

# An Analysis of Residential Window Waterproofing Systems

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Austin Parsons

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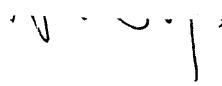
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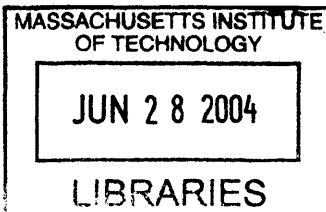
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On January 16, 2004 in Partial Fulfillment of the Requirements for the Degree of  
Masters of Science in Building Technology

**Abstract**

The prevalence of vinyl nail-on windows in the North American new home construction market has prompted ASTM International to write ASTM E2112-01 “Standard Practice for Installation of Exterior Windows, Doors and Skylights”. This thesis focuses on the window jamb flashing recommendation in ASTM E2112-01 for vinyl nail-on windows by asking the question of whether a vinyl window’s integral nail-on flange is by itself an adequate jamb flashing.

To answer this question, the Jamb Drip Test was designed and completed on fourteen (14) window/wall details. The answer to the question depends on the window/wall construction sequence. When the weather resistant barrier (WRB) is installed prior to the window, it isn’t. When the WRB is installed after the window, the nail-on fin is by itself an adequate jamb flashing.

Based on this Jamb Drip Test study, a recommended window/wall construction sequence of sheathing- flashing (sill, jamb and head) – vinyl nail-on window – WRB – siding option is proposed. This sequence recognizes that while the nail-on fin may be an adequate jamb flashing, without flashing, the designer cannot take full advantage of the symbiotic relationship between the nail-on flange and the space it creates between the adjoining building elements (e.g. sheathing and the WRB). In this capacity, jamb flashing is added to the construction sequence to protect the sheathing from wetting and aid in directing incidental water to the exterior.

Based on this proposed construction sequence, effort was focused on improving the present state of the art window/wall weatherproofing detail. An alternative to the use of high performance sealant to create the seal between the flashing and the window’s nail-on flange is proposed. The present recommendation uses a one-piece folded sheet that envelops the window flange, WRB and at the same time incorporates the window flashing function.

This novel, dual function (window seal + window flashing system) product is called w-Flashing. The thesis ends with a description of w-Flashing’s performance attributes, prototype design and recommended installation sequence around a vinyl nail-on window.

Thesis Supervisor: Leon R. Glicksman  
Title: George Macomber Professor of Construction Management  
Professor of Building Technology



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## 1.0 Introduction

A building is designed and built to create a sustainable, comfortable indoor space. To meet this objective, the separate elements that collectively make up the building must perform as a system.

The building envelope – the roof, wall and foundation system – is one element of a building. The building envelope's role is to separate the indoors from the outdoors both physically and environmentally. Environmentally, the building envelope controls the flow of air, heat and moisture across the indoor-outdoor boundary. As with the whole building's performance, the exterior wall's performance as a space and environment mediator depends on whether the separate building envelope elements joined together to create the wall perform as a system.

Depending on how the wall is designed, this environmental separation is controllable. A properly designed wall can control the movement of wind, rain, solar radiation, heat, noise, insects, animals and people between the indoor and outdoor environment. To exercise the required control, the wall design must correctly resolve a set of competing and conflicting requirements.

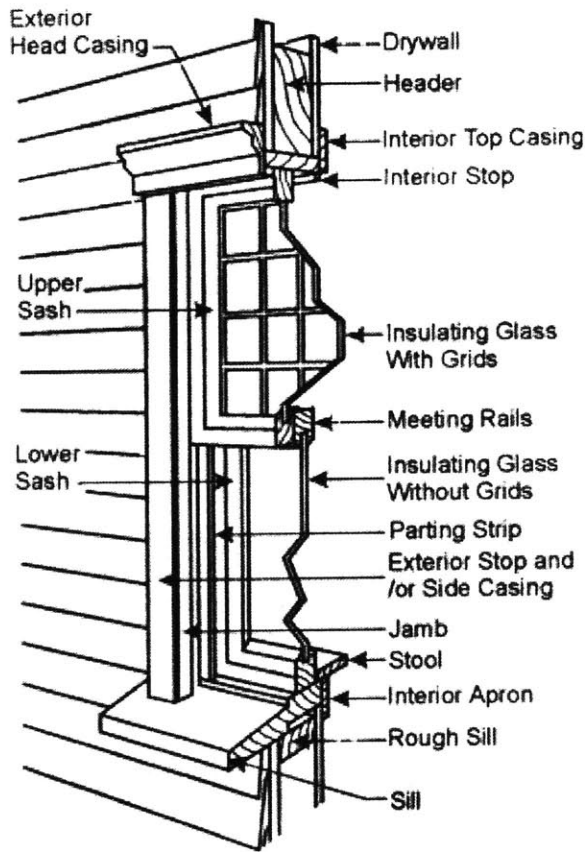
For example, windows are a means of controlling natural light and air into the indoor space. When a window is inserted into a wall, if not properly detailed, it can also allow uncontrollable wind, noise and rain into the indoor environment. The design challenge becomes one of providing a controllable entry point for light and air, but at the same time, not compromising the wall's ability to control unwanted wind and water entry.

The focus of this study is the in-service performance of a vinyl nail-on window's mounting flange<sup>1</sup> as a window jamb flashing. The nail-on window frame and its associated mounting flange or nailing fin was introduced in the California/Western United States new home market in the 1960s. Since then, the nail-on window frame has traveled west to east replacing the flush fin (a.k.a. brick mold) framed window as the most commonly installed window frame in the United States' new home construction market. This rise in popularity of the nail-on window frame has come with the rise in popularity of vinyl windows and is in part due to improvements in vinyl material, the cost of vinyl windows compared to windows made from wood and the low maintenance characteristics of a vinyl window (Russell, 2003 personal communication).

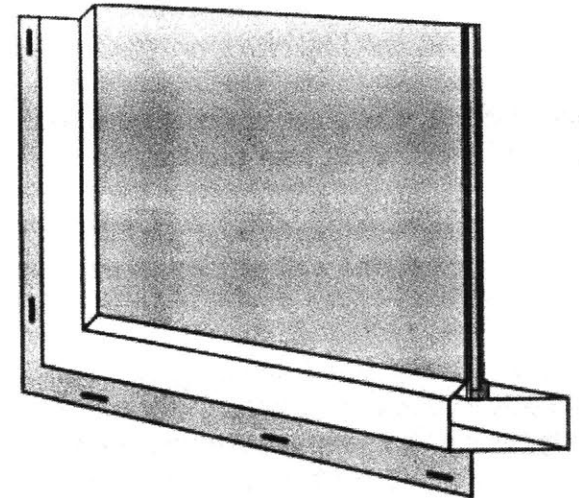
The nail-on window frame has a different frame configuration than the flush fin or brick mold framed window and the box frame window. As a result of these structural differences, each window frame type has a particular installation and waterproofing procedure.

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<sup>1</sup> There are three residential window frame types. They include the nail-on fin window, the flush fin window and the box window. These window frame types are described in **1.3 Residential Window Types**.



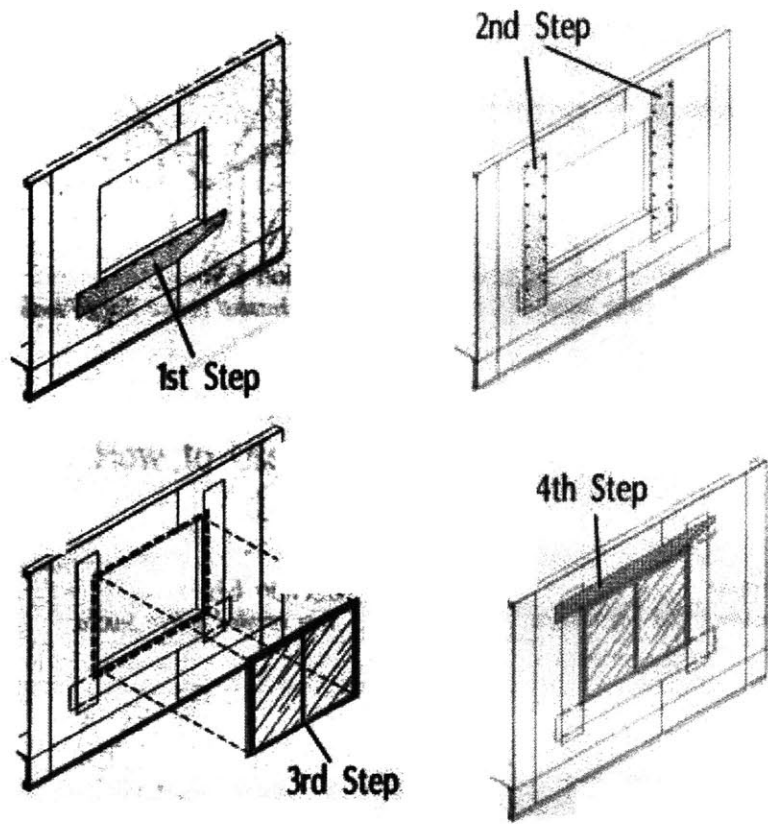
**Figure 1-1 Double Hung Window**  
source: AAMA (2000)



**Figure 1-2 Nail-on Window**  
source: AAMA (2000)

To inform window installers of the required installation procedures for a given window frame type, several installation guides have been written over the past decade (e.g. Bateman, 1995, JLC, 2003, McBride, 2002). ASTM International published an installation practice in September 2002. The practice- “Standard Practice for Installation of Exterior Windows, Doors and Skylights” details a number of different procedures on how to install windows, doors and skylights into the façade of a residential/light commercial type building. The practice is intended to provide technical guidance to organizations that are developing training programs for installers of fenestration units (i.e. windows, doors and skylights) in low-rise residential and light commercial buildings.

The recommended window installation details highlighted in ASTM E2112-01 (see Figure 1-3) are based on traditional window flashing details initially applied to flush fin framed windows (see Figure 1-4). If one references previous work in this field, the details highlighted in ASTM E2112-01 were first published in the AAMA Level RLC-1 training manual (2000) and Bateman (1995). In turn, in Bateman’s work there is a direct reference to an earlier design guide (i.e. Thallon, 1991) that includes a flush fin window flashing detail.



**Figure 1-3 Nail-on Window Flashing Detail**

**source: Bateman (1995)**

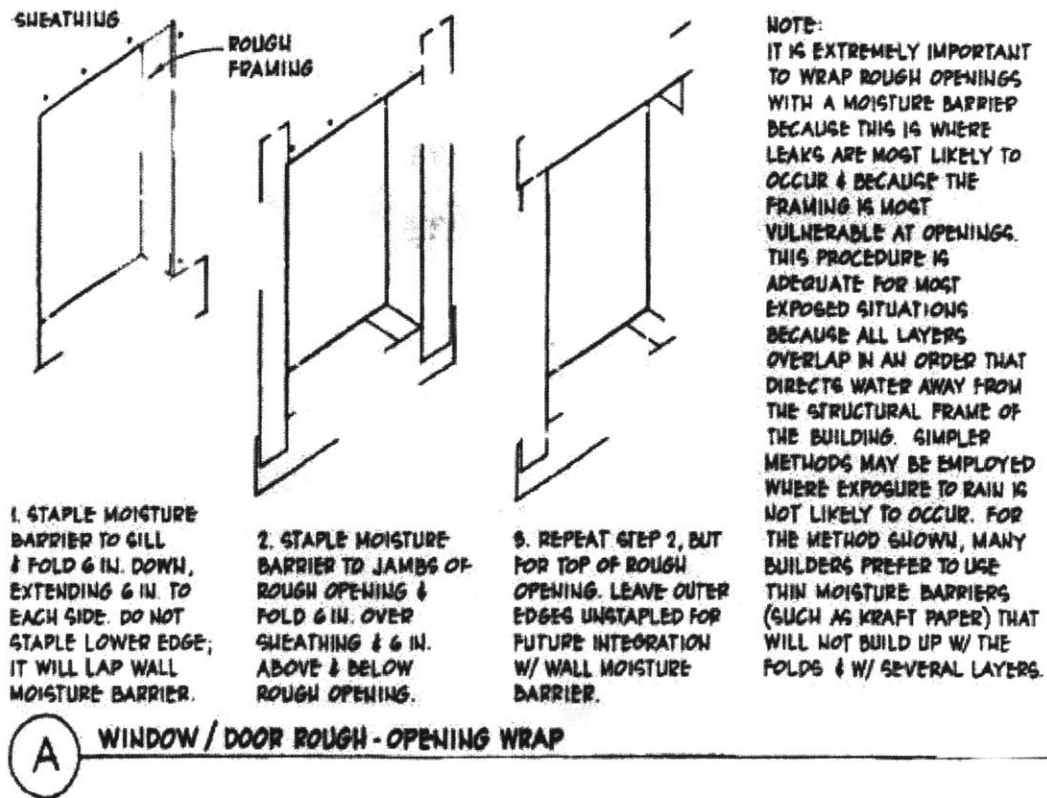


Figure 1-4 Flush Fin Window Flashing Detail source: Thallon (1991)

The significance in noting this “reference trail” is recognizing that the flashing detail for a nail-on window is based directly on the flashing detail for a flush fin window. Given the differences in construction sequence between the two window frame types, the author questioned whether the flashing details between the two window types had to be similar. In particular, there was a question about whether jamb flashing was needed for a nail-on window given the existence of the window’s mounting flange and where this flange is located in the wall assembly.

This study is not theoretical in nature. It completes a series of physical modeling and testing studies. The information from these studies is then qualitatively reviewed. This approach is in part a response to the difficulty of theoretically modeling water flow over and within a wall assembly, but also to what this study is attempting to achieve. A qualitative analysis is sufficient in terms of the recommendations made about the appropriateness of existing window flashing details.

The study’s contribution to the field is two fold. It recommends a window/wall construction sequence for a vinyl nail-on window. It then introduces a novel window waterproofing assembly that both seals the window’s mounting flange to a wall without the use of a sealant and provides a flashing system along a drain plane situated around the window’s perimeter.



## 1.1 Principles

For a wall to leak, three conditions must exist. There must be a source of water, a force that pushes the water and a course that leads from the outside to inside. Water, in either its liquid or vapor state, can be made to move by a number of different mechanisms. The direction water moves for a given situation depends on what mechanism dominates (Addleson and Rice, 1991, DeFreitas et al, 1996).

Liquid water will flow downward under the effect of gravity, over the surface of the building or material. It can travel against the pull of gravity vertically and laterally by either capillary action (through porous materials such as soil, brickwork, plaster, timber, or between sheets of non-porous material in close contact), kinetic energy and/or external pressure gradients. Finally, as a gas, it can diffuse through air or porous materials under the influence of a vapor pressure gradient.

This study is concerned with unintentional rainwater entry. Condensation of internally or externally generated water vapor within the assembly is not considered. This simplification is based on the study's objective and observations noted in the field. Most observed residential wall moisture problems are water-entry or leakage problems, not vapor condensation problems (Holladay, 2000).

For rainwater to enter into a wall assembly under the influence of a given force, a course or hole must exist in the assembly. Once the size of the hole is determined, the designer can correlate the hole's size with the force(s) responsible for water movement. The following table lists these relationships (Garden, 1963).

<b>Table 1: Forces that Lead to Moisture Penetration and the Associated Critical Crack Size (t)</b>	
<b>Force</b>	<b>Hole Size (t)</b>
Kinetic Energy	> 5 mm
Capillary Action	< 5 mm
Gravity	> 0.5 mm
Air Pressure Gradient	0.5 mm < t < 6 mm
Air Pressure Gradient and Capillary Action	t < 0.5 mm h > ? P

Most moisture problems occur because there has been a failure to control either the force, source or course. This lack of control translates to an improper detail, (e.g. poor flashing practice (creating a course)), an unforgiving architectural detail (e.g. a flat façade (not controlling the source)) or an improper product installation (e.g. a sealant that cannot adhere to a given substrate resulting in a gap in the air barrier (not controlling the force)).

## **1.2 Controlling Above Grade Water Flow: Surface Barrier Walls and Membrane/Drainage Walls**

When a wall has the capability of managing rainwater entry it is considered waterproofed (Kubal, 2000). An exterior above grade wall can be waterproofed either as a surface barrier wall or as a membrane/drainage wall.

Surface barrier walls keep water out of the inner assembly by sealing the exterior surface with a waterproofing agent. They rely on sealants around most building penetrations, including the windows, to prevent water from entering the wall assembly. They make no provision for drainage of incidental moisture that enters the wall space. These systems have little tolerance for construction variations or defects, or for compensating for through-wall cracks that develop as a result of weathering.

This is an “all or nothing” approach. The moisture-tight exterior surface is the wall’s sole waterproof barrier. Examples of residential and light commercial sector barrier wall systems include some versions of EIFS (exterior insulation and finish system)<sup>2</sup>, concrete panels and single wythe masonry. The latter two examples are more common in light commercial buildings (Ruggiero and Myers, 1991).

A membrane/drainage wall waterproofing strategy (a.k.a. water-managed wall (Lstiburek, 2003)) is not an “all or nothing” approach. It is expected that incidental water will penetrate the wall’s outer surface. The design compensates for this “unintentional” entry by detailing a weather resistant barrier (WRB) behind the exterior surface. The role of the WRB is to collect and divert water back to the exterior.

The components of a membrane/drainage wall include the exterior surface (i.e. cladding), flashing system, weep holes, and the WRB.<sup>3</sup> Examples of residential and light commercial sector membrane/drainage wall systems include stucco, siding veneers, panels, shingles, wood shakes, metal panels, or tile.

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<sup>2</sup> An EIFS wall is a non-load bearing outdoor wall finish made up of a thermal insulation board, an attachment system, a reinforcement system and a compatible finish (ASTM E2112-01). EIFS systems are proprietary and different systems will have different requirements in terms of how to design and install the waterproof system.

<sup>3</sup> If the wall is designed as a pressure equalized wall, then the WRB takes on the added responsibility of preventing air leakage across its plane. When it takes on this additional responsibility, it is sometimes referred to as a weatherproof barrier.

### 1.3 Residential Window Types

As implied in the introduction, windows are a typical component of a residential wall. A window can leak through the window unit itself or around the rough opening.<sup>4</sup> Water leakage through the window unit itself is a question of manufacturer quality control and is not discussed in this study. Water leakage through the rough opening is a question addressed presently.

ASTM E2112-01 describes various procedures on how to make the window/wall assembly waterproof. These procedures are based on two design variables:

- 1) whether the window unit is being installed into a barrier wall or a membrane/drainage wall; and
- 2) the type of window frame being used.

There are three types of window frame assemblies:

- 1) flush fin or brick mold;
- 2) box frame; and
- 3) nail-on window.<sup>5</sup>

This window classification scheme is separate, or independent from the classification scheme that identifies residential windows according to how they open and close (i.e. double hung, casement, awning). Given this independence between schemes, it is possible to have a double hung window framed as a brick mold, box frame or nail-on window, and describe it as such.

A brick mold or flush fin is an exterior trim molding which forms a boundary between bricks or other siding and the window unit. The brick mold is positioned at or near the window's outside surface. The mold is left exposed and creates both the window's exterior trim and weather seal. The brick moldings are factory-applied to the window frame. The window is secured in the rough opening by nailing through the brick moldings into the framing members or by screwing through the shimmed head and side jambs.

A box frame (a.k.a. block frame or replacement window) has a boxlike appearance. It is delivered to the job site with no attached factory-applied flanges (i.e. flush fins). It is installed into the rough opening either by driving fasteners through the shimmed head and side jambs or by the use of installation clips or brackets.

Exterior moldings or casings may be supplied with the window for installation after the unit is secured in the rough opening. If not, they can be milled on site or at the builder's workshop.

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<sup>4</sup> A rough opening is the space between the wall frame and window unit. The rough opening is typically the height of the window unit + ½" by the width of the window unit + ½".

<sup>5</sup> A nail-on window is also referred to as a fin window, nailing fin or a flange window. These terms are synonymous and are used interchangeably in the text.

A nail-on window has a permanent 1 ½ to 2 inch vinyl mounting flange (a.k.a. fin) protruding from each side jamb of the window's body. Anchors (usually nails) penetrate the fin at intervals between 6 to 8 inches to secure the window to the wall. The nailing fin is later covered by siding or trim.

There are four types of nail-on windows:

- 1) Integral, structural flanges;
- 2) Integral, non-structural flanges;
- 3) Applied, structural flanges; and
- 4) Applied, non-structural flanges.

These categories define the window in terms of whether the flange's corners are fused together and whether the fin is installed in the factory or in the field. In this classification scheme, integral implies that the flange is continuous and seamless.

While nail-on flanges can be applied or "snapped on" to a wood framed window, the most durable, problem free option is to use integral flanges. An integral flange can only be done with a window frame made from vinyl. It is applied in the factory, the corners are welded and it is part of the window jamb/frame extrusion. This construction results in a one-piece assembly that provides a continuous surface around the window perimeter.

With the applied nailing flange, the corners are not welded, instead adhesive tabs are used as a bridging element. This detail creates a non-continuous assembly around the window perimeter. An applied flange would require more elaborate flashing and sealing details to ensure that the window mounting flange is watertight.

Structural implies that the flange can be used as an anchoring device or nailing flange and that the flange is capable of sustaining the structural load requirements of the fenestration unit in its location in the building. On the other hand, non-structural flanges must not be used as the sole means of anchoring the window (ASTM E2112-01).

The focus of ASTM E2112-01 and by default, the focus of this study is the nail-on window. However, all residential window frame types and wall assemblies must be made watertight. The different frame types dictate not only how the window is attached to the wall, but how it is made watertight. Recognizing these differences, ASTM E2112-01 includes procedures on how to make each window frame assembly inserted into either a barrier wall or a membrane/drainage wall watertight.

#### **1.4 Making a Residential Window Watertight**

When installing a window into a barrier wall, independent of window frame, the window/wall assembly is made watertight at the exterior joint between the window and wall. A brick mold window creates a fillet joint between the window trim and the wall assembly. A nail-on window and box frame window create a butt joint. In the case of the nail-on window, this butt joint is between the window trim and siding. A box frame window creates a butt joint between the window jamb and wall assembly. The wall unit

is made watertight by extending the wall to the window jambs. There would be no exterior window trim in this (box frame) installation.

In terms of installing a nail-on, flush fin and box frame window into a membrane/drainage wall, ASTM E2112-01 details specific step-by-step procedures with diagrams on how to make these window frames watertight. ASTM E2112-01 differentiates particular procedures or methods depending on the construction sequence. Four construction sequences are identified in the practice and are identified as Method A, Method B, Method A1 and Method B1. The following table identifies these Methods according to the construction sequence. Each method is presented in its entirety in Appendix 1.0.

**Table 2: ASTM E2112-01 Recommended Construction Sequence**

Method	1	2	3	4	5
A	sheathing	window	flashing	WRB <sup>1</sup>	siding
B	sheathing	flashing	window	WRB <sup>1</sup>	siding
A1	sheathing	WRB <sup>2</sup>	window	flashing	siding
B1	sheathing	WRB <sup>2</sup>	flashing	window	siding

Notes: The construction sequence is ordered by step starting at step 1.

WRB: weather resistant barrier

1. The WRB in this instance would be #15 or #30 asphalt felt, Grade D paper or 3’ wide strips of house wrap.
2. The WRB in this instance would be 5’ to 9’ width sheets of housewrap.

#### 1.4.1 The Role of the Window Flashing System

The window flashing system is one component of a residential window waterproofing system. The WRB, the window fin (either a flush fin or a nail-on fin) and the siding are the waterproofing systems other components. The window flashing system’s primary role is to collect and direct incidental water back to the exterior. From a water exclusion performance perspective, it integrates the window with the wall creating a continuous wet/dry boundary while compensating for the window and wall’s separate movements due to thermal expansion (Addleson and Rice, 1991).

It is expected that the flashing system must prevent the flow of water into a wall due to gravity (Addleson and Rice, 1991, Lstiburek, 2003). As such, it is designed to work with gravity, using this force to direct water away from the wall. It controls gravity via the lapping principle creating a geometrical seal between the window and wall. In practice, the flashing system elements are overlapped so that “which is above overlaps that which is below” (McBride, 2002).

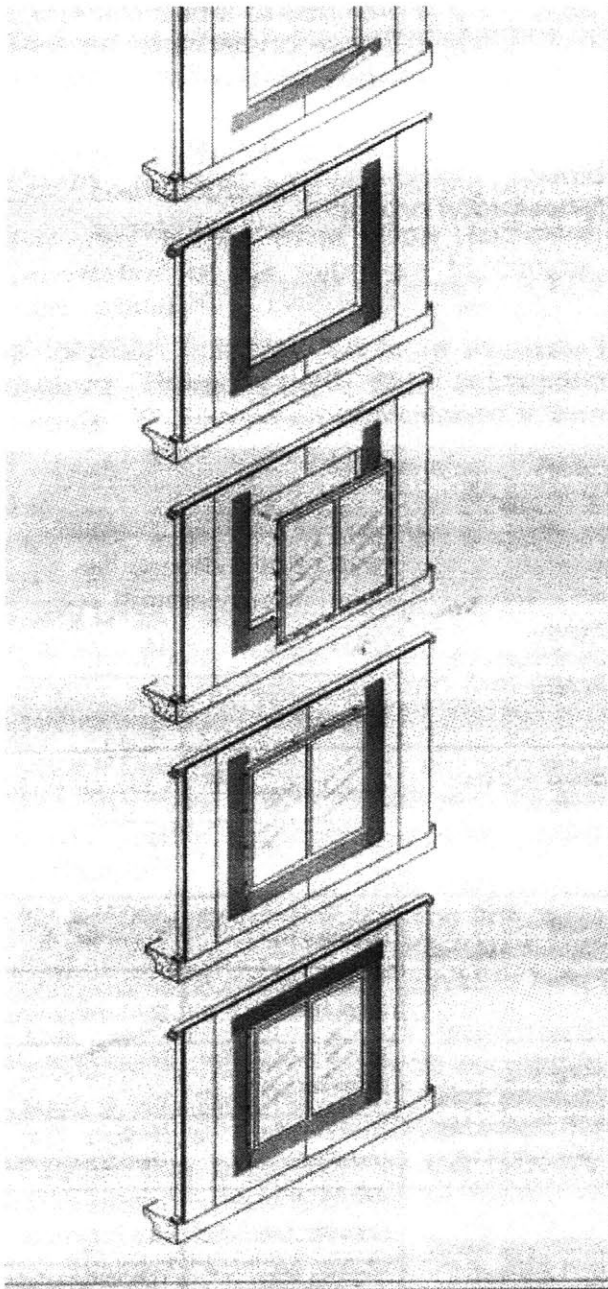
There is a range of possible materials one could select as a window flashing system. Given that the flashing system will get wet, the key consideration is that the material must be impervious to water.

ASTM E2112-01 defines the flashing system as the “integrated system of flashings intended to move incidental water to the building exterior.” Flashing is defined as “sheet material that bridges and protects the joint (gap) between the window and door frame

members and the adjacent construction for the purpose of preventing water penetration by draining water away from the window or door penetration” (ASTM E2112-01, 2002).

For the purposes of this study, the role of the window flashing system is collect and direct incidental water back to the exterior under the influence of gravity.

## 2.0 Is an Integral Nail-on Flange an Adequate Window Jamb Flashing?



Typical Flashing Application  
(Flashing Applied in Weather-Board Fashion)

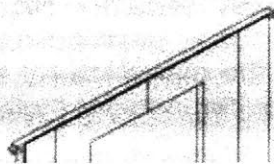


Figure 2-1

source: AAMA, 2000

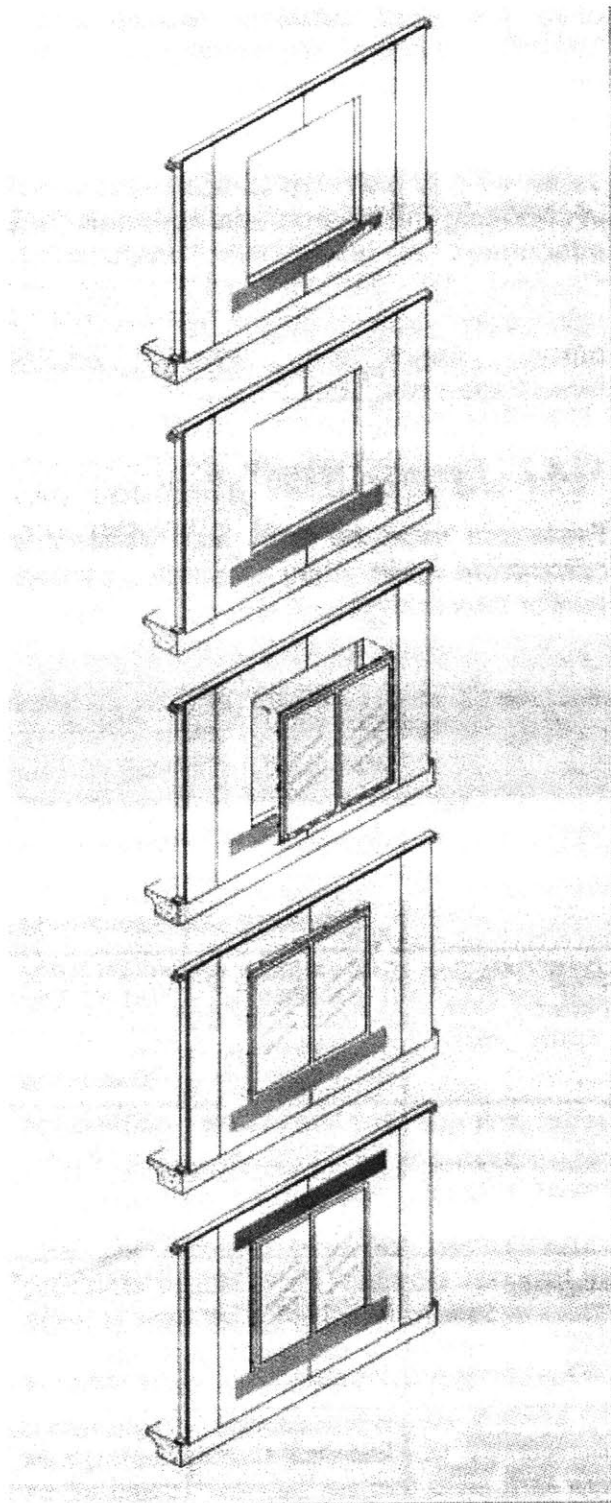
Figure 2.1 shows the accepted shiplap or “weather-board” flashing sequence for a nail-on vinyl window. ASTM E2112-01 requires a nine (9) inch minimum jamb flashing be included in the detail

By definition, a flashing creates a drain path – the course - under the influence of gravity – the force - to collect and direct water to the exterior. An adequate flashing is defined as a detail that in isolation, without the assistance of other details, creates a drain path that collects and directs water to the exterior.

The chapter answers the question of whether an integral nail-on mounting flange is by itself an adequate window jamb flashing for a drainage/membrane type residential wall? If so, then the nine inch wide jamb flashing can be eliminated from Figure 2.1 and Figure 2.2 illustrates the modified flashing sequence for a nail-on window. If jamb flashing is required, then a series of follow up questions that include whether ASTM International’s recommendation are appropriate, what is an ideal window/wall waterproofing detail and conversely what is the primary weakness of existing window flashing details must be addressed.

To answer these questions, a novel modeling and testing program has been designed and implemented. This testing program was created because there is no existing ASTM International test that focuses only on the performance of the nail-on flange as a flashing element.

The set of existing ASTM International tests include both lab tests and field tests. The relevant lab tests are:



**Figure 2-2 flashing application without the jamb flashing**

- 1) ASTM E283-91 (measure air infiltration of the window unit);
- 2) ASTM E547-86 “Standard Test Method for Water Penetration of Exterior Windows, Curtain Walls, and Doors by Cyclic Static Air Pressure Differential”(measures water penetration of the window or door unit);
- 3) ASTM E331-86 (measures water penetration of the window or door unit)

The field tests are:

- 1) ASTM E1105-86 “Standard Test Method for Field Determination of Water Penetration of Installed Exterior Windows, Curtain Walls, and Doors by Uniform or Cyclic Static Air Pressure Difference” (this test measure the performance of the installed unit);
- 2) AAMA 501.2: “Field Check of Metal Curtain Walls for Water Leakage” (a.k.a. AAMA 501.2 94: Field Check of Metal Storefronts, Curtain Walls, and Sloped Glazing Systems for Water Leakage) (The procedure sprays a window unit with a 19mm (3/4”) diameter hose fitted with a Type B-25, #6.030 brass nozzle.)



These tests either focus on testing the performance of the un-installed window unit (the lab tests) or the performance of a complete window/wall assembly under a pressure differential (the field tests). Neither condition applies to the present question. What is needed in this case is a test that simulates the performance of a single detail as part of a construction system under a failure condition, not the performance of the entire window element or the performance of an “intact” window/wall assembly during a driving rain event.

## 2.1 Jamb Drip Test

Recalling a point made in chapter 1.0, for a water leak to occur in a wall, three conditions must coexist. At a particular location, there must be source of water, a force to move the water and a course for the water to follow. The Jamb Drip Test creates a situation where these three conditions co-exist.

In this test a measurable, verifiable amount of water is introduced in front of or behind the weather resistant barrier (WRB) at the junction between the window head nail-on fin and the jamb nail-on for a particular construction sequence. The subsequent steady state path taken by the water under the influence of gravity is recorded. Several construction sequences are tested, and based on these observations the question is answered.

The Jamb Drip Test is empirical. Its operating premise is that once a source of water is deliberately introduced at the point of interest, the flow of water from this point is a function of the relevant force and course created by the construction sequence in question. To determine if the nail-on fin is an adequate flashing, one has to understand how the nail-on flange performs not in isolation but as part of a construction system created by the order in which the different elements were assembled (i.e. the construction sequence). The test is designed to provide this answer. Given the nature of what is trying to be accomplished, this type of test is referred to as a point of failure test.

Success or failure of the assembly in question is ultimately based on whether the introduced water is collected and directed to the outside along the window jamb edge. However, in addition to knowing whether water exits the wall assembly, the path taken by the water is also important. This last point will help determine the ideal window nail-on fin jamb-flashing configuration.

Different window/wall assemblies are tested to determine how the nail-on flange performs as a flashing. To this end, the tests begin with the performance of the nail-on fin in isolation and then progresses to the nail-on fin’s performance in complete assemblies. When completed assemblies are tested, the choice of installing the WRB before or after the window as per ASTM E2112-01’s **Installation Procedure Selection Chart (Windows)**<sup>1</sup> becomes a focus providing an order to the Drip Jamb Test sequence. For each complete assembly (i.e. an assembly that includes a window, WRB and siding), three siding options are evaluated:

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<sup>1</sup> See Appendix 1

- 1) a clear clapboard (see below for an explanation of why this type of siding was included in the tests);
- 2) cedar clapboard; and
- 3) vinyl siding.

As well, to include a drain plane type wall, a test on a furred out wall<sup>2</sup> (that assumes the WRB is installed prior to the window) will be done.

ASTM E2112-01 was used as a guide to select the material used for the WRB in each construction sequence. Housewrap (i.e. Tyvek) was used as the WRB, when the WRB was applied before the window. When the WRB was applied after the window, asphalt felt was used as the WRB. In the case of the furred out wall, ASTM E2112-01 provides no guidance on the recommended WRB. Neither is there an industry consensus for this type of wall construction. The author has experience with housewrap in this type of construction, so it was used in the present test.

Before the actual test procedure is described, information about the construction of the base window/wall assembly, the procedure used to introduce a measurable, verifiable and repeatable amount of water for each test and the visual techniques employed in the tests are discussed.

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<sup>2</sup> A furred out wall is one where a 1" x 3" piece of strapping is installed vertically over the housewrap at 16" on center. The siding is then nailed to the strapping. This detail creates a 16" wide drainage plane at 3" increments across the wall surface.

### 2.1.1 The Construction of the Base Window /Wall Assembly

In the Jamb Drip Test, the ability to photograph results is paramount. Equally important, is consistency between results. As a result, a single or base window/wall assembly mockup is used for all tests.



The base window-wall mockup is made from 2"x 3" dimensional lumber and sheathed with a 33 1/2" x 90" 1/4 thick acrylic sheet. It is framed using conventional platform framing techniques.

The mockup's outside dimensions are 35 5/8" x 91 1/2". The acrylic sheet's outside dimensions are 33 1/2" x 90". An 18 1/2" x 64 1/2" cut is made in one side of the acrylic sheet (For this explanation, this side will be considered the right side of the sheet). The resulting form of the acrylic sheet resembles a C. The overall dimensions of this C shaped sheet have an 18 1/2" x 64 1/2" inside cut thirteen inches from the sheet's top and bottom, and fifteen inches from its left side.

The 1/4" acrylic sheet is installed flush to the wood frame's left side. This results in the need to insert thirteen-inch support blocks against the acrylic sheet's right side. To compensate for the sheet's 1/4", a 1/4" x 1 1/2" strip is fastened to the mockup's right hand side vertical outside stud. The resulting construction creates a 19" x 64 1/2" rough opening. The nail-on window is introduced into this opening and the mockup braced in a vertical position.

