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COLD CLIMATE HOUSING INFORMATION CENTER

UNIVERSITY OF MINNESOTA

Moisture Sources Associated with Potential Damage in Cold Climate Housing

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This publication documents moisture sources that may adversely affect performance of cold climate housing. It identifies research and opinions that have evolved since the landmark 1948 Purdue study by S. C. Hite and J. L. Bray, Research in Home Humidity Control *(13), a study still cited as the authoritative investigation by organizations such as the American Society of Heating, Refrigerating and Air Conditioning Engineers. This publication includes information helpful to builders, designers, inspectors, remodelers, and others concerned about moisture sources in housing.*

A popular version of this publication, entitled Home Moisture Sources *(CD-FS-3396), is available from county offices of the Minnesota Extension Service or from the Distribution Center, Coffey Hall, University of Minnesota, St. Paul, MN 55108.*

Background

Moisture damage associated with elevated winter indoor humidity in cold climate housing remains a controversial issue. Moisture problems were common in new homes built in the late 1940s and early 1950s, especially in small, tight, prefabricated homes (13:1), as well as in small all-electric homes in the early 1960s (15:236), and in mobile homes in the 1970s. The problems included exterior paint peeling, delamination of plywood roof sheathing, attic frost, room corner frost, mildew, and window and wall condensation.

In the early 1980s, the Canadian Mortgage and Housing Corporation received indications of moisture-induced problems in housing built from 1973 to 1981. Subsequent investigations revealed that at the time of inspection, about 6 percent of the homes had serious unrepaired moisture problems significant enough to cause a financial loss (26:6). The problems included mold and mildew, window condensation, attic condensation, wall cavity condensation, and siding damage.

To reduce the risk of damage due to excessive humidity, homeowners are routinely advised to control or lower indoor humidity as outdoor temperatures drop. Homeowner efforts to do so are not always successful. Contractors and others are often at a loss to explain what sources are contributing to excessive humidity and how to correct or prevent moisture problems. In part, this difficulty is associated with two points: first, current professional knowledge is often based on secondhand citation of research reported 40 years ago (e.g., 13 in 1). Second, it is difficult to quantify the amount of moisture that can be contributed by several potentially significant sources. These sources include moisture associated with soil gas leakage through foundations (34), moisture brought into the house during mildly cold periods due to air leakage (6, 34), moisture related to failure of combustion venting (such as chimneys) (29), and release of moisture stored in building materials and furnishings (6, 34).

This publication identifies references on a variety of moisture sources that can contribute to excessive humidity in cold climate housing. The accompanying chart summarizes a range of potential household moisture sources, from minor to major, that may be continuous, long-term, or short-term. A brief discussion of each potential moisture source follows.

Generalizations

There are many potential sources of moisture associated with excessive winter humidity in cold climate housing. Research on the interplay of home moisture sources is incomplete. Moisture generation and release rates in a home are often site- and occupant-specific; that is, moisture generation and release must be examined on a case-by-case basis and require individualized treatment. Although symptoms of excessive moisture usually can be easily seen, some sources of moisture are difficult to detect and may be costly to control.

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.

Despite the individualized nature of moisture sources and problems, the following generalizations may be helpful:

