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COLD CLIMATE HOUSING INFORMATION CENTER
UNIVERSITY OF MINNESOTA

Ceiling Airtightness and the Role of Air Barriers and Vapor Retarders

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This publication discusses the importance of vapor retarders and air barriers in controlling vapor diffusion and air leakage in ceilings. As houses are "tightened" to improve thermal efficiency, particular attention must also be given to the quality of indoor air and to increased levels of humidity that often develop. For this reason, a controlled ventilation system is a necessity for today's well-built energy efficient home.

Thermal Envelopes and Moisture Control

Insulated ceilings and walls that enclose heated space make up the *thermal envelope* of a house (see Figure 1). A vapor-retarder and air-barrier system is a necessary part of this thermal envelope. A ceiling air-barrier and vapor-retarder system on the warm side (interior) of the insulation is designed to stop movement of air and water vapor through the ceiling. The principal function of a vapor retarder is to retard or control the passage of moisture as it *diffuses* through the assembly of materials in a ceiling. Air barriers, on the other hand, serve to control air leakage.

Warm humidified air tends to rise in a house, leaking through any unsealed openings in the ceiling, or diffusing through building materials. This results in the following problems:

1. A wasteful, uncontrolled flow of warm air out of the house.
2. A buildup of condensation in the attic or roof structure, resulting in wet insulation and other water damage.
3. The warming of the underside of the roof, which causes snow to melt. The water formed by this process runs down the roof and freezes at the eaves. Ice buildup at the eaves can cause water to collect on the roof and back up under the shingles and through the roof.
4. The development of a low or even negative pressure in the lower portions of the house, which can cause chimneys to draft poorly.
5. The diffusion of water vapor through ordinary ceiling plaster or sheetrock (unless it is painted with a vapor barrier sealer-paint or backed with a vapor-retarding polyethylene film).

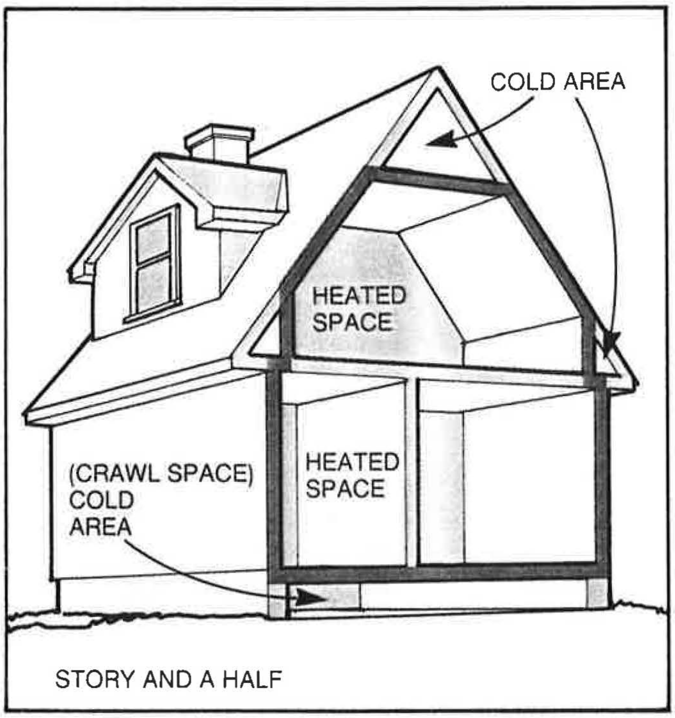
Air barriers are used to address the first four problems while a vapor retarder is normally installed to deal with vapor diffusion.[1]

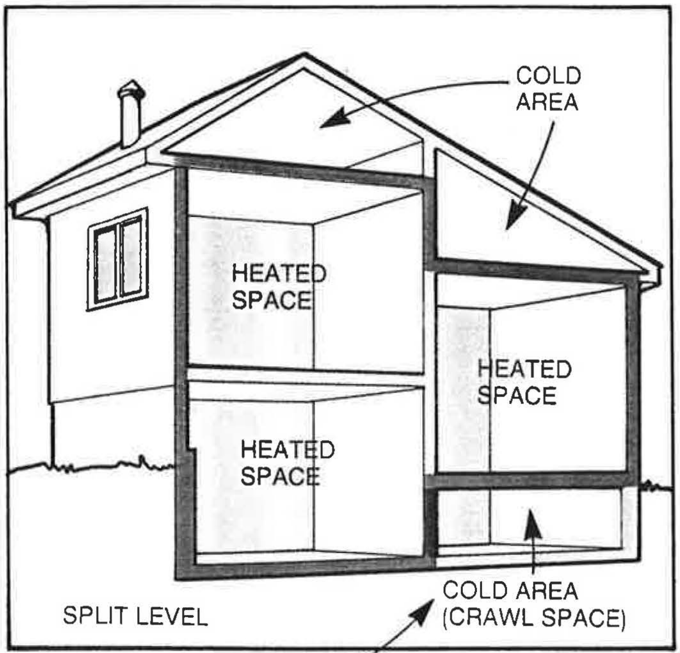
The tendency of warm air to rise and flow through openings in the ceiling is called *the stack effect* because it is similar to the operation of a chimney stack. Figure 2 shows how warm humidified air rises to the uppermost ceiling and flows through openings (called *exfiltration*), while cool outside air infiltrates through various openings or air intakes in the lower part of the house.