As per ASTM E2112-01, a 3/8" bedding joint (prior to compression) was installed between the nail-on flange and the acrylic sheet and/or WRB for each test. Once compressed the bedding joint "bleeds out" along the edge of the flange.

Figure 2-3 typical base mockup assembly

### 2.1.1.1 Description of the Cedar Clapboard and Vinyl Siding

Each piece of cedar clapboard was 5 1/2" high x 14 3/4" long. Cedar clapboard has a tapering profile widening from 1/8" at its top edge to 3/8" at its bottom edge. Finished (one side smooth) Western Red cedar clapboards were used in the present set of tests.

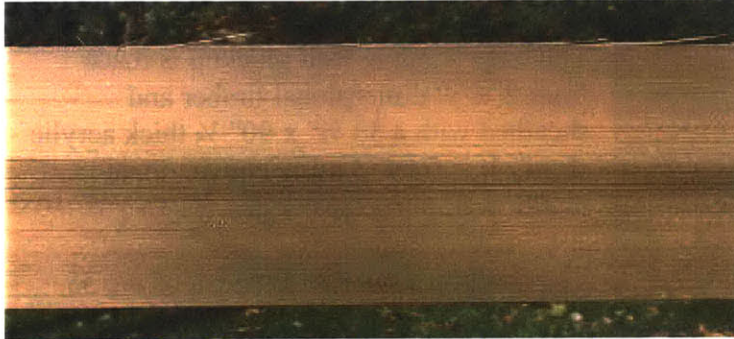


Figure 2-4 cedar siding profile (finished side out)

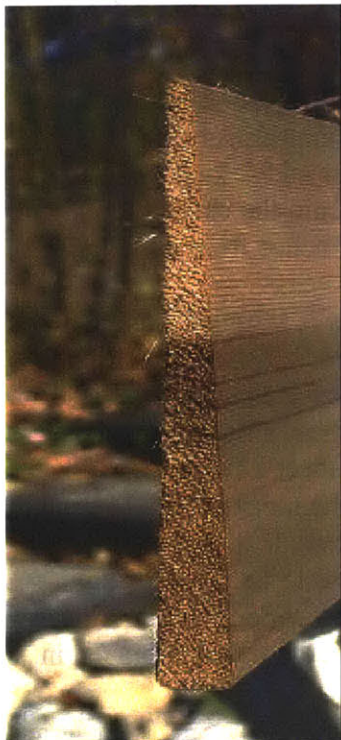
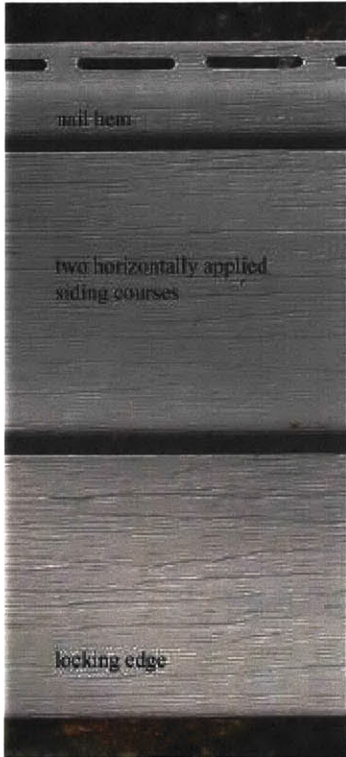


Figure 2-5 cedar siding side profile

Each piece of vinyl siding was 9 1/2" high x 14 3/4" long. The vinyl was made from PVC. The vinyl siding used in the experiments simulated horizontal lap siding with two siding courses per panel. The top edge of the vinyl siding had a single thickness nail hem. The bottom or locking edge had a post-formed edge.



**Figure 2-6 vinyl siding profile**



**Figure 2-7 vinyl siding side profile**

### 2.1.1.2 The Design of a Clear Clapboard

A clear clapboard was designed so that the flow of water behind a typical clapboard could be photographed. The clear clapboard was designed to have a similar wall side profile as a cedar shingle.

To create this profile, a clear shingle was constructed from a  $14 \frac{3}{4}$ " x  $5 \frac{3}{8}$ " sheet of  $\frac{1}{8}$ " thick acrylic. To provide the necessary offset, a  $\frac{1}{4}$ " x  $\frac{1}{4}$ " clear acrylic strip was glued in place four inches from the bottom of the sheet. This geometry resulted in the  $\frac{1}{4}$ " x  $\frac{1}{4}$ " strip being one inch from the sheet's top edge. At the point of the  $\frac{1}{4}$ " x  $\frac{1}{4}$ " strip, the total thickness of the clear shingle was  $\frac{3}{8}$ ".

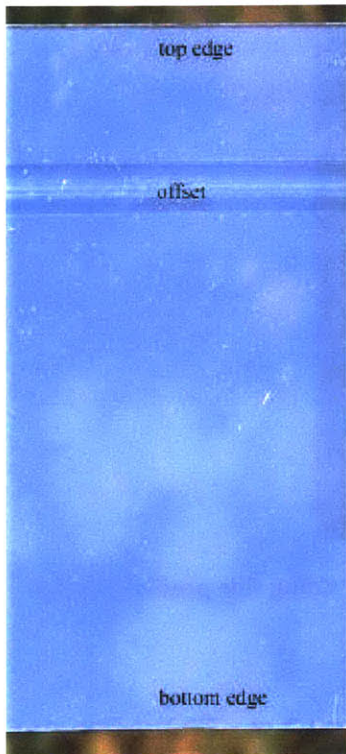


figure 2-8 clear clapboard profile

The clear shingle has a blue tint in this picture because the protective film was not removed at this point.

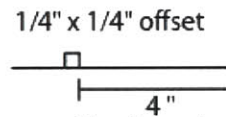
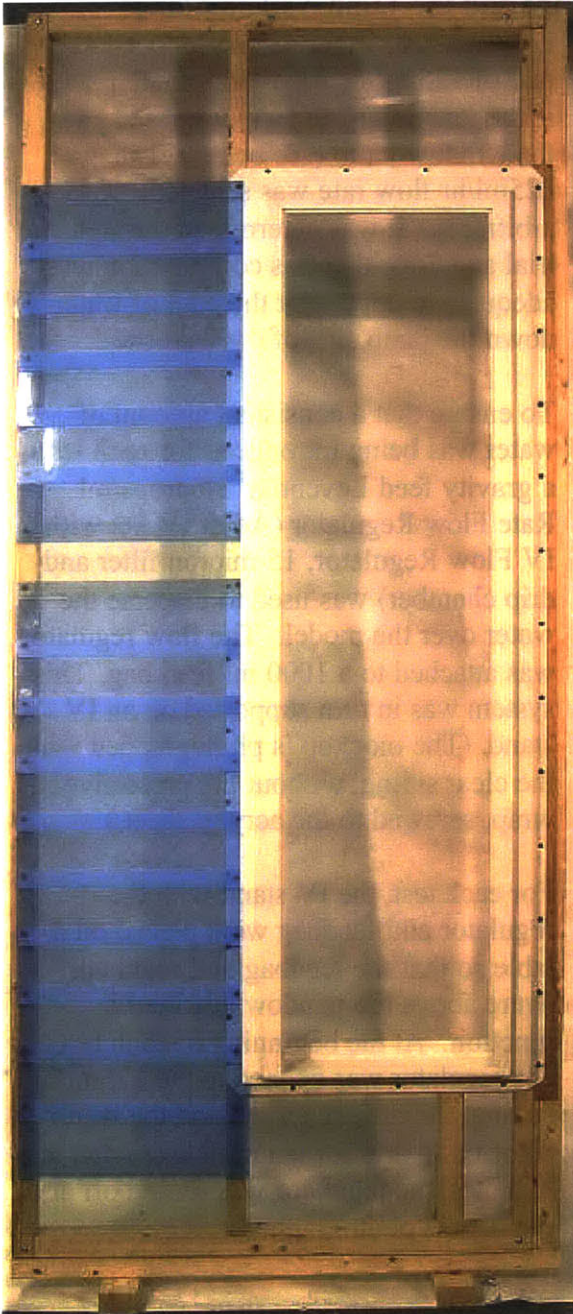


Figure 2-9 profile of the clear clapboard

### 2.1.1.3 Siding Options



**Figure 2-10 installation of the clear clapboards on the mockup**

Using the base window/wall assembly, the WRB, furring strip and siding options were added as required. Each siding option was installed along the left side of the mockup and water was introduced at the left junction of the window's head and jamb nail-on flange.

To facilitate the installation and removal of the clear, cedar and vinyl sidings, the clapboards were numbered as they were installed on the mockup. The numbering system provides a point of reference in the following discussion of the test results.

The clear clapboard, cedar clapboard and vinyl siding were installed in a bottom to top fashion typical of all residential siding installations. The cedar and clear clapboards were numbered 1 to 18 given their individual heights. Clapboard 1 was installed first. Clapboard 18 was installed last. The vinyl sidings were numbered 1 to 10 given their individual heights. Vinyl siding 1 was installed first and vinyl siding piece 10 (a half piece) was installed last.

Each sheet was installed with the sheet's top edge facing upwards and the  $\frac{1}{4}$ " x  $\frac{1}{4}$ " strip facing outwards (away from the sheathing). To create the "four inch to weather" clapboard pattern, a clear sheet was installed against the acrylic sheathing and the next sheet was installed above this sheet with its edge flush to the bottom edge of the  $\frac{1}{4}$ " x  $\frac{1}{4}$ " strip of the previously installed sheet.

In this photo, the protective wrap was not removed from the clear sheets. Blue was the typical color of the protective wrap with the exception of the first and twelfth sheets whose protective wrap was colored light green.

### 2.1.2 The Procedure Used to Introduce a Measured Amount of Water at the Junction of the Window's Head Nail-on Flange and the Jamb Nail-on Flange

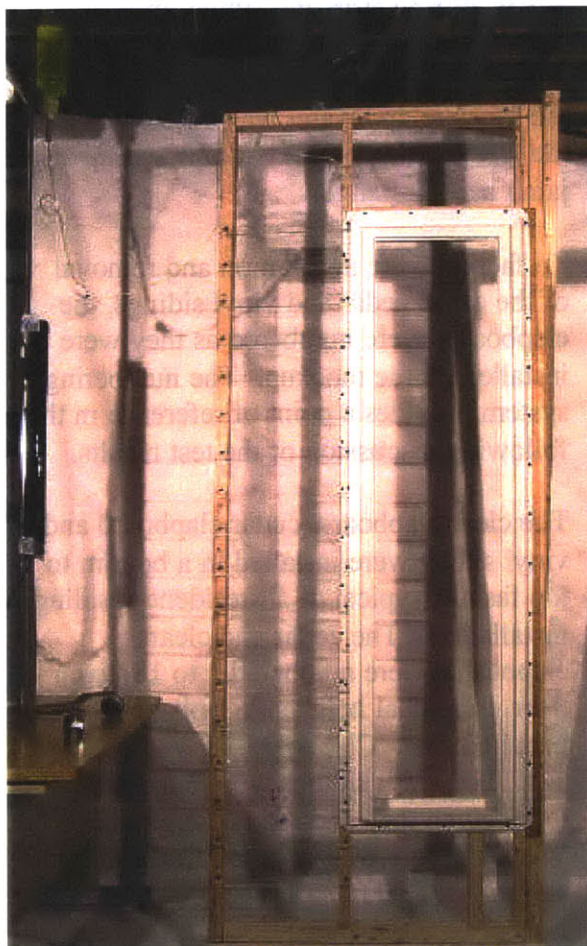


Figure 2-11 Jamb Drip Test Set up

For each test, water was introduced at a rate of 125 ml/hr for a ten-minute period at the junction of the window head and the window jamb (see below). The 125ml/hr flow rate was selected arbitrarily. It was determined through trial and error that this combination was adequate to document the path of water down the jamb side of the window.

To ensure that a consistent amount of water was being introduced for each test, a gravity feed Leventon<sup>3</sup> 20 drops/ml Rate Flow Regulator (Adult IV Set with IV Flow Regulator, 15 micron filter and drip chamber) was used to disperse the water over the model. The flow regulator was attached to a 1000 ml feed bag. This system was in turn supported on an IV stand. (The mockup is photographed with the clear siding, without the protective wrap, screwed to the acrylic sheet.)

For each test, the IV stand with the regulator and feedbag were placed on a table so that the feedbag and regulator were above the window head/jamb junction. At the beginning of each test, the regulator was opened to the 125ml/hr setting, the time recorded and the water allowed to drip for ten minutes. After ten minutes, the regulator was turned off and the results photographed.

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<sup>3</sup> Leventon, SA  
Poligono CAN Sunyer, 11  
08740 Sant Andreu de la Barca  
Barcelona, Spain



### 2.1.2.1 Water Introduction Points

Water was introduced directly over the nail-on flange and immediately next to the nail-on flange. The water introduction point locations are consistent for each test.



Figure 2-12 water introduction point directly over the nail-on flange



Figure 2-13 water introduction point next to the nail-on flange (front view)



Figure 2-14 water introduction point next to the nail-on flange (back view)

### **2.1.3 Recording the Path Taken by the Water as it Travels Down the Window Jamb under the Influence of Gravity**

Each test was photographed on the MIT campus, in the Heat Transfer Lab. A space was sheeted off using Tyvek housewrap as a backdrop and photos were taken with an Olympus C-740 digital camera. The images were saved as JPEG files.

Post photo manipulation was done using Adobe Photoshop 6.0 and was limited to cropping, and altering the JPEG image's color brightness and contrast manipulation. The background shadows cast by the mockup onto the Tyvek sheet was left in the image. For document consistency, all images were sized with a 3" width and printed at a resolution of 150 pixels/inch for publication.

Since the objective was to record the water path, images were photographed under both white light and black light. When photographing in white light, 3 120V/300W LowelTOTA-light lamps were used. When photographing in black light four 48" black lights were used. Two black lights were connected to a 48" florescent light tray. The trays were positioned around the model to illuminate the water path as required.

So that the water path would illuminate under black light, it was dyed with a 40% concentrated aqueous sodium fluorescein<sup>4</sup>. The dye solution was mixed to a ratio of 0.5 ml sodium fluorescein to 1000 ml water. Once mixed, 1000 ml of the dye solution was poured into the feedbag. This mixture was then dripped over the model via the drip regulator. While the dyed water could be seen under white light, it showed best under black light.



**Figure 2-15** fluorescein dye illuminated under white light      **Figure 2-16** fluorescein dye illuminated under black light

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<sup>4</sup> The author contacted the seller of the Fluorescein dye, Mr. Daniel K. Afrides who informed him that the dye was not a biohazard and could be used safely in this study.

#### **2.1.4 Drip Jamb Test Procedure Recap**

Each Drip Jamb Test was completed under an identical three-step procedure:

1. construct the desired WRB/window/siding option on the base window/ wall assembly;
2. introduce water at a rate of 125 ml/hr for ten minutes at the junction between the window head nail-on fin and the jamb nail-on fin via the feedbag/flow regulator set up; and
3. photograph the steady state path taken by the water after ten minutes using white or black light.

Fourteen (14) tests were completed. The results follow.

## **2.2. Water Drainage Paths**

The following series of tests provide information about the in-service performance of the nail-on fin as a flashing element in isolation - when it is the only element attached to the base mockup and when it is part of a system of assembled components. A description of each test is included. This body of information is then considered as a whole to answer the question of whether the nail-on mounting flange alone is an adequate window jamb flashing for a drainage/membrane type residential wall?

The first set of Drip Jamb Tests focused on the in-service performance of the nail-on fin as a flashing element in isolation of the other wall elements. This set of six tests is collectively termed the **isolation tests**. Tests were completed for the clear clapboard, the cedar clapboard and the vinyl siding. Water was introduced directly over, and next to the nail-on fin.

### **isolation tests**

Test 1: no WRB or clapboard, water introduced directly over the nail-on fin

Test 2: no WRB, clear clapboard, water introduced directly over the nail-on fin

Test 3: no WRB, cedar clapboard, water introduced directly over the nail-on fin

Test 4: no WRB, cedar clapboard, water introduced next to the nail-on fin

Test 5: no WRB, vinyl siding, water introduced directly over the nail-on fin

Test 6: no WRB, vinyl siding, water introduced next to the nail-on fin

### 2.2.1 Test 1: no WRB or Clapboard, Water Introduced Over the Nail-on Fin

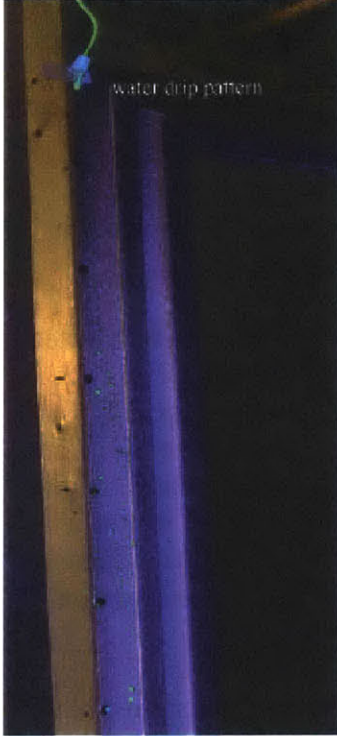


Figure 2-17 Test 1 drip pattern at the window head

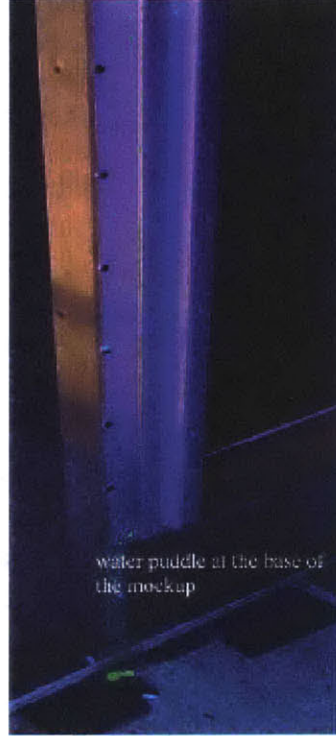


Figure 2-18 Test 1 drip pattern at the window sill

The water path that developed began as a continuous, single file line of vertical drips. This pattern then dispersed or spread into a fan shape one third of the way down the nail-on fin. This fan shape was made up of five separate drip lines. The five separate lines moved parallel to each other up to the mid-point of the nail-on fin.

At the mid point, five separate lines re-joined into one line that traveled along the inside edge of the window's j channel to the base of the nail-on fin. At this point, the water traveled onto the acrylic sheet down to the base of the mockup at which point it dripped onto the floor below. This pattern developed once the test started and continued until the test stopped.

This drip pattern illustrates how water travels down the window jamb when the window assembly is separated from the WRB and siding. It shows that the mounting flange acts as a jamb flashing. If water was introduced at the window head it would travel along the length of the window over the mounting flange and out the assembly via the sill flashing. This test documents that the mounting flange does act as a jamb flashing by design.

### 2.2.2 Test 2: no WRB, Clear Clapboard, Water Introduced Over the Nail-on Fin

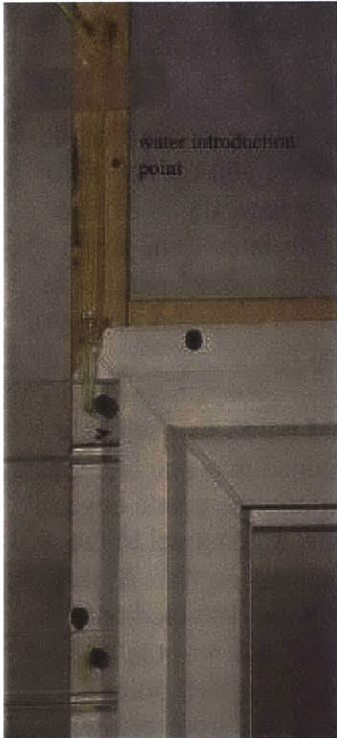


Figure 2-19 Test 2 drip pattern at the window head



Figure 2-20 Test 2 drip pattern (side view)

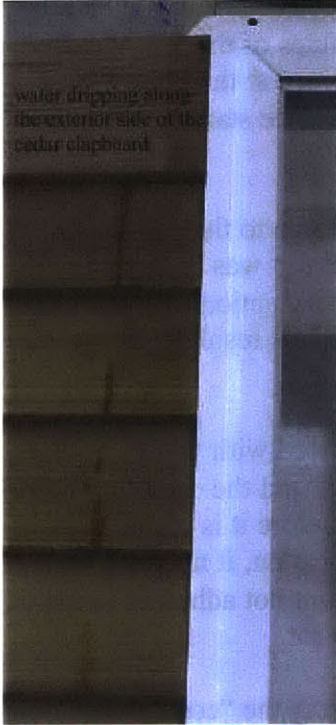
Initially, a drip pattern was noted as water traveled down the first two clapboards. The water left the tube in plane with clapboard 18. It then free fell to the top edge of clapboard 17. This pattern repeated itself between clapboards 17 and 16.

At clapboard 16, water collected, began to pool at the 1/4" x 1/4" strip. The water eventually exited between clapboard 17 and 16 to the exterior. The exit point of the water was not in-line with the insertion point, but within an inch to the left of the insertion point.

At this point, water sprayed over the exterior of the window/wall assembly dripping on both the clear clapboards and the window frame. This water path was established within two minutes of starting the test and continued over the next eight minutes until the test was concluded.

Within the limit of how the clear clapboard approximates the cedar clapboard, this test is an acceptable visualization of how water travels between the mounting flange and the clapboard. In this test, water did not travel down the entire length of the mounting flange, but exited the assembly within two clapboards. From the test, it was observed that water dripped from the top to the bottom of the first clapboard. It then migrated between the interface of the top clapboard and the one immediately below it exiting the assembly via this lap joint. This test demonstrates how the clapboard system directs incidental water to the exterior and by extension, how the clapboard system acts as a contained drain plane.

### 2.2.3 Test 3: no WRB, Cedar Clapboard, Water Introduced Over the Nail-on Fin



A similar water path was observed with the cedar siding. Water traveled behind clapboard 18 and then exited between clapboards 18 and 17. In this case, (it is assumed), water did not travel along the nail-on fin, but free fell directly to the intersection of clapboards 18 and 17 where it was diverted to the exterior due to the clapboard's lap design.

This test verifies the results and conclusions of Test 2. The noted exterior water drip pattern verifies that when water is present between the window's mounting flange and the clapboard system it will exit the building due to the design of the clapboard system.

Figure 2-21 Test 3 drip pattern

#### 2.2.4 Test 4: no WRB, Cedar Clapboard, Water Introduced Next to the Nail-on Fin



**Figure 2-22 Test 4 water stains along the window jamb edge**

Water dripped along the acrylic sheet down the entire length of the window jamb. Within five minutes of the test, water stains begin to appear on cedar clapboard at the point where the nail-on fin touched the clapboard. The staining was most noticeable in clapboard 17.

This suggests that water was being drawn to the nail-on fin from the acrylic sheathing. At this point it was in direct contact with the porous cedar. Capillary action then drew the water into the individual cedar clapboards resulting in the observed staining pattern.

This test points to the problem associated with water traveling between the mounting flange and the cedar clapboard. If the cedar is not sealed before it is installed in the wall, it will get wet. Given the location, it may not be able to dry out. This could lead to paint not adhering to the clapboard to premature failure due to rot.

The value of this test was in recognizing the “cost” associated the siding acting as a drain plane. The cedar clapboards should be sealed (i.e. back primed) before they are installed on the wall.



### 2.2.5 Test 5: no WRB, Vinyl Siding, Water Introduced Over the Nail-on Fin

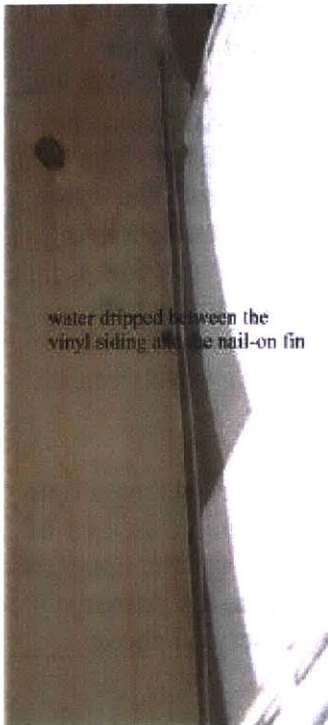


Figure 2-23 Test 5 drip pattern

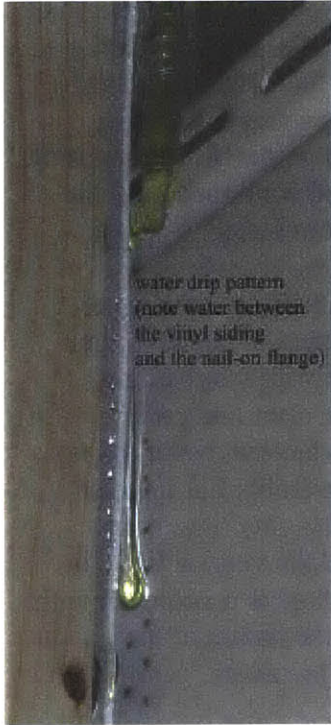


Figure 2-24 Test 5 drip pattern at the window sill

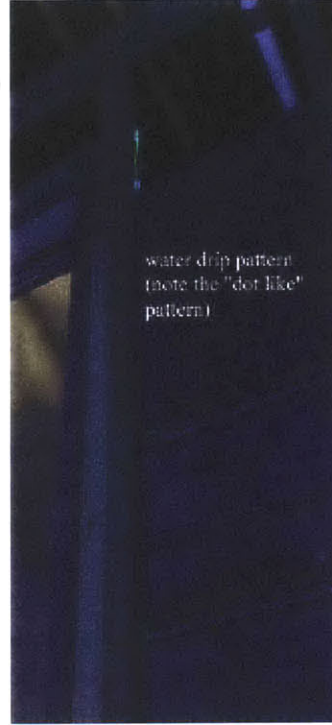
Water dripped down the length of the nail-on fin onto the acrylic sheet and then puddled on the floor. This straight-line path developed within five minutes of the test and continued until the test was terminated.

The test illustrates how water travels along the window jamb when clad with vinyl siding. Unlike the clear and cedar clapboard pattern, water did not exit the assembly but traveled between the vinyl mounting flange and the vinyl siding. In this case there is no concern with rot given the nature of the materials involved.

### 2.2.6 Test 6: no WRB, Vinyl Siding, Water Introduced Next to the Nail-on Fin



**Figure 2-25 Test 6 drip pattern**



**Figure 2-26 Test 6 dot pattern**

Water dripped onto clapboard 9's nailing band from the water introduction tube. The water then dripped from this nail band onto clapboard 8's nail band. The pattern continued with the water dripping onto each successive nail band. When viewed as a whole, the water drip pattern looked like a dot pattern with each dot equally spaced from its neighbors.

While some water splattered onto the acrylic sheet in the vicinity of clapboard 9, this splatter appeared to be incidental to the primary drip pattern described above.

The concern with this test is whether water would travel over an oriented strand board or plywood sheet as it does over the acrylic. Assuming that water would travel over new oriented strand board or plywood as it did in this test, the significance of this test is in demonstrating the existence of a drain plane between the acrylic sheet and the vinyl siding. Water, under the influence of gravity traveled along the mounting flange and exited the assembly.

The significance of Tests 1-6 was in demonstrating that the mounting flange collects and directs water to the exterior. It completes this function both in isolation and when it is combined with clear clapboard, cedar clapboard or vinyl siding. The tests illustrated the presence of a continuous drain plane along the length of the mounting flange. This mounting flange was present along the length of the mounting flange as well as immediately next to it.

The second set of tests simulated a window/wall assembly with the WRB (Tyvek Housewrap) installed prior to the window. This set of four tests is collectively termed the **WRB- window tests**. Similar to the **isolation tests** completed above, tests were done for clear clapboard, cedar clapboard and a vinyl siding. Since these are visual tests, to establish a benchmark, water was inserted in front of and behind the WRB in the case of the clear clapboard. Water was inserted behind the WRB, next to the nail-on fin in the case of the cedar clapboard and vinyl siding.

In these tests, a sill-flashing element was applied to the WRB as per ASTM E2112-01.

Test 7: WRB, clear clapboard, water introduced in front of the WRB directly over the nail-on fin

Test 8: WRB, clear clapboard, water introduced behind the WRB next to the nail-on fin

Test 9: WRB, cedar clapboard, water introduced behind the WRB next to the nail-on fin

Test 10: WRB, vinyl siding, water introduced behind the WRB next to the nail-on fin

### 2.2.7 Test 7: WRB, Clear Clapboard, Water Introduced in Front of the WRB Over the Nail-on Fin



Figure 2-27 Test 7 drip pattern at the window head

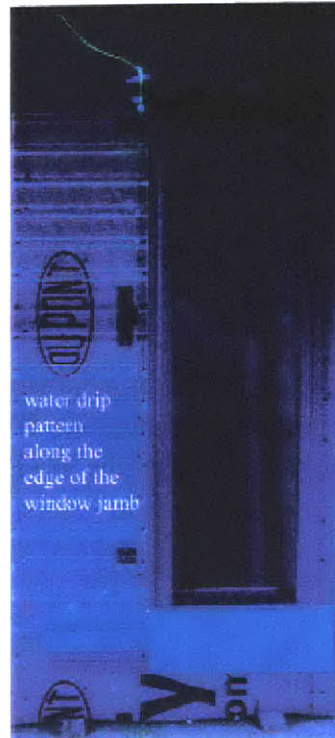


Figure 2-28 Test 7 drip pattern along the entire length of the window jamb

The observed water drip pattern was similar to the one noted in Test 2. The WRB is behind the nail-on fin, and with the water introduced in front of the nail-on fin; the WRB does not influence the water flow along the jamb. For the purposes of the study, the above water pattern (to a first order) is assumed to take place behind cedar and vinyl sidings.

This test illustrates how the water drip pattern is affected by the presence of the weather resistant barrier. Water travels over the mounting flange, but once it comes in contact with the sill flashing it is not directed to the exterior but deviates horizontally within the wall assembly.

### 2.2.8 Test 8: WRB, Clear Clapboard, Water Introduced Behind the WRB Next to the Nail-on Fin

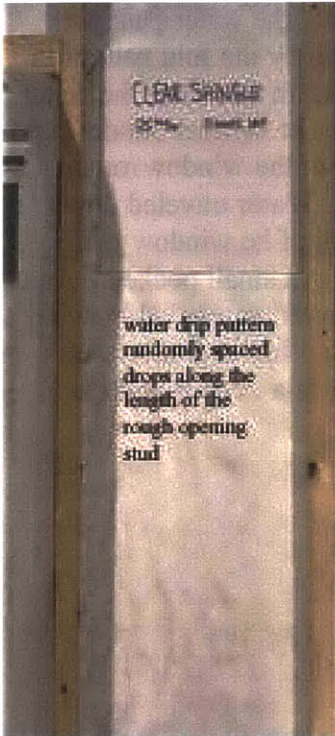


Figure 2-29 Test 8 drip pattern 1

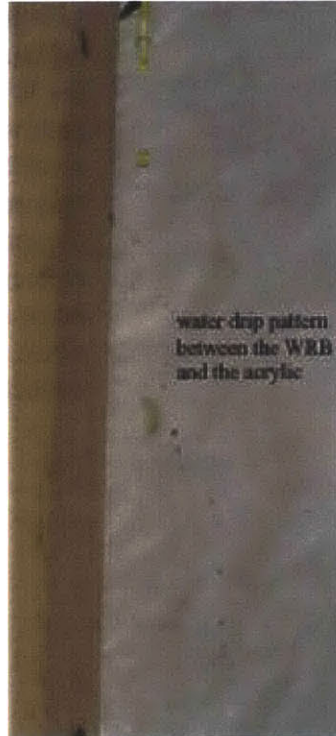


Figure 2-30 Test 8 drip pattern 2

Water flowed between the WRB and the acrylic sheet. The eventual path was downward, but random. The water path appeared to follow the contours in the WRB.

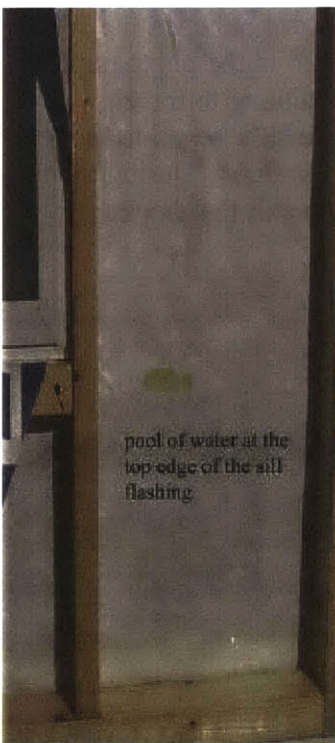
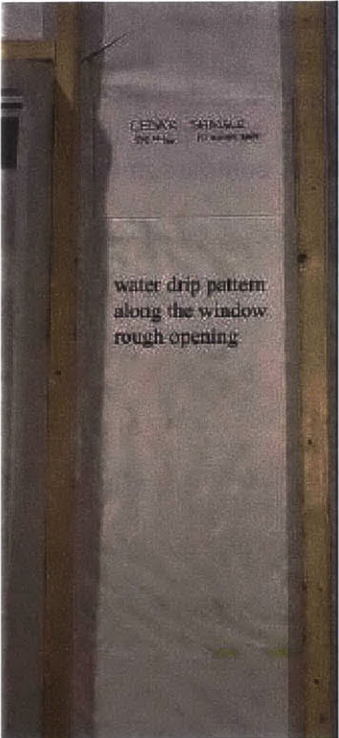


Figure 2-31 Test 8 sill puddle

At the sill, in line with the sill flashing, water pooled against the acrylic sheet and a pocket in the WRB. This pocket was created when the sill flashing was installed over the WRB.

**2.2.9 Test 9: WRB, Cedar Clapboard, Water Introduced Behind the WRB Next to the Nail-on Fin**

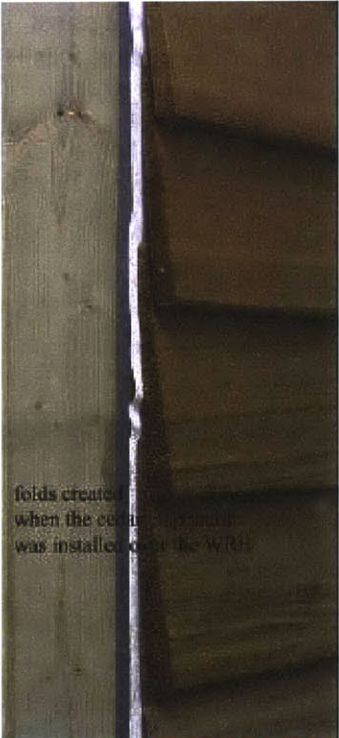


**Figure 2-32 Test 9 drip pattern**



**Figure 2-33 Test 9 water pool above a clapboard edge**

Like test 8, the water path was influenced by the fold pattern in the WRB. In this case, the water path was not vertical but deviated away from the window rough opening. Water traveled down the length of the window jamb collecting in small pockets. At a point approximately half way down the window frame, water collected in a two large folds.



**Figure 2-34 Test 9 fold in the WRB due to cedar clapboard installation**

These folds were located where clapboard bunched the WRB in a fold pattern similar to the one noted in the photograph. These folds prevented water from continuing to travel downward. As water gathered in the fold, it began to move away from the window parallel with the floor. During the ten (10) minute test, no water was noted to exit the mockup.

### 2.2.10 Test 10: WRB, Vinyl Siding, Water Introduced Behind the WRB Next to the Nail-on Fin



Figure 2-35 Test 10 drip pattern

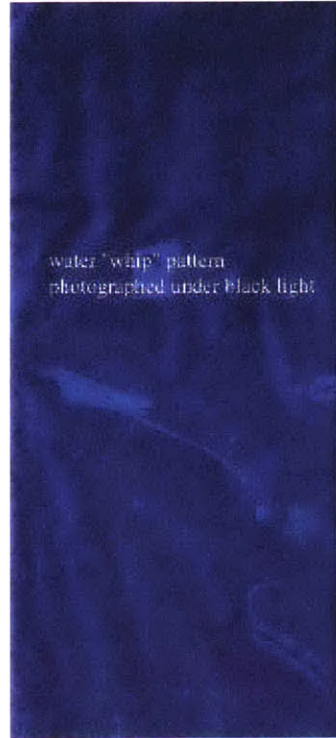


Figure 2-36 Test 10 whip pattern

When the water dripped behind the vinyl siding it displayed a whip or "S" like pattern. There appeared to be no reason for this drip path other than the manner in which the WRB was folded during the installation of the vinyl siding.

The results of Tests 9 and 10 highlight what happens once an internal drain plane (between the mounting flange and sheathing) is not present.

