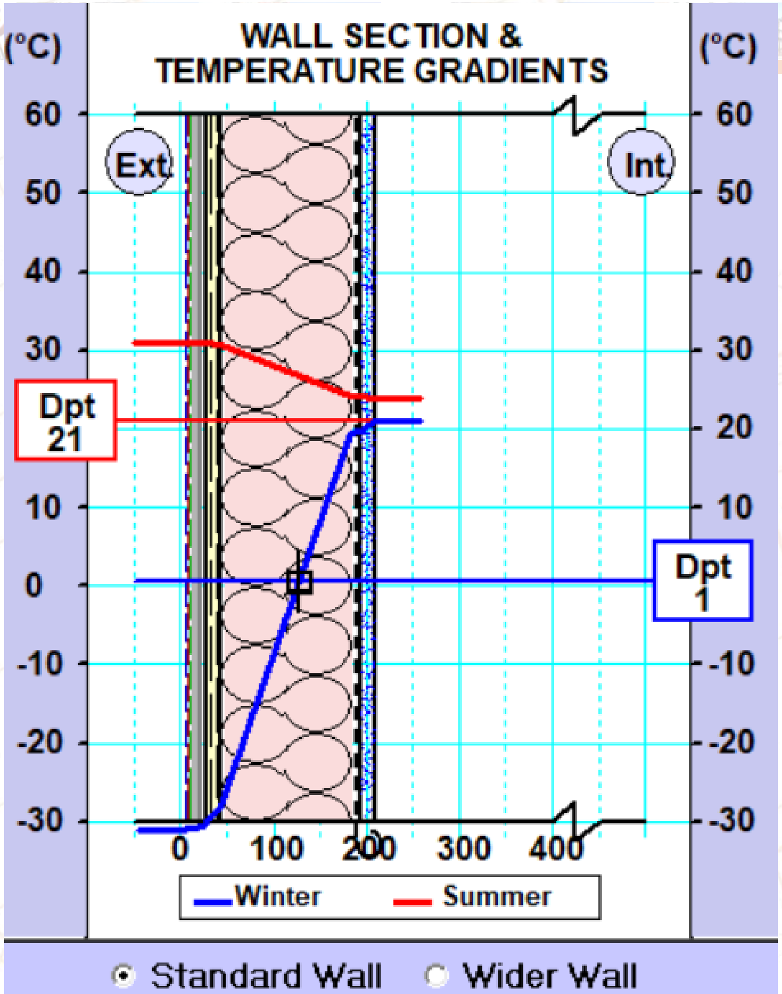
Design Recommendation

- Consider use of a vapour permeable membrane air/water barrier applied to exterior sheathing; crack-bridging and self-sealing to fasteners.

- Consider spray-foam at interfaces and junctions not readily accessible or conducive to membrane sealing, such as attic roof/wall interfaces, foundation/main floor joist pockets, and ceiling penetrations.

