

WHITE PAPER



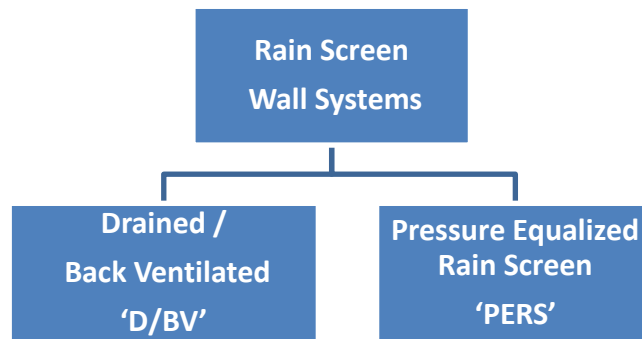
Understanding Rain Screen Wall Systems

Introduction

Understanding Rain Screen Wall Systems is published to clarify to the architectural and design community the key principles and background information employed in **Drained / Back Ventilated** or **Pressure Equalized Rain Screen** wall systems. It is also available as a resource to the General Contractor, Code Official or Owner communities to explain how the design properties of these two systems accomplish water infiltration management and prevention. Both systems employ some amount of open joinery and generally allow a certain amount of water into the cavity area between the outer and inner leafs. **Drained / Back Ventilated (D/BV)** systems rely on the ventilation cavity to both drain and dry-out the residual water. **Pressure Equalized Rain Screen** systems (PERS) also employ a ventilated and drainable cavity but add **compartmentalization** to limit water penetration in wall areas such as building corners where wind and wall cavity pressures can vary significantly. In these areas the compartmentalization of the wall cavity will facilitate rapid pressure equalization. PERS systems will greatly minimize and in some designs eliminate water penetration into the rain screen cavity. Rain screen wall systems may be designed as D/BV or PERS systems using a variety of cladding materials such as Metal Composite Materials (MCM) or single skin metal products.

Wall system designers' concern for entrapped moisture and the related consequences, such as mold and metal corrosion have increased the demand for rain screen wall systems which offer needed venting and drying potential while controlling rainwater. Since these wall systems are constructed from several inter-related components which must work as an assembly to obtain the desired performance, there is much confusion about how the components should be specified, contracted, and constructed. This document defines the most common metal-faced rain screen systems and their performance features. Also reviewed are recent test protocols written by AAMA for testing both system types. The Metal Construction Association (MCA) is aware and concerned about the level of confusion and misinformation feeding the increased presence of Pressure Equalized Rain Screen metal-based cladding systems in the domestic commercial design and construction marketplace. If not corrected, this misunderstanding will result in structures with water and air leakage failures which will inevitably be blamed on the system suppliers. Only when the design and performance of rain screen systems are understood as an acceptable standard of quality for the industry will the threat of failure, via an unexpected volume of water in the wall system cavity, be dramatically diminished. This requires proper design, detailing, fabrication, testing, and installation. As an extreme example, although too commonly seen, rain screen systems should never be applied to horizontal or skyward sloping surfaces. The open joinery typical of rain screen systems simply cannot control the buildup of water on horizontal surfaces that is common with rain-producing weather events. An alternate means of water control must be used for these surfaces.

It should be noted that the performance of all D/BV and PERS systems, rely upon a properly selected, detailed, and installed air/water barrier that is appropriate for the project climate zone. It must also be recognized that in all air/water barriers, a certain level of imperfection will exist after installation. Air barrier imperfections create a worst case assembly in that they reduce pressure equalization and are recognized and introduced within the testing standards AAMA 508-07, 'Voluntary Test Method and Specification for Pressure Equalized Rain Screen Wall Cladding Systems' and AAMA 509-09 'Voluntary Test and Classification Method for Drained and Back Ventilated Rain Screen Wall Cladding Systems'.