The housewrap physically separates the mounting flange from the sheathing. With the housewrap in place, there is no separation between the sheathing and WRB. Water is not collected and directed to the exterior between the sheathing and the WRB but travels down the window jamb based on the separations created when the housewrap was installed over the sheathing. These separations are random, a function of the given housewrap installation. This randomness, and its associated affect on performance cannot be accounted for in any individual design, but measures can be taken to minimize this randomness through the selection and sequencing of the building materials used to construct the window/wall assembly. More is said about this point latter in the text.

The third set of tests simulated a window/wall assembly where the window was installed prior to the WRB (asphalt felt). This set of three tests is collectively termed the **window-WRB** tests. Similar to the **isolation tests** and the **WRB-window** tests completed above, tests were done for clear clapboard, cedar clapboard and vinyl siding.

In this testing sequence, the sill flashing was installed directly onto the acrylic sheet before the window so that it would be behind the WRB. The sill flashing was installed before the window to simulate an installation that allowed water to drain from the window/wall assembly.

Test 11: WRB, clear clapboard, water introduced behind the WRB next to the nail-on fin

Test 12: WRB, cedar clapboard, water introduced behind the WRB next to the nail-on fin

Test 13: WRB, vinyl siding, water introduced behind the WRB next to the nail-on fin



### 2.1.11 Test 11: WRB, Clear Clapboard, Water Introduced Behind the WRB Next to the Nail-on Fin

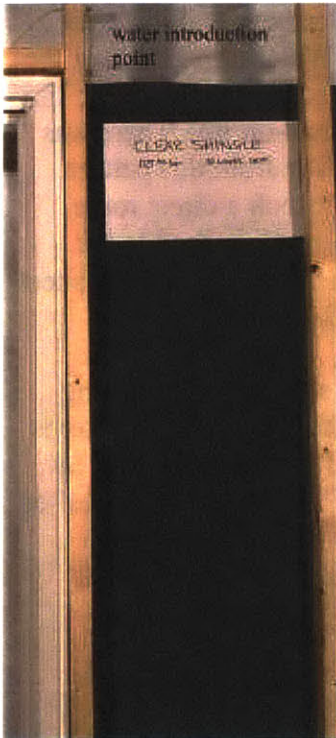


Figure 2-37 Test 11 drip pattern

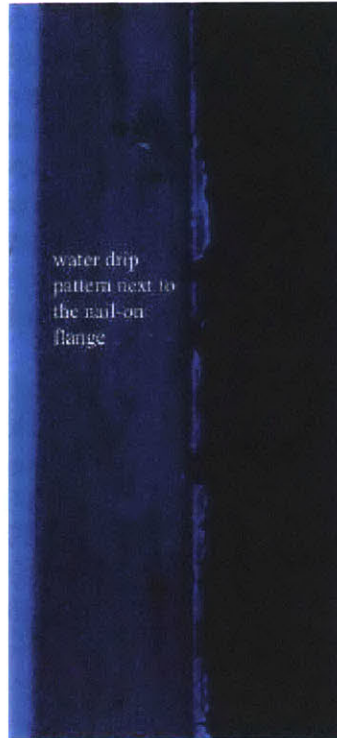


Figure 2-38 Test 11 drip pattern along the window jamb edge

Water dripped along the edge of the rough opening in line with the nail-on fin. There was no deviation from this pattern. The water took a direct route from the window head to the windowsill onto the acrylic sheet and off the mockup.

There is some water smearing next to the flange. This water is located in the space created by the 1/16" thickness of the nail-on fin. This water didn't stay in place, but migrated down the window jamb edge.

### 2.2.12 Test 12: WRB, Cedar Clapboard, Water Introduced Behind the WRB Next to the Nail-on Fin



Figure 2-39 Test 12 drip pattern



Figure 2-40 Test 12 drip pattern along the window jamb edge

The drip pattern was identical to test 11. Water dripped along the edge of the rough opening in line with the nail-on fin. There was no deviation from this pattern. The water took a direct route from the window head to the windowsill onto the acrylic sheet and off the mockup.

There is some water smearing next to the flange. This water is located in the space created by the 1/16" thickness of the nail-on fin. This water didn't stay in place, but migrated down the window jamb edge.

### 2.2.13 Test 13: WRB, Vinyl Siding, Water Introduced Behind the WRB Next to the Nail-on Fin



Figure 2-41 Test 13 drip pattern



Figure 2-42 Test 13 drip pattern along the window jamb edge

The drip pattern was identical to tests 11 and 12. Water dripped along the edge of the rough opening in line with the nail-on fin. There was no deviation from this pattern. The water took a direct route from the window head to the windowsill onto the acrylic sheet and off the mockup.

There is some water smearing next to the flange. This water is located in the space created by the 1/16" thickness of the nail-on fin. This water didn't stay in place, but migrated down the window jamb edge.

The final test was done on a furred out wall. In the **furred wall** test, a WRB (Tyvek Housewrap) was installed over the acrylic sheet followed by 3/4" strapping was installed around the window. Since, by design, no siding is installed directly over the WRB, water will travel down the exterior side face of the siding following the as installed fold pattern and drain to the outside. This test introduced water behind the WRB next to the strapping.

### 2.1.14 Test 14: WRB, Strapped Wall, Water Introduced Behind the WRB Next to the Strapping

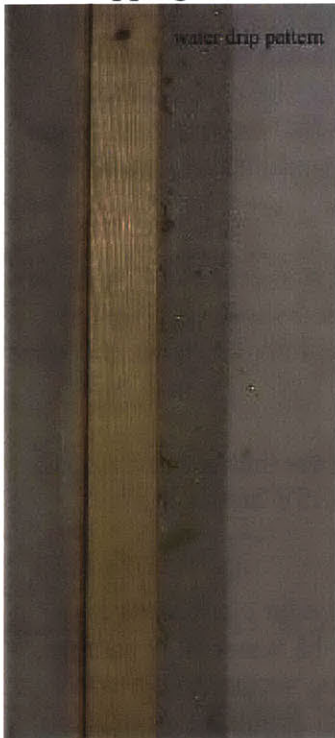


Figure 2-43 Test 14 drip pattern

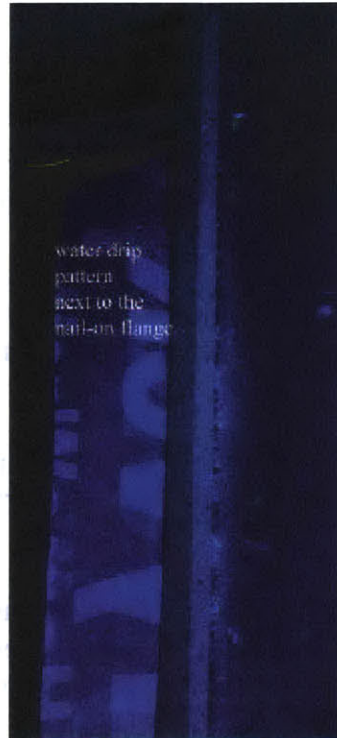


Figure 2-44 Test 14 drip pattern along the window jamb edge

Water followed the WRB's fold pattern as it traveled along the window jamb. Unlike the WRB fold patterns created in Tests 7-10, this fold pattern was not influenced by a siding installation. Yet, the water path pattern that displayed some randomness like those in Tests 7-10, but also demonstrated the straight-line path like those in Tests 11-13.

The above four tests (Test 11, Test 12, Test 13 and Test 14) demonstrate the importance of having a drain plane between the WRB and the sheathing.

With the window installed next to the sheathing, its mounting flange provides a separation between the sheathing and WRB. This separation creates a drain plane that collects and directs water to the exterior. The presence of this drain plane mitigates the influence of the house wrap installation over the internal water drip pattern.

## **2.3 Conclusions**

The strength and weakness of the Jamb Drip Test is its empirical, visual approach. When, through a combination of clear elements (e.g. tests 1-14), an open line of sight exists between the camera and the phenomenon under review, data can be collected. When the line of sight is blocked by an opaque element, data cannot be collected (e.g. introducing water in front of the nail-on fin when it is covered by building paper). In the latter case, the best that can be done is to extrapolate how water would travel down the fin based on how it traveled down the fin between clear elements.

There are also questions raised by the use of the acrylic sheet and the clear clapboard. In particular, does water travel over acrylic like it does over a plywood sheet, an oriented strand board (OSB) sheet, cedar clapboard or vinyl siding. Comparative tests were done in this study.

When water travels down the acrylic sheet, it does so in beads rather than a continuous path. When water travels down new, dry plywood and new, dry OSB board, it also travels in beads.

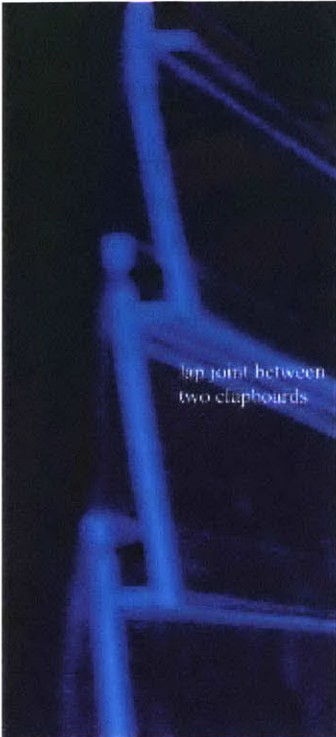
It was also shown that there is a similarity between the clear and cedar clapboards in terms of how water flows down these elements. To a first order, the water flow pattern between an asphalt felt WRB and new (dry) cedar is assumed to be similar to the water flow pattern noted for the asphalt felt/clear clapboard test (Test 7). A similar conclusion cannot be made about how water flows between the asphalt felt and vinyl siding.

Water was introduced onto the model from the IV tube that has an inner diameter of  $1/16$ ". The following conclusions are based on the results from this resulting drop. A future study will be conducted that introduces drops of different diameters on the model. The purpose of this work is to determine if there is a sensitivity in the results of the Jamb Drip Test due to the initial water drop diameter. Given these limits, the following conclusions are presented based on the findings of Tests 1-14.

### **2.3.1 The Nail-on Fin in Isolation (Tests 1-6)**

When water flows over the vinyl nail-on flange unobstructed by a siding element (Test 1), it beads but travels in a continuous, direct path off the window/wall assembly. Water does not deviate off the nail-on fin in its travel down the window jamb. One possible explanation for the noted fan dispersal pattern could be that a particle or obstruction was present on the nail-on fin during the test. When the water drop struck this obstruction, it dispersed creating the observed fan-like pattern. If the nail-on vinyl window were installed in isolation, the nail-on fin would be an adequate jamb element.

When siding was added to the assembly, water dripped over the nail-on fin onto the floor below in the case of the vinyl siding (Test 5) but it exited to the exterior in the case of the clear and cedar clapboards (Tests 2 and 3 respectively). In Test 5 no water was observed to have deviated onto the acrylic sheet.

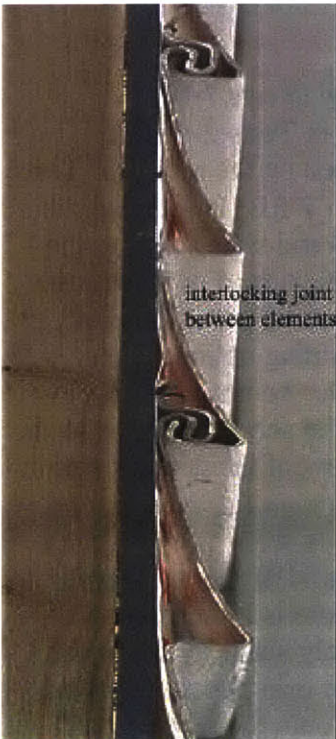


**Figure 2-45** lap joint between two clear clapboards



**Figure 2-46** lap joint between two cedar clapboards

One explanation for the reason why water exited to the exterior for Tests 2 and 3, but didn't for Test 5 could be in the type of joint created between two individual components when installed in the field. In the case of the clear clapboard and the cedar clapboard, a simple lap joint is created between two elements. If water contacts this joint, it will be immediately directed to the exterior.



**Figure 2-47** interlocking joint typical of the vinyl siding

In the case of the vinyl siding, the installation sequence requires an interlocking joint between two elements. Unlike the cedar and clear siding elements, there is no direct path to the exterior. While some vinyl siding elements come with pre-drilled drain holes along the individual elements bottom edge, the siding used in this study did come with these pre-drilled holes.

When water was introduced next to the nail-on fin (Tests 4 and 6), the fin did not play a direct role in collecting and directing water to the exterior. However, a case can be made for the nail-on fin playing an indirect role in directing and collecting water to the exterior.

The nail-on fin is 1/16” thick. When the siding was installed flush to the fin, immediately next to the fin, this thickness created a space between the siding and the nail-on fin. Water freely moved – collected – in this space. In the case of the vinyl siding (Test 6), water traveled to the exterior via a “dot pattern, making a puddle on the floor directly below the space. In the case of the cedar siding (Test 4), a water stain was observed on each of the clapboard’s “backside” in line with the space created by the nail-on fin.

A symbiotic relationship has been created. When water is introduced next to the nail-on fin, a triangular or wedge shaped space is created by the combination of acrylic sheet, nail-on fin offset and siding. This space acts as a drain plane collecting and directing water to the exterior.



Figure 2-48 space created by the thickness of the nail-on fin

The space would not exist if the assembly was not constructed in this sequence. In this situation, the nail-on fin acts in conjunction with other elements to create a flashing. By itself, it is not an adequate flashing.

### 2.3.2 WRB (Tyvek Housewrap) Installed Prior to the Window (Tests 7-10)

The difference between this installation and the installation done in Tests 2-6 is the addition of a weather resistant barrier over the acrylic sheet. Based on the results of Tests 4 and 6, it can be concurred that when a weather resistant barrier (WRB) is added to the construction assembly and water is introduced between the WRB and siding next to the nail-on fin, water will collect in the space and be directed to the outside. For those cases where water is introduced directly over the nail-on fin (Tests 2,3 and 5), it will travel down the nail-on fin but its ultimate path will be dictated by the siding option. The question remains: what is the effect of the WRB on the water path. To answer this question, water was introduced behind the WRB between it and the acrylic sheet next to the nail-on fin (Tests 7-10). This situation could also simulate the flow of incidental water in the field due to a rip or tear in the WRB.

In terms of the water path, the common observation between tests 7-10 was the erratic nature of the path as it traveled along the window jamb. Since there is no separation between the WRB and sheathing, the folds in the WRB are the only space available for water to move within on its downward path. As a result, the water drip pattern followed the folds in the WRB created during the installation of the WRB onto the window/wall assembly. These folds existed when the WRB was installed without siding directly over it (Test 14) or when siding was installed over it (Tests 7-10).



These “in-service folds” are created when the installer places the WRB over the wall sheathing. These folds change location and direction between installations. The cedar siding is attached directly to the sheathing. This contact point is continuous over the wall plane pinning the WRB at these locations. The vinyl siding contacts the sheathing across its top edge. However, since the vinyl is nailed in place at discrete points, the contact point is not continuous.

As a result, the performance of the detail itself is unpredictable. For example, in Test 8, water pooled above the sill-flashing element attached to the outside of the WRB as per ASTM E2112-01. In Test 9, water followed along a fold created by the upper edge of cedar clapboard. Water traveled thirteen inches horizontally away from the edge of the window. If this occurred in the field, the ASTM E2112-01 recommended nine (9) inch flashing width would be inadequate to collect and direct this water flow out to the exterior. These deficiencies are a consequence of the particular WRB installation, and as a result unpredictable.

There is no way a designer can predict the location of these folds a priori or the influence they will have on water flow. The one conclusion a designer can use from this part of the study is that these folds will exist in the as built wall and they will influence the water flow pattern along the window jamb.

The solution to this problem is not modifying the installer’s practice, but in changing the detail. To mitigate the influence of these folds, based on Tests 2-6, a drain plane must be created between the WRB and sheathing. Installing a corrugated flashing material behind the WRB or altering the sequence of WRB-window installation can create this drain plane. More is said about this option below.

With regards to Methods A1 and B1 in ASTM E2112-01, the detail of installing the window flashing after the house wrap serves no purpose as a flashing. As shown in Tests 2 and 3, depending on the siding option, the clapboard can act as a flashing element collecting and directing water to the exterior independent of other elements. If vinyl siding is used, and if it comes with pre-drilled holes, this siding option will also collect and direct water to the exterior. For those vinyl sidings that do not come pre-drilled with drain holes, another study will need to be conducted to determine the fate of water collected in the interlocking joint. However, based on anecdotal field observations, the author is not aware of water remaining in vinyl siding, and by extension being a problem in terms of storing water behind the siding. If the siding is furred out (Test 14), the WRB acts as a flashing element in isolation.

Ultimately, what is at issue in this construction sequence is creating a positive, long term, durable seal between the nail-on fin and house wrap so that water does not migrate between the nail-on fin and house wrap entering the rough opening (see 2.5 Next Generation Window/Wall Flashing System). At this point, the seal is created via sealant. The benefit of Methods A1 and B1 is that if peel and stick flashing is used, redundancy is added to the system in terms of providing a backup to the sealant in creating the seal

between the nail-on fin and house wrap. However, this seal can be created by other means such as flashing tape (e.g. Fortifiber's E-Z seal or Dupont's Tyvek FlexWrap).

In terms of whether the nail-on fin is an adequate flashing, if appropriately sealed and if water is introduced behind the siding in front of the WRB, it would collect and direct water to the exterior without an additional jamb flashing. If water was introduced behind the WRB, the nail-on fin plays no role in this situation and a flashing element would have to be added to the construction sequence.

### **2.3.3 WRB (asphalt felt) Installed after the Window (Tests 11-13)**

In this set of tests, water was introduced behind the asphalt felt between it and the acrylic sheet next to the nail-on fin.<sup>1</sup> In terms of the water path, the common observation between Tests 11-13 was its consistency. Water flowed in the space created by the nail-on fin's thickness. Water collected and was directed to the exterior independent of the siding option. The reason for this consistency in water path was the existence of the drain plane created by the nail-on fin offset.

As mentioned above, the offset creates a symbiotic relationship between the sheathing, siding and nail-on fin. Because of this relationship, the nail-on fin in this installation is not an adequate flashing. In terms of enhancing the system's durability, and in particular a means of protecting the sheathing from wetting, the flashing system should be installed behind the house wrap (i.e. McBride, 2002). For the assembly to perform, a flashing must be added behind the nail-on fin so that when water collects in the space next to the nail-on fin, it does not wet the sheathing. As well, a flashing should be added so that the path in the space next to the nail-on fin is without interruption.

### **2.3.4 Is the Nail-on Fin an Adequate Jamb Flashing?**

As mentioned in the above sections, the answer to the question of whether the nail-on fin is an adequate flashing depends on the construction sequence. In the case when the WRB is applied prior to the window, the nail-on fin is an adequate flashing. When the window is installed prior to the WRB, the nail-on fin is not an adequate flashing.

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<sup>1</sup> Since the window nail-on fin was separated from the siding by the asphalt felt, testing the flow of water between the asphalt felt and the siding was beyond the scope of this study.

## **2.4 A State of the Art Window/Wall Flashing System Construction Sequence**

The answer to the question of whether jamb flashing is needed along the vertical edges of a nail-on window depends on whether the window is installed before or after the WRB.

*With the WRB installed prior to the window*, when water was introduced in front of the WRB, it was collected and directed to the exterior by the siding alone. Flashing was not needed to perform this task. When water was inserted behind the WRB, it showed an erratic flow pattern, dependent on how the WRB was installed.

*With the window installed before the WRB*, when water was introduced in front of the WRB, it was directed to the outside. This conclusion is not based on direct observation but on anecdotal evidence. When water was introduced behind the WRB, with the gap or space created by the 1/16" thickness of the nail-on flange, a consistent water path, independent of WRB installation or siding option, was observed.

Based on these results, a more significant finding emerged from the study. To create an installation independent, predictable window-wall detail that would collect and direct incidental water back to the exterior irrespective of where this water is introduced, a drain plane<sup>1</sup>, placed to the interior of the WRB, must be detailed between the sheathing and the window perimeter. By design, this drain plane is created if the window in question is a vinyl nail-on window via the mounting flange.

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<sup>1</sup> A working definition of a drainage plane is those locations where gravity is the dominant force that controls the incidental flow of (rain) water back to the exterior. For a drainage plane to exist, a gap or space must exist between elements.

To create this drain plane for a given window installation, a proposed construction sequence would be sheathing, flashing, window, WRB, siding. This sequence is similar to ASTM E2112-01 Method B<sup>2</sup> as well as the one proposed by McBride (2002) illustrated in Figure 2-3.<sup>3</sup>

**PREPPING A ROUGH OPENING FOR A WINDOW**

**Housewrap and Window Flashing Details**

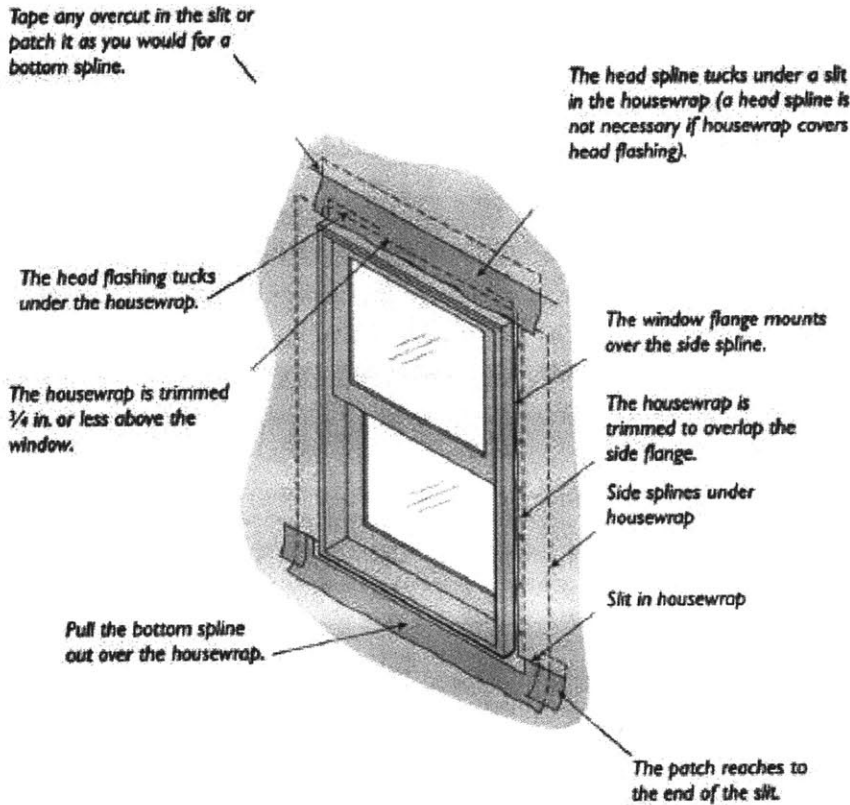


Figure 2-49 recommended vinyl nail-on window construction sequence graphic: McBride (2002 )

The advantage of this construction sequence is that incidental water would exit the assembly irrespective of whether the water is introduced in front of, or behind the WRB or how the WRB is installed.

Peel and stick flashing was used on the Jamb Drip Tests. It was observed that depending on how the peel and stick flashing was installed, folds developed within the flashing sheet.

<sup>2</sup> See Appendix 1.0 for an explanation of Method B.

<sup>3</sup> The difference between ASTM E2112-01 Method B and McBride’s (2003) construction sequence is the use of building paper for the WRB in the former and housewrap for the WRB in the latter.

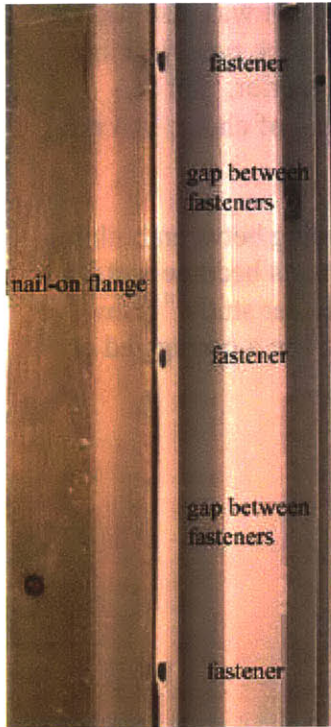
These folds introduce a similar problem to the one noted with the WRB installation. The water path over the peel and stick flashing was determined only after it was installed on the wall. For any given installation, it is possible that the peel and stick type flashing could collect and direct water toward the window rather than the exterior. For this reason, in this proposed construction sequence, the flashing material of choice is a non-stick flashing (i.e. Fortifiber's Moistop Next).

The drainage planes identified above assume that the required spacing between building elements will exist when the assembly is dry. Once these components become wet, and whether the space remains between components is the focus of another study.<sup>4</sup> However, if material-to-material contact is an issue, one solution could be to use a corrugated or dimpled flashing sheet and/or WRB (i.e. StuccoWrap).

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<sup>4</sup> The question to be tested in this instance is whether the offset provides a sufficient separation between materials in a wet state to maintain a drainage plane. Inherent in this study is determining how the various materials one could use shed and absorb water.

## 2.5 A Next Generation Window/Wall Flashing System



**Figure 2-50** gap between the fasteners

The above proposed construction sequence provides an assembly with the necessary internal drain plane. However, in this assembly, the use of sealant to create the seal between the nail-on flange and the WRB/flashing/sheet/sheathing is still a performance issue.

This statement is not based on the results of a durability test performed in this thesis. Rather, it is based on discussions with builders, designers, manufacturers, building science consultants and colleagues. The general impression about the performance of the sealant bead after talking to this group of industry professionals was that either the joint wouldn't be sealed continuously in the field or it "couldn't be trusted to perform over time" (Baker, 2003, McCombe, 2003).

At this point, these statements are anecdotes. They are subjective, and can be dismissed as perceptions. Yet, the consensus of opinion suggests that the use of sealant to close the lap joint between the nail-on flange and the wall assembly is a design issue and it must be addressed to improve the overall performance of the window/wall assembly.

A Jamb Drip Test of a non-sealed nail-on window to wall connection was done as part of the larger set of experiments conducted for this study. The objective of the test was to determine if water flowed between the nail-on flange and the wall assembly.



**Figure 2-51** water in the gap between the fasteners

When the mockup for this assembly was constructed, it was noted that the nail-on flange conformed to the fastener pattern once the window was installed in place. At five (5) inch intervals, where the flange was fastened to the wall, the nail-on flange was pressed against the assembly. Between these fastening points, the nail-on flange displaced away from the wall assembly creating a gap between the fastener locations. This "gap pattern" repeats itself around the window's perimeter.

During the Jamb Drip Test, water traveled behind the nail-on flange as it moved down the wall plane (note the green colored drips spanning the gap between the nail-on flange and the acrylic sheet). In this case, the water traveled the length of the nail-on flange exiting the assembly.

ASTM E2112-01 recommends this joint be sealed with a high performance sealant<sup>5</sup> according to Figure 2-52.

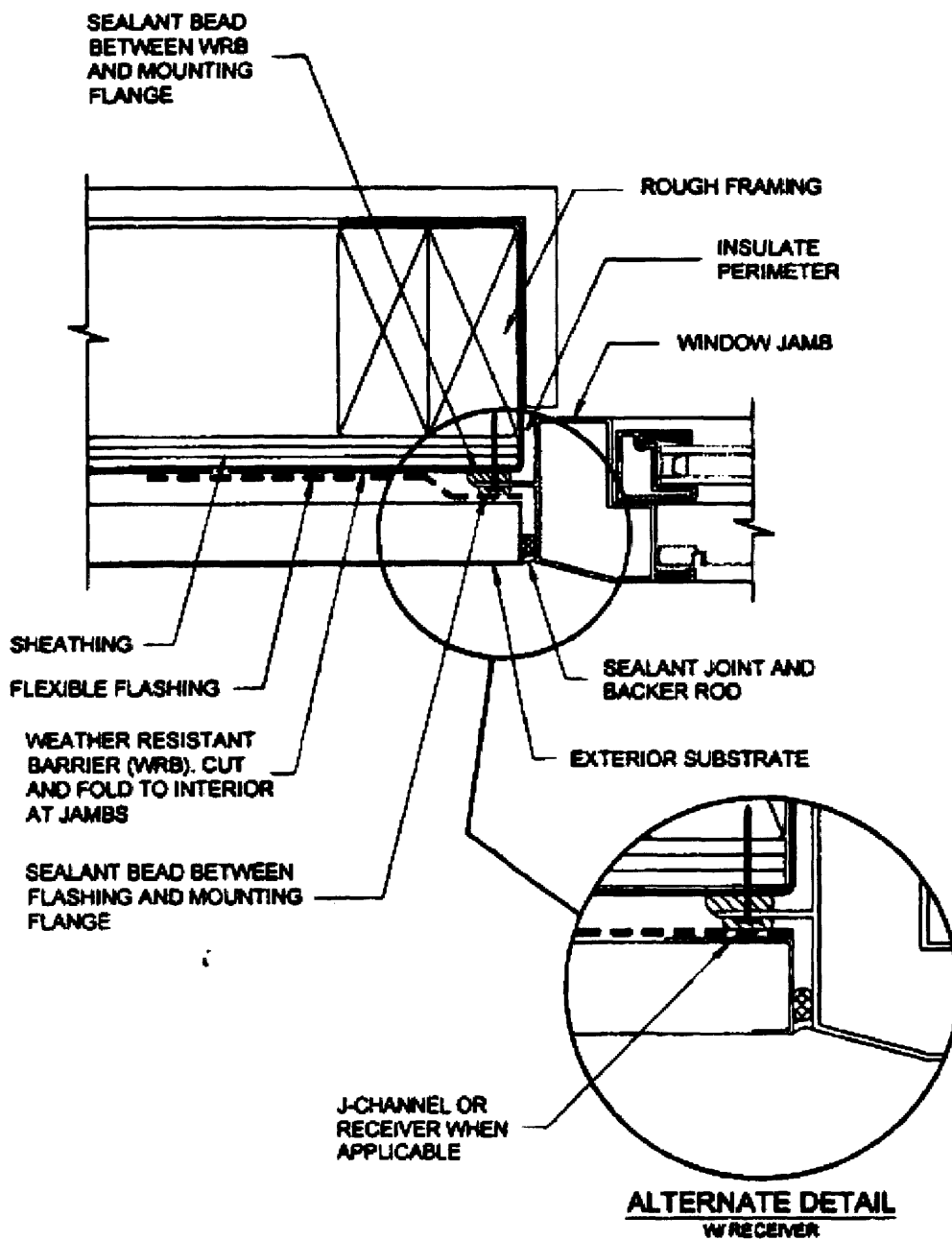


Figure 2-52 ASTM E2112-01 recommended lap joint detail

source: ASTM E2112-01

It is expected that the sealant will be applied in a continuous  $\frac{3}{8}$ " bead around the entire window frame. It is further assumed that once the bead is pressed against the wall assembly as the window is put in place, the sealant spreads across the nail-on flange closing the gap between fasteners.

<sup>5</sup> A high performance sealant is one that meets ASTM standard C920.



This procedure was done in the lab with the results shown in the accompanying photograph. Effort was taken to ensure that the sealant was applied as per the ASTM E2112-01's recommendation. Yet, the resulting bead was inconsistent in terms of its application over the window perimeter. Based on a visual inspection, the bead was assumed to be continuous. However, it was not tested (i.e. a pressure differential applied across the bead and then monitored for air leakage).

Professional window installers have more experience with this technique. One can expect their work to be more consistent than the above effort. However, a concern remains about the sealant's performance in this detail. One solution to this problem is a re-design of the connection between the nail-on flange and the wall assembly.

**Figure 2-53 sealant applied in the lap joint**



Figure 2-54 is a proposed re-design of this connection. The re-design uses a material joint made from one sheet of material rather than sealant to complete the seal between the window and wall. The material can be designed to integrate the window and wall through a series of strategically placed folds.

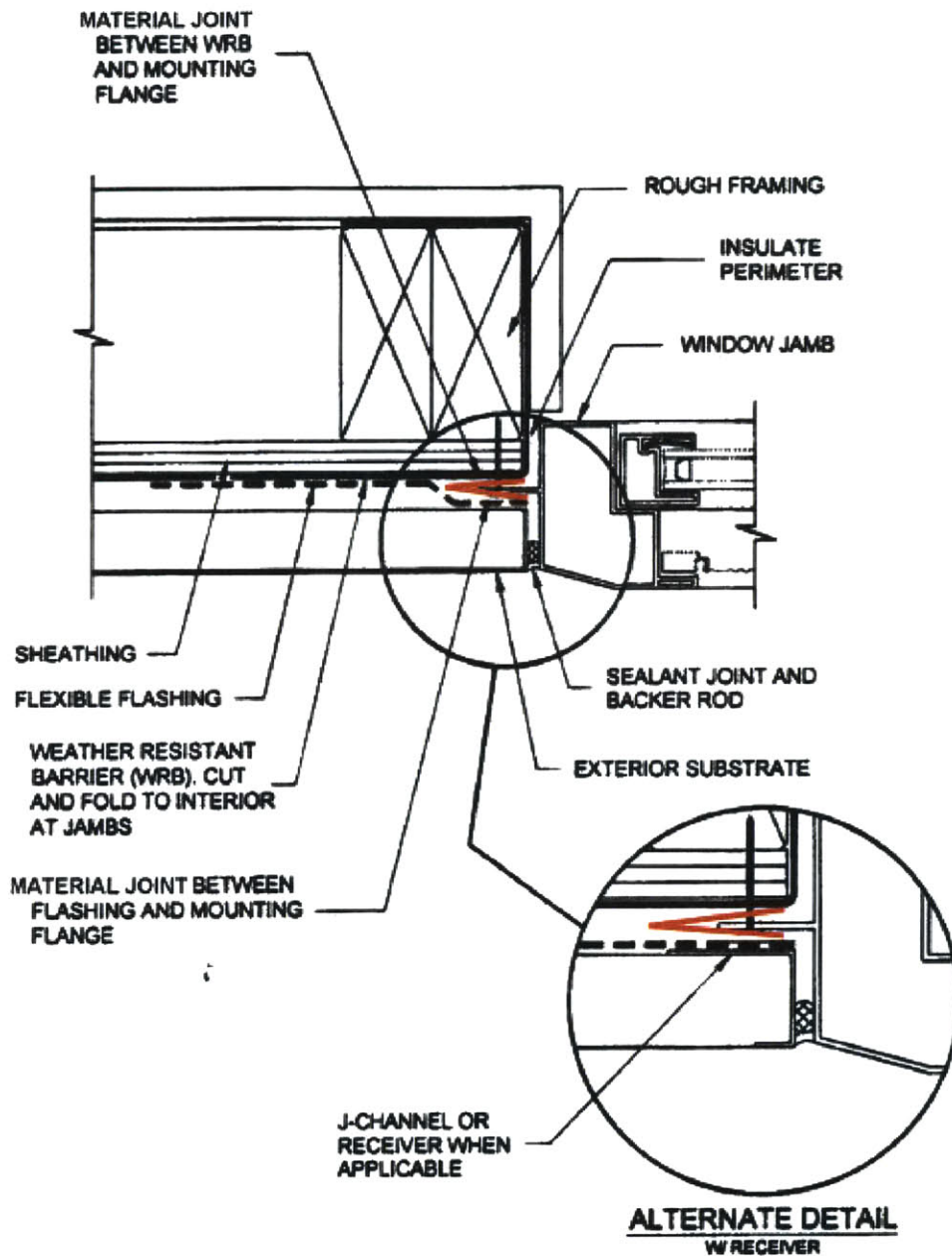


Figure 2-54 modified lap joint detail

Since this material joint would lap the flashing sheet as per the recommended installation sequence proposed above, the sheet could combine the two functions of sealing the window/wall assembly and providing a flashing for the window system.

In the figure, the proposed material configuration is an abstraction representative of the concept, rather than an actual profile. This design is described in the following chapter.

### 3.0 A Seal + Flashing System

This chapter describes one idea for a seal + drain waterproofing system. The working premise behind the idea is that a multiple folded element made from a single piece of material can fit between the window's mounting flange and WRB. Via this geometric fit, a continuous, durable waterproof barrier can be created between the window and wall. This single element is both a flashing system - enhancing the existing nail-on fin perimeter drain plane collecting and directing water to the exterior - and a seal - maintaining a wet/dry interface under the influence of a pressure differential. It can complete these two functions without the use of a sealant. The novelty of this idea is in transforming a 2D sheet of flashing membrane into a 3D flashing sheet through the incorporation of an accordion like fold profile along one of its edges.

The difference between this idea, and the flashing systems studied in chapter 2.0 is its dual functionality. As such, this idea is not a flashing system in the strictest sense of the definition, but a waterproofing system.

The present version of the idea developed over two iterations. In profile, the first iteration incorporated one fold taking the shape of a v. Given this shape, this invention was called v-Flashing. The author described this idea to Mr. Fred Baker, Corporate Technical Director of Fortifiber Corporation during a September 2003 meeting at Fortifiber Corporation's North Attleboro, Massachusetts office.<sup>1</sup>

The v is made up of one fold that creates two sheets. For explanatory purposes, the sheets have been numbered.



