ENHANCED HVAC INFECTION CONTROL: HUMIDITY

Schnackel University

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Introduction

Next in our ongoing series of white papers on Enhanced HVAC Infection Control, we examine one of the most significant factors affecting the spread of disease within buildings - humidity.

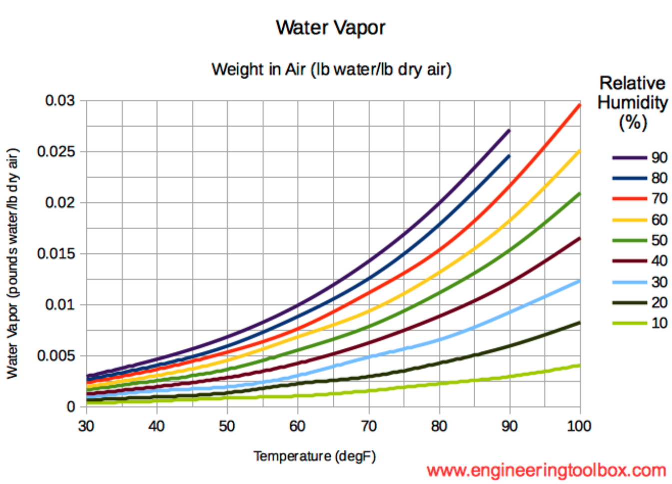
Humidity vs. Relative Humidity

The word "humidity" used on its own is a general term that does not define a specific measurable property of air. To be precise and measureable humidity must be classified as either Absolute, Specific or Relative.

Absolute Humidity is defined as the amount of water vapor (moisture) contained in the air, regardless of the temperature of the air. Absolute Humidity is typically measured in *lbs/ft*^{3} or *grains/ft*^{3} (*kg/m*^{3} or *g/m*^{3}).

Specific Humidity is defined as the ratio of the mass of water vapor in air to the total mass of the mixture of air and water vapor being measured. Specific Humidity is typically measured in *grains/lb (g/kg)*.

Relative Humidity is defined as the amount of water vapor contained in the air expressed as a percentage of the maximum amount of water vapor that the air can hold at the given temperature. The saturation level of air is the point at which water vapor will begin to condense out of the air and become liquid again (e.g. rain). The relative humidity at saturation is, by definition, 100%.



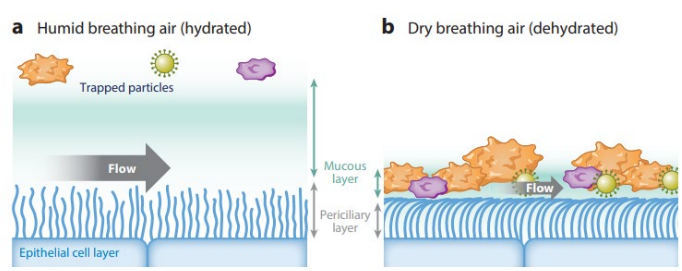
Relative Humidity vs. Temperature

When someone speