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COLD CLIMATE HOUSING INFORMATION CENTER
UNIVERSITY OF MINNESOTA

Exterior Wall 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 walls. 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.

Introduction

In order to provide comfort during winter months, many homeowners maintain high indoor humidity levels—often in the 40-50 percent range. This relatively high level of humidity necessitates special protection of exterior walls from moisture, especially when outdoor temperatures drop below 0°F. Higher humidity means more water vapor in the air (at a given temperature) and higher vapor pressure inside the house. This often results in serious moisture problems in cold weather regions. In order to prevent these problems from developing, walls should be constructed in a manner that will

- ☐ Maintain dry insulation in wall cavities
- ☐ Maintain dry framing and sheathing
- ☐ Prevent interior surface condensation
- ☐ Create a wall that is forgiving over a wide range of conditions (i.e., allow for escape of moisture that may find its way into the wall)
- ☐ Allow ventilation behind siding materials to permit removal of moisture and reduce build-up of heat.
- ☐ Use reasonable construction methods and materials.

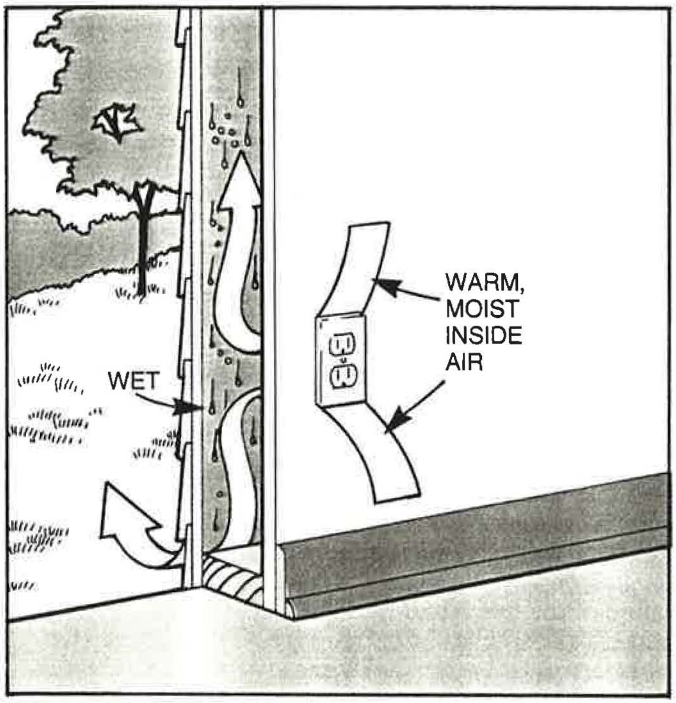

Figure 1 Convection (exfiltration) of moisture-laden air around an electrical outlet can result in condensation within the wall.

Water Vapor Movement Mechanisms

Water vapor in indoor air can penetrate into an exterior wall in two ways, by convection and/or by diffusion. Both ways can cause condensation and wetting inside the wall. Figure 1 illustrates one of these ways.

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1. *Convection* occurs when humidified air moves from the living space through openings in the interior surface of an exterior wall (cracks, chimneys, and air leaks) (see Figure 1). *Convective loops* occur where humidified indoor air enters a wall through an interior-side opening, flows within the wall for some distance, and then comes back into the living space (see Figure 2).
2. *Diffusion* occurs when water vapor pressure pushes water vapor through pores in the vapor retarder or building materials, and moves toward the cold side where vapor pressure is lower (see Figure 3). A vapor retarder with a perm rating of 1.0 or lower is generally adequate to control diffusion. Considerably more moisture is lost in a home through convection than through diffusion, although both water vapor movement mechanisms are present (see Figure 4).

Controlling air leakage is extremely important in neutralizing the effects of excessive indoor humidity in tightly constructed houses. The moisture flow (by convection) through a one cm^2 opening is 100 times greater than the moisture movement (by diffusion) through one cm^2 of sheetrock without a vapor retarder.

Preventing In-Wall Condensation

Insulation must stay dry to provide maximum energy savings and comfort. However, the interior living space of a house is relatively moist, because people prefer some moisture in the air (as noted, usually in the range of 40-50% humidity). In order to keep the insulation dry, some method is needed to hold the moisture (water vapor) in the living space and prevent it from penetrating into the walls. Both vapor transfer mechanisms must be controlled in order to keep the wall dry. *Vapor retarders* installed on the *interior* side of the wall and airtight sealing of the *interior* side using an air-barrier system[1] are needed to keep a wall dry (see Figure 5). Of these two systems, the air barrier is the one that requires the most rigorous attention to quality control and continuity. Controlled ventilation systems, making use of exhaust/supply fans, can remove excess vapor from the interior living space as needed.