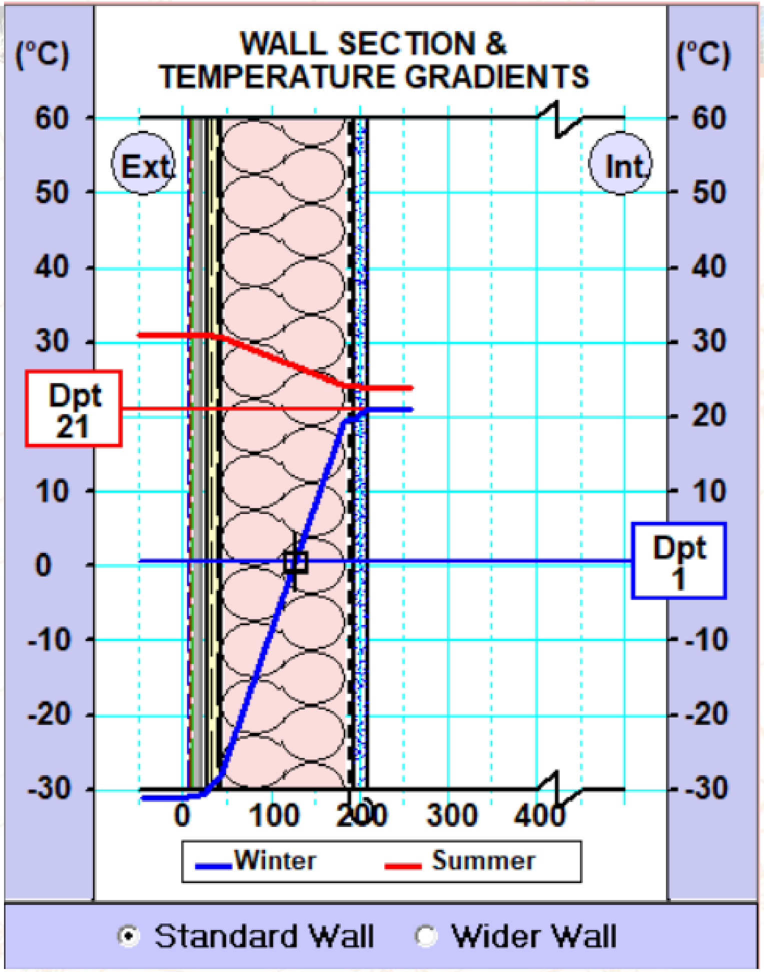
2. Conduction

Improving Thermal Resistance



Conventional 6” stud wall provides for Rgross 18 or Reffective about R13

Impact of Exterior Insulation



1.5" XPS increase Rgross to R25 or Reffective R22

Exterior Insulation

1.5” Exterior Insulation keeps OSB sheathing above dew point for more than 90% of year.

Design Recommendation

Consider application of 1.5” (minimum) XPS exterior insulation.

Precipitation Management

Rain penetration depends on:

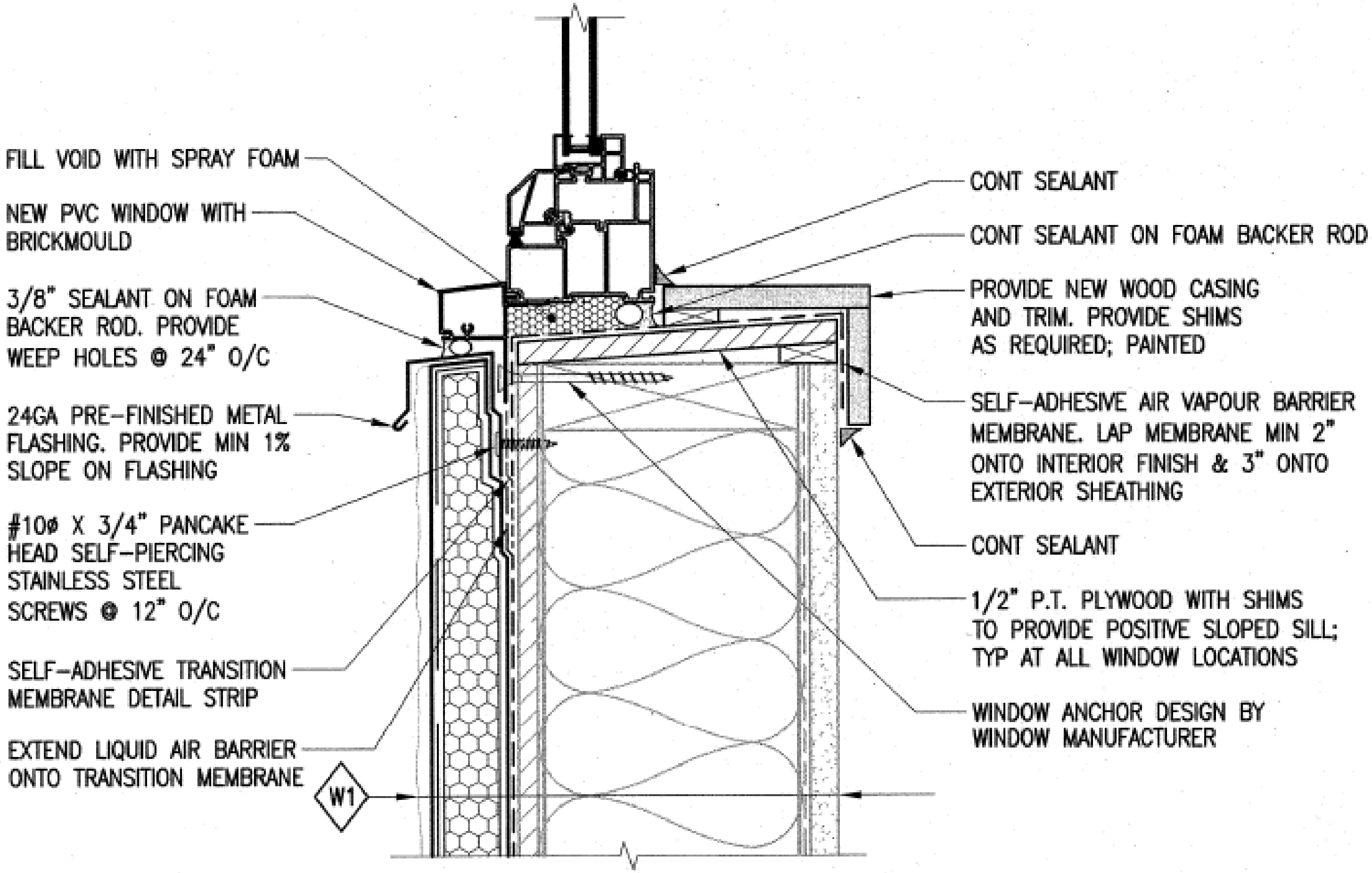
- Film of water accumulating on or within the wall system.
- Openings from which water can pass.
- A force to move water from the exterior to the interior through discreet openings, typically kinetic, gravity, and air pressure differences.

