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# Challenges with Using ASTM E 2112 in North American Climate Zones

Kevin C. Day

William C. Brown, P.Eng  
Member ASHRAE

## ABSTRACT

*Designing and constructing window-wall interfaces for long service life must include consideration of potential pathways for water ingress and egress; through both the window system and the interfacing cladding(s). ASTM E 2112 prescribes the installation of windows, patio-type doors and skylights as used primarily in residential and light construction commercial buildings. Adopting ASTM E 2112 allows designers to rely solely on windows to resist water penetration, independent of the adjoining wall assembly. However, experience of the authors has demonstrated that this approach has considerable risk.*

*When mass load-bearing walls, i.e., concrete and masonry, were the norm for buildings, the risk of damage from periodic water penetration at windows (in particular through the framing elements into the sub-sill cavity between the wall and window) was low because the walls had a high tolerance to moisture. In addition, the interior finishes, such as the traditional lime-based wall and ceiling plasters used widely in the 19th and early 20th centuries, were more robust to periodic wetting. Design practices have evolved to include non-load bearing walls with less moisture resistant structural systems, e.g., wood and steel studs, and paper-faced gypsum sheathings, combined with windows that attempt to manage water by intercepting it at the face of the assembly, and draining at the operable interface. Notwithstanding the advances in the performance of sealants and membrane materials, reliance upon face sealed systems has a higher risk of water penetration because of the inherent aging of the materials and loads imposed, thus reducing the overall resistance to water penetration and consequent damage.*

*This paper presents an overview of the design considerations for window installation relative to climate zones across North America. It also presents a series of conceptual details that focus on the control of water ingress from rain, air leakage, and vapor pressure across the window-wall interface.*

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## INTRODUCTION

The building construction industry in North America has been challenged since the early 1980's to address the large number of malfunctioning building envelopes. Many consumers have been inconvenienced and financially distressed by the fiasco of water penetration problems associated with windows. Allegations of damage and mold-related problems have been widespread; the assessment of the situation has been pervasive in symposia and academic forums over the last two decades.

The list of technical papers and articles (too long to cite here) which delineate problems between windows and walls typically highlight the interface of the sheathing membrane

with the concealed portion of the window framing. However, there has been a significant difference in the approach to making a water resistant connection. In particular, the degree to which windows are assumed to be water-tight, both by their construction and by their installation, and how water penetration is defined when it enters the wall assembly (or penetrates to the occupied interior space). Although windows are referenced throughout this paper as the generic fenestration element for the purpose of discussion, sliding glass (patio) and conventional doors must adopt the same principles regarding the window-wall interface details.

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*Kevin C. Day is a building science specialist for Halsall Associates Ltd., Richmond Hill, ON. William C. Brown is a senior building scientist specialist, Morrison Hershfield Ltd., Ottawa, ON.*

In contrast to the espoused theories of water resistant windows, evidence from investigations by the authors demonstrates that windows may resist water penetration, but cannot be expected to be waterproof (especially during extreme rain-storm scenarios). In particular, operable window units pose the greatest challenge to prevent water penetration. Therefore, the logical consideration is the risk of storm scenarios, which must also consider the window exposure, protection afforded by the building architecture, climatic loads, etc. Evaluating these variables leads to a cursory discussion on the relative risk associated with both the performance capabilities of the window unit and the associated interface details.

## A RISK MANAGEMENT APPROACH TO WATER PENETRATION

A risk management approach to moisture control in wall assemblies, as summarized by Day [2003], provides a subjective rationale for assessing the application of the variables affecting water penetration resistance. Hence, at the design stage, consider following qualitative formula:

$$Risk = Probability \times Cost \quad (1)$$

where

- Risk* = the legitimate, literal consequence should a critical event (failure) occur, including damages and repairs to return to a usable state
- Probability* = the occurrence or frequency of loads that may cause failure
- Cost* = the implication of damages and repairs, the financial obligation to restore the assembly, and associated costs

Assessing the risk of water penetration around or through a window, can be determined by considering both the probability and the cost of damage. When considering the minimum requirements set forth in building codes for both steel and wood framed construction, the construction industry must be reminded that the consumer is deserving of a building envelope wherein the risk of water penetration and resulting damage is reduced to a minimum. Considering the factors affecting the risk of moisture in exterior walls by Day [2003], only concrete and masonry mass walls can be expected to periodically absorb moisture as a result of water penetration, and be stored without adverse effects until later dissipated. Hence, it is not a prudent design rationale in wood- or steel-framed wall construction. Rainscreen walls, which include drained cavities in combination with the cladding, may offer an approach to managing water ingress through windows; a discussion of this design approach is discussed further in this paper.

