Technics | Rain Screen Principles in Practice

Architect **Richard Keleher** of Wallace, Floyd, Associates discusses the principles of rain screen design and how they are used on a current project.

Abstract

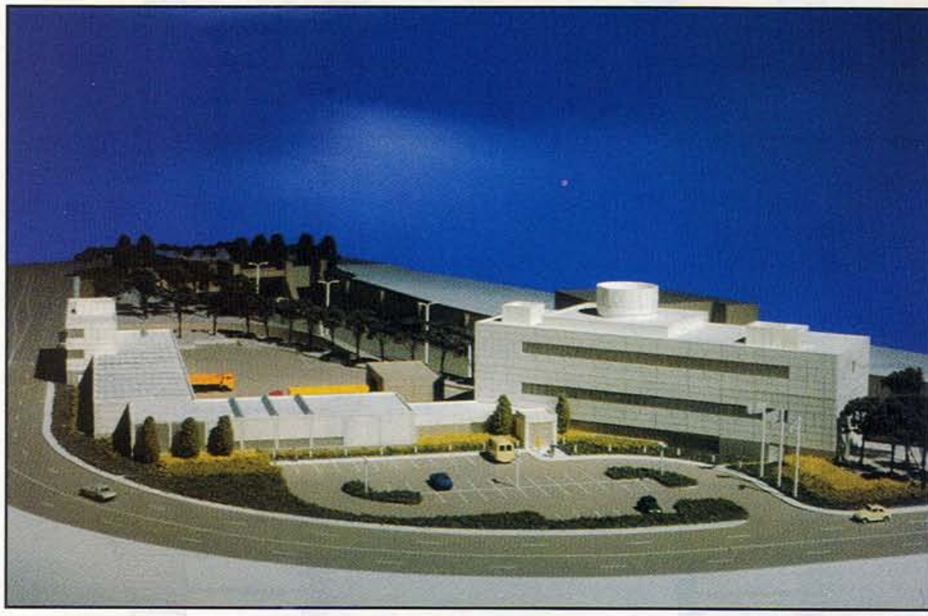
The design of exterior walls has traditionally been based on the concept of the building's skin acting as a single layer to keep out the rain as well as to retain conditioned air and to resist the forces of wind and air pressure. Such skins are vulnerable to leaks. Rain screen cladding uses principles of controlled water leakage and equalized air pressure to repel rain from the wall cavity. There are two rain screen types, suitable for specific installations: drained/back ventilated and pressure-equalized/compartmented. The Boston Central Artery/Tunnel project, now under construction, employs several rain screen principles discussed in this article.

The traditional choices for wall cladding are cavity walls with either concrete masonry unit or metal stud backup; or panels, which are usually made of precast concrete or metal units and typically use a face seal at the joints. These cladding systems have a weakness: they rely entirely on a single barrier to shed water. On site it can be very difficult to ensure that every last corner and crevice is sealed. *Nearly* weathertight seals create low pressure in the void behind joints, and that low pressure often sucks water through nearly sealed joints in much greater quantities than can get in through open joints.

Among the factors threatening familiar organic sealants such as polyurethanes are common atmospheric pollutants, ozone, sunlight, ultraviolet radiation, rain, snow, temperature extremes, and differential thermal movement of the cladding. Even silicone sealants, which are known to be more resistant to these factors, can be relied on to last only 20 years, even if perfectly installed. Once interruptions in the sealant occur, either at the time of installation or later, as a result of adhesion or other failure, further degradation is accelerated because water is acting on the joints from within the wall cavity as well as from without.

Recognizing these problems, prudent designers often detail sealed joint cladding systems with a backup gutter system, which must itself be flashed, sealed, and provided with drainage holes or tubes. Many of the worries about quality control that pertain to sealed joints apply to these backup systems.

In contrast to sealed systems, rain screen systems do not employ sealants at the vulnerable exterior of the wall system, and in their pure pressure-equalized form they do not require interior guttering, since little water penetrates the outer wall.



Peter Vanderwarker

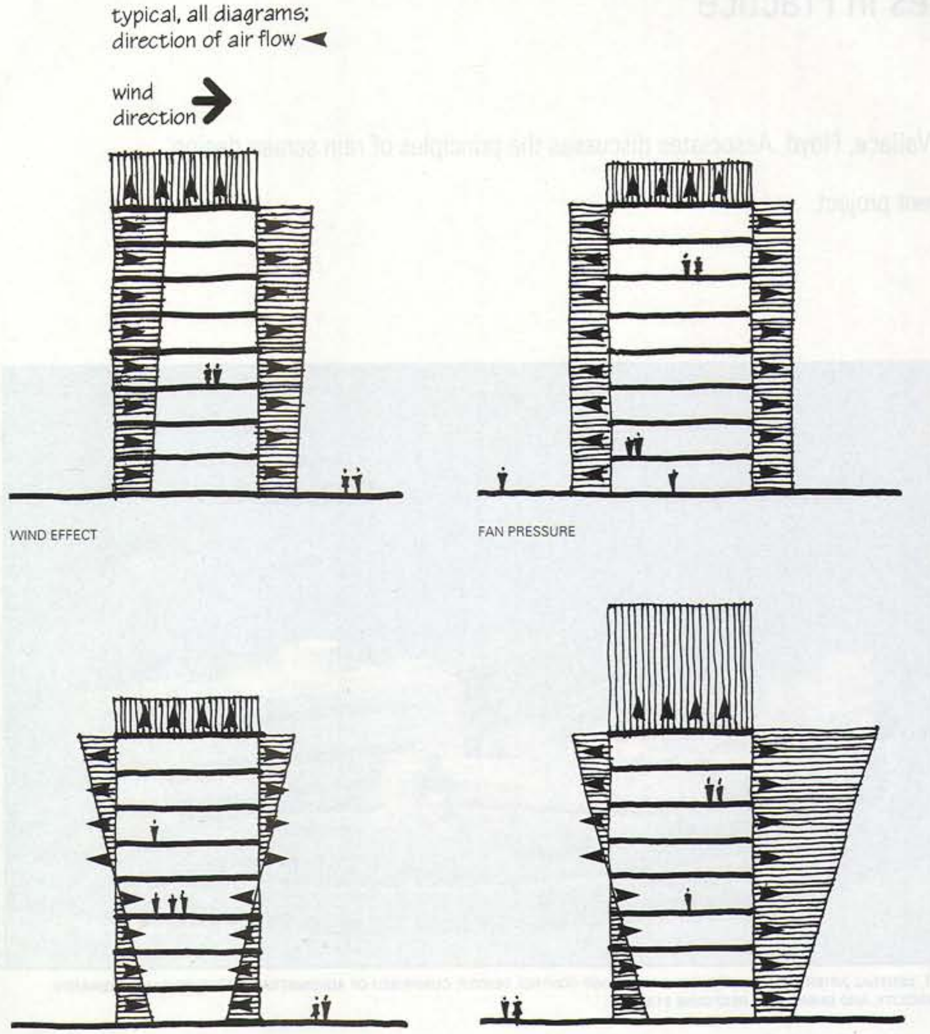
1 CENTRAL ARTERY/TUNNEL PROJECT OPERATIONS CONTROL CENTER, COMPRISED OF ADMINISTRATION BUILDING, MAINTENANCE FACILITY, AND EMERGENCY RESPONSE STATION