Rain Screen Wall Systems

A rain screen wall design will have two distinct components: *an outer leaf and an inner leaf*. The *outer leaf* or cladding element sheds and controls most of the rain water. Joint designs in the outer leaf have openings through which allow the cavity to pressure equalize with the exterior pressure. This pressure equalization thus eliminates the water entering the cavity that would normally occur due to a pressure difference across the outer leaf. The more joint openings, the easier it is to achieve pressure equalization. However the more openings in the outer leaf also will allow a greater chance of rainwater entry through means other than pressure difference across the outer leaf. The *inner leaf* performs multiple functions. It is 1) a water barrier, 2) an air barrier 3) a thermal barrier and 4) possibly, a vapor barrier as well as 5) the wall structural element.

In a **PERS system** the allowable amount of water entering the cavity and **contacting the air barrier** is strictly limited in the AAMA 508-07 test protocol. This is typically achieved through compartmentalization and smaller and protected joint openings in the outer leaf.

In a **D/BV system** the joints are more open and the water entering the cavity and contacting the air and water barrier is unlimited. The AAMA 509-09 test protocol is a classification method and not a pass/ fail test. Hence D/BV systems will likely have much more water in the cavity than a PERS system. It is important for the designer and detailer to understand the volume of water that must be managed and drained from the D/BV systems via the AAMA 509-09 test.

Specifying these systems is often confusing. Since the outer leaf and inner leaf are often by different suppliers in different specification sections, the system performance criteria is frequently incorrectly applied to the open outer leaf by itself since this element has no air or water tightness alone. Specified performance features need to be for the **system** and not the separate components.

It should be noted that a D/BV system that has enough openings to pressure equalize the cavity does not make the system a pressure equalized system. Unless it has the mandated compartments and can pass the AAMA 508-07 test with very limited wetting of the air barrier it is not a PERS system.

As JM Anderson and JR Gill stated in Rainscreen Cladding a Guide to Design Principles and Practices “The Rainscreen approach to weather protection developed into two distinct techniques. First there is the drained and back-ventilated rainscreen which involves draining off most of the rain water at the outermost surface of the wall and providing for cavity drainage and evaporation of the remainder. Second there is the pressure-equalized rainscreen. Here the aim is to eliminate penetration through the rainscreen not by tightly sealing joints, but by leaving some or all of them open to the passage of air *but not of water*. Both approaches can work successfully, but care must be taken that the two are not confused, since the adoption of hybrid versions can result in unsatisfactory performance.”

Different from Anderson and Gill's D/BV definition, it should be noted that in today's wall system market the definition of the D/BV rain screen has been expanded to include joints in the outer leaf that are totally open with no back up channels in the joinery to divert moisture to the exterior. This was recognized in the AAMA 509-09 document which develops data regarding the volume of water entering the cavity and contacting the air barrier, and the amount of ventilation allowed by the joint design. This data can be used to compare one system to another.

Let's take a look at the two fundamental wall systems using rain screen designs in more detail:

Drained / Back Ventilated (D/BV) Rain Screen Wall System

The D/BV system employs ...

- 1) A series of sheets, panels, or planks (collectively called ‘Cladding’) fixed to vertical support channels or rails as the exposed outer leaf or barrier. Joints in the outer leaf are open, but most are designed to obstruct water penetration by kinetic energy and wind force. It must be understood that the joinery is designed to minimize but not prevent water penetration. Water leakage resulting from variable wind-induced air pressure differentials will occur. Thus, at times, relatively large amounts of water can and will penetrate the outer leaf through its open joinery. Wetting of the inner leaf surface can occur and is permitted. AAMA 509-09 will help define the volume of water that may contact the air and water barrier that must be controlled and drained to the exterior.
- 2) In some designs vertical channels may be introduced to collect the penetrating water and drain it through gravity action to the bottom and exterior of the outer leaf.
- 3) Fenestrations and system penetrations must be continuously flashed and detailed to collect and direct water to the exterior or re-direct the water into vertical drainage channels.
- 4) A cavity (or minimum allowable depth of air space) between the outer and inner leafs is necessary to facilitate positive back-ventilation. This ventilation promotes rapid evaporation of any rain water deposited on the surfaces of the inner leaf or on the interior surfaces of the outer leaf. However, research has demonstrated that this cavity should be a minimum of 25mm (1”) deep for brick or masonry veneer walls (in order to keep the cavity reasonably clear of mortar accumulation). For other cladding materials, a minimum of 10mm (3/8”) is recommended in order to promote proper ventilation .¹The cavity depth should be in addition to the depth of exterior applied insulation material so as not to restrict the ventilation flow.

