



COLD CLIMATE
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Home Indoor Winter Relative Humidity: What is Acceptable?

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This publication addresses the issue of indoor relative humidity in cold climate housing according to the following variables:

- Window condensation
- Other visible interior surface condensation, mold, and dust
- Human health considerations
- Furniture considerations
- Concealed condensation
- Occupant comfort

Collectively taking these variables into consideration, it may be concluded that indoor winter relative humidity is most desirable around 40 percent; generally this level may be maintained without excessive window condensation when windows have three or more glazings; and residents must be alert to other indicators of visible and concealed condensation.

Window Condensation

Window condensation is frequently cited as the key visible indicator of excessive indoor relative humidity. To prevent condensation-related damage to window components and finishes, a number of sources list the maximum allowable indoor relative humidity (assuming 70° indoor air temperature) by outdoor air temperature (assuming 15 MPH wind) and type of window. The table on the next page summarizes approximate values.

These values will vary depending on window tightness, distance and nature of spacing between glazings, direction and speed of wind, actual indoor room temperature, and air movement across the inside window surface. For example, if a window is deeply recessed or covered in a way that restricts indoor air currents from reaching the window, condensation can occur at a lower indoor relative humidity. Restrictive coverings that may increase condensation include curtains, blinds, and interior screens. Also, if a window sash is not tightly weatherstripped and/or a storm window is very tight,

condensation can occur on the storm window at a lower indoor relative humidity. Finally, short-term window condensation may occur with cold weather and high wind until indoor humidity falls below these values.

A major limitation in popular window condensation calculations involves a focus upon thermal properties at the center of glass sheets or glazings. This procedure neglects the thermal conductivity of spacers separating the glazings, the thermal conductivity of window frames, convective heat transfer dependent upon airspace and temperature variations, window airtightness, comfort related to radiant heat transfer, and interior or exterior window insulation. More efficient windows use plastic, not metal, spacers between glazings as well as wood, vinyl, composite, or metal with thermal breaks for window frames.

THE VALUES IN THIS TABLE MUST BE INTERPRETED WITH CAUTION. Concealed condensation within wall and ceiling can take place at these or lower levels of relative humidity. Furthermore, visible condensation on ceilings and walls can take place at these or lower levels due to poor circulation or stratification of room air (especially in bedrooms of houses that do not have forced-air heating), thermal bridges related to nails and framing, lower room temperatures, and convection of air in cavities including that due to "wind washing." In addition, maximum permissible relative humidity to prevent condensation-related damage to windows does not necessarily reflect what may be best for human health or for maintenance of furniture.

Other Visible Interior Surface Condensation and Mold

These problems are often indicators of insulation voids or excessive indoor relative humidity and generally appear most noticeably in areas of poor ventilation and

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Type of Window (Approximate R-Value)	Indoor Relative Humidity— Condensation Expected by Outdoor Temperature (°F)							
	+40°	+30°	+20°	+10°	0°	-10°	-20°	-30°
Single Glazing (0.7 to 1.1)	43%	32%	24%	18%	12%	8%	5%	2%
Window Plus Usual Storm (1.6 to 2.3)	58	48	40	32	27	22	18	14
Sealed Double Glazing (1.7 to 2.3+)*	63-68	54-58	47-50	40-43	32-37	28-30	24-28	20-24
Window Plus Tight Storm (1.7 to 2.3)	72	65	58	52	47	41	37	32
Sealed Double Glazing Plus Storm (2.5 to 3.2+)*	72-75	68-70	60-63	54-58	48-52	43-48	39-43	36-39
Sealed Quadruple Glazing (3.5 to 4.0+)*	78	73	69	64	60	57	54	50

*Plastic films, gas-filled sealed windows, low-E or low-emissivity coatings, and interpane baffles increase thermal resistance or R-Value; see Nisson in reference section for more information.

colder surfaces. Common areas include outside walls in closets, cabinets or behind furniture; surfaces over wall studs and ceiling joints; and carpet-covered concrete floors in direct contact with soil. Wall and ceiling staining over framing may be compounded by wood-burning heating. Adding insulation, reducing winter indoor humidity, and/or improving ventilation can lessen these problems. Also, increased air circulation over condensation-prone surfaces will reduce surface condensation.

