



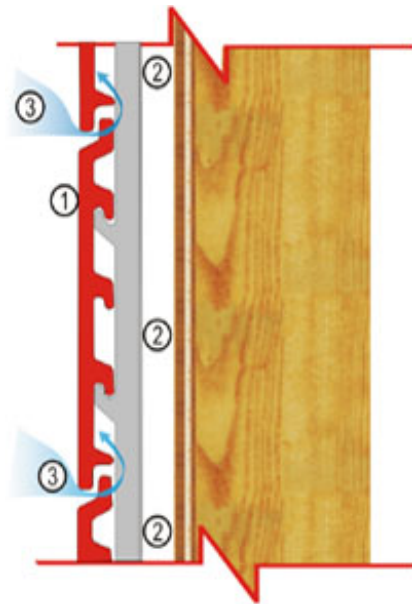
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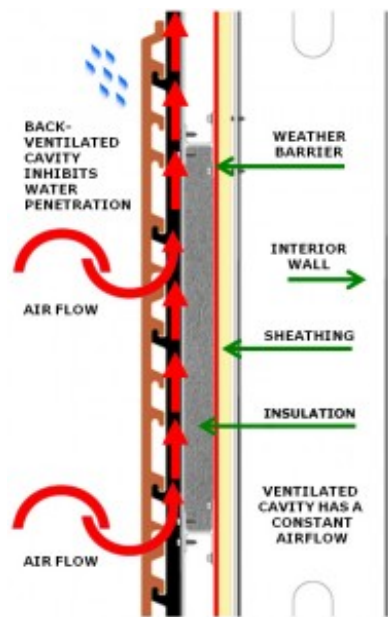
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Rainscreen Principles



A Brief History of Rainscreens



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In the building industry, there is a debate over what a rainscreen is or is not, and what types of designs should fall under that name. The problem is rooted in a lack of understanding about the history and nature of rainscreens and the 'open rain screen' principle.

Early examples of rainscreens can be found in the wall construction of Norwegian style barns dating back a hundred years or so. These barns, both in the U.S. and in Norway, were built using a layer of open-joint wood battens or siding set over a traditional stone wall. This type of construction was later called "two-stage weather-tightening". This design certainly allowed for ventilation and drainage, while some applications may have inadvertently moderated the effects of pressure differences along the cladding²⁶.

In 1953, the Alcoa Building (now the Regional Enterprise Tower), a 30 story skyscraper in Pittsburgh, PA., was built using 1/8" thick aluminum panels with open, labyrinth-type, pressure- moderating joints. In addition, in the late 1940s and 50s the concepts of weather-screens, cavity walls, drainage, and back-ventilation was being discussed by researchers in the U.S., Canada, and Britain,

and applied to masonry veneer walls²⁷.

The rainscreen principle was formalized by Birkeland in 1962 and by G.K. Garden in 1963. Birkeland, a Norwegian, "suggested that venting the cavity behind the a screen would equalize the pressure on either side of the screen and essentially eliminate air pressure differences as a rainwater penetration force." Birkeland was looking back at the open cladding walls used on old Norwegian barns. Garden, working in Canada, coined the terms 'rain screen' and the 'open rain screen principle'²⁸.

Garden opens his discussion of rain penetration in the Canadian Building Digest with:

"Although a number of traditional wall systems have had a measure of success, it is only recently that scientific studies have been undertaken to explain the mechanisms of rain penetration. Through better understanding of these mechanisms it should be possible to design and construct walls from which the problem is virtually eliminated."²⁹

And later remarks:

"With the many advantages of the open rain screen, its full development should be pursued by all building designers."³⁰

Building researchers and scientist thought the 1960s and 70s continued to test and validate open rainscreen systems as well as simple, vented and drained systems. The Architectural Aluminum Manufacturers Association (AAMA) published the first guide for pressure equalizing designs in 1971. Today, while research and testing on rainscreens continues, there is a growing initiative to standardize rainscreen specifications and criteria³¹.

