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"The physician can bury his mistakes, but the architect can only advise his client to plant vines—so they should go as far as possible from home to build their first buildings."

Frank Lloyd Wright
New York Times, October 4, 1953

Introduction

Damaging moisture originates not only from outside a home; it is created inside the home as well. Moisture is produced by smoking; breathing; burning candles; washing and drying clothes; and using fireplaces, gas stoves, furnaces, humidifiers, and air conditioning. Leaks from plumbing, unvented bathrooms, dishwashers, sinks, toilets, and garbage disposal units also create moisture problems because they are not always found before water damage or mold growth occurs. Figure 7.1 provides an overview of the sources of moisture and types of air pollutants that can enter a home.

Solving moisture problems is often expensive and time-consuming. The first step is to do a moisture inventory to eliminate problems in their order of severity. Problems that are easiest and least expensive to resolve should be addressed first. For example, many basement leaks have been eliminated by making sure sump pumps and downspouts drain away from the house. On the other hand, moisture seeping though basement or foundation walls often is very expensive to repair. Eliminating such moisture is seldom as simple as coating the interior wall, but often requires expert consultation and excavating around the perimeter of the house to install or clean clogged footing drains. Sealing the outside of the basement walls and coating the exterior foundation wall with tar or other waterproofing compounds are often the only solutions to eliminate moisture.

Moisture condensation occurs in both winter and summer. The following factors increase the probability of condensation:

- Homes that are ineffectively insulated and are not sealed against air infiltration in cold climates can result in major moisture problems.

- Cool interior surfaces such as pipes, windows, tile floors, and metal appliances; air conditioner coils with poor outside drainage; masonry or concrete surfaces; toilet tanks; and, in the winter, outside walls and ceilings can result in moisture buildup from condensation. If the temperature of an interior surface is low enough to reach the dew point, moisture in the air will condense on it and enhance the growth of mold.