- 5) D/BV walls **require** an air/water barrier at the rear of the cavity. This barrier generally is placed on the outer face of the inner leaf. The reason for this is that the inner leaf, by design, is allowed to be wet at certain times. This continuous barrier serves to control airflow through the wall, reduces static air pressure differences across the cladding and allows the rain screen cladding and second line of defense (the inner leaf) to perform more effectively. The inner leaf surface, in addition to having a barrier applied, must be completely flashed to eliminate water penetration into the building and direct run-off of any water infiltration to the outer leaf.
- 6) The inner leaf is generally the structural building enclosure wall and should be designed to envelop the building's interior environment.
- 7) Water resistant insulation can be applied to the exterior side of the moisture barrier to meet the building's thermal design requirements. Use of insulation in this manner helps to maximize usable building space and should minimize the chances of condensation and cold bridging to the inner face of the inner leaf.
- 8) While there are many opinions on the level of wind load to design both the exterior leaf and inner leaf to, there is currently no design support to reduce the wind load impact on either element. Each leaf and its attachments should be designed to withstand 100% of the building's wind load.
- 9) Ventilation can be achieved in either vertical or horizontal exterior leaf joints. To achieve air flow and enhance drying of wetted cavity elements, one would generally find multiple openings in the exterior leaf joints.

Anderson and Gill state that the main point is that D/BV **claddings** are not designed to be watertight, and no deliberate attempt is made to minimize the structural or water penetrating effects of wind by pressure-equalization. Instead, the cavity behind the outer leaf is drained and positive back-ventilation is used to promote rapid evaporation of any rainwater deposited on the inner leaf surface.

Additionally, conventional air and water test criteria cannot be applied to the outer leaf alone (due to its open joinery design), but should more properly be applied to the completed wall system including the inner leaf.

To document the amount of ventilation through the exterior cladding and the amount of water contacting the air and water barrier on the inner leaf through a series of static and dynamic water tests AAMA has published 509-09, a Voluntary Test and Classification Method for Drained and Back Ventilated Rain Screen Wall Cladding Systems. Since DB/V systems vary greatly from a totally open cladding joint system to more tight systems, AAMA 509-09 will establish a classification for the amount of air allowed through the cladding and the amount of water passing through the cladding and contacting the inner leaf and air barrier. There is not a pass/fail criteria for this test. It is important for the designer to understand the specific requirements related to their project to properly use the information obtained from an AAMA 509-09 rain screen test report

Refer to figures 1 and 2 for representations of a D/BV rain screen panel system's horizontal and vertical joinery. This example uses the European 'Hook & Pin' open joinery method which is a D/BV rain screen system. Other joinery details can be employed under the D/BV theory of design and they do not need to be the 'Hook & Pin' type. Spline joinery systems also classify under this rain screen design type, so long as suitable bottom to top venting is provided for.

Key elements for Figures 1 and 2:

- (1) The 'Outer leaf' cladding system (or the 'rain screen')
- (2) Vertical drainage channel
- (3) Penetration flashing
- (4) Ventilation cavity
- (5) Air/water barrier
- (6) Approved ' Air/water Barrier' compatible flashing membrane tape at all penetrations
- (7) The 'Inner leaf' or face of building structural wall
- (8) Moisture resistant insulation (Optional, as required by thermal design requirements)
- (9) Ventilation path
- (10) The building structural wall

