PERSIST—Pressure Equalized Rain Screen Insulated Structure Technique—Design Approach

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ABSTRACT

Many buildings have problems with the performance and durability of their envelopes largely related to inadequate control of air leakage. The discovery of the shortcomings in achieving the expected performance is often only realized when the building is in operation, even though many problems can often be predicted simply by review of the construction documents. Buildings with envelope problems are rarely in imminent danger of collapse, but by not fulfilling their intended purpose and increased operating and repair costs, they can become a liability. Building owners and operators are further affected by litigation over comfort, health, and safety issues.

The Pressure Equalized Rain Screen Insulated Structure Technique, PERSIST, is recommended by Alberta Public Works in the design of new buildings. This approach is also recommended for the retrofit of existing buildings with serious envelope problems. This paper discusses the PERSIST design concept and some of the construction details and methods that enhance its application.

INTRODUCTION

In cold climates many buildings have problems with the performance and durability of their walls, windows, and roofs because of inadequate control of air and water movement (Hutcheon and Handegord 1983). In large part, these problems arise because there are unintentional, often hidden, openings in the building envelope. These openings are present either because the construction was discontinuous to start with or the elements intended to stop the movement of air and water failed.

Investigations of many buildings in Alberta with air leakage problems have revealed striking similarity in the sources of these problems:

- Inadequate details for penetrations through and connections with walls and roofs.
- Designs that ignored constructability of the air barrier system.
- Constructions that did not allow drainage or drying.
- Use of materials that did not withstand the loads imposed.

Alberta Public Works (Supply and Services, Technical Resources and Standards Division) has for many years encouraged a fail-safe design approach to avoid these problems. This approach has long been known and advocated by numerous building science researchers, investigators of building envelope problems, and some designers and building material suppliers. Review of construction using this technique has shown it to be quite forgiving to the imperfections and surprises normally found in most construction projects. This is the same approach that has been articulated in numerous *Canadian Building Digests* from the National Research Council Canada and also in Brand and Van Norstrand (1990). However, as far as the authors can determine, the approach described below has remained unnamed, unlike other approaches such as the airtight drywall and face seal approach. With the Latin saying, "Nomen est numen (To name is to know)" in mind, we have coined the term PERSIST (Pressure Equalized Rain Screen Insulated Structure Technique) to aid in understanding. This approach to the arrangement of the main functional components of walls has been described as follows:

"The advantages inherent in designs based on the open rain screen principle go far beyond those associated with rain penetration control. Movements and minor imperfections in the joint seal between prefabricated components become less critical, and the life of sealants is extended by

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shading from solar radiation. Although there may be problems regarding adequate ties and support of the rain screen when this principle is applied to the total wall covering, it should be noted that the exterior cladding is relieved of much of the normal wind load. It must be resisted by the remainder of the wall. A complete rain screen approach can result in easy handling of cladding movements and cracks after construction, and in reducing air conditioning loads, and permits rapid drying of cladding materials. It also permits the better positioning of insulation and minimizes the risk of condensation within the wall. With the many advantages of the open rain screen, its full development should be pursued by all building designers" (Kerby 1963).

"Application of insulation over the entire exterior of a wall provides an ideal solution of the problems by thermal bridges. Although a light cladding is required to protect the wall, the number and size of the supporting ties that pass through the insulation are small" (Brown and Wilson 1963).

Hutcheon (1964), by applying the PERSIST principles to a masonry wall, demonstrated the many advantages of that configuration. These included reduced thermal effects on the structure, inner wythe, and windows, reduced rain penetration and reduced wind loads on the cladding, reduced problem of thermal bridges, reduced possibility of degradation by wetting and wet freezing, and greater tolerance for movements in the cladding.

Garden (1965a, 1965b) illustrates some of the differences between wall and roof design and some of the necessary compromises but importantly advises,"Ease the duties imposed on each material by judicious selection and positioning in the assembly."