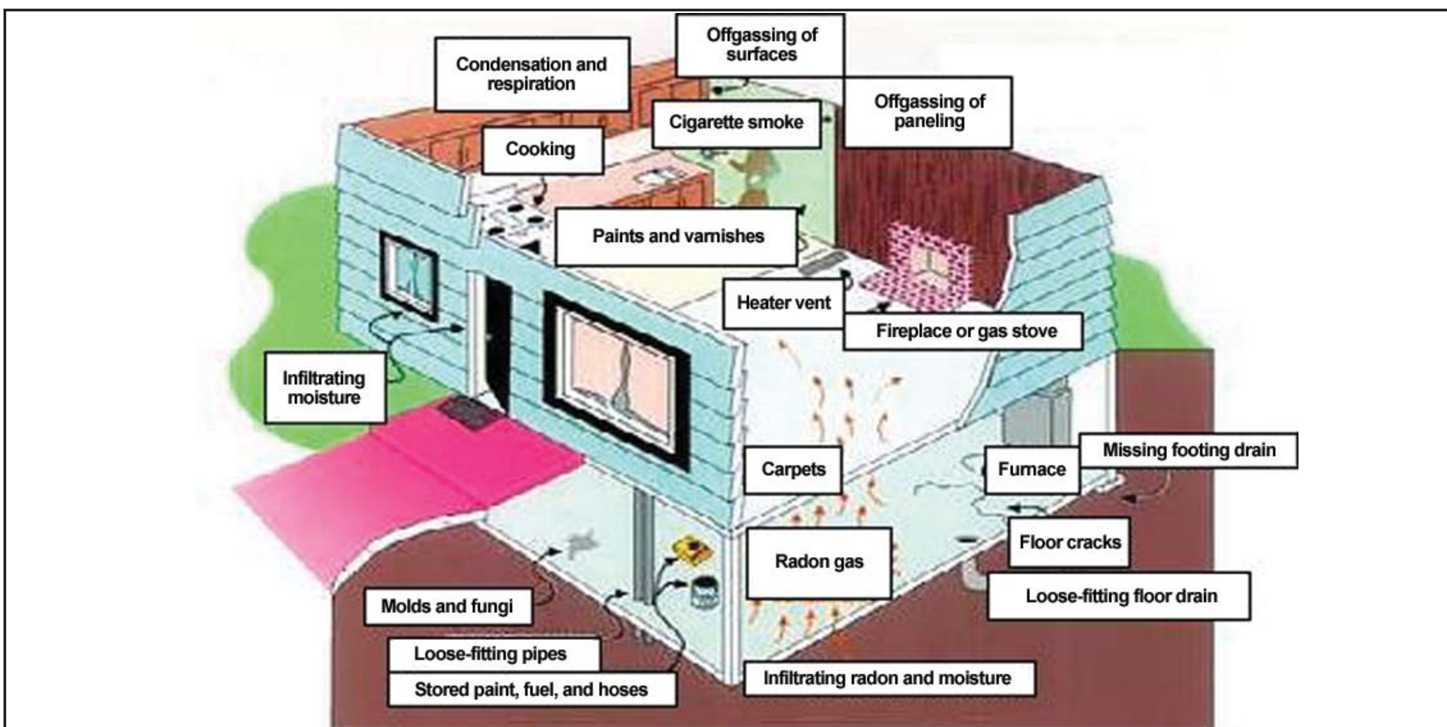

Figure 7.1. Sources of Moisture and Air Pollutants [1]

- Dehumidifiers used in regions where outside humidity levels are normally 80% or higher have a moisture-collecting tank that should be cleaned and disinfected regularly to prevent the growth of mold and bacteria. It is best if dehumidifiers have a drain line continuously discharging directly to the outside or into a properly plumbed trap. This is also true in climates where air conditioning units are used on a full-time or seasonal basis. Their cooling pans provide an excellent environment for the growth of allergenic or pathogenic organisms.

- Moisture removed from clothing by clothes driers ends up in the dryer vent if it is clogged by lint or improperly configured. Moisture buildup in this vent can result in mold growth and, if leakage occurs, damage to the structure of the home. The vent over the cooking area of the kitchen also should be checked routinely for moisture or grease buildup.

Roof

The control of moisture in a home is of paramount importance. It is no surprise that moisture control begins with the design and integrity of the roof. Many types of surfacing materials are used for roofs-stone, composition asphalt, plastic, or metal, for example. Some have relatively short lives and some, such as slate and tile, have extraordinarily long lives. As in nearly all construction materials, tradeoffs must be made in terms of cost, thermal efficiency, and longevity. However, all roofs have two things in common: the need to shed moisture and protect the interior from the environment.

When evaluating the roof of a home, the first thing to observe is the roofline against the sky to see if the roof's ridge board is straight and level. If the roofline is not straight, it could mean that serious deterioration has taken place in the structure of the home as a result of improper construction, weight buildup, a deteriorated or broken ridge beam, or rotting rafters. Whatever the cause, the focus of an inspection must be to locate the extent of the damage.

The next area to inspect is around the flashing on the roof. Flashing is used around any structure that penetrates the surface of a roof or where the roofline takes another direction. These areas include chimneys, gas vents, attic vents, dormers, and raised and lowered roof surfaces. One of the best ways to locate a leak around flashing is to go into the attic and look carefully. Leaks often are discovered when it rains; but if it is not raining, the underside of the roof can be examined with the attic lights off for pinpoints of daylight.

Roofing material should lay relatively flat and should not wave or ripple. The roof should be checked for missing or damaged shingles, areas where flashing should be installed, elevation changes in roof surfaces, and evidence of decomposing or displaced surfaces around the edge of the roof [1–3].