Rain Screen Types

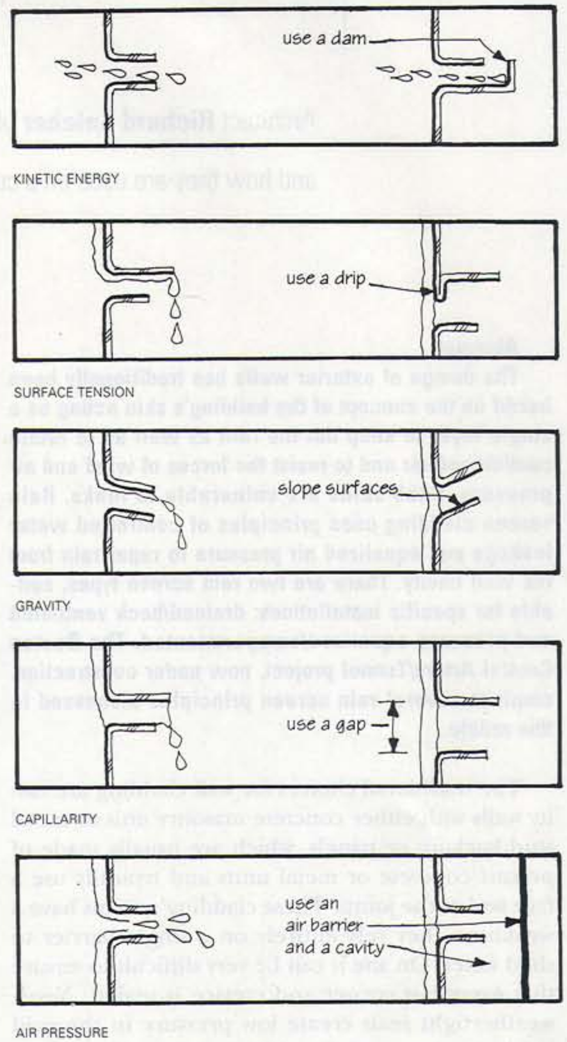
There are generally two types of rain screens: drained/back-ventilated, and pressure-equalized/compartmented. Anderson and Gill[1] describe drained/back ventilated rain screens (4) as a series of sheets, panels, or planks fixed to vertical support rails. The joints are designed to provide protection against the kinetic energy of wind-driven rain. This is achieved by incorporating baffles or by stringently controlling the width of narrow open joints. Such joints obstruct the passage of wind-driven droplets of rainwater, but they do not prevent leakage resulting from gravity and wind-induced air pressure differentials. Thus relatively large quantities of rainwater penetrate the joints and run down the reverse, hidden face of the cladding assembly.

According to Anderson and Gill, the main point about the drained/back-ventilated approach is that claddings are allowed to leak, and no deliberate attempt is made to minimize the effects of wind by 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.

It should be noted that drained/back-ventilated walls require a water barrier at the back of the cavity. The cavity should be carefully and completely flashed and the run-off water brought to the outside



2 CONSTITUENTS OF AIR PRESSURES ON THE BUILDING ENVELOPE



3 FORCES THAT CAUSE WATER PENETRATION

frequently. The brick cavity wall, as promoted by the Brick Institute of America and as used extensively in current building projects, is a simplified variant of this type of rain screen wall.

Pressure-equalized/compartmented rain screens (5) are similar in design to the drained/back-ventilated wall, but go one step further by also controlling the most significant force (2) that causes water penetration – air pressure differentials – by the introduction of a pressure-equalization chamber.

A pressure-equalization (PE) chamber in the cavity or at the joint nullifies the external force of wind-driven rain. A critical component of the PE chamber is an impermeable air barrier that will effectively seal the inner leaf of the wall so that pressure leakage will not compromise the positive pressure built up in the cavity.

Dale Kerr[2] describes pressure equalization as pressure difference created across the walls when wind is present, forcing water on the surface to penetrate any openings through it. The outer layer, or cladding, of a rain screen wall is vented to allow air to flow through it into the cavity. Thus the air pressure in the cavity increases until it equals the applied wind pressure. Kerr describes this phenomenon as pressure equalization. She observes that rain penetration through the cladding is markedly reduced as the force of the wind on the cladding – which would drive the rain into the cavity – is reduced. The wind pressure will be exerted on the air barrier, but since water should not reach the air barrier, rain penetration should not occur.

Rapid Pressure-Equalization

It is important that PE be rapid, since for as long as there is a pressure differential to carry water across the joint, water can be carried into the cavity, or PE chamber. In order to enable the pressurization to be rapid, four factors must be taken into consideration:

1. The walls of the cavity should be as tight and rigid as practical to avoid the "pumping" action which can draw water into the cavity during wind gusts and eddies that can occur when the walls of the cavity are not airtight and rigid.

2. The tendency of the air to migrate around the building to areas of lower pressure requires that cavity closures be used to compartmentalize the cavity. The compartment seals must be designed for at least the full wind load. This is especially important

with tall and wide buildings. Also, projecting elements, such as column covers, may have pressure differentials acting across them.

3. The volume of the cavity should not be too large (a few inches deep is sufficient).

4. The ratios between the venting area, the volume of the cavity, and the leakage of the air barrier are of critical importance.