Some in the building industry are raising concerns that the term 'rainscreen' is being improperly used and that the industry at large needs to carefully define standards and specifications for rainscreen systems. Some of the debate is over semantics and can be resolved with better information and definition. For instance, some want there to be clear distinction between 'rainscreen' and other 'screened-drained' designs. They maintain that Garden's and Birkeland's definition of the open rainscreen principle is the proper definition, and other designs that merely use 'screened-drained' designs should not be called rainscreens. If the wall system does not allow ventilation, and more importantly, pressure moderation then it is not fully following the 'open rainscreen principle'³². Some also worry that the misuse of the term 'rainscreen', and the absence of regulations and standards may hurt its reputation in the industry³³. Some organizations have used such terminology as 'pressure -equalized rainscreens' or 'pressure-equalized and compartmented rainscreens', in order to stress the addition of pressure moderation, and end the debate³⁴.

What is the Rainscreen Principle?

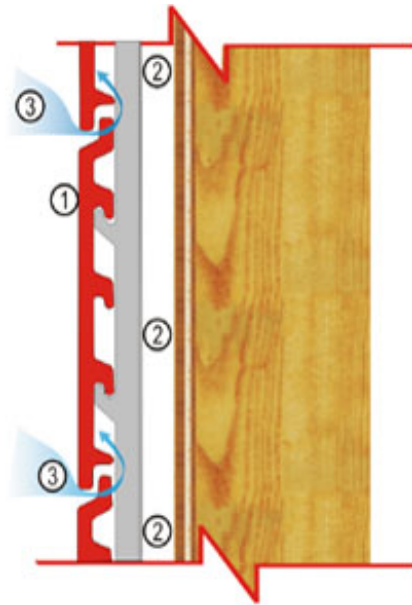


Figure 10: Basic Rainscreen Components.

The Rainscreen Principle as we know it today owes much of its development to such men as Garden, Birkeland and others. Although the terms 'rain screen' and 'the open rain screen principle' emerged in the 1960s, one can point to much earlier examples of rainscreens dating back to the 19th century (see "A Brief History of Rainscreens").

Garden examined the five forces that cause rain penetration in a wall (see Figures 1-5), and also looked at existing wall designs that used cavity walls and interior drainage to control water egress. He hypothesized that if all of the five forces behind water penetration through a wall can be controlled or eliminated, then water (even if present on the wall) will not infiltrate.

"It is not conceivable that a building designer can prevent the exterior surface of a wall from getting wet nor that he can guarantee that no openings will develop to permit the passage of water. It has, however, been shown that through-wall penetration of rain can be prevented by incorporating an air chamber into the joint or wall where the air pressure is always equal to that on the

outside. In essence the outer layer is then an “open rain screen” that prevents wetting of the actual wall or air barrier of the building³⁵.” (italics added)

Garden and Birkeland both reasoned that air pressure differences between the interior and exterior of the wall results in air currents that in turn carries water or moisture into the wall. Most designs at that time did not provide a strategy to relieve air pressure differences that a wall experiences, and if any designs did moderate pressure, it was incidental. Air pressure was a cause of water penetration that many had not even considered, but studies have shown that this force is a major contributor to water leakage³⁶.

What is a Rainscreen Wall System?

Rainscreens use the ‘open rain screen principle’, are a subset of the ‘screened-drained’ category of wall designs, that incorporate those characteristics with one important addition. The hallmark of the ‘open rain screen’ is its ability to equalize air pressures and allow ventilation. To do so, all rainscreens have three very basic components: (see Figure 10)³⁷

1. A ‘screen’ or outer layer³⁸.
2. A Pressure Equalization Chamber (PEC)³⁹ that is sealed on all sides except at the vent(s).
3. An opening or vent connecting the air chamber and the outside⁴⁰.

More specifically, in order to counter the other four forces that cause rain penetration, rainscreens have other features. Figure 11, is a more comprehensive design that fully develops the ‘open rainscreen principle.’

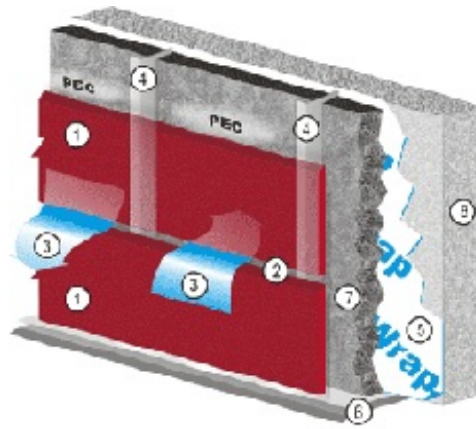


Figure 11: More Rainscreen Components.

