#4344

Moisture Problems

The material for these publications was developed in consultation with the Canadian Home Builders' Association for a series of builders' workshops held across the country.

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Contents

Introduction

The purpose of this guide is to help the builder understand what causes moisture problems in buildings, how to repair them, and how to avoid them. The guide is divided into two parts. The first discusses the three main approaches to solving moisture problems: Controlling Moisture Sources, the Air-Barrier System and the Rain-Screen Principle. The second part is divided into six sections, each dealing with a particular area of the building: attics, wall cavities, basements and crawl space, exterior siding, interior surfaces, and windows. Each of the six sections identifies some common moisture problems, explains their probable causes and suggests possible solutions.

Controlling Moisture Sources

Moisture, directly or indirectly, causes more problems in buildings than any other single cause. Moisture in vapour form is generally not harmful or damaging. It is when moisture changes from vapour to liquid or from liquid to solid (ice and frost) that damage occurs.

Moisture problems can be divided into two groups: surface problems and concealed problems. The concealed problems may cause serious damage to a building before anyone even notices that there are problems.

Reducing the humidity levels in a dwelling can help reduce both surface and concealed problems. One way of doing this is with ventilation; another is to tackle the source of the moisture that produces the high humidity conditions.

Every moisture-induced problem discussed in this guide can be lessened or eliminated by reducing the moisture level in the dwelling. Moisture can be controlled either by reducing the amount produced from various sources, or by diluting the moisture with sufficient quantities of outside air to maintain a moderate relative humidity. Note that it is generally less expensive to remove or eliminate moisture at its source, rather than try to control it once it is produced.

The sources of moisture in a house fall into the following four categories:

1. construction moisture
2. ground sources
3. seasonal storage
4. occupants.

Construction Moisture

The materials used in construction often contain significant quantities of moisture. For example, the wood materials used in construction today are usually still quite wet or green, and concrete requires substantial quantities of water to make it workable. During the first year or two after a house is constructed, the drying of lumber and the curing of concrete release a certain amount of moisture. It is therefore not surprising that many complaints of high relative humidities and condensation problems appear in the first year or two after construction *(fig. 1)*.

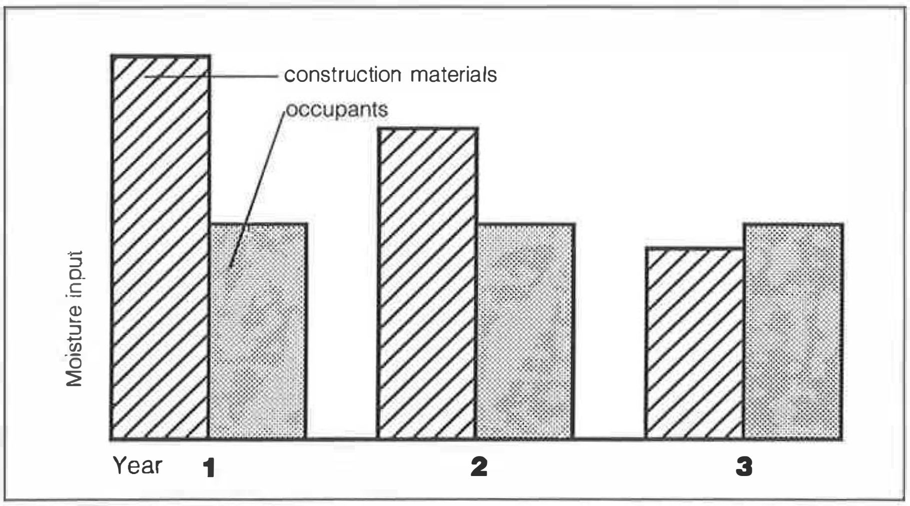

Fig. 1. Release of moisture.

Many construction activities — casting a concrete foundation and floor slab, painting, or spraying on a ceiling texture finish — produce moisture, which is stored by the house. Ventilating and dehumidifying the house shortly after occupancy will reduce the amount of moisture being released in the first few years after occupancy.

Measures to reduce construction moisture include the following:

During construction:
- avoid using propane or gas heaters — they can be major sources of moisture
- use dry construction materials (pay particular attention to the framing lumber which, in some parts of the country, has been found to have very high moisture content)
- store lumber close to where it will be used and protect it from rain
- use less water in the concrete.

Advise occupants to:
- provide as much natural and mechanical ventilation as possible during the first six months after construction to assist the house-drying process.

Ground Sources of Moisture

A wet or damp basement generates much more moisture than all other sources combined. Even if it seems dry, the basement still contributes significantly to the amount of moisture in the house. Ground moisture sources include:

- diffusion through the concrete
- infiltration of moist air
- wicking of moisture through the concrete (capillarity)
- blocked drainage or flooding
- evaporation from the soil in the crawl space.

Some of the steps that can be taken to eliminate ground moisture are described below.

During construction:
- dampproof the floor slab with a sheet of 6 mil poly
- dampproof the foundation walls and insulate on the outside with a draining insulation *(fig. 2)*.

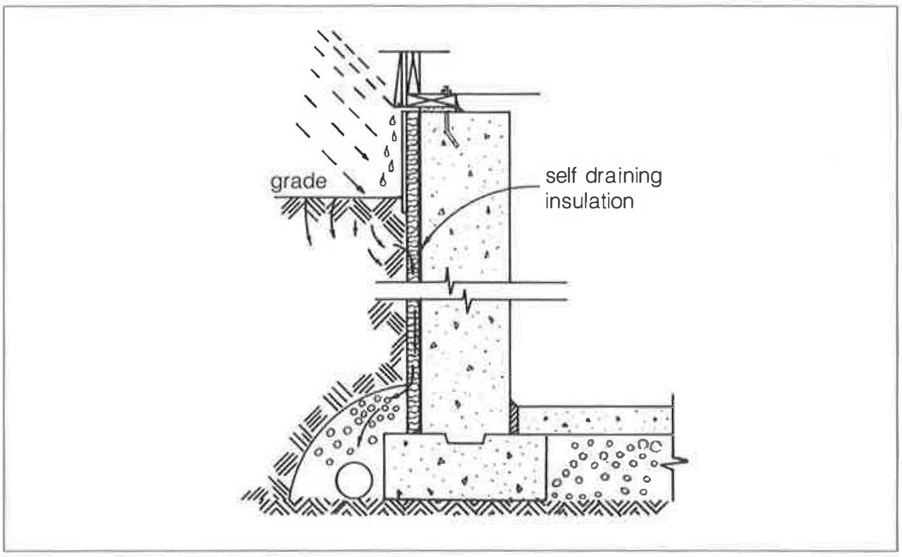

Fig. 2. Basement / foundation-wall drainage detail

- follow good construction practices to prevent cracking in the concrete wall and floors
- seal the joint between the floor slab and the foundation walls
- repair and seal cracks in the concrete or mortar
- do not drain downspouts down the sides of the foundation walls
- seal cracks between paved areas and the foundation walls
- make sure that air is not leaking through the drain trap, and install a trap primer to ensure that the trap never goes dry
- dampproof the exposed exterior of foundation walls
- cover and vent the sump to the outside
- do not use a crawl space as a warm air plenum unless it is totally sealed from moisture sources
- provide sealed removable covers for floor drains and sump pits
- connect drain tiles to the sump pit or to a storm sewer
- install drain tiles under the floor if the water table is high
- provide proper grading — slope all surfaces away from the house.

Advise occupants to:
- dehumidify the basement in the summer.

Note: A finished basement may decrease the amount of moisture released from the basement. The finished wall will have a vapour barrier that will reduce the storage and release of moisture from the concrete, and an air barrier that will reduce the infiltration of moist air. In addition, some floor coverings, such as vinyl flooring and rubber-backed carpets, will prevent moisture from diffusing through the concrete.

Seasonal Storage of Moisture

With the changing seasons, furnishings and construction materials such as wood, gypsum board, concrete, and curtains and carpets undergo a cyclical storage and release of moisture. During the summer months, the outdoor relative humidity may range from 60 to 90 per cent. Given that most houses are vented in the summer, the relative humidity in the house will likely be in the same range. The materials in the house will absorb water from moist air. When fall and winter arrive and the indoor relative humidity is lower, much of the stored moisture in the furnishings, wood and concrete reappears in the indoor air. A substantial portion of the stored moisture is released rather quickly in the early fall when the outdoor temperatures and indoor relative humidities are falling rapidly. This is the usual cause of condensation complaints around this time of year.

There is little that can be done to prevent furnishings or framing from absorbing and releasing moisture. Ventilating the house well into the fall may help reduce the build-up of stored moisture in the house.

Concrete contributes significantly to the moisture level in the house. By dampproofing the interior basement walls and basement floor slab, the amount of moisture absorbed by the concrete in summer will be reduced.

Advise occupants to:
- dehumidify the basement during the summer – this may help reduce moisture from concrete.

Occupants

The occupants and their activities also represent a moisture source. Generally, this source of moisture is beyond the control of the builder. However, the builder should make the occupants aware that some activities may produce high moisture levels and therefore high humidity conditions.

Occupant-related moisture sources can include:

- excessive numbers of house plants
- drying of clothes indoors
- firewood stored indoors
- indoor swimming pools, whirlpool baths or hot tubs
- unvented dryer
- humidifiers.

Builders should consider leaving an information sheet on these matters in all new houses they build.

The Air-Barrier System

Relative humidity refers to the amount of water that air can hold as vapour. As the temperature of the air decreases, the amount of moisture it can hold also decreases. When the air temperature drops below a certain point, some of the water vapour in the air will be deposited on cold surfaces as liquid or frost. This moisture is called condensation: the temperature at which it occurs is called the dew point.

Condensation occurs whenever moist air touches a surface that has a temperature below its dew point — one example is condensation on a cold glass of water on a hot summer day. Condensation occurs in a similar way in buildings. In almost all cases of concealed condensation, air leakage is the major cause of moisture getting into cavities. Warm interior air leaks into the building envelope, reaches a surface that is at a lower temperature than its dew point, and forms condensation in the envelope cavity.

It is of the utmost importance to establish a plane of airtightness in the building envelope to prevent air leakage through the wall. (The building envelope comprises all the elements of a building which serve to separate the inside environment from the outside environment, including the wall assemblies, the roof assembly, and the doors and windows.) In addition, a plane of airtightness is essential to the performance of the rain-screen wall. An air barrier is a combination of materials within the wall and roof systems which meets the four requirements described below.

1. An air barrier must be continuous. Air will leak through even the tiniest opening, rendering the wall or roof airtightness ineffective.
2. An air-barrier system must be strong and rigid. The air-barrier assembly of any wall or roof system must be able to resist the peak air pressures of the wind without tearing, ripping or popping off its support.
3. An air barrier must be made up of materials that resist the flow of air. The air barrier should not be confused with the vapour barrier (or vapour retarder) whose function is to resist the flow of water vapour.
4. An air barrier must be durable and easy to maintain over the service life of the building.

The air barrier can be placed anywhere in the wall assembly and still perform its function. However, locating the air barrier on the warm (interior) side of the house is more advisable; with the air barrier on the inside, it may be easier to locate and repair any defects. Also, the air barrier will be located in a more stable environment, not exposed to the harsh climate, and may last longer *(fig. 3)*.

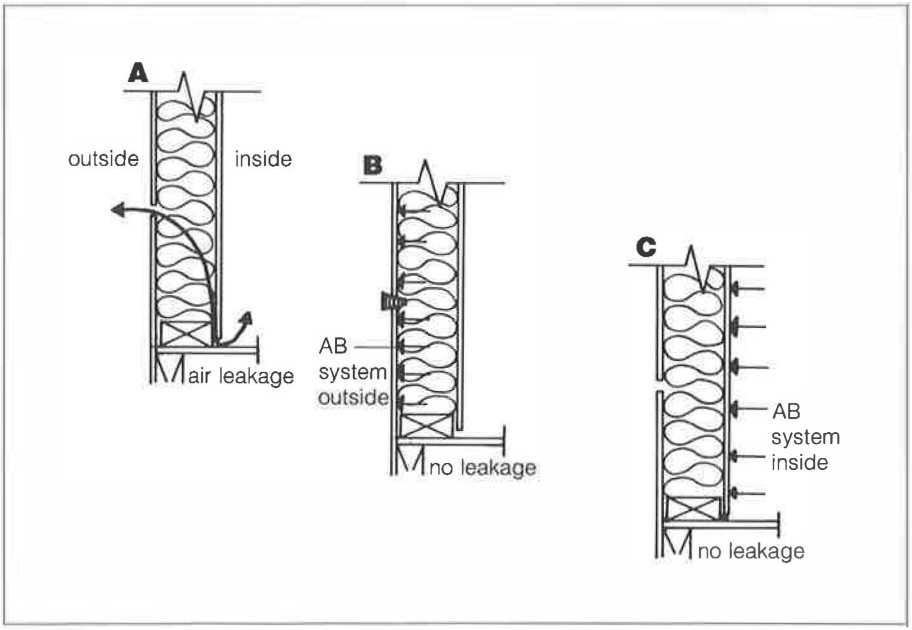

Fig. 3. Location of air barrier in wall

While no standards exist for measuring a material's resistance to air flow, several materials which are generally already used in house construction are considered suitable for forming part of the air-barrier system, including polyethylene, cast-in-place concrete, plywood, structural lumber and gypsum wallboard. Materials which have an air leakage rate of less than 0.1 L/s/m^2 can be considered good candidates for forming part of the air-barrier system. A list of materials which were tested for their air leakage characteristics is included at the back of this book. While a sheet material like polyethylene may be resistant to air flow, it is not a rigid material. When it is subjected to wind it will deform, pull at the joints and staples, and allow air to flow in. It is not, therefore, suitable by itself as an air barrier. A sheet material should be sandwiched between two rigid products if it is to perform structurally *(fig. 4)*.

