# Evaluating relative humidity: Key factors and measurements

Application Note

Understanding the relationship between dry bulb temperature, wet bulb temperature, relative humidity, and dew point temperature is essential in all facets of air conditioning. These psychrometric processes play an especially important role in building and materials integrity, occupant health and comfort, and overall indoor air quality.


The Fluke 971 Temperature Humidity Meter measures temperature from -20 °C to 60 °C (-4 °F to 140 °F), dewpoint, wetbulb, and relative humidity from 5 % to 95 %.

The good news, strangely enough, is that poor humidity and temperature levels are likely to cause occupant discomfort. Occupant complaints open a window of opportunity for the HVAC contractor to proactively discover related undesirable psychrometric effects on materials integrity and indoor air quality, including microbial propagation.

To evaluate relative humidity, wet bulb temperature, and dew point, HVAC technicians traditionally used a sling psychrometer and psychrometric chart. Now-days they use "humidity" meters that are accurate, more convenient, and usable in confined locations unsuitable for sling psychrometers.

## Standards adoption

Many states have adopted ANSI/ASHRAE Standards 55-2004 on humidity and 62-2004 on IAQ into their building codes. Since both standards have been newly updated, the following descriptions may help inspectors and contractors update practices to meet new requirements.

## Relative comfort

ANSI/ASHRAE standard 55-2004, Thermal Environmental Conditions for Human Occupancy, sets an *upper limit* to absolute humidity levels (0.012 humidity ratio, or 0.012 x 7000 = 84 grains moisture/lb dry air, also equivalent to a dew point (DP) of 62 °F), above which most occupants become uncomfortable.

Since all occupants won't be satisfied by the same thermal conditions, especially all at the same time, the standard attempts to identify a norm based on a PMV (Predictive Mean Vote) of 80 % satisfaction. From that, a PPD (Predicted Percentage Dissatisfied) of 10 % is calculated for general thermal comfort dissatisfaction and 10 % PPD from local ("my ankles are cold") comfort dissatisfaction.

The standard lists six primary factors that affect thermal comfort: metabolic rate, clothing insulation, air temperature, radiant temperature, air speed, humidity.

Understanding the combined affects of these factors can help technicians configure building systems appropriately.

## Humidity levels

ANSI/ASHRAE Standard 62-2001, Ventilation for Acceptable Indoor Air Quality, specifies that "Relative humidity in habitable spaces preferably should be maintained between 30 % and 60 % relative humidity to minimize growth of allergenic or pathogenic organisms."

The updated ANSI/ASHRAE Standard 62.1-2004, Ventilation for Acceptable Indoor Air Quality, is more specific. Now, relative humidity upper limits are based on peak values. "Occupied space relative humidity shall be

**Psychrometrics has a language all its own. To better understand how the various parameters interact to support thermal comfort, here are some of the more common terms described in this document:**

**Wet bulb temperature:** Represents the cooling effect of evaporating water, the temperature air will cool to when water evaporates into unsaturated air.

**Dewpoint temperature:** The temperature under which water will condense out of the air.

**Dry bulb temperature:** Air temperature determined by an ordinary thermometer.

**Relative humidity:** Ratio of water vapor pressure (amount currently in the air) to the saturation vapor pressure (the amount the air can hold) at a given air temperature.

**Met(abolic) rate**: The rate by which the body transforms chemical energy into heat and work through activity. In ASHRAE 55, this rate is measured in "met units" (18.4 Btu/h*ft$^2$).

**Sensible cooling:** Factors such as people, appliances, solar radiation, and infiltration create heat gain, each adding a sensible load to the environment within a house, office, etc. This sensible load raises the dry-bulb temperature. The process by which the sensible, or dry bulb, temperature is reduced without changing the moisture content of the air is referred to as a sensible cooling process.

**Latent cooling:** An amount of moisture is added to the inside air by plants, people, cooking, and other sources. A latent cooling process involves the condensation of moisture out of the air, reducing the wet bulb, dewpoint, and humidity levels, but leaving the dry bulb temperature untouched.