Based on the assessed level of risk, there are four potential outcomes:

1. Low-exposure, water-tight assembly
2. Low-exposure, risky assembly
3. High-exposure, water-tight assembly
4. High-exposure, risky assembly

The obvious observations are that outcome #1 may be over compensating and outcome #4 resembles the problems observed in coastal climate regions around North America. Ultimately, these combinations of risk and performance attributes led both the risk adverse and potentially risky assemblies being represented in window installation standards, such as ASTM E 2112.

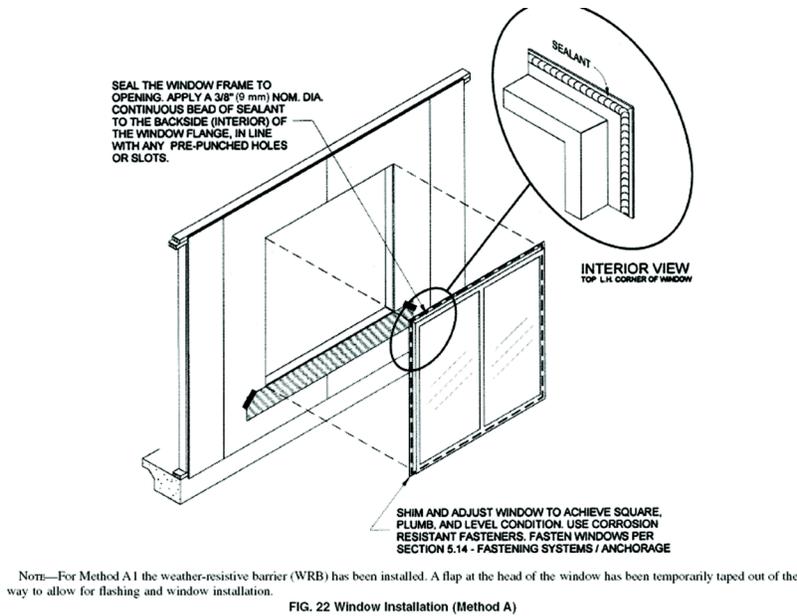
## STANDARDS FOR WINDOW INSTALLATION

Amidst the controversy surrounding building envelope failures, many standards and guidelines were developed to promote good practice for design and construction of walls, cladding and fenestration. However, when many standards and guidelines were initially developed, a key aspect of fenestration performance was overlooked; specifically the ability to resist water penetration through the junction between the frame and the wall. Historically, the assessment of the performance of proprietary window units was based on resisting a wind-driven rain pressure from the exterior to the interior, and the interface of the window frame and wall opening was not considered.

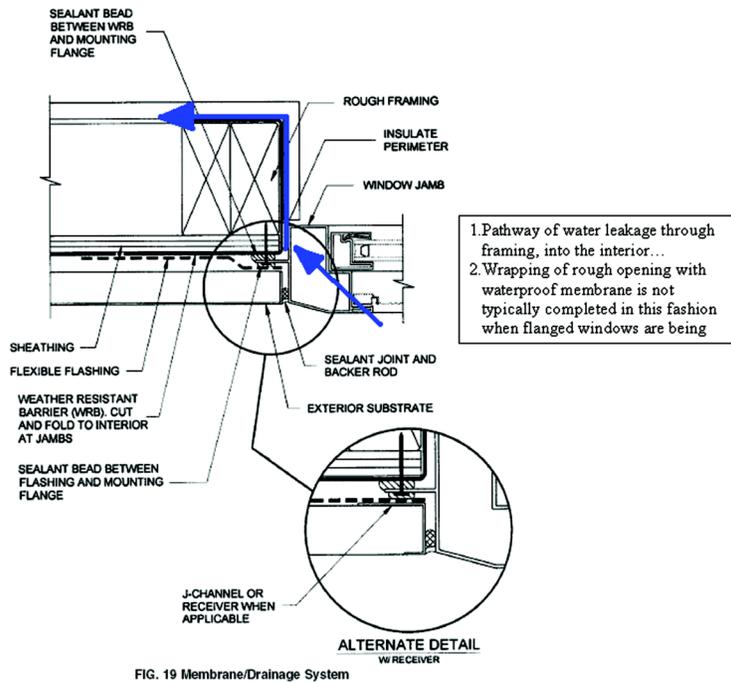
The building science community has confirmed on numerous occasions that installation practices are often non-compliant with relevant code and standard requirements. Nevertheless, such requirements are necessary and, in view of the fact that windows could leak into wall assemblies, the long-term durability of the window-to-wall interface certainly requires consideration.