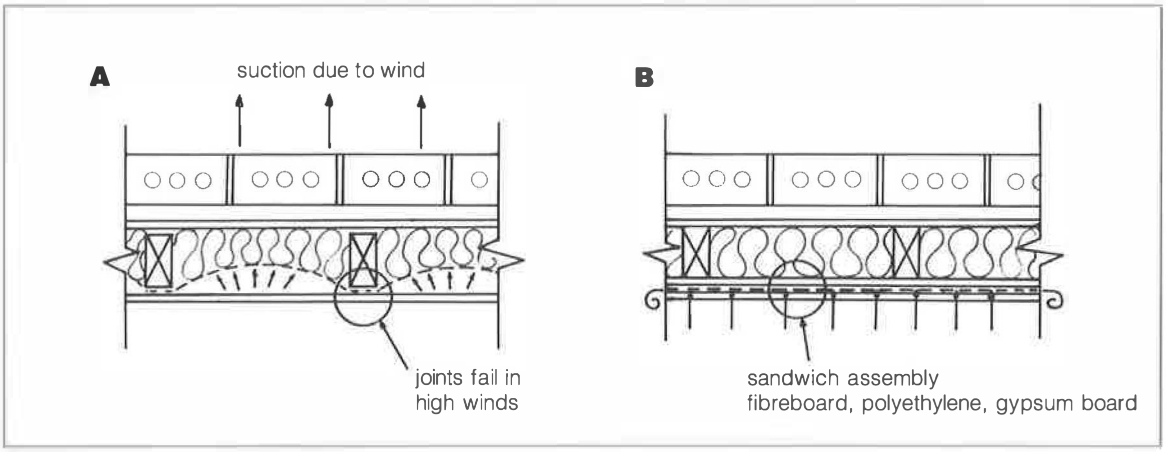

Fig. 4. Plan: stud wall

The air barrier can be most easily adapted into conventional building construction by using materials already being used in the building. The obvious choice for the main component of the air-barrier system is the drywall, which meets three of the four requirements outlined above and is located on the inside of the wall. The fourth requirement, that of continuity, is the critical point. All connections of the drywall with floors, windows, doors, partition walls, electrical outlets and switches must be made structurally airtight. This airtightness can be achieved by tying the drywall to the other elements of the building structure, primarily with gaskets. Gaskets accommodate movements in the structure that occur because of temperature or moisture shrinkage without affecting the airtightness of the joints. Gaskets are also easier and faster to install than caulking and can be cheaper.

A few of the details of a drywall air-barrier system are presented in figures 5 to 12 to illustrate how the drywall can be tied to the other elements of the building structure to create an airtight air-barrier system. As will be seen, the system is extremely simple. There are very few changes to conventional construction materials or sequencing. The gaskets between the framing members can be installed easily by the framing carpenters and the gaskets between the drywall and the framing can be installed by labourers before the drywall is installed.

Basement floor/foundation wall interface.
If the basement is unfinished, the air barrier may consist of the concrete foundation wall and the concrete floor slab, but the joint between the wall and floor must be sealed *(fig. 5,B).* A concrete block foundation wall has a high rate of air leakage and cannot replace the cast-in-place concrete wall in this air-barrier system unless it is suitably parged.

If the basement is finished, the air barrier consists of the concrete floor slab, the interior drywall, and a compressible gasket between these components *(fig. 5,A).* The best material to use as the gasket is an asphalt-impregnated urethane. Other materials have been tried but have been less successful.

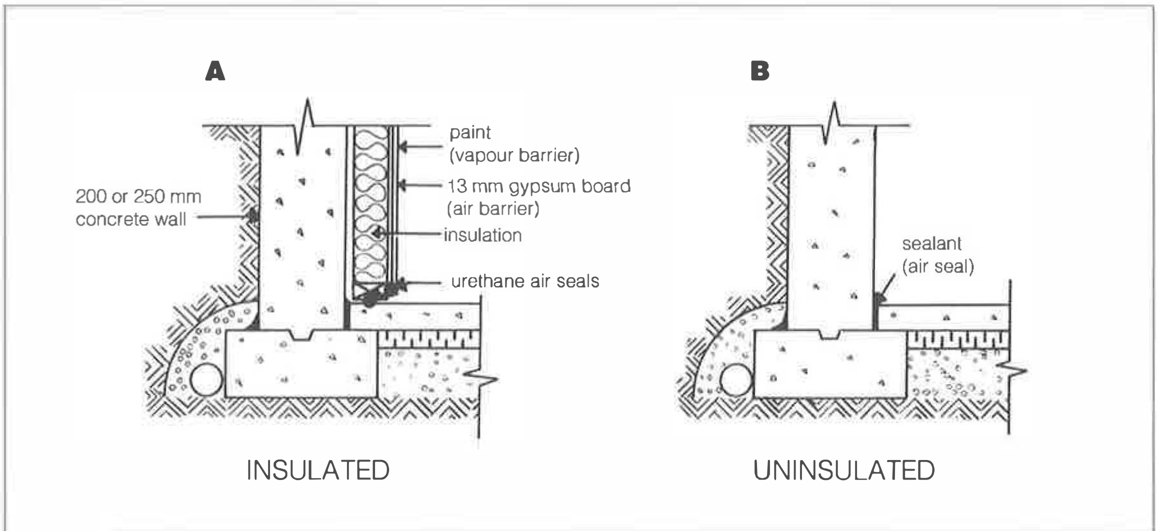

Fig. 5 . Foundation wall/floor air-barrier detail

Foundation wall/first floor interface.

At the foundation wall/first floor interface, the air barrier consists of the drywall, sole and sill plates, headers, end joints and the floor sheathing. Again, a gasket compressed between these members ensures the continuity of the air barrier. Where the basement is not finished, the sill plate is sealed to the concrete foundation wall with a gasket or sealant *(fig 6).*

To maintain airtightness, any joints in the headers or sill plates must also be sealed; caulking can be used for this purpose.

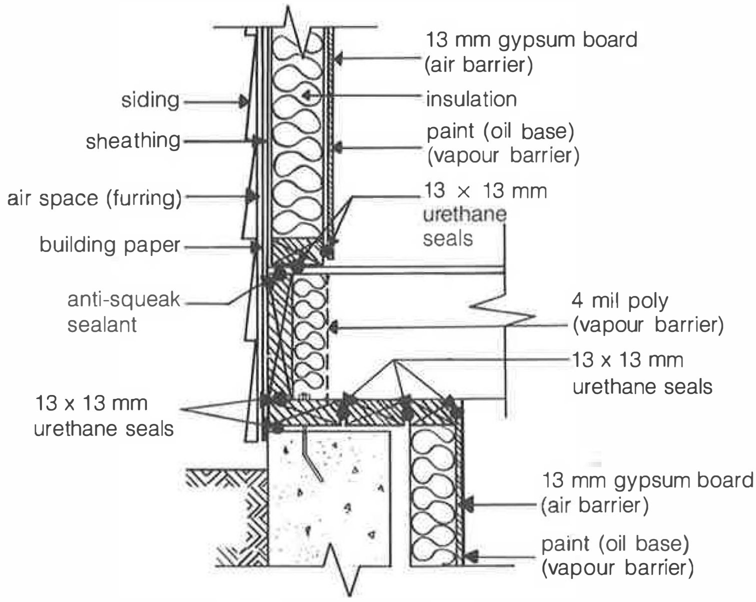

Fig. 6 . Wall/floor/foundation air-barrier detail

Exterior wall/second floor interface.

The detail for the exterior wall/upper floor interface is similar to that at the foundation wall/first floor interface. The components of the air barrier system are the drywall, sole plate, headers, joists, top plates and the floor sheathing. A compressible gasket is used between the components to ensure continuity of the air barrier system *(fig. 7).*

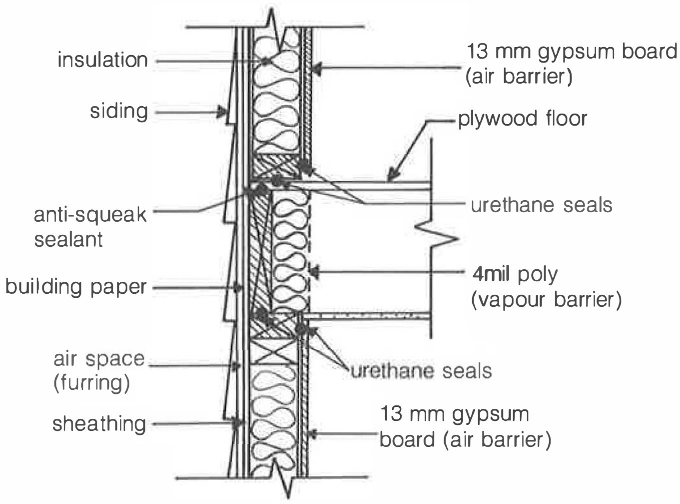

Fig. 7 Exterior wall: second floor air-barrier detail

Partition wall/ceiling interface.
The ceiling drywall prevents air leakage into the attic space. To ensure its continuity, the ceiling drywall must be continuous over the top of the interior partitions. The interior partitions are constructed with only one top plate, making them about 40 mm (1 1/2") shorter than normal. This allows room for the ceiling drywall to be slid into place over the partition wall *(fig. 8, A)*. Alternatively, if the partition is load-bearing and cannot be constructed with only one top plate, the exterior wall drywall can be sealed to the top plate with gaskets and the partition wall drywall can be taped to the exterior wall drywall in the usual fashion *(fig. 8, B)*.

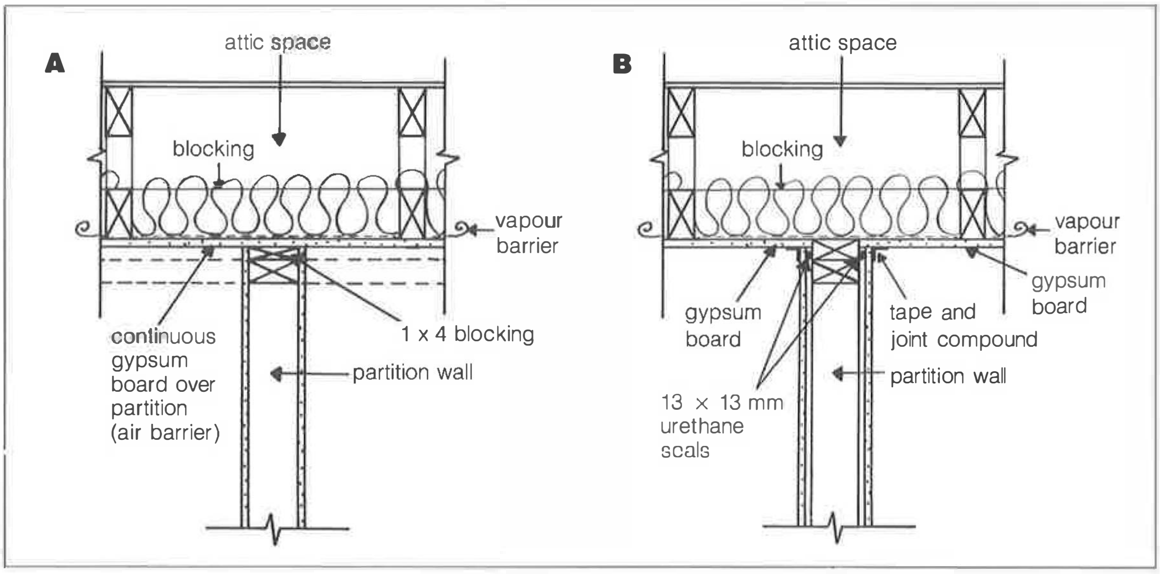

Fig. 8. Partition wall / ceiling air-barrier detail

Exterior wall/partition wall interface.
The drywall on the exterior wall must be continuous behind the partition wall. The last stud of the interior partition is framed about 40 mm (1 1/2") away from the exterior wall to allow the drywall to be slipped into place. An alternative to framing the interior partition short of contacting the exterior wall is to place a gasket on the face of the last interior stud of the intersecting partition *(fig. 9,A)*. Since the drywall must be installed to be continuous, the wires running from switches or outlets on interior walls should also not penetrate the exterior wall; instead, these wires should go down the interior walls through the subfloor and run between the joists to the junction box *(fig. 9, B)*.