Latta uses precast concrete construction as an example of the application and advantages of PERSIST. Others, such as Brand and Van Norstrand (1990), reiterate the PERSIST principles with the following:

The Rules

1. "Enclose the building in a continuous air barrier.
2. Provide continuous support for the air (seal) barrier against wind loads.
3. Ensure that the air (seal) barrier is flexible at joints where movement may occur.
4. Provide continuous insulation to keep the air barrier warm and to conserve energy in the building.
5. Keep the insulation tight to the air barrier.
6. Protect the insulation with a rain screen/sun screen supported out from the structure in a way that does not penetrate the insulation with excessive heat bridges.
7. Provide enough open space for drainage and construction clearances between the rain screen and the insulation.
8. Drain the wall cavity to the outside."

PRESSURE EQUALIZED RAIN SCREEN INSULATED STRUCTURE TECHNIQUE

The term *pressure equalized* is intended to apply not only to the concept of pressure equalization of cladding and joints, as described in Kerby (1963), but to whole building pressure equalization. Overpressurization of building interiors should be avoided. The term *insulated structure* refers to the practice of placing the insulation to the outside of the structural frame as opposed to insulating inside or between the structural frame (Figures 2 and 3). When the insulation is situated outside the structural frame, installation of the air sealing element becomes much easier and its performance greatly improved. Increased airtightness of the building envelope ironically creates a need for mechanical system designers to adjust their building leakage estimates so that overpressurization does not occur. The conventional compact roof design, while generally not pressure equalized, although it can be, exemplifies the insulated structure concept in that the position above the structure makes the process of obtaining continuity simple. Where such roofs join walls or parapets, obtaining continuity is greatly eased when a protected membrane detail is used (Figure 4).

PERSIST can accommodate more stringent interior environments, while at the same time allowing the flexibility necessary for a variety of aesthetic design approaches. This technique is based on a sequence of steps in the construction of the building envelope, which differs only slightly from normal practices. It is helpful to consider the envelope as a series of planes.

- The structural framework and infill walls are constructed to maintain, as much as possible, simple planes from foundation to wall and from wall to roof. A wide variety of structural and infill systems can be used but with as few variations in plane as possible.
- A bituminous membrane (air sealing element) is fully adhered to the exterior plane of the structure and infill wall elements. Penetrations of this plane required to support the exterior cladding(s) are designed to: minimize thermal bridging, endure occasional wetting, allow for construction tolerances, and allow the membrane to easily achieve an air seal. Other penetrations for mechanical and electrical are also specifically designed to be sealed at the membrane plane. The membrane acts to seal the structure and infill walls to fulfill the air barrier function of the building envelope. Note that this system must be designed to withstand the imposed loads of stack effect, mechanical pressurization, and wind pressures.
- Insulation is mechanically fastened tight to the air barrier system. This prevents air from circulating behind the insulation and reducing its effectiveness and ensures that the membrane is kept warm at or near the interior building temperature.
- The cladding is installed exterior of the insulation, creating an air space that can be pressure equalized through openings. The openings at the bottom of the cladding