The Importance of Fresh Air Intake

Although it is important for the ceiling and upper portions of a house to be airtight, the lower portion of the house (usually the basement) must have one or more intake points for fresh air. The intake points allow fresh air to flow into the house when exhaust fans are turned on to remove odors and excess humidity. Ventilation fans provide airflow as needed when used with a timer, humidity control, or manual switch control. Separate fresh air intakes are also needed for air supply to fuel-burning equipment or atmospheric-type combustion appliances.

The Cold Climate Housing Information Center is a part of the Minnesota Cold Climate Building Research Center, and is administered through the Minnesota Extension Service.





In Minnesota, the crawl space is usually included inside the envelope due to the lack of good floor insulation systems.

As previously mentioned, a house has many openings in the ceiling. These openings, combined with the stack effect, result in an upward flow of air that can cause problems. One effect of the upward airflow is development of a negative pressure zone in the lower portions of the house (see Figure 3). In addition, if the lower levels of the house are leaky, the upward draw at the top causes cold air to infiltrate into the lower level continuously. (Outside air pressure is considered neutral, or zero.) Lower portions of the enclosed space tend to have slightly lower pressure than outdoors, which causes cold drafts to enter. Low or negative interior pressure can interfere with proper venting of furnaces, water heaters, fireplaces, or woodstoves.

A house that is tightly constructed, with a vapor-retarder and air-barrier system in the walls and ceiling, will tend to be free of the problems already discussed. However, other problems may show up if fresh air intakes are not provided. In tight houses, fresh air intakes are needed in areas where fuel-burning appliances are located. Some appliances may allow intakes to be coupled directly to them. In houses equipped with exhaust fans, adequate intake vents are needed to replace air that is exhausted. Ideally, a supply air fan is used to provide the correct quantity of makeup air.

What is a Vapor Retarder?

Materials that resist the passage of water vapor are called *vapor-retarder materials*. Polyethylene film, paint-on vapor-barrier sealers, and aluminum foil are vapor

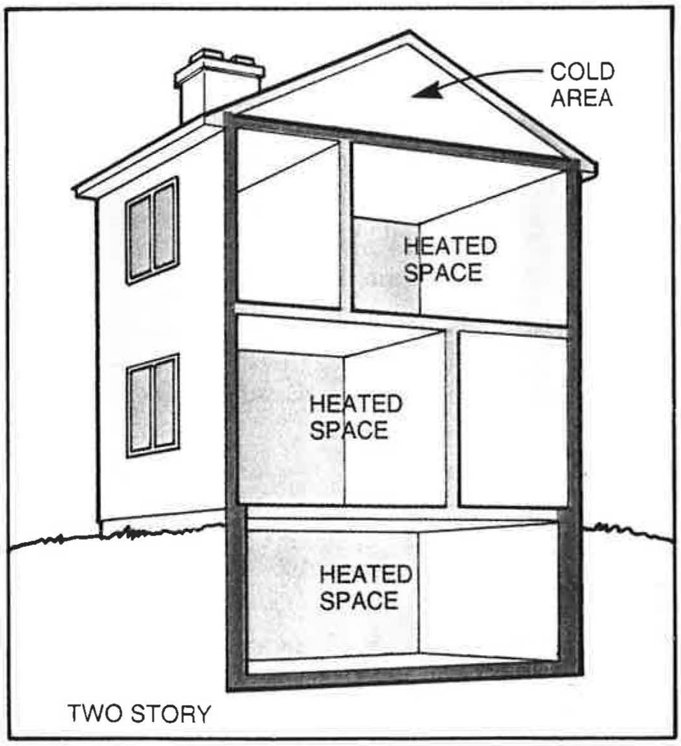


Figure 1 Insulated ceilings and walls that enclose heated space make up the thermal envelope of a house.