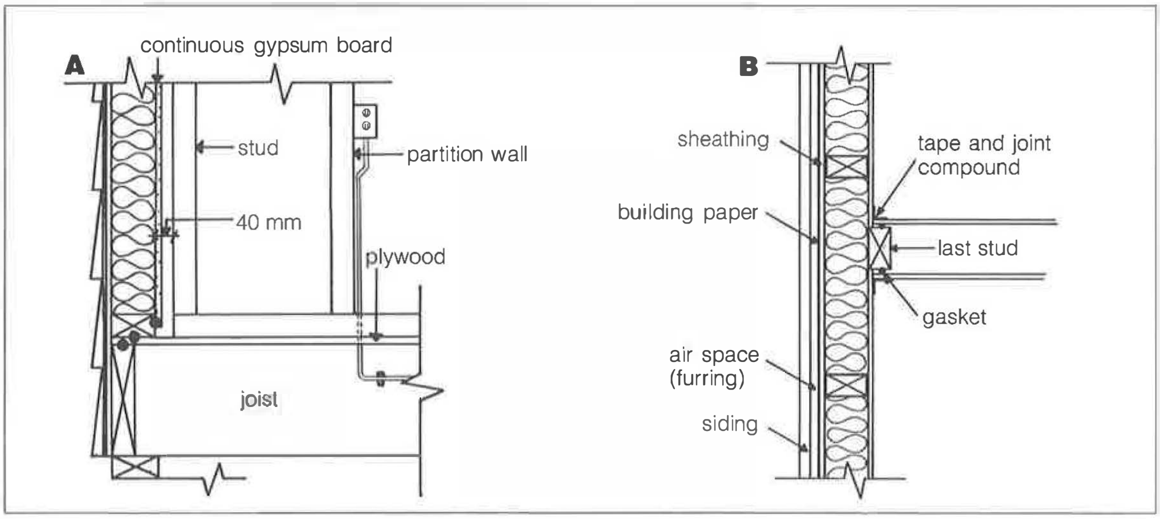

Fig. 9. Exterior wall/partition wall air-barrier detail

Windows and door interfaces

To maintain the continuity of the air barrier, the drywall must be sealed to the frames of the windows and doors. The windows and doors themselves are a part of the air-barrier system so that care should be taken in selecting them *(fig. 10).*

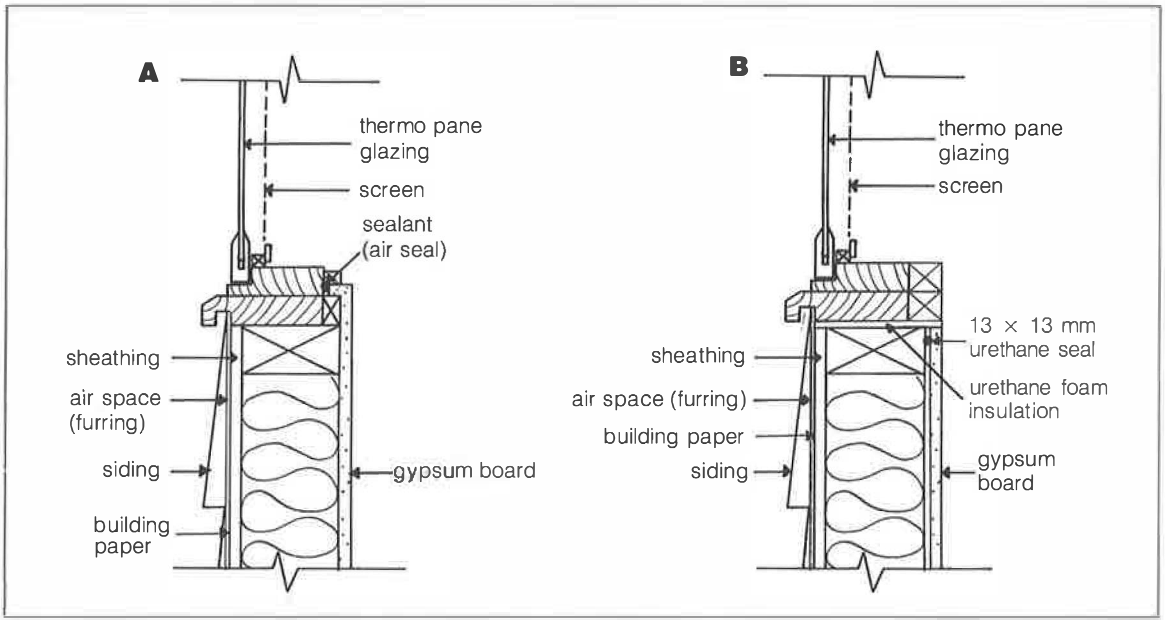

Fig. 10 . Window frame / wall air-barrier detail

If at all possible, penetrations of the air barrier (drywall) should be avoided; electrical outlets and wall switches should be put on interior walls. If penetrations must be made in the exterior wall, sealed plastic outlet boxes should be selected and a compressible gasket should be installed under the cover plate outlets, or switches should run directly to the junction box and should not penetrate the air-barrier system again *(fig. 11).*

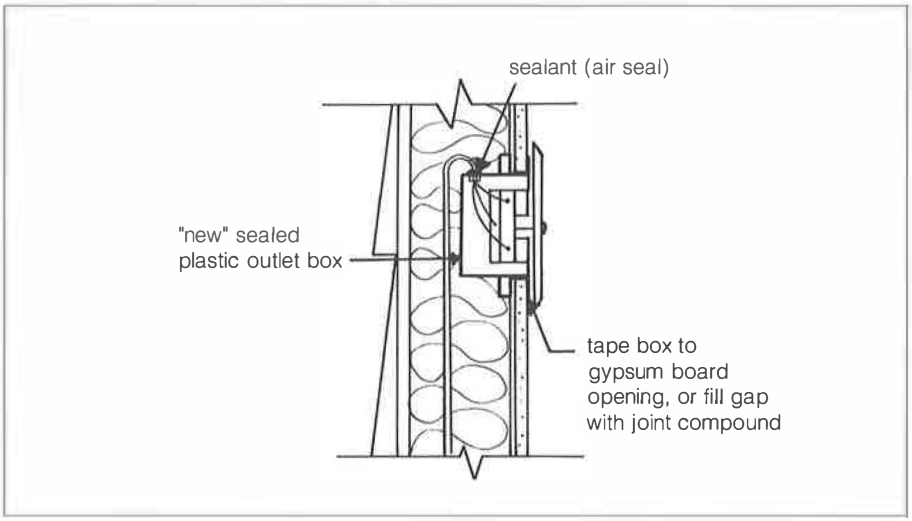

Fig. 11. Air-sealing electrical outlets

Other openings, such as those for pipes, ceiling fixtures or exhaust ducts, should also be eliminated as much as possible, especially when they penetrate the attic. If openings must be made, they should be as small as possible and should be carefully sealed *(fig. 12).*

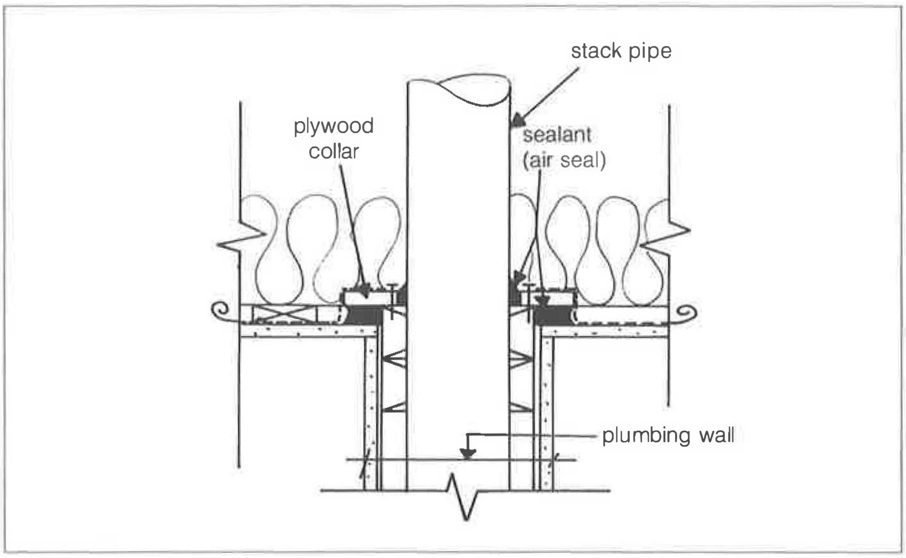

Fig. 12. Stack pipe air-barrier detail

The Rain-Screen Principle

A frequent source of moisture is rain. Rain penetration is one of the oldest problems home owners have to deal with, and yet it still cannot be fully controlled. The usual method is to caulk or seal every crack or joint on the exterior surface. This method works, but only for a short time. A better approach uses the rain-screen principle. This method uses a drained and vented cladding to keep the rain out of the wall. But, to be successful, an effective air barrier is needed.

The objective of a rain-screen wall is to prevent rain penetration. Rain water can penetrate the wall of a building in any one or more of the four following ways:

1. direct entry
2. gravity flow
3. capillary action
4. air pressure difference.

While all four are important, the first three have been dealt with extensively in the design of the cladding systems themselves. The last, that is, air pressure difference, is considered the most significant and is discussed below.

For wind-driven rain to penetrate, three conditions must exist: 1) there must be water on the surface of the wall; 2) there must be an opening through which the water and air can pass; and 3) there must be a force (the wind) to push the water through the opening. If any one of these conditions is eliminated, rain penetration will be significantly reduced.

It is impossible to prevent rain from reaching the sides of a building. Most traditional methods of preventing rain penetration have concentrated on eliminating any openings through which the water could pass. However, as water will pass through even the smallest hole or crack, for this type of method to be successful, the outside of the building must be perfectly sealed, a difficult condition to achieve and virtually impossible to maintain.

The rain-screen wall works because it eliminates the effect of the main force which causes water penetration (the wind). Although it is impossible to prevent wind from blowing on a house, it is possible to counteract the pressure of the wind so that the pressure difference across the exterior cladding of the wall is close to zero. If the pressure difference across the cladding is zero, the main force causing rain penetration is eliminated. This is how the rain-screen wall works.

The rain-screen wall incorporates two layers separated by an air space or cavity. The inner layer of the wall is airtight (the air barrier), while the outer layer (cladding) is vented to the outside. When the wind blows on the building, a pressure difference is created across the cladding. With a rain-screen wall, a small amount of air enters the cavity and is trapped by the inner airtight layer, causing the pressure in the cavity to increase until it equals the exterior pressure *(fig. 13)*. The air trapped in the cavity counteracts the wind blowing on the building and, as a result, the pressure difference across the cladding of the wall is reduced. Therefore, as there is no force to cause the water on the surface of the wall to move inwards, rain penetration is effectively reduced.

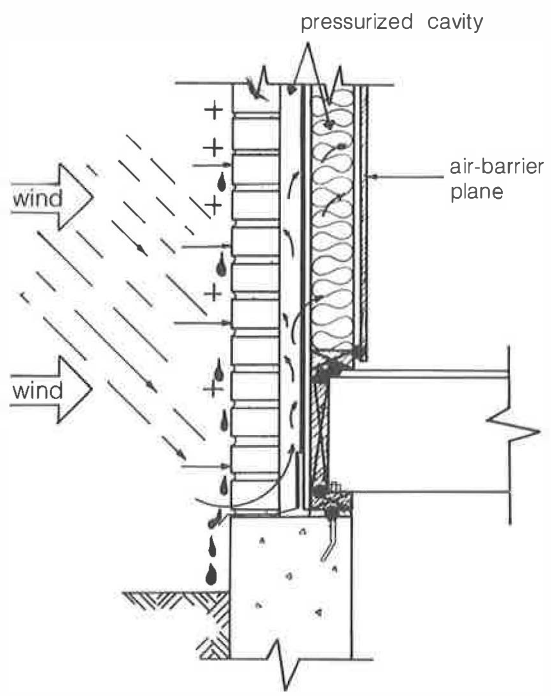

Fig. 13. The rain-screen wall

For the rain screen to function, it is important that the inner layer of the wall is airtight. If there are leakage openings in the inner layer, the pressure in the cavity will not equalize with the exterior pressure and rain penetration may occur. However, it is easier to seal this inner layer than it is to seal the outside of the wall, and the seal will last longer, because the inner layer is not exposed to the harsh exterior environment.

Any water that does penetrate the outer layer, because of gravity forces or capillarity, should drain back to the exterior face of the wall. Flashing details in the cavity are thus very important.

It is also important that the cavity is not continuous around the sides of the building. When wind blows on the face of a building, it creates a positive pressure on that face. However, a negative pressure is created on the sides, roof and rear of the building. If the cavity between the two layers is continuous around the corner of the building, air will blow through the cavity to the sides of the building and pressure equalization will not occur. This could force rain into the cavity and water leakage could occur. A similar action will occur if the cavity is open at the top of the wall *(fig. 14).*

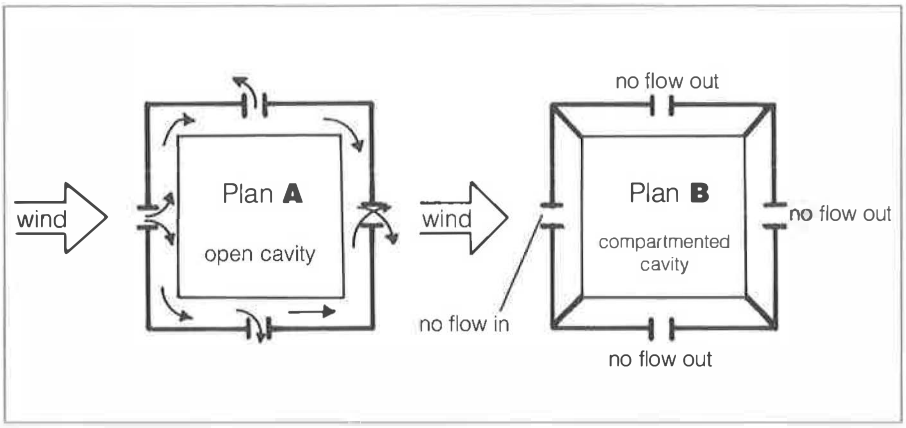

Fig. 14. Open and compartmentalized cavities

To make the rain screen function, the cavity must be divided into "compartments." Each of these compartments must be airtight to allow pressure equalization to occur *(see fig. 14).* The formation of these compartments at corners also eliminates the cooling effect of wind washing into the insulation as discussed in the section Condensation on Wall, Ceilings and Other Surfaces. Fig 15 illustrates one way of sealing the cavity behind the siding at the corner of the building.