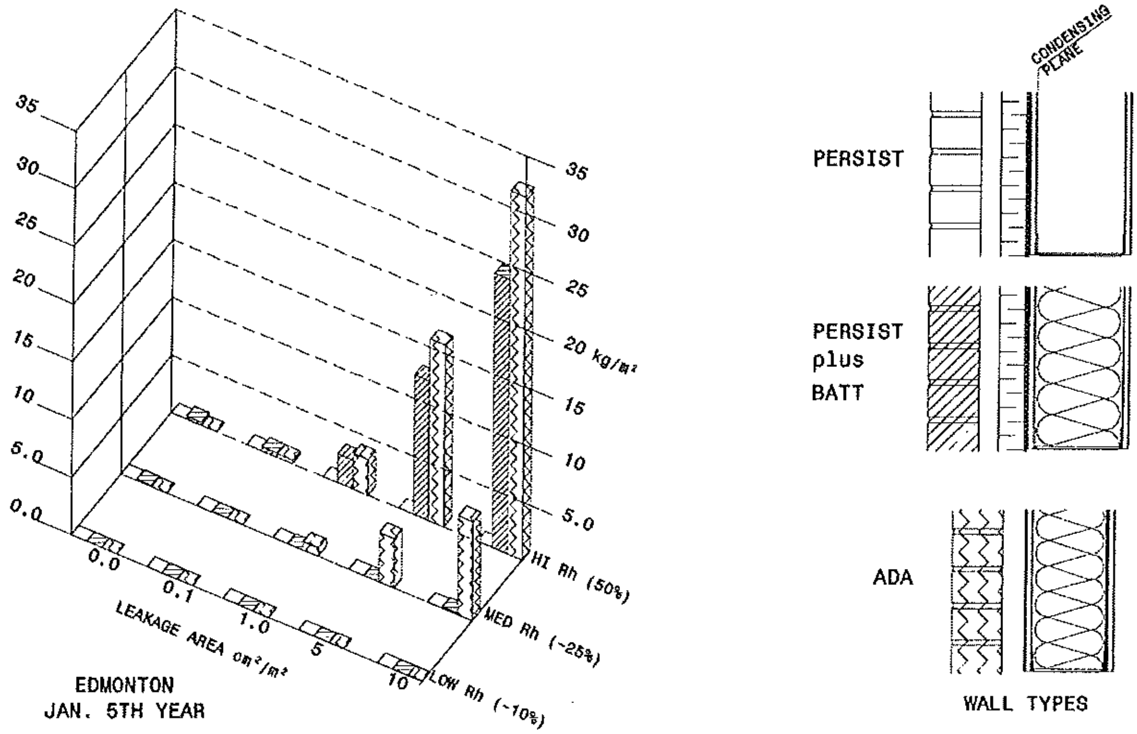

Figure 1 EMPTIED calculated moisture accumulation.

should allow water, which may pass through the exterior cladding, to drain. Compartmentalization should be attempted in the design where possible.

- The glazing system(s) should be selected and positioned for similar performance. The details provided in this paper show the use of an exterior glazed pressure equalized rain screen window. Continuity of the air seal is achieved by the use of membrane adhered to the membrane of the wall and adhered to the aluminum frame at its plane of air seal. The membrane is additionally mechanically secured to the frame by an anti-rotation channel and screws.

Advantages and Benefits of PERSIST

- Electrical and mechanical services can be run within the exterior backup wall cavity. Where these services penetrate the plane of air sealing, they can be easily sealed during construction.
- Special detailing is not necessary for future interior renovations to ensure airtightness of the drywall.
- The structure of the building is interior of the plane of insulation, thereby minimizing thermal movement. Thermal bridging of the structure is not prevalent.
- The sequential approach of material installation promotes good construction detailing, construction, and inspection. If small imperfections do occur within the plane of the air seal, the resulting condensation from exfiltration would occur most likely in the drained cavity between the cladding and membrane. Large leakage openings, which could allow condensation during conditions of infiltration (windward side), are unlikely to be constructed.
- Maintenance of exterior caulking, while still important in minimizing water entry into the wall cavity, is now more a visual concern rather than a key to the building envelope providing separation between inside and outside environments as it would be in a face seal design.
- The air seal is protected from UV degradation and thermal cycling.
- Additional insulation may, under some conditions, be installed interior of the membrane within a stud wall infill system in buildings with low interior humidity levels. For example (Figure 1), when modeled in the computer program EMPTIED using the climatic data for Edmonton over a five-year period (the assemblies ADA [RSI 2.11] and PERSIST with batt [RSI 5.29]), with insulation interior of the plane of air seal, an accumulation of moisture at high interior humidity levels was indicated. It should be noted that the calculations did not model mechanical pressurization of the buildings. This shows the inherent safety of PERSIST (RSI 10).
- When retrofitting existing buildings with PERSIST, the building can remain occupied as the majority of the implementation is from the exterior.