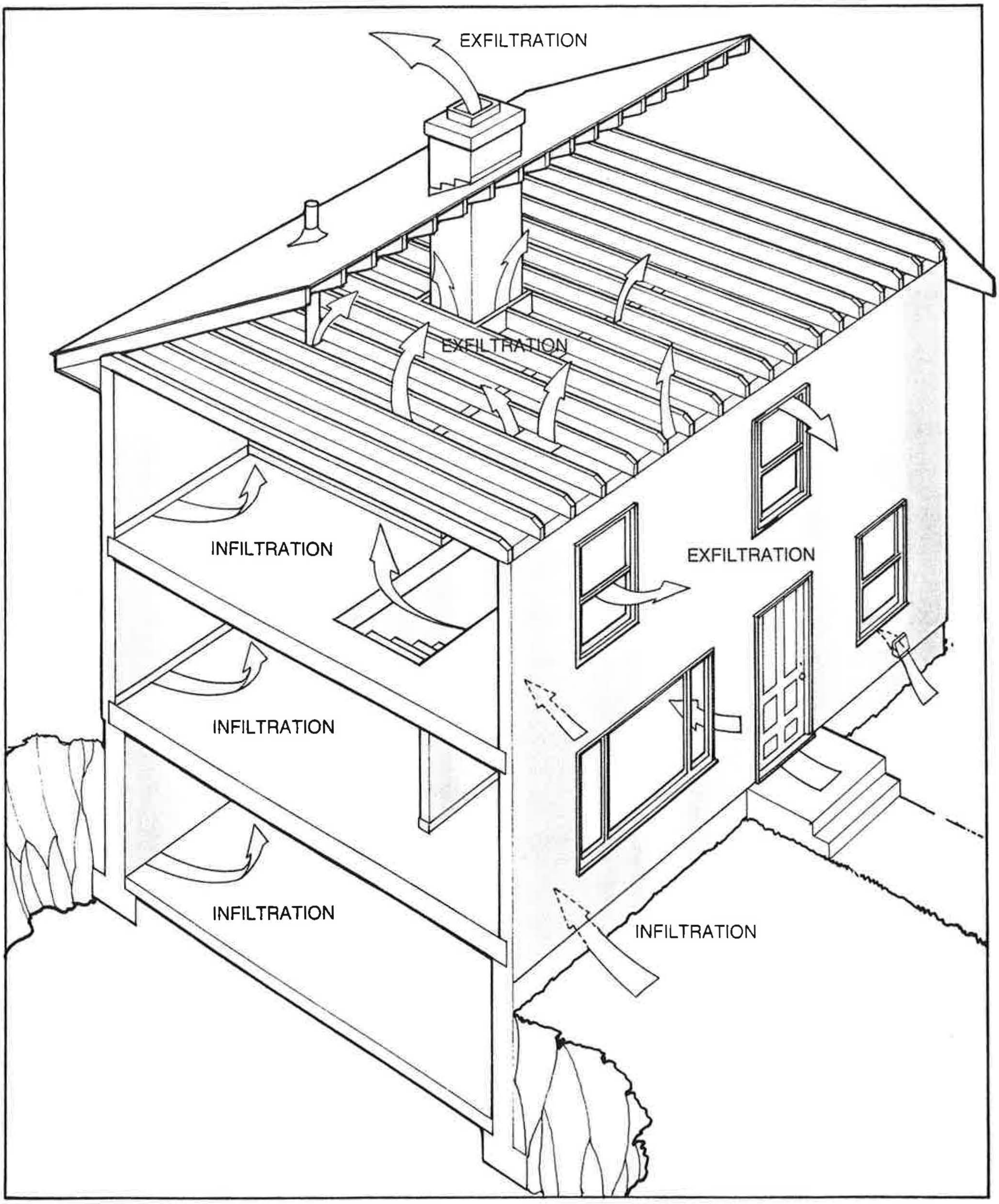


Figure 2 The stack effect in a house causes exfiltration of warm air at upper levels and infiltration of cool air at lower levels.

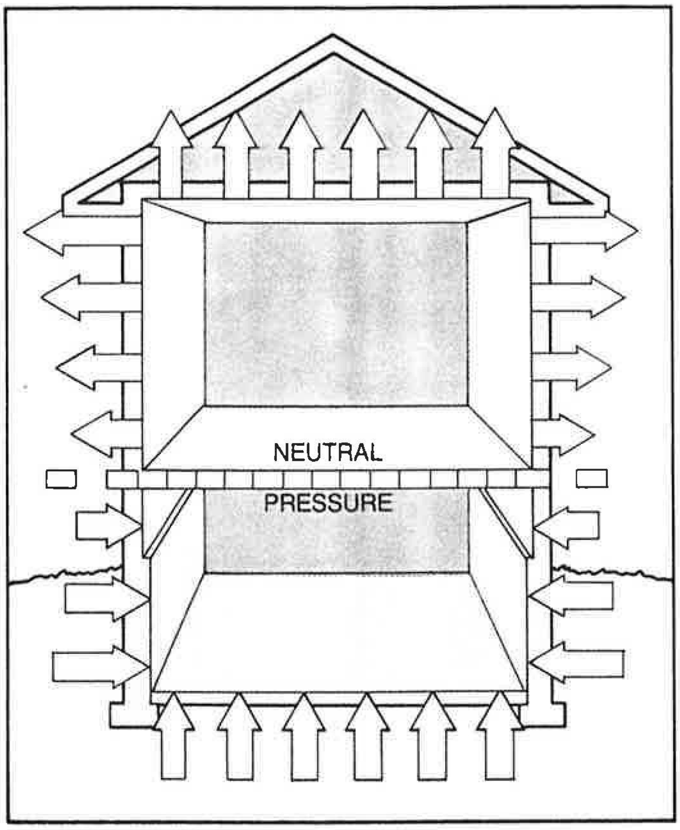


Figure 3 Upward airflow results in a negative pressure zone in lower levels of a house.

retarders. The effectiveness of a vapor-retarder material is measured by its perm (permeance) rating. Low perm means low passage of water vapor. Plastic films, foils, sealers, or paints with a perm rating of less than 1.0 are generally considered adequate as vapor retarders.[2] A combination of materials may be used in the vapor-retarder system. The vapor retarder must be on the ***interior*** (warm side) of the ceiling structure so that it will stay warm enough to prevent condensation from occurring on the retarder itself.[3]

An Air-Barrier System

Vapor retarders are not to be confused with air barriers. A well-constructed vapor-retarder system, using high-quality materials that are uniform in thickness and resistant to degradation in use, *can* serve as an air barrier. However, construction practices currently in use in the United States generally lack the quality control required for vapor retarders to also serve as air barriers.

Why the need for an air-barrier system? Considerably more moisture is lost in a home through convection than through diffusion. Convection losses occur when water vapor escapes the house through open windows, the chimney, cracks, and other air leaks (TenWolde and Suleski 1984). Air-barrier systems are designed to reduce air leaks through the building envelope. They may be inside, outside, or within the envelope. There are several materials that may be used as an air barrier if they meet the following requirements (Lstiburek 1987b):

- ☐ They are continuous.
- ☐ They are sufficiently impermeable to air (0.1 liters of air or less passing through the system per second per square meter at 75 Pascals).
- ☐ They withstand the air pressure loads on them—including the local minimum wind design loads, the influence of mechanical systems, and stack effects.
- ☐ They are stiff enough to maintain pressure equalization behind exterior cladding.
- ☐ They are durable and easy to maintain over the service life of the building.

Although polyethylene film has been promoted as an air barrier (and generally meets the first two requirements of continuity and impermeability), most poly materials used in this country do not meet the last three requirements. Gypsum board,[4] stress-skin panels, and sprayed-in-place foams do meet all five requirements (Lstiburek 1987b).

It is important to note that the installation of an air-barrier system within a house creates a very tight structure. *Consequently, controlled ventilation systems must also be installed in conjunction with air-barrier systems.* Also, buildings are especially leaky at top plates of exterior walls. Therefore, any strategy used to construct an airtight air barrier must not leave the barrier discontinuous in this area.

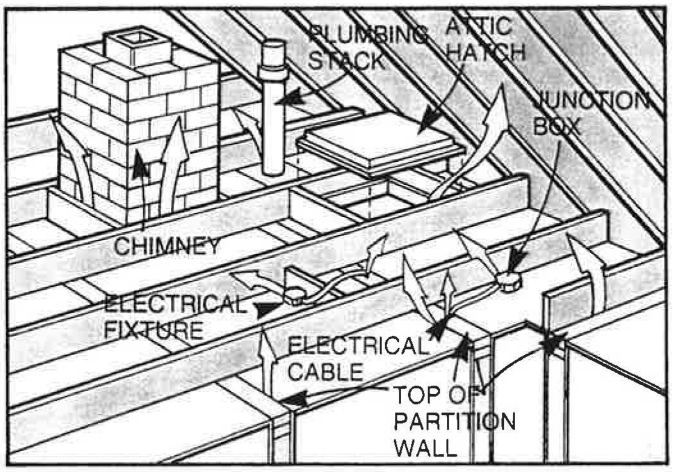


Figure 4 Bypasses (or spots where warm air can leak from the structure) occur along wire and pipe holes, around recessed lights, gaps in partition walls, and spaces around chimneys and attic hatch doors.