Although the rain-screen wall may sound like a new concept, it has been used for years in brick-veneer construction, where the air space behind the face brick is vented or drained at the bottom. A vented and drained cladding is not a true rain-screen wall until it is compartmentalized and the inner layer of the wall is made airtight. It is easy to adapt this concept to conventional construction to create a true rain-screen wall.

Figures 15 and 16 show a few of the details that may be considered for rain-screen design in wood frame construction: siding to siding compartment, and siding to brick veneer compartment, at the corners of a wood frame house.

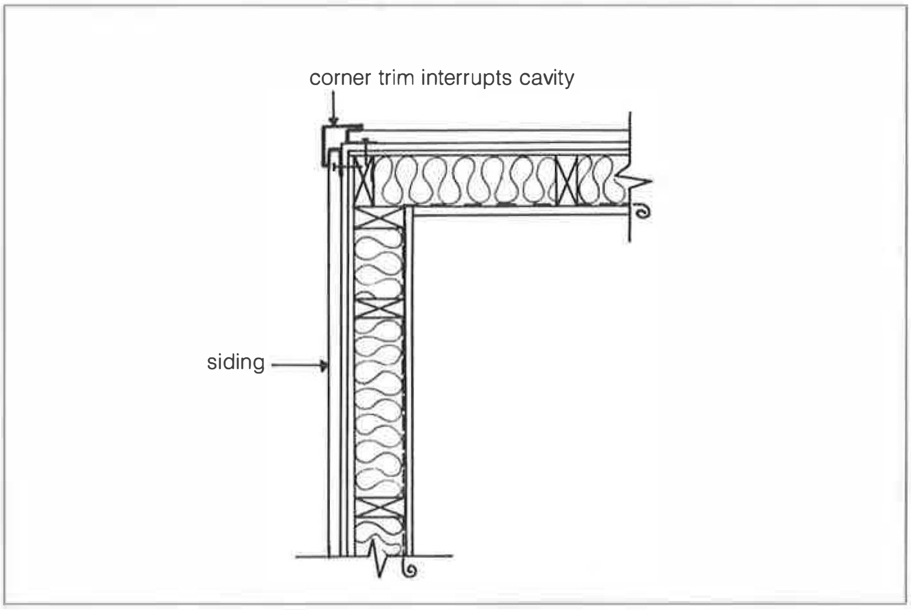

Fig. 15. Plan: corner detail

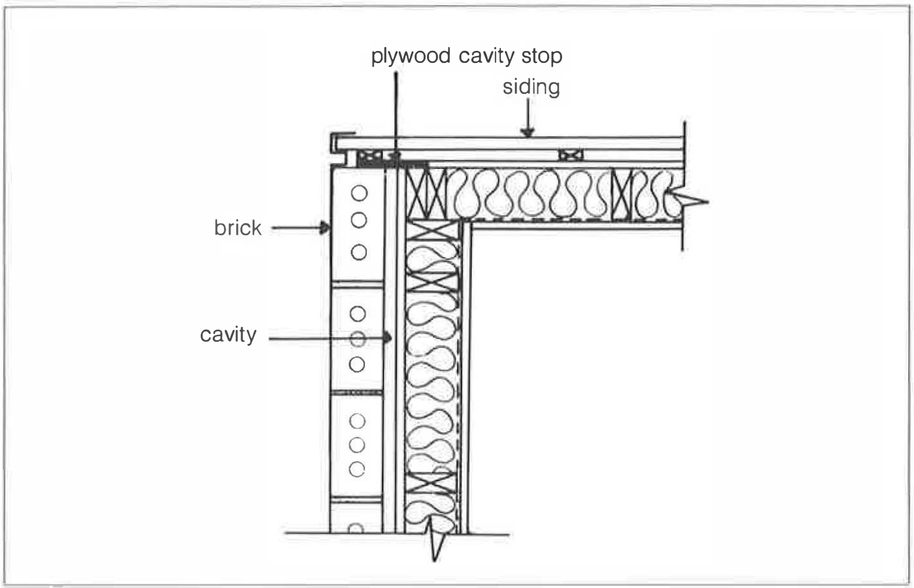

Fig. 16. Plan: corner detail

Moisture Problems in the Attic

Although rain penetration can cause attic moisture problems, condensation of warm inside air which has leaked into the attic space is the more common cause.

Moisture in the attic is more prevalent, if appropriate precautions are not taken, in northern Canada and some parts of the Prairies, where outside temperatures are cold and winters are long. Moderately cold areas can also experience attic moisture if the outdoor air is very humid for long periods. These areas include some parts of British Columbia, some parts of the Maritimes, and Eastern Québec.

Condensation in attics is generally more severe than condensation in walls. First, indoor air always wants to seep up and into the attic on its way out of the house through the soffits and vents. There are many paths for air to seep up, including fixtures, partition walls, stack-pipe opening, and chimneys.

Second, the attic spaces in houses are generally better insulated than they were in the past. Since the air space in the attic is thus cooler, there is less potential for outdoor ventilation air to absorb attic moisture and to carry it away. Roof sheathing and truss members also stay cooler, making them more susceptible to condensation.

Since there is little opportunity for drainage of moisture in attics and little opportunity for drying attic space in many parts of Canada, the best strategy for preventing attic moisture problems is to prevent or cut down the amount of warm, moist air that leaks into the attic from the living spaces below.

Problems and Related Symptoms

- Wetness or frost build-up on roof sheathing and truss members.
- Mould and mildew growth on roof sheathing.
- Sagging of roof sheathing. (It is possible for this deterioration to become so bad that the roof collapses when someone walks on it.)
- Corrosion of truss plates.
- Wet and compacted insulation (decreased thermal resistance).
- Icicles under the soffit area and around roof vents.
- Wet or stained ceilings below the attic space.
- Paint peeling on the ceiling or in the soffit area.
- Cracked ceiling drywall caused by truss uplift. This happens when the upper and lower chords of the truss go through cycles of wetting and drying. The truss warps, causing the drywall below to crack.
- Damp spots around light fixtures or water collecting in light fixtures.

Cause

Condensation caused by air leakage.

Solution

- Seal holes leading to and from the house below. These will include light fixtures, plumbing vents, chimneys, openings for electrical wires, and partition walls between the gypsum board and framing. Refer to The Air- Barrier System for how to do this.

Cause Condensation caused by vapour diffusion.

Solution

- Install a vapour barrier along the ceiling by painting the drywall with two or three coats of oil-based paint or by installing 6 mil polyethylene under the insulation.

Cause Rain penetration.

Solutions

- On sloped roofs, seal shingles, ridges, gable ends, and roof vents.
- Install flashings in valleys and saddles behind chimneys.
- On flat roofs ensure drainage control by building up the roof so that there is a slope to the drain of at least 3 mm per 300 mm (1/8" per foot).

Cause Snow blowing into the attic.

Solution

- Install baffles in soffits, and vents with screen filters *(fig. 17)*.

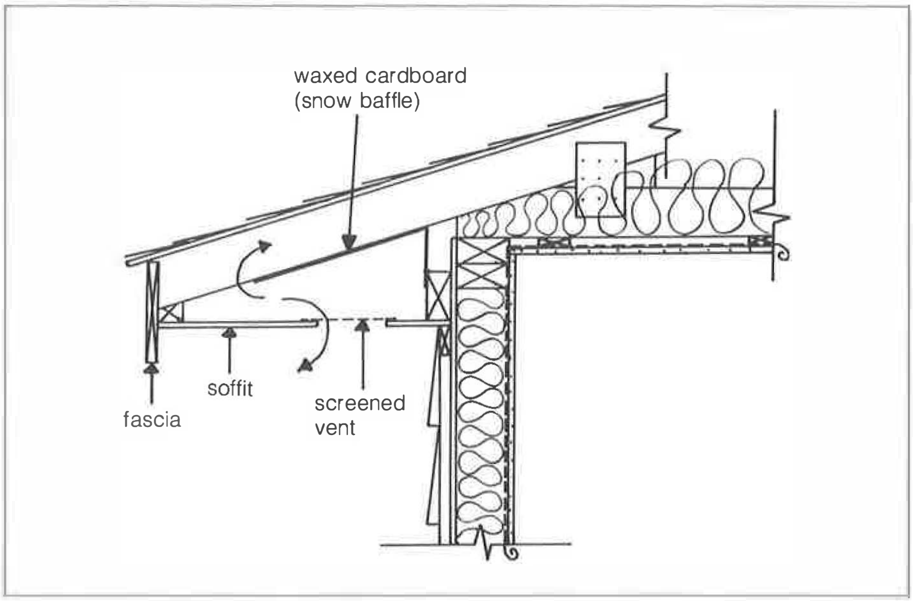

Fig. 17. Soffit baffle prevents entry of blowing snow

Cause Water penetration due to ice damming.

Ice damming is the build-up of ice at the edge of the roof caused by heat escaping from the house and melting snow. The depth of the trapped water can become greater than the vertical overlap of the shingles and water can leak through the roof. Peeling paint in the soffit area is an indication of possible roof leakage problems caused by ice damming.

Solutions

- Install eave protection from the fascia extending at least 900 mm (3') up the roof *(fig. 18)*.
- Use high heel trusses, insulate to the outside of the top plates, and install cardboard baffles to ensure ventilation at the eaves.

Cause

Inadequate attic ventilation.

Solutions

- Reduce the need for attic ventilation by air sealing all holes and openings in the ceiling at partitions, plumbing and chimney penetrations, electrical wiring, and ceiling fixtures. See The Air-Barrier System.
- Increase the ventilation area to the attic by installing ridge, gable, and soffit vents. The vents should be distributed on opposite sides of the building to provide cross ventilation. For attic spaces, at least 1 m^2 of vent area must be provided for every 300 m^2 of attic area. Since flat, shed or cathedral roofs are more subject to problems, it is important to make the ceiling as airtight as possible.(See The Air-Barrier System.)
- Use baffles or cardboard to ensure vents are not blocked by insulation.

Cause

High humidity conditions in the dwelling.

Solution

- Ventilate the house during construction.

Problem

Dripping water from exhaust fans.

Cause

Water drips from fans when the ducts pass through the attic and as a result are cold; condensation then occurs in the cold duct and drains back to the interior.

Solution

- Insulate the exhaust duct to the under side of the sheathing. The exhaust should be an inverted elbow so that condensation at the mouth area does not drain back into the fan housing *(fig. 19)*.