The design freedom afforded by PERSIST is just being recognized. Cladding systems do not have to be restricted to the immediate location of the structure of the wall. Architectural articulations can be more flexible, as they do not have to

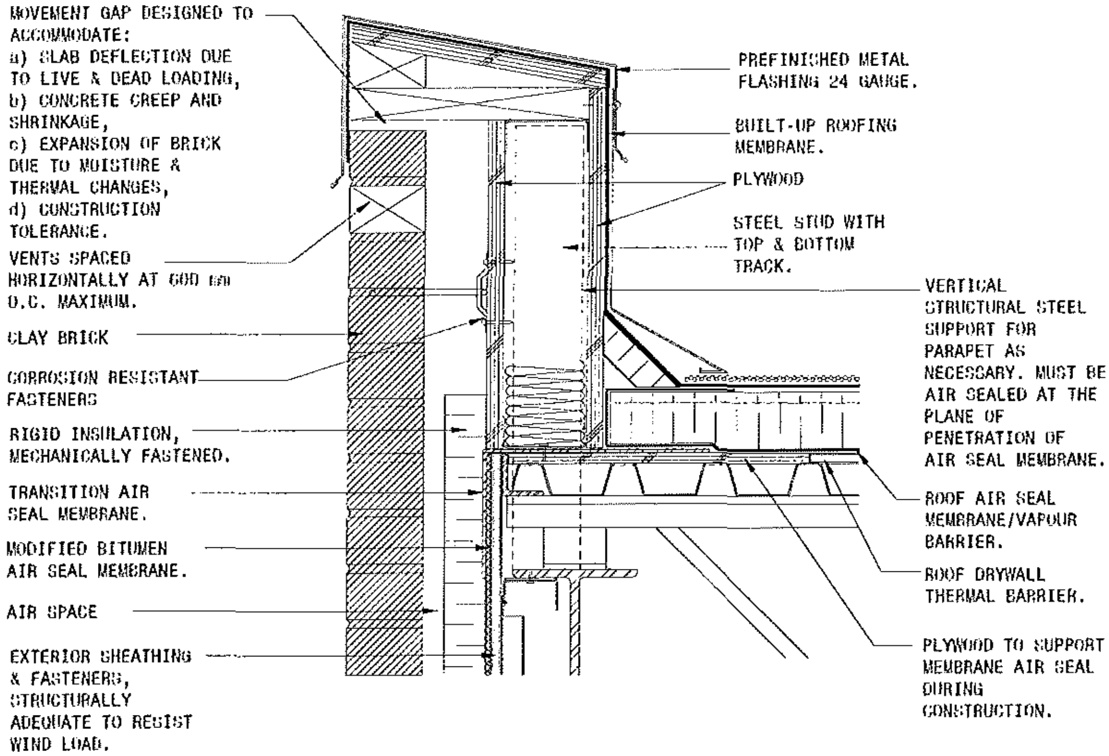

Figure 2 Roof parapet detail.

conform to the plane of the air seal. Lightweight claddings such as fabrics can provide the building with a multi-faceted exterior, while the base building is an economical layout.

Variations of PERSIST using insulated panels exterior of the structure are possible provided that the attachment of panels allows access for air sealing at supports and panel joints.

The use of membranes adhered to the backup wall was introduced to Alberta in the early 1980s. Since then it has gained acceptance in other parts of Canada and the northern United States. The membrane can be either self-adhered (SA) or thermally fused (TF) to the backup wall.

The self-adhering membranes have a release paper on one side. The most common SA membranes in Alberta use polyethylene as the carrier and reinforcement for the SBS bitumen, which can vary in thickness but is commonly about 1.2 mm thick. The polyethylene can be subject to damage by subsequent trades so there is sometimes a need for more stringent inspection. Joints of the membrane are lapped in a shingle fashion to allow water to flow over the joint. Some manufacturers have additional compatible sealants that they recommend for some joint applications. With adhesion only on one side of the membrane, the need to simplify the planes to which the membrane must adhere is beneficial. These membranes are recommended for retrofit projects where the building is occupied as there is not a potential for fire. Cold temperature limitations (–5°C) must be carefully followed in winter construction to ensure proper adhesion.