1. 'Screen' or Cladding

- Must be durable material that is as non-porous as possible⁴¹;
- Usually in the form of panels⁴².
- Allows water to run off both sides⁴³.

2. Open Joints / Air Vents

- Must include gaps for ventilation⁴⁴.
- 'labyrinth' type or interlocking dry joints will control gravity, momentum, surface tension and capillary action forces. (see Figures 1 -5)⁴⁵
- 'wet seals' such as caulk can be eliminated or used behind the cladding and thus are better protected from the elements⁴⁶.
- Carefully sized to allow enough air to enter the pressure equalization chamber, and to promote drying⁴⁷.

3. Air Flow into and out of PECs

Pressure Equalization Chamber (PEC)

- The wall is divided into many smaller, self-contained chambers⁴⁸.
- Each chamber size is carefully determined, and as air tight as possible.
- The bigger and deeper the chamber is the more air intake is needed and the

bigger the vents need to be⁴⁹.

4. Chamber Baffles

- These are the side walls of the PEC and must resist the wind and pressure loads inside the PEC.
- Baffles need to be relatively airtight.
- Baffles may be any sort of divider, including the structural connector or fasteners that support the cladding⁵⁰.

5. Air (and Moisture) Barrier

- Must create an airtight barrier between the PEC and the inside of the building.
- Must be strong enough to handle the wind and pressure loads⁵¹.
- Some materials can double as both an air barrier and a water barrier⁵².

6. Flashing, Drip Edges, and Drainage Channels

- Flashing and Drip edges are used to funnel water out of the PECs and away from the building⁵³.
- Panels may have built-in channels that evacuate water that either drains along the face or the back sides of the panel.

7. Waterproof Insulation (optional)⁵⁴

8. Inner Wall Structure

How A Rainscreen Works

The first and obvious defense a rainscreen wall provides is the ability of the screen to deflect rainwater striking the exterior face of the wall. When water contacts the surface it forms a film that clings to the face of the wall. The forces of gravity and cohesion drive the water down and along the wall face. Every joint, opening or break in the continuity in the wall face presents an opportunity for water

to gain access. Rainscreen panels have open joints that are designed permit airflow, yet discourage water flow past the joint using labyrinth shaped and/ or interlocking connections. The specific designs vary from product to product, but all need to control capillary action, surface tension, and gravity flow.

The 'open rain screen' wall system moderates and limits the force of air pressure. A wall is exposed to the dynamic forces of wind and temperature, which in turn creates differences in barometric pressure between the interior of the wall (or building) and the outside face of the wall. Such differences result in cross currents flowing through the walls in order to establish equilibrium⁵⁵.

The rainscreen safely moderates pressure differences by allowing outside air to enter the pressure equalization chamber (PEC), just behind the cladding when the outside pressure is greater than the inside pressure. This air will increase the chamber pressure until its pressure and the outdoor pressures are equal. Naturally, the direction of airflow may reverse if the exterior pressure is lower relative to the pressure within the PEC. When all five of the forces causing rain penetration are reduced or eliminated, water that wets the face of the screen will not penetrate the cladding even if the joints are open. The result is a very effective means of controlling water infiltration that does not rely on one single barrier of protection, or even the absence of water on the wall.

Those familiar with wall design may ask, if most wall designs strive to eliminate airflow through the wall (because such airflow naturally carries water and moisture) then how can a rainscreen promote such currents and claim to control water penetration? The answer is that the 'open rain screen principle'

limits the ventilation to the cladding and the PEC. Also, the system is designed so that the strength and volume of air flowing past the screen are sufficient enough to equalize the chamber pressure, yet remain relatively weak and therefore can not carry moisture with them. Pressure moderation for each PEC must occur as quickly as possible to reduce suction forces and lower the wind load on the screen itself⁵⁶.