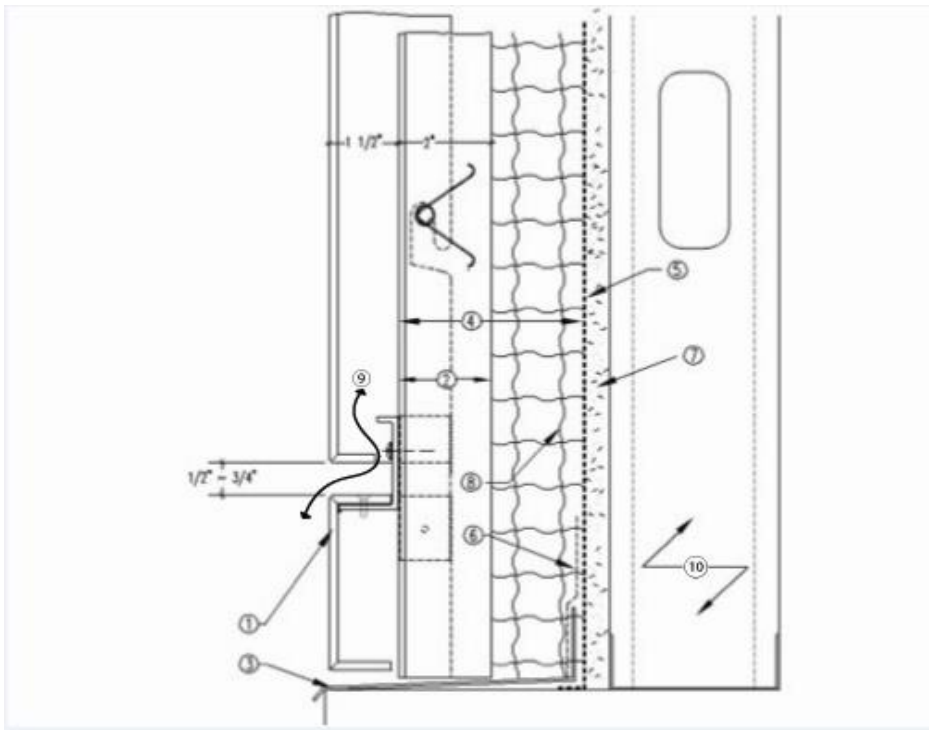


Figure 1: Typical horizontal joint detail for D/BV rain screen panel system

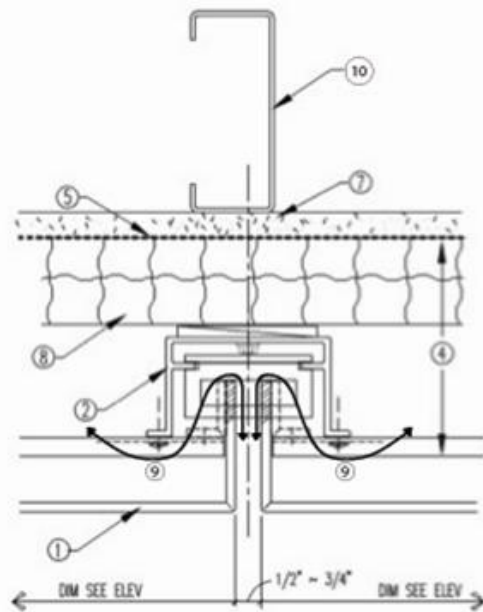


Figure 2: Typical vertical joint detail for D/BV rain screen panel system

Pressure Equalized Rain Screen (PERS) Wall System

Pressure equalized rain screen walls are generally more design intensive. As such, they are sensitive to design variations and deviations from the PERS design principles. The openings in the PERS wall cladding joints must be specifically designed to allow both static and dynamic pressure equalization to take place across the rain screen with very limited water passing through the outer leaf (cladding) into the cavity. The essential defining attribute that differentiates PERS from D/BV systems is the design and use of compartmentalization within the cavity. The reasoning for compartmenting is that pressure equalization can only occur within very brief time periods (seconds) if the internal volume of the cavity behind the rain screen is known and controlled. This compartmentalization is essential because wind pressures across a building face are typically not uniform and are constantly changing. The number and geometry of the vent openings are calculated based upon the known cavity volume to allow sufficient air flow in and out of the compartmented ventilation cavity quickly enough to respond to ever-changing wind dynamics. This facilitates pressure differences across the outer leaf to be minimized when compared to the ventilation cavity pressures. Equalizing the air-pressure on the external and internal sides of the outer leaf reduces, if not eliminates the rain-driving forces. The effective area of the vent holes depends upon 1) the air tightness of the air/water barrier system on the inner leaf, 2) the stiffness of the outer leaf (rain screen cladding) and inner leaf and 3) the volume of the individual compartments that make up the ventilation cavity. These ventilation cavities are an essential element of proper pressure-equalized design as they 1) control vertical and lateral air flow, 2) dictate the size of the vent openings that must be designed to facilitate pressure equalization, limit water infiltration, and control water drainage at times of air-pressure disequilibrium. Non-compartmentalized ventilation cavities cannot be classified as pressure-equalized since larger volumes of water may enter the cavity as a result of varying cavity pressures.

There are a number of the PERS systems with construction elements that are similar to the drained/back-ventilated rain screen, but have several significant and important differences.

What is similar between the DB/V and PERS systems?

(Refer to the D/BV outline above and figures 1 and 2).

Elements (1), (3), (4), (5), (6) and (7) are common construction elements of the D/BV and PERS systems.