Thermalfusible membranes have either a glass fiber or polyester reinforcement with SBS on both surfaces. Various release surfaces are used to keep surfaces of SBS from adhering before installation. Thermalfusible membranes are applied by melting off or imbedding the release material in order that the SBS can be melted so that it will flow and key into the surface of the wall. The potential for fire with some substrates must be carefully reviewed by the designer. A fire watch should be undertaken after every day's work to minimize the risk. Jointing of the TF membrane is lapped and heated to fuse the SBS of both sheets. A few manufacturers have formulated the SBS to be installed as a peel and stick and at the same time some heating can be used without damaging the reinforcing of the membrane.

The wall structure and backup shown in Figure 2 are composed of a steel frame, columns, and beams with metal stud infill and exterior grade gypsum board. This could be a variety of other structural and infill systems. The roof is detailed as open web steel joists, metal deck, and gypsum board. An SBS membrane fully adhered to the exterior of the gypsum board seals the structure to create the air barrier system.

While the air seal membrane could in theory be installed up and over the parapet, the detail shown (Figure 2) installs the membrane through the parapet at the plane of air seal of the roof. This prevents moist interior air from entering into the parapet construction and condensing.

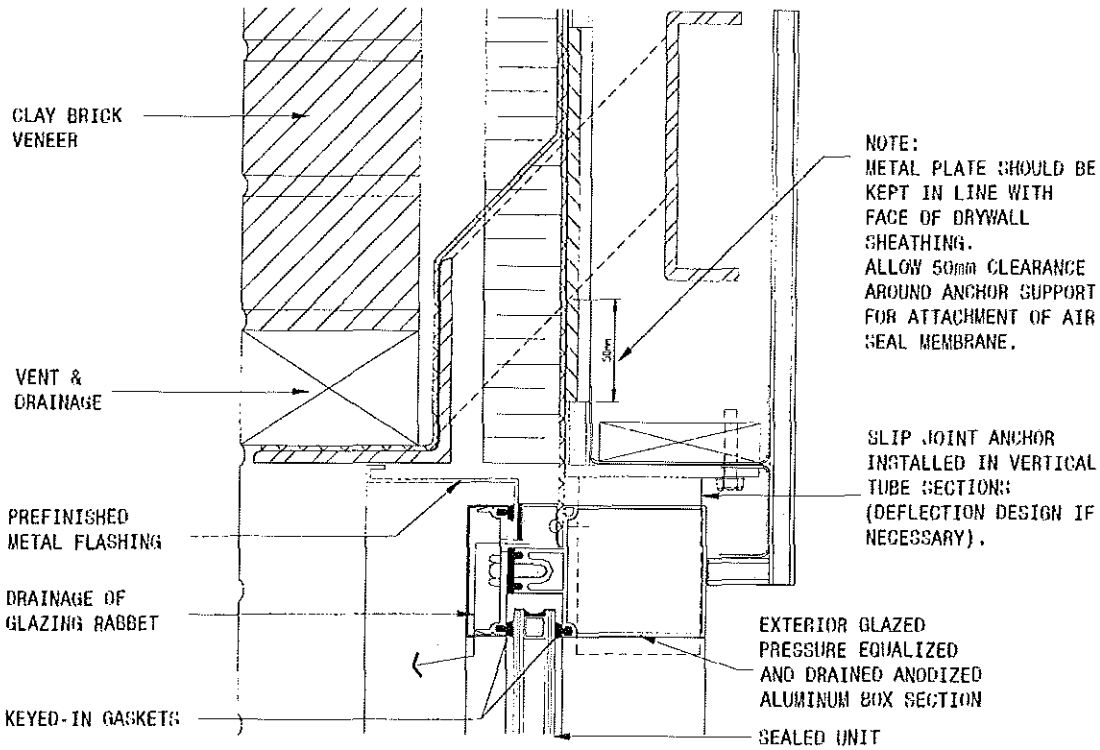

Figure 3 Window head detail (PERSIST).