Preventing Interior Surface Condensation

Wall areas with missing or thin insulation, with thermal bridging, or constructed so that cold wind can penetrate into the wall may have cold interior surfaces that can cause condensation. Cold wind penetrating into the wall may cause cold spots on the inside that permit condensation to develop. Thermographic scanning has enabled inspectors to "see" cold areas that may need to be reinsulated.

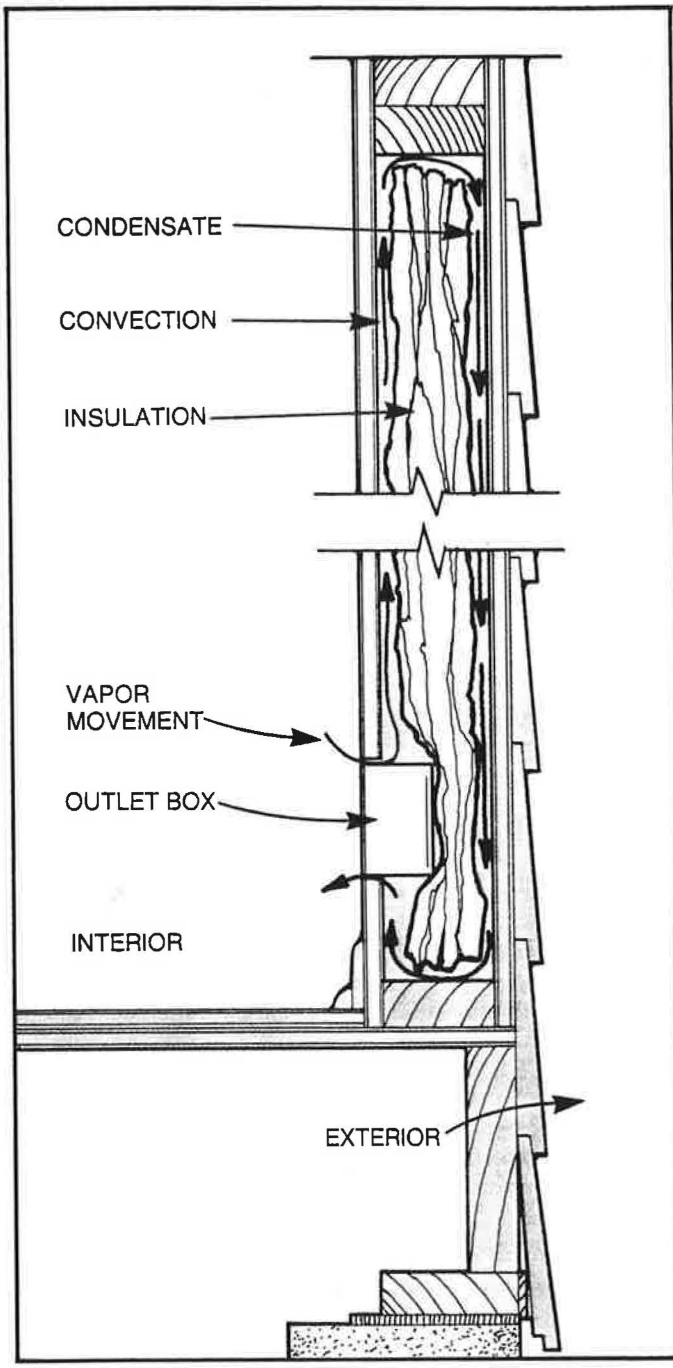

Figure 2 Convective loops and condensation within the wall cavity.

The inside surfaces of exterior corners tend to be prone to condensation for several reasons. For one reason, they have outdoor exposure to the cold on two sides, which draws heat away rapidly. Secondly, framing is concentrated in the exterior corners, which creates thermal bridges. On the inside, warm air does not circulate very well into corners. Any cold interior surface is prone to condensation and the result can be dampness, mold, or peeling of paint. Methods that may be used to eliminate cold interior surfaces include use of thicker wall framing (e.g., 2x6 framing) to improve corner insulation or addition of exterior insulating sheathing to 2x4 walls. Also, an external wind or air barrier is recommended in order to prevent wind-washing in the corners (see Figure 7). In existing houses, insulating sheathing can be added to the exterior if it is being resided, or on the inside of the wall if the interior is being remodeled.

