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Relative Humidity

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Introduction

What relative humidity should I have in my home? Seems like a simple enough question. However, the answer can sometimes be difficult to understand.

Elevated relative humidity at a surface – 70 percent or higher - can lead to problems with mold, corrosion, decay and other moisture related deterioration. When relative humidity reaches 100 percent, condensation can occur on surfaces leading to a whole host of additional problems. An elevated relative humidity in carpet and within fabrics can lead to dust mite infestation and mildew (mildew is mold growing on fabrics).

Low relative humidity can lead to discomfort, shrinkage of wood floors and wood furniture, cracking of paint on wood trim and static electricity discharges.

The key is not to be too low and not to be too high. High enough to be comfortable, but low enough to avoid moisture problems associated with mold, corrosion, decay, and condensation.

Unfortunately, determining the correct range depends on where the home is located (climate), how the home is constructed (the thermal resistance of surfaces determines surface temperatures), the time of year (the month or season determines surface temperatures), and the sensitivity of the occupants.

Limits to Relative Humidity—Comfort and Health Aspects

How low can you go? Comfort wise at least, the 2001 ASHRAE Fundamentals (8.12) tells us that at dew point temperatures of less than 32 degrees F, complaints of dry nose, throat, eyes, and skin occur. A dew point of 32 degrees converts to a relative humidity of 25 percent at 68 degrees.

How high can you go? Again, using comfort as the criteria, the 2001 ASHRAE Fundamentals (8.12) tells us that a relative humidity of 60 percent should not be exceeded.

This is consistent with ASHRAE Standard 62-2001 Ventilation for Acceptable Indoor Air Quality, which recommends that the lower boundary of the relative humidity range be limited to 25 percent and the upper boundary of the relative humidity range be limited to 60 percent (Figure 1).

Now, it is important to consider the ASHRAE definition of comfort: "combinations of indoor space environment and personal factors that will produce thermal environmental conditions acceptable to 80 percent or more of the occupants within a space." Remember that you can't please all of the people all of the time.

The ranges cited above do not consider health, except indirectly. Some people love to live in desert climates, and some people love to live in the tropics. The upper limits from a health perspective are indirectly derived from a desire to control the growth of mold, bacteria, and other disease vectors. Similarly, for the lower limits, although the lower limits tend to be arguably “healthier” from a disease vector perspective. Dry conditions do not favor mold, most bacteria, and other disease vectors. However, some have argued that dry conditions dry out the mucus linings of the respiratory system and therefore make it more difficult for the body to fight off invaders. The other side of the argument is that there are fewer invaders to worry about.

As can be expected, individual sensitivities and susceptibilities vary greatly, and it is typically very difficult to generalize with respect to relative humidity and health. Having said it is difficult to generalize, we will do so anyway. Keeping relative humidity in the 25 percent to 60 percent range tends to minimize most health issues – although opinions vary greatly.

Incorrect recommendations in the popular press often lead occupants and homeowners to over humidify homes during the winter. The range of 40 percent to 60 percent relative humidity is commonly incorrectly recommended for health and comfort reasons. As we will see, there is a big difference between 25 percent as a lower limit rather than 40 percent – particularly in very cold and cold climates.

To complicate things further, most people are not capable of sensing relative humidity fluctuations within the range of 25 percent to 60 percent. If the relative humidity drops below 25 percent, most people can sense it. Similarly, if the relative humidity rises above 60 percent most people can sense it. In the range of 25 percent to 60 percent the majority of people cannot sense any difference. The range of 25 percent to 60 percent is typically defined as the comfort range for this reason. This is very different than people sensing temperature variations. Most people can sense a difference in temperature within a range of 1 to 2 degrees. Less—below 0.1 degrees—if they are married (just kidding).

Comfort is of course different than health. When relative humidity drops below 25 percent there have been some reports in the medical literature of eye irritation in office workers using computers. Breathing difficulties have been reported in some individuals when relative humidities drop below 15 percent due to the mucus linings of the respiratory system desiccating. However, there is no medical consensus in this regard.

Determining the Humidity Limits—the Debate

Many people believe that 25 percent relative humidity as a lower level is still too high. The debate breaks predictably into several camps with the engineers (the aircraft people being the most vocal) arguing for no lower limit for health and only a discussion on comfort. Whereas the lung researchers and some MD’s argue that until there is definitive research, why not keep the level high from a prudent avoidance perspective. This of course terrifies the microbiologists and mold researchers since higher lower limits clearly lead to mold growth in buildings and are associated with microbial contamination in typical residential humidifiers.

So on the lower limit there is no real consensus, but only a current compromise recommendation. It is pretty clear that the lower limit will not go up. The only question is how low it will end up. At present, 25 percent relative humidity is the current compromise recommendation within ASHRAE.