A galvanized sheet metal angle can be introduced to provide structural support for the membrane at the roof to wall transition to accommodate alternative constructions.

Plywood is substituted for the gypsum board at the roof perimeter to avoid construction damage and provide solid backing for the parapet. A detail to allow penetration of structural steel through the plane of the air seal has been developed. The detail incorporates a steel weld plate at the plane of air seal, which allows a minimum 50 mm of adhesion surface for the membrane. This weld plate can then have a channel, tube, or gusset welded to it depending on the support needed.

The insulation at the roof perimeter is end wrapped as a backup against water entry into the roof insulation. The roofing stripping is carried over the parapet and is protected by metal flashing.

Figure 3 depicts the steel plate at the plane of the air seal as described in Figure 2. In this detail the gussets which are welded to it to support the exterior masonry are offset to allow for adequate adhesion of the membrane to the wall structure surrounding the window opening.

A pressure-equalized and drained rain screen window is installed using anchorage of the main frame, which will allow uninterrupted adhesion of the membrane from the surrounding wall to the tube face of the glazing rabbit. Removal of the screw spline at the mullion junctions is necessary for continuous adhesion of the membrane. An anti-rotation channel mechanically fastens the membrane to the tube face and provides a surface to mechanically secure metal perimeter flashings. No caulking is necessary.

The window framing system uses dry, keyed-in gaskets both as the interior air seal and the exterior weather seal for aesthetic and long-term maintenance concerns. The glazing rabbit is drained to the exterior through slots in the pressure plate and in the cover cap.

The detail shown in Figure 4 terminates the rain screen cladding at a sufficient height above the roof plane to allow the membrane of the roofing to adhere to the membrane of the PERSIST wall. Plywood is installed on the wall structure to allow for nailing of roof stripping to the wall. Membranes are shingled to ensure that water cannot enter the roofing system. The roofing insulation is end wrapped.

The wall insulation is continued below the cavity and in a protected membrane design, held in place by vertical furring that is secured through the insulation and membrane to the plywood. The furring then allows prefinished metal flashing to be mechanically fastened to it to protect the insulation and provide an aesthetic finish to the transition.

CONCLUSION

PERSIST is by no means a panacea to all the ills of building construction today. The application of PERSIST has distinct advantages in terms of design flexibility, constructability, and building performance. This technique allows the various components of the building envelope to efficiently resist the imposed environmental loads, resulting in greater

