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HOUSING Family Living Education

Moisture Problems in the Home

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Persistent condensation on windows, mold on ceilings and walls, and musty odors are all signs of moisture-related problems in the home. These problems are not only annoying, but can damage the home if allowed to persist.

To solve moisture problems in your home, you must first recognize the nature of the problems and understand their cause. This publication introduces you to the simple physics and basic terminology associated with humidity and condensation. It also points out the many ways in which common leaks are often mistaken for condensation problems. Armed with this basic understanding of moisture problems, you will be better able to solve the problems yourself or evaluate the solutions proposed by others.

Topics Covered in this Pamphlet

Understanding Moisture in the Home
Moisture Terminology
Measuring Humidity Levels
Moisture Movement
Effects of Weatherization
Solving Moisture Problems
Solve Water Problems First
- Seal All Leaks
- Correct Improper Surface Drainage
- Seal Basement Walls

Reduce Water Vapor Generation
- Reduce Moisture Generation in Crawl Spaces

Remove Excess Moisture
- Use Dehumidifiers
- Increase Ventilation
  - Ventilation with Exhaust Fans
  - Ventilation with Heat Recovery

Warm Up Surfaces
Trouble Spots
- Remove Mold and Mildew
- Provide Adequate Insulation in Corners

Conclusion

Understanding Moisture in the Home

Water vapor, the gaseous form of water, is the invisible source of many home moisture problems. Most air contains some water vapor, or humidity; the actual amount of water vapor the air holds depends on the temperature and available moisture. The following terms will be used throughout this publication, so it is important that you understand them.

Moisture Terminology

Relative humidity is a measure that describes the amount of moisture the air holds relative to the maximum it could possibly hold at any given temperature. For example, if the air temperature is 70°F, a relative humidity of 40 percent means that the air at that temperature contains only 40 percent of the moisture it is capable of holding. If the temperature then drops from 70°F to 55°F, the relative humidity will climb to nearly 70 percent even though the actual amount of moisture in the air has remained unchanged. This happens because colder air cannot hold as much moisture as warmer air. If the temperature drops still further, to 44°F, the relative

humidity will be 100 percent. At this point some of the water vapor in the air will begin to condense to water because the air can no longer contain it. In this case, 44°F is the dew point.

Temperature (Farenheit)	Relative Humidity %	Dew Point (Farenheit)
85°	100	85°
	60	70°
	40	58°
	20	40°
75°	100	75°
	60	60°
	40	49°
	20	31°
65°	100	65°
	60	51°
	40	40°
	20	23°
55°	100	55°
	60	41°
	40	31°
	20	15°

Figure 1: Dew points for selected temperature-humidity combinations

Air temperature determines how much water vapor the air can hold. The warmer the air, the more water vapor it can hold. The **dew point** is the temperature to which air with its given humidity level must be cooled for some of the humidity it contains to condense from water vapor to water. Figure 1 lists samples of dew points for common temperature-humidity combinations. Condensation that occurs on windows and other household surfaces in the winter results from moist air coming in contact with surfaces that are below its dew point. The condensation on basement walls and floors in the summer is a result of this same process, since basement wall temperatures will often be below summer dew points.

Absolute humidity is a measure of the total amount of water vapor in the air. Absolute humidity is measured in grains of water or pounds of water per pound of dry air. If absolute humidity is expressed in percentage terms, moisture content ranges from as little as one tenth of one percent in the winter to about one percent in the summer.

Measuring Humidity Levels

One of the first steps often recommended for diagnosing the cause of moisture problems is to measure the humidity level.

One way to determine the *approximate* indoor relative humidity level is by observation; is there condensation on the windows? Condensation on bare, double glazed windows that persists during the day when outside temperatures are zero or above and inside temperatures are approximately 70°F indicates humidity levels above 40 percent. If you keep your home cooler, the humidity level that yields persistent condensation will be somewhat lower; for example, 34 percent for indoor temperatures of 55°F. You may not need a more accurate measurement of humidity.

Figure 2 gives information which you can use to assess the approximate indoor relative humidity in your home. For example, if your home is equipped with triple glazed windows and you are having persistent condensation when outside temperatures are 20°F and your thermostat is set at 70°F, your humidity level is over 60 percent.