Reducing Exterior Siding Problems

Figure 6 shows blistering and peeling of paint on exterior siding resulting from the lack of an adequate interior-side vapor retarder and/or a suitable air barrier. The paint problems can be reduced by installing a full coverage, interior-side vapor retarder (see Figure 7) or by painting interior surfaces with vapor-resistant interior paint and sealing interior-side cracks and holes. Providing a ventilation space behind the siding through the use of nailing strips over sheathing will also help reduce problems. Moisture soaked up between the laps of the siding by capillary action must have the potential to dry out when siding is installed over low permeability sheathing. Therefore, the venting space created by nailing strips is especially important.

Generic Wall Design for Cold Climates[2]

Figure 8 shows a recommended design for a wood-framed wall supported by a concrete block foundation. A permanent wood foundation (PWF) is also a viable option. The details of the wall-to-floor and platform-to-foundation connections are important.

A full coverage, interior-side vapor-retarder and air-barrier system (including sealing of interior-side openings) is necessary to prevent the penetration of water vapor into insulated walls (and ceilings). A vapor retarder can be made using polyethylene film, aluminum foil, special paint or sealer, or other vapor-resistant material. It must be installed on the *interior* (heated) side of insulated walls (and ceilings), or close enough to the interior so that condensation will not occur on the retarder itself.[3]

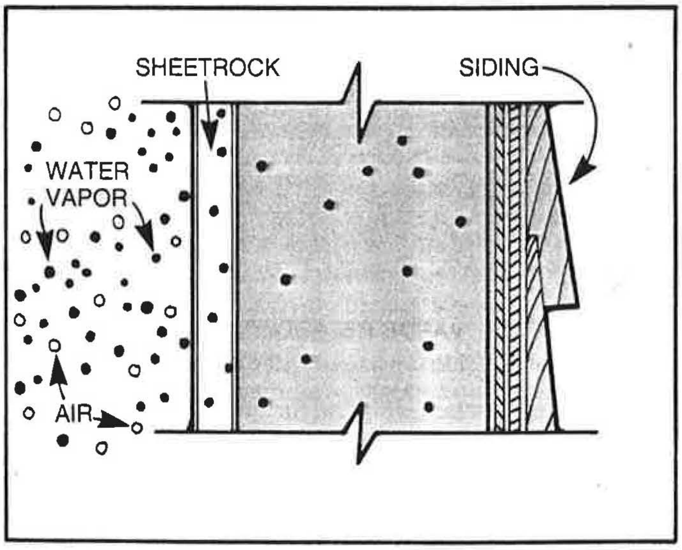

Figure 3 Diffusion through material.

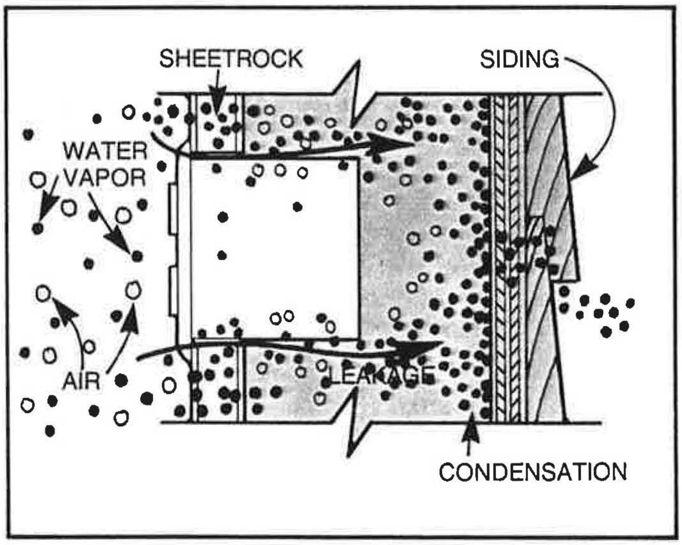

Figure 4 Combination water vapor movement via convection and diffusion, which leads to condensation within wall or behind siding.