Conventional systems' weep holes are not sufficient in most cases to create PE, since it must occur within a fraction of a second. An eddy moving alongside a building can create sudden positive or negative pressure. When only a few small weep holes are used in an attempt to achieve PE, the water in the eddy actually gets sucked into the cavity. Graphs of year-long tests of two buildings (6a, 6b) show the dramatic difference that a properly designed pressure-equalized rain screen can make.[3]

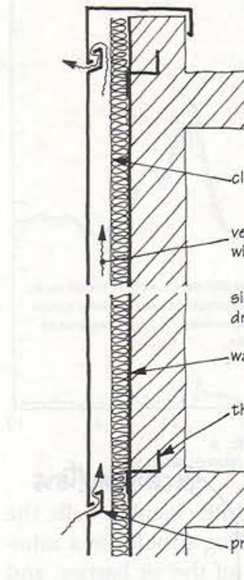
Rules of Thumb

As noted earlier, flexible cavity walls and gusting winds can cause "pumping" of water into the cavity and consequent leakage. Four factors should be considered when determining the appropriate parameters for design: flexible and rigid PE chambers, and steady and gusting winds. The rules of thumb offered below are intended to give architects only a rough idea as to the magnitude of some of the elements of the design.

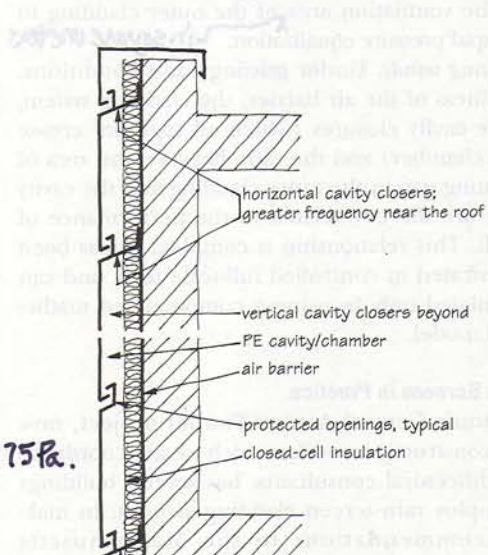
Effects of air barrier quality. The venting area must be properly proportioned to achieve a balanced ratio of cavity size to perimeter outer panel venting, (when the air barrier either is applied to a rigid material such as masonry or is itself a rigid material such as cast-in-place concrete) a rough rule of themb can be suggested: the leakage of the air barrier should not exceed 0.02 liters per square meter per second ($L/m^2/sec.$). However, when the air barrier or the PE chamber walls consist of relatively flexible materials, such as tight steel liners or curtain walls, a careful evaluation of the inner-wall airtightness and computer models should be used to determine the venting area and the allowable leakage of the air barrier.

Rigid barriers and steady winds. When the air barrier is rigid and tight (0.02 $L/m^2/sec.$) the wind load is taken by the liner component of the exterior wall system. Theoretically, a perfect air barrier would take all of the wind load off the rainscreen through pressure equalization. In practice, a more conservative approach should be taken; a well-designed air barrier will be assumed by designers to experience no more than 50 percent of the total steady wind pressure. When the air barrier is rigid under steady-state conditions the pressure drop across the outer cladding is proportional to the area of leakage of the air barrier divided by the area of the venting gap in the outer cladding (rain screen). Also when the air barrier is rigid under steady-state conditions the load on the barrier is inversely proportional to the area of leakage of the air barrier divided by the area of the venting gap in the outer cladding.

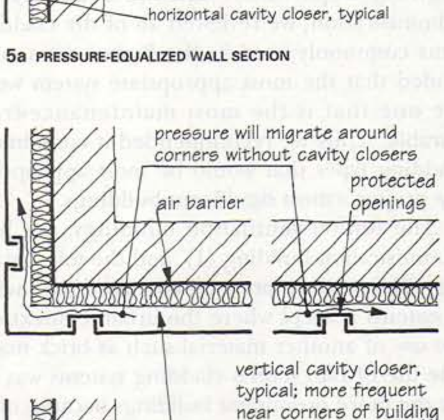
Limitations on vent area and volume of the PE chamber. Rough rules of thumb can be offered for buildings which are not subject to gusting winds. For rain screen