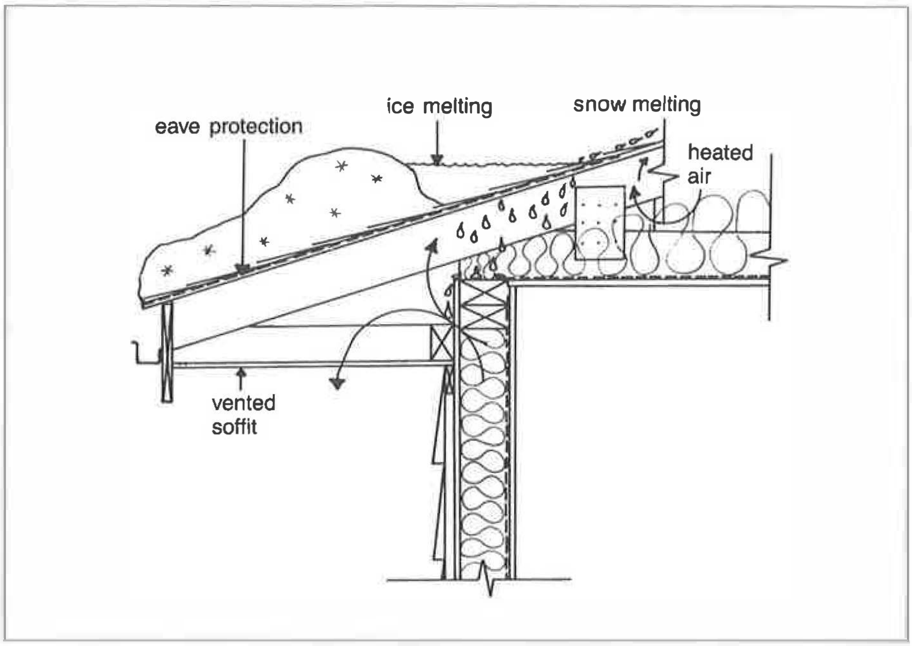

Fig. 18 . Ice damming at edge of roof

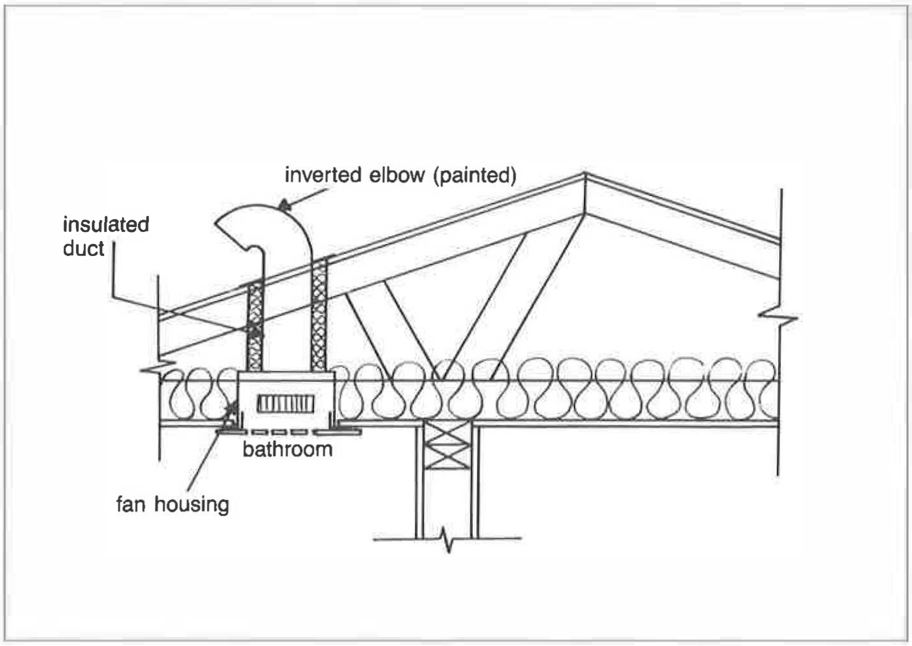

Fig. 19. Bathroom fan / duct installation detail

Moisture Problems in the Wall Cavity (Concealed Condensation)

Almost all cases of wall-cavity (concealed) moisture problems arise from rain penetration or from humid indoor air penetrating into the cavity and condensing into liquid. Condensation caused by air leakage (exfiltration) is the major contributor. It occurs more often in the upper storeys of a house where more air exfiltration takes place because of the stack effect (warm air, which is lighter, pushing on the ceiling, somewhat like hot air rising in a chimney).

The amount of concealed condensation caused by air exfiltration in a wall depends on the relative humidity of the inside air, the temperature of the sheathing and cladding surfaces in the wall assembly, and the amount of air moving through the wall. The total exfiltration depends on the area of the leakage openings in the wall and ceiling and on the air pressure difference between the inside and the outside.

Severe concealed condensation problems are more likely to occur in areas subject to sustained cold temperatures and extended winter seasons. Windy regions will promote exfiltration from the leeward side of a house.

Problems and Related Symptoms

- Rotting of wall framing members and exterior sheathing. (This deterioration can proceed to the point of structural collapse.)
- Staining of exterior siding, warped wood siding, efflorescence or spalling of brick or stone.
- Peeling of paint on exterior siding.
- Corrosion of metal fasteners.
- Mould and mildew on wall framing members and on exterior sheathing.
- Wet or damp spots on interior finishes.

Cause

Condensation inside the wall cavity caused by air leakage.

Solution

- Reduce air leakage through the walls by one or more of the following actions:
- seal all drywall boards to the floor using sealant or caulking
- seal all electrical outlets on outside walls
- seal header joist and sill plates at foundation using sealant or other material suitable for this task, such as gaskets or grout
- seal air leakage path through exterior frame wall in mansard type roofs; sheath and seal exterior wall if required
- seal all window frames to rough openings with sealants or urethane foam
- seal all plumbing pipe and/or electrical wire penetrations into or out of the outside wall
- install a low-flow exhaust fan set to continuous operation. This depressurizes the house during the winter season. As a result, cold air, which is relatively dry, will infiltrate through the cracks and holes and reduce the potential for moisture problems in walls.

Note: For more information on air sealing, see The Air-Barrier System.

Cause

Condensation caused by vapour diffusion. This is a rare problem but it may occur if no vapour diffusion protection is present in the wall or ceiling.

Solution

- Install a vapour barrier. This can be done by simply painting the inside surface of the outside walls or the ceiling with a vapour-barrier paint or with two to three coats of oil-based paint. When the materials used for exterior sheathing have a low vapour permeability (such as polystyrene rigid board insulation, plywood, or waferboard), a Type 1 vapour barrier (such as polyethelyne) must be installed on the warm side of the insulation.

Cause

Rain penetration.

Solutions

- Check for open holes and cracks and seal exterior gaps and openings.
- Slope the flashings, gutters, and sills to the outside.
- Build a rain-screen wall. (See The Rain Screen Principle.)
- Wedge thin shims between siding boards or use round head nails to leave a space between the boards to reduce wetting by the capillary action of rain water *(fig. 20).*
- Provide weepholes in brickwork every third brick or 600 mm (24").

Note: Do not seal bricks or stone veneer with exterior coatings. Coatings prevent the brick from "breathing," moisture gets trapped in it and then freezes and causes the brick to spall.

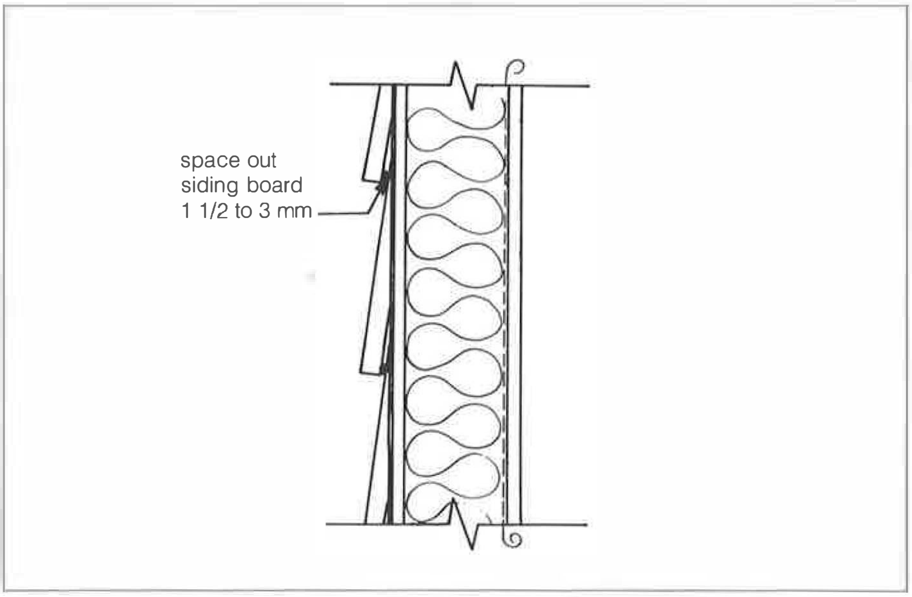

Fig. 20. Wetting of wall by capillary action

Cause

Inadequate wall drying.

Solution

- Provide a cavity which is drained and vented between impermeable sidings (such as vinyl and aluminum) and sheathing materials.

Cause

High moisture levels in the dwelling.

Solutions

- Advise the house owner to:
  - increase house ventilation using openable windows or fans
  - use a dehumidifier.

Moisture Problems in the Basement or Crawlspace

Many of the more serious moisture entry problems occur in the basement or crawl space. Crawl space and basement problems are both discussed here.

The conditions that affect basement walls and floors are quite different from those that affect the above-grade walls. The soil surrounding the basement is always moist. During winter, the soil around footings and below slabs in crawl spaces generally has a higher vapour pressure than the air in the basement; therefore, water vapour is continually diffusing into the concrete floor slab and walls.

The basement is generally at a slight negative pressure, as a result of stack effect, which causes air to infiltrate through any cracks in the foundation walls or floor slab. As the air flows around drain tile and through the moist soil to reach these cracks, it often becomes saturated and, as a result, carries moisture into the basement (fig. 21).

Basement and crawl spaces are also subject to water penetration from severe rain storms, high water tables, melting snow and ice and sometimes blocked perimeter drains.

Another mechanism through which water moves from one place to another is capillary action. If a porous material such as concrete is placed in contact with water, some of this water will rise up into the pores of the concrete, like water soaking into a sponge. A concrete basement floor slab can become saturated by the capillary action of the water in contact with the underpart of the slab; yet it will not show any visible signs on the surface.

Basement moisture problems are generally more severe in places where the water table is high or surrounding drainage is poor, or if the building is in a low-lying area.

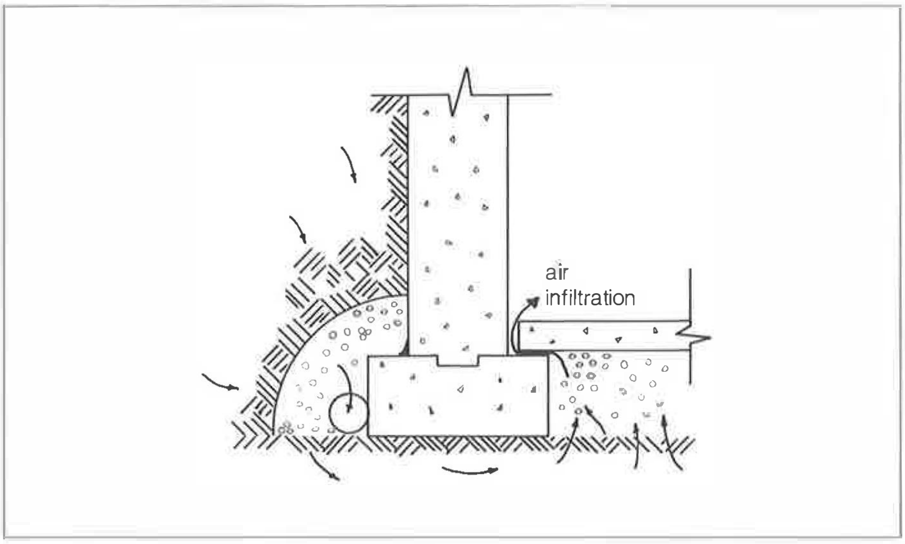

Fig. 21. Air infiltration at foundation / floor joint

Problems and Related Symptoms

The following problems appear during a spring thaw or a severe rain storm:
- flooding
- water leakage through cracks and joints
- water penetration at the top of the foundation wall
- wet or damp floors.

Cause

Inadequate site drainage.

Solution

- Slope all surface grades away from the house. A slope of 10 per cent should be adequate. This includes paved as well as grassed areas *(fig. 22)*.

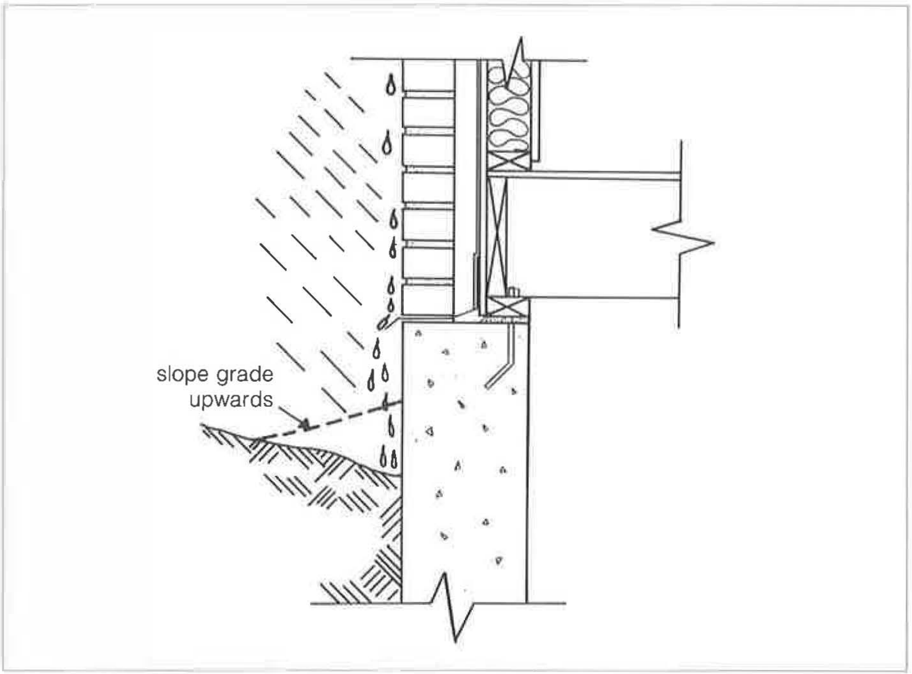

Fig. 22. Water entry into basement area

Cause

Eavestrough discharge too close to foundation.

Solution

- Drain downspouts away from the side of the house and provide a splashblock. If there are any cracks in the wall, the water will likely leak into the basement. If downspouts must be drained into the weeping tile, increase the diameter of the weeping tile as excess water could cause back-up of water and flooding of the basement. Also, do not drain downspouts next to the house.