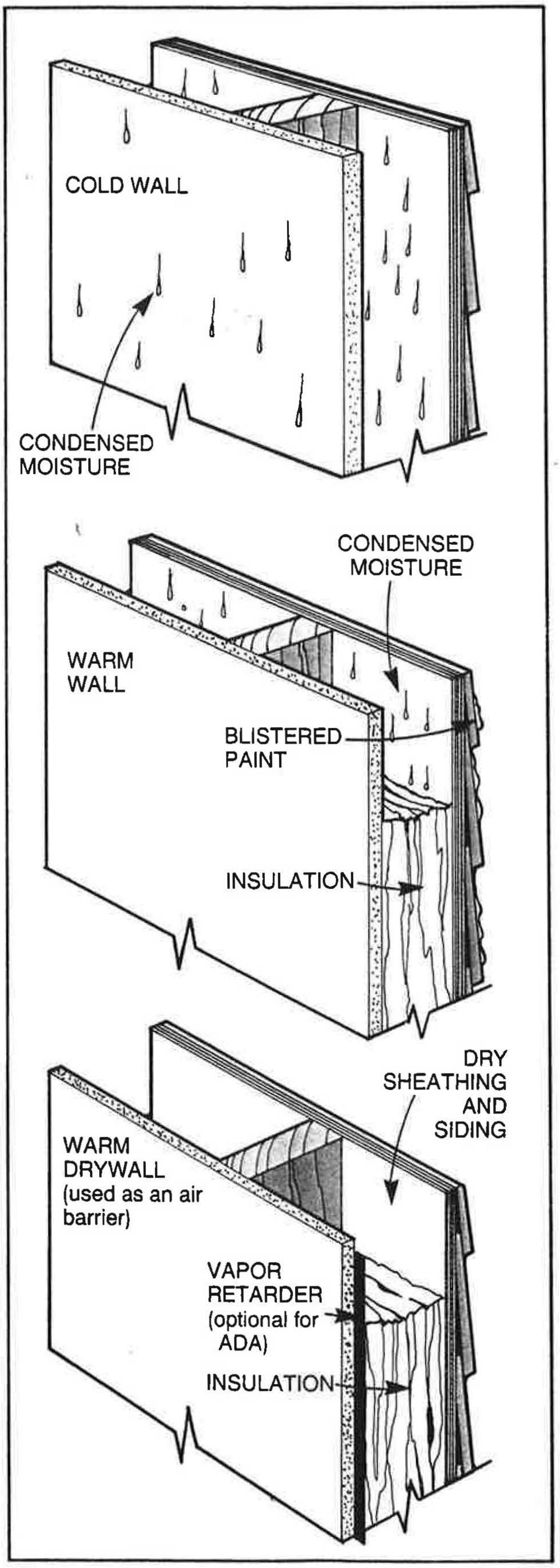

Figure 5 A wall constructed without adequate insulation, a vapor retarder, and an air barrier is prone to moisture damage.

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INSULATION WITHOUT VAPOR RETARDER OR AIR BARRIER

FULL INSULATION, VAPOR RETARDER, AND AIR BARRIER

The drywall is installed using the Airtight Drywall Approach (ADA) and serves as an air-barrier system. For more information on the ADA system, see the Iowa DNR (1987) and Lstiburek (1987a) references.

In comparison to the vapor retarder, the air barrier requires that more rigorous attention be paid to quality control and continuity. Holes and gaps in the air-barrier system must be sealed because water vapor has a tendency to find openings and leak out. As noted previously, air leakage is the major mechanism of moisture movement through wall components. Special tape, rubber gaskets, and high-quality sealants for vapor-retarder and air-barrier systems are now available at reasonable cost. *Note: Tightly constructed houses will likely require a controlled ventilation system.*

The quality of a vapor retarder is measured by its "perm" rating. Low perm indicates a low rate of diffusion of water vapor through a material. Materials with 1.0 or lower perm rating are generally considered adequate vapor retarders, provided that (1) they are properly installed on the interior side (and holes are sealed) and (2) the outside of the wall has a perm rating of 5.0 or higher (in order to allow outward movement of any moisture that may reach the wall cavity).