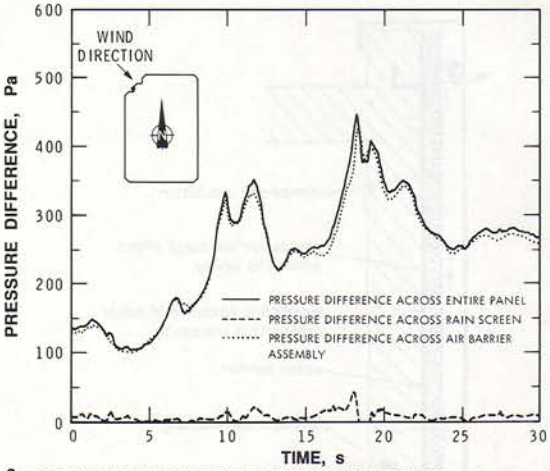
4 DRAINED/BACK-VENTILATED WALL SECTION



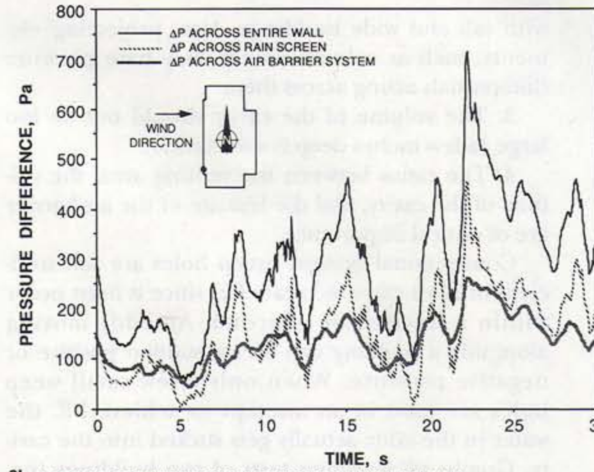
5a PRESSURE-EQUALIZED WALL SECTION



5b PRESSURE-EQUALIZED WALL PLANS



6a RESPONSE OF CAVITY IN WELL DESIGNED RAIN SCREEN WALL



6b RESPONSE OF CAVITY IN POORLY DESIGNED RAIN SCREEN WALL

walls with rigid air barriers and PE chamber walls, the ventilation of the outer cladding should be a minimum of 10 times the leakage of the air barrier, and the volume of the PE chamber [in cubic meters] should not exceed 100* times the ventilation area of the outer cladding [in square meters] to allow rapid pressure equalization.

*use 1/10 at corners

Gusting winds. Under gusting wind conditions, the stiffness of the air barrier, the cladding system, and the cavity closures (which all together create the PE chamber) and the ratio between the area of the venting gap in the outer cladding and the cavity volume are directly related to the performance of the wall. This relationship is complex, as has been demonstrated in controlled full-scale tests, and can be simulated only by using a computerized mathematical model.

Rain Screens in Practice

Boston's Central Artery/Tunnel project, now under construction and for which we are coordinating architectural consultants, has several buildings that employ rain screen cladding systems. In making recommendations to the Massachusetts Highway Department and the Federal Highway Administration, we reviewed all of the cladding systems commonly used in the Boston area and concluded that the most appropriate system would be the one that is the most maintenance-free and durable. Thus we recommended a combination of cladding types that would be most appropriate for the project's most significant buildings.

The tunnel ventilation buildings, the highway administration building (1), and the toll plaza building will be clad in pressure-equalized flat metal panel systems (except where the urban context dictates the use of another material such as brick masonry). The use of rain screen cladding systems was chosen for the more prominent buildings because of uncertain funding for maintenance of public projects.

The maintenance buildings will be clad in corrugated metal suitable for their function. These buildings do not require the quality or the durability of the other more prominent buildings, and therefore the rain screen principle is not utilized in their design. They will employ gaskets at their most common joints, thereby avoiding some of the problems associated with the use of sealants.

Details (8) are included to give an example of the adaptation of rain screen cladding to this project. The panels have been designed with joints that have a dam to resist kinetic energy, a drip to resist surface tension, slopes to control gravity, gaps to break capillarity, and a cavity behind the panels to act as the PE chamber. Note that the air and vapor barriers are together to avoid potential problems of vapor entrapment between them, a serious concern in the New England climate. The insulation is in intimate contact with the air barrier to prevent heat loss and is outboard of the vapor barrier to prevent condensation within the insulation. The structure of the wall and the air barrier is protected from ultraviolet light and the weather by the insulation and the rain screen, and any condensation or entry of snow will occur outside of the air barrier, which has been specified as a waterproofing type of material and will therefore carry any accumulation of water in the cavity to the outside. The insulation has been specified as a closed-cell type, so that it will not be affected by any moisture in the cavity.