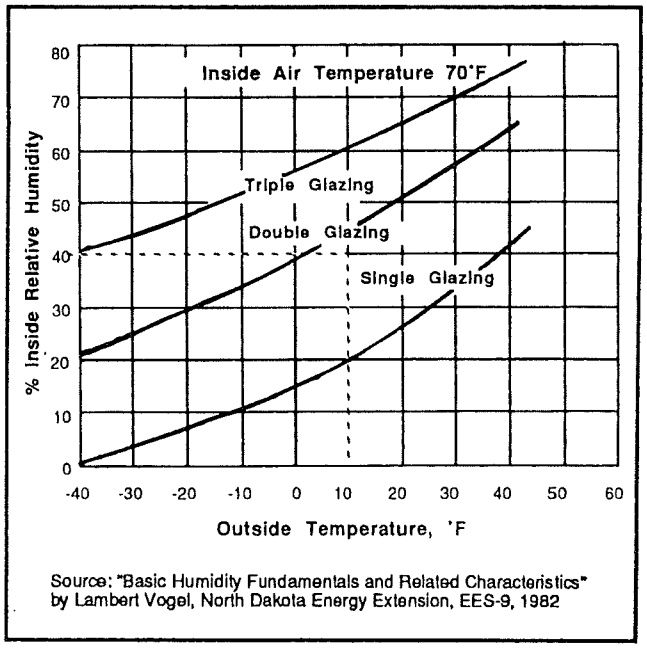


Figure 2: Condensation on window surfaces.

Moisture Movement

Water vapor moves primarily by two means, diffusion and air movement. Air movement simply means that as air moves through and about your home it carries water vapor with it. Diffusion refers to water vapor's tendency to move from areas of high concentration to areas of low concentration. As a result of diffusion, water vapor moves very quickly from one room to another and absolute humidity evens out, although relative humidity may differ from room to room.

Two natural forces cause air movement: the stack effect and wind pressure. The **stack effect** occurs because warm air, being lighter than cool air, rises. A familiar example of stack effect is heat rising up a chimney. As warm air rises up and out of your home, cool air enters at the base of the structure through the sill area and cracks on the first floor (such as under doors and around windows).

As the wind blows against your house, it tends to force air through cracks on the windward side of the house and to create low pressure causing air to escape on the opposite side of the house. This effect is called **wind pressure**.

During the heating season the effect of air movement brings cool outside air into your home. Even though this outside air may have a high *relative* humidity it contains only small amounts of moisture because it is so cool. After the cold air enters your home its temperature increases and its relative humidity declines. Once the air is warmed, it picks up water vapor generated by household activity. The warm moist air then rises and exits through the chimney, cracks around windows and other openings in the walls and ceilings of your home. Warm air escaping around second story windows condenses on the storm. This is why you often see frost on the inside of storm windows on the second story, while the first story windows remain clear.

Older construction techniques allow the stack effect and wind pressure to exhaust warm moist air and to introduce large amounts of outside air into homes. As a consequence, indoor humidity levels in winter are often so low that humidifiers are needed to add humidity.

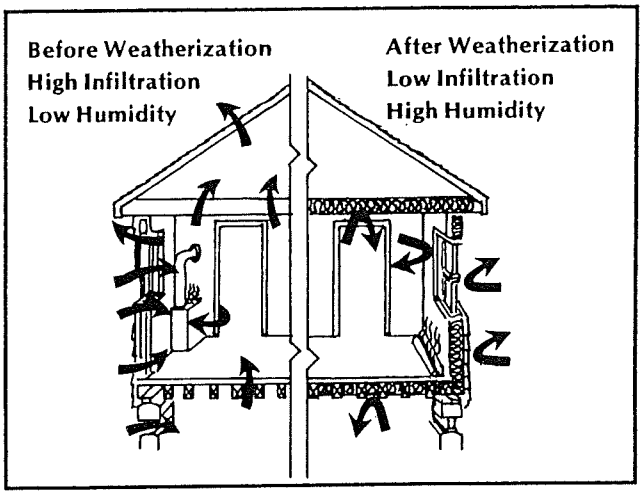


Figure 3: Weatherization can sometimes have undesirable side effects.

Effects of Weatherization

The same air movement that removes moisture also removes heat. Energy conservation practices such as caulking and weatherstripping are aimed at trapping heated air indoors and reducing the infiltration of cold outside air. Sometimes, as a side effect of these practices, moisture is also trapped indoors and outside air is not introduced to reduce humidity levels. (See Figure 3.)