However, item (4) the ‘Ventilation Cavity’ must be more specifically designed and controlled as to its size and volume to facilitate pressure-equalization. Item (5) the ‘moisture barrier’ must be an air/water barrier which can significantly deter air leakage into the building’s interior thus cutting off air-pressure differentials that can bleed the ventilation cavity and reduce pressure equalization. . The design and installation of the air / water barrier is a prime consideration in any rain screen system. The Air Barrier Association of America (abaa) has developed a master specification section 01410 “The Air Barrier System” that details the design considerations that must be addressed when specifying the air / water barrier to be installed. To insure a higher quality air barrier installation, but recognizing the likelihood of minor installation flaws, AAMA 508-07 defines a minimum level of air leakage that the wall assembly must accommodate for testing.

As noted in AAMA 508-07, at this point in time there is insufficient evidence to substantiate any reduction in the structural design load for the connection system of rain screen cladding elements (outer leaf) for the PERS systems.

What is different? (Refer to figures 3 and 4)

The outer leaf cladding’s (1) joinery design is altered to create extensions back to the face of the inner leaf (5) or insulation (7) creating ‘pressure-controllable compartments’ at both vertical and horizontal joints. The size of the cladding and the compartmentalization behind requires a series of special calculations that in reality must be proven-out by testing*. Each building has its own wind dynamics which must be taken into consideration so a ‘one-size-fits-all’ approach is not recommended.

The vertical drainage channels (2) are typically interrupted by the bottom horizontal joinery of each compartmented unit. This is due to the fact that the primary design intent for a PERS is to create isolated cladding units with internal cavities that self-drain any incidental water penetration.

The moisture barrier (5) must be a dual performing air and water barrier as discussed in ‘What is similar in both?’

Anderson and Gill note that for **drained and back-ventilated rainscreens:**

“The main point to note about the drained and back-ventilated approach is that claddings are allowed to leak, and no deliberate attempt is made to minimize the effects of wind by means of pressure equalization. Instead, the cavity behind the cladding is drained and positive back-ventilation is used to promote the rapid evaporation of any rainwater deposited on the inner leaf. The same process is used to evacuate the water vapour which permeates through the inner leaf and its insulating layer.”

Anderson and Gill further offer the following main point for **pressure-equalized rainscreens**...

“The main point to note about the pressure-equalized rainscreen approach is that without relying on the use of sealants or gaskets, every effort is made to minimize or eliminate leakage through the joints in the cladding assembly... There may, however, be some minor leakage into the cavity and a precautionary drainage mechanism is therefore necessary. Positive back ventilation is also used to promote the rapid evaporation of residual rainwater and to evaporate the water vapour which permeated through the inner leaf.”