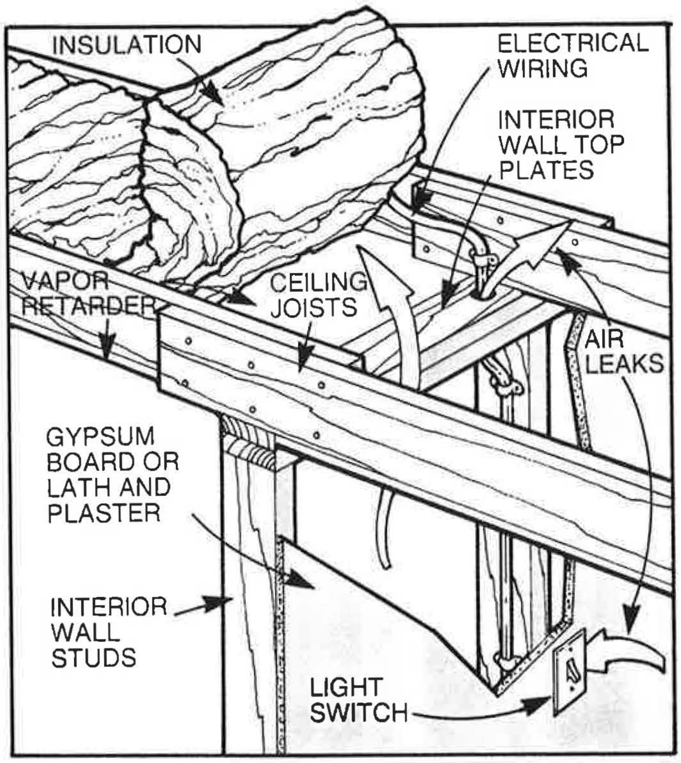


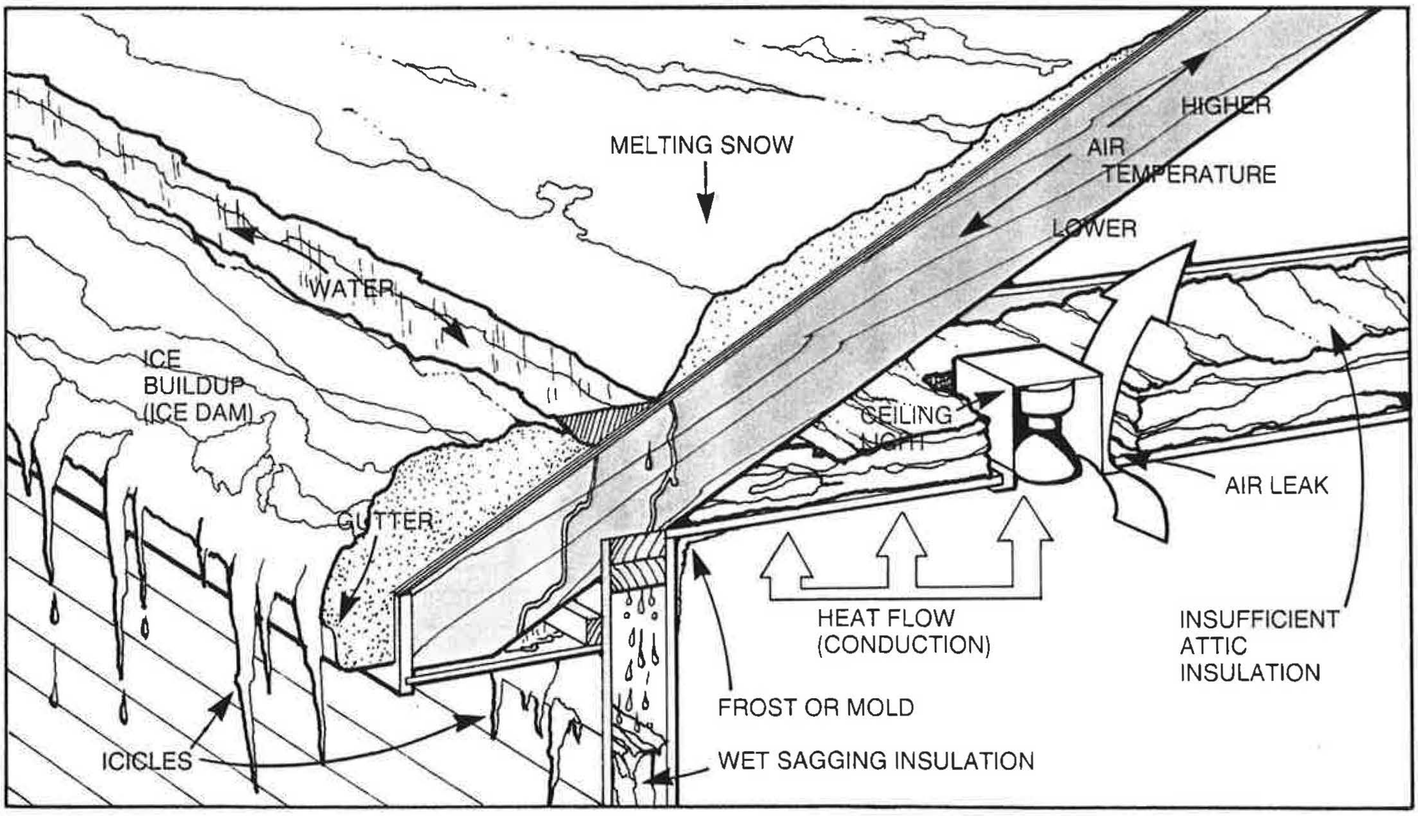
Figure 5 Switch plates and associated wire runs and gaps in partition walls create bypasses that are commonly overlooked.

Bypasses or Hidden Air Leak Passages

Indirect or hidden paths and openings where warm humidified air can leak through the structure are called *bypasses*. Examples of bypasses are wire and pipe holes through the tops of walls, drop ceilings, soffits, recessed lights, gaps in the tops of partition walls, and gaps around chimneys and attic access doors (see Figures 4 and 5). Evidence of bypasses in older houses may include water stains on the attic floor, ceiling joists, or roof boards (from condensation) or dust buildup in the insulation (from house air filtering through). Special inspectors can scan the attic with an infrared viewer to find the location of bypasses (look under "Building Inspection Services" in the Yellow Pages or call your community energy office or county extension office for more information).

Flow of warm air from any bypasses (and other holes) warms the underside of the roof and can melt snow during subfreezing weather. The melted snow runs down the roof shingles and refreezes at the eaves, forming an ice dam (see Figure 6). The ice buildup at the eaves can then cause water to collect on the roof and seep through

Figure 6 Ice dams can form when heated air leaking into an attic warms the underside of the roof deck. Water from melting snow runs to the roof overhang where it refreezes, forming a dam, causing water to back up under shingles and leak through the roof.



the shingles, resulting in a wet roof deck and wet attic insulation, soffits, ceilings and walls, and wall insulation. Repeated episodes can eventually lead to rot in the roof deck or walls.

Creating the Air Barrier and the Vapor Retarder

Air barriers are designed to control air leakage and vapor retarders are designed to control vapor diffusion.

Polyethylene ("poly") film is a commonly used vapor-retarder material that does a good job if it is properly installed. Figures 7 and 8 illustrate methods to install a polyethylene vapor retarder and to seal connections and openings so that the air barrier and vapor retarder become one system.[5] Materials other than polyethylene are also available, including rubber gaskets and drywall with special vapor-seal paint or foil backing. Using the Airtight Drywall Approach, gaskets and sheetrock may be combined to create an effective air-barrier system (see Figure 9).