On the upper end, there is an emerging consensus. Interior relative humidity should be maintained so that a 70 percent relative humidity at a building surface is avoided in order to control mold growth and should never rise above 60 percent in any event.

Relative Humidity, Surface Humidity, and Condensation

Consensus among microbiologists gives the critical relative humidity for adverse biological activity to occur on building envelope surfaces to be 70 percent. Where a relative humidity above 70 percent occurs at surfaces, mold growth, dust mite growth, decay, corrosion, etc. can occur. Therefore, conditions should be maintained within a building such that the critical 70 (or higher) percent relative humidity at a building envelope surface does not occur. Due to climate differences, interior conditions which must be maintained to avoid the critical relative humidity at a surface vary from region to region and time of year. They also vary based on the thermal resistance of the building envelope.

This means in winter months in cold climates interior relative humidity should be kept as low as possible but within the comfort and health range (i.e. above 25 percent if you believe ASHRAE Standard 62-2001). In the summer months it means that interior relative humidity should never exceed 60 percent for both comfort and health reasons.

There is a fundamental difference between relative humidity measured in the middle of a conditioned space, and the relative humidity found at surfaces due to the significant difference in temperature typically found between surfaces and the air in the middle of a conditioned space.

For a given sample of air containing water, relative humidity goes up as the temperature goes down. If the air in the middle of a room is 70 degrees at a relative humidity of 40 percent, any surface below 45 degrees will be able to condense water. Any surface below 54 degrees will have air adjacent it at a relative humidity of 70 percent – the mold limit.

Whereas when air in the middle of the room is 70 degrees at a relative humidity of 25 percent, the temperature of a condensing surface drops to 32 degrees from 45 degrees. And a surface with a relative humidity adjacent to it of 70 percent drops to 40 degrees from 54 degrees.

In other words, for condensation to occur with air at 70 degrees and a relative humidity of 25 percent, surfaces need to be colder than 32 degrees. For mold to grow, surfaces need to be colder than 40 degrees. Of course, in a nice and happy coincidence, mold does not like to grow at surfaces below 40 degrees, but will happily grow at 54 degrees. What does this tell us? Well, if surfaces are likely to be cold – say like in the winter - you are better off having a lower relative humidity.

Where relative humidities near surfaces are maintained below 70 percent, mold and other biological growth can be controlled. Since relative humidities are dependant on both temperature and vapor pressure, mold control is dependant on controlling both the temperature and vapor pressure near surfaces.

Surface Humidity and Building Assemblies: Applications in Heating Climates

In heating climates, mold growth on interior surfaces occurs during the heating season because the interior surfaces of exterior walls are cool from heat loss and because moisture levels within the conditioned space are too high. Mold growth control is facilitated by preventing the interior surfaces of exterior wall and other building assemblies from becoming too cold and by limiting interior moisture levels. The key is to prevent relative humidities adjacent surfaces from rising above 70 percent. The thermal resistance of the building envelope and the local climate determine the interior surface temperatures of exterior walls and other building assemblies. Controlled ventilation and source control limit the interior moisture levels.

Experience has shown, that where interior moisture levels in very cold climates during the heating season are limited to the 25 percent relative humidity at 70 degrees, relative humidities adjacent to the interior surfaces of exterior walls (of typical code minimum thermal resistance) fall below 70 percent and mold growth is controlled. The colder the climate (for the thermal resistance of any given building envelope) the lower the interior relative humidity necessary to prevent 70 percent relative humidities occurring adjacent interior surfaces of exterior walls. Building enclosures of similar thermal resistance (building code minimums) located in Minneapolis, MN and Cincinnati, OH should be limited to different interior moisture levels during the heating season. A 25 percent interior relative humidity at 70 degrees would be appropriate for Minneapolis. Whereas interior relative humidities up to 35 percent at 70 degrees would be appropriate for Cincinnati – which is located in a cold climate rather than a very cold climate like Minneapolis. Correspondingly, the higher the desired interior relative humidity, the higher the thermal resistance necessary to control relative humidities adjacent to interior surfaces.

In a mixed climate, during the heating season, interior moisture levels should be limited to 45 percent relative humidity at 70 degrees. This limits the relative humidity adjacent to the interior surface of exterior walls to below 70 percent for the typical thermal resistance found in most building assemblies in this climate zone.

Surface Humidity and Building Assemblies: Applications in Cooling Climates

In cooling climates, interior mold growth also occurs because interior surfaces are typically cold and then exposed to moisture levels that are too high. The cold surfaces in cooling climates arise from the air conditioning of enclosures. When exterior hot air is cooled, its relative humidity increases. If the exterior hot air is also humid, cooling this air will typically raise its relative humidity above the point at which mold growth can occur (70 percent).