A "strapped" wall construction[4] technique is designed to allow installation of wiring and piping without penetration of the vapor retarder. In this case, a space is made by nailing 2x2 wood strips across the wall studs on the interior side of the retarder (see Figure 8); a polyethylene film retarder would most commonly be used here. The space created by the 2x2 strips allows wiring, electrical boxes, small pipes, etc. to be run on the interior side of the vapor retarder without penetrating through it. In the "strapped" wall technique, the poly also serves as an air barrier. This system protects the vapor retarder (and air barrier if the vapor retarder and air barrier functions are combined) from accidental damage during occupancy of the house. The major portion of the insulation is on the exterior side of the barrier, in the stud wall frame. Sheetrock is fastened to the inside of the 2x2 wood strips to form the interior wall surface. *Runs of large pipe (over 1 inch) or duct in exterior walls are not recommended—interior walls or interior chases should be used for these runs.*

Other methods are available to avoid penetration of the vapor retarder by electrical wiring, such as installing electrical outlets in floors, or using baseboard moulding wire runs and outlets. If wiring is run through the vapor retarder or air barrier, care must be used to seal all penetrations.

A construction method that makes use of sheetrock or drywall in creation of an air-barrier system is known as the Airtight Drywall Approach (ADA).[5] This system has advantages over polyethylene retarder/barrier systems. Drywall is rigid and not as subject to damage as a polyethylene film. It is also not as difficult to maintain. When ADA is used, openings in the drywall (or sheetrock) must be avoided or repaired and a special paint or sealer used to create a vapor retarder. The air barrier, in contrast, consists of a drywall (gypsum board) and gasket system that is designed to create an airtight envelope.

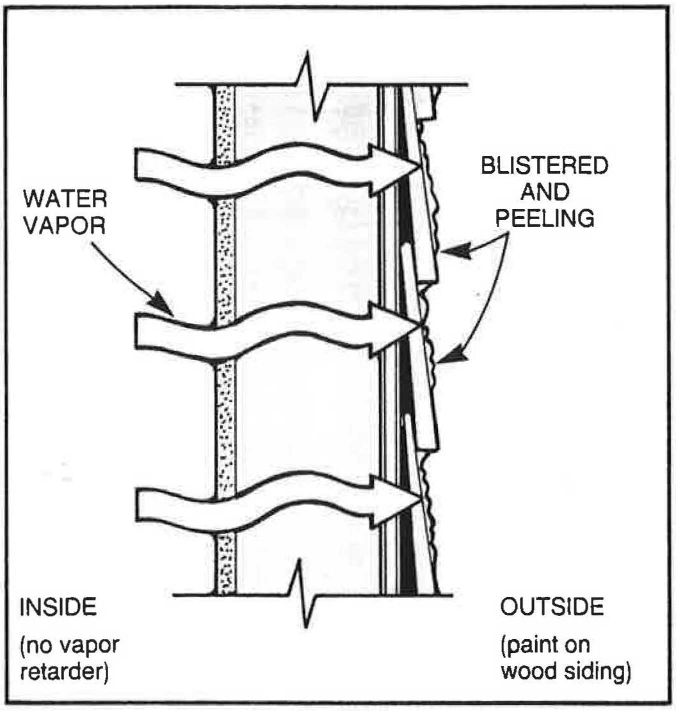

Figure 6 Exterior paint damage in a wall without a vapor retarder.

One Method for Retarding Air and Vapor Movement at the Rim Joist

When insulating and creating a vapor-retarder and air-barrier system, it is important to give attention to the rim joist area. In Figure 7, one method for properly constructing the rim joist area is shown. Permanent wood foundation (PWF), treated CDX plywood (exterior grade), is rip-cut and installed as a "rim joist" that also serves as a combination vapor retarder and air barrier. As shown in Figure 7, the plywood covers the ends of the floor joists, and the sill plate and gaskets at the top and bottom provide an airtight rim joist area. EPDM rubber or closed-cell polyethylene are common gasket materials. Two inches of insulating sheathing on the outside of the plywood provides adequate insulation if installed with continuous coverage as shown in Figure 7. Where floor joists run parallel to the exterior wall, a load-bearing joist must be installed to support the wall (in addition to the CDX-PWF plywood exterior).