Roof Inspection

1) Is the roofline of the house straight?
2) Are there ripples or waves in the roof?
3) What is the condition of the gutters and downspouts?
4) What is the condition of the boards the gutters are attached to?
5) Does the flashing appear to be separated or damaged?
6) Is there any apparent damage in the attic or can sunlight be seen through the roof?
7) Is there mold or discoloration on the rafters or roof sheathing?
8) Is there evidence of corrosion between the gutter and downspouts and any metal roofing or aluminum siding?
9) Do the downspouts route the water away from the base or foundation of the home?
10) Are the gutters covered or free of leaves? Are they sagging or separating from the fascia?
11) Does the gutter provide a mosquito-breeding area by holding water?

Figure 7.2. Blown Attic Insultation

Figure 7.3. Depth of Attic Insulation

Insulation

A house must be able to breathe; therefore, air must not be trapped inside, but must be allowed to exit the home with its moisture. Moisture buildup in the home will lead to both mold and bacteria growth. Figure 7.2 demonstrates insulation blown into an attic, to a depth of approximately 12 inches (Figure 7.3). Figure 7.4 shows the area extending from a house under the roof, known as the soffit. The soffit is perforated so that air can flow into the attic and up through the ridge vents to ventilate the attic.

If insulation is too thick or installed improperly, it restricts proper air turnover in the attic and moisture or extreme temperatures could result in mold or bacteria growth, as well as delamination of the plywood and particleboards and premature aging of the roof's subsurface and shingles.

Care also must be taken in cold climates to ensure that the insulation has a vapor barrier and that it is installed face down. When insulation is placed in the walls of a home, a thin plastic vapor barrier should be placed over the insulation facing the inside of the home. The purpose of this vapor barrier is to keep moisture produced inside the house from compromising the insulation. If the barrier is not installed, warm, moist air will move through the drywall and into the insulated wall cavity. When the air cools, moisture will condense on the fibers of the insulation making it wet; and, if it is cellulose insulation, it will absorb and hold the moisture. Wetness reduces the effectiveness of the insulation and provides a favorable environment for the growth of bacteria and mold [4,5].

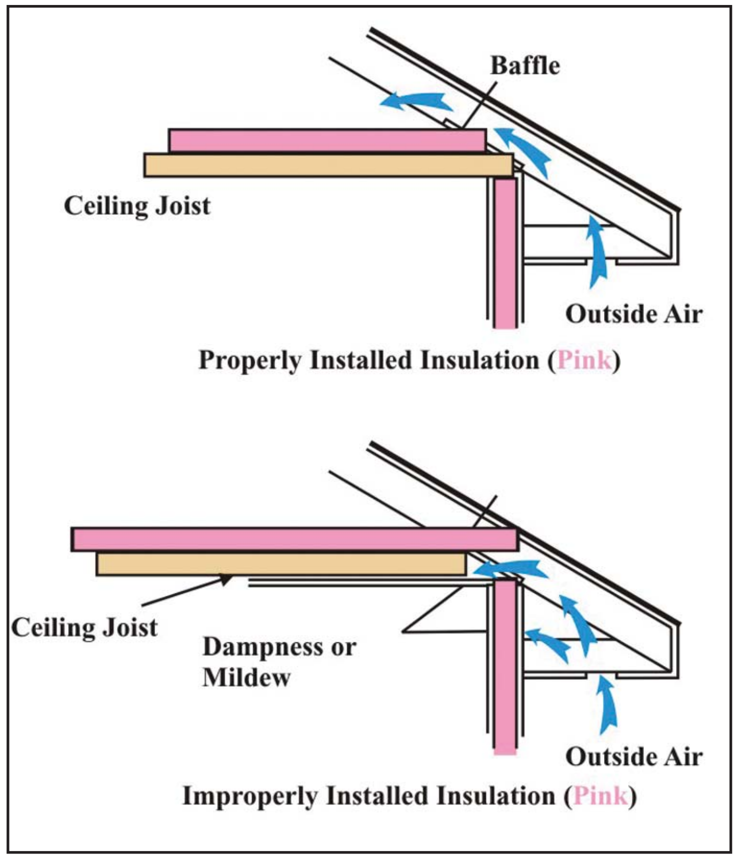

Figure 7.4. Blown Attic Insultation

Siding

Good siding should be attractive, durable, insect- and vermin-resistant, waterproof, and capable of holding a weather-resistant coating. Fire-resistant siding and roofing are important in many areas where wildfires are common and are required by many local building codes.