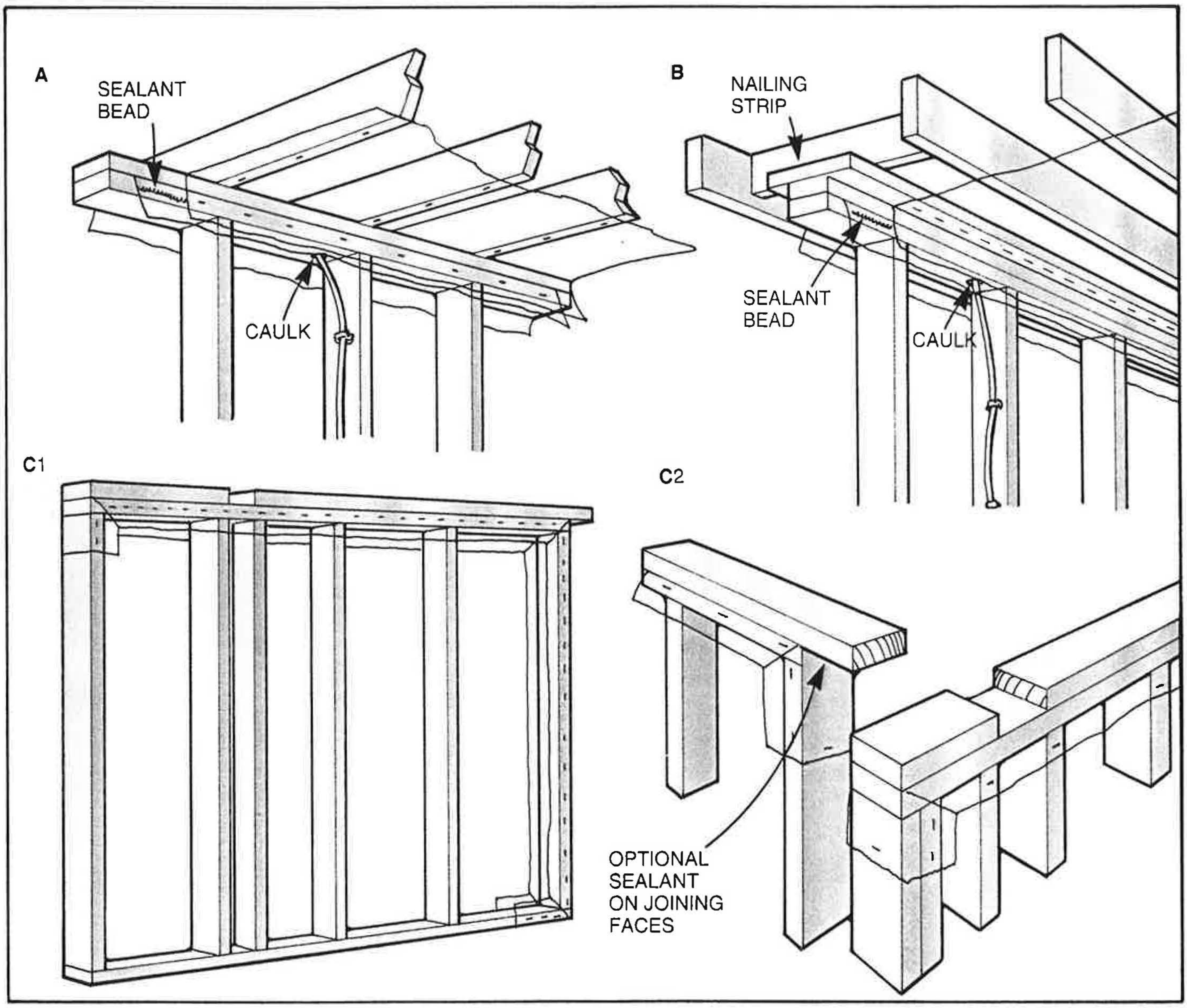


Figure 7 Techniques used to effectively create a combined vapor retarder/air barrier using polyethylene include (A) use of a sealant bead where poly covering, walls, and ceiling join, (B) use of a sealant bead in combination with a ceiling nailing strip, and (C) careful sealing along joints where exterior walls are joined.

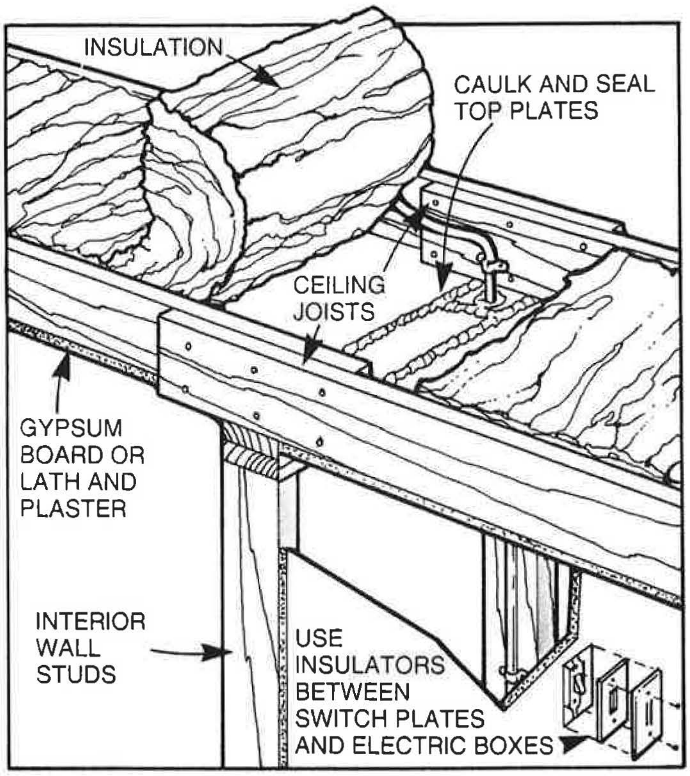
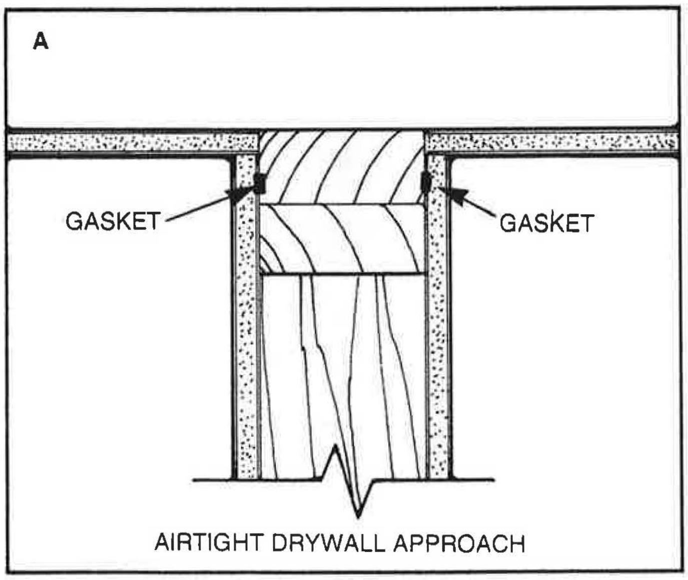