Figure 3-1

v-Flashing Profile

Sheet 1 is 9 inches wide as per ASTM E2112-01. Sheet 2 is 1 inch and is based on the length of a typical vinyl nail-on window-mounting flange.

The v-Flashing would be installed before the nail-on window and the WRB. The nail-on flange would be installed over sheet 2 creating a compressed folded seal at this lap joint.

---

<sup>1</sup> There is precedent for this type of assembly. The v-shape has been used in the application of leaf type weatherstripping doors and windows to control air leakage. V-shaped weatherstripping comes in different metals (bronze, brass, and stainless steel) as well as plastic. The v shape is installed around the exterior door perimeter with the fold pointing inward (for an inward opening door). Once the door is closed, the v is compressed preventing the unintentional passage of air.

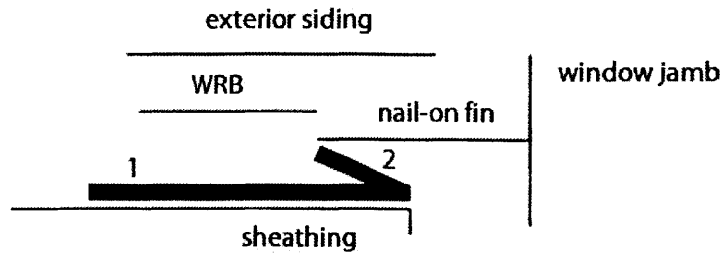


Figure 3-2 location of the v-Flashing in the window/wall assembly

In practice, sheet 1 would be fastened to the sheathing so that the fold is along the edge of the rough opening. The v-Flashing would be installed in weatherboard fashion beginning with the sill and then proceeding to the jamb flashings. Up to this point, sheet 2 would be to the exterior of sheet 1 with the fold pointing toward the rough opening.

In order to prevent incidental water from collecting at the head, the v-Flashing would be installed with sheet 1 fastened to the sheathing but with the fold pointing away from the rough opening and sheet 2 to the interior of sheet 1. The v-Flashing would be installed so that the flat edge of sheet 1 laps the window head in standard fashion.

Two performance related problems were identified with the v-Flashing:

- 1) There is no bond breaker<sup>2</sup> between the window-siding butt joint.  
If a flat profile, rather than a j-channel profile is installed, then the installer will caulk the window-wood siding butt joint. This act can potentially become a three-point joint as the sealant makes contact with the nail-on fin, wood siding and vinyl window. To mitigate this problem a bond breaker should be installed over the nail-on fin.
- 2) a seal is needed between the window and housewrap<sup>3</sup>.  
If it is not taped to the nail-on flange, the housewrap is not continuous and becomes a potential performance liability (i.e. unintentional air and/or water leakage).

The author developed an improvement to the v-Flashing in October 2003. This new profile, the second version of the idea, takes the form of a w. The flashing sheet takes its

<sup>2</sup> A bond breaker or backer material has a non-adhering surface that prevents a sealant (i.e. high performance silicone, latex, polyurethane) from sticking to it. The bond breaker material also serves to shape and support the profile of the sealant and serve as a secondary barrier. The breaker must be compatible with the sealant material and durable. As well, it should be chemically inert and resistant to oils, gasoline, solvents, and primer, if required. Finally, the bond breaker shall not stain or adhere to the sealant.

Bond breakers are made from polyethylene, polyurethane or polyolefin. They come as either a rod or in tape form. Open joints (i.e. butt joints) commonly use a compressible tube or rod shaped material held in place by friction. Closed joints (i.e. lap joints) use a tape like material with the sealant bridging from either side like a bandage.

<sup>3</sup> Given the present preference of housewrap over building felt for siding applications, the present installation sequence focuses on housewrap only. If building felt is used and lapped accordingly, the installations would be identical.

name from this form: w-Seal and Flash.<sup>4</sup> This name recognizes the two functions performed by the assembly. However, the terminology is awkward. In this study, w-Seal and Flash is referred to as w-Flashing.

Figure 3-3 is an illustration of the w-Flashing profile.



Figure 3-3 w-Flashing Profile

The w is made up of three folds that create four separate sheets. For explanatory purposes, the sheets have been numbered. The dimensions of these sheets are based on the ASTM E2112-01 recommendation for a flashing width and the profile of a typical vinyl nail-on window. Sheet 1 is 9 inches in length. Sheet 2 is 1 1/4 inches. Sheets 3 and 4 are 1 inch.

The w-Flashing is installed between the sheathing and exterior siding. It is orientated so the bottom of the w faces the window rough opening. The nail-on fin is inserted into one fold created by sheets 2 and 3 and the WRB is inserted in the other fold created by sheets 3 and 4. Figure 3-4 highlights the installation of the w-Flashing between window and wall along the left window jamb.

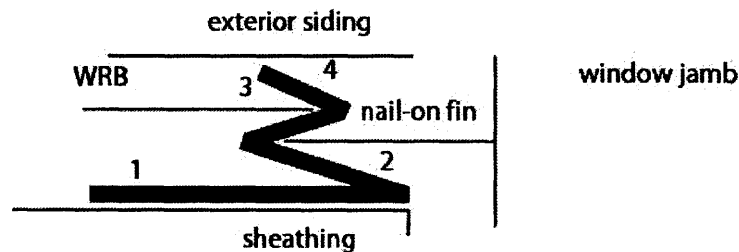


Figure 3-4 location of the w-Flashing in the window/wall assembly

Because of the w design, the folds are “back to back”. The key performance aspects of the w-Flashing idea are a result of this design feature. The “back to back” folds provide the material seal between the nail-on fin and the wall assembly. This continuity prevents water from traveling into the rough opening. The w-fold provides a slip type system capable of compensating for the expected displacements between window and wall due to thermal stress and deflection. The w fold maintains the existing nail-on fin offset

<sup>4</sup> The author is not aware of an existing precedent for this assembly in terms of controlling air or water leakage in residential buildings other than the leaf weatherstripping systems described above.

enhancing the necessary drain plane along the window's perimeter. These attributes are done without a sealant being applied to the lap joint.

### 3.1 w-Flashing System Installation Sequence

A prototype w-Flashing was made from a sheet of asphalt felt. The felt was selected because of its availability and it could be folded and worked to the desired w-form.

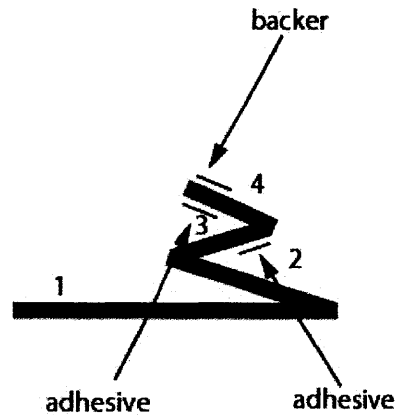


Figure 3-5 prototype w-Flashing Profile

A piece of  $\frac{3}{4}$  inch 3M double-sided tape was applied along the underside of sheets 3 and 4. The use of this adhesive was an “afterthought” included after the w-Flashing was initially designed, but before the installation sequence was considered. It has been added to the design because of the perceived need to seal the w-Flashing to the nail-on fin and the WRB to the w-Flashing. Whether this material is included in the final version of the product depends on the results of the field testing to be completed in a latter study (see 3.3 The Next Steps). The reader is reminded that a bond breaker material would be applied to the cladding side of sheet 4.

This prototype w-Flashing was used in the following installation sequence. w-Flashing's accordion profile dictates that the window-wall construction sequence be the one recommended at the end of chapter 2.0: sheathing – flashing system-window-WRB. The installation procedure is written in the same form as found in ASTM E2112-01. This procedure assumes that a drain pan has been installed in the rough opening. Where appropriate, commentary is provided as to the reason why certain installation steps are proposed.

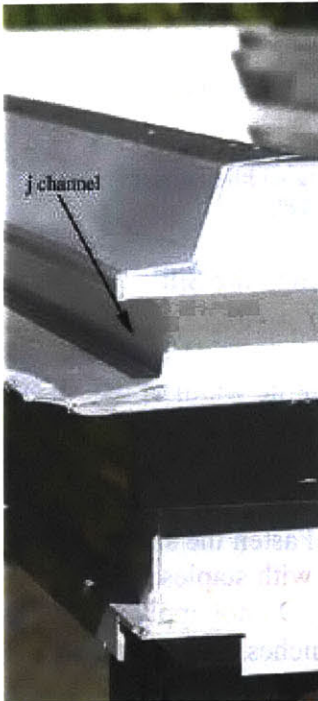


Figure 3-6 j channel profile



Figure 3-7 L channel profile

Vinyl nail-on windows come in two side profiles. A j channel in which the siding can be inserted behind the exterior window trim and a flush or L profile that has no return. In the following window/wall assembly mockup, an 18"x 64" L channel nail-on vinyl window frame<sup>5</sup> is inserted into a 37<sup>1</sup>/<sub>2</sub>" x 83<sup>1</sup>/<sub>4</sub>" wall mockup.

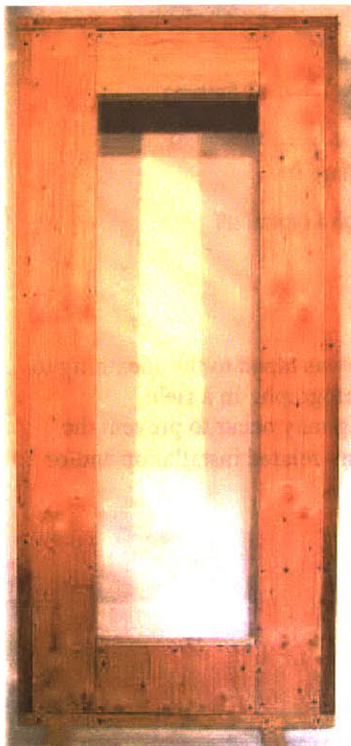


Figure 3-8 constructed mockup

The mockup is framed in 2 x 3 dimensional spruce and sheathed with 16/32 " plywood. The window rough opening (R.O.) is 19"x 64 1/2". The mockup was constructed using drywall screws so that it can be disassembled at the end of the study.

The w-Flashing construction sequence was photographed on October 24, 2003. A space was sheeted off using Tyvek housewrap as a backdrop and photos were taken with an Olympus C-740 digital camera. The images were saved as JPEG files. The mockup was lit using 3 120V/300W LowelTOTA-light lamps.

Post photo manipulation was done using Adobe Photoshop 6.0 and was limited to cropping, and altering the JPEG image's color brightness and contrast manipulation. The background shadows cast by the mockup onto the Tyvek sheet was left in the image.

For document consistency, all images were sized with a 3" width and printed at a resolution of 150 pixels/inch for publication.

<sup>5</sup> Harvey Industries, Waltham Massachusetts, provided the window frame. The author would like to thank Harvey Industries for their support of this project.

## Weather-Resistant Barrier (WRB) Applied after the Window Installation – w-Flashing Applied to the Mounting Flange

Note 1 - Asphalt felt or housewrap can be used in this installation. In either case, the window and w-flashing are installed before the WRB.

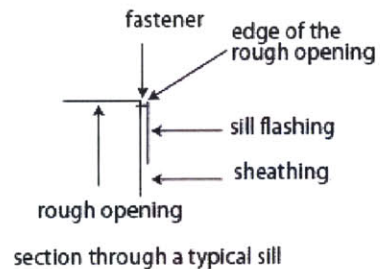
Note 2 - Using the cut formulas found in ASTM E2112-01 and with a w-Flashing width of nine (9) inches, the sill w-Flashing is 37", the jamb flashings are 81<sup>1</sup>/<sub>2</sub>" and the head flashing is 39".



### Step 1: Drainage through the Sill

*Using a flat piece of flashing:*

Cut the sill flashing eighteen (18) inches (480 mm) longer than the width of the window's rough opening. Center the horizontal sill flashing on the rough opening and apply it level with the rough opening's top edge. Fasten the sill flashing to the wall assembly with staples or other appropriate fasteners. Do not apply a fastener within two inches of the window jamb.



Note 3 - The flashing was taped to the sheathing to keep it flat for the photograph. In a field installation, this taping may occur to prevent the flashing experience any related installation and/or wind damage.

Figure 3-9 w-Flashing installation sequence - step 1



### 3.1.1 Modifying the w-Flashing Sill Detail to Allow Water Passage

If the installer opts to use w-Flashing instead of a flat piece of flashing in this instance, there are three methods that can be used. The first method is to cut the w-Flashing along the fold between sheets 1 and 2. This act would create a flat sheet of flashing and the installation sequence would be similar to the one described above.

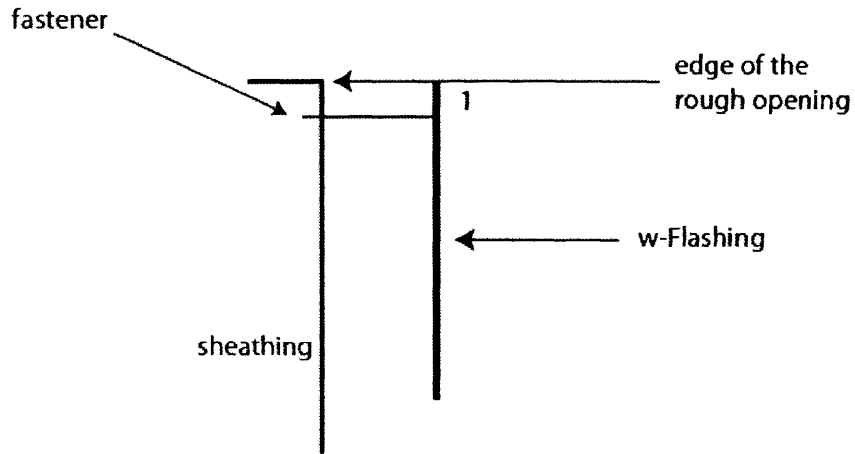


Figure 3 - 10 w-Flashing Sill Method 1

The second method installs the w-Flashing along the sill by pressing sheets 2-4 against the sheathing with sheet 1 facing the exterior. Effectively, this technique installs the w-Flashing backwards. The w-Flashing is oriented so that the fold between sheets 1 and 2 is positioned along the edge of the rough opening. A fastener is driven through sheets 2-4. No fastener is driven through sheet 1. Using this technique, sheet 1 is a continuous drain plane covering sheets 2-4. It is up to the installer as to whether he or she uses the adhesives to attach sheet 2 to 3 and sheet 3 to 4.

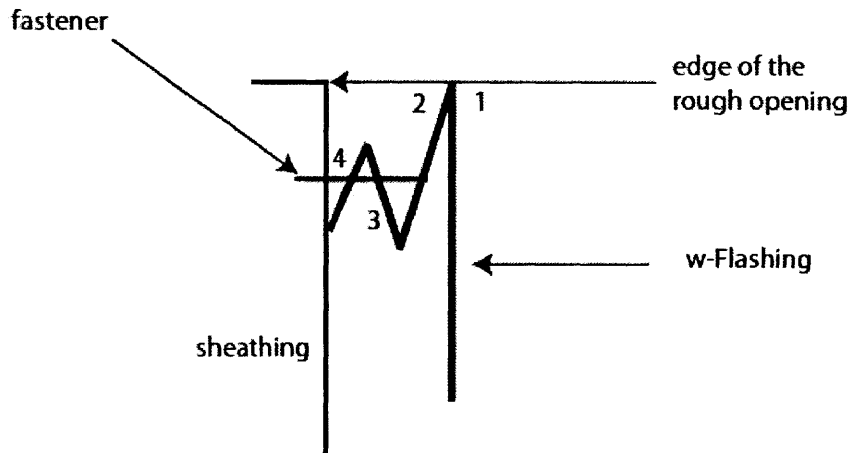


Figure 3 - 11 w-Flashing Sill Method 2

The third method installs the w-Flashing by fastening sheet 1 against the sheathing with the fold between sheet 1 and 2 oriented along the edge of the rough opening. The w-Flashing is then being pulled taut and the adhesive strip along the underside of sheet 4 is attached to sheet 1. This action would remove the fold between sheets 3 and 4 creating a flat surface from sheet 2 to 4.

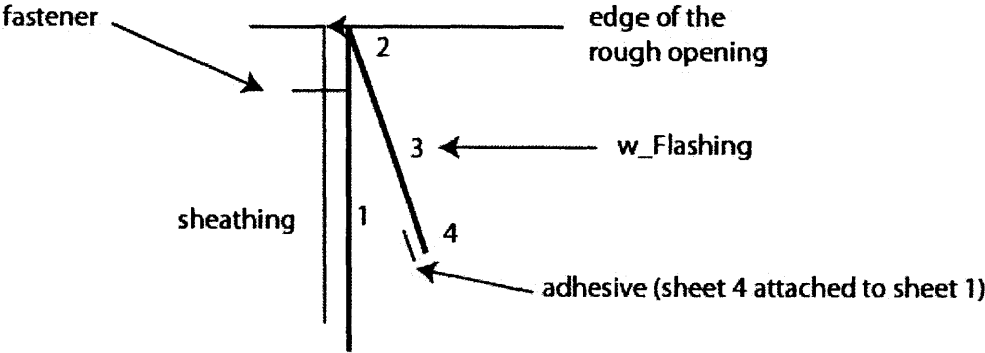
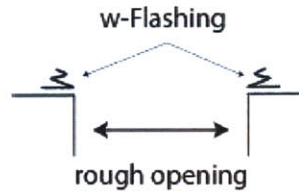


Figure 3 - 12 w-Flashing Sill Method 3

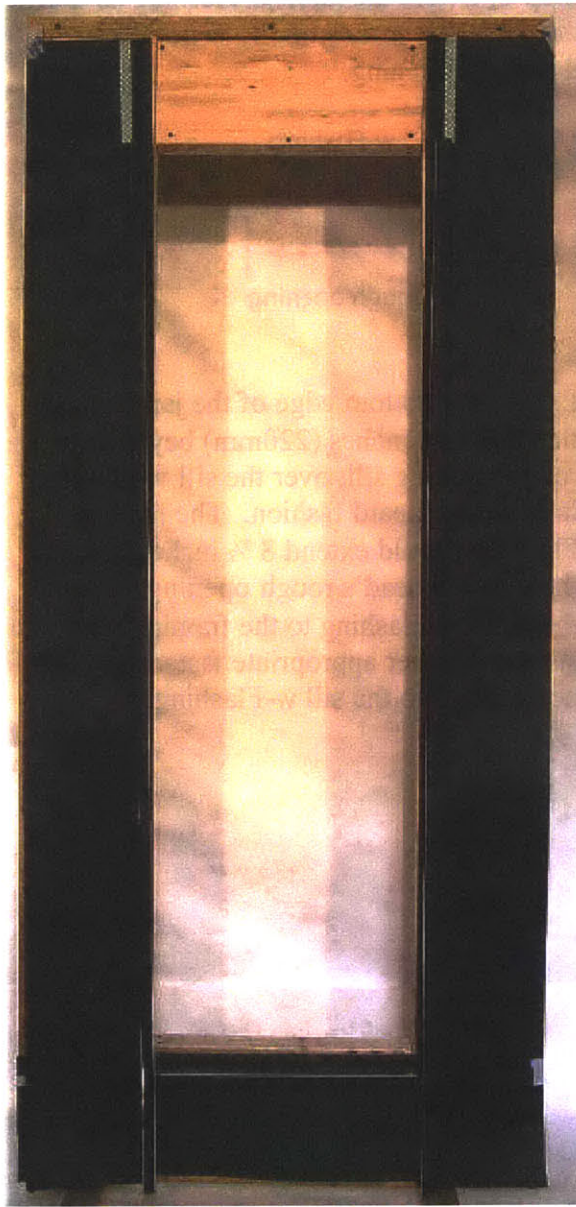


Step 2: Orient the jamb w-Flashing so that the folds that makes up the w point toward the rough opening.



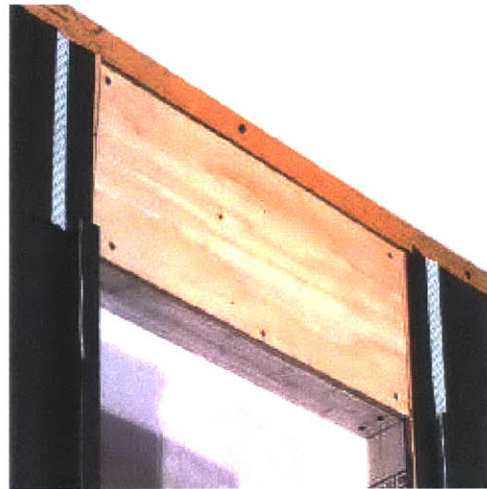
Extend the bottom edge of the jamb w-flashing 8-½ inches (220mm) beyond the rough opening sill, over the sill w-Flashing in a weatherboard fashion. The jamb w-Flashing should extend 8 ½ inches beyond the window head's rough opening. Fasten the jamb w-Flashing to the framing with staples or other appropriate fasteners. Do not staple into the sill w-Flashing.

Figure 3-13 w-Flashing installation sequence – step 2



**Figure 3-15 w-Flashing installation sequence – step 3**

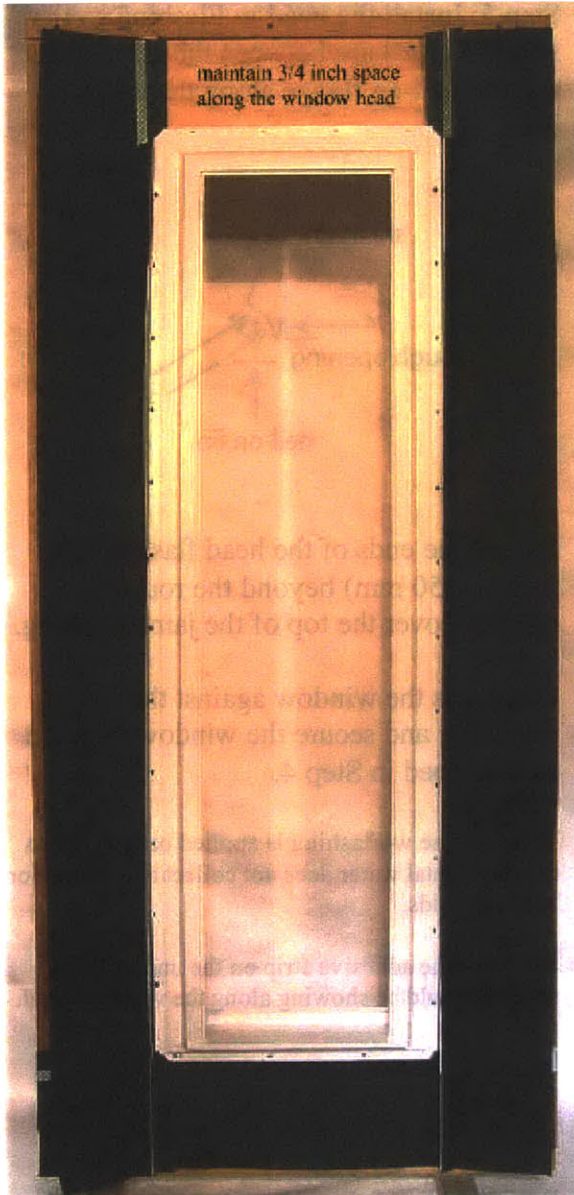
Step 3: Cut sheets 1, 2 and 3 of the jamb w-Flashing in-line with the horizontal edge of the rough opening along the window head. Keep the cut in-line with the intersection of the head and jamb rough opening.



**Figure 3-14 jamb – head detail – step 2**

Attach the adhesive strip on the underside of sheet 4 to sheet 1 on the flap above the rough opening. Complete this exercise for both sides of the window jamb.

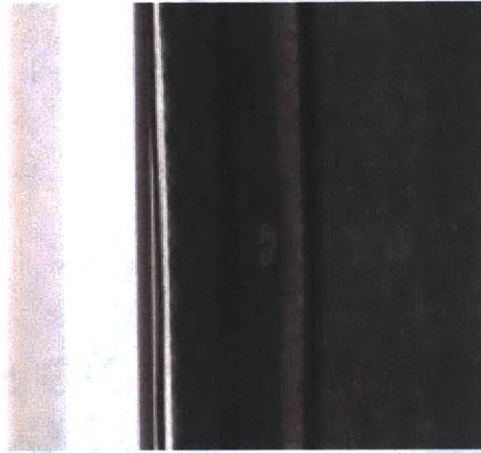
Note 4 - This operation is equivalent to method 3 for the w-Flashing sill Method 3.



**Figure 3-17 w-Flashing installation sequence – step 4**

Step 4: Insert the nail-on window in the rough opening. Place the nail-on fin between sheets 2 and 3 along the jambs. Shim as required.

Fasten the window in place through sheets 1-3. Do not fasten sheet 4 to the mounting flange.

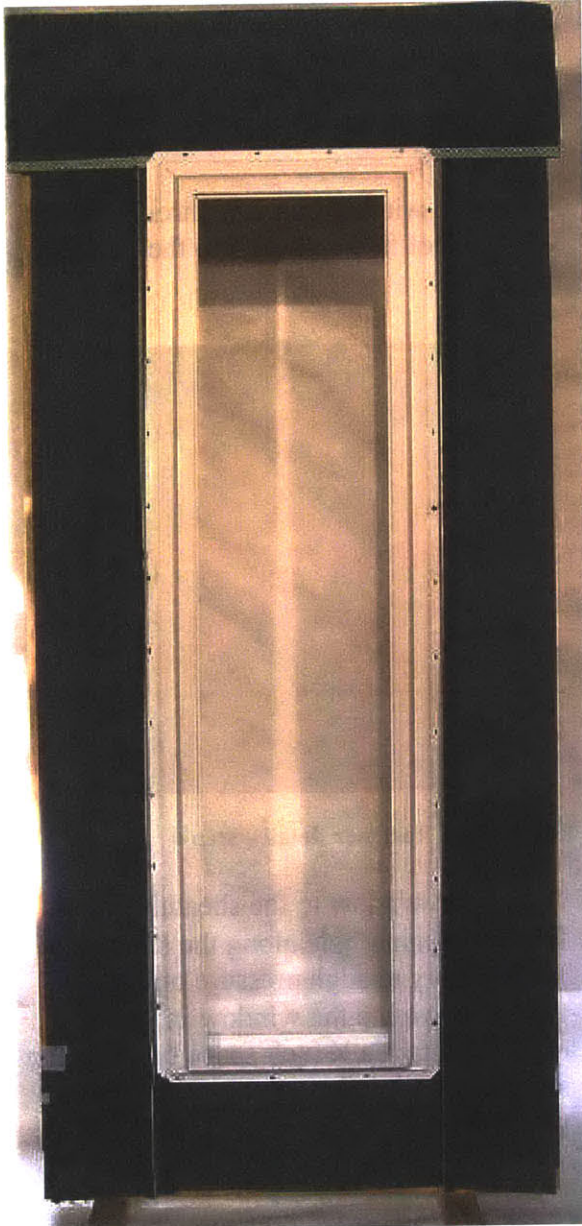


**Figure 3-16 fastener detail – step 4**

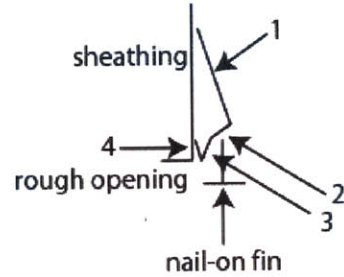
Fasten the window to the sheathing every fourth fastening hole along the sill and jamb. Apply enough pressure on the fasteners to keep the window in place only. Maintain a  $\frac{3}{4}$  inch space between the sheathing and nail-on flange along the window head.

Note 5 - The w-Flashing is installed so that the nail-on fin is between sheets 2 and 3. A fastener is then inserted through sheet 3 into a pre-punched fastener hole in the nail-on fin, and through sheets 1 and 2 as it contacts the sheathing. The fasteners are installed as per the window manufacturer's specifications. Sheet 4 is not secured at this point in time, but is made ready to accept the WRB.

*Author note:* In practice, it would be difficult if not impossible for the installer to fasten the w-Flashing through each pre-punched hole because the w-flashing material will be opaque. This being the case, the w-Flashing could be manufactured with a fastener spacing on the material. This issue would have to be resolved after discussions with the window manufacturers.



Step 5: Install the head w-Flashing so that sheets 3 and 4 are between the sheathing and the nail-on flange along the window head.



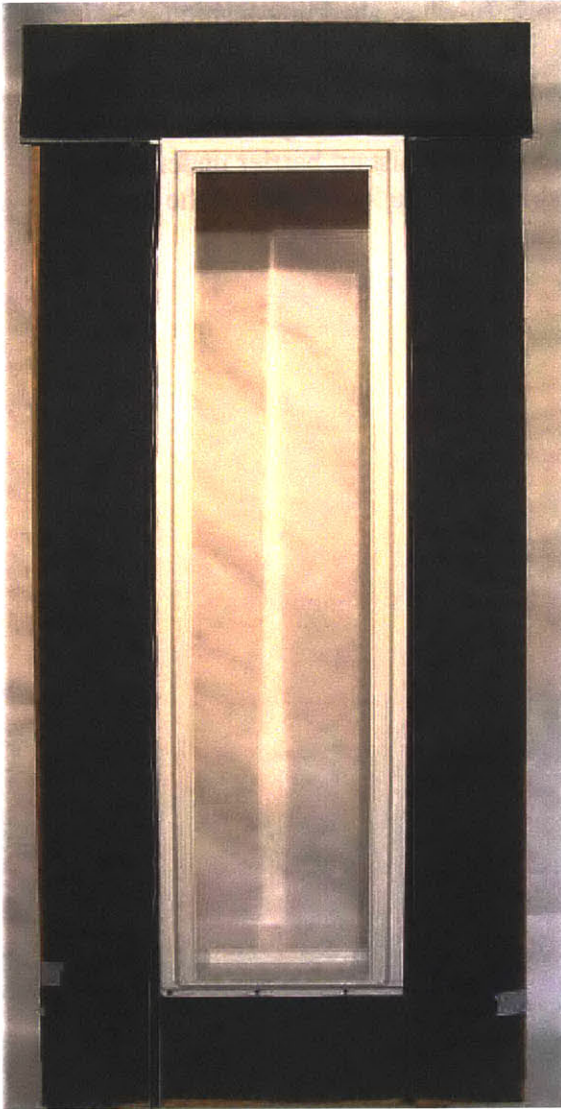
Extend the ends of the head flashing 10 inches (250 mm) beyond the rough opening, over the top of the jamb flashing.

Compress the window against the sheathing and secure the window in place as described in Step 4.

Note 6 – The w-Flashing is applied backwards so that incidental water does not collect at the junction between folds.

Note 7 - The adhesive strip on the underside of sheet 3 should be showing along the window head.

Figure 3-18 w-Flashing installation sequence – step 5

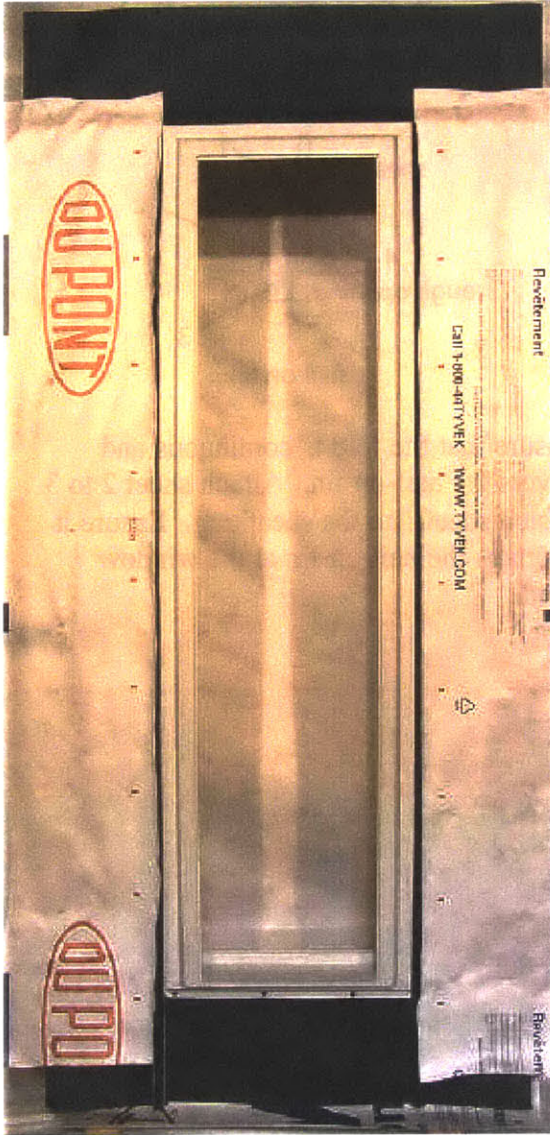


Step 6: Fold sheet 2 over the nail-on fin along the window head.



Ensure that the fold is continuous and covers the nail-on fin. Attach sheet 2 to 3. Fasten sheet 1 to the sheathing. Ensure it overlaps the nail-on fin at the window head.

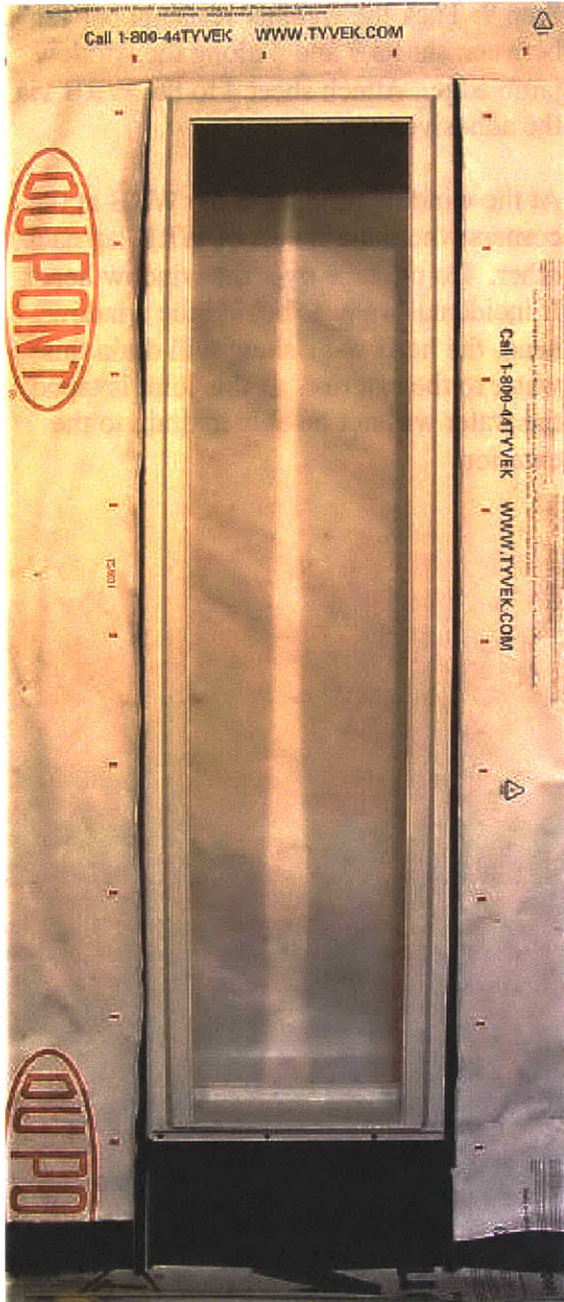
Figure 3-19 w-Flashing installation sequence – step 6



Step 7: In water shedding fashion, starting at the base of the wall and working toward the top, install the weather resistant barrier to the face of the sheathing. At the sill, tuck the weather resistant barrier under the sill flashing and the loose ends of the jamb flashing.

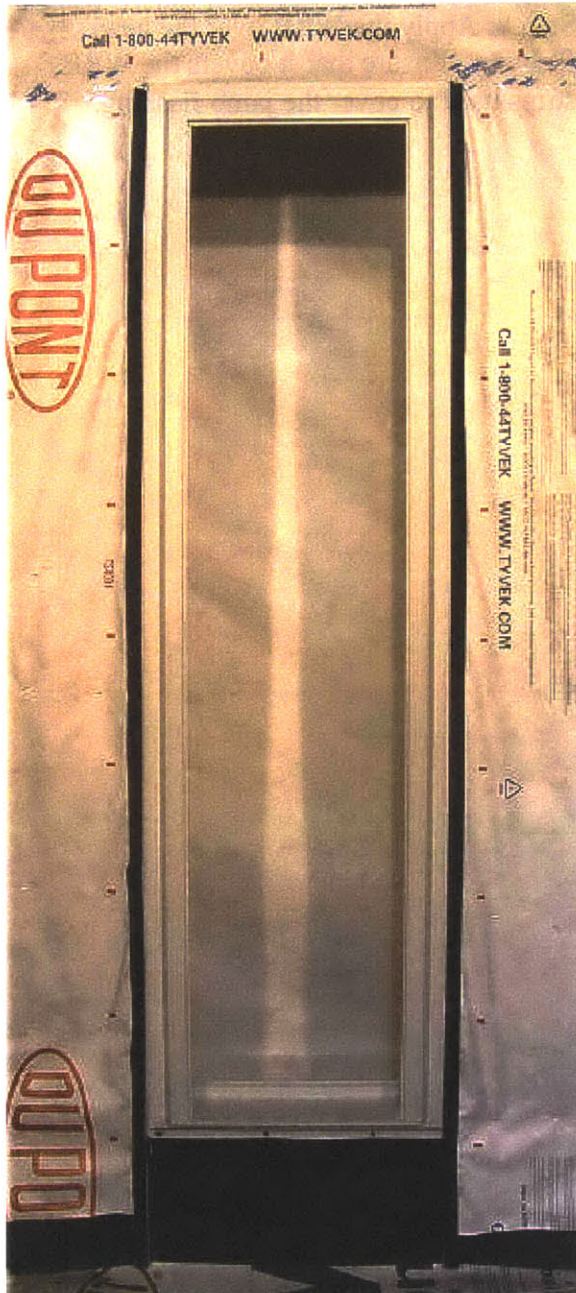
**Figure 3-20 w-Flashing installation sequence – step 7**





Step 8: Apply the WRB over the head flashing. Ensure that it covers the WRB strips used to cover the jamb flashing.