As Figure 3 illustrates, the solution to one problem, wasteful use of energy, can sometimes cause another, excess indoor humidity. However, the solution to excess humidity is not to go back to loosely constructed homes that allow free movement of air in and out of the home. These homes are at the mercy of outside weather conditions; the forces that cause air movement into and out of the home are most active when temperatures outside are coldest and winds are strongest. Consequently, loosely constructed homes are likely to be over-ventilated on the coldest days, resulting in drafty, dry homes. By the same token, on fall and spring days when temperature differences between inside and outside are slight, such homes may be stuffy if windows are not opened.

Solving Moisture Problems

Condensation and its resulting problems such as mold and mildew, occur when moist air (air with a high relative humidity) comes in contact with surfaces that are at or below its dew point. Solving such problems requires reducing the relative humidity of the air, eliminating contact between moist air and cool surfaces, or warming these cool surfaces to a temperature above the dew point for existing temperature humidity conditions.

Solve Water Problems First

Sometimes problems that appear to have been caused by excess humidity actually are the result of leaking water. Stains on walls and ceilings and high humidity levels may be symptoms of ice dams, a leaky roof, leaky plumbing, moisture movement through foundation walls or rain being driven through cracks in the siding. Before assuming condensation is at fault, eliminate the possibility that the symptoms you see result from water leaks.

Seal All Leaks

Leaks in a roof or plumbing can be difficult to identify. The water damage may not appear near the leak and the symptoms may appear gradually. Generally, however, the symptoms are localized to one area of the house.

Correct Improper Surface Drainage

Moisture may penetrate foundation walls only after heavy rainfall or during periods of rapid snow melt, and it may only affect certain sections of wall. These conditions are a good indication of drainage problems on your property. Check the grading around your home. The ground surface should slope noticeably away from the foundation at all points. If you have gutters and downspouts make sure they are functioning properly and the downspout directs the water away from the foundation. If there are no problems with your grading or gutters and the moisture problem appears to be slight, commercial damp-proofing compounds may solve the problem. These are applied like paint to inside wall surfaces. If water problems are severe, contact a reputable contractor.

Seal Basement Walls

Porous basement walls are another possible moisture source. Even when there are no visible cracks, moisture may migrate through concrete basement walls. You can check whether this is a problem by taping a small piece of plastic to the inside of an exposed section of basement wall. Remove the plastic after a day or two. If moisture condensed on the back side of the plastic, moisture is entering the basement through the wall. The same test may be used on basement floors. Another indicator of such moisture movement is staining on the walls where moisture has penetrated and then evaporated.

Reduce Water Vapor Generation

One way to reduce relative humidity is to reduce the generation of water vapor in the home. As Figure 4 shows, considerable water vapor is generated in the course of daily living. For example, a family of four persons will generate 12 pints of water vapor a day just by breathing. There are ways to reduce the amount of water vapor that is being generated.