Where air conditioned "cold" air is supplied to a room, and this air can be "blown" against an interior surface due to poor diffuser design, diffuser location, or diffuser performance, creating cold spots on the interior gypsum board surfaces. Although this cold air is typically dehumidified before it is supplied to the conditioned space, it can create a mold problem on room surfaces as a result of high levels of airborne moisture within the room contacting the cooled surface. This typically leads to a rise in relative humidity near the surface and a corresponding mold problem.

If exterior humid air comes in contact with the interstitial cavity side of cooled interior gypsum board mold and other biological growth can occur. Cooling this exterior hot, humid air by air conditioning or contact with cool surfaces will raise its relative humidity above 70 percent. When nutrients are present mold and other growth occurs. This is exacerbated with the use of impermeable wall coverings such as vinyl wallpaper that can trap moisture between the interior finish and the gypsum board. When these interior finishes are coupled with cold spots (from poor diffuser placement and/or overcooling) and exterior moisture, mold and other growth can occur.

Accordingly, one of the most practical solutions in controlling mold and other biological growth in cooling climates is the prevention of hot, humid exterior air, or other forms of moisture transport, from contacting the interior cold (air conditioned) gypsum board surfaces (controlling the vapor pressure at the surface). This is most commonly facilitated by maintaining the conditioned space at a positive air pressure to the exterior and the installation of an exterior vapor diffusion retarder. Pressurization of building assemblies is expedited by airtight construction.

Interior moisture levels within the conditioned space should also be limited to 60 percent relative humidity at 75 degrees by dehumidification and source control to prevent mold growth on the interior surfaces within the conditioned space.

Humidity and Dust Mites

Experience has also shown that where conditions for mold growth are controlled, other biological growth such as dust mite infestations can also be controlled. Specifically, for dust mites to grow, 70 percent relative humidities are also necessary. Carpets located on cold surfaces, such as concrete slabs are particularly sensitive to dust mite growth. Carpets on cold surfaces should be avoided, or these surface temperatures should be elevated by the use of appropriate thermal insulation.

Humidity and Wood Shrinkage

Many people are concerned about wood floors and wood furniture being damaged if humidifiers are not installed. More often than not, people tend to over humidify their homes in an attempt to protect their wood floors and wood furniture. They need not do so if relative humidities are maintained in the range of 25 to 60 percent between winter and summer.

Let us examine the effect of varying humidity inside of a home between a low of 25 percent and a high of 60 percent on wood. Wood moisture content changes directly with exposure to varying relative humidity. The relationship is extremely well understood by generations of wood workers and furniture makers (Figure 2 from Hoadley). The moisture content of wood will vary from 5 percent moisture content by weight at 25 percent relative humidity to 11 percent moisture content by weight at 60 percent relative humidity. This results in a maximum change in dimension of approximately 2 percent tangential to the grain (Figure 3 from Hoadley). If the wood in question is oak, and the board is 4 inches wide, the maximum movement is 0.08 inches.

If we have a wood floor installed with 4 inch wide wood boards initially conditioned to the mid range of expected moisture content, i.e. 8 percent moisture content by weight, the range in movement is plus and minus 0.04 inches or approximately the thickness of a credit card. This is not an aesthetically displeasing or unacceptable range of movement. Of course if the wood is not initially conditioned to the mid range of the expected moisture content, then the movement can be two credit card thicknesses.

References

ANSI/ASHRAE Standard 55-1992: Thermal Environmental Conditions for Human Occupancy, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., Atlanta, GA, 1992.

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Hoadley, R.B.; *Understanding Wood*, The Taunton Press, Newtown, CT, 1989.