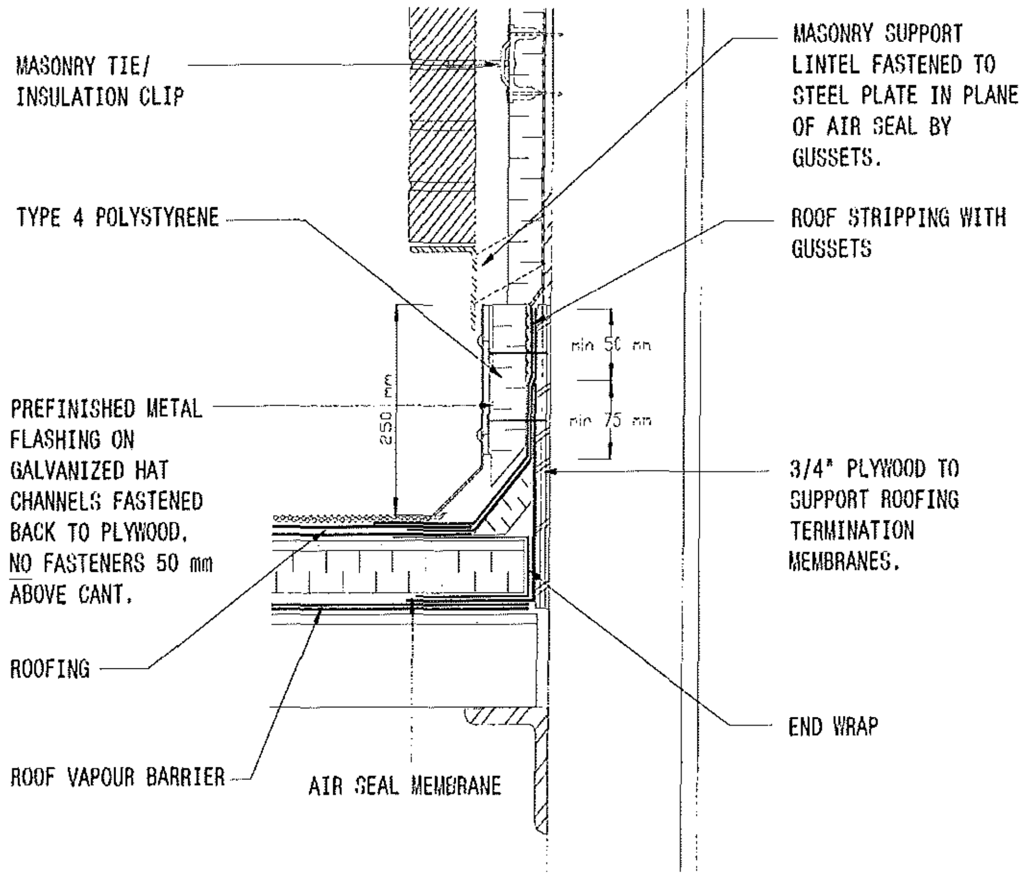

Figure 4 Roof/wall junction detail.

control of the interior environment. Current construction practices are not substantially changed by this technique.

REFERENCES

Brand, R., and R. Van Norstrand. 1990. *Architectural Details for Insulated Buildings.*

Brown, W., and A.G. Wilson. 1963. *Thermal Bridges in Buildings, Canadian Building Digest* #44. National Research Council Canada.

Garden, K. 1963. *Rain Penetration and Its Control, Canadian Building Digest* #40. National Research Council Canada.

Garden, K. 1965. *Fundamentals of Roof Design, Canadian Building Digest* #67. National Research Council Canada.

Garden, K. 1965. *Thermal Considerations in Roof Design, Canadian Building Digest* #70. National Research Council Canada.

Hutcheon, N. 1964. *Principles Applied to an Insulated Masonry Wall, Canadian Building Digest* #50. National Research Council Canada.

Hutcheon, N., and G. Handegord. 1983. *Building Science for a Cold Climate.* Wiley & Son.

Latta, K. *Precast Concrete Walls—A New Basis for Design, Canadian Building Digest* #94. National Research Council of Canada.

RECOMMENDED READING

Baker, M. 1980. *Roofs.* Multi Science Publications.

Construction Specifications Canada. 1990. *Air Barriers,* TEK-AID Digest 07195. Toronto: CSC.

Handegord, G. 1996. *Building Science and the Building Envelope.* Handegord and Company, Inc.

Johnson, G. 1991. *Alberta Building Envelope Failure Analysis.* Alberta Municipal Affairs.

National Research Council Canada. 1984. Performance of materials in use. *Building Science Insight '84,* NRCC 24968. Ottawa: NRCC.

Persily, A. Development of thermal envelope design guidelines for federal office buildings. #PB 91112839, National Institute of Standards and Technology. National Technical Information Service.

Quirouette, R. 1985. The difference between a vapour barrier and an air barrier. *Building Practice Note No. 54.* Ottawa: National Research Council Canada.

Reginato, L., and G. Handegord. 1990. A procedure for estimating moisture performance of building envelope "emptied." Proceedings, 5th Conference on Building Science and Technology, Toronto.

Wilson, A., and K. Garden. 1966. Moisture accumulation in walls due to air leakage. Technical Paper No. 227 DBR, NRC 9131.