Health Considerations

In general, it is agreed that too much humidity is as undesirable as too little. The effects of relative humidity (rh) appear to reflect the following pattern (see Figure 1):

- bacteria increase at 30 percent or less and 60 percent or more rh.
- viruses increase at 50 percent or less and 70 percent or more rh.
- fungi increase at 60 percent or more rh.
- mites increase at 50 percent or more rh.
- respiratory infections increase at 50 percent or less and unknown above 50 percent rh.
- asthma difficulties increase at either less than or higher than 50 percent rh.
- chemical interactions increase at 30 percent or more rh.
- ozone production increases at 75 percent or less rh.

Overall, the optimum range of relative humidity for health purposes for the general population is believed to be between 40 to 60 percent. However, this range may result in concealed condensation that can adversely affect structural components. Or, it can result in visible condensation that can damage windows and support mold growth on surfaces where room air circulation is poor, where thermal bridges occur due to framing, or where convection occurs in cavities. Mold growth in such cases can lead to upper respiratory irritation.

Furniture Considerations

While it is generally accepted that excessively low humidity will cause glued joints in furniture to loosen

and, perhaps, cause delamination of some veneers, the level at which problems occur has not been documented. It is also generally recognized that low humidity may damage wooden musical instruments. On the other end of the humidity continuum, it is known that formaldehyde used as adhesive (water soluble) in some new furniture, carpeting, paneling, cabinets, and other building products is released faster when humidity is above 50 or 60 percent.

The U.S. Forest Products Laboratory's recommended moisture content (MC) for wood used for interior furniture flooring and woodwork is an average of 8 percent MC (6 to 10 percent MC range) at time of installation in Minnesota and most areas of the United States. An 8 percent MC (6 to 10 percent range) in wood is at equilibrium when relative humidity is held at 40 to 45 percent (30 to 55 percent range) at 70°F. The durability of glued wood products depends on the type of glue used, moisture conditions, and other factors. Commonly-used woodworking glues generally retain their strength when wood does not exceed about 15 percent MC (about 75 percent rh at 70°F).

Although documentation has not been found, it is probably wise to avoid subjecting fine furniture and wooden musical instruments to sudden or frequent humidity or moisture changes. Severe changes to avoid may include moving items from a heated home to a humid basement or unheated attic; placement of items near fireplaces or other heat sources; placement of items near outside doors; and large temperature changes related to thermostat set-back.

Concealed Condensation

Concealed condensation in wall and ceiling-roof cavities is primarily associated with airflow from the indoors into the cavities, which is called *exfiltration*. The air flow paths include electrical outlets and switches; holes drilled for wiring and plumbing; cracks between interior trim and drywall; and poorly-fitted exhaust fan ducts. During the winter, moist indoor air that penetrates into cavities condenses on wall and roof sheathing, as well as on the backside of siding. Siding condensation may be more pronounced in higher locations in walls with fiberboard sheathing and, in other walls,