Different from the AAMA 509-09 Classification Method, AAMA 508-07 a Voluntary Test Method and Specification for Pressure Equalized Rain Screen Wall Cladding Systems quantifies and limits the amount of water entering the cavity and contacting the inner leaf and air barrier.*

Key elements for Figures 3 and 4:

- (1) The ‘Outer leaf’ cladding system (or the ‘Rain screen’)
- (2) Vertical drainage channel
- (3) Penetration flashing
- (4) Ventilation cavity/compartment
- (5) Air/water barrier (commercial building wrap)
- (6) Approved ‘Air/water barrier’ compatible flashing membrane tape at all penetrations
- (7) The ‘Inner leaf’ or face of building structural wall
- (8) Moisture resistant insulation (optional, as required by thermal design requirements)
- (9) Ventilation path for pressure equalization and drainage
- (10) Horizontal air dam used to create compartmentalization
- (11) The building structural wall

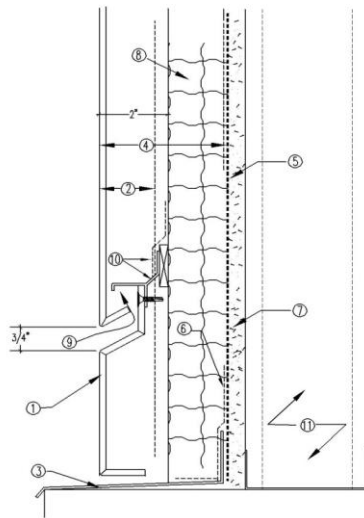


Figure 3: Typical horizontal joint detail for rain screen PERS panel system

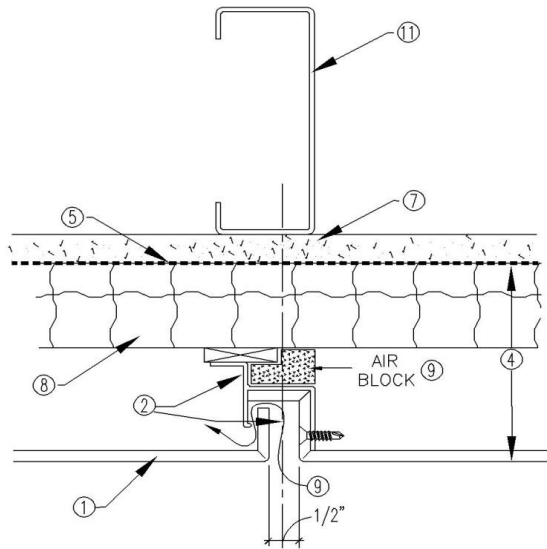


Figure 4: Typical vertical joint detail for rain screen PERS panel system.

* One of the key elements of substantiating the existence of pressure equalization within a system is testing. While critical design calculations are a must for proper design, testing will prove the validity of these calculations. Up until 2005, there was no industry recognized testing protocol for proving-out pressure equalization. AAMA has released a test method which incorporates both cyclic and dynamic testing using air barriers with a defined level of imperfections. The AAMA 508-07 ‘Voluntary Method and Specification for Pressure Equalized Rain Screen Wall Cladding Systems’ © 2005, dated December 2005 is the first recognized domestic testing protocol to be adopted specifically addressing rain screen performance. Subsequently the AAMA 509-09 protocol was written for the DB/V rain screen wall systems. Copies of the testing procedures can be obtained (for a small fee) at www.AAMANet.org (enter in search: ‘508’ or ‘509’)

In Conclusion

There should be no confusion between rain screen types, yet confusion seems to be widespread. Too often, we are faced with specifications that commingle the elements of both rain screen system types and even introduce elements of other non-rain-screen cladding designs.

JM Anderson and JR Gill stated in their highly recognized technical book Rainscreen Cladding a Guide to Design Principles and Practice ... “Successful application in design, however, particularly as regards detailing, demands clear understanding of the scientific principles underlying the main approaches to rainscreen cladding ... Successful rainscreen design depends on proper understanding of both of the design principles and of the way in which the technology originated and developed ... confusion may lead to the development of hybrid versions, which may or may not achieve the design objectives.”