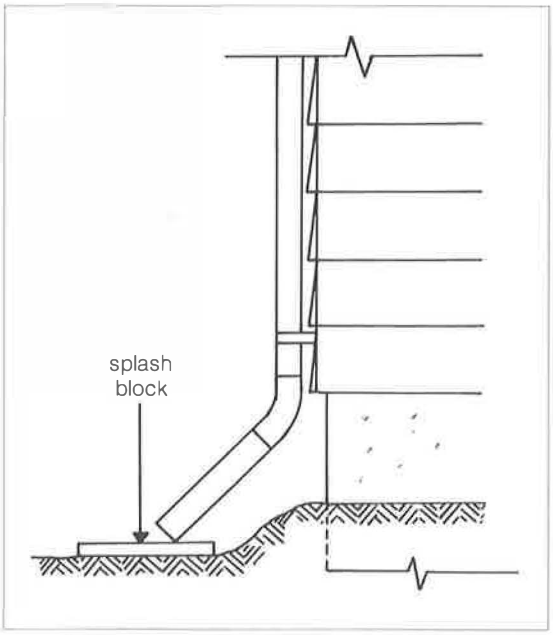

Fig. 23. Drain eavestrough away from house

Cause Water enters between paved areas and the foundation walls.

Solution

- Raise asphalt and slope it up to the foundation wall. Water cannot drain through the pavement, but if the pavement slopes downward to the foundation wall, rain and snow meltwater will move towards the foundation wall and drain through the joint between the foundation and the pavement.

Cause Blocked drainage at base of wall siding or brick wall.

Solution

- Install siding correctly and ensure that all brick weepholes are clear.

Problem

Humid, damp, and musty basement or crawl space.

Cause Air leakage through cracks in the floor slab or foundation walls.

Solutions

- Seal the joint between the floor slab and foundation walls with caulking, single-component urethane or single-component silicone.
- Air seal block foundation surface with dampproofing or suitable paint.
- Ensure that air is not leaking in from the floor drain. Install a trap primer to ensure that the trap never gets dry. This is especially important if the presence of radon gas is suspected.
- Follow good construction practices to prevent cracking in floor slab and foundation walls (see also the Builders' Workshop booklet, *Concrete Foundations,* pagcs 1 to 12).

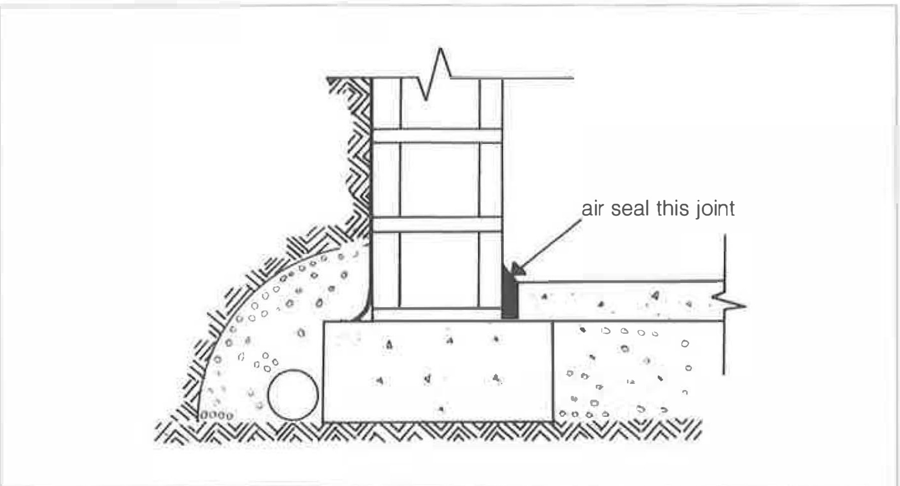

Fig. 24. Air leaks into basement

Cause Water vapour diffusion through concrete wall and floor.

Solution

- Dampproof the concrete wall and floor surfaces with a coat of asphalt emulsion to prevent or reduce the amount of moisture entering the basement. (There are also many new products being sold for this purpose.) Alkalyd paints can be used to control the diffusion of water through the slab or wall, but they are not always durable, particularly if the concrete is poor. Install a polyethylene film below the concrete slab.

Cause

Moisture wicking through the floor slab or walls.

Solutions

- Slope perimeter drainage to the sump pit.
- Set the sump pump to a good operating level.
- Dampproof the foundation on the inside and outside walls.
- Paint the concrete floor with an oil-based paint.

Cause

Moisture generated from the ground below the crawl space.

Solution

- Install a moisture barrier on the exposed ground in the crawl space. The moisture barrier could be 50 mm (2 ") asphalt, 10 MPa (1,500 PSI) Portland cement concrete, 2.2 kg/m² roll roofing or 0.10 mm polyethene film. The joints should be lapped more than 150 mm (6") and should be weighted down with stone or some other suitable ballast material *(fig 25).* Air seal the crawl space from the ground surface.

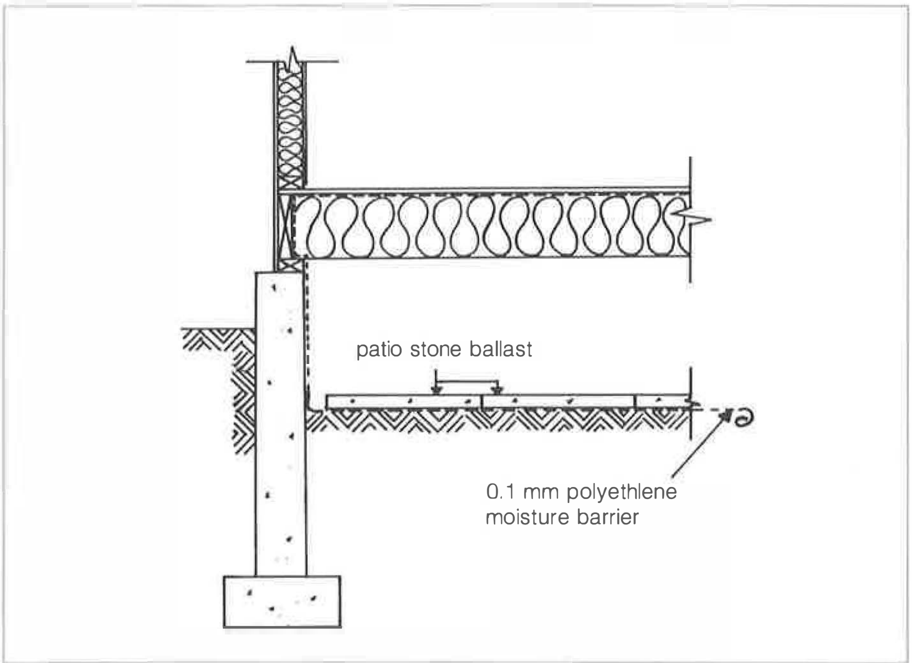

Fig. 25. Moisture barrier over ground covers

Cause

Inadequate ventilation of crawl space.

Solutions

- Increase the vent area and provide mechanical ventilation if necessary. Natural ventilation should be supplied during the summer and fall by a vent area of not less than 0.1 m² for every 50 m² of floor area. The vents should be evenly distributed on opposite sides of the building to provide cross ventilation. During winter and spring, the vents should be closed, unless the underside of the floor is insulated. The vents should also be able to prevent the entry of snow, rain and insects. Mechanical ventilation should also be considered.
- Advise homeowners to dehumidify the crawl space in the summer.

Problem
Condensation on wall or floor surfaces and water pipes.

Cause
High humidity levels.

Solution
- Advise the homeowner to:
- dehumidify the basement. (See Controlling Moisture Sources).
- increase ventilation in fall and winter
- not to ventilate the basement in the summer, particularly in geographic zones where high humidity prevails (Atlantic and B.C. regions).

Cause
Cold surfaces.

Solutions
- Insulate the basement walls. Add vapour and air barriers over insulation. Insulation can be either interior or exterior. If interior insulation is used, care must be taken to ensure that there is a good vapour barrier and a continuous air barrier to prevent moisture from reaching the cold concrete walls (See fig. 5, A.)
- Put an insulated subfloor over the basement floor.

Cause
Excessively cold water in pipes.

Solution
- Insulate pipes with foil-faced insulation.

Problem
Rotting of headers, floor joist ends and sill plates.

Cause
Condensation or rain penetration.

Solutions
- Advise homeowners to:
- lower the humidity level in basement or crawl space
- increase ventilation in basement or crawl space.
- Provide an air barrier and a vapour barrier if the basement wall is finished or insulated, particularly in the area of the first floor joists *(fig. 26)*.
- Install flashing to prevent rain water draining inside instead of outside or if condensate from walls is draining over the headers and joist ends.

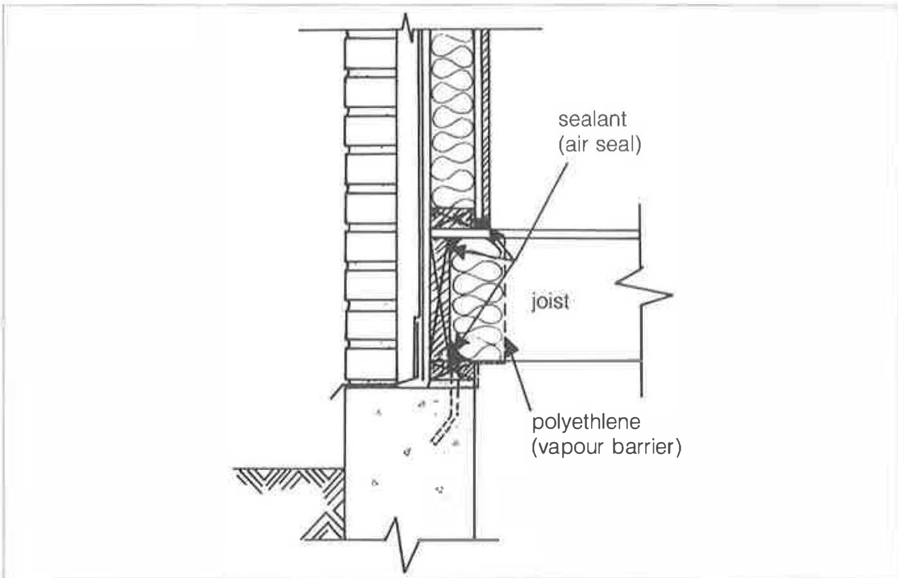

Fig. 26 . Air and vapour barriers: header/joists detail

Moisture Problems in Brick, Stone and Exterior Siding

Brick, stone and siding moisture problems are varied but most often relate to rain penetration or air leakage. Unfortunately, because the symptoms are similar, it is often difficult to determine which is the actual cause of the problems. Symptoms are warped, buckled siding, peeling paint, brick efflorescence and spalling. If the affected areas are mostly in the upper floors and on the leeward side of prevailing winds, air leakage should be suspected.

Problems and Related Symptoms

- Warped and buckled siding.
- Peeling paint.
- Rotting of siding.
- Water stains, mould and mildew appearing on trailing edge of siding.
- Efflorescence and spalling of brick and stone.

Cause

Rain penetration. Rain water penetration may occur by any of the following four mechanisms: direct entry, gravity, capillary action, and wind *(fig 27).*

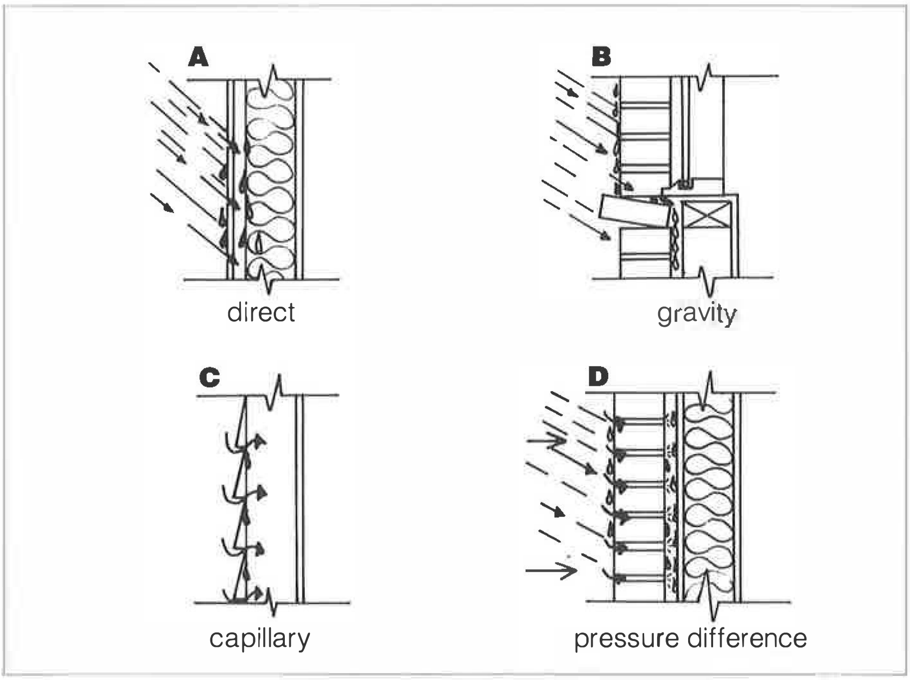

Fig. 27. Rain penetration

Solutions

- Eliminate the possibility of rain entering by covering open holes and by sealing or protecting openings with baffles *(fig. 28)*.
- Correct drainage problems by using shiplap joints and proper flashing details.
- Eliminate the force due to capillarity by creating a gap of 2.5 mm (1/10") in the lap joint of the siding, and use drips such as saw kerfs under the sills of windows and doors *(fig 29)*.
- Neutralize the force of the wind acting on the siding by using a rain screen wall (see The Rain-Screen Principle).