- Newly constructed houses release elevated levels of moisture from building materials, especially during the first heating season.
- Certain types of conditions are related to excessive winter condensation. One such condition is a large number of people living in a small, tight house that lacks adequate ventilation.
- Discretionary human activities or practices may contribute unnecessary moisture and can be altered at little or no expense. Such activities or practices include indoor clothes drying, indoor venting of a clothes dryer, indoor firewood storage, use of a humidifier, use of an unvented kerosene space heater, and cooking in uncovered pans.
- Difficult to detect sources can contribute staggering amounts of moisture. Examples include ground moisture migration through basement floors and walls, backdrafting or spillage of combustion exhaust gas into the home, plumbing leaks, rain penetration, and snowmelt leakage.
- House materials and furnishings absorb moisture during nonheating seasons and release moisture during the heating season. This release of moisture is generally related to condensation problems during the beginning of the heating season. These problems are often intensified by the reduced effectiveness of ventilation due to the high outdoor humidity that is common in the fall.
- Moisture problems can be compounded by certain building practices or components that result in cold surfaces or allow moisture laden air to move freely into insulated cavities. Examples include windows that have loose fitting interior sashes and tight exterior storms, air leakage from the house into wall or roof cavities, open top cores in concrete block foundation walls, improperly placed vapor retarders, little air circulation in clothes closets on exterior walls, shower stalls on exterior walls, tight doors on kitchen cabinets on exterior walls, cantilevered floor-wall sections, and exterior air leakage under ceiling insulation.
- Although moisture sources are commonly cited as "fixed rate" or fixed amount per activity (as reflected in this publication), the rate of moisture contributed by a source is related to indoor humidity level. For example, the rate at which floors dry, clothes dry, perspiration evaporates, plants transpire, and materials release moisture is inversely related to indoor humidity. Furthermore, it appears that some moisture sources, such as those associated with below and aboveground air leakage into the home, are dependent on the natural air leakage out of the home.

Effective moisture management strategy begins with reducing unnecessary moisture generation in the home and then limiting moisture migration into the structure. The second aspect involves sealing inside cracks, trim, and plumbing as well as wiring penetrations to lessen moisture transfer by air leakage into window, ceiling, and wall cavities. Third, a moisture management strategy usually involves a mechanical ventilation system. Such a ventilation system should be properly designed and installed (20) and may include heat recovery for comfort as well as energy efficiency.

This publication focuses on one important step in moisture management: identifying moisture sources. Resources that address additional aspects of home moisture management are available from the Minnesota Energy Information Center (in the Minneapolis-St. Paul area: 296-5175 or in greater Minnesota: 1-800-652-9747, ask for "Energy") or the Minnesota Extension Service's Cold Climate Housing Information Center (contact your county extension service office).

Sources of Household Moisture

Aquariums

Aquariums are not commonly considered to be significant sources of household humidity. The amount of humidity contributed is equal to the amount of water added to replace evaporative loss.

Attached Greenhouses

If a horticultural greenhouse is directly attached to the home and if greenhouse air is vented into the home, home humidity may become excessive. It is not possible to generalize from existing literature about the humidity load of a greenhouse.

Bathing

Moisture added through bathing is a relatively small amount: .1 pint for a standard sized tub bath and .5 pint for a 5-minute shower (11:11). Humidity can be reduced during showering by using the lowest comfortable water temperature and by running an exhaust fan during and for about 20 minutes after showering or using a fan that is shut off by a humidistat control. The humidity added is a function of water temperature and flow rate; it is greatest for the initial minute and increases with higher water temperature and flow (11). Existing estimates of moisture released from bathing apparently do not take into account moisture released from towels, washcloths, and bath mats or rugs, or from hair drying.

1 gallon of water equals

8.33 pounds
4 quarts
8 pints
3.7 liters

Clothes Washing and Drying

Moisture added through clothes washing is assumed to be zero in an automatic washing machine directly discharging to a drain (13:14). Clothes drying adds minimal moisture unless clothes are dried on a line indoors or in a clothes dryer that is vented indoors. Nonvented, condenser clothes dryers are available; the moisture collected can be drained into a standpipe. The amount of water retained in a standard load of clothes (primarily cotton)* after the spin of the washing machine cycle is 4.68 pints. A short rather than normal spin retains about 1 additional pint per load. About .5 pint of additional water is retained with a cold rather than a

*A standard 8-pound load includes: two flat sheets, two pillow cases, three boxer shorts, two T-shirts, four handkerchiefs, one tablecloth, two shirts, ten washcloths, and three bath towels (17).