Damage is a function of retention time.

Damage by Design

Exterior building paper taped and sealed to sill nail flange, over window detail wrap, trapping water in wall system.

Leave Sill Unsealed



Continuity of air seal provided by interior continuous sealant

Provide Enhanced Drying

Provide furring for precipitation control, drainage and venting

Water Damage and Energy

- Moisture reduces thermal resistance of fiberous insulation and open cell insulation.
- As damage progresses, increases in water penetration and air leakage occur through the building envelope.

Design Consideration Summary

1. Introduce exterior insulation.
2. Consider use of crack-bridging vapour permeable membrane on exterior sheathing for air/water barrier.
3. Introduce furring for enhanced drying of wall system and precipitation control.
4. Incorporate CSA A440 Best Practice details for window installation.

Example Problem: Window Replacement

Two Options

- Establish Design Service Life of component relative to building. Two options for replacing windows in existing buildings:

1. **Box Unit Replacement**

- Typically window is installed within the frame of the existing window.

2. **Complete Tear-Out**

- Existing frame is removed exposing original buck to facilitate installation of membrane and flashing assemblies to protect rough opening

Box Unit Replacement

Advantages:

- Cost
- Less disruption to residents

Disadvantages:

- Does not address rough opening
- Shortened effective service life
- Significant differences in thermal coefficient of expansion

Box Unit Replacement

Box Unit Example

CKP therefore does not recommend box unit replacements.

Replacement Considerations

- Budget versus DSL of window and building.
- Window type; punched versus curtain wall
- Frame material; PVC, Fiberglass, Aluminum
- Performance versus Code issues; Fire, Strength, U-value, condensation index, etc.
- Plane of window within wall
- Method of heat delivery to exterior walls

Performance Considerations

- Number of panes; dual versus triple glazing.
- Low emissivity coating type
- Plane or location of Low Emissivity Coating
- Tint of glass
- Spacer type
- MB Hydro Grant(?)

Design Considerations

- Window performance design based on CSA A440 requirements, referenced under the MBC 2011.
- Need to be aware of not over-designing or under-designing performance requirements.
- Be aware of Code requirements for combustibility and guard requirements.
- Ensure rough opening details are clearly shown.