The PEC should also be as air tight as possible. An airtight chamber will leak less and thus require less airflow in order to maintain a certain level of pressure. This in turn decreases the size of the vent. The overall depth of the PEC also affects the pressure-equalization process because a larger PEC will require a higher volume of air to relieve or build-up its internal pressure. To handle a greater volume of airflow, the vents will naturally need to be larger. As the pressure differences at the screen are being neutralized, the net suction force on the cladding becomes very low (or zero) the wind load is then carried by the PEC, baffles, and structural wall. Clearly, the PEC as a whole (the side baffles, and the back wall) must be strong as well as airtight⁵⁷.

As part of the larger group of wall designs called 'screened-drained' systems (see "Approaches to Wall Design"), rainscreens also possess a secondary defense against rain and moisture penetration. The PEC is also a drainage cavity that the system uses to capture and evacuate water away from the wall structure. The cavity acts as a capillary break between the outer and inner wall layers. . As mentioned above, the PEC is a well ventilated chamber. One of the most effective ways to quickly dry a wall assembly in addition to drainage, is to promote ventilation⁵⁸.

When a rainscreen system is designed, another consideration is also important, namely the sizes and locations of the PECs. In contrast to a simple air cavity, the PEC is not a wide-open space behind the cladding, but rather it is a series of independent, adjacent, carefully sized chambers. One basic factor in determining the size of the chambers for a particular wall, is the range of air pressures that section of the wall will likely face. typically, wind loads are greater and more dynamic along the outer edges of a wall than at the center where the wind loads are more static. Therefore, the PECs will be smaller along the perimeter of the wall, than at the center. In general, a smaller PEC can reach equilibrium faster than a larger one, and therefore is better able to keep pace with higher, and more dynamic pressure levels^{59 60}.

A Comparison of Wall Designs

Of the three main categories of wall designs used to date, the 'face sealed' and the 'screen-drained' methods are used in most modern construction projects. In general, the 'screened-drained' approach has many advantages over the 'face sealed' method. Rainscreens are a further improvement on the 'screened-drained' method of wall designs and hold the most promise for current as well as future wall designs.

The 'face sealed' concept is a very straightforward strategy of rain control, it simply attempts to form a perfect, impermeable envelope around the building structure that will stop all water penetration. This system solely relies on the outer face seal as the only defense against water and moisture penetration. Advances in construction materials when this approach

was being developed, may have spurred some to propose that a perfectly sealed barrier could now be constructed. Despite the technological improvements, very little attention was given to the role of air pressure as a contributor to rain penetration⁶¹. This oversight may explain why 'face sealed' systems are ill-equipped to manage the force of air pressure, which is the biggest weakness to the 'face sealed' approach. Although this factor was not always well understood, scientists later realized that it is not only the most harmful of the factors, but also the most difficult to eliminate.

When a difference in air pressure exists between the exterior and the interior sides of a wall, air from the high-pressure area will attempt to flow into the low-pressure area in order to achieve equilibrium. Such air currents are persistent, and able to carry moisture or water with them as they try to flow through the wall assembly. This suction will act on any crack or pour in the wall face. As long as the barrier can handle the stress of air pressure forces and remain perfectly sealed, it will perform well.

A true face sealed system is not only incomplete in its approach, but also problematic and impractical to use in many circumstances. In most cases, the face-sealed barrier is located on the outside of the envelope where it is exposed to the elements. Using wet-applied sealants to seal joints on the wall face presents a potential liability because as time passes, the less-durable sealants begin to lose their elasticity, and potential gaps can appear on the surface of the wall.

To further complicate matters, some 'face sealed' systems may perform well in controlled environments, however, human error during installation can drastically affect

the systems ability to control water penetration. Installation errors can happen anywhere, but for these types of systems that must create a near perfect barrier seal in order to work, improper installation is also a major liability. When mistakes happen, how practical is it to use systems that offer no secondary rain control methods if the primary barrier leaks⁶²?

Furthermore, many in the building industry are being turned off from 'face sealed' walls because they dislike another side effects of wet sealants namely, leaching⁶³. Leaching is the unsightly streaks and stains left on a wall when caulk degrades. Therefore, many have looked to dry-joint 'rainscreen' cladding systems as a solution.