Overview of household moisture sources

Moisture source by type	Estimated moisture amount (pints)
Household produced	
Aquariums	Replacement of evaporative loss
Bathing: tub (excludes towels and spillage)	0.12/standard size bath
shower (excludes towels and spillage)	0.52/5-minute shower
Clothes washing (automatic, lid closed, standpipe discharge)	0+/load (usually nil)
Clothes drying: vented outdoors	0+/load (usually nil)
not vented outdoors or indoor line drying	4.68 to 6.18/load (more if gas dryer)
Combustion—unvented kerosene space heater	7.6/gallon of kerosene burned
Cooking: breakfast (family of four, average)	0.35 (plus 0.58 if gas cooking)
lunch (family of four, average)	0.53 (plus 0.68 if gas cooking)
dinner (family of four, average)	1.22 (plus 1.58 if gas cooking)
simmer at 203° F., 10 minutes, 6-inch pan (plus gas)	less than 0.01 if covered, 0.13 if uncovered
boil 10 minutes, 6-inch pan (plus gas)	0.48 if covered, 0.57 if uncovered
Dishwashing: breakfast (family of four, average)	0.21
lunch (family of four, average)	0.16
dinner (family of four, average)	0.68
Firewood storage indoors (cord of green firewood)	400 to 800/6 months
Floor mopping	0.03/square foot
Gas range pilot light (each)	0.37 or less/day
House plants (5 to 7 average plants)	0.86 to 0.96/day
Humidifiers	0 to 120+/day (2.08 average/hour)
Pets	Fraction of human adult weight
Respiration and perspiration (family of four, average)	0.44/hour (family of four, average)
Refrigerator defrost	1.03/day (average)
Saunas, steambaths, and whirlpools	0 to 2.7+/hour (see text)
Vegetable storage (large-scale storage is significant)	0+ (see text, not estimated)
Nonhousehold produced	
Combustion exhaust gas backdrafting or spillage	0 to 6,720+/year
Desorption of materials: seasonal	6.33 to 16.91/average day
new construction	10+/average day
Ground moisture migration	0 to 105/day
Plumbing leaks	0+ (see text, not estimated)
Rain or snowmelt penetration	0+ (see text, not estimated)
Seasonal high outdoor absolute humidity	64 to 249+/day

warm rinse; the temperature of rinse water is a bigger factor when a short spin is used. Humidity addition during the actual washing process occurs when water is drained into rinse tubs rather than a standpipe or if the machine is filled manually and the wash lid is left open for any period of time. Evaporation occurs more rapidly with higher temperature water.

The Purdue estimate of moisture release from clothes washing and drying for a family of four per week (26 pounds of clothes) is 4.16 pints in a wringer washing machine and 25.32 pints for indoor hang drying of washed clothes (13: 51-54).

Combustion Exhaust Gas Backdrafting or Spillage

Incomplete exhaust of fossil fuels used to heat the home can be an unsuspected source of a large amount of winter indoor humidity (13). When burned, fuels combine with oxygen to produce heat, carbon dioxide, water, and other byproducts. A recent Canadian study of 1,000 houses found that 10 percent of gas-heated houses and a greater percentage of oil-heated houses had excessive spillage (22:25). In another Canadian study of 100 "problem-prone houses," 36 percent of the homes had chimney backdrafting and 34 percent had chimney spillage (29:27). A majority of the problems related to oil or gas furnaces, followed by fireplaces.

The Purdue study places the moisture contribution due to an unvented gas water heater used by an average family of four at 4.67 pints per day (13:18). The specific amount of humidity attributed to exhaust gas backdrafting (complete ongoing chimney reversal) or spillage (short-term partial venting failure) in any home is ideally zero. One reference places the potential amount at 1 gallon (8 pints) of moisture per gallon of oil burned in nonvented oil-fired equipment and, in North Carolina, up to 840 gallons (6,720 pints) of moisture per heating season in nonvented gas-fired heating equipment (23). (The amounts would be higher in colder climates, depending on operating time and equipment efficiency.) Another reference places natural gas moisture production at 1 gallon (8 pints) per 1,000 cubic feet of gas burned (16). An experimental portion of the Purdue study indicated that the water formed when burning 100 cubic feet of natural gas was 1.86 pints; with propane, it was 3.84 pints (13:47).