Figure 8 In creating the air-barrier system it is important to seal electrical boxes and insulate switch plates and to caulk and seal top plates of partition walls. For greater detail on techniques used to make an air-barrier system via the Airtight Drywall Approach (ADA), see the Iowa DNR (1987) and Lstiburek (1987a) references.

During construction, ceiling insulation should be installed immediately if the weather is cold. The situation where a poly vapor retarder and sheetrock are installed in cold weather, but installation of ceiling insulation is delayed, can lead to problems. Without insulation, water vapor can condense on the poly vapor barrier and drip on the sheetrock. In existing houses, vapor barrier sealer-paint can be used on the plaster or sheetrock, together with sealing of openings. A paint-on vapor barrier usually requires two coats to achieve full coverage with a perm rating of 1.0 or less.

Proper Attic or Ceiling Insulation

Ceiling insulation must be adequate in all locations to prevent condensation on interior surfaces. High-heel roof trusses are designed to allow sufficient space in the attic to install full-depth ceiling insulation to the edge of the ceiling (see Figure 10). Extra insulation for the ceilings over high-humidity areas (such as bathrooms) may be helpful in maintaining warmer ceiling surfaces and thus preventing condensation on interior surfaces when they are exposed to steamy humid air.



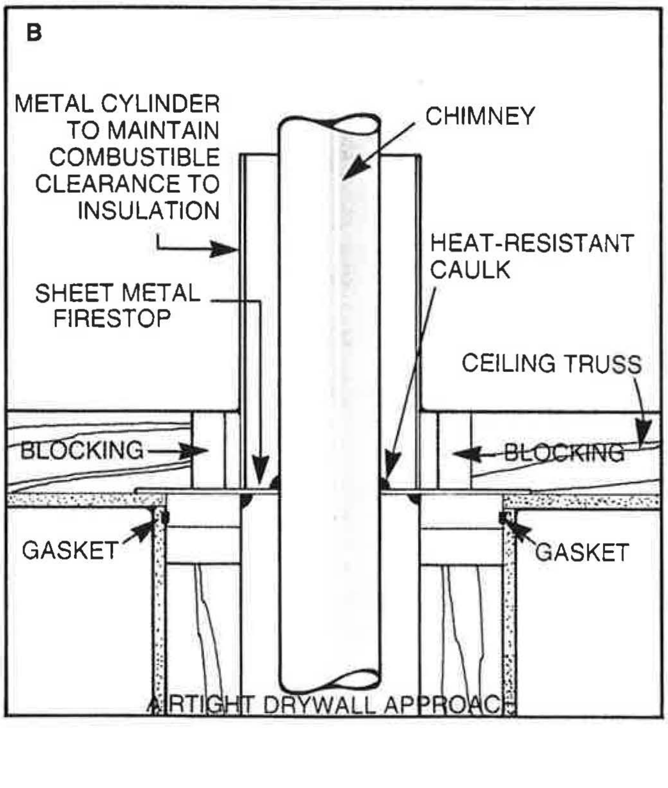


Figure 9 Using the Airtight Drywall Approach, gaskets and sheetrock are combined to form an air barrier for an (A) interior wall/ceiling junction and (B) sealing around a metal chimney .