All exterior surfaces will eventually deteriorate, regardless of manufacturer warranties or claims. Leaks in the home from the outside occur in many predictable locations. The exterior siding or brick should be checked for cracks or gaps in protective surfaces. Where plumbing, air vents, electrical outlets, or communication lines extend through an exterior wall, they should be carefully checked to ensure an airtight seal around those openings. The exterior surface of the home has doors, windows, and other openings. These openings should be caulked routinely, and the drainage gutters along the top should be checked to ensure that they drain properly.

Exterior surface materials include stucco, vinyl, asbestos shingles, brick, metal (aluminum), fiber cement, exterior plywood, hardwood, painted or coated wood, glass, and tile, some of which are discussed in this chapter [6,7].

Fiber Cement

Fiber cement siding is engineered composite-material products that are extremely stable and durable. Fiber cement siding is made from a combination of cellulose fiber material, cement and silica sand, water, and other additives. Fiber cement siding is fire resistant and useful in high-moisture areas.

The fiber cement mixture is formed into siding or individual boards, then dried and cured using superheated steam under pressure. The drying and curing process assures that the fiber cement siding has very low moisture content, which makes the product is stable—no warping or excessive movement—and its surface good for painting.

Weight is a minor concern with fiber cement products: they weigh about 1½ times what comparably sized composite wood products do. Other concerns relate to cutting fiber cement: cutting produces a fine dust with microscopic silica fibers, so personal protective equipment (respirator and goggles) are necessary. In addition, special tools are needed for cutting.

Brick

Brick homes may seem on the surface to be nearly maintenance free. This is true in some cases, but, like all surfaces, brick also degrades. Although this degradation takes longer in brick than in other materials, repairing brick is complex and quite expensive. There are two basic types of brick homes. One is brick veneer, which is a thin brick set to the outside of a wooden stud wall. The brick is not actually the supporting wall. Brick veneer typically has the same pattern of bricks around the doors and windows; a true brick wall will have brick arches or heavy steel plates above the doors and other openings of the building. Some brick walls have wooden studs behind the brick to provide an area for insulation, plumbing, vents, and wiring. It is important that weep holes and flashing be installed in brick homes to control moisture.

Improperly constructed building footers can result in major damage to the exterior brick surface of a home by allowing moisture, insects, and vermin to enter. A crack, such as the one in Figure 7.5, is an example of such a failure. This type of damage will require much more than just a mortar patch. Buildings constructed of concrete block also experience footer failure. The damage is reason to not skimp when installing and inspecting the footing and reinforces the need for appropriate concrete mix, rebar, and footing drains.

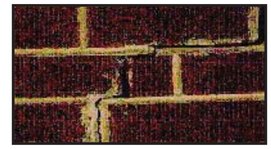

Figure 7.5. Brick Structural Defect

Stucco

Synthetic stucco (exterior insulation and finish system; EIFS) is a multilayered exterior finish that has been used in Europe since shortly after World War II, when contractors found it to be a good repair choice for buildings damaged during the war. North American builders began using EIFS in the 1980s, first in commercial buildings, then as an exterior finish to wood frame houses.

EIFS has three layers:

- **Inner layer**—foam insulation board secured to the exterior wall surface, often with adhesive;
- **Middle layer**—a polymer and cement base coat applied to the top of the insulation, then reinforced with glass fiber mesh; and
- **Exterior layer**—a textured finish coat.