Four ventilation buildings utilize rain screen metal panel cladding systems. Of particular note, Vent Building No. 5 (7) employs both types of rain screens. The metal panels will be a pressure-equalized rain screen. The brick veneer is proposed as a back-ventilated rain screen. It has open head joints eight inches on center for two courses at the bottom with a fully-reticulated open-cell filter foam with ten cells per inch as a weep baffle, and a continuous ventilation slot at the top of the wall protected by flashing, all to promote back-ventilation. This building therefore will utilize both types of rain screens. **Richard Keleher, AIA** ■

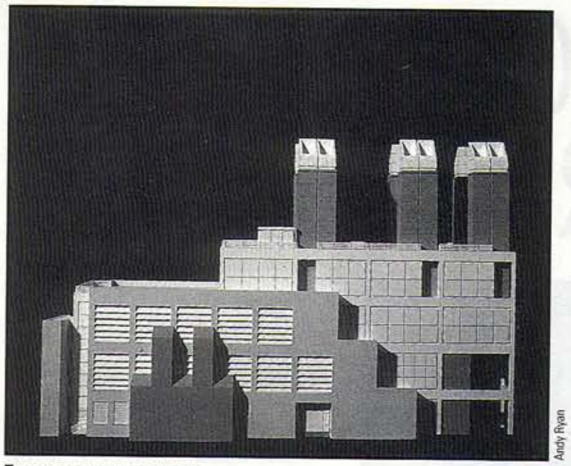
The author is a senior architect with Wallace, Floyd, Associates in Boston, and is technical researcher and the quality reviewer for the Chief Architect on the Central Artery/Tunnel Project. The section on Rules of Thumb was prepared with the assistance of Michael Sommerstein, P.E., Engineering Manager, VicWest Steel, Oakville, Ontario.

Recent development: AAMA 508-05 Voluntary Test Method And Specification for Pressure Equalized Rain Screen Wall Cladding Systems addresses these issues and should be specified for pressure-equalized rainscreen cladding systems.

Water Penetration Forces

Forces that cause water penetration (3) can be mitigated through proper design:

- *Kinetic Energy.* **Wind-driven rain, sleet, or snow. Incorporate a dam, baffle, or labyrinth in the joint design.**
- *Surface Tension.* **The tendency of water to run across the underside of horizontal surfaces. Incorporate a drip.**
- *Gravity.* **Avoid inward sloped surfaces on the cladding and control water that enters the cavity by draining it to the outside.**
- *Capillarity.* **The tendency of water to be drawn into narrow passages bound by wetable surfaces. Incorporate a discontinuity behind the cladding, such as a cavity. Openings should be at least $^3/_8$-inch-wide to create a capillary break.**
- *Air Pressure Differentials.* **Anderson and Gill note that if the air pressure on the outer face of a wall or wall cladding is greater than that acting on its reverse face, rainwater will be forced inwards through unprotected openings or through joint seal imperfections in the soaked outer face. If the air pressures on either side of the openings and joint seal imperfections can be equalized, water will not be forced inwards by this means alone. The ideal condition would be to devise a system such that the interior cavity would at all times have a higher air pressure than the outside envelope pressure.**



7 VENTILATION BUILDING NO. 5

Acknowledgments

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References

1. *Rainscreen Cladding,* J.M. Anderson and J.R. Gill, Butterworth Publishers, Stoneham, Massachusetts (800) 366-2665, 1988.

2. The Rain Screen Wall," Dale D. Kerr, P/A, August 1990, pp. 47–52.

3. "Field Testing of Pressure-Equalized Rain Screen Walls," Brown, Rousseau, and Dalgliesh, in "Exterior Wall Systems," edited by Barry Donaldson, American Society for Testing and Materials, publication STP 1034, Philadelphia (215) 299-5585, 1991.