Figure 1

Relative Humidity and Comfort

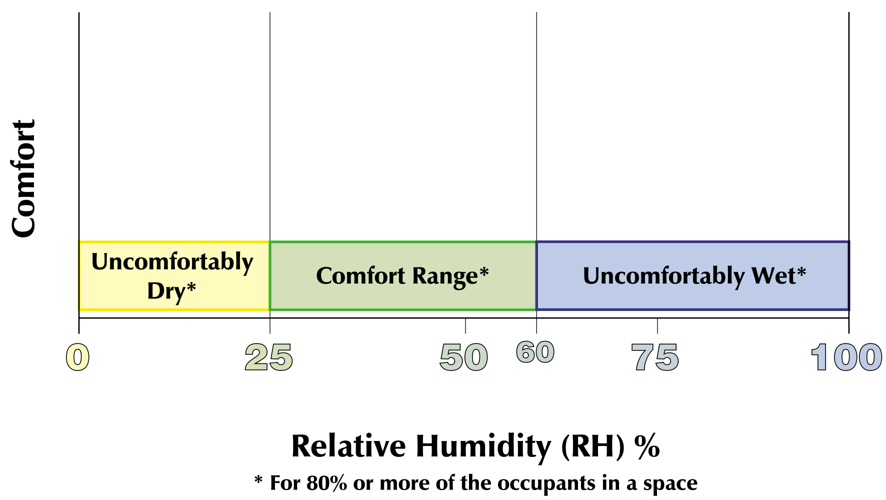
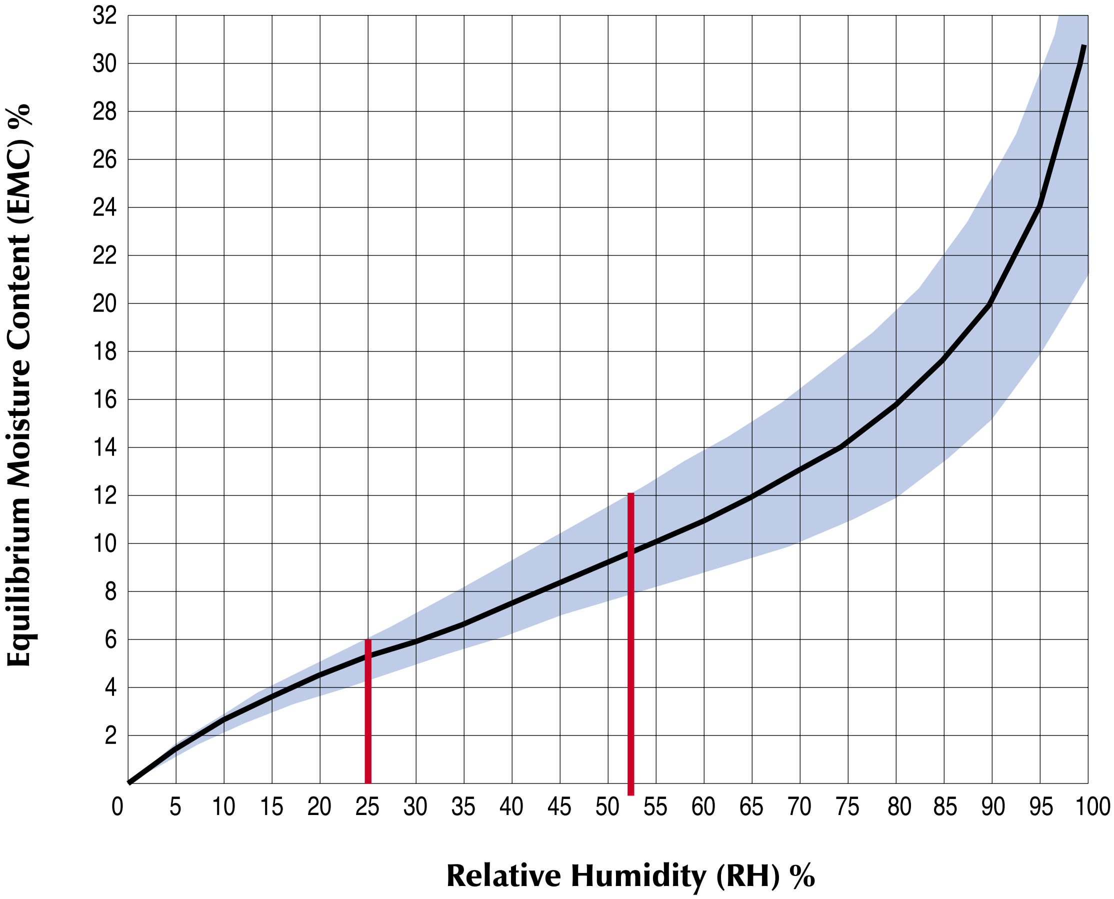


Figure 2

Moisture Content vs. Relative Humidity



The amount of bound water in wood is determined by the relative humidity (RH) of the surrounding atmosphere; the amount of bound water changes (albeit slowly) as the relative humidity changes. The moisture content of wood, when a balance is established at a given relative humidity, is its equilibrium moisture content (EMC). The solid line represents the curve for white spruce, a typical species with fiber saturation point (FSP) around 30% EMC. For species with a high extractive content, such as mahogany, FSP is around 24%, and for those with low extractive content, such as birch, FSP may be as high as 35%. Although a precise curve cannot be drawn for each species, most will fall within the color band.

Figure 3

Shrinkage vs. Moisture Content

Shrinkage vs. moisture content in northern red oak, a typical species