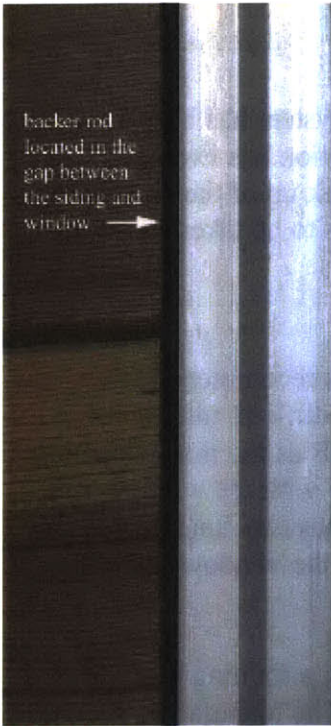
Figure 3-21 w-Flashing installation sequence – step 8



**Figure 3-22 w-Flashing installation sequence – step 9**

Step 9: Tuck the weather resistant barrier between sheets 3 and 4 along the window jamb edge. Attach sheet 4 to the WRB via the adhesive strip.

At the window head, tape the WRB at the corners where the sheets of WRB lap each other. Do not tape over the window head. If incidental water is behind the window head, the head w-Flashing will drain this water to the exterior. If this joint is taped, the water will not be able to drain to the exterior.



Step 10: Ensure that the bond breaker is visible and is located next to the window frame edge extending from the edge a 1/8". If not, make the appropriate correction by moving sheet 4. Nail the siding in place. Caulk the butt joint between the window frame and the siding.

**Figure 3-23 w-Flashing installation sequence – step 10**

### 3.2 A Critique of the w-Flashing System

Up to this point, an idea for a one-piece window seal + flashing system has been described and shown how it would be installed in place. This section has two parts. The first part describes four areas of concern that arose during the work up of the construction sequence. The second part presents an overview of the next steps to be taken in the w-Flashing's design development.

#### 3.2.1 Installation Concerns

w-Flashing is a more complicated installation than the techniques recommended in ASTM E2112-01 or in McBride (2002). The reason it is a more difficult installation is that it has to be properly integrated with the window and the WRB as the three elements are attached to the wall. If w-Flashing is not integrated correctly with the window and WRB, it will not work. On the other hand, w-Flashing incorporates two functions in one product. Its use eliminates the need to seal the lap joint between the window and wall with a sealant.

Installers would need to be trained to install w-Flashing correctly, a training cost that would need to be borne by both the manufacturer and installer. The manufacturer would need to develop the appropriate training materials (e.g. manuals, videos). The installer would have to commit the time to learn these techniques (i.e. class time).

As a result of this reality, industry inertia against this idea can be expected. It will have to be shown that w-Flashing is indeed a better idea than present practice before the industry's players can be expected to use the product. "All roads point" to the next step. This idea must be developed into a tested, viable product.

As part of this development, four concerns about the installation of the product are described. These four concerns are:

- 1) the relationship between the w-Flashing design and the rough opening;
- 2) how best to install the window into the sheathing through the w-Flashing;
- 3) the interface between the head flashing and the weather resistant barrier; and
- 4) the time it takes to complete a proper installation

##### 3.2.1.1 The Relationship Between the w-Flashing Design and the Rough Opening

The w-Flashing design used in the mock up was fitted for the window frame only. In this case, for a Harvey Industries window having the following window profile.

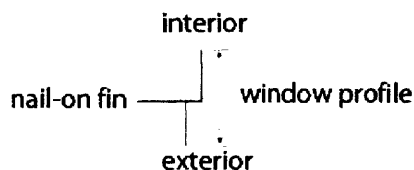


Figure 3 - 24 Harvey Industries, Inc. vinyl nail-on window side profile

Based on this window profile, the dimensions for the w-Flashing were sheet 1 equal to 9", sheet 2 equal to 1 ¼" and sheets 3 and 4 equal to 1".

As designed, the w-Flashing did not compensate for the rough opening when the fold pattern was developed. This oversight resulted in two conditions. Initially, the nail-on fin was not covered. Once the asphalt felt sheet was refolded to compensate for this deficiency, the resulting assembly was taut. One of the operating principles of the w-Flashing is that because of its fold design, it can compensate for any expected thermal or structural related movement. Slack or give is a requirement of the assembly, if there is no give in an installation, the assembly cannot be expected to perform as intended. As a result, a premature failure of the w-Flashing system can be expected because of this "field fix".

In practice, the window will not be installed into the wall without a rough opening. The rough opening is typically ½" greater than the window width at each jamb and ½" greater than the window height at the head (McBride, 2002). To compensate for this rough opening, and provide the w-Flashing with the required amount of give, the assembly can be re-designed by adding ½" to each sheet. This would result in a w-Flashing assembly with sheet 1 being 9", sheet 2 equal to 1¾" and sheets 3 and 4 1½" long.

At the same time, the assembly can be installed ½" beyond (i.e. proud or strong) to the edge of the rough opening.

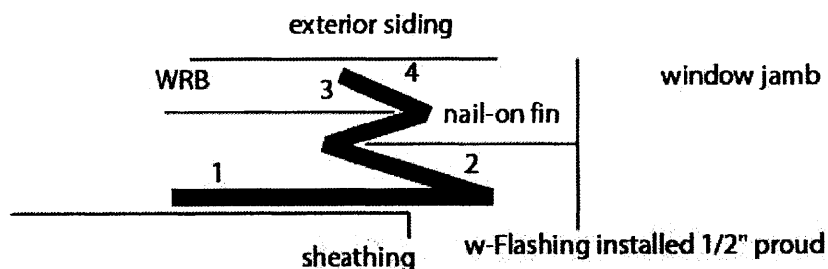


Figure 3-25 w-Flashing installed 1/2" proud in the rough opening

Ultimately, the w-Flashing manufacturer has no control over what the actual rough opening dimensions will be for a particular window. Given that the nail-on flange is a known dimension and the rough opening cannot exceed this overall dimension if the window is to be installed in the wall, from the perspective of the w-Flashing manufacturer, the individual sheet lengths can be sized so it is the nail-on fin dimension for the given window (i.e. 9"sheet + fin length + 1 1/8"). The 1 1/8" dimension assumes that the nail-on fin must cover the rough opening by 1/8" to be fastened in place.

For this idea to work, two conditions must occur. First, the manufacturer must make different w-Flashing profiles to use with each of the available vinyl windows. On the w-Flashing package, the manufacturer would need to state what windows could be used with the given profile. Second, when installing the w-Flashing, the installer must first measure the rough opening width, subtract the window width and divide this value by 2. This number will tell the installer how far beyond the rough opening edge the first fold

(between sheets 1 and 2) must be fastened. Needless to say, this recommendation is complicated and demands coordination between the installer, window supplier, w-flashing supplier and retailer.

Another solution to this problem could be to reduce the field installation component to installing an integrated window/w-Flashing assembly in place (K. McCluskey, 2003 personal communication). From the installer's perspective, this would be no different than existing practice. The innovation would occur in the window manufacturer's assembly plant.

The manufacturer would attach the w-Flashing in place using the cut formula of the window dimensions + 1 1/8" and adhering to the overlap principle described in the construction sequence. Window manufacturers will be consulted about the feasibility of this idea.

### 3.2.1.2 How Best to Install the Window into the Sheathing Through the w-Flashing

The present installation sequence suggests that the w-Flashing be pinned through sheets 1-3 at the same interval used to secure the window to the wall. In the present case, this was every 5".

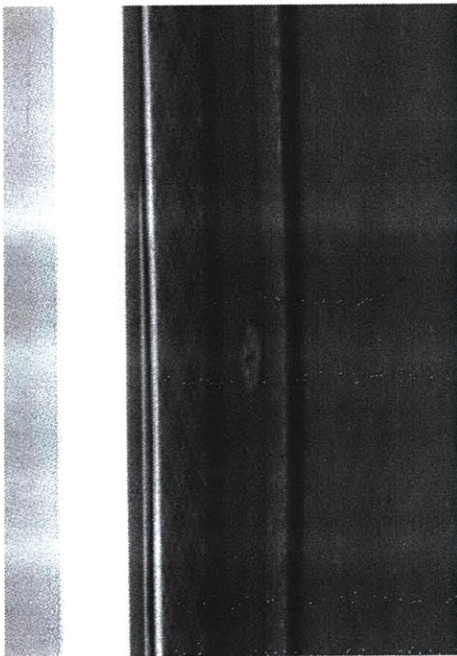


Figure 3-26 pinning the w-Flashing

Three issues are identified with this proposed installation technique. The first is whether w-Flashing pinned through sheets 1-3 would be able to compensate/respond to thermal and structural stress as suggested in the initial design statement. Specifically, does the act of pinning the w-Flashing through sheets 1-3 inhibit its ability as a weather seal as the window/wall system strains due to thermal and structural stressors.

The second question is how does pinning sheets 2-3 between the nail-on fin affect the long term durability of the connection. Is a stress concentration created that results in premature tearing of the w-Flashing.

The third question that arises from this installation is whether it is a potential point of incidental water intrusion. This would occur if the window deflects/moves relative to the wall and over time,

and the fastener holes expand. The increased hole diameter would in turn become a potential pathway for incidental water.

As part of any modeling and testing scenario, these questions must be answered. The answers to these questions will aid in determining the appropriate construction sequence but the ultimate material selected for the w-Flashing.

### 3.2.1.3 The Interface Between the Head Flashing and the Weather Resistant Barrier

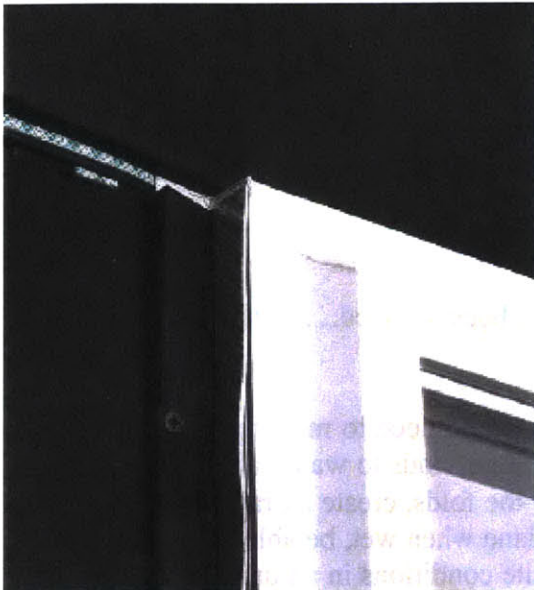


Figure 3-27 head/jamb gap

During the installation mock up, a gap was observed between the head w-Flashing and the jamb w-Flashing. This gap is a result of the inaccuracies associated with cutting the jamb w-Flashing (step 3), using a different installation sequence for the jamb and the head (compare step 4 with steps 5 and 6) resulting in a dimensional offset, a shift in the window installation due to shimming it in place or installing the window in an out of plane rough opening.

Irrespective of the cause, the result is a gap in the w-Flashing systems coverage. Similar to the situation created in the jamb drip tests of chapter 2.0, incidental water can “find its way” to this location.



Figure 3-28 tape as the solution

While the situation could be alleviated either by taping the WRB once it is in place or manufacturing a corner w-Flashing element, the problem remains: what happens to any water that gets behind the WRB?

It is expected that the perimeter window drain plane maintained by the w-Flashing will direct this water back to the exterior.

This expectation has to be tested, but if it doesn't then either the design is faulty, and/or the installation sequence is faulty.

Once again, this question can only be answered via a testing regime.

### 3.2.1.4 The Time it Takes to Complete a w-Flashing Installation

It was noted during the mock up installation sequence that the w-Flashing construction sequence is a more time intensive process when compared to a typical flashing sequence. This additional time is in part due to the novelty of the installation; but without question, additional time is needed (when compared to the typical installation) to ensure that the fit between the w-Flashing system and the window is continuous and flexible enough to compensate for any expected strains and to install the housewrap.

Whether or not this additional time is invested in the job depends on the benefits obtained by completing the work. If it can be shown that the w-Flashing is a better idea, and it saves the builder money through reduced callbacks and provides the homeowner with

peace of mind, then builders may absorb this cost or consumers may be willing to pay more for the product. Only time can answer this concern.

### **3.3 The Next Steps**

The next two steps in w-Flashing's product development are to determine the material used to produce the w-Flashing and the design and implementation of a modeling and testing regime.

#### **3.3.1 Selecting a w-Flashing Material**

At this point in time, a w-Flashing material has not been selected. Asphalt felt was used as a surrogate w-Flashing material in this study.

The eventual material selected for the w-Flashing would need to meet the following performance specification. The material must be impervious to water, able to be folded, able to withstand tearing and the stress created by the folds, create a drain plane when the material is both dry and wet, maintain the drain plane when wet, be able to be produced and packaged cost effectively, able to withstand site conditions in an uninstalled state (i.e. inadvertent wetting and drying), recyclable, made with a minimum amount of embodied energy, and benign (i.e. safe to the installers, compatible with the other products installed in the wall and does not cause any adverse performance issues (i.e. staining)).

It is expected that two to three material candidates will be identified. These materials will then be compared using the above specification. At this point in time, no weighting to the different performance attributes has been determined. Part of the material selection process will be consulting different industry players to determine how the performance attributes mentioned above should be ranked relative to each other.

#### **3.3.2 Modeling and Testing the w-Flashing's Performance**

Once a material for the w-Flashing has been selected, the assembly will be tested to determine if it meets its performance expectations. Like the work done in chapter 2.0, a series of verifiable, repeatable tests must be developed/selected and done. These tests are not done in this study, but are the project's next steps.

The issues to be tested include whether the w-Flashing is adversely stressed and/or will leak due to a proposed installation technique, how it performs as part of a window/wall system subject to wind driven rain, thermal cycling, and deflection and how well the assembly performs relative to installer inaccuracies (i.e. fastener "pops", inadvertent tears, improper installation (e.g. when it is installed in a rough opening that is out of plane)).

To answer these questions, two types of tests will be done. Point of Failure Tests, similar to the Jamb Drip Test will be designed to obtain a better understanding of the component's limits of performance. For example, what amount of strain is required to cause a plastic deformation in the selected material and subsequent failure of the folds? How does the attachment pattern of the w-Flashing affect its ability to adjust to changes in its environment?



The second type of tests will focus on the performance of the whole window/wall assembly under wind driven rain conditions, pressure differentials and thermal cycles. These tests will answer questions about the effectiveness/concerns with the proposed installation sequence as well as the sensitivity of the w-Flashing to installation errors.

#### **4.0 Conclusions and Recommendations**

The idea for the thesis began with the question of whether the window jamb flashing was needed when a vinyl nail-on window was being installed into a wall. The answer to this question started with a review of ASTM E2112-01. ASTM E2112-01 is one example of a recommended residential vinyl nail-on window installation practice. Other recommended practices can be found in McBride (2002) and JLC (2003). In these last two examples, these practices can be considered to represent the publisher's recommendation of the two leading residential industry construction magazines: Fine Homebuilding and the Journal of Light Construction.

Each of these recommended practices include the use of a jamb flashing or spline in their details. However, there was no reason given for including the jamb flashing in the detail. In chapter 1, the argument was made that the inclusion of the jamb flashing was an artifact from past window flashing practice. Before the vinyl nail-on window was developed, flush fin windows were the norm. These windows did not have mounting flanges and used jamb flashing. The practice was continued when vinyl nail-on windows replaced the fin window as the common residential window in new home construction even though these windows had mounting flanges.

The thesis then determined the in-service performance of the mounting flange as a flashing element for different residential window/wall constructions based on the details of ASTM E2112-01. The Jamb Drip Test was designed to complete this testing exercise. Fourteen tests were done and the results photographed. Water was introduced at a constant rate (125ml/hr for five minutes) via an IV unit at two locations: over the mounting flange and next to the mounting flange at the intersection between the window head and window jamb. Water drip tests were done with non-dyed water photographed under white light and water dyed with sodium fluorescein and photographed under a black light. Based on the experiment's results, the conclusion was that the construction sequence determined whether the jamb flashing was needed, but it is good practice to include a jamb flashing as part of recommended practice.

The thesis presents a recommended practice of sheathing – flashing (spline) – window – weather resistant barrier. This detail is similar to ASTM E2112-01 method B, McBride (2002) and JLC (2003).

The reason this detail is recommended is that the mounting flange's thickness creates a space between the window and sheathing and/or weather resistant barrier. This space in turn creates a drain plane where gravity controls the flow of water within the assembly. Under the influence of gravity, the drain plane collects and directs water out the wall assembly. Since water is flowing next to the mounting flange, a jamb flashing element is needed to prevent the sheathing from getting wet.

When the window is installed prior to the weather resistant barrier, the drain plane is created behind the barrier so that any water that penetrates the barrier due to incidental tears or rips can be directed back out the assembly without compromising the assembly's long-term performance. It was observed as part of the Jamb Drip Test experiments that

the siding acts as a flashing element directing water out when it is pressed against either the weather resistant barrier or the nail on flange.

In conclusion, the vinyl nail-on window brings to a window/wall assembly an internal drain plane due to the presence of the mounting flange that was not present with the flush fin window. To take full advantage of this internal drain plane, the flashing system should be installed prior to the window that is in turn installed prior to the weather resistant barrier. When siding is installed over this assembly, incidental water is directed out the assembly irrespective of whether it is introduced before or after the weather resistant barrier.

An additional step was taken with the work. The question asked was how could the window/wall assembly (i.e. the detail) be improved? Based on conversations with different industry players, the greatest concern with the detail was the use of sealant at the lap joint created when the mounting flange is pressed against the wall. The common concern was that either the sealant would not be installed correctly, or it would not last over the operational life span of the assembly.

This problem was addressed by replacing the sealant with a one-piece material design that sealed the wall with the window. This design, named w-Flashing completed two functions. It sealed the window with the wall, preventing water and air entry along the jamb and head and also provided the recommended flashing element collecting and directing incidental water around the window's perimeter to the exterior. In the recommended installation sequence, the decision was made to not use w-Flashing at the window sill. This recommendation was based on the observation that the window element leaks and the need to create a drain point for this water to move back to the exterior. The thesis ended with a discussion of how to improve the w-Flashing design based on what was noted in the installation sequence as well as future tests to be performed.

It was unpredicted that the thesis would end as it did. Once the initial question was answered, the work took a direction based on what was discovered and what next step needed to be answered. The thesis is no more than a series of connected steps. Each step based on earlier work and tied together through the desire of designing a better window/wall detail.

What was also unexpected was how much I enjoyed doing this work. My hope is to continue developing the ideas introduced in the thesis. I will develop more window/wall design point of failure tests leading to a window/wall design tool. I will also follow through with the w-Flashing idea, developing the prototype into a marketable commodity.

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**Appendix 1.0 ASTM E2112-01 (2002) Recommended Window Installation Methods**


The particular recommended window installation sequence is a function of whether the window is installed prior to, or after the weather resistant barrier (WRB). The installer is asked to reference Table 7 Installation Procedure Selection Chart (Windows) in ASTM E2112-01.

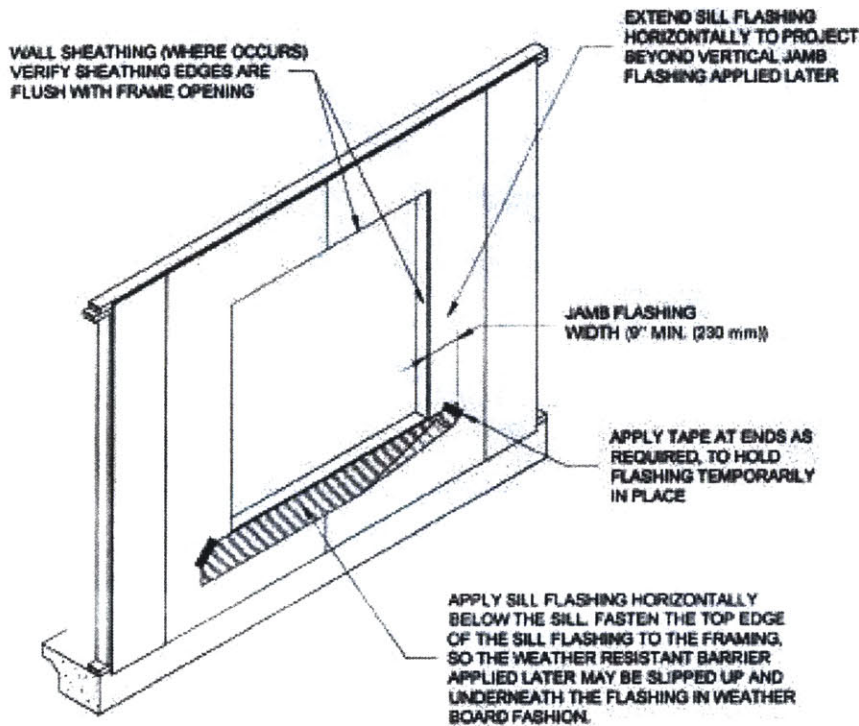
<b>Table 3: ASTM E2112-01 - Table 7 Installation Procedure Selection Chart (Windows)</b>		
Note 1 – Based on windows with integral fins being installed in drainage type wall systems		
	Head and jamb flashing will be applied over the face of the integral mounting flange	Head and jamb flashing will be applied behind the face of the integral mounting flange
Weather resistant barrier is to be applied after window installation	Use Method A	Use Method B
Weather resistant barrier is to be applied prior to window installation	Use Method A1	Use Method B1

Once the window/wall construction sequence is identified for the job in question, Table 7 suggests a particular window installation method depending on whether the head and jamb flashing are applied over or behind the integral mounting flange. The Methods referenced in the chart follow. They are copied verbatim from ASTM E2112-01 (2002).

## A 1.1 Method A: Weather Resistant Barrier (WRB) Applied after the Window Installation – Flashing Applied Over the Face of the Mounting Flange

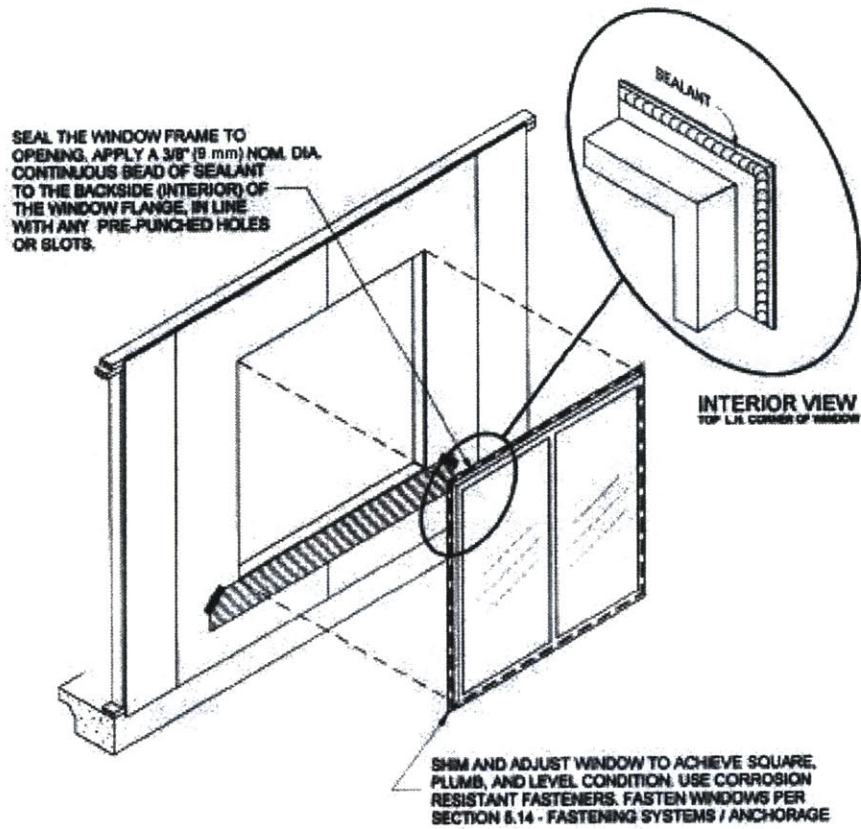
8.1.1.3 .1 Step 1: Apply the horizontal sill flashing material first, level with the top edge of the rough opening. Cut the sill flashing long enough to extend an equal distance beyond the 9-inch (230mm) jamb flashing, which will be applied later. (see figures 14 and 15) Fasten the top edge of the sill flashing to the framing. Place fasteners along the edge of the rough opening where they will be covered by the mounting flange of the window later.

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**NOTE: FOR METHODS "A1" AND "B1" THE WEATHER RESISTANT BARRIER (WRB) HAS BEEN INSTALLED. A FLAP AT THE HEAD OF THE WINDOW HAS BEEN TEMPORARILY TAPED OUT OF THE WAY TO ALLOW FOR FLASHING AND WINDOW INSTALLATION.**

FIG. 14 Sill Flashing (Methods A and B)



NOTE 1—For Method A the weather resistant barrier (WRB) has been installed. A flap at the head of the window has been temporarily taped out of the way to allow for flashing and window installation.

FIG. 15 Window Installation (Method A)



8.1.1.3.2 Step 2: Apply a continuous bead of sealant to the back side (interior surface) of the mounting flange of the window. Sealant selection and bead design shall be in accordance with 5.18 (Sealants – Selection and Use) of the Standard. Immediately set the window into the opening, and apply shims as required to ensure the unit is plumb, level and square. Fasten the window perimeter securely as described in 5.14 (Fastening Systems/Anchorage) of the installation procedures.

Note 21 – Apply the sealant in line with the pre-punched holes or slots on the mounting flange when provided (see figure 15).

8.1.1.3.3 Step 3: Next, apply a continuous bead of sealant to the exposed mounting flange (exterior surface) at the side jambs of the installed window.  
(1) Continue the sealant bead at the jambs vertically 8.5 inches (220 mm) above the rough opening at the head of the window (to the face of the header), to allow for application of the top portion of the jamb flashing into sealant in the next step.

Note 23 – Apply the sealant in line with the pre-punched holes or slots on the mounting flange when provided and over the heads of the fasteners.

(2) For windows with mechanically joined mounting flanges, apply sealant to the full length of the joints or seam where the flanges meet. (see figure 13).

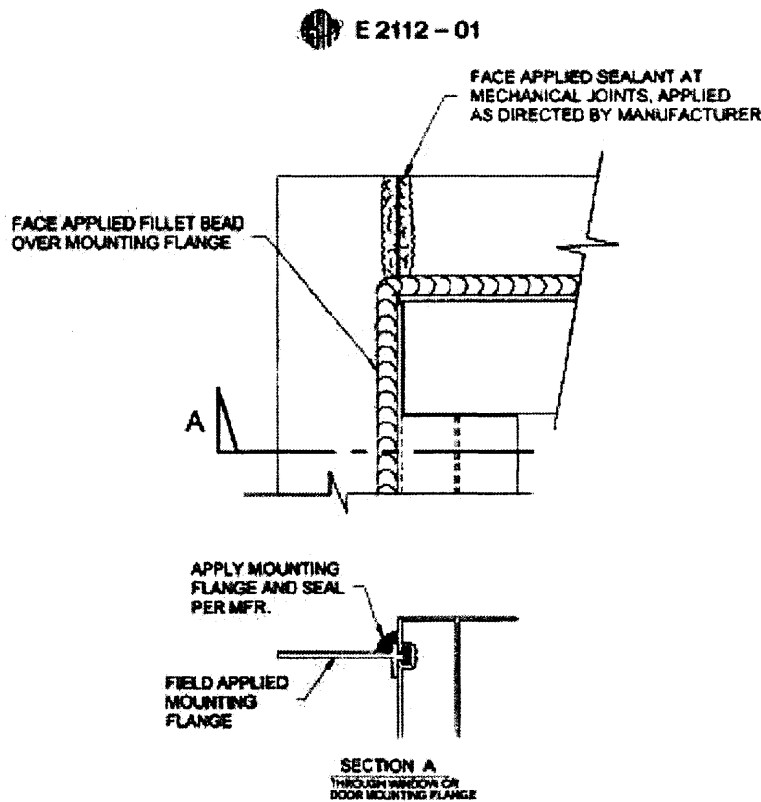
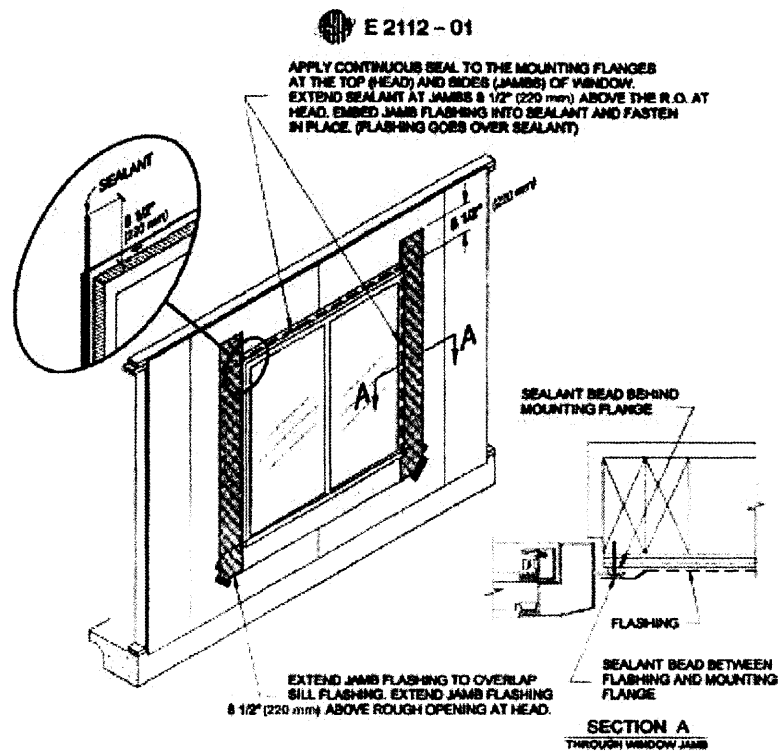


FIG. 13 Applied Flanges and Mechanical Joints

- 8.1.1.3.4 Step 4: Install the jamb flashing next, by pressing the flashing into the sealant beads previously applied to the exterior face of the mounting flanges. Attach the flashing into position to the rough opening framing using staples or other appropriate fasteners. Extend the bottom edge of the jamb flashing 8.5 inches (220 mm) beyond the rough opening sill, and extend the top edge 8.5 inches (220 mm) beyond the rough opening head. (see figure 16).



NOTE 1—For Method A1 the weather resistant barrier (WRB) has been installed. A flap at the head of the window has been temporarily taped out of the way to allow for flashing and window installation.

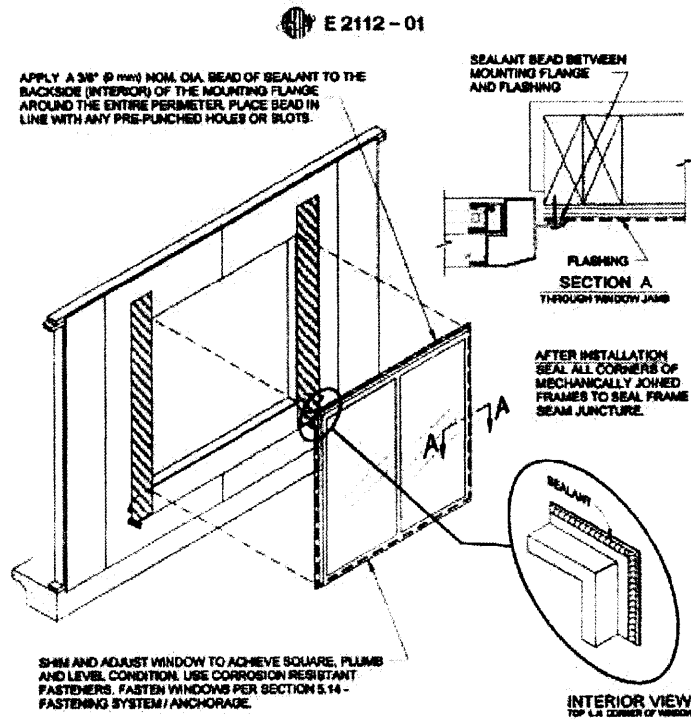
FIG. 16 Jamb Flashing (Method A)

Note 24 – Do not attach the bottom of the jamb flashing until after the weather resistant barrier is applied later.

8.1.1.3.5 Step 5: Next, apply a continuous bead of sealant to the exposed mounting flange (exterior surface) at the head of the installed window.

Note 25 – The application of sealant to the flange is not necessary if using self-adhesive type flashing over the mounting flange.

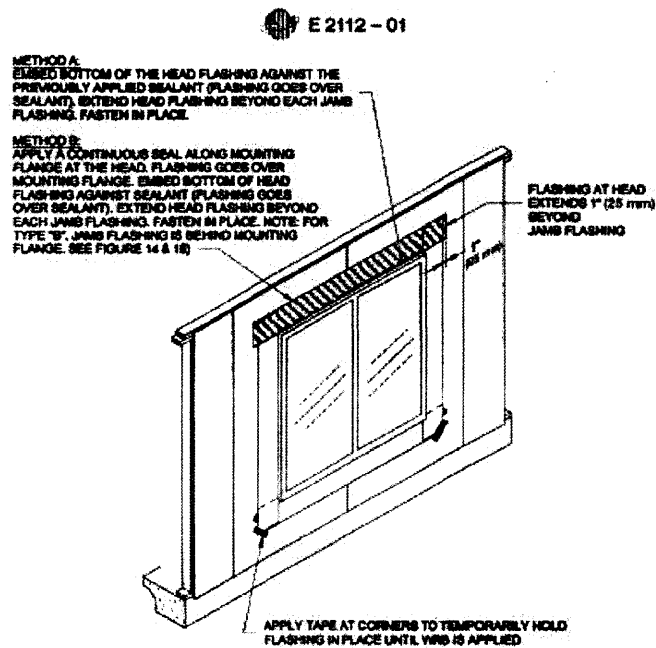
Note 26 – Apply the sealant in line with the pre-punched holes or slots on the mounting flange when provided and over the mounting flange. (see figure 17).



Note 1—For Method B1 the weather resistant (WRB) has been installed. A flap at the head of the window has been temporarily taped out of the way to allow for flashing and window installation.

FIG. 17 Window Installation (Method B)

8.1.1.3.6 Step 6: Install the head flashing by pressing the flashing into the sealant bead previously applied across the mounting flange. When applying the head flashing, press the bottom edge of the flashing into the sealant until the sealant appears. This will ensure that no voids remain between the flashing and the mounting flange. Extend the ends of the head flashing 10 inches (250 mm) beyond the rough opening, over the top of the jamb flashing. Fasten the head flashing in place along the top edge using staples or other appropriate fasteners. (see figure 18). (**Warning** – The building shall be constructed in such a manner to secure or support the flashing to prevent destruction or displacement prior to installation of the weather resistant barrier. The flashing shall never be left unsupported and vulnerable to wind damage.)



Note: 1—For Methods A) and B) the weather resistant barrier (WRB) has been installed. A flap at the head of the window has been temporarily taped out of the way to allow for flashing and window installation.