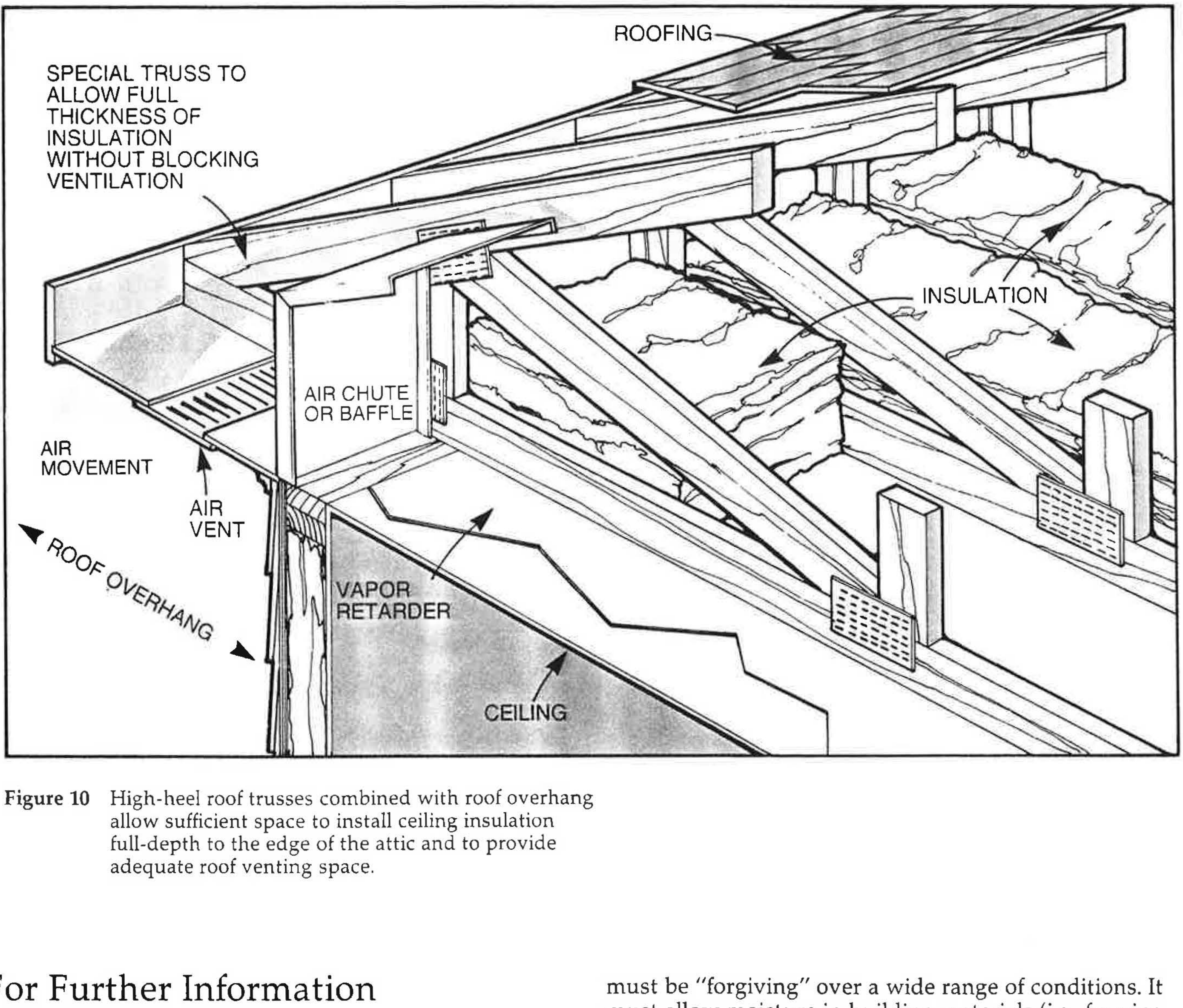


Figure 10 High-heel roof trusses combined with roof overhang allow sufficient space to install ceiling insulation full-depth to the edge of the attic and to provide adequate roof venting space.

For Further Information

For information on the principles of humidity, moisture movement, and condensation, see *Humidity and Condensation Control in Cold Climate Housing* (CD-FO-3567). Your county extension office has a *Home Energy Handbook,* which lists further reading materials.

Summary

Mechanical ventilation systems are needed in airtight houses to reduce humidity levels and the risk of condensation-related damage. *Tightly constructed houses without suitable ventilation systems may also have poor indoor air quality.* Adequate insulation must be installed to keep inside surfaces warm enough to prevent surface condensation (of particular importance in corners and bathrooms). Finally, the building and wall system itself must be "forgiving" over a wide range of conditions. It must allow moisture in building materials (i.e., framing lumber) and concealed condensation to rapidly dry to the outdoors.

Endnotes

1. For a more complete discussion on how air barriers and vapor retarders function, please see *A Systems Approach to Cold Climate Housing,* CD-FO-3566, Minnesota Extension Service, 1988.
2. Proper design of insulated ceilings and walls for cold climates generally requires that the interior side of the thermal envelope have a perm rating of 1.0 or less, and that the exterior side have a perm rating of 5.0 or greater (to allow for removal of any water vapor that may penetrate through the interior-side vapor retarder). If lower perm outside materials are used, the

interior vapor retarder must have a correspondingly lower perm so that the 5:1 ratio (outside perm: inside perm) or more is maintained.

3. An effective method for installing polyethylene film to serve as a vapor retarder and as an air barrier in a ceiling is to stretch the film across the ceiling area and nail 2x2 furring strips to secure the poly film *before* inside walls are erected. With this method, the film can be installed in large continuous sheets across the entire ceiling in one step. Then, interior walls are erected and nailed to the 2x2 furring strips. Where "nailers" of metal supports for ceiling sheetrock must be installed at the top plate of the wall, this should be done prior to erecting the wall, because the poly film will make it difficult to work from above after the wall is erected. With this method, electricians can run wire anywhere across the ceiling on the warm side of the vapor retarder without making holes through the vapor retarder/air barrier. Joints in the poly film should be taped securely on solid backing (a tape such as 3M Y-8086 is recommended). Heavyweight poly film, such as 8 mil Tenoarm, or cross-laminated polyethylene, such as Tu-Tuff, can support the weight of insulation, so ceiling insulation can be installed as soon as the poly film has been secured with the 2x2 strips. With this method, the sidewall wood framing top-to-bottom dimension must be 2 inches greater than standard 8-foot height (to allow adequate height for sidewall sheetrock).
4. Often associated with the Airtight Drywall Approach (ADA). For more information on this system, please refer to the Iowa DNR (1987) and Lstiburek (1987a) references.
5. For further discussion of air-barrier systems, please refer to the Latta (1985) and Peterson and Hendricks (1988) references. Three approaches to building airtight, well-insulated houses with controlled ventilation are detailed in *A Builder's Guide to Iowa's Ideal Homes* (Iowa DNR 1987). These techniques include the Airtight Drywall, the Strapped 2x6, and the Double 2x4 Approaches.

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