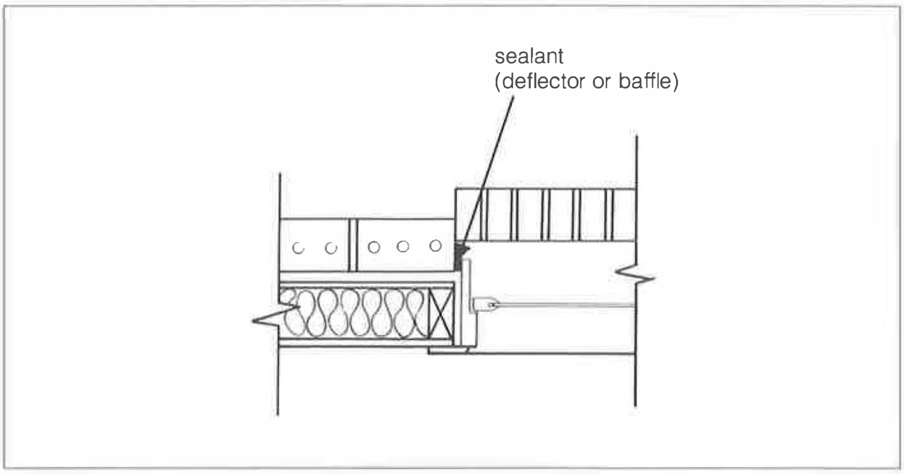

Fig. 28. Direct entry of rain stopped with deflector seal or brick-stop baffle

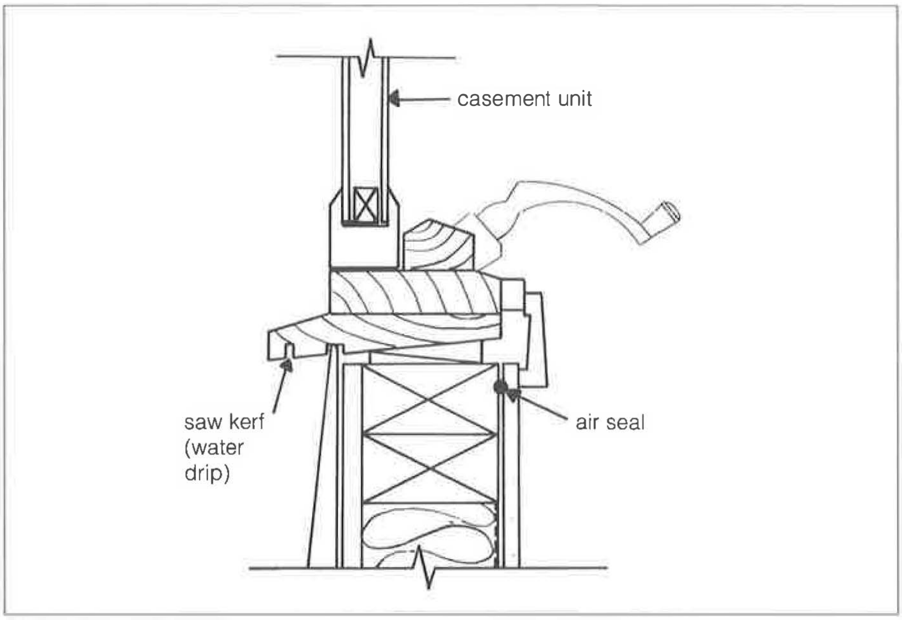

Fig. 29. Saw kerf prevents water from entering behind siding

Cause

Condensation forming on the back side of brick, stone or siding from exfiltration or diffusion of indoor air.

Solutions

- Provide an effective wall/air seal to prevent leakage of moist interior air into wall cavity (see The Air-Barrier System).
- Provide an effective vapour barrier on the warm side of the wall.
- Use building materials that are dry to prevent moisture transfer from the framing lumber to the sheathing and siding.
- Advise occupants to lower the house pressure by using an exhaust fan on continuous operation during the winter.

Condensation on Walls, Ceilings and Other Surfaces

The formation of mould and mildew is often one of the early warning signs of more serious moisture problems. Mould and midden appear as dark stains on the surface of walls or ceillings.

Condensation on wall surfaces generally appears at intersections of the wall and ceiling and at corners of two exterior walls. It sometimes occurs behind furniture and drapes although this is not as common. Condensation may also occur at or near kitchen exhaust fan vents, on the electrical conduit from the electrical panel and on toilet bowls and tanks.

Problems and Related Symptoms

- Condensation at corners and on interior finishes.
- Mould and mildew growth.
- Staining of drywall below windows.
- Water marks along the corners of exterior walls.
- Shadow lines of trusses.

Cause

Cold air leaking into the house.
The infiltration of cold air into the house can cause cooling of the nearby surfaces. Common places where air infiltration may occur are sills, headers, joists and overhangs, rough stud openings framed to accommodate doors and windows, and around plumbing pipes and openings for electrical outlets.

Solution

- Provide an effective air seal at these locations (see The Air-Barrier System).

Problem

Condensation at the joint between exterior wall and ceiling.

Cause

Thermal bridging effect caused by wood studs, joints and metal fasteners.

Solution

Insulate corners with cant strip insulation, and install vapour barriers and gypsum board finish. Insulation can be added to the interior or exterior of the wall, or foam insulation can be injected into the cavity. If insulation is added to the interior, care must be taken to ensure that an air barrier is installed over the insulation and that no air can leak past the insulation. (see The Air-Barrier System).

Cause

Cold spots on the surface of the wall caused by wind washing.
In some situations, cold exterior air can blow around the cavity of an exterior wall without the air necessarily entering the building interior. The result is a reduction in the effectiveness of the insulation and a cooling of the interior wall surfaces. This problem is common at exterior corners, at the intersection of the exterior wall and upper ceiling, and at cantilevered areas.

Solutions

- Compartmentalize the top and corners of exterior walls. (See The Rain-Screen Principle.)
- Install sheathing or building paper (non-vapour barrier) to prevent the wind from blowing directly into the wall cavity or around the corner of the building *(fig. 30)*.

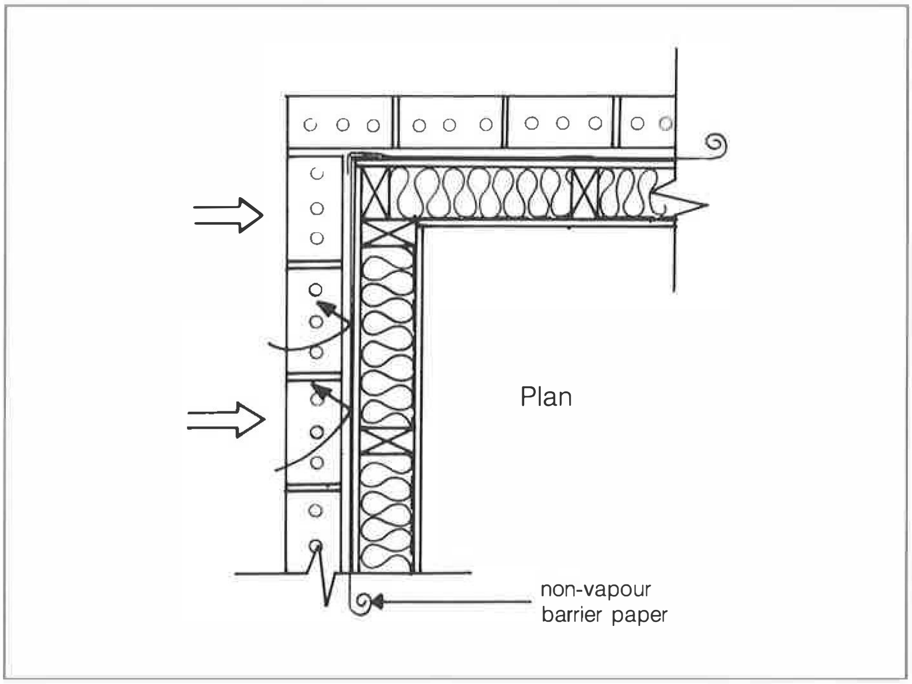

Fig. 30. Building paper minimizes wind washing into insulation

Cause

High moisture levels in the dwelling.

Solutions

- Eliminate any sources of moisture that may contribute significant amounts of humidity. (See Controlling Moisture Sources.)
- Provide fresh air ventilation, install ventilation system with humidistat control.

Cause

Poor air circulation.
The circulation of warm air inside the dwelling helps to warm the interior surfaces of the building. Areas where the circulation is poor include corners, closets, behind furniture pressed against the wall, and behind wall hangings. Condensation is more likely in these areas, and when it does occur, it takes longer for the moisture to dry out.

Solutions

- Improve the air circulation in the house by the following means:
  - increase the number and distribution o return air grills
  - where possible supply fresh air to each bedroom and living area
  - undercut each interior door
  - keep duct work short and use as few elbows as possible
  - use high side wall registers.
- Advise the homeowners to move clothing away from walls

Moisture Problems in Windows

Problems and Related Symptoms

The greatest window moisture problem is condensation. Small amounts of condensation on a window should not be cause for concern because, under extreme weather conditions, minor condensation occurs on all windows. Large amounts of condensation over long periods of time, however, indicate a problem. Most problems are caused when frost on the window condenses quickly and runs off before it can evaporate.

Three factors influence the occurrence of condensation on windows:

1. the temperature on the inside of the window;
2. the interior moisture level or relative humidity; and
3. the outside air temperature.

Inside air temperature and to some extent the humidity level are controlled by the lifestyle of the occupants. Tables have been developed to indicate the moisture level or relative humidity that certain types of windows will support without condensation occurring. As a general rule of thumb, a relative humidity greater than 30 per cent will cause condensation to occur on a double-glazed window and a relative humidity greater than 45 per cent will cause condensation on a triple-glazed window at temperatures of lower than -40^0 C.

As the interior surface temperature of the window decreases, condensation is more likely to form. The interior surface temperature is affected by the outside temperature, the R-value of the window and air circulation near the face of the window *(fig. 31).*

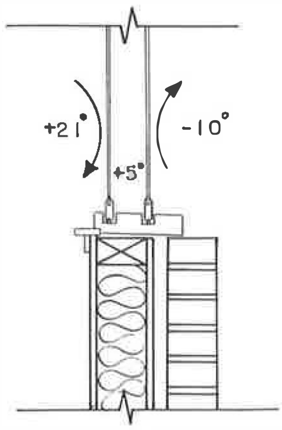

Fig. 31. Temperature distribution in a double-pane wood slider window (R2)

Condensation can also occur between panes of glass on multi-glazed windows. It is more often observed on upper floor windows or on the leeward side of the building on a cold windy day *(fig. 32).*

Rain penetration through the window members or between the frame and the rough opening can also be a problem.

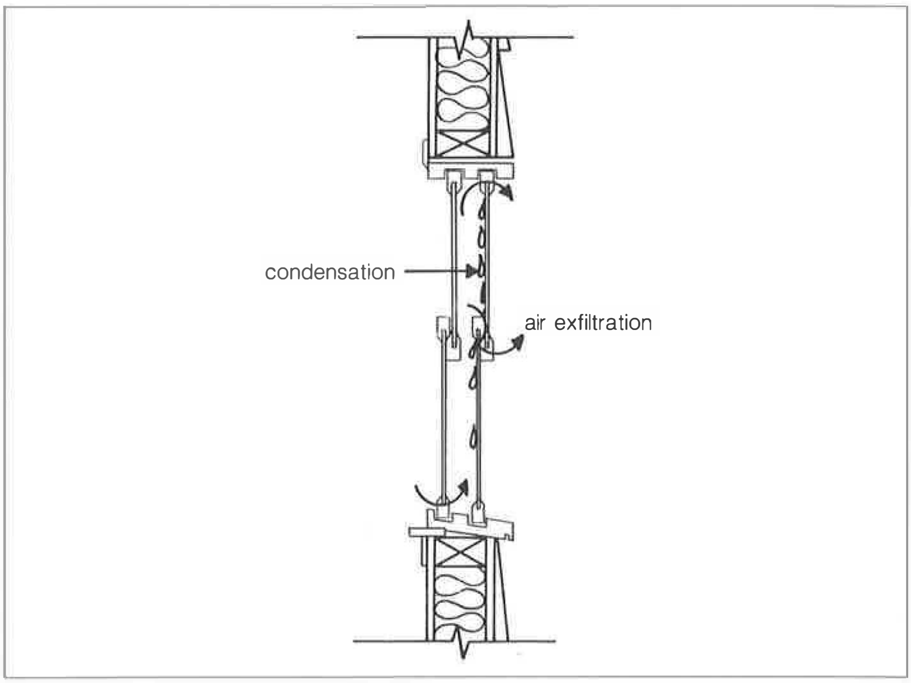

Fig. 32. Condensation of humidity between window panes

Problem

Condensation on window glass.

Cause

Low R-value of the glass or frame. A window with a low R-value will have a lower interior surface temperature and is therefore more prone to condensation.