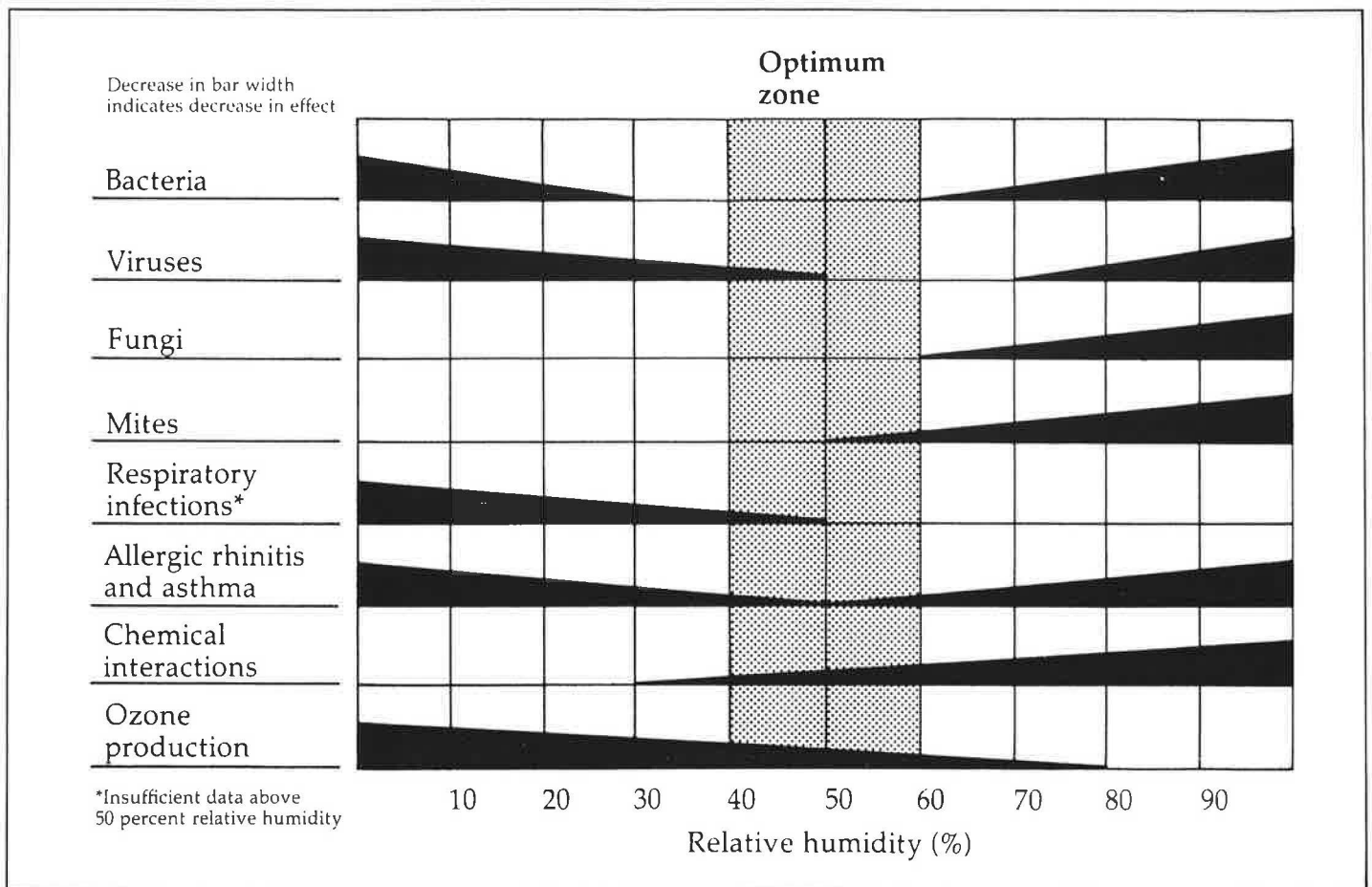


Figure 1. Optimum relative humidity ranges for health. (From: Sterling, Arundel, and Sterling. "Criteria for Human Exposure to Humidity in Occupied Buildings." *ASHRAE Transactions*. 1985, Vol. 91, Part 1)

concentrated at joints of plywood and rigid insulated sheathing.

It appears that most wall and ceiling cavity condensation dries rapidly at the end of the heating season and there is little risk of decay. However, if sheathing paper or other components severely retard the drying of concealed condensation, rapid decay can occur. Furthermore, other superficial indicators of concealed condensation are generally unacceptable: buckling of siding; moisture blisters in exterior paint; moisture staining of exterior paint; and ceiling damage due to melting of frozen condensation in roof-ceiling cavity (may be mistakenly blamed on roof ice-damming).

The risk of concealed condensation should be reduced by sealing air leakage bypasses into wall and roof-ceiling cavities. For further information, contact:

- the Minnesota Energy Information Center at 296-5175 in the Minneapolis/St. Paul area or 1-800-652-9747 (ask for "Energy") elsewhere in Minnesota; or
- the National Center for Appropriate Technology (NCAT) at 1-800-428-2525; or
- your local utility.

Occupant Comfort

Information on this subject related to relative humidity has not been completely established through objective standards. This is partially due to the fact that human thermal comfort is determined by the interplay of air temperature, air movement, and radiant heat transfer as well as relative humidity. These factors are further complicated by differences in human activities and thus, respiration and perspiration, and differences in human clothing. Static electricity, under some conditions and with certain materials, has a maximum occurrence when relative humidity ranges from 25 to 35 percent. Generally, relative humidity of 45 percent will eliminate or reduce static shock with many materials. Wool and some synthetic fabrics may require higher relative humidity to eliminate static nuisance. However, higher humidity (over 50 or 60 percent) can result in chilliness or clamminess.

According to the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE), "...it seems logical that extremes of humidity are undesirable and that, for human comfort, relative

humidity should neither exceed 60 percent nor be less than 20 percent."

Special comfort problems, such as cold drafts, cold floors, and cold windows or walls are more appropriately addressed by action other than increasing indoor winter humidity.

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