In summary, there are two basic types of rain screen systems currently in use – The Drained/Back-Ventilated (D/BV) and the Pressure-Equalized (PERS). Both systems employ open joinery and allow water into the ventilation cavity between the outer and inner leafs. Drained/Back-Ventilated systems rely on the ventilation cavity to both drain and dry-out the residual water. AAMA 509-09 test protocol documents the volume of water entering the cavity and contacting the air barrier, and the amount of cavity venting. Pressure-Equalized Rain Screen systems employ drainable compartmentalization to limit water penetration during periods of pressure disequilibrium and to facilitate rapid pressure equalization. AAMA 508-07 establishes the performance criteria for PERS systems relative to the volume of water in the cavity contacting the air barrier. Also established in AAMA 508-07 is the ability of the wall system to quickly pressure equalize.

It should be well understood by the design and construction professionals that since the various rain screen system elements (outer leaf, insulation, air/vapor barrier and inner leaf) can likely be supplied by different sources/subcontractors, specifications and contracting methods need to be closely coordinated and controlled to assure satisfactory performance of the integral system. Contractually, the overall warranty and performance of a rain screen wall must ultimately be designed and defined by the construction professionals. The open-ended and non-specific nature of many specifications are leading to confusion and reliance upon one source from one rain screen element (usually the ‘outer leaf’ supplier) to solve all function and performance criteria without requiring such responsibility within the specifications and/or contract. As much as inappropriate design and representation of a rain screen system by its supplier/manufacturer, the inappropriate specification and contracting of a rain screen system will ultimately lead to lower than desired performance levels relative to weather tightness.

Footnotes:

1. NRC-CNRC Construction Technology Update No 9: Evolution of Wall Design for Controlling Rain Penetration© 1997, by G.A. Chown, W.C. Brown and D.F. Poirer. National research Council of Canada December 1997 ISSN 1206:1220

The design intent for the true ‘rain screen’ panel/cladding system is more clearly defined and discussed in a variety of reputable publications available through the internet and industry sources. Following is a short bibliography:

Primary source: American Architectural Manufacturers Association (1540 East Dundee Road - Suite 310, Palatine, IL 60067 (847)202-1350)

The Rain Screen Principle and Pressure-equalized Wall Design (AAMA Aluminum Curtain Wall Series) (copyright© 1996) [Note: The original article can be found in the Architectural Aluminum Manufacturers Association (AAMA - 35 East Wacker Drive, Chicago, IL 60601): Aluminum Curtain Wall Design Guide Manual, Volume 2 (copyright© 1979)]

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- NRC-CNRC Construction Technology Update No.34, Designing Exterior Walls According to the Rainscreen Principle, by W.C. Brown, G.A. Chown, G.F. Poirier and M.Z. Rousseau (copyright © 1999) – National Research Council of Canada, Institute for Research in Construction <http://www.nrc.ca/>
- Rainscreen Cladding a Guide to Design Principles and Practice, by JM Anderson and JR Gill, CIRCA (Construction Industry Research and Information Association) publications, 1988, London, England NRC-CNRC Construction Technology Update No.46, A Method for Evaluating Air Barrier Systems and Materials, by Bruno DiLenardo (copyright © 2000) – National Research Council of Canada, Institute for Research in Construction <http://www.nrc.ca/> 60025-1485

Notes:

- 1) The illustrations in this document are conceptual in nature and are not intended to represent any manufacturer's system. Any representation to the contrary is purely coincidental.
- 2) The information contained herein should not be used as a basis for reduction of the load-resisting characteristics of the outer leaf.
- 3) This document is meant to serve as a conceptual explanation and not a design guideline for rain screen systems.

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METAL CONSTRUCTION ASSOCIATION

8735 W. Higgins Road, Suite 300, Chicago, IL 60631

847.375.4718 | mca@metalconstruction.org | www.metalconstruction.org

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