ASTM E 2112-07 Standard Practice for Installation of Exterior Windows, Doors & Skylights [ASTM, 2007] was first introduced in 2001 to address the interface of fenestration with exterior wall systems. Many details and guidelines are provided, yet most of the approaches provided are without consideration of the in-situ performance of the given window unit. Conceptually, the design of the assembly will either assume a) the window is sufficiently resistant to water penetration and does not require secondary protection of the rough opening, or b) the window may leak at some point during its service life and the rough opening must be protected. The following illustrations from ASTM E 2112 have been identified by the authors as either water-tight windows or not:

The isometric detail in Figure 1 illustrates the installation of a window with nailing flange being sealed to the weather resistive barrier (sheathing membrane). This installation is further illustrated in Figure 2. Although this approach affords the wall assembly a degree of protection if the outer sealant should fail, this assembly does not provide any protection for the rough opening (surrounding framing) if the window itself should leak. Typically the qualification of the window for selection and use in construction is the manufacturer's testing according to ASTM E 331. This qualification typically measures the water resistance through the window at a specified air pressure differential, but does not consider water leakage through the window frame into the concealed space between the window sill and the rough opening.



**Figure 1** ASTM E 2112-07: Isometric detail of an assumed water-tight window sealed to sheathing and sheathing membrane at the window sill.



**Figure 2** ASTM E 2112: Jamb detail of water-tight window seal—water that enters the window framing or leaks through the window corners migrates into the wall assembly (blue arrows).

In considering the concept of a water-tight window frame, the defined risk would be based on whether or not water could leak through glazing seals and the connections of the individual framing elements, in particular at the miter or butt joints between the window sill and jambs. Figure 2 illustrates that if

the corner joints of the window frame were to leak, then water could enter into the wood framed stud cavity by-passing the weather resistant barrier. Note the phrase “water could enter into the wood framed stud cavity...” Hence the risk is delineated, and will vary based upon (listed in order of priority) a)

the quality and performance capabilities of the proprietary windows (over the service life of the windows), b) the level of exposure to wind-driven rain, and c) the level of maintenance.

Both Figures 1 & 2 illustrate a level of reliance upon the window frame connections and glazing seals to remain water tight for the service life of the window unit; thus leading to the consideration of the loads over the service life, i.e., the number of times the window will be exposed to wind driven rain that would lead to water penetration, and the durability of the joints under thermal and mechanical cycling.

In warm climates with little rainfall, the net effect of having incidental moisture leak through the window frame may be negligible, however, such a selection should be a calculated (or subjective) risk in the design. The risk associated with a window frame that may only leak in severe driving rain (noting that rainfall and wind patterns are two variables associated with this risk) may be so slight that the details illustrated in Figures 1 & 2 could perform satisfactorily in a warm climate with little rainfall.

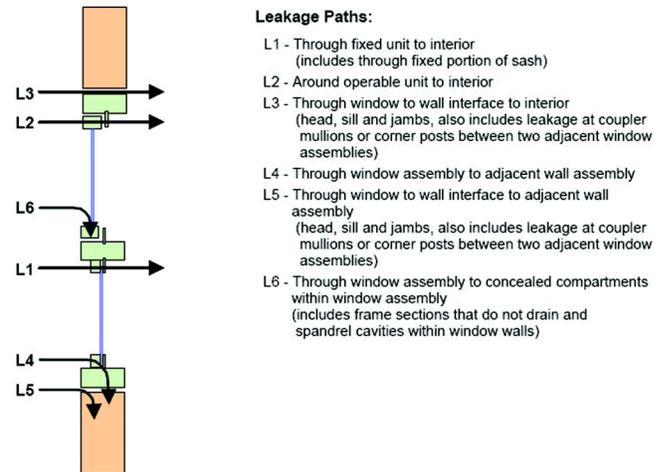
If there is a legitimate risk of water penetration occurring through the window framing, then the installation of a sill pan flashing (sub-sill flashing with end-dams) must be provided. Although ASTM E 2112 typically illustrates the drainage of the rough opening out onto the weather resistive barrier, there are two options that must be considered for sill flashing a) to drain behind the cladding and out through the base of the wall (or through cladding expansion joints), or b) deflect rain water out of the wall assembly at the base of the window, extending the sill flashing through the entire through-wall opening of the window and over the cladding.