Solutions

- Use double or triple glazing. The R-value of a single pane of glass is approximately RSI-0.2 (R-1) and is due almost entirely to the air films which naturally hug the glass surfaces; glass alone has a thermal resistance of only RSI-0.004 (R-0.02) for a 3 mm (1/8") thickness. Two panes of glass separated by an air space can increase the R value to RSI-0.4 (R-2) and three panes of glass separated by two air spaces can increase the value to RSI-0.6 (R-3).
- Use insulating glass units with a larger air space between panes.

- Use low-e glazing. Low-e (low-emissivity) glass is a relatively new product on the market. A virtually invisible ultra-thin metallic coating is applied to the glass during manufacture. This coating is applied to the outside surface of the inner pane of an insulating glass unit. In an ordinary double-glazed unit, the inner pane is warmer than the outer pane so that it radiates heat to the exterior. The low-e film inhibits this radiative heat transfer by reflecting the heat back into the room. Since the low-e glazing is more resistant to heat flow, it has a higher R-value than normal double-glazed units. In fact, the R-value of a low-e double glazed unit is comparable to that of a triple-glazed unit. The advantage of using low-e glazing is that the R-value of a triple unit is obtained without the extra thickness or weight of the triple-glazed unit.

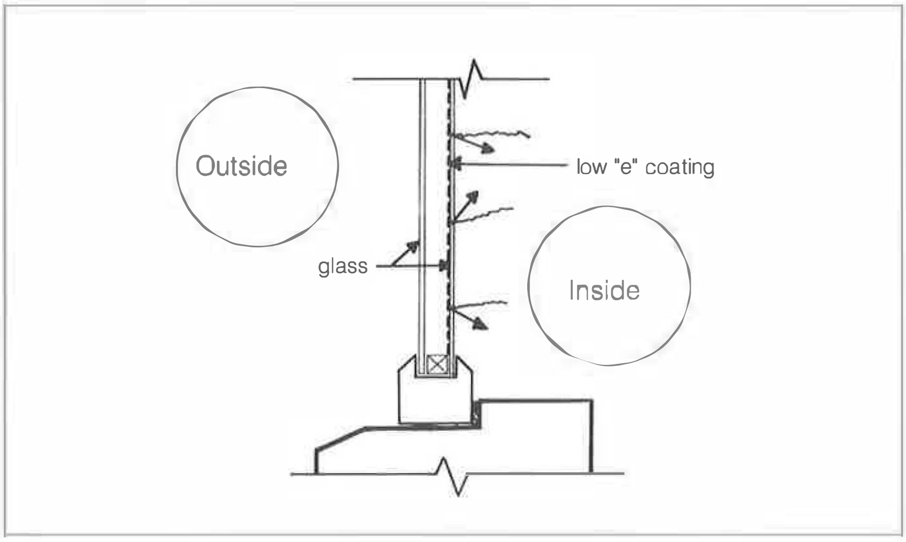

Fig. 33 . Sealed unit with low "e" coating

Problem

Condensation on window frame.

Cause

Thermal bridging.
A thermal bridge is an easy path for heat flow along in an otherwise thermally resistant construction. For example, in a conventional wood-frame wall, the studs are thermal bridges because they provide much less thermal resistance to the flow of heat than the cavity insulation. Thermal bridging of windows occurs mostly with metal or plastic frame windows that do not have some sort of thermal break in their design.

Solutions

- Install windows that have a thermal break or check and verify that a thermal break can be incorporated on the existing frame. A thermal break is a material such as PVC or urethane which is incorporated into the frame of the window so that the metal is not continuous from the outside to the inside. The manufacturer's literature or CMHC Materials Evaluation Reports should provide information on the thermal break used in various windows.
- Install windows so that the thermal break of the window is not by-passed. If the window is not properly installed, the inner sashes could be in contact with a conductive material, thereby short-circuiting the thermal break.

Cause

Air circulation between the window frame and the rough opening.
If the space between the window frame and the rough opening is not properly sealed, cold air can leak in the house and cool down the window frame. Common practice is to pack fibreglass insulation into this space; this may be acceptable for insulating purposes, but it does not prevent air leakage (fig. 34).

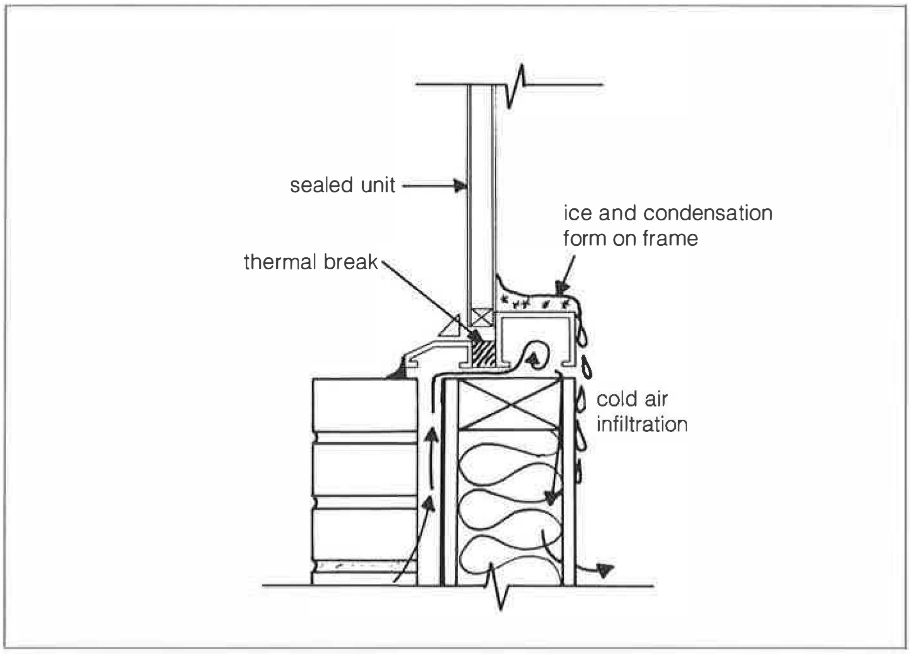

Fig. 34. Window frame not air-sealed to wall

Solution

- Seal the opening between the window frame and the rough opening. If the space is not wide, it can be sealed using a polyethylene backing rope and sealant or caulking. If the space is wider, it can be sealed by running the gypsum board to the side of the frame and sealing or caulking it to the window frame. Alternatively, this space could be filled with expanding foam insulation.

Problems and Related Symptoms

- Mold and mildew growth.
- Rotting of window frame.

Cause

Poor air circulation.
The circulation of warm air aids in keeping the surface temperature of window and frame warmer. This reduces the potential for condensation (fig. 35).

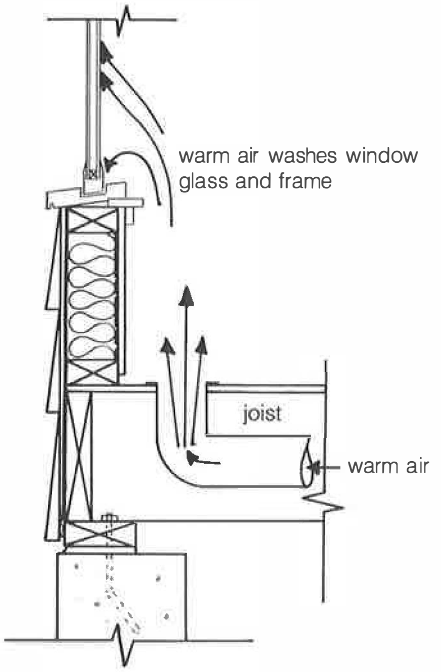

Fig. 35. Circulation of warm air

Solutions

- Explain to home owners how to improve air circulation by opening blinds and curtains or by using air deflectors.
- Use sloped sills for extreme conditions.
- Place the warm air duct close to the window.

Cause

High moisture level within the dwelling.

Solution

- Follow steps to reduce the moisture levels (see Controlling Moisture Sources).

Cause

Rain leakage through window.

- Seal the window frame.
- Use windows that have been tested for resistance to rain penetration.

Problem

Condensation between inner and outer pane.

Cause

Moist air leaking into the air space between glazing lights.

Solutions

- For windows with double sashes, make the prime (inner) sash airtight and vent the storm (outer) sash. The more airtight the inner sash, the less likely that air will leak through the window unit. Also, by venting the outer sash, any air that does leak from the house can escape through to the outside, reducing the amount of condensation. If the outer sash is not vented, any moist air between the glazing will be trapped and condensation will occur.
- Use windows with cavities that are vented and drained (see CMHC Materials Evaluation Reports). Condensation in an insulating glass unit is usually caused by the failure of the seal of the unit. Moisture that enters the cavity gets trapped inside and the unit must be replaced. Windows that are glazed with vented cavities prevent the rain from entering. If water does enter it can escape *(fig. 36)*.

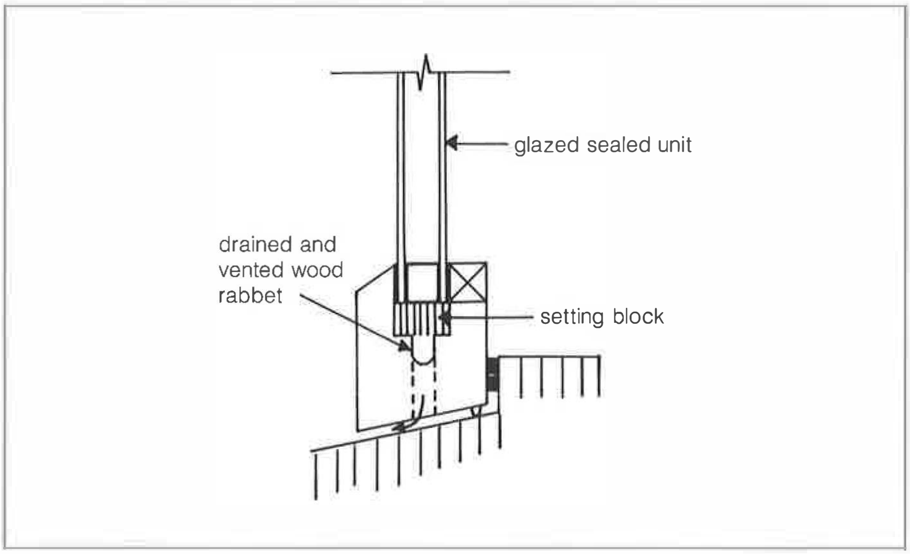

Fig. 36. Lower glazing – sash wood window

Additional Reading

Source	Publication
Canada Mortgage and Housing Corporation 682 Montreal Road Ottawa, Ontario K1A 0P7 (613) 748-2000	*Construction Principles to Inhibit Moisture Accumulation in Walls of New Wood-Frame Housing in Atlantic Canada:* 1985. NHA 5855
National Research Council of Canada Institute for Research Construction Publications Section Ottawa, Ontario K1A 0R6 (613) 993-2463	*The Difference Between a Vapour Barrier and an Air Barrier* 1985. BPN 54 *Humidity, Condensation Ventilation in Houses,* 1984. NRCC 23293. *Moisture Problems in Houses,* 1986. (CBD) 231).
James K. Lischkoff and Joseph Lstiburek Iowa State University Research Foundation	*The Airtight House.*

List of Materials Tested for Air Leakage

Material		Air Leakage Rate @ 75 Pa ($L/s \cdot m^2$)
2 mm	smooth-surface roofing membrane	no measurable leakage
2.7 mm	modified bituminous torch on grade membrane (glass fibre mat) aluminum-foil vapor barrier	no measurable leakage
1.3 mm	modified bituminous self-adhesive membrane	no measurable leakage
2.7 mm	modified bituminous torch on grade membrane (polyester reinforced mat)	no measurable leakage
9.5 mm	plywood sheathing	no measurable leakage
38 mm	extruded polystyrene	no measurable leakage
25.4 mm	foil-back urethane insulation	no measurable leakage
24 mm	phenolic insulation board	no measurable leakage
42 mm	phenolic insulation board	no measurable leakage
12.7 mm	cement board	no measurable leakage
12.7 mm	foil-back gypsum board	no measurable leakage
8 mm	plywood sheathing	0.0067
16 mm	waferboard	0.0069
12.7 mm	gypsum board (MIR)	0.0091
11 mm	waferboard	0.0108
12.7 mm	particle board	0.0155
	reinforced non-perforated polyolefin	0.0195
12.7 mm	gypsum board	0.0196
15.9 mm	particle board	0.0260
3.2 mm	tempered hardboard	0.0274
	expanded polystyrene type 2	0.1187
30 lb	roofing felt	0.1873

Material		Air Leakage Rate @ 75 Pa ($L/s \cdot m^2$)
15 lb	non-perforated asphalt felt	0.2706
15 lb	perforated asphalt felt	0.3962
	Glass fibre rigid insulation board with a spunbonded olefin film on one face	0.4880
11 mm	plain fibre board	0.8223
11 mm	asphalt-impregnated fibre board	0.8285
	spunbonded olefin film	0.9593
	perforated polyethylene #1	4.0320
	perforated polyethylene #2	3.2307
	expanded polystyrene (type 1)	12.2372
	tongue-and-groove planks	19.1165
	fibreglass insulation	36.7327
	vermiculite insulation	70.4926
	cellulose insulation	86.9457