Since spillage or backdrafting poses a life threatening risk of carbon monoxide poisoning, suspected problems should be examined immediately by a competent service person.

Combustion in Unvented Kerosene Heaters

Humidity attributed to the use of unvented kerosene space heaters apparently has not been well documented. Various estimates place the moisture contribution at about 7.6 pints (14, 19, 24:18) of moisture per gallon of kerosene. Since the fuel consumption of an 8,000 to 20,000 BTU/hour space heater ranges from about ¼ to ½ quart of kerosene per hour, the moisture released would be about .5 to 2 pints per hour.

Cooking

Humidity added through cooking is less when food is cooked at a simmering temperature or lower and when a tight fitting lid is used. Cooking food at a "boil" temperature, with or without a lid, can add .5 pint or more of moisture every 10 minutes (9):

	7-inch pan		6-inch pan	
Temperature	Lid on	Lid off	Lid on	Lid off
Simmer at 203° F. for 10 minutes	Less than 0.01	0.20	Less than 0.01	0.13
Boil 10 minutes	0.66	0.65	0.48	0.57

The Purdue average estimate of moisture released from cooking typical meals for a family of four is .35 pint for breakfast (plus .58 pint if gas range), .53 pint for lunch (plus .68 if gas range), and 1.22 pints for dinner (plus 1.58 pints if gas range) (13:15). Moisture release varies greatly according to the cooking methods. For a family of four using gas for cooking, a breakfast of oatmeal, toast, and coffee produced three times as much moisture (about 1.1 pints) as a meal of french toast, syrup, and coffee (about 0.4 pint); a dinner meal of steak, french fried potatoes, corn on the cob, and coffee produced more than twice as much moisture (about 3.7 pints) as a meal of oven fried fish, baked potatoes, steamed carrots, and coffee (about 1.6 pints). Most of the water vapor generated during cooking can be removed with an exhaust system (5).

Desorption of Moisture from Materials (Construction and Furnishings)

Moisture released from construction materials and furnishings can be very significant, although difficult to quantify. Building materials commonly used in houses, such as concrete, gypsum, and wood, as well as furnishings have hydroscopic characteristics; that is, they absorb moisture when humidity is high and release moisture when humidity is low (13:19-23). These changes may be very significant, especially following construction. They are gradual on daily and seasonal cycles, depending partially on temperature change. For this reason, there is current interest in the impact of large night-time temperature setback and in changes associated with wood burning stoves and closure/opening of rooms (29:Appendix II:1-15).

Seasonal Desorption

The equilibrium moisture content (MC) of wood is 11.0 percent (weight of water) at 70° F. and 60 percent relative humidity (RH) and 6.2 percent at 70° F. and 30 percent RH (10:3-8). The first condition is likely to be common during the nonheating season, whereas the second is likely to be common during the winter. Hansen estimates that 211 pints of water each year are released during heating seasons by wood flooring and framing assemblies that gained 4 percent MC in a 1,200-square-foot one-story house with a full basement (12:231-1; see also 24:21).

Quirouette places the amount of seasonally released moisture in a 34 cubic yard concrete foundation at 1,268 pints or about 10.5 pints per average day (24:21). In total, he estimates that all materials and furnishings release an average of 6.3 to 17 pints per average day from seasonal storage alone (more in the fall and early winter, less in late winter and spring).