## WATER PENETRATION THROUGH WINDOWS AND WINDOW INTERFACES

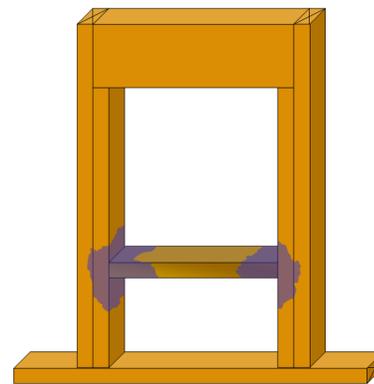
Canada Mortgage & Housing Corporation sponsored a study [CMHC, 2002] to document known problems with water penetration through windows and window interface details. A useful illustration that summarizes the potential locations of water penetration is shown in Figure 3. Thus far, this paper has discussed water penetration through those leakage pathways identified as water entering the rough opening of the wall assembly, namely pathways L4 & L6, as follows:

- L4, rainwater would fill the window assembly, through slider tracks or operable sash pockets, trickling in through the frame connections.
- L6, rainwater could enter the window framing through either the framing connections, or through the glazing gaskets, or through the interconnections of window segments (such as between fixed and operable units, or mullion splines that join a series of window units)

The key concern should be, and remains to be, preventing any level of damage occurring to the wall assembly as a result of periodic rainwater penetration. The vulnerable areas are illustrated in Figures 4 and 5. Irrespective of the type of clad-



**Figure 3** Illustration of water leakage paths—vertical section (from CMHC study on window leakage [CMHC 2002]).



**Figure 4** Moisture vulnerable areas.



**Figure 5** Water damage as a consequence of leakage at a window—Wilmington, NC.



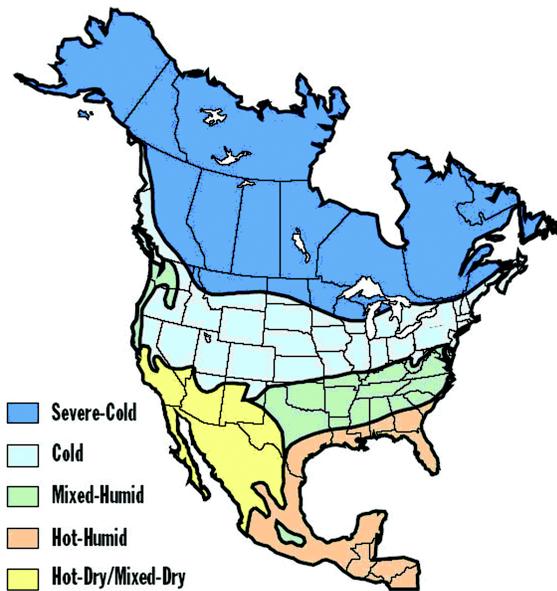


Figure 8 Hygrothermal zones for North America (CWC 2000).

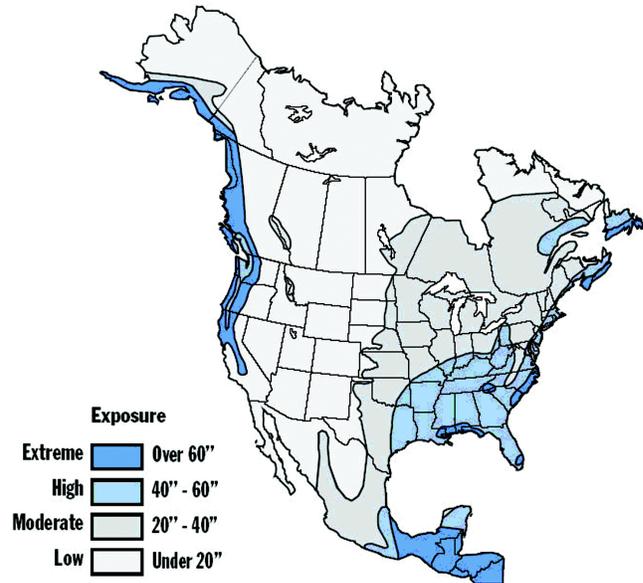


Figure 9 Rain zones for North America (CWC 2000).