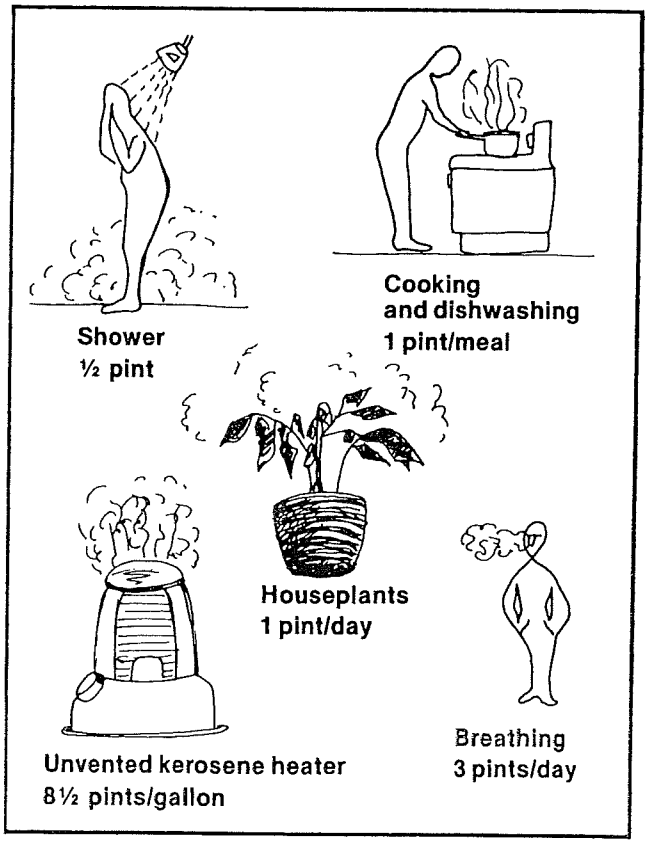


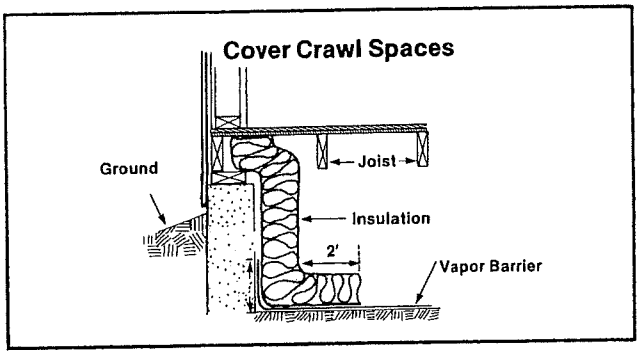
Figure 4: Approximate amount of water vapor produced per day by selected indoor sources.

Many families today vent clothes dryers indoors as an energy saver. Some people store cord wood in the basement. Both of these practices can introduce considerable moisture into the home. Stove top cooking in open containers, extended showers or baths, large numbers of house plants, and using unvented kerosene heaters are other sources of moisture.

Water leaks, as previously mentioned, are also a source of water vapor. See the previous section for discussion

Reduce Moisture Generation in Crawl Spaces

If your home is built over a crawl space, moisture may be evaporating from the soil and entering your home. Reduce moisture from this source by covering the crawl space with a moisture resistant material such as 6 mil polyethelene plastic. Roll the material several inches up the edge of the foundation. If seams are necessary, be sure to overlap them. Use stones, bricks or dirt to keep the material in place.



Remove Excess Moisture

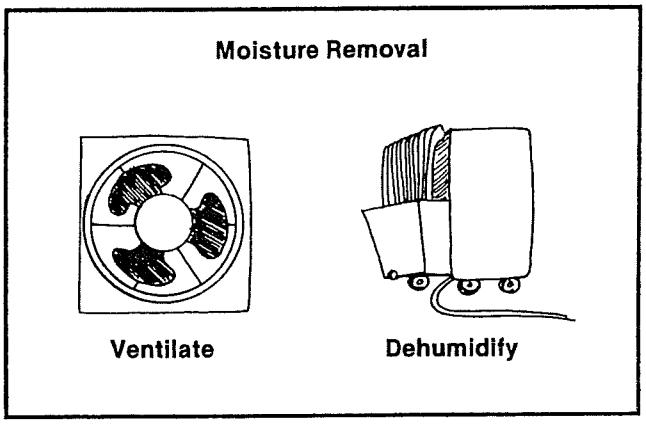
If moisture generation has been reduced to the extent practical, but moisture condensation problems persist, it may be necessary to remove excess moisture. There are two ways to do this: by using a dehumidifier or by ventilating the space, using fans to remove moist air.

Use Dehumidifiers

A dehumidifier is similar to an air conditioner: it too, has a refrigeration unit and condensing coils. A dehumidifier works by lowering the temperature on the coils below the dew point, causing condensation to occur on the coils.

Dehumidifiers are rated by their ability to condense water from air at 80°F and 60 percent humidity. Dehumidifier manufacturers market models ranging in condensing capacity from approximately 15 pints to 40 pints per day.

There are some drawbacks to dehumidifiers, however. First, they consume energy; a 25-pint dehumidifier may use from 8 to 12 kilowatt hours of electricity per day when it is working at full capacity. This makes it roughly equivalent to a 15 cubic freezer in energy consumption. However, while it operates the dehumidifier produces heat which would result in a net energy gain for the home. Second, most dehumidifiers sold for home use are most effective at warmer temperatures (65°F and above). At cooler temperatures, the coils freeze and must be defrosted. Third, most home models are designed to operate at humidity levels above 50 percent. This level may be too high to solve many residential moisture problems.



Increase Ventilation

As suggested earlier, problems with excess moisture during winter months have become more severe in cold climates since houses have been weatherized to reduce air infiltration. Therefore, the solution to these problems is to increase ventilation through the use of windows, doors, exhaust fans and/or air-to-air heat exchangers. Unlike the traditional home in which natural forces determine ventilation rates, this new approach to ventilation allows the occupants to determine how much ventilation will occur.