Perils of Unwise Decisions

Rough Opening Detailing

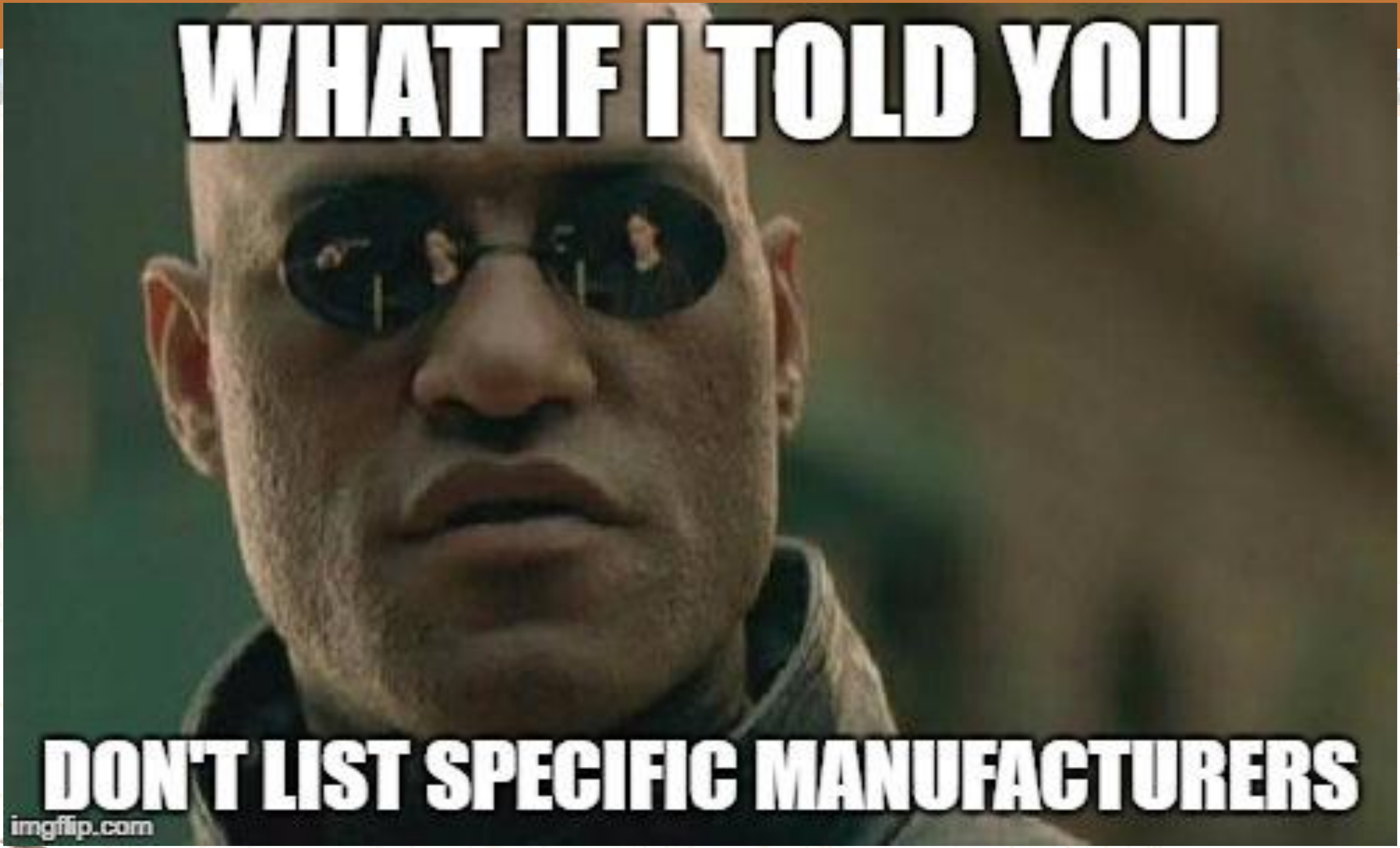
Window Rough Opening

Procurement Considerations

1. Direct to window manufacturers/suppliers.
2. Retain consultant to provide system design drawings and specifications.
3. Tender to General Contractor versus Manufacturer/Supplier?

Design Documents

- Drawings and specifications need to show clearly sill, head, and jamb conditions.
- Type of fenestration; curtain wall vs punched window, frame material type, etc.
- Performance requirements; PC and PG, Design performance metrics.
  - **Acceptable manufacturers???**


WHAT IF I TOLD YOU
DON'T LIST SPECIFIC MANUFACTURERS
imgflip.com

Consider Window Geometry

Simple fixed window easily passes A440.

Standard Fixed

Complex Window Geometry

- Will compound window meet performance specifications?

Leakage from fabrication issue

Performance Based Specification

Performance Requirement	Fixed Units FW	Operable Units
Class	LC	LC
Minimum Design Pressure	1.2 KPa	1.2 KPa
Minimum Structural Pressure	1.8 KPa	1.8 KPa
Minimum Water Pressure via ASTM E547	180 Pa	180 Pa
Air Leakage @ 75 Pa	0.20 l/s/m^2	1.50 l/s/m^2
Forced Entry	Grade 10	Grade 10
Insect Screens	N/A	SMA 1201
Thermoplastic Corner Weld Test	Pass	Pass
Weatherstrip	AAMA 701	AAMA 701
U_{frame}	1.70 max	2.00 Max
$U_{centre\ of\ glass}$	1.20 max	1.40 Max
U_{window}	1.50 max	1.70 Max
Condensation Resistance	70	70

Manufacturer Performance

Personal Observations:

1. Quality and consistency varies amoung the manufacturers.
2. Predictably, material performances vary; eg. Aluminum versus fiberglass vs PVC.
3. Not all manufacturers aware of MBC requirements, particularly regarding combustibility, opening restrictions, and guardrail requirements.

Installation

Leakage at Head

The "Classic"

Before Mobilization…

Step 1: Shop drawing approval.

Step 2: Laboratory test of proposed window for specification performance confirmation.

Step 3: Pre-construction conference

Testing

- Testing of mock-up(s) installation is critical for confirmation that window installed conforms to project specifications.
- Enables Owner to review installation and sets “Standard of Acceptance” for remainder of the project.
- Performance requirements should have been well established prior to tender and site testing of mock-ups.

Testing

- Testing completed typically to ASTM E1105
- AAMA 501.1
- Important to evaluate both the window and the rough opening, the interface between the window frame and the building wall.

When and where to test…

Better Now than Later

Summary and Conclusion

- Need to know the cause(s) of the problems in order to develop cost-effective solutions.
- Consider the DSL of the component in relation to the building.
- Consider a scope which enables “apples-to-apples” comparison on performance and cost.
- Always include mock-ups for testing and visual validation.

Thank You!

Questions?

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