Table 1. Classification of Detailing Window-to-Wall Interfaces

Rainfall Zone	Climate Zones				
	Severe Cold	Cold	Mixed-Humid	Hot-Humid	Hot/Mixed-Dry
Extreme >60 in.	Level 3	Level 3	Level 3	Level 3	n/a
High 40–60 in.	Level 3	Level 3	Level 3	Level 3	n/a
Moderate 20–40 in.	Level 2	Level 2	Level 2	Level 2	Level 2
Low <20 in.	Level 1	Level 1	n/a	n/a	Level 1

construction sequence tends to often result in the duplicity of problems with water penetration when neither the builder nor trades recognize the vulnerability of the window wall interface. Unless the contract documents require that a) methods provided in ASTM E 2112 be followed, b) the selection of the wall, window, and sheathing membrane components are specified, and c) it can be verified by a qualified third party; the installer is likely to install the windows without a proper interface detail. Hence, the dichotomy in track-housing construction is, does the builder rely on the window installer, or does the window installer rely on the builder for effective installation?

Ultimately, the adoption of ASTM E 2112 into the Building Code(s) could provide the contractual basis to enforce proper detailing and construction of the window interface, however, as shown above, there are at least two conceptual approaches, leaving the dilemma of which approach is appropriate, and who has the authority to both determine and enforce the requirements. Historically, requirements in the Codes have not always been followed, which has led to many of the problems associated with water penetration in both residential and commercial construction.

## WINDOW UNIT PERFORMANCE

Although window performance can be qualified to some extent by water resistance testing according to ASTM E 331 or AAMA, for a given wind and water pressure scenario, there are two necessary considerations for the application of such performance criteria: a) the window unit must be fairly representative of the manufacturer's line of windows, and b) the window unit's performance should be representative of the service life of the window unit when installed with good workmanship.

After pondering these two considerations, a determination must be made as to whether a window unit may, at some time during its service life, allow water penetration into a) the rough opening of the wall assembly (thus causing damage to the structure), and/or b) the interior (thus causing damage to the finishes). In consideration of a) or b), the frequency and degree of wetting could be evaluated from a risk management approach, e.g., if it once in every 10 years, and would quickly dry out, this would not likely lead to damage. However, based on the fact that both wood and steel framed wall assemblies afford little tolerance to moisture, it would be prudent to

always manage potential water penetration through windows. Therefore, designing the rough opening to provide drainage of incidental moisture ingress should be on a scale that is proportional to the comparative risk.

## USING RISK MANAGEMENT TO SELECT CLIMATE ZONES

In several publications over the last decade, the rationale for considering climate conditions as part of the building envelope design has become more common. Lstiburek identified hygrothermal zones for continental North America in several publications [best summarized in Lstiburek, 2001]. The Canadian Wood Council, accepting the challenge of proving the durability of wood framed construction in the aftermath of the 1990s leaky condo crisis in the lower mainland of British Columbia [CWC, 2000], developed a guide for illustrating the concepts of durable wood framed construction. Therefore, the use of hygrothermal zones for design consideration of the window wall interface would be most appropriate.

Utilizing the climate zones delineated in Figures 8 & 9, the authors propose that Table 1 delineate the moisture management strategy for window-to-wall interface details:

- **Level 1:** Sealing the perimeter of the window frame to the sheathing membrane (as per Figure 1) assumes the window is installed in a location with low rainfall and qualifies as being water-tight.
- **Level 2:** Sealing the inside perimeter of the window frame to a waterproof sub-sill flashing, and drainage of the rough opening is provided, either through the wall or to the exterior.
- **Level 3:** As per Level 2, but the design should incorporate reduced wind-driven rain exposure by deflection elements within the building envelope, i.e., flashing with large drip edges and large roof overhangs.

Notwithstanding the recommended detailing levels prescribed above, thermal considerations must still be addressed for the placement of the window (insofar as the ther-

mal breaks or relative mass for PVC and pultruded glass fiber window frames) to both; a) the thermal mass of the wall, and b) placement of the insulation within the surrounding wall assembly.

## CONCLUSION

In consideration of the risk equation discussed earlier, the combination of wood- or steel-framed construction with windows that may leak at some point during their life cycle leads the authors to conclude that a) only the hot and dry hygrothermal zone may be tolerant of periodic wetting and b) secondary protection of the window opening is required in all other hygrothermal zones.

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