Recommended Reading

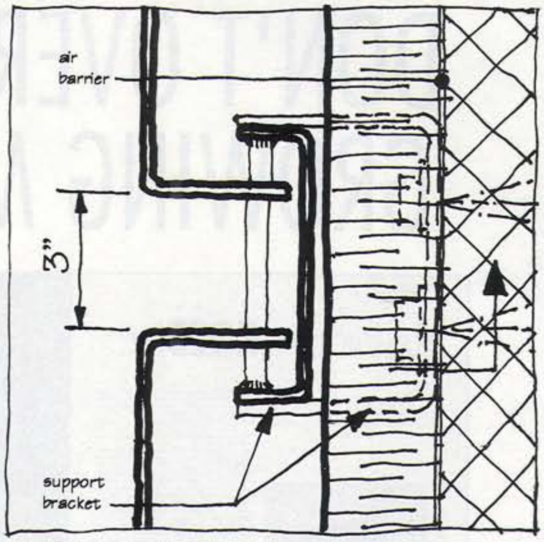
Air Barriers, TEK-AID Digest 07195 Construction Specifications Canada, Toronto: (416) 777-2198, 1990, 52 pp.

"Air and Vapor Barriers", R.L. Quirouette, P/A, September, 1991, pp. 45–51.

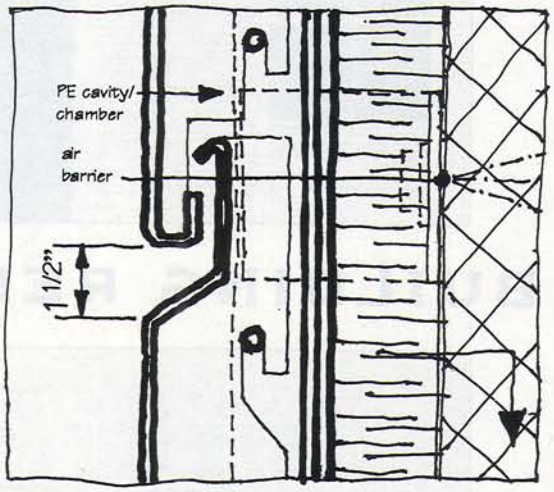
"Rain Penetration and its Control," G.K. Garden, *Canadian Building Digest 40,* National Research Council Canada, Ottawa (613) 993-2463, 1963, 4 pp.

"The Rainscreen Principle and Pressure-Equalized Wall Design," Volume 2, *Aluminum Curtain Wall Design Guide Manual,* American Architectural Manufacturer's Association, Palatine, Illinois (708) 202-1350, 1979, pp. 22–31.

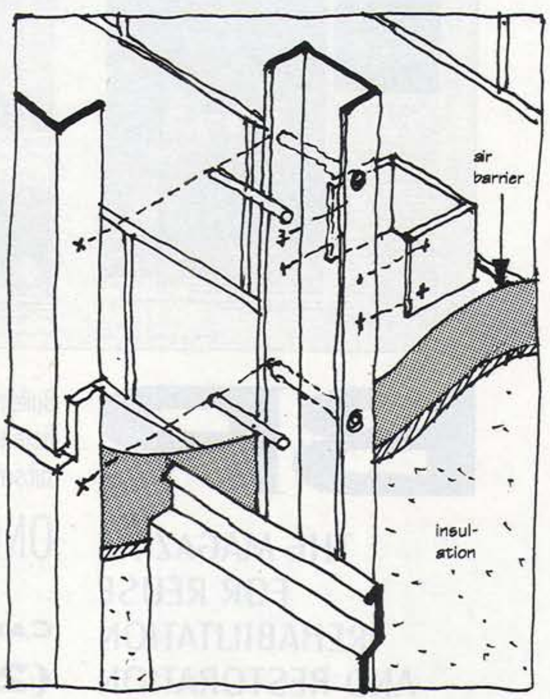
What You Ought to Know About Air Barriers and Vapor Retarders, Paul Shipp and Maurice J. Marchello, pamphlet, U.S. Gypsum Company, Tarrytown, NY (312) 606-5845, 1989.



PLAN AT HORIZONTAL JOINT



SECTION AT HORIZONTAL JOINT



ISOMETRIC OF VERTICAL AND HORIZONTAL JOINTS

8 CENTRAL ARTERY/TUNNEL VENTILATION BUILDING DETAILS