All 'face sealed' wall systems eventually fail, and essentially function by default as either a mass wall system or as a 'screened-drained'⁶⁴ system. In other words, the when water breaches the face of the wall, what happens then? If water penetrates the wall surface, it may remain locked within the wall, or it may seep further inward, or perhaps evacuate. If the wall is not designed to contend with water leakage ahead of time, then anything could happen.

Lately, there has been some controversy over E.I.F.S. walls systems and there performance. E.I.F.S. is a type of artificial stucco that uses a layer of foam board over the structural back-up wall to provide insulation, and then applies an outer layer of synthetic stucco to seal the face. The E.I.F.S. system is primarily designed as a 'face sealed' wall. There are cases where water has breached the face (perhaps through a caulk joint), and collected in the insulation foam within the wall, and this trapped moisture caused structural damage and mold growth. For these kinds of 'face sealed' systems, the very things that were

intended to keep water out, may have also precluded the moisture from evacuating⁶⁵.

The most successful transition from the former 'mass' wall designs, used for centuries, to modern walls was the adoption of internal drainage and air cavities. 'Screened-drained' walls solved several problems at once. Because modern building walls needed to be thinner, and less massive than their predecessors, the new walls did not work well as 'mass' or 'storage' systems. A good 'mass' wall is thick enough to hold the water it can not deflect, and then allow that water to evaporate before it seeps inside the building. When brick or masonry walls were constructed with an air and drainage cavity between the veneer and the back-up wall, they remained drier and well ventilated which better controlled water penetration⁶⁶. Because of the severe difficulty of creating a 'perfect barrier' against rain and the elements, it is only prudent that the design accommodates the eventual water leakage and condensation buildup. The 'screened-drained' approach is the best, and most practical way to accomplish that. Even E.F.I.S. systems are being modified to use drainage cavities similar to masonry cavity walls⁶⁷.

Further developments lead to the discovery of 'open rain screens' which built upon the principles of the 'screened-drained' wall type, yet solved the causes of rain penetration like nothing else prior.

The Rainscreen is similar to the 'screened-drained' system in that both use a two-part wall assembly, comprising of an outer screen or cladding separated from the back-up support wall by an air space. The cladding or screen is fitted with vents that allow airflow back into the air space. Depending on the type of materials used to construct the screen, the amount of and location of the

vents can vary. For both rainscreens, and 'screened-drained' walls the screen acts as the first line of defense against driving rain; much of the water will wet the surface but run down the face. Both systems have a ventilated air cavity behind the screen that promotes drying, interrupts the capillary action, and allows water or condensed moisture within the wall assembly to escape down the cavity and then outside. Neither approach rely solely on the performance of the outer face to keep out water or moisture, rather they make accommodations for any sort of water penetration over the life of the building. Unlike the 'face sealed' approach, these systems can use an open, dry-joint cladding design without compromising performance.

A rainscreen wall system possesses a special characteristic that no other type of wall design has, the ability to moderate air pressure. Air pressure is the only cause of rain penetration that is not dealt with by the 'face sealed' or 'mass' wall systems. While some 'screened-drained' wall types may marginally moderate pressure, it is merely incidental. Bear in mind, the 'open rain screen' principle is only a solution to rain penetration if the forces of air pressure at the face of the wall are moderated and eliminated, along with the remaining forces. G.K. Garden, the building scientist credited with coining the term 'open rain screen' in 1963, took a logical approach to solving the problem of water penetration. His purpose was to understand the mechanics and causes involved then designed a system that counteracted each of them. If the forces behind water infiltration are neutralized then water will not leak even if the wall is wet, and an entry point is available.

As product manufacturers and designers have worked to implement the 'open rain screen' principle, new rainscreen wall systems

incorporating high-tech materials, they have emerged. These systems offer exciting solutions and opportunities to architects, developers and contractors who are not only interested in solving rain penetration, but in all areas of wall performance.

Rainscreens

› Overview

› A History of Rainscreens

› Causes of Water Penetration and Damage

› Approaches to Wall Design

› [Rainscreen Principles](#)

› Footnotes and Bibliography

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