Release of moisture during the heating season can be compounded by condensation inside wall and ceiling cavities. One roofing consultant attributes apparent roof leaks to condensation due to leakage of warm indoor air into roof cavities (25). An engineer in an experimental study found that the cold side of the top plate in north facing wall test panels (72° F. and 50 percent RH interior) with an exterior vapor retarder (not recommended) increased from about 10 percent MC in November to about 80 percent in late May (33). Field studies at the U. S. Forest Products Laboratory in Madison, Wisconsin, indicated that:

- Moisture content at the siding-sheathing interface exceeded 20 percent from December to April in insulated wall panels lacking a membrane vapor retarder.
- Application of two coats of vapor-resistant paints to interior wall surfaces reduced wall moisture content more effectively than did exterior 1-inch diameter vents (31, 32).
- Moisture content at the siding-sheathing interface cycled with cool summer nights and warm, dry days (especially with sun exposure).
- No condensation occurred from January through February in walls with unpenetrated 6-mil polyethylene vapor retarders, whereas condensation did occur behind electrical outlets (30).

Heating season saturation of wall and ceiling cavities can contribute to undesirable winter indoor humidity levels and increased potential for rot and fungus growth as outdoor temperatures rise in the spring.

New Construction Desorption

Building materials also can gain moisture during construction when exposed to weather. Concrete and mortar also release moisture as they slowly cure. According to Canadian research, the moisture input of construction materials is about 50 percent greater than that of occupant-produced moisture in the first year after construction (24:20). In an "average (new) Canadian house," about 420 pints, or more than 50 gallons, of moisture were attributed to lumber drying from 19 percent MC to average conditions and about 5,000 pints, or over 625 gallons, of moisture were attributed to a concrete foundation (27:35, 24:20). Assuming an 18-month drying period, it is estimated that, on the average, 8 to 10.5 pints of moisture are released per average day (more initially) (24:20).

Construction material moisture absorption and release can be a very important factor, but it is difficult to quantify in specific houses.

Dishwashing

Moisture added during hand dishwashing is greatest during the hot water rinsing of dishes. Warm water should not be substituted for hot water rinsing because of the sanitation factor. Humidity can be reduced by eliminating any unnecessary running of water such as rinsing under a continuously running faucet. Moisture addition during machine dishwashing is minimal; in some dishwashers the moisture left on the dishes is released to the room.

The Purdue estimate of moisture release from dishwashing for a family of four is .21 pint for breakfast, .16 pint for lunch, and .68 pint for dinner (13:16).

Firewood Storage Indoors

Firewood, just like building materials, releases moisture when it is saturated and humidity is low and absorbs moisture when it is dry and humidity is high. The amount of moisture in firewood depends on species, portion of sapwood and heartwood content, and degree of seasoning or dryness. The moisture in green or unseasoned firewood ranges from about one-third to double the weight of oven-dry wood. The amount of water in green firewood is estimated at 90 gallons or 720 pints per ton of wood (at 60-percent MC) (10:13) to 435 gallons or 3,480 pints per cord of "typical" firewood (14).

Dried or seasoned firewood that has been stacked outdoors in a sunny open area for at least 6 months of favorable drying weather will have about 40 gallons or 320 pints of water per ton (at 20 percent MC) (21:13). This amount of firewood is equal to about one-half cord of white oak, three-fourths cord of paper birch, or one cord of aspen. Stored indoors, moisture content will generally drop to 6-11 percent, thus releasing about 20 gallons or 160 pints of humidity (21:14). A Canadian building scientist estimates that a 10-percent drop in moisture content of a cord of firewood releases about 275 pints (softwood) to 530 pints (hardwood) of water (24:18). He further estimates that three cords of firewood used over a 6-month heating season release about 10.5 pints per day (24:19). The rate at which this drying occurs depends on temperature and humidity.

Floor Mopping

Moisture added through floor mopping is usually minor. The moisture is estimated in the Purdue study to be approximately .03 pint per square foot of floor area washed and rinsed with a tightly wrung 24-ounce mop (13:14).

Frost-Free Refrigerator

Refrigerator defrost is not a significant source of household humidity. One manufacturer has estimated that 7.2 pints of moisture per week evaporate from an automatic defrost refrigerator-freezer. The user initiates the defrosting of a manual defrost refrigerator and of the freezer section of a cycle defrost refrigerator-freezer; defrost water collecting in the drain pan can be emptied.