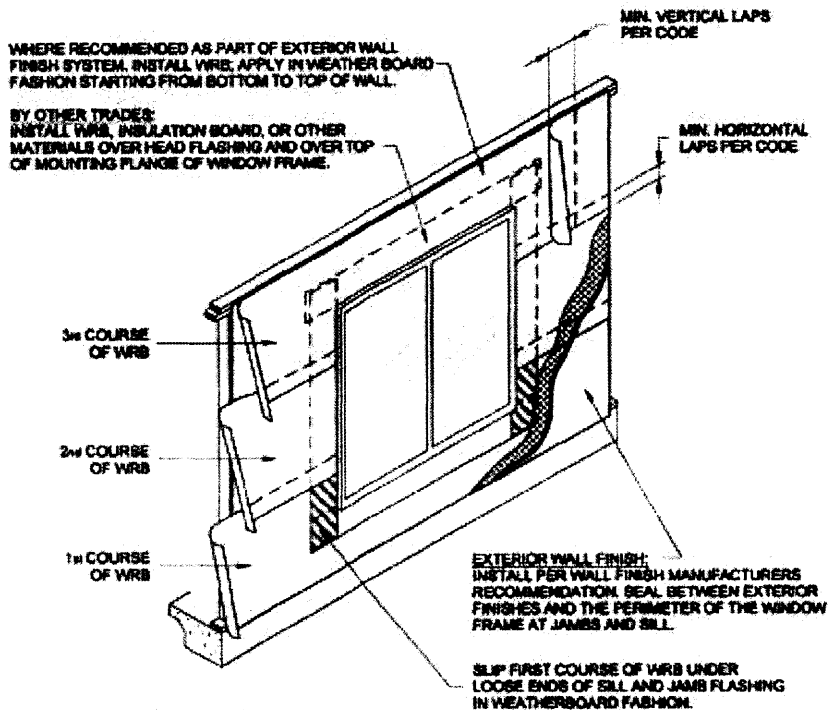
FIG. 18 Head Flashing (Methods A and B)

Note 27 – Where recommended as part of the exterior wall finish system, install the WRB as outlined. The application of the WRB may be by trades other than the window installer. The contractor shall coordinate this work as required.

8.1.1.3.7 Step 7: In water shedding fashion, starting at the base of the wall and working towards the top, install the weather resistant barrier to the face of the building framing or sheathing. At the sill of the window, tuck the weather resistant barrier under the sill flashing and loose ends of the jamb flashing. Next, continue to apply the weather resistant barrier in water shedding fashion over the jamb flashing and over the head of the window. (see figure 19). Attach the WRB into position using staples or other appropriate fasteners.

Note 28 – Whenever applying the weather resistant barrier, flashing or other materials do not penetrate the mounting flange with the fasteners.

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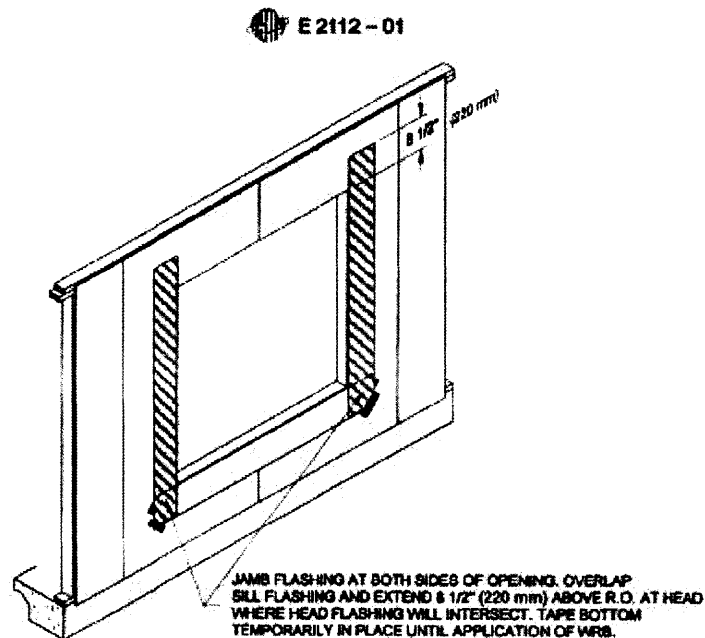


**FIG. 19 Weather Resistant Barrier (WRB) Application (Methods A and B)**

## A 1.2 Method B: Weather Resistant Barrier (WRB) Applied after the Window Installation – Flashing Applied Behind the Face of the Mounting Flange

8.1.1.3.2.1 Step 1: Apply the horizontal sill flashing material first, level with the top edge of the rough opening. Cut the sill flashing long enough to extend an equal distance beyond the 9 inch (230mm) jamb flashing, which will be applied later. (see figure 20). Fasten the top edge of the sill flashing to the framing. Place fasteners along the edge of the rough opening where they will be covered by the mounting flange of the window later.

Note 29 – Do not fasten the bottom edge or the last 9 inches (230 mm) of each end, as the weather resistant barrier will be applied under the flashing in a water shedding fashion later. It is recommended that the corners and bottom edge be temporarily taped at 24 inches (610 mm) on center, to prevent wind damage.




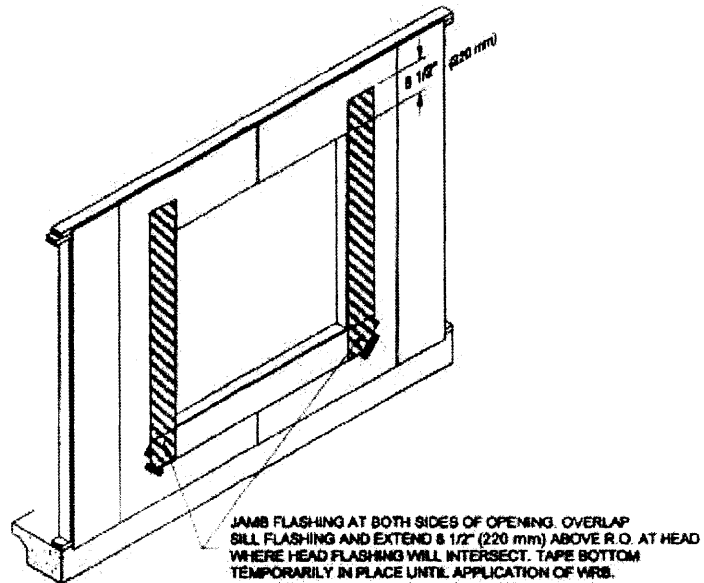
Note: 1—For Method B1 the weather resistant barrier (WRB) has been installed. A flap at the head of the window has been temporarily taped out of the way to allow for flashing and window installation.

FIG. 20 Application of Jamb Flashing (Method B)

8.1.1.3.2.2 Step 2: Apply the jamb flashing to the edge of the framing at each jamb. Place fasteners along the edge of the rough opening where they will be covered by the mounting flange of the window later. Extend the jamb flashing 8.5 inches (220 mm) beyond the rough opening dimension at the head and sill. The bottom end of the jamb flashing is to overlap the sill flashing (2 x Flashing Width) – 1 inch (25 mm).

Note 30 – Do not attach the bottom of the jamb flashing until the weather resistant barrier is applied later (see figure 20).

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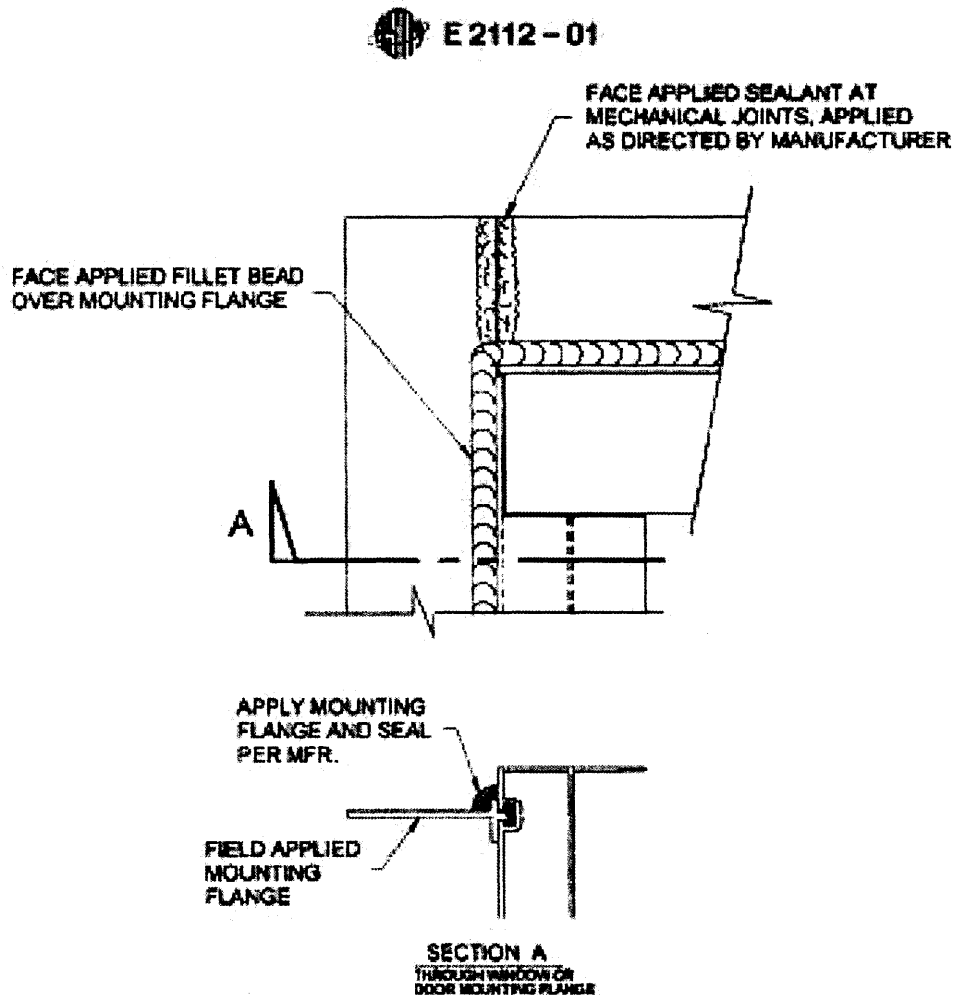
Note: 1—For Method B1 the weather resistant barrier (WRB) has been installed. A flap at the head of the window has been temporarily taped out of the way to allow for flashing and window installation.

FIG. 20 Application of Jamb Flashing (Method B)

8.1.1.3.2.3 Step 3: Apply a continuous bead of sealant around the full perimeter of the back side (interior surface) of the window mounting flange. Sealant selection and bead design shall be in accordance with 5.18.

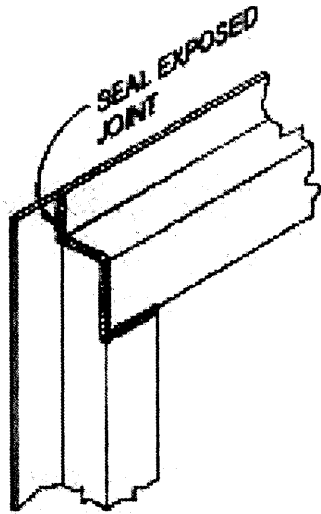
Note 31 – Apply the sealant in line with the pre-punched holes or slots on the mounting flange when provided.

8.1.1.3.2.4 Step 4: Immediately install the window into the opening pressing against the framing to compress the sealant. Apply shims as required to ensure the unit is plumb, level and square. Fasten the window perimeter securely into position as described in 5.14. For windows with mechanically joined mounting flanges, apply sealant to the full length of the joinery or seam where the flanges meet. (see figures 13 and 21).

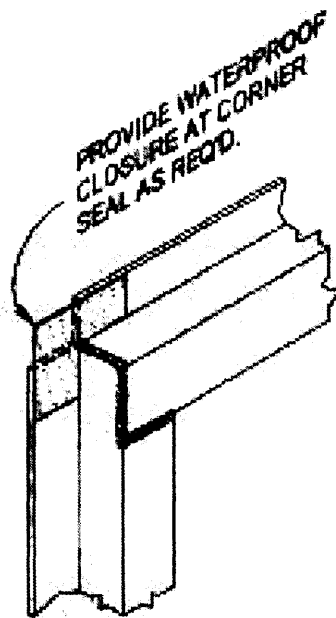


**FIG. 13 Applied Flanges and Mechanical Joints**





**BUTT JOINT**



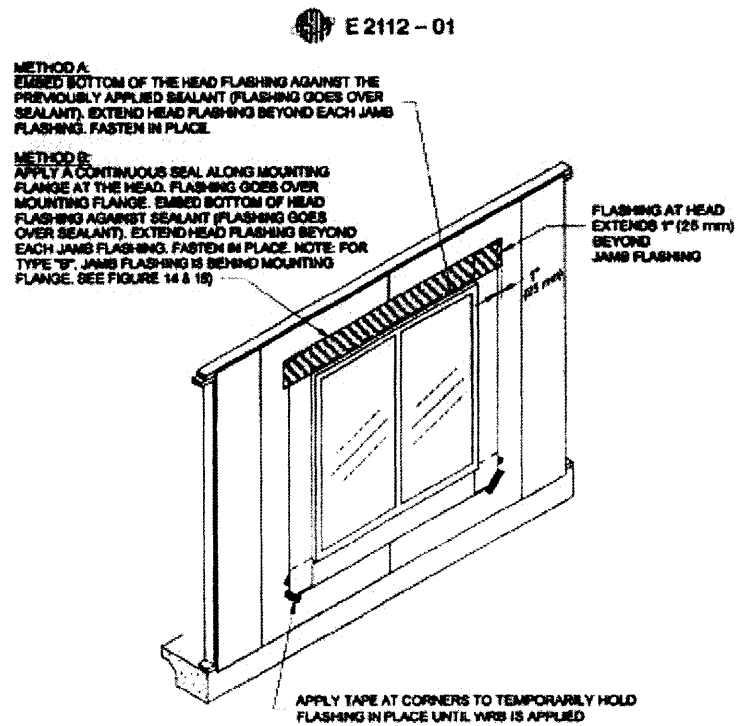
**OPEN ("NOTCHED") CORNER**

**FIG. 21 Common Frame Joints (Head-Jamb)**

8.1.1.3.2.5 Step 5: Apply a continuous bead of sealant horizontally across the face of the exposed mounting flange (exterior surface) at the head of the installed window.

Note 33 – The application of sealant to the flange is not necessary if using self-adhesive type flashing over the mounting flange.


Note 34 – Apply the sealant in line with the pre-punched holes or slots on the mounting flange when provided and over the mounting flange. (see figure 18).

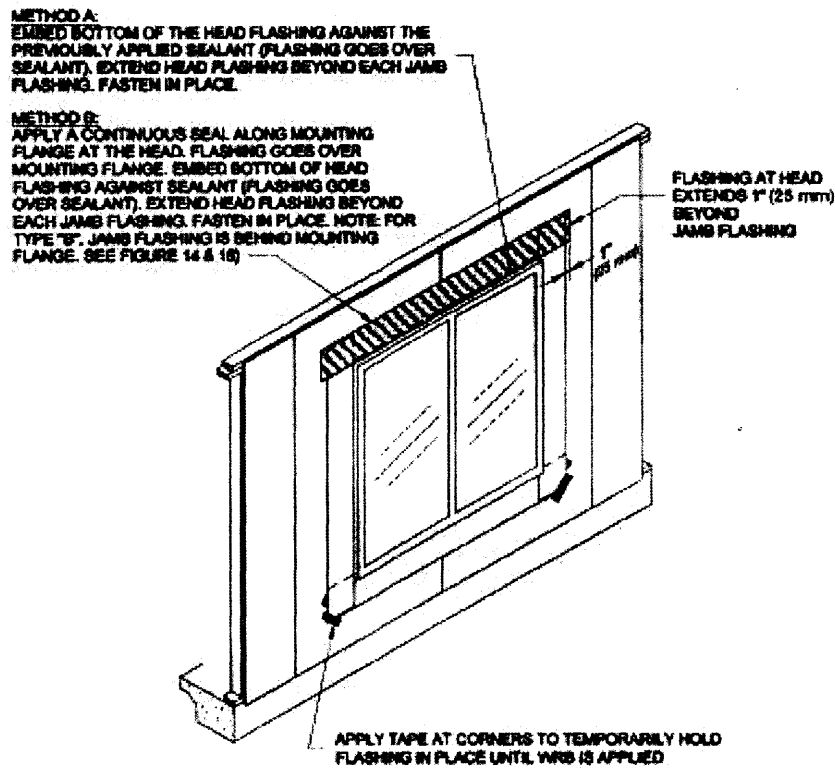


Note: 1—For Methods A) and B) the weather resistant barrier (WRB) has been installed. A flap at the head of the window has been temporarily taped out of the way to allow for flashing and window installation.

FIG. 18 Head Flashing (Methods A and B)

8.1.1.3.2.6 Step 6: Install the head flashing by pressing the flashing into the sealant bead previously applied to the mounting flange. When applying the head flashing, press the bottom edge of the flashing into the sealant until the sealant appears. This will ensure that no voids remain between the flashing and the mounting flange. Extend the ends of the head flashing 10 inches (260 mm ) beyond the rough opening, over the top of the jamb flashing. Fasten the head flashing into place along the top edge using staples or other appropriate fasteners. (see figure 18). (**Warning** – The building shall be constructed in such a manner to secure or support the flashing to prevent destruction or displacement prior to installation of the weather resistant barrier. The flashing shall never be left unsupported and vulnerable to wind damage.)

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Note: 1—For Methods A1 and B1 the weather resistant barrier (WRB) has been installed. A flap at the head of the window has been temporarily taped out of the way to allow for flashing and window installation.

FIG. 18 Head Flashing (Methods A and B)

8.1.1.3.2.7 Step 7: In water shedding fashion, starting at the base of the wall and working towards the top, install the weather resistant barrier to the face of the building framing or sheathing. At the sill of the window, tuck the weather resistant barrier under the sill flashing and loose ends of the jamb flashing. Next, continue to apply the weather resistant barrier in water shedding fashion over the jamb flashing and over the head of the window. (see figure 19). Attach the WRB into position using staples or other appropriate fasteners.

Note 36 – Whenever applying the weather resistant barrier, flashing or other materials; do not penetrate the mounting flange with the fasteners.

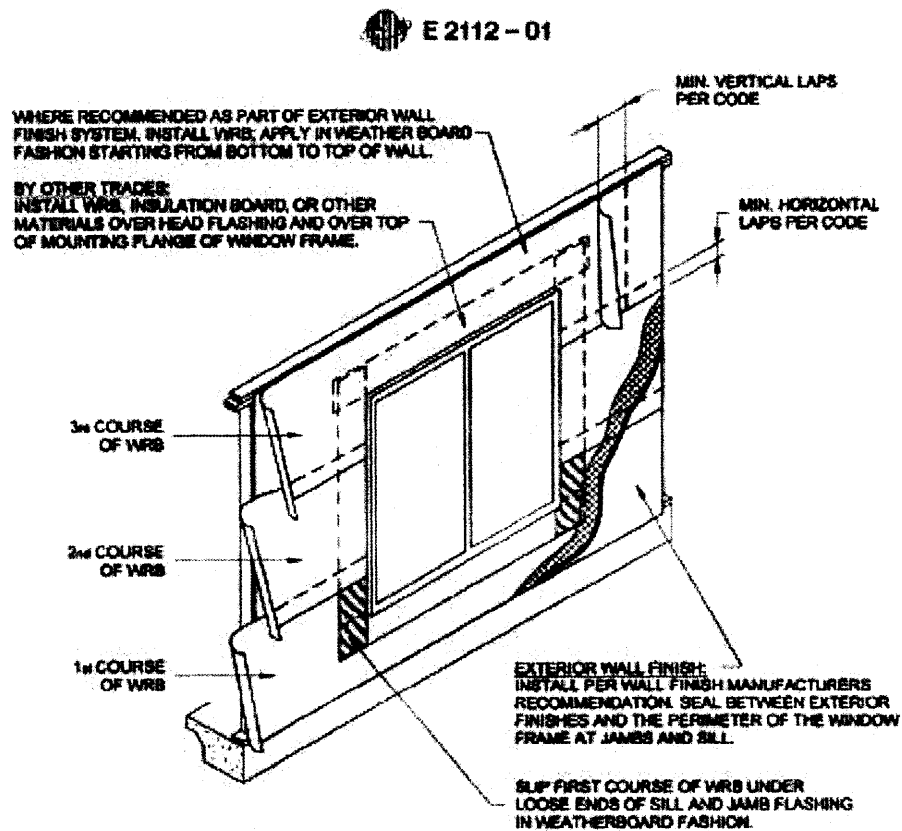
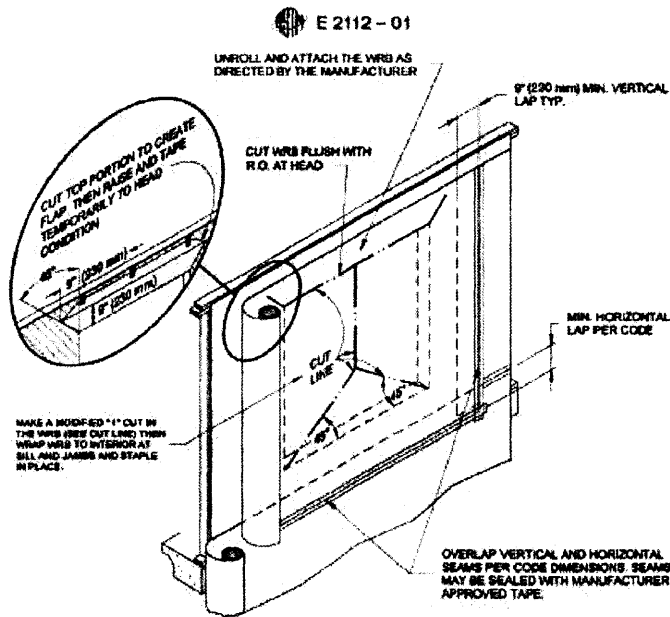


FIG. 19 Weather Resistant Barrier (WRB) Application (Methods A and B)

**A 1.3 Method A1: Weather Resistant Barrier (WRB) Applied Prior to the Window Installation – Flashing Applied over the Face of the Mounting Flange**


8.1.1.3.4.1 Step 1: Where a weather resistant barrier (WRB) is used, apply the WRB in water shedding fashion, starting at the base of the wall and working towards the top. Install the weather resistant barrier to the face of the building framing or sheathing flush with the rough opening of the window head, jamb and sill. At the head of the opening, starting at the top corner of the window, measure from the corner 9 inches (230 mm) up and 9 inches (230 mm) over and mark. At a 45° angle, carefully cut the barrier on a diagonal. Gently raise the top edge of the barrier up and temporarily tape the top corners and center to the exterior weather resistant barrier surface above. This is done in order to allow for installation of the window and flashing later. Once the weather resistant barrier is applied as described in this step, proceed immediately to step 2. Alternatively, you can follow the same procedures as outlined for house wrap type WRB. Where the weather resistant barrier used is a building paper type material and covers the window, carefully cut the barrier in a modified “I” pattern as shown in figure 22. Fold the bottom and side flaps over and behind the interior side of the rough opening. At the head of the opening, starting at the top corner, measure from the corner 9 inches (230 mm) up and 9 inches (230 mm) over and mark. At a 45° angle, carefully cut the barrier on a diagonal as shown in figure 22. Gently raise the top edge of the barrier up and temporarily tape the top corners and center to the exterior weather resistant barrier surface above. This is done in order to allow for installation of the window and flashing later.

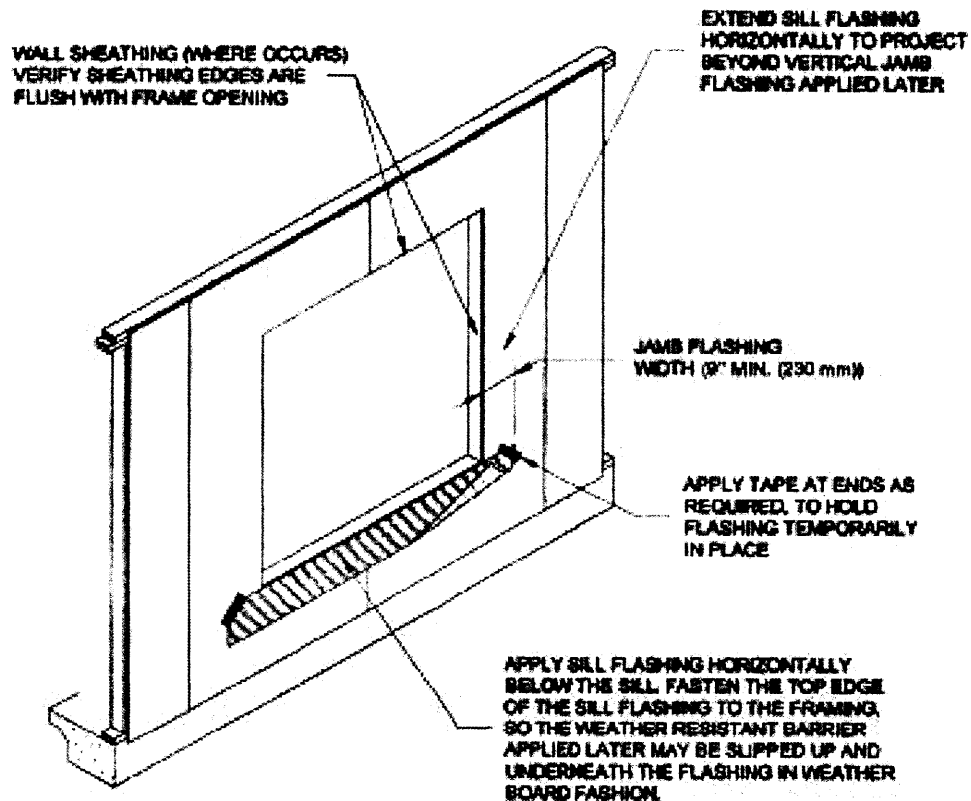


WRB FOR FLOORS OR LEVELS BELOW SHALL BE OVERLAPPED WITH WRB ABOVE IN WEATHER BOARD FASHION.

FIG. 22 Weather Resistant Barrier (WRB)-House Wrap

8.1.1.3.4.2 Step 2: Apply the horizontal sill flashing material next, level with the top edge of the rough opening. Cut the sill flashing long enough to extend an equal distance beyond the 9 inch (230 mm) jamb flashing, which will be applied later. (see figure 14). Fasten the top edge of the sill flashing to the framing. Place fasteners along the edge of the rough opening where they will be covered by the mounting flange of the window later.

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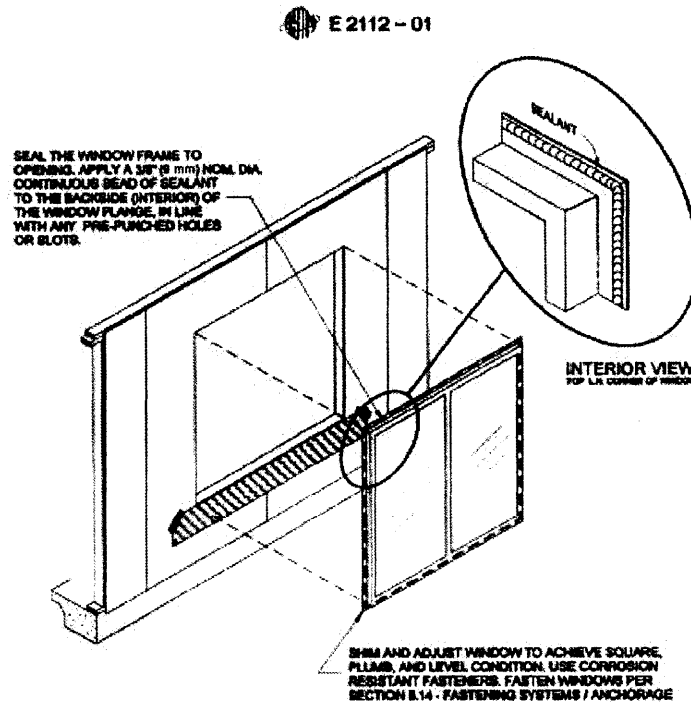


**NOTE: FOR METHODS "A1" AND "B1" THE WEATHER RESISTANT BARRIER (WRB) HAS BEEN INSTALLED. A FLAP AT THE HEAD OF THE WINDOW HAS BEEN TEMPORARILY TAPED OUT OF THE WAY TO ALLOW FOR FLASHING AND WINDOW INSTALLATION.**

**FIG. 14 Sill Flashing (Methods A and B)**

8.1.1.3.4.3 Step 3: Apply a continuous bead of sealant to the back side (interior surface) of the mounting flange of the window. Sealant selection and bead design shall be in accordance with 5.18 of the installation procedures. Immediately set the window into the opening, and apply shims as required to ensure the unit is plumb, level and square. Fasten the window perimeter securely into position as described in 5.14.

Note 37 – Apply the sealant in line with the pre-punched holes or slots on the mounting flange when provided (see figure 15).



Note: 1—For Method A1 the weather resistant barrier (WRB) has been installed. A flap at the lead of the window has been temporarily taped out of the way to allow for flashing and window installation.

FIG. 15 Window Installation (Method A)

8.1.1.3.4.4 Step 4: Next apply a continuous bead of sealant to the exposed mounting flange (exterior surface) at the side jambs of the installed window.

Note 38 – The application of the additional bead of sealant to the flange may not be necessary if using self-adhesive type flashing over the mounting flange, as long as the flashing securely adheres. Some flashing manufacturers may require the use of primer materials to help facilitate the bonding of various substrates. When using sealant near self-adhesive flashing, do not use sealant that contains solvent. Always consult with the flashing supplier to determine compatibility with various installation materials and to obtain specific installation instructions. Refer to 5.12.3.1.2,

- (1) Continue the sealant bead at the jambs vertically 8.5 inches (220 mm) above the rough opening at the head of the window (to the face of the header, to allow for application of the top portion of the jamb flashing into sealant in the next step.

Note 39 – Apply the sealant in line with the pre-punched holes or slots on the mounting flange when provided and over the heads of the fasteners.

- (2) For windows with mechanically joined mounting flanges, apply sealant to the full length of the joints or seam where the flanges meet. (see figures 13 and 21).

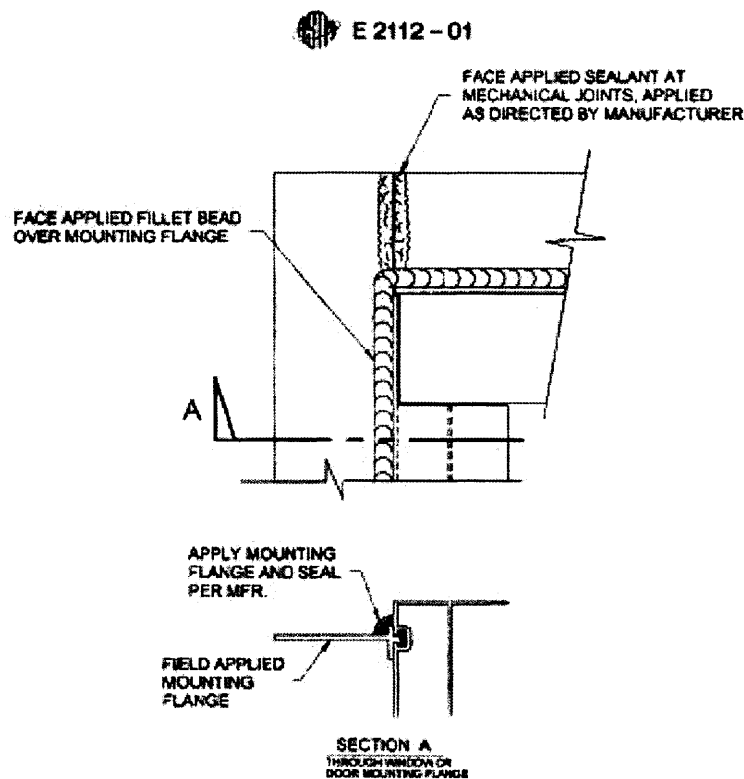

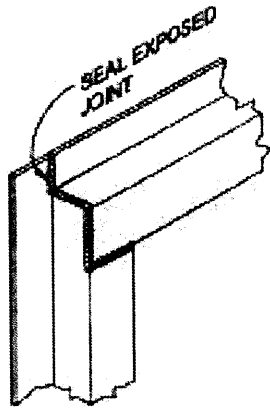


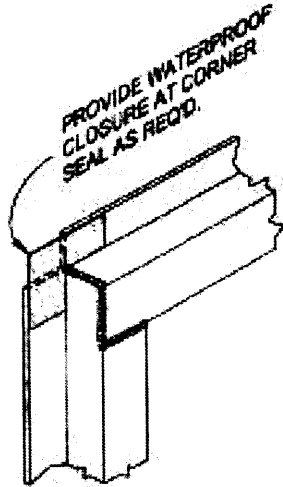
FIG. 13 Applied Flanges and Mechanical Joints



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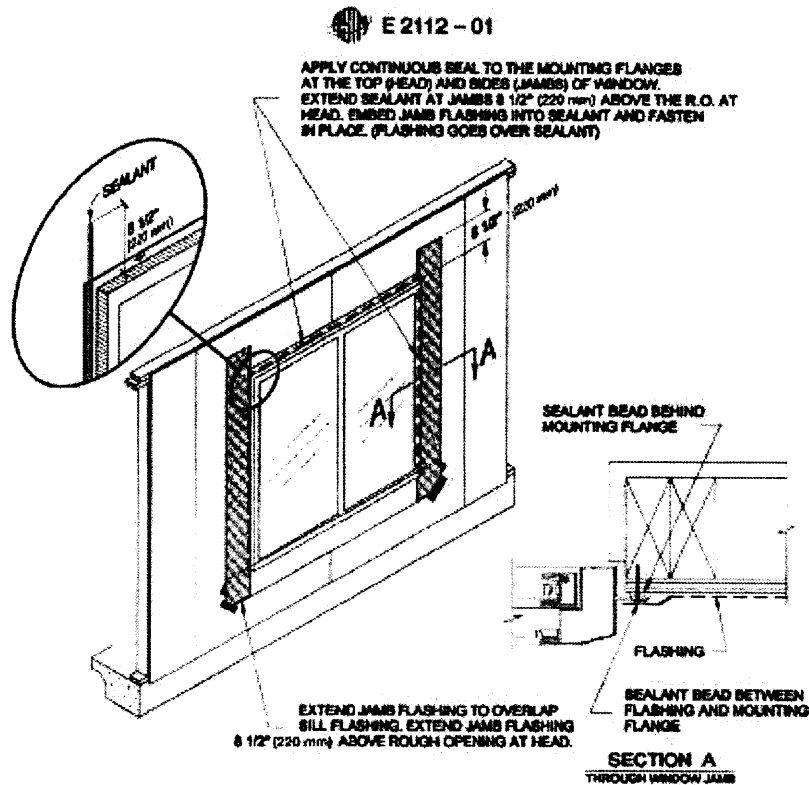
BUTT JOINT



OPEN ("NOTCHED") CORNER

FIG. 21 Common Frame Joints (Head-Jamb)

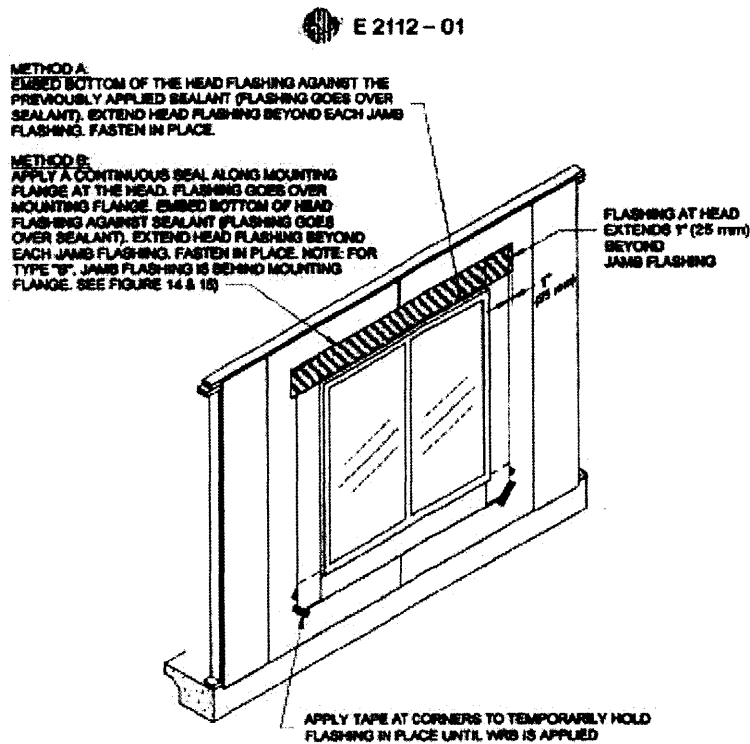
8.1.1.3.4.5 Step 5: Install the jamb flashing next, by pressing the flashing into the sealant beads on the mounting flanges. Attach the flashing into position to the rough opening framing using staples or other appropriate fasteners. Extend the bottom edge of the jamb flashing 8.5 inches (220 mm) beyond the rough opening head, where the head flashing will be placed next. Tuck the top of the jamb flashing under the flap of weather resistant barrier at the head. (see figure 16).



Note: 1.—For Method A the weather resistant barrier (WRB) has been installed. A flap at the head of the window has been temporarily taped out of the way to allow for flashing and window installation.

FIG. 16 Jamb Flashing (Method A)

8.1.1.3.4.6 Step 6: Next, apply a continuous bead of sealant to the exposed mounting flange (exterior surface) at the head of the installed window. (see figure 18).




Note: 1.—For Methods A1 and B1 the weather resistant barrier (WRB) has been installed. A flap at the head of the window has been temporarily taped out of the way to allow for flashing and window installation.

FIG. 18 Head Flashing (Methods A and B)

Note 40 – The application of sealant to the flange is not necessary if using self-adhesive type flashing over the mounting flange.