**S/T ratio:** Sensible to total heat ratio, or sensible heat factor. Of the total capacity of a cooling system, there is a sensible capacity and a latent capacity. The sensible capacity cools the air by absorbing heat to lower the dry bulb temperature. The latent capacity absorbs the latent heat of vaporization to remove moisture from the air without changing the actual dry bulb temperature. The S/T ratio, when used with a psychrometric chart, will provide the temperature at which a cooling coil must operate in order to support both sensible and latent heat removal.

**"Dirty socks syndrome":** A common condition during the cooling season that describes
an odor generated by burning airborne contaminants on an indoor coil, typically during the heat pump defrost cycle.

**clo:** A unit of measurement to express the amount of thermal insulation provided by clothing and other garments.

- Example: An ensemble including briefs, t-shirt, calf-length socks, shoes, straight trousers, long-sleeve dress shirt, double-breasted (thick) jacket totals 1.14 *clo**
- Example: An ensemble including briefs, short-sleeve knit sport shirt, walking shorts, sandals totals .31 *clo**

*clo values per ASHRAE 55-2004

designed to be limited to 65 % or less at either of the two following design conditions:

1. at the peak outdoor dew-point design conditions and at the peak indoor design latent load
   **or**
2. at the lowest space sensible heat ratio expected to occur and the concurrent (simultaneous) outdoor condition."

Good HVAC equipment selection practices generally recommend:

- 68 °F to 70 °F and 30 % RH (relative humidity) winter design,

**and**

- 74 °F to 76 °F and 50 % to 60 % RH summer design

**at**

- outdoor conditions of 97.5 % winter and 2.5 % summer dry bulb (DB).

This means that on average, 2.5 % of the extreme seasonal temperatures will be beyond equipment capacity. The equipment will be effectively undersized during these times.

This is critically important in equipment selection, since only 30 % of the operating hours of comfort cooling equipment occur within 5 % of outdoor design dry bulb temperature. Summer latent load control is more difficult to control at part load conditions, although most commercial equipment is staged or has some form of capacity control.

If comfort cooling equipment is oversized, moisture related complaints and problems will increase. Residential heat pumps should be selected according to the cooling requirements, not the heating requirements, especially in geographic areas where "dirty socks syndrome" is prevalent and air handling equipment is located in a crawlspace.

## Fungus

With enough knowledge and measurement, HVAC systems can be set at the appropriate summer and winter psychrometric conditions to discourage fungal growth. Conditions for fungal growth include spores settling on a surface, a micro-environment ensuring oxygen, optimal temperatures, nutrients, and moisture. Four of these conditions are found in nearly every environment. The most controllable variant is moisture.

Relative humidity above 60 % can support fungal growth on hygroscopic (sorbent) surfaces and hygroscopic surfaces at 80 % RH are likely to promote fungal growth. Nearly all surfaces are, or can become, sorbent and include painted surfaces, gypsum dry wall, carpets, wall coverings, and masonry products. Even glass with a dirt film and dust on it can support fungal growth.

Masonry products such as brick, cinder block and concrete are excellent sorbents and can adsorb vast quantities of moisture and become an inviting breeding environment for molds. The vapor pressure within the pores of manufactured masonry can be less than the vapor pressure of the ambient air which moves moisture from the air into the masonry pores. As the pores become wetted, capillary action takes over and fills the pores, thus providing an ideal breeding ground for fungal proliferation. This explains why some surfaces above dew point can become wetted.

## Condensation

Conditions that allow condensation to form on surfaces are more obvious, so action can be taken immediately. When a surface temperature is at or below the dew point temperature, condensation will form. Likely places for this to occur are on basement surfaces, crawlspace surfaces, cold water pipes, on air handling equipment and duct work, and unseen within envelope walls.