Wind Barrier

An airtight wind barrier is needed on the exterior to keep cold wind and wind-driven rain from entering the wall cavities. Openings, penetrations, and joint connections in the wind barrier must be sealed. A wind barrier must be relatively permeable to water vapor, to

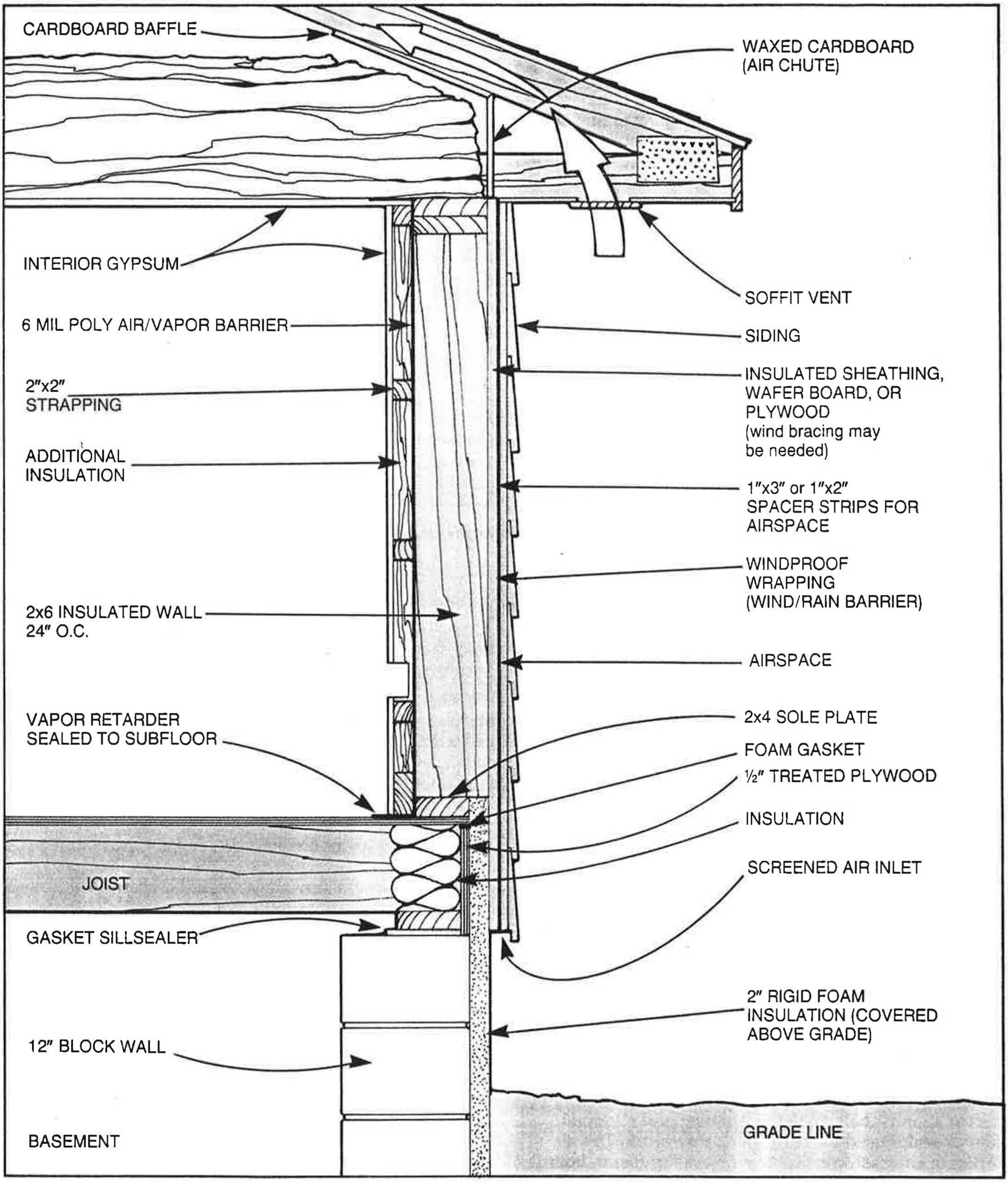

Figure 7 Generic wall design for cold climates using the Strapped 2x6 Approach (new construction).