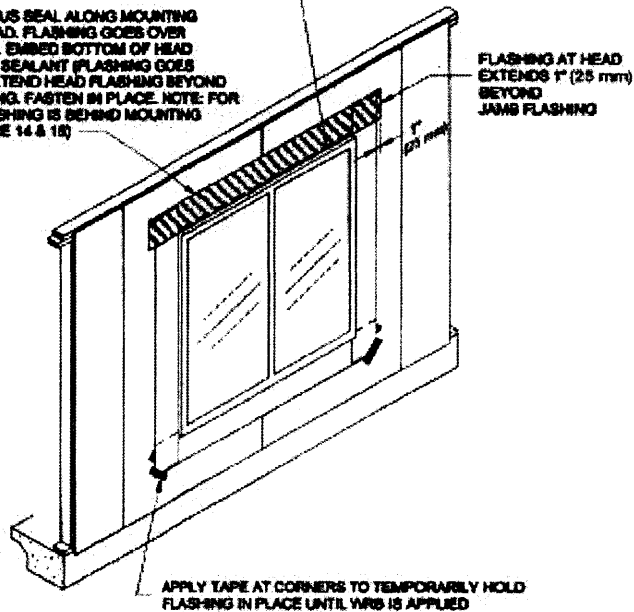
Note 41 – Apply the sealant in line with the pre-punched holes or slots on the mounting flange when provided and over the heads of the fasteners.

8.1.1.3.4.7 Step 7: Install the head flashing by pressing the flashing into the sealant bead previously applied across the mounting flange. When applying the head flashing, press the bottom edge of the flashing into the sealant until the sealant appears. This will ensure that no voids remain between the flashing and the mounting flange. Extend the ends of the head flashing 10 inches beyond the rough opening, over the top of the jamb flashing. Fasten the head flashing into place along the top edge using staples or other appropriate fasteners. (see figure 18).

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**METHOD A:**  
EMBED BOTTOM OF THE HEAD FLASHING AGAINST THE PREVIOUSLY APPLIED SEALANT (FLASHING GOES OVER SEALANT). EXTEND HEAD FLASHING BEYOND EACH JAMB FLASHING. FASTEN IN PLACE.

**METHOD B:**  
APPLY A CONTINUOUS SEAL ALONG MOUNTING FLANGE AT THE HEAD. FLASHING GOES OVER MOUNTING FLANGE. EMBED BOTTOM OF HEAD FLASHING AGAINST SEALANT (FLASHING GOES OVER SEALANT). EXTEND HEAD FLASHING BEYOND EACH JAMB FLASHING. FASTEN IN PLACE. NOTE: FOR TYPE "B", JAMB FLASHING IS BEHIND MOUNTING FLANGE. SEE FIGURE 14 & 15)



NOTE 1—For Methods A1 and B1 the weather resistant barrier (WRB) has been installed. A flap at the head of the window has been temporarily taped out of the way to allow for flashing and window installation.

FIG. 18 Head Flashing (Methods A and B)

8.1.1.3.4.8 Step 8: Remove the previously applied tape, which holds the flap of the weather resistant barrier at the head. Allow the flap to lay flat over the head flashing. Apply a new piece of sheathing tape over the entire diagonal cut made in the weather resistant barrier. The tape should be compressed against the weather barrier and the head flashing, which extends over the jamb. (see figure 23).

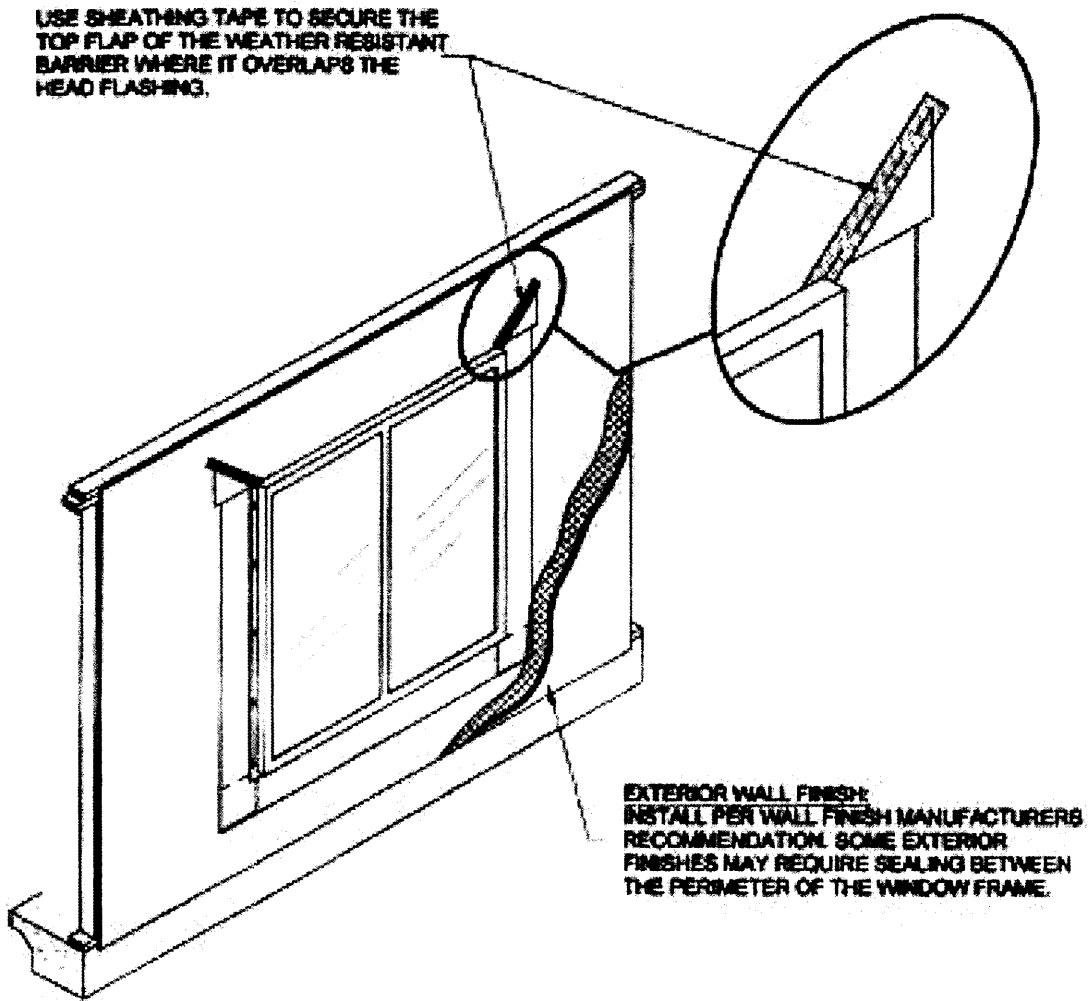
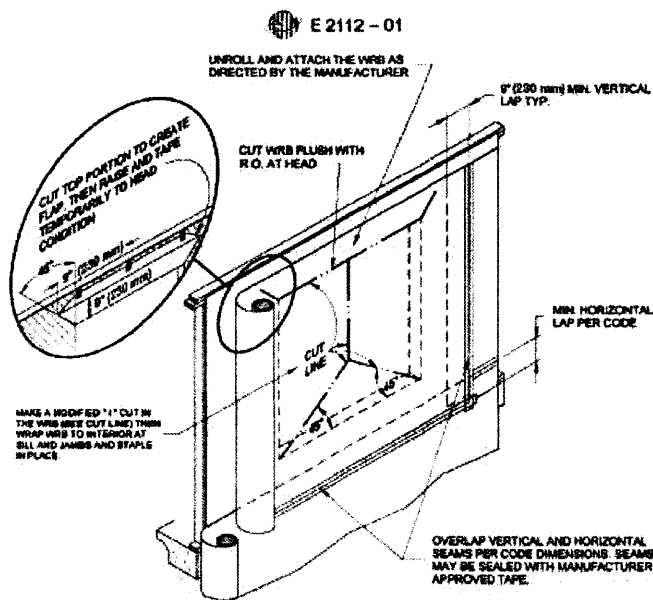


FIG. 23 Secure WRB at Head (Method A1 and B1)

## A 1.4 Method B1: Weather Resistant Barrier Applied Prior to the Window Installation – Flashing is Applied Behind the Mounting Flange


8.1.1.3.4.1 Step 1: Where a weather resistant barrier (WRB) is used, apply the WRB in water shedding fashion, starting at the base of the wall and working towards the top. Install the weather resistant barrier to the face of the building framing or sheathing flush with the rough opening of the window head, jamb and sill. At the head of the opening, starting at the top corner of the window, measure from the corner 9 inches (230 mm) up and 9 inches (230 mm) over and mark. At a 45° angle, carefully cut the barrier on a diagonal. Gently raise the top edge of the barrier up and temporarily tape the top corners and center to the exterior weather resistant barrier surface above. This is done in order to allow for installation of the window and flashing later. Once the weather resistant barrier is applied as described in this step, proceed immediately to step 2. Alternatively, you can follow the same procedures as outlined for house wrap type WRB. Where the weather resistant barrier used is a building paper type material and covers the window, carefully cut the barrier in a modified “I” pattern as shown in figure 22. Fold the bottom and side flaps over and behind the interior side of the rough opening. At the head of the opening, starting at the top corner, measure from the corner 9 inches (230 mm) up and 9 inches (230 mm) over and mark. At a 45° angle, carefully cut the barrier on a diagonal in figure 22. Gently raise the top edge of the barrier up and temporarily tape the top corners and center to the exterior weather resistant barrier surface above. This is done in order to allow for installation of the window and flashing later.

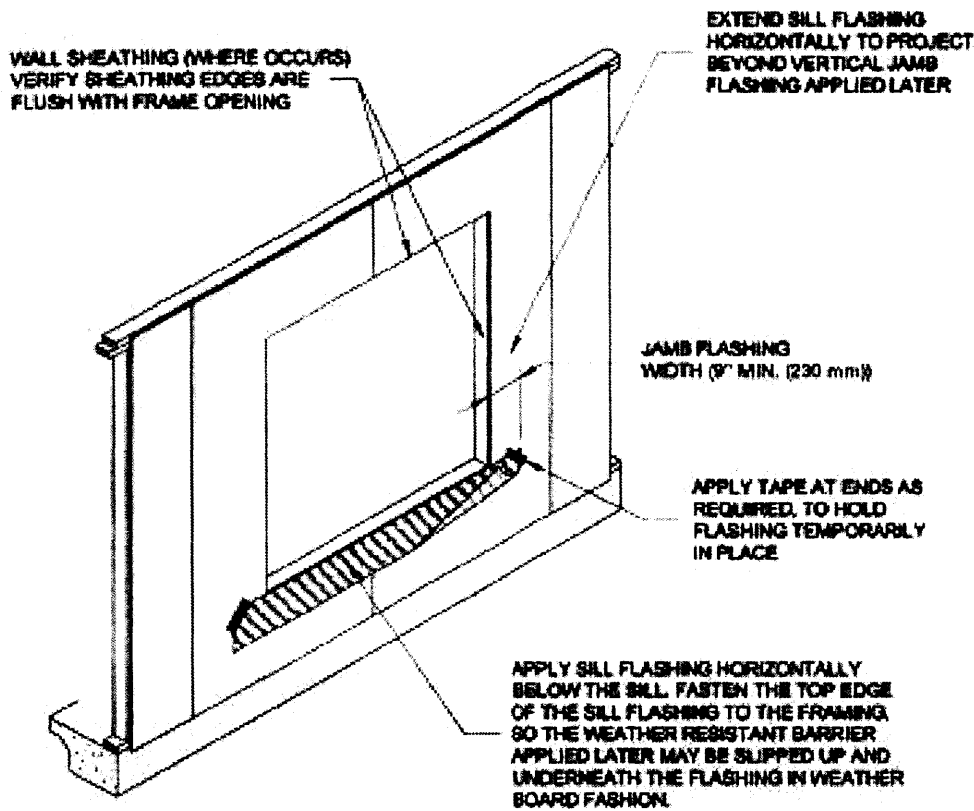


WRB FOR FLOORS OR LEVELS BELOW SHALL BE OVERLAPPED WITH WRB ABOVE IN WEATHER BOARD FASHION.

FIG. 22 Weather Resistant Barrier (WRB)-House Wrap

8.1.1.3.4.2 Step 2: Apply the horizontal sill flashing material next, level with the top edge of the rough opening. Cut the sill flashing long enough to extend an equal distance beyond the 9 inch (230 mm) jamb flashing, which will be applied later. (see figure 14). Fasten the top edge of the sill flashing to the framing. Place fasteners along the edge of the rough opening where they will be covered by the mounting flange of the window later.


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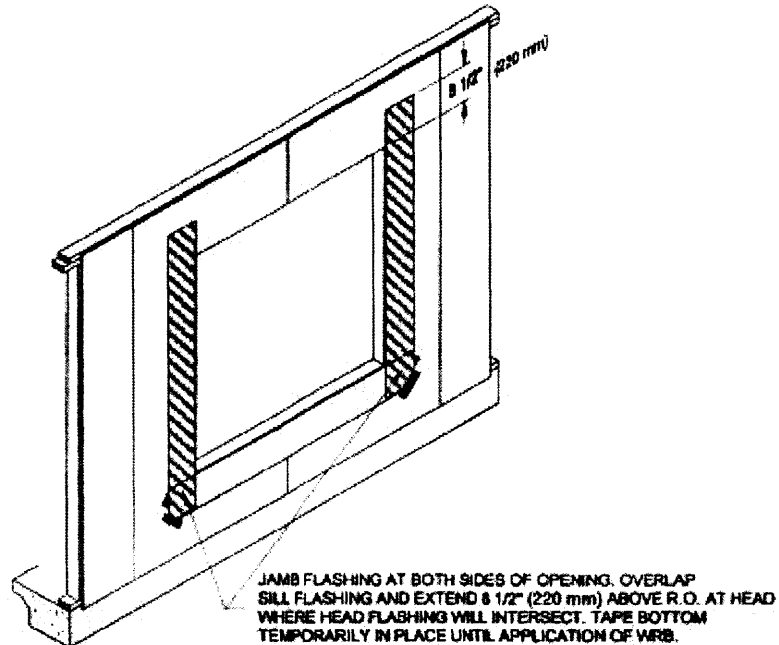


**NOTE: FOR METHODS "A1" AND "B1" THE WEATHER RESISTANT BARRIER (WRB) HAS BEEN INSTALLED. A FLAP AT THE HEAD OF THE WINDOW HAS BEEN TEMPORARILY TAPED OUT OF THE WAY TO ALLOW FOR FLASHING AND WINDOW INSTALLATION.**

**FIG. 14 Sill Flashing (Methods A and B)**

8.1.1.3.4.3 Step 3: Apply the jamb flashing to the edge of the framing at each jamb. Place fasteners along the edge of the rough opening where they will be covered by the mounting flange of the window later. Extend the jamb flashing 8.5 inches (220 mm) beyond the rough opening dimension at the head and sill. The bottom end of the jamb flashing is to overlap the sill flashing. The head flashing applied next will overlap the top end of the jamb flashing. (see figure 20).

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Note: 1—For Method B1 the weather resistant barrier (WRB) has been installed. A flap at the head of the window has been temporarily taped out of the way to allow for flashing and window installation.

FIG. 20 Application of Jamb Flashing (Method B)



8.1.1.3.4.4 Step 4: Apply a continuous bead of sealant around the full perimeter of the back side (interior surface) of the window mounting flange. Sealant selection and bead design shall be in accordance with 5.18.

Note 42 – Apply the sealant in line with the pre-punched holes or slots on the mounting flange when provided and over the heads of the fasteners.

8.1.1.3.4.5 Step 5: Immediately install the window into the opening pressing the window against the framing to compress the sealant. Apply shims as required to ensure the unit is plumb, level and square. Fasten the window perimeter securely into position as described in 5.14.

Note 43 – Exercise caution to avoid disrupting the continuous seal. Always install the window immediately after the application of the sealant.

(1) For windows with mechanically joined mounting flanges, apply sealant to the full length of the joinery or seam where the flanges meet. (see figures 13 and 21).

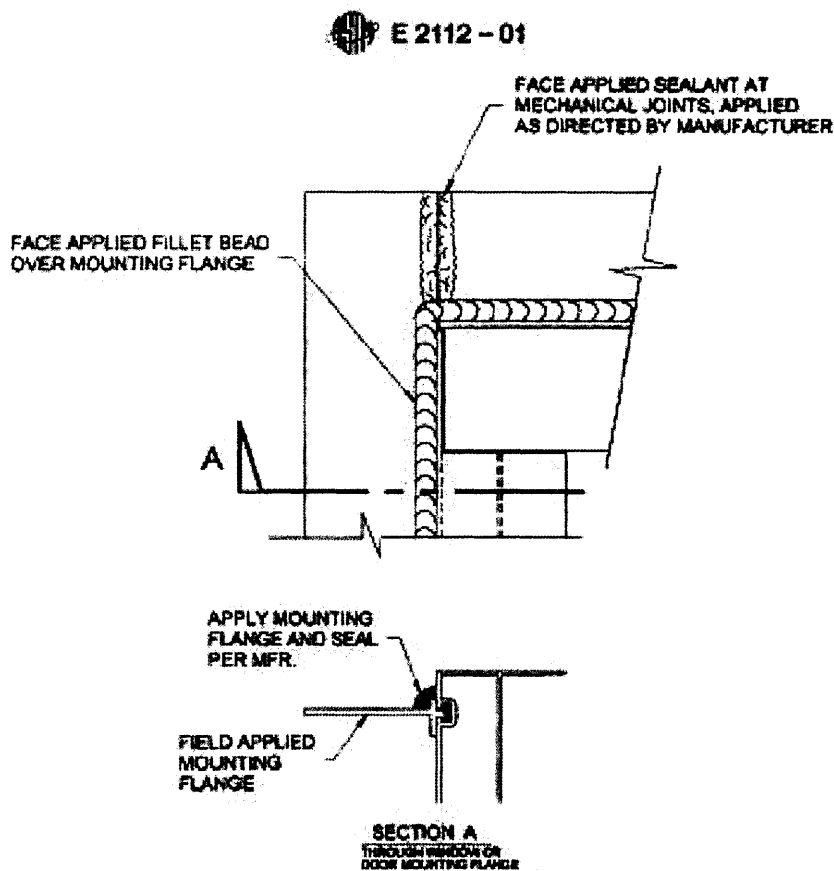
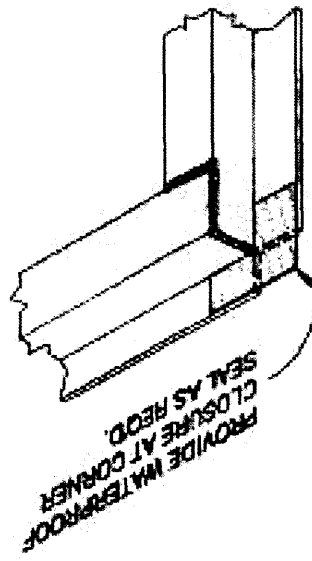
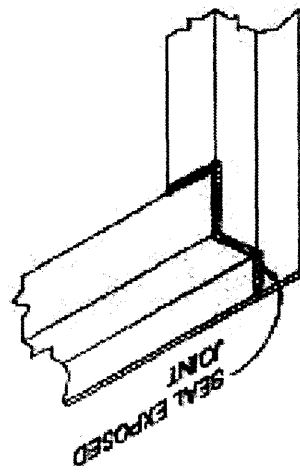


FIG. 13 Applied Flanges and Mechanical Joints

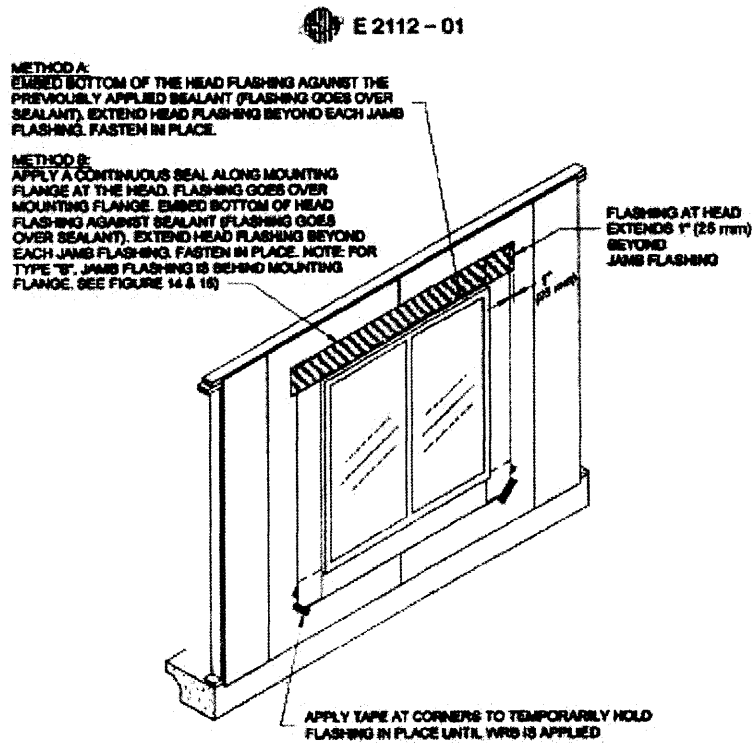
FIG. 21 Common Frame Joints (Head-Jamb)  
OPEN ("NOTCHED") CORNER



BUTT JOINT



8.1.1.3.4.6 Step 6: Apply a continuous bead of sealant horizontally across the face of the exposed mounting flange (exterior surface) at the head of the installed window. The sealant bead on the header should be placed in line where the top of the flashing (8.5 inches (220 mm) above the rough opening) will be placed, so the top of the flashing can be pressed into the sealant in the next step. Continue the sealant bead over the top edge (exterior side) of the jamb flashing in order to fully integrate the head and jamb flashing together. (see figure 18).

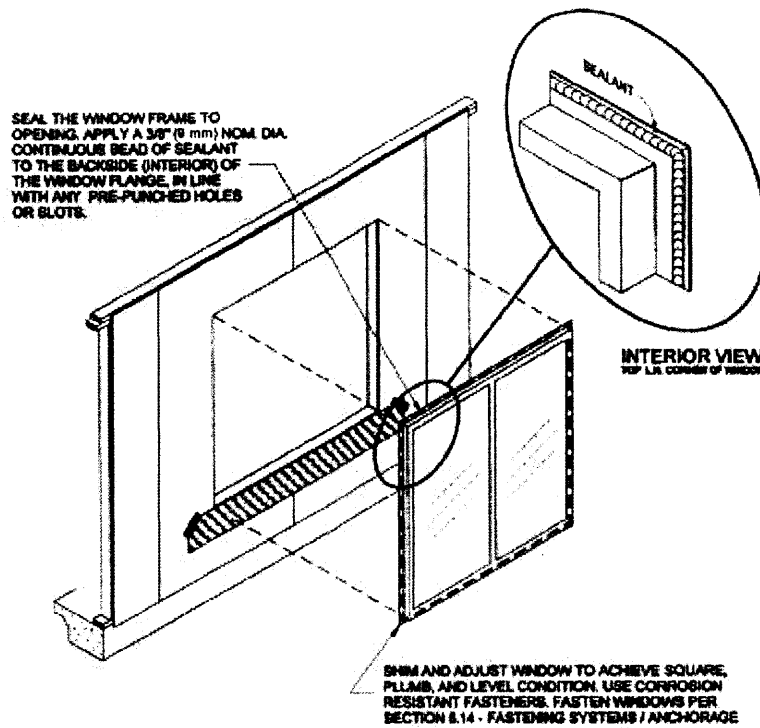


Note 1—For Methods A1 and B1 the weather resistant barrier (WRB) has been installed. A flap at the head of the window has been temporarily taped out of the way to allow for flashing and window installation.

FIG. 18 Head Flashing (Methods A and B)

Note 44 – The application of sealant to the flange is not necessary if using self-adhesive type flashing over the mounting flange.

Note 45 – Apply the sealant in line with the pre-punched holes or slots on the mounting flange when provided and over the heads of the fasteners. (see figure 15).



Note: 1—For Method A the weather resistant barrier (WRB) has been installed. A flap at the head of the window has been temporarily taped out of the way to allow for flashing and window installation.

FIG. 15 Window Installation (Method A)

8.1.1.3.4.7 Step 7: Install the head flashing by pressing the flashing into the sealant bead previously applied to the mounting flange. When applying the head flashing, press the bottom edge of the flashing into the sealant until the sealant appears. This will ensure that no voids remain between the flashing and the mounting flange. Extend the ends of the head flashing 10 inches (260 mm) beyond the rough opening, over the top of the jamb flashing. Fasten the head flashing into place along the top edge using staples or other appropriate fasteners.

8.1.1.3.4.8 Step 8: Finally, remove the previously applied tape, which holds the flap of the weather resistant barrier at the head. Allow the flap to lay flat over the head flashing. Apply a new piece of sheathing tape over the entire diagonal cut made in the weather resistant barrier. The tape should be compressed against the weather barrier and the head flashing which extends over the jamb. (see figure 23).

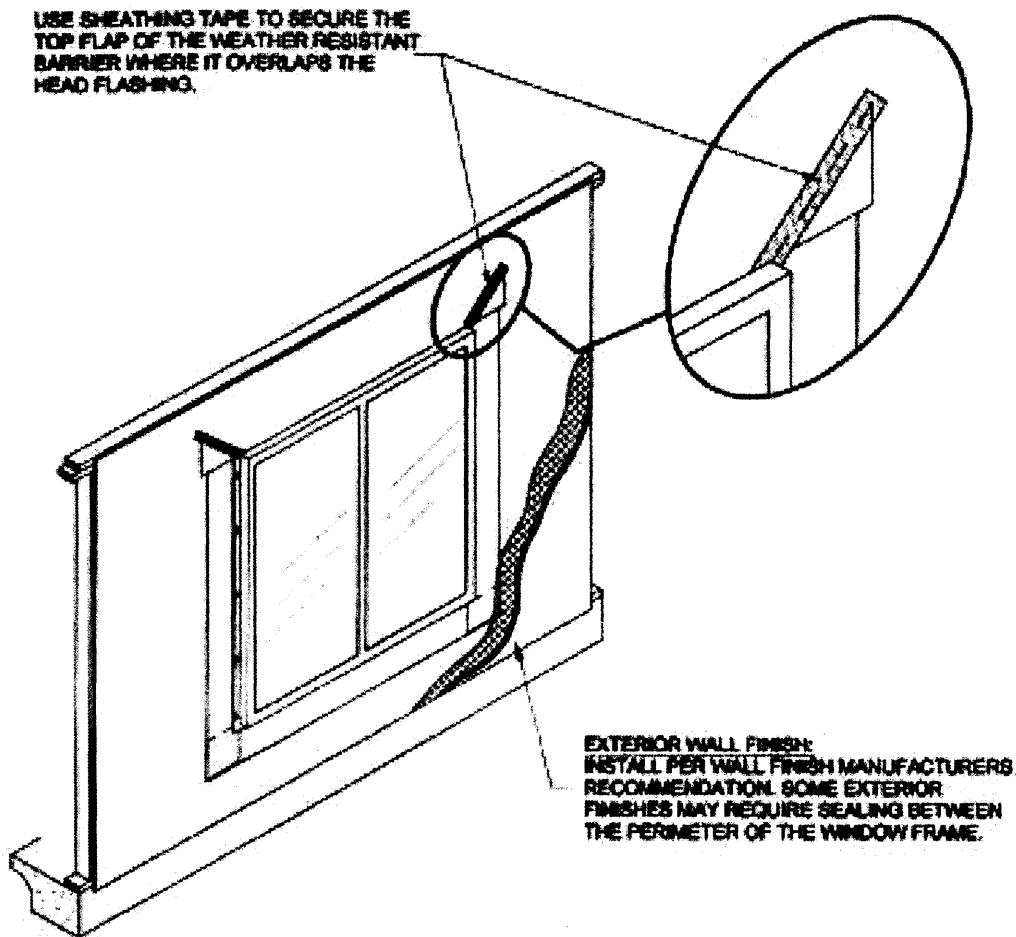


FIG. 23 Secure WRB at Head (Method A1 and B1)

## A 1.5 Non-Finned Windows in Membrane/Drainage Type Walls:

### 8.1.2.1 Integration of Non-Finned Windows with the Drainage Membrane

Non-finned windows do not have mounting flanges (nail fins), which are typically integrated with flashing sheets. Non-finned windows should be sealed to the wall's weather resistive membrane at the jamb moldings and where the sill horn extends beyond the sides of the rough opening. To meet this requirement, the window shall be installed after the weather resistant barrier (WRB) is installed. The WRB shall wrap into the rough opening at the base and sides of the opening. The WRB shall not however wrap into the top of the rough opening. Starting with the WRB trimmed even with the top edge of the rough opening, two diagonal cuts are made in the membrane at the top corners of the rough opening, (see figure 24) to form a flap in the membrane above the rough opening. A horizontal strip equal to the width of the window unit's head trim is then cut off the bottom edge of this flap (see figure 24). This is to allow installation of the window unit without interference with or damage to the flap. The remaining flap will later be integrated with window head flashing.

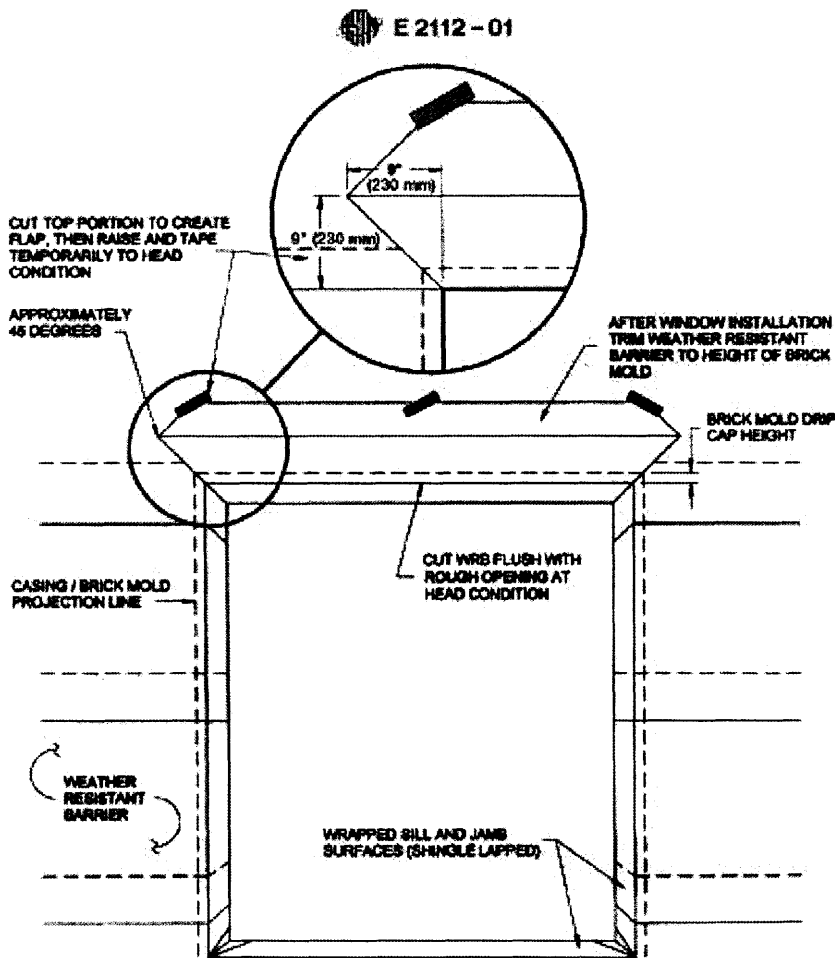


FIG. 24 Membrane/Drainage System-Wrapping of Rough Opening (Non Finned Window)

### 8.1.2.2 Use of Pan Flashing

This practice recommends that pan flashing be used below non-finned windows. For pan flashings to serve their purpose, they shall be integrated with the wall's weather resistant barrier in shingle-lap fashion, and should be sealed to the weather resistant barrier at the sill of the rough opening with a discontinuous bead of sealant. Although non-finned windows should be sealed to the weather resistant barrier on their sides and where the sill horns extend beyond the rough opening, sealant shall not be used between the window unit's sill and any portion of the pan flashing outboard of the sheathing. Do not seal the front of the pan. This is because application of sealant at this location could prevent outward drainage from the pan flashing. (see figure 25).

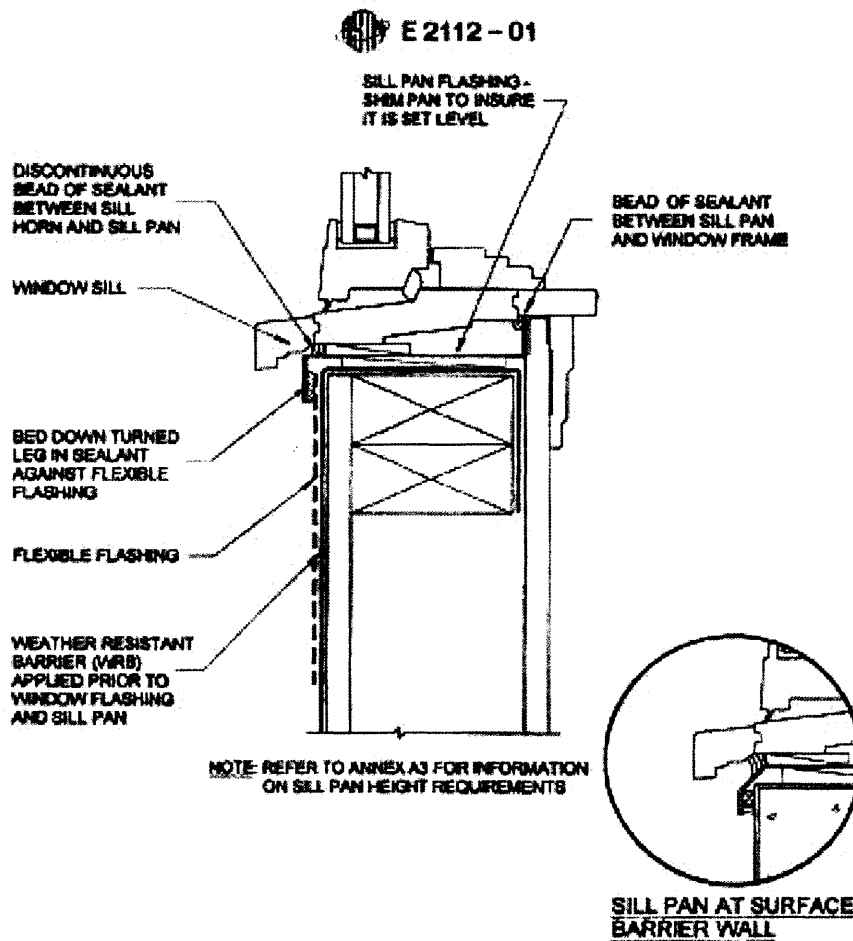


FIG. 25 Membrane/Drainage System-Installation of Sill Pan

#### 8.1.1.4 *Installation of Pan Flashing*

Pan flashings are installed after installation of the weather-resistant barrier (WRB) and before the window is installed. They are placed at the sill of the rough opening, over the wrapped rough opening sill and jamb faces. A continuous bead of sealant is applied to the back side of the outer vertical leg of the pan flashing. This will allow the flashing to seal directly to the WRB. (see figure 26). Once the pan flashing is set in place, a sealant is applied between the upturned legs that form the end dams of the pan flashing and the side jambs of the rough opening. The sealant is tooled to create a smooth surface, which will allow water on the jamb surfaces of the rough opening to easily drain into the sill pan. The pan flashing should be secured in place to prevent movement. Driving fasteners through the pan will reliably hold pan flashings in place, but will compromise the water-tightness of the pan if done carelessly. For this reason, attachment by driving fasteners through the pan shall be done carefully and with sealant at the fasteners. Use of pan-head screws is recommended. A minimum of three (3) screws is used, and screws should not be closer than 16 inches (410 mm) (except when the minimum 16 inches (410 mm) spacing would result in use of fewer than three screws). To install screws, drill holes in the pan at the appropriate locations, fill the holes with sealant, and drive the screws. Once screws are driven, seal over the screw heads with sealant to create a watertight installation. Once the pan flashing is secured, fillets of sealant are applied between the upper edge of the outer leg of the pan flashing and the barrier (slightly above the bottom corners of the opening), and the fillet beads are smoothed. The window unit may then be installed in the opening. Nails used to install the window unit shall not puncture the pan flashing, as it is impossible to seal these punctures with sealant.