Gas Range Pilot Lights

In Minnesota, gas range pilot lights are found only in ranges sold before 1979 and in ranges without a power supply cord. Two pilot lights would consume no more than 350 BTU/hour of gas and could produce insignificant moisture (.74 pint per day).

Ground Moisture Migration

Humidity attributed to vapor and capillary migration of moisture from saturated soil through crawl spaces or basements is not commonly estimated in traditional residential moisture literature (13). Nevertheless, the humidity load associated with soil moisture migration is generally believed to be staggering. A Canadian National Research Council authority has stated that as much as 85 to 105 pints of moisture per day can be released by exposed soil in a crawl space (27:36). Research performed more than 30 years ago at the U.S. Forest Products Laboratory indicated that 97 pints per day of moisture evaporated from a 1,000-square-foot surface of finely textured soil when the water table was located 30 inches below the surface (28:3). Furthermore, testing at this laboratory found the following rates of moisture transfer through 1,000-square-foot, 4-inch concrete slabs located over a loam soil with the water table 12 inches below the slab (28:3-6):

- 19½ (19.6) pints with unfaced kraft paper over 4 inches of coarse washed gravel.
- 4½ (4.64) pints with a two-layer, 15-pound asphalt felt, hot-mopped membrane over 4 inches of coarse washed gravel.
- 7¾ (7.76) pints with a one-layer, 15-pound asphalt felt, hot-mopped membrane over 4 inches of coarse washed gravel.
- 2 (1.94) pints with a one-layer, 45-pound felt, hot-mopped membrane over 4 inches of coarse washed gravel.
- 15 (15.2) pints with a one-layer, 15-pound felt, hot-mopped membrane over 4 inches of coarse washed gravel and a waterproofing admixture in the concrete slab.
- 9 (8.88) pints with unfaced kraft.

One of the conclusions of this study was that heating the slab appeared to increase the transmission of moisture if no vapor retarder was provided. Recommendations included use of a membrane vapor retarder (also serves as a capillary retarder), waterproof membranes on below ground walls as well as perimeter wall, and underfloor drainage. Quirouette, reporting on early results from a Canadian study, indicates that 4¼ to 6⅓ pints of moisture pass through average basement walls and floor per day (24:22). The amount may be as much as 17 to 21 pints per day in concrete block walls that are visibly wet for several feet above the floor around the entire perimeter. Furthermore, he calculates that an 875-square-foot flooded basement would vaporize at 12½ pints per hour (24:23). Finally, he notes that saturated soil gas leakage into a basement may contribute to elevated home humidity (amount not estimated). Two other Canadian researchers, White and Skover, agree with Quirouette and note "...there is now more reason to believe that soil gas may be a major contributor of water (as it is of radon)..." (34:1).

House Plants

Moisture added through transpiration of house plants is estimated in the Purdue study to be about 1 (.96) pint per day for seven common variety plants in three sizes of containers "watered thoroughly once each day" or an average of .04 pint per hour (13:18, 56-57). With daily watering, the amount of water vapor appeared to depend on plant size and type and little on the amount of water added. Weekly watering of plants is believed to be a more common commercial and residential practice (2), however, so the Purdue estimate of plant moisture contributions may not be valid. Canadian research places house plants at a lower level: about .4 liter or slightly more than .8 pint for "5 average size plants/day" (27:37). Taking into account variations in number, size, and species of plants as well as household plant watering practices, one may wish to estimate plant moisture contribution to be an amount equal to the water periodically added to plants in the home.

Humidifier

Moisture added through mechanical humidification (portable or furnace mounted) depends on a number of factors, including the rated capacity of the humidifier. Portable household humidifiers are rated by capacity; the large models are capable of adding 96 to 120 pints of moisture per day to the home (7). The Purdue moisture estimates place the average furnace-mounted humidifier contribution at 2.08 pints per hour (13:24). Since humidifier use is highly variable, it may be best to estimate contribution on a case-by-case basis. NOTE: Using a humidifier in a tight home generally is not necessary. Indoor relative humidity may feel different to different people, and inexpensive humidity gauges may be inaccurate. In general, then, humidifier use should be approached with caution. Some people use humidifiers to reduce winter upper respiratory problems, even though they may experience adverse reactions to mold due to high humidity intensified by humidifier use.