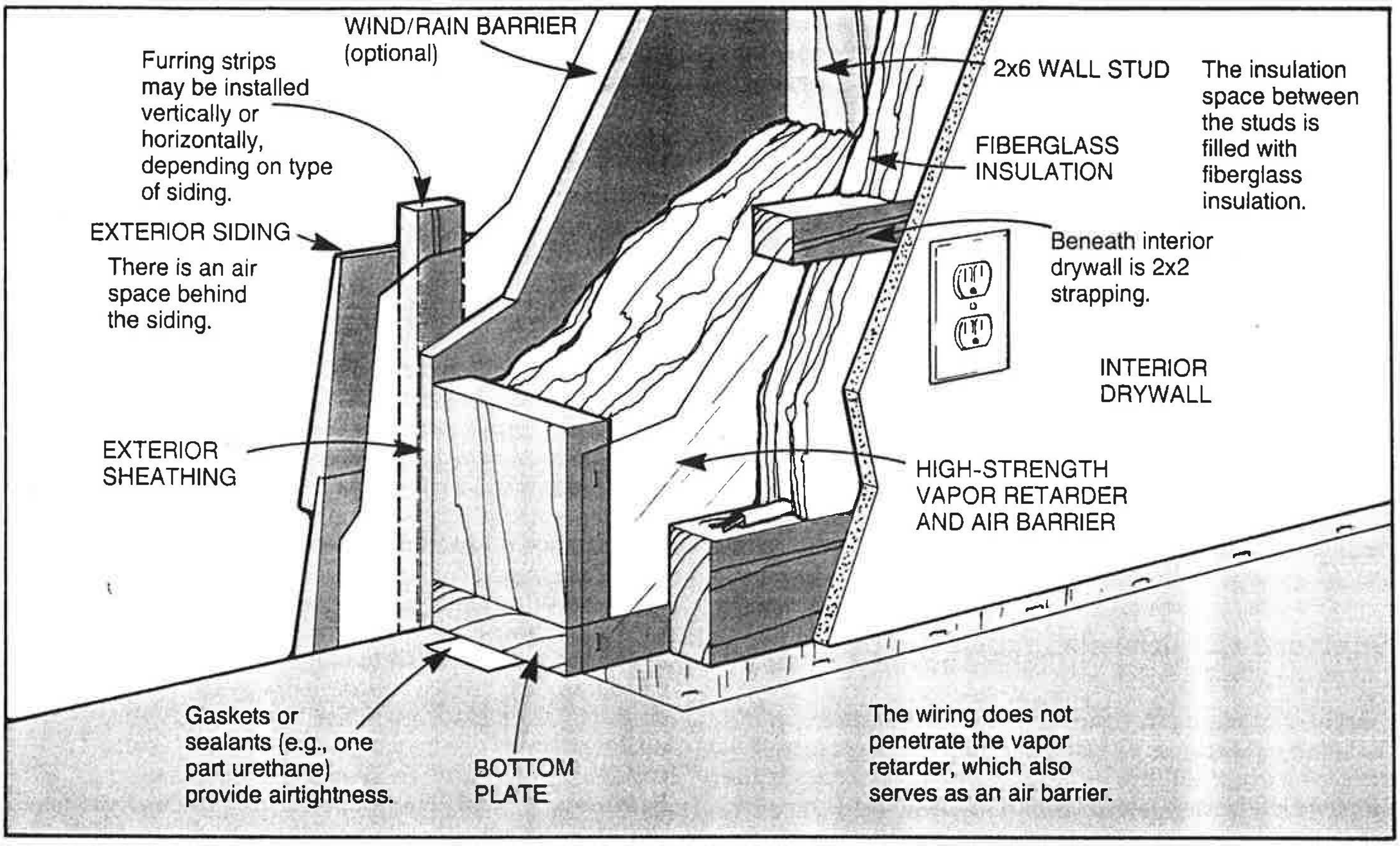

Figure 8 Cutaway of wall design for cold climates (new construction) using the Strapped 2x6 Approach. For additional details, see the Iowa DNR (1987) reference.

allow moisture to exit if there is moisture in new framing lumber or rain-wetted construction materials. Special wind barrier materials have been developed to block wind but allow water vapor to pass through (water molecules are smaller than air molecules). This is similar in principle to Goretex® sportswear which provides wind protection along with water vapor passage.

Wind barrier materials are available on rolls up to 9 feet wide. The material must be tear-resistant to withstand rough handling during installation and resist wind pressure once installed. Newly developed tapes, such as 3M brand Y-8086, are available that adhere to Tyvek® and similar olefin materials (as well as polyethylene) to seal joints and penetrations.

Although it is true that a material for exterior use that combines windproofing with a high-perm vapor rating is an important new development in cold climate building, used alone it does not offer a solution for wall moisture problems. A carefully installed interior-side vapor retarder and air barrier (with all openings sealed) is essential in cold climates, regardless of the exterior materials used.