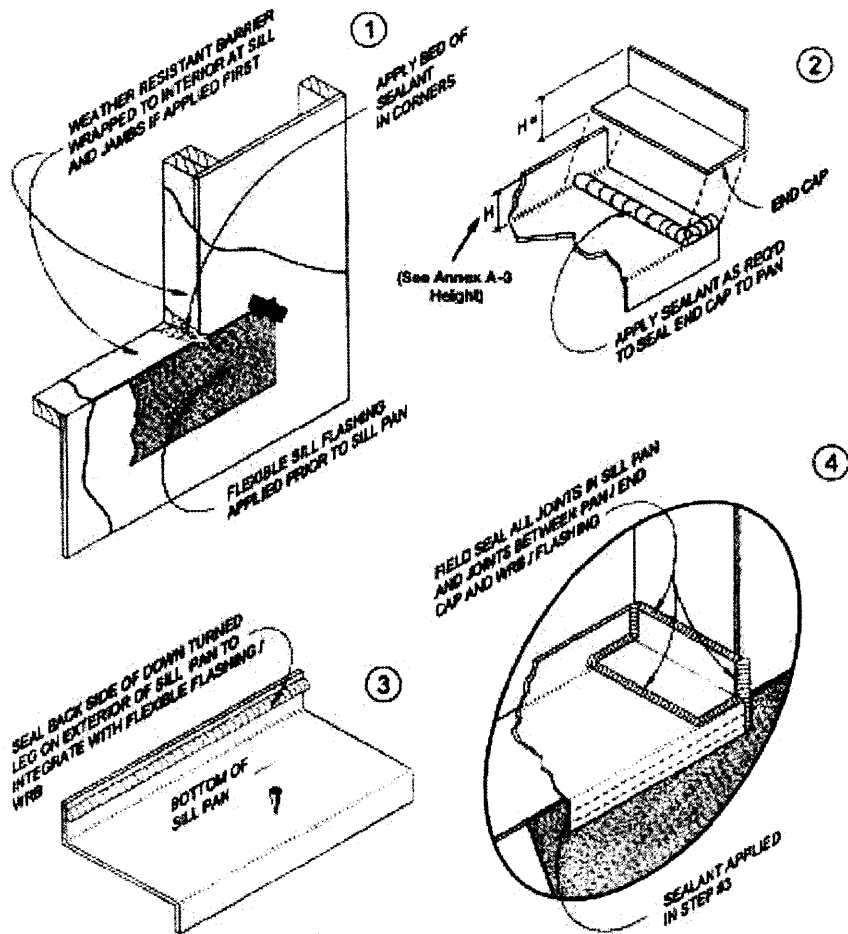


FIG. 26 Installation of Sill Pan Flashing

### 8.1.2.3.1 Pan Flashings with Window Shimming

Use of pan flashings substantially complicates shimming of units, because the interior vertical leg of a pan flashing makes insertion of the shims in the rough opening space below the sill much more difficult. In no case should the interior vertical leg of the pan flashing be cut or bent, or both, or hammered flat to facilitate insertion of shims from the interior, because doing so would compromise the design intent of a pan flashing. Leveling shims used below the side jambs need to be cut to the thickness needed for leveling. These leveling shims are either inserted toward the jambs (that is, away from the center of the opening in a direction parallel with the plane of the wall; this being done with the window fully inserted into the opening), or tacked to the bottom of the jambs (before the window is fully inserted into the rough opening). Sill support shims, (used to prevent sagging of sills of wide window units), are put into position running parallel with the plane of the wall, just outboard of the interior vertical leg of the pan flashing.

#### 8.1.2.3.2 *Pan Flashings and Air Infiltration Seals*

Air infiltration seals installed around window perimeters may, if carelessly applied, obstruct drainage from pan flashings. To reduce the chance of this occurring, air infiltration seals at window sills should be made at the inboard vertical leg of pan flashings, and should not extend outward for more than one-third of the wall thickness. By limiting wind-induced air infiltration, infiltration seals at window unit sills may be expected to result in build-up of stagnation wind pressures in the rough opening gap below the window, which will impede entry of wind-blown precipitation. As indicated previously in this section however, air infiltration seals shall be carefully installed so that they do not interfere with outward drainage from pan flashings.

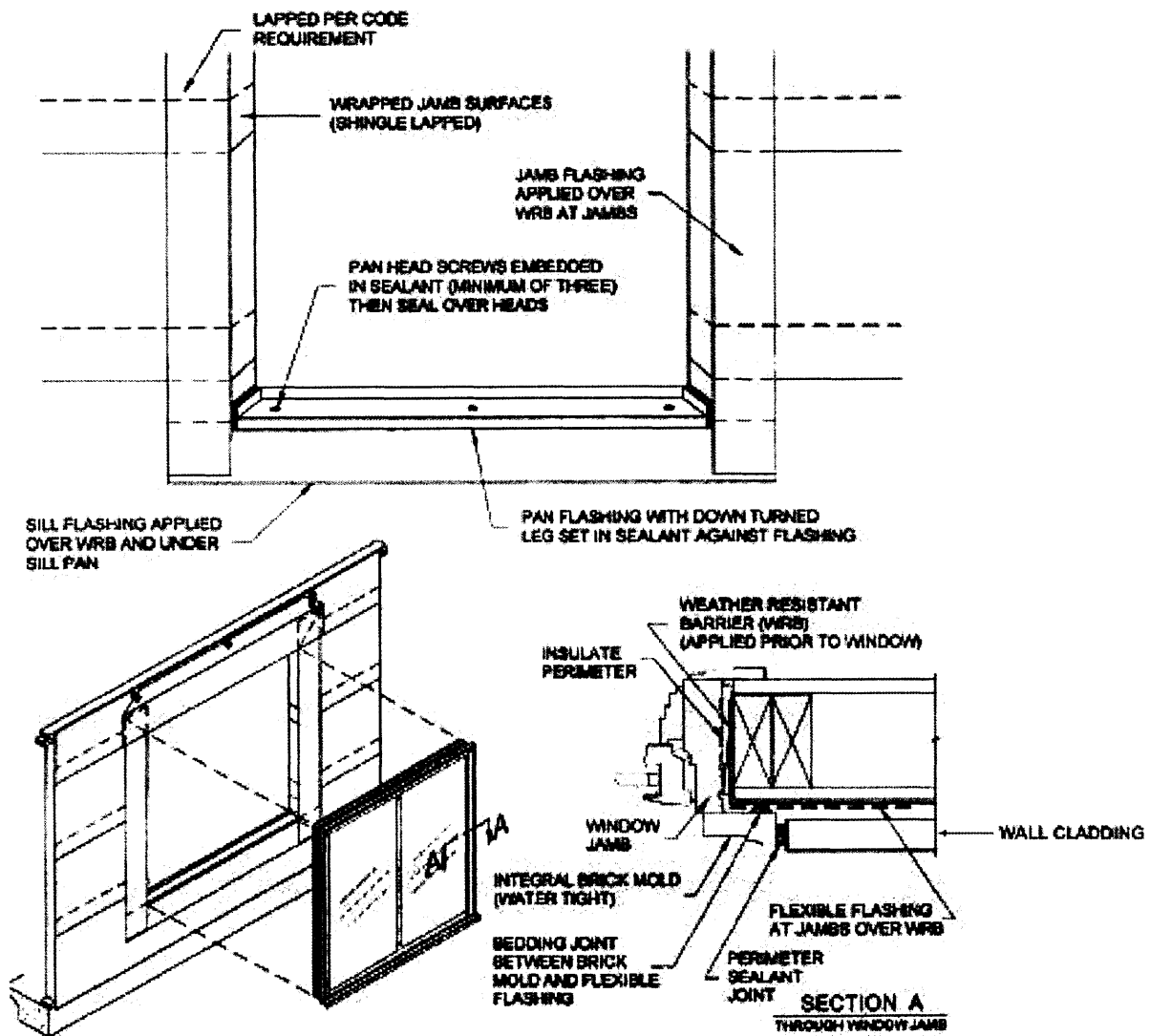
#### 8.1.2.3.3 *Pan Flashings as Thermal Bridges*

Pan flashings, by design, extend through most of a wall's thickness. When fabricated from sheet metal, pan flashings may therefore act as thermal bridges. When this may pose a problem, (for example buildings in cold climates whose occupancies require that they be operated at moderate to high levels of indoor humidity), fabricating pan flashings from material with lower thermal conductivity than sheet metal may be justified. Selection of pan flashing material on the grounds of thermal conductivity is the responsibility of the building designer, not the window installer who often is unaware if there are special building occupancy requirements, and who cannot reasonably be expected to perform thermal conductivity and dew point analyses). Be aware that climate and special building occupancy requirements can influence the selection of pan flashing material. In cases where pan flashing materials are not specified, the installer should confer with the building designer to identify if there are special requirements.

8.1.2.4 Drip Caps

Unless the window unit's head trim has a top surface that slopes toward the exterior and has a pronounced drip edge, a drip cap, which has these characteristics and extends outward beyond the head trim's outermost surface, shall be installed over the window unit's head trim. The end-grain surfaces of wood drip caps should be sealed with water-repellent or water-repellent preservative at time of installation. (see figure 27). If a drip cap is required, it shall be installed underneath the flap cut in the weather resistant barrier above the window.

E 2112 - 01

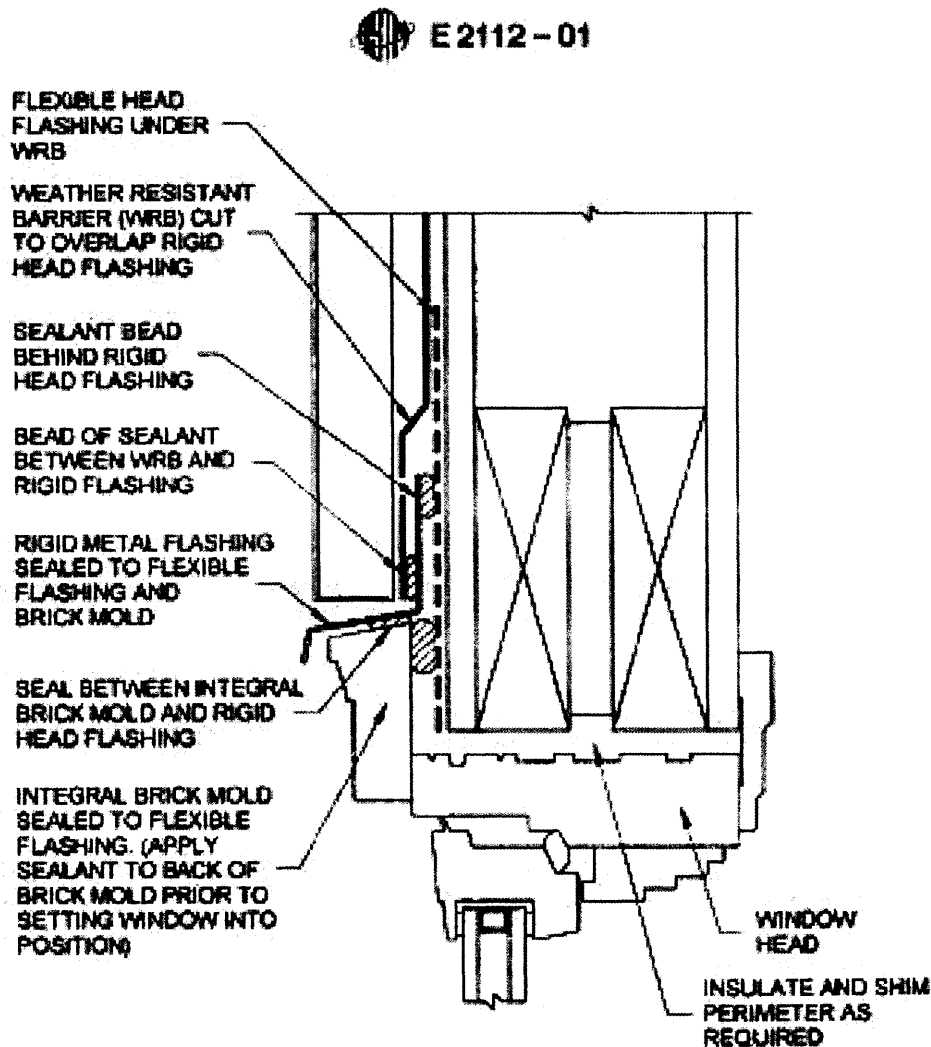


BLOCK FRAME WITH INTEGRAL BRICK MOLD INSTALLATION SHOWN (NON-INTEGRAL SIMILAR)

FIG. 27 Wrapped Jamb Surfaces (Shingle Lapped)(Non-Finned Windows)

8.1.2.5 *Head Flashing (see figures 28-31)*

The top edge of a wood drip cap (or the top edge of the window unit's head trim; if it meets the requirements outlined at the start of 8.1.2.3) should be covered with a rigid metal flashing, and the upper leg of this flashing shall be integrated with the wall's weather resistant barrier (WRB). This is performed by installing the head flashing underneath the flap cut in the WRB, trimming the membrane so that it will cover the upper leg of the head flashing but not extend below the upper leg of the flashing, sealing the barrier to the upper leg of the head flashing with a bead of sealant, and fastening the flap in place. Depending on installation details, it may be possible to use rigid metal flashing to serve the combined purposes of drip cap and flashing.



**FIG. 28 Head of Non-Finned Window (Integral Brick Mold)**

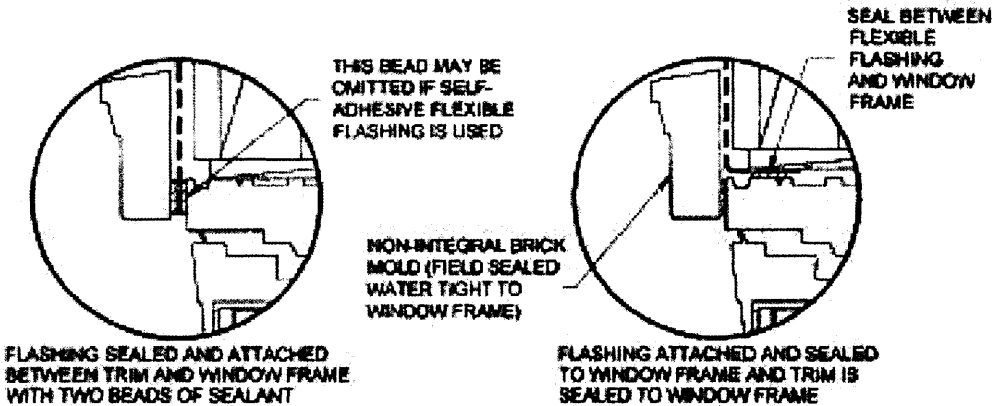
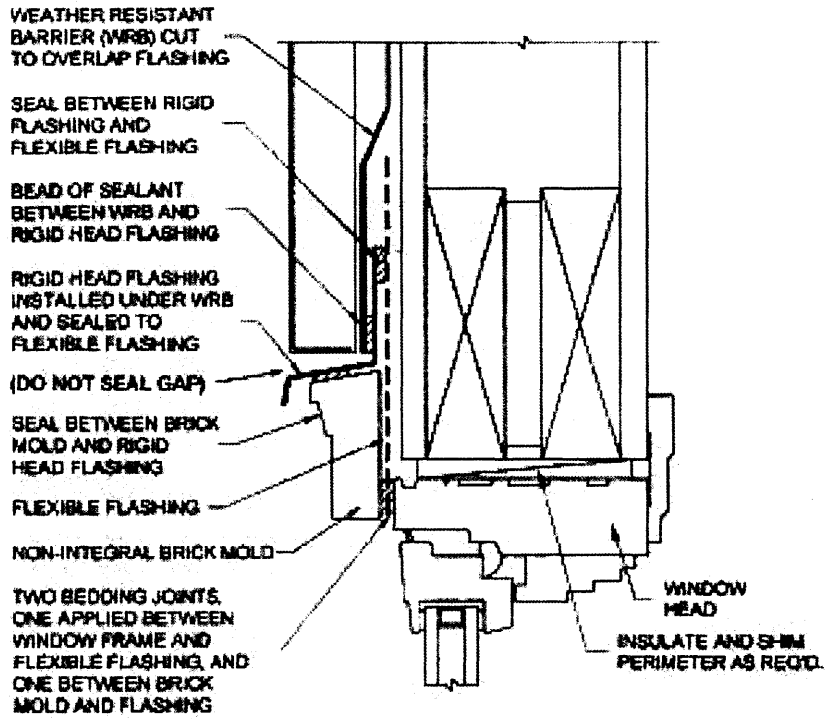


FIG. 29 Head Detail of Non-Finned Window (Non-Integral Brick Mold)

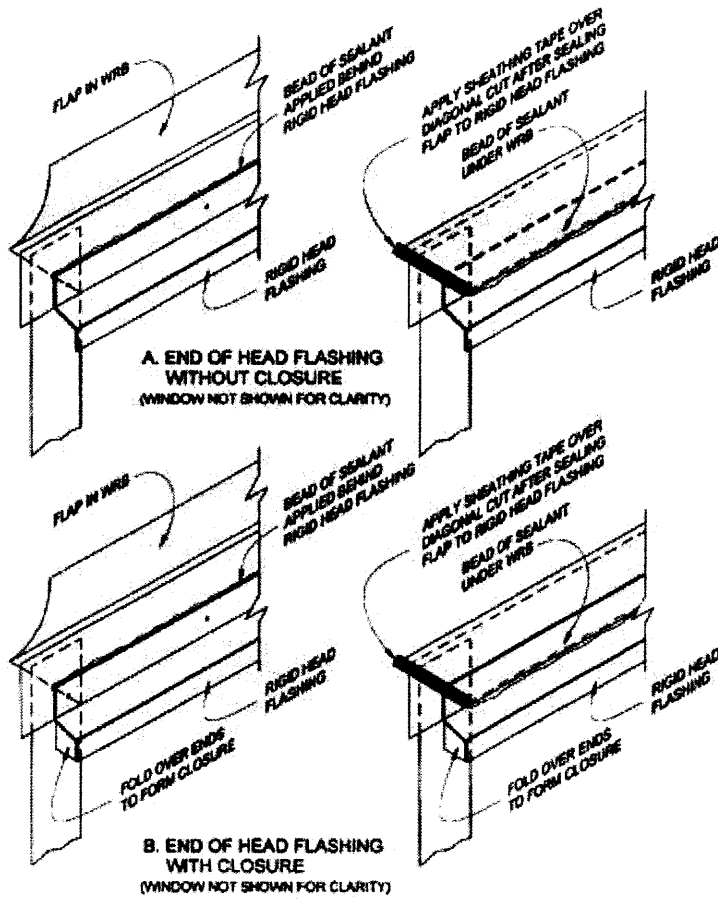


FIG. 30 Common Rigid Head Flashing Details

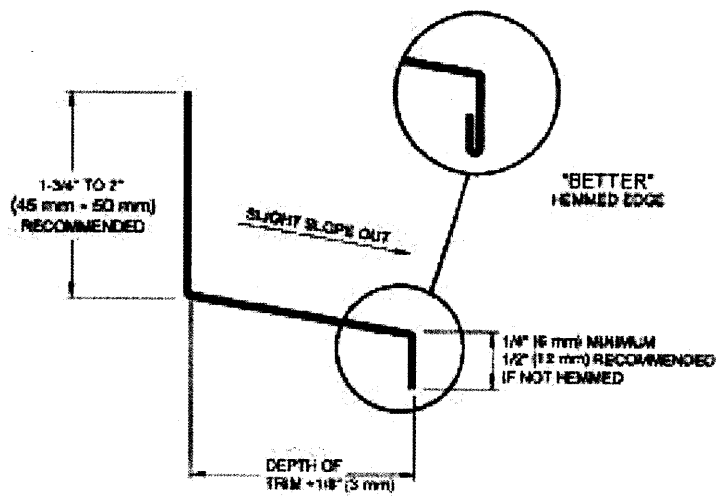


FIG. 31 Typical Head Flashing Detail

8.1.2.6. *Trades Responsibility for Drip Cap and Flashing*

This practice recommends that drip cap and head flashing be installed by the window installers. If these items are not installed by the window installers, the following undesirable events may occur: (1) water may intrude at the window head before the drip cap and head flashing are installed, (2) the flap in the barrier above the window may be damaged by wind or by workers installing or removing fasteners or batten strips used to temporarily secure it. Although it is less than ideal, head flashings are sometimes installed by the cladding system installers. Regardless of which trade group installs window head flashing, proper integration of it with the drip cap or window trim, with the weather resistive barrier, and with the cladding system is essential. Special flashing details that are specific to different cladding systems and their variations may be necessary (for example, jamb flashings on *downhill* sides of diagonally-applied wood siding). Such special flashing details are beyond the scope of this practice.

## **Appendix 2.0: Waterproofing Materials**

The set of materials available to a builder to waterproof a window/wall assembly include sealants, flashings and weather resistant barriers. A discussion of each class of material follows. Each material is described in terms of a general introduction, material properties, and applicable standards.

### **2.1 Sealants**

A sealant is defined as any of a variety of compounds used to fill and seal joints or openings in wood, metal, masonry, and other materials (ASTM E2112-01). In the residential market, builders and homeowners use sealants for perimeters of wall and roof openings such as doors, windows, chimneys, vent stacks, mechanical system penetrations and for glazing and for sealing tub and shower stalls. Approximately 80% of sealants used in the residential market are for exterior uses (Panek and Cook, 1991).

All sealants are formulated using a “backbone” or base polymer and a set of assorted ingredients including fillers, plasticizers, solvents, adhesion promoters, UV absorbers, pigments and curing agents. The sealants described in the following section are limited to those ones that meet most of the performance requirements set out in ASTM C-920. The building industry refers to this class of sealants as high performance sealants (Jackson, 1997). Most high performance caulks are based on one of four base polymer types: silicone, polyurethane, acrylic latex and synthetic rubber (a.k.a. solvent-based block copolymer).

High performance sealants are good candidates for exterior, one-stage sealing operations for both working joints, and by default, non-working joints. A working joint is defined as one that changes its size or shape with the relative movement of the adjoining parts. A non-working joint also has the ability to change its size and shape. However, these changes are restricted in scope because the relative movement between adjoining parts is either minimized or eliminated by the details of construction (Panek and Cook, 1991)<sup>1</sup>.

A sealant can be classified, or selected, according to its generic type, movement capability, hardness, shrinkage (percentage of weight loss after heat aging), resistance to heat aging, resistance to weathering, compression set resistance, ultimate tensile strength and elongation, tensile adhesion, adhesion in peel, resistance to water, tear resistance, modulus of elasticity, solvent and chemical resistance, abrasion resistance, toxicity, electrical properties, color retention, staining of masonry and building surfaces, cyclic tension and compression resistance, cure mechanism, compatibility with other materials, availability and cost.

#### **A 2.1.1 Silicone**

Silicone sealants are extremely moisture vapor permeable. They are differentiated according to their modulus. High modulus (stress/strain) silicone sealants are used as adhesives in the structural attachment of glass and metal to curtain walls. Medium modulus silicone sealants are used as general weatherproofing sealants. Ultra low

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<sup>1</sup> The reader is referred to 7.0 Appendix: Joint Design for a complete discussion of joint design.



modulus silicones are formulated as self-leveling or non-sag materials used in parking decks and concrete pavements.

Silicones cure in one of two ways, either the silicone is acid cured, or it is air cured. Acid curing silicones produce acetic acid. These silicones work best on non-porous surfaces.

A silicone should perform up to 30 years (Panek and Cook, 1991).

#### **A 2.1.2 Polyurethane**

Polyurethane is formed by the reaction of diisocyanate and a polyol in the presence of a catalyst. Properly formulated sealants with good polymer bases can be expected to have a service life of over 25 years. These sealants have a movement capability of +/- 25%.

#### **A 2.1.3 Latex Sealants**

Latex sealants are one-component gun grade materials that are non-staining to most substrates. This class of sealants can be used in an outdoor application but are limited to joints that have a movement no greater than +/-7.5%. They are categorized as the first generation, low plasticized latex sealants.

The chief materials for this class of latex sealants are acrylic, vinyl acrylic, and polyvinyl acetate. As a generic class, latex is flexible, has a low recovery and is prone to shrinkage because of its water-based nature (30% by volume, which produced between 15 to 20% weight loss). There are no curing agents used in latex sealants, so once dry it is cured.

Latex can be applied to a damp surface and will adhere to most building materials without the use of a primer. Acrylic latex sealants can be used outdoors, but any exposure to continuous wetting will lead to an adhesion failure.

#### **A 2.1.4 Plasticized Acrylic Latex Sealants (a.k.a. Elastomeric <sup>2</sup>Latex Sealant)**

The main difference between this class of sealants and the Latex sealants described above is the amount of plasticizer used. The latex sealants are formulated with a ratio from 3:1 to 4:1. The plasticized acrylic sealants are formulated with a ratio of 2:1. This change in formula results in a flexible sealant with a movement capability of +/-25%.

#### **A 2.1.5 Block Copolymers**

These sealants are known as the “super clear caulks” (Holliday, 2000).

They are prone to shrinkage. After the solvent flashes off, the bead can be as much as 35% smaller.

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<sup>2</sup> An elastomeric sealant is one that returns to its initial dimensions and shape after substantial deformation.

### Sealant Performance Summary

Generic type (one part)	Fabrication technology		Shrinkage	Movement Capability
Silicone			Very low	+/- 25% MC
Polyurethane			Low	+/- 25% MC
Acrylic Latex			high	+/-25% MC
Block copolymers			high	

Bateman, 1995

### A 2.2 Flashing

Flashing is defined as those materials or systems installed to redirect water entering through the building skin back to the exterior. Typically, flashing is applied to the head, sill and jambs of a window' rough opening. There are two broad classes of flashing:

- 1) rigid; and
- 2) flexible.

Rigid flashing, as the name implies, does not conform to the shape of the substrate it is being fixed against. Rigid flashings are generally made of galvanized metal or copper. They are typically custom fabricated to the window opening and are most commonly used as a Z or L type head flashing.

Flexible flashing describes a broad category of both peel and stick and non-stick flashings that include self-adhering bituminous tapes, flashing tapes, waterproof tapes, flexible window flashing, flashing membranes and wall tapes (Holladay, 2001). There are two general classes of flexible flashing - non-stick and stick (adhesive backed).

Taken as a broad class, peel and stick flashings are becoming the industry standard in terms of how to flash a window's rough opening replacing the traditional asphalt felt spline.

There are five general categories of flexible flashing, three are non-stick and two are stick. The non-stick flashings include paper flashing, polyethylene coated flashing and bitumen flashing. The stick flashings are a polyethylene flashing with an adhesive strip and a bitumen type flashing.

Paper flashing is typically made from two sheets of kraft paper laminated with asphalt and reinforced with fiberglass yarn. These products are required to have a 24+hr water resistance and conform to ASTM D779 (ASTM E2112-01).

Polyethylene coated flashing is reinforced with fiberglass yarn and has a polyethylene-coated exterior. Within this definition, there are two types of polyethylene-coated flashings. One has a polyethylene coating on both sides. The other has a polyethylene

coating on one side with kraft paper on the other side. This set of products has a 48-hr water resistance and conforms to ASTM D779 (ASTM E2112-01).

Bitumen flashing has a bitumen type filler between two sheets of polyethylene and/or polypropylene (ASTM E2112-01).

The stick flashings are variations of the non-stick flashings. They are a non-stick flashing that has had a sticky surface applied to one side.

Polyethylene flashing with an applied adhesive strip is a piece of polyethylene coated flashing with a 3 inch adhesive strip designed to cover the window flange to provide additional sealing between the flange and either the flashing under the flange or the frame, or both, depending on which installation method is used to install the window (i.e. Method A or B – see chapter 4). These products should not be used without another flashing. They are to be used in conjunction with another flashing material (ASTM E2112-01).

Bitumen type flashings are typically made from a rubberized bitumen material applied to a sheet of polyethylene, polypropylene or aluminum foil. In the majority of these products, the release sheet is pulled off, exposing the rubberized bitumen adhesive, which is then put down on the flange or frame, depending on the installation method being used. These products provide a complete seal, as their adhesive is across the entire product (ASTM E2112-01).

A discussion of various non-stick and stick flashings follows.

#### **A 2.2.1 Non-Stick Flashings**

Non-stick flashings, as the name implies, do not self-stick to a substrate, but must be nailed or stapled. The proponents of non-stick flashings like these materials because they will be less likely to trap moisture in the wall assembly (i.e. a wrong side vapor barrier).

There is no proprietary technology when it comes to non-stick flashings. Different manufacturers have created non-stick flashings using different base materials (see the Flashing Performance Summary table).

#### **A 2.2.2 Peel and Stick Flashing: Rubberized Asphalt (a.k.a. Bitumen Flashing)**

Most peel and stick flashings are made from rubberized asphalt. A typical flashing membrane is made by laminating a thin sheet (8 mil) of cross-laminated, high-density polyethylene (or aluminum foil) to the rubberized asphalt. The other side of the flashing membrane is protected with a siliconized paper release sheet. The asphalt is rubberized by modifying an asphalt base with styrene butadiene styrene (SBS). The complete cross section thickness is between 20 and 40 mil.

The polyethylene laminated rubberized asphalts should not be exposed to the weather because these products are UV sensitive. Manufacturers recommend they be covered within 30 days of installation.

Once rubberized, the asphalt becomes elastic and obtains an ability to accommodate thermal movement in the substrate (i.e. the sheathing). Another benefit of rubberized asphalt is because of its “cold flow” characteristic, it can seal around fasteners.

Rubberized asphalt can stick to a number of substrates including plywood, dimensional lumber, steel, aluminum, hard vinyl, asphalt felt and plastic wrap. To stick, the surface must be warm and dry when the membrane is applied. Rubberized asphalt will not stick well to concrete, masonry or OSB unless the surface is primed.

### **A 2.2.3 Peel and Stick Flashing: Butyl Rubber**

Butyl flashings are black like the rubber asphalt products, but can be distinguished from them by their lack of an asphalt smell as well as feeling more rubbery (Holladay, 2003). Like the rubberized asphalt flashings, butyl rubber can come with either a polyethylene or aluminum foil backing with the same concern about UV degradation for the polyethylene backed butyl rubber flashings. There is also a product from DuPont that is backed with a corrugated layer of Tyvek (i.e. Flexwrap). Another type of butyl rubber flashing is one laminated to a top layer of EPDM. This product is referred to as cover tape or flashing tape.

In general, butyl flashings cost twice to six times more (i.e. Flexwrap and the EPDM butyl flashings) than the asphalt rubber flashings. This price difference can be attributed to the advantages butyl rubber has over asphalt rubber (according to the manufacturers). These advantages include longer lasting stickiness, less staining, less high temperature oozing and temperature range for installation (Holladay, 2003). However, butyl flashings are incompatible with asphalt products.

### Flashing Performance Summary

product	Fabrication technology	performance
Sisal kraft paper	layer of asphalt paper sandwiched between two layers of brown kraft paper.	Easily cut by sharp objects, develops wrinkles when wet
Rubberized Butyl	20 mil rubberized butyl membrane sandwiched between either a 4 mil or 8 mil polyethylene or aluminum foil sheet on the face, and a siliconized paper release sheet.	Incompatible with asphalt
Rubberized Asphalt	20 mil rubberized asphalt membrane sandwiched between either a 4 mil or 8 mil polyethylene or aluminum foil sheet on the face, and a siliconized paper release sheet.	Polyethylene sheet products are UV sensitive, incompatible with flexible vinyl
Non-stick flashing	20 mil rubberized asphalt membrane sandwiched between either a 4 mil or 8 mil polyethylene or aluminum foil sheet on the face, and a metalized polyester on the back	Less likely to be a wrong side vapor barrier
Non-stick flashing	layer of kraft paper sandwiched between two layers of polyethylene	Doesn't wrinkle when wet, not intended for horizontal applications, can't seal around fastener holes

Note: with any peel and stick membrane, adhesion problems have been noted in the field (Holladay, 2003).

### A 2.3 Weather Resistant Barriers

There are five types of weather resistant barrier (WRB) available to the builder:

- 1) Asphalt Felt;
- 2) Grade D building paper;
- 3) Housewrap;
- 4) Wrinkle Wrap; and
- 5) Insulated Sheathing

The first three WRBs are flat; the fourth category is wrinkled or corrugated providing a relief. This last category of WRBs is in response to the Exterior Insulation Foam System (EFIS) market demand for a drainable plane within the building envelope. These products can also be installed behind other types of sidings (e.g. wood). As such, they are an option to be considered.

#### A 2.3.1 Asphalt Felt

Asphalt felt was originally made from cotton rag felt. Contemporary "felt" isn't made from cotton, but recycled corrugated papers mixed with sawdust (Holliday, 2000).

Asphalt felt is sold in two categories: #15 Asphalt Felts and #30 Asphalt Felts. At one time, the numbers 15 and 30 would have referred to the number of pounds 100 square feet of material weighed (e.g. 15 lbs per 100 square feet, 30 lbs per 100 square feet).

Today, due to pricing pressures, manufacturers make lighter products. In place of the 15lbs or 30lbs per 100 square feet, these materials are described as #15 and #30. #15 asphalt felt can weigh between 7 lbs to 14 lbs. #30 asphalt felt can weigh between 15 lbs to 28 lbs.

Within these two categories, manufacturers produce ASTM approved asphalt felt and non-rated asphalt felt. ASTM has established two standards for asphalt felt, ASTM D 4869 and ASTM D 226. In its standard system, #15 felt is referred to as Type 1 felt and #30 felt is referred to as Type 2 felt.

ASTM D 4869 requires Type 1 felt to weigh at least 8 pounds per 100 square feet. ASTM D 226 requires Type 1 felt to weigh at least 11.5 pounds per 100 square feet and Type 2 felt to weigh at least 26.4 lbs per 100 square feet. The non-rated asphalt felts are lighter weighing 7.6 lbs per 100 square feet.

One consequence of the different weights is the thickness of the felt - the heavier the paper, the thicker the paper. Thickness in turn affects how much water can be absorbed by a given piece of paper and its permeance<sup>3</sup>. Asphalt felt has a permeance of 5 perms when dry and 60 perms when wet. There is a debate about the relevance of the permeance of a building wrap. This position is based on the observation that with OSB board and plywood the most common sheathings, and with typical permeances of less than 1, the permeance of the asphalt felt is moot. However, from a water penetration perspective, it is recognized that if the felt gets wet, it soaks up the liquid water and then gradually dries to the exterior.

### **A 2.3.2 Grade D Paper**

Grade D paper is an asphalt impregnated kraft paper that resembles a lightweight asphalt felt (Holliday, 2000). It differs from asphalt felt in two ways. It uses the lighter weight paper and the paper is made from virgin paper pulp rather than recycled cardboard. The asphalt used to saturate Grade D paper and asphalt felt are equivalent.

The term Grade D originated with federal specification UU-B-790 that in turn was used by the Uniform Building Code (standard 14-1). It is within the context of 14-1 that the Grade D standard is used.

A Grade D specification refers to residential construction and requires a minimum water water-resistance rating of 10 minutes, and a minimum water vapor transmission rate that corresponds to a permeance rating of 5 perms.

The water resistance rating is in turn based on ASTM D 779 and is referred to as the “boat test”. A piece of paper is made into the shape of a boat and placed within a dish of water for 10 minutes. If the boat can withstand the soaking, it passes the test.

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<sup>3</sup> Water vapor permeance is the rate of water vapor transmission induced by a difference in vapor pressure through a certain area of material.

### A 2.3.3 Plastic Housewrap

Plastic housewraps are (generally) made from either polyethylene or polypropylene.

Housewraps can be divided into two categories:

- 1) perforated; and
- 2) non-perforated.

Perforated housewraps are made from vapor tight plastic films that are needle punched with small holes to allow for vapor transmission across the wrap. Non-perforated housewraps are made from non-vapor tight materials, and as a consequence, allow water vapor to pass through the material by design.

In general, housewraps have a measured permeance between 6 and 59. When a housewrap is installed within a wall assembly, it blocks the passage of bulk water. Water can only pass through to the exterior as a vapor.

### A 2.3.4 Wrinkled Wraps

As a response to the industry requirement for an interstitial drainage plane, as of 2000, four manufacturers have each developed a proprietary type of wrinkled or corrugated building wrap. Two of the products are draining versions of Grade D paper, and two are versions of housewrap.

Wrinkle Wraps	
product	Base material and/or technology
Stucco Wrap (DuPont)	Tyvek, corrugations less than 20 thousands of an inch
Perm-Vent (Hal Industries)	Two joined piles of Grade D paper, corrugations are 3/16"
Pink Wrap Plus (Owens Corning)	Housewrap, corrugations less than 20 thousands of an inch
Senergy (Drainage Wrap DF)	Grade D paper bounded with a 3D tangled net of plastic filaments

Holliday, 2000

While there is no consensus at this time about a minimum corrugation height, (1/8" is a suggested minimum) (Holliday, 2000), these products may allow a builder to provide drainage behind a wood sided building without installing a rain screen with vertical strapping.

### A 2.3.5 Insulated Sheathing

Rigid insulated boards can also be used as a WRB. In residential construction, the two materials that have been used in this capacity are foil faced rigid polyisocyanurate and extruded polystyrene (Lstiburek, 2003). In each case, the joints between sheathing boards (that come in 2'\*8' sheets) are taped with red Tyvek tape (Dupont Corporation).

Insulated Sheathing	
product	Base material and/or technology
Foil faced rigid polyisocyanurate	polyisocyanurate
Extruded polystyrene (Dow Chemical)	polystyrene