Pets

Moisture attributed to the breathing of pets is usually minor, although it apparently has not been documented. It may not be unreasonable to assume that pets contribute moisture to indoor air in a ratio proportionate to the body weight of adult humans.

Plumbing Leaks

Moisture added through plumbing leaks is difficult to measure, although it may be especially important in specific cases. Leaks may include drainlines saturating the basement floor or crawl spaces and deteriorated mortar in shower stalls that allows saturation of wallboard.

Rain or Snowmelt Penetration

Moisture attributed to rain or snowmelt penetration through the building envelope is highly variable as well as site-specific and, therefore, is not commonly or easily estimated. Examples of such penetration include: roof leakage due to ice damming, roof flashing failure, deteriorated caulking that allows wind-driven rain to penetrate around door or window casings, and capillary seepage through siding laps.

A limited amount of research has examined weather data in Canada and Great Britain (8). These studies have computed driving rain indexes that measure combined rainfall, windspeed, and wind direction on the assumption that exposed exterior building component deterioration is proportional to these factors. Initial efforts identified exposure gradings. The Canadian gradings ranged from 1 (sheltered) to 13 (severe), with ocean coastal areas generally rated as severe, eastern Great Lakes and St. Lawrence River areas generally rated as moderate, and interior areas generally rated as sheltered.

Climate and micro-climate factors are important with respect to potential rain or snow penetration. Proximity to large bodies of water, especially on downwind locations, may be relevant. There are no known Minnesota data that replicate findings elsewhere (18) indicating that capillary flow of wind-driven rain through siding laps is significant.

Respiration and Perspiration

Moisture added through human breathing and sweating is estimated in the 1948 Purdue study as about .45 or .46 pound (.44 pint) per hour for an "average family of four" (13:57). This value reflects .45 pound per hour at night when the family is resting and .46 pound during the day when the husband is away and others are active. Human-contributed humidity becomes important as a continuous source in small and tight houses with many occupants. It may also be important as a short-term moisture source when a large number of additional people are in the house (for parties, family get-togethers, etc.).

Seasonal High Outdoor Absolute Humidity

During the mild portion of the heating season the absolute moisture content of cool outdoor air may briefly exceed that of warm indoor air. This situation may be most relevant during the fall, when it can retard the effectiveness of ventilation in reducing indoor humidity. A recent Canadian study of 14 homes tested in the late winter/early spring revealed that between 64 and 249 pints of moisture per day were brought into the houses due to above-grade air leakage (34:5)—an amount several times greater than that assumed to be produced by a typical family of four (13).

Vegetable Storage Indoors

Moisture added through indoor storage of fresh vegetables, such as potatoes and onions, apparently has not been estimated. Isolated reports by building officials of excessive winter humidity attributed to large-scale indoor storage of potatoes have been received (3).

Whirlpoools, Steambaths, and Saunas

Moisture added through whirlpools, steambaths, and saunas is not commonly estimated or known. Humidity contribution from a sauna is generally minor because usually only small quantities of water are poured over hot rocks (for example, one dipper of a pint or less of water at a time). A residential steambath generator uses about 6 to 8 pints of water per bath, which should be largely contained in a tight steambath enclosure. Humidity from a whirlpool depends on water temperature (generally around 95° F.) and amount of exposed agitated water surface. Quirouette calculates that the moisture generated from a square foot standing pool of 78° F. water in a room at 68° F. and 50 percent RH is .05 pint per hour (24:55). With standing water temperature at 100° F., this amount increases to .075 pint per hour (for a 6x6 hot tub with 100° F. standing water, moisture generated would be 2.7 pints/hour). In an equal size whirlpool, water-air jets would increase this amount.

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