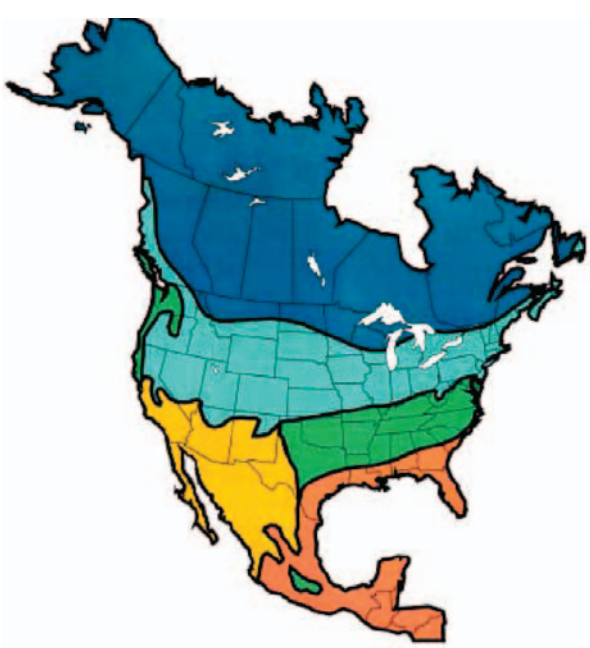
Basements typically require supplemental dehumidification equipment, since comfort cooling equipment can't control humidity in basements with minimal heat gain. Crawlspaces are particularly difficult and expensive to deal with, but sealing them with vapor barriers up to outside ground level, as well as insulating, and incorporating them into the conditioned space and adding additional means of dehumidification can control many crawlspace moisture problems, provided standing water or excessive ground moisture is not present (this assumes free crawlspace ventilation air is not required for fossil fuel burning equipment). Water pipes can be insulated. Air handling equipment and ductwork must be sealed air tight and insulated with no breaks in the vapor barrier especially when located outside of the conditioned envelope. Ductwork in all walls must be sealed to reduce unseen moisture migration due to air pressure differentials.

In cooling systems, relative humidity in supply ducts can be 95 % or higher, and evaporators and condensate pans will be wet. So, since moisture control is not feasible, control of airborne spores and food (dust and airborne particles) with good, tight fitting filtration systems in place is essential to control fungus growth. If evaporator components are resistant to UV radiation, a UVC "germicidal" light that can see the entire evaporator surface can kill mold and microbes. UVC lights should be selected that do not emit ozone, which is an irritant. Oversized equipment will experience reduced operating times resulting in less condensate production which may actually *increase* the microbial colonization on the fin surfaces.

## Temp-humidity meters

From dry bulb temperature and relative humidity measurements, temperature-humidity meters such as the Fluke 971 can calculate wet bulb temperature and dew point temperature, psychrometric points that are essential for HVAC evaluations and diagnostics.

- **Wet bulb** is very closely related to enthalpy, or the total heat in the air (dry bulb and wet bulb). In a psychrometric chart, the wet bulb lines are nearly parallel the enthalpy scale values. Return wet bulb temperature is mandatory for accurately charging a cooling system that incorporates a fixed restrictor metering device.
- **Supply and return wet bulb temperatures** across an evaporator can be used with a psychrometric chart or enthalpy table to calculate total cooling capacity, sensible and latent capacity, and S/T ratio.
- **Total heat** may be found by multiplying cfm x 4.5 x enthalpy difference across evaporator ($Q_t$ = cfm x 4.5 x $\Delta h$).



### Legend

Severe-Cold: A severe-cold climate is defined as a region with approximately 8,000 heating degree days or greater.

Cold: A cold climate is defined as a region with approximately 4,500 heating degree days or greater and less than approximately 8,000 heating degree days.

Mixed-Humid: A mixed-humid climate is defined as a region that receives more than 20 inches of annual precipitation, has approximately 4,500 heating degree days or greater or less and where the monthly average outdoor temperature drops below 45 °F during the winter months.

Hot-Humid: A hot-humid climate is defined as a region that receives greater than 20 inches of annual precipitation and where the monthly average outdoor temperature remains above 45 °F throughout the year*.

Hot-dry/Mixed-Dry: A hot-dry climate is defined as a region that receives less than 20 inches of annual precipitation and where the monthly average outdoor temperature remains above 45 °F throughout the year;
A mixed-dry climate is defined as a region that receives less than 20 inches of annual precipitation, has approximately 4,500 heating degree days or less and where the monthly average outdoor temperature drops below 45 °F during the winter months.