Concern about saving energy may cause reluctance to open windows and let that expensively heated air escape. However, managed ventilation can actually cost very little in terms of energy lost. One source indicates that in a well insulated 1200 square foot home a fan exhausting 30 cubic feet of air per minute and running 24 hours a day would only contribute 5 percent to the heat loss for the home. About 2 kilowatt hours of electricity per day would be required to power the fan.[1]

[1] Anton Ten Wolde and Jane Charleton Suleski, "Controlling Moisture in Houses," *Solar Age, January 1984.*

Ventilation with Exhaust Fans

For most homes, exhaust fans are a good ventilation choice. Many homes are already equipped with exhaust fans so there will be no installation cost. Be aware that ductless kitchen and bath fans do not exhaust air but simply filter and recirculate the air. Fans associated with infrared heat lamps in bathrooms only help to circulate the air. A true exhaust fan will be installed in a wall or ducted through the roof or an exterior wall and will exhaust air from the home.

As a first step in removing moisture, run exhaust fans for 20 minutes after showers, and 30 minutes following cooking and dish washing. If this is inconvenient or inadequate, consider installing a dehumidistat control to operate your exhaust fan or wiring the fan to the light switch so it is activated when the light is switched on. It can be set to switch on whenever moisture exceeds a certain level. If you decide to purchase a dehumidistat control be sure you select a reputable dealer.

If you need to install a fan, look for one with a tight fitting exterior damper. Also look for a fan with a very low noise level so that family members will willing to use it. A bath fan should supply 8 air changes per hour and a kitchen fan, 12–15.

Increased ventilation may not have an immediate effect. This is because the wood structure and trim of your home stores large amounts of water. The amount will drop gradually when the relative humidity level in your home is lowered.

Ventilation with Heat Recovery

For unusually tight houses where heat loss is a concern, air-to-air heat exchangers may be the answer. These devices exhaust stale air and bring in fresh air. In the process, some of the heat from the stale air (up to 70 percent) is transferred to the fresh, incoming air. Some air-to-air heat exchangers also exchange a small amount of moisture.

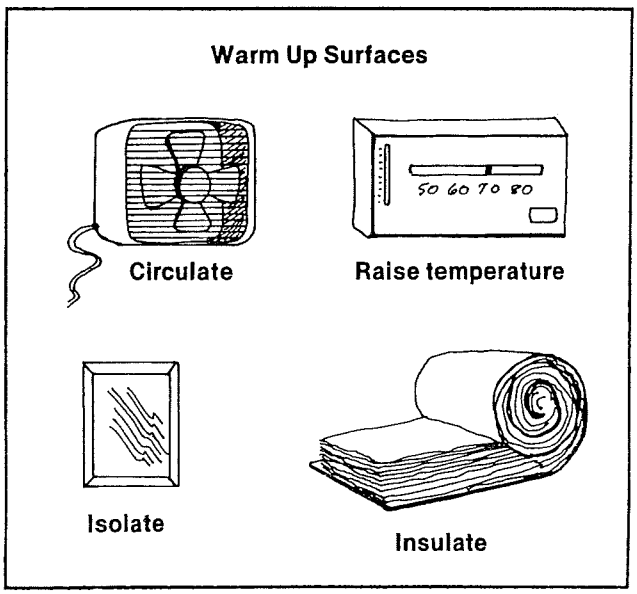
Air-to-air heat exchangers should be evaluated from an economic standpoint. The cost of the unit will be several hundred dollars and the payback period in a tight house may be 5–7 years. In a house with normal infiltration, the payback period may be much longer. A major advantage to incorporating heat exchange into ventilation is that the owner will be likely to use it more often. This is particularly important in winter and when outdoor temperatures are quite low and the natural tendancy would be to avoid ventilation.

Warm Up Surfaces

In many cases high relative humidity levels are not the cause of moisture problems. In homes where the relative humidity is in the acceptable 30 to 40 percent range, moisture problems can occur because surface temperatures drop below the dew point for air with that amount of humidity. Single pane windows offer a convenient example. A single layer of glass has very little insulating value; consequently, the inside surface temperature of the glass will be close to the outdoor temperature.

A review of Figure 2 reveals that room air at 70°F with a moderate 30 percent relative humidity could still produce condensation on the surface of single glazed windows when the outside temperature dropped below 20°F. This is because the inside surface temperature of the glass would be 33°F, or roughly 4° below the dew point. By adding another layer of glazing, you would raise the surface temperature above the dew point of 37°F and eliminate condensation.

When your humidity levels are higher or outside temperatures are lower, the second layer of glazing might not be enough. For example, if the outside temperature drops to 0°F, condensation can be expected on double glazed windows if the relative humidity remains at 30 percent. A third layer of glazing will stop condensation in most situations. Double glazed windows with a low emittance coating may also be effective.