Better Insulated Bathrooms to Prevent Condensation

Since bathrooms usually have the highest humidity of all the rooms in the house, special control of moisture condensation may be needed if a bathroom has an exterior wall. It is particularly important to have well-insulated walls, windows, and ceilings in bathrooms to keep interior surface temperatures as warm as possible to control surface condensation. In new houses, extra insulation can be easily installed in exterior bathroom walls by means of extra-deep furred-in stud framing, provided that the design provides adequate space in tub enclosure areas. In addition to carefully installed insulation, vapor retarders are needed in bathrooms to prevent potential condensation in walls or ceiling insulation. Windows in bathrooms should have an R value of 3.0 or greater. If these measures are employed, enhanced long-term performance of the dwelling, as well as greater bathroom warmth and comfort, is likely. *Mechanical ventilation fan systems are especially recommended for bathroom and kitchen areas where moisture generation and accumulation are likely.*

Interior surfaces of all walls and ceilings in bathrooms are exposed to frequent steam and spray from showering. Materials used in bathrooms should be moisture-proof or moisture-resistant. Shower areas in particular must be built of materials which do not deteriorate in the presence of high moisture.

Avoid Moisture Overloading

To avoid dampness or leakage in basement walls (which tends to overload a house with moisture) the foundation backfill area must have proper groundwater control. Both permanent wood foundations (PWF) and concrete foundations need a drainage material, such as crushed rock, coarse sand, pea gravel, or man-made drainage materials, to relieve groundwater pressure and carry groundwater to a suitable drain system. Slope of the ground surface away from the house is also important to provide for removal of surface water.

Structural Condensation Problems from Uncontrolled Moisture

If the vapor-retarder and air-barrier systems are not installed properly or if indoor humidity is frequently excessive, the resulting repeated condensation can lead to substantial damage, as well as loss of insulating performance. Severe condensation-related damages recently discovered in a large group of houses in Minnesota, Michigan, and Wisconsin[6] have reemphasized the need to build walls properly. These tightly constructed 1970s houses were found to have a poorly designed vapor-retarder system and an insufficient mechanical ventilation system to cope with moisture generation within the house. To make matters worse, the walls had a low-perm, asphalt-impregnated building paper installed over low-perm plywood on the cold side (exterior side)! Severe wood rot occurred in the exterior plywood and wood framing on some of the houses.

Many homeowners are suffering recurring property losses and high energy bills because of improperly built walls. Wetness in wall insulation reduces a wall's insulating value and results in high heating bills. Mold or wood rot may also develop within the wall as a result of dampness caused by condensation. In addition, interior surface condensation and mold may result because a wet wall loses its insulating value.

Summary

Exterior walls are a major part of the thermal envelope of a house. Carefully installed insulation, an inside vapor retarder, an air-barrier system, an exterior wind barrier, and vented siding are recommended to provide comfort, energy efficiency, and low maintenance. Control of condensation is essential for energy efficiency (dry insulation) and low cost maintenance (reducing water damage). Thermographic techniques are becoming widely available to "see" deficient areas of insulation. Homebuyers may use these techniques to inspect a house before buying. Whole-house airtightness testing, combined with thermographic inspection, can often help locate openings in the interior side.

Specifically, a full-coverage, interior-side air barrier is needed in a cold climate (such as in Minnesota) to prevent exfiltration of humidified air, which tends to occur if there are openings in the interior side. Such openings include unsealed electrical outlet boxes, or other unsealed penetrations (such as those associated with wires, pipes, ducts, or structural members). Exfiltration of moist air will tend to result in condensation within the wall in winter months. A vapor retarder is needed in a cold climate to minimize diffusion of interior water vapor through the interior side, which might condense upon reaching the cold exterior side.

In addition, 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 (particularly important 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. 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. For more information on how vapor retarders differ from air barriers, see *A Systems Approach to Cold Climate Housing*, CD-FO-3566, Minnesota Extension Service, 1988.
2. 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. For more information on the Airtight Drywall Approach (ADA) see the Iowa DNR (1987) and Lstiburek (1987a) references.

3. If a vapor retarder is located within a wall, as is sometimes the case in special designs, there must always be two-thirds of the total insulating value outside the vapor retarder to keep the retarder warm enough to prevent condensation from occurring on the retarder itself.
4. For more information on strapped wall construction, see the Iowa DNR (1987) reference.
5. For more information on ADA construction, see the Lstiburek (1987a) reference.
6. See the Angell (1988) reference.

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