*This definition characterized a region that is almost identical to the ASHRAE definition of hot-humid where one or both of the following occur:
- a 67 °F or higher wet bulb temperature for 3,000 or more hours during the warmest six consecutive months of the year; or
- a 73 °F or higher wet bulb temperature for 1,500 or more hours during the warmest six consecutive months of the year.

- **Sensible vs. latent cooling and S/T ratio** can be found by plotting conditions on a psychrometric chart or from a psychrometric calculator.
- **Dew point** is critical in both summer and winter evaluations. Duct surface temperature must be maintained above dew point to prevent condensation whether inside or outside of the conditioned space.
- Winter indoor **relative humidity** must be kept low enough to ensure inside wall and window surface temperatures do not approach dew point. If condensation appears on window or wall surfaces, condensation hidden within envelope walls will be likely.

## Addressing comfort related complaints

With equipment that does not have capacity control, or is staged, most humidity-related comfort complaints occur at part load conditions when run times based on thermostat dry bulb temperatures are shorter. Less operating time means less moisture removal. Oversized equipment will only exacerbate this as well as increasing occurrences of detrimental coincidental conditions. Changing from a fixed restrictor metering device to a thermal expansion valve will ensure maximum evaporator capacity at part load conditions and utilize more coil surface for moisture removal.

Most cooling equipment can tolerate reduced air volumes of about 20 %. If evaporator air volumes are reduced from 400 cfm/ton down to around 325 cfm/ton, the evaporator temperature will fall further below dew point and remove more moisture from the air. This change will also reduce duct surface temperature and register temperature in the direction of dew point temperature and register throw, affecting air patterns in occupied spaces.

A dehumidistat can lower air volumes at increased humidity levels. Another alternative is to use a Timed-On-Control device, to provide reduced cfm for the first 5-10 minutes of cooling demand, and then switch to the design cfm to finish the cooling cycle. A portable dehumidifier can be located in areas of high humidity, such as a basement, reducing humidity, increasing heat gain, and forcing longer cooling cycles. Make sure rooms with intermittent high moisture gain, such as bathrooms, kitchens, and laundry areas are ventilated to the outdoors (not the attic or crawlspace).

## Addressing dew point and/or fungus related complaints

Ducts in unconditioned spaces carrying cool, humid air must be sealed airtight using an NFPA approved duct mastic. Any air leaks in a duct will render the insulation useless at that point and condensation is likely to occur. Duct wrap insulation must not be compressed by hangars. Hangars must be placed underneath duct wrap insulation. Duct wrap insulation barriers must be unbroken and sealed at the seams.

In unconditioned attics, increasing attic temperature may increase heat gain on ceilings below, but will reduce the occurrence of condensation on ducts. Attics in homes of newer construction techniques may result in lower attic temperatures, but this increases the chance of condensation on duct or air handler surfaces. Sealing attic vents and adding humidistat controlled flood lights to increase attic temperature can compensate for this.

Crawlspaces present unique opportunities. Typical crawlspace vent sizing is inadequate for controlling moisture by ventilation. 100 % ground cover vapor barrier up the inside wall to a height equal to the outside ground level, sealing the vents, insulating the perimeter walls, and treating it as a conditioned space is a preferred method of moisture control, often requiring additional supplemental dehumidification. Air handling equipment in a crawlspace must have excellent particulate filtration in place with no return side air leaks to reduce microbes and their food sources in the evaporator and supply duct. Humidity levels in basements must be regulated to less than 60 % RH to discourage microbial growth. Painting the surfaces of hydroscopic masonry (cinder blocks, brick, mortar) will reduce moisture retention, discouraging microbes.

## Resources

If the complex subjects briefly treated here pique interest for further study, additional resources are available through ASHRAE, at www.ashrae.org. The ASHRAE handbooks and monthly journal are an exceptional vehicle for discovery. Psychrometric charts are now available inside software programs that make easy work of the calculations. Other HVAC organizations include:

- ACCA (Air Conditioning Contractors of America) (**www.acca.org**),
- PHCC (Plumbing Heating Cooling Contractors) (**www.phccweb.org**),
- SMACNA (Sheet Metal and Air Conditioning Contractors' National Association) (**www.smacna.org**), and
- RSES (Refrigeration Service Engineers Society) (**www.rses.org**).

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