Trouble Spots

Covering the window with a loose fitting drape would make the condensation problem worse because it would lower the temperature of the window surface without keeping room air from contacting the surface. This is similar to the problem that sometimes occurs behind furniture positioned against outside walls or in closets with outside walls. Condensation and mold may grow on these wall surfaces because the heated room air doesn't circulate there to warm them, yet they are open enough to room air so that moisture moving through diffusion can condense on these wall surfaces.

Provide Adequate Insulation in Corners

Another trouble spot in some homes is the corner between outside walls and ceilings. Attic insulation often is thin at this point because either there isn't adequate space between the ceiling and the roof deck to accommodate the full amount of insulation, or there are additional structural members at this point which displace insulation. Other possible reasons are: wind through attic vents may blow insulation away from this area; wall insulation may settle; or air circulation to this area of the room is usually limited. (See Figure 5.)

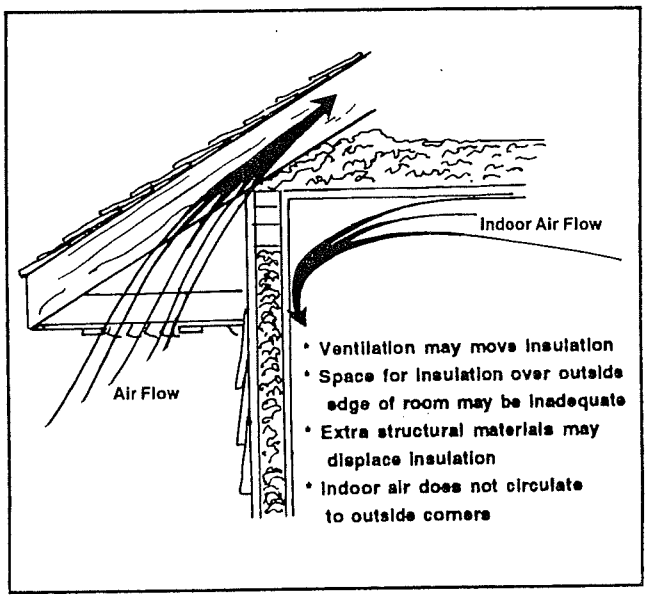


Figure 5: Moisture problems often develop in the corner between outside walls and ceilings.

In most cases, reducing indoor humidity levels will cure these problems. Where this solution is not effective, some means of warming the surfaces must be found. The simplest solution is to improve air circulation to the cold surfaces, either by moving furniture away from walls when problems are occurring, or by leaving closet doors open. Another possible solution is to raise the temperature in the problem rooms. The ideal long-term solution is to improve insulation for the surfaces where problems are occurring.

Remove Mold and Mildew

Once mold or mildew has developed on household surfaces, it can be removed by a dilute bleach solution: one cup of sodium hyperchlorite to one gallon of water. Wash surfaces with this solution and let dry. Avoid using cleaning solutions that contain phosphate, since they may leave a residue that could provide nutrients for future mold or mildew growth.

Conclusion

Moisture problems can be difficult to solve. The solution may often involve several steps or there may be several solutions available. It is up to you to choose the right approach. You will read articles in the newspaper or see products advertised which will claim to solve problems; you must evaluate this information and these claims. We have provided you with basic information regarding moisture problems which you may refer to in making choices and in developing your own solutions.

We hope you will use this information to think of problems in terms of their basic causes and that this approach will ultimately save you time, trouble and money by making choices more effective.

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Checklist for Diagnosing Indoor Moisture Problems

Are water leaks causing the problem?

- ☐ Do downspouts carry water away from the foundation?
- ☐ Does ground slope away from the foundation?
- ☐ Are gutters clear of leaves and other material?
- ☐ Do patios, driveways, and sidewalks slope away from the home?
- ☐ Are roof and flashing in sound condition?
- ☐ Are crawl spaces protected to prevent evaporation from soil?

Does moisture on double glazed windows persist above 0°F?

- ☐ Is air movement to window surface blocked by window shades or drapes?
- ☐ Is clothes dryer vented indoors?
- ☐ Is firewood stored indoors?
- ☐ Are there large numbers of house plants?
- ☐ Is laundry dried indoors?
- ☐ Are there other reducible sources of moisture?

Is condensation persistent on walls (but not on windows)?

- ☐ Can temperature of affected rooms be increased?
- ☐ Can wall insulation be improved?
- ☐ Is air circulation to affected areas limited, e.g., closets?
- ☐ Do pipes in walls leak?

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