EIFS layers bond to form a covering that does not breathe. If moisture seeps in, it can become trapped behind the layers. With no place to go, constant exposure to moisture can lead to rot in wood and other vulnerable materials within the home. Ripples in the stucco could be a sign of a problem. On the surface it may look like nothing is wrong, but beneath the surface, the stucco may have cracked from settling of the house. With a properly installed moisture barrier, no moisture should be able to seep behind the EIFS, including moisture originating inside the home. Drains in the foundation can be designed to enable moisture that does seep in to escape.

Other signs of problems are mold or mildew on the interior or exterior of the home, swollen wood around door and window frames, blistered or peeling paint; and cracked EIFS or cracked sealant.

Vinyl

Standard vinyl siding is made from thin, flexible sheets of plastic about 2 mm thick, precolored and bent into shape during manufacturing. The sheets interlock as they are placed above one another. Because temperature and sunlight cause vinyl to expand and contract, it fits into deep channels at the corners and around windows and doors. The channels are deep enough that as the siding contracts, it remains within the channel.

Siding composed of either vinyl or aluminum will expand and contract in response to temperature change. This requires careful attention to the manufacturer's specifications during application. Cutting the siding too short causes exposed surfaces when the siding contracts, resulting in moisture damage and eventual leakage. Even small cracks exposing the undersurface can create major damage.

Vinyl has some environmental and health concerns, as do most exterior treatments. Vinyl chloride monomer, of which polyvinyl chloride siding is made, is a strong carcinogen and, when heated, releases toxic gases and vapors. Under normal conditions, significant exposures to vinyl chloride monomer are unlikely.

Asbestos

Older homes were often sided with composites containing asbestos. This type of siding was very popular in the early 1940s. It was heavily used through the 1950s and decreasingly used up until the early 1960s. The siding is typically white, although it may be painted. It is often about ¼-inch thick and very brittle and was sold in sections of about 12×18 inches. The composite is quite heavy and very slatelike in difficulty of application. As it ages, it becomes even more brittle, and the surface erodes and becomes powdery. This siding, when removed, must be disposed of in accordance with local, state, and federal laws regulating the disposal of asbestos materials. The workers and the site must be carefully managed and protected from contamination. The composite had several virtues as siding. It was quite resistant to fire, was not attractive to insects or vermin, provided very good insulation, and did not grow mold readily. Because of its very brittle nature, it could be damaged by children playing and, as a result, often was covered later with aluminum siding.

Metal

If metal siding is used, the mounting fasteners (nails or screws) must be compatible with the metal composition of the siding, or the siding or fasteners will corrode. This corrosion is due to galvanic response.

Galvanic response (corrosion) can produce devastating results that often are only noticed when it is too late. It should always be considered in inspections and is preventable in nearly all cases.

When two dissimilar metals, such as aluminum and steel, are coupled and subjected to a corrosive environment (such as air, water, salt spray, or cleaning solutions), the more active metal (aluminum) becomes an anode and corrodes through exfoliation or pitting. This can happen with plumbing, roofing, siding, gutters, metal venting, and heating and air conditioning systems.

When two metals are electrically connected to each other in a conductive environment, electrons flow from the more active metal to the less active because of the difference in the electrical potential, the so-called "driving force." When the most active metal (anode) supplies current, it will gradually dissolve into ions in the electrolyte and, at the same time, produce electrons, which the least active (cathode) will receive through the metallic connection with the anode. The result is that the cathode will be negatively polarized and hence be protected against corrosion.

Thus, less noble metals are more susceptible to corrosion. An example of protecting an appliance such as an iron-bodied water heater would be to ensure that piping

Metal Corrosion Prevention

1. Use like metals when possible
2. Use metals with similar electronegativity levels
3. Use dielectric unions for plumbing
4. Use anodes that are inexpensive to replace

Remember: Use metals with less susceptibility to protect metals that are more susceptible to corrosion.

Figure 7.6. Corrosion in Piping Resulting From Galvanic Response

connections are of similar material when possible and follow the manufacturer's good practice and instructions on using dielectric (not conductors of electricity) unions [8].

Figure 7.6 shows examples of electrochemical kinetics in pipes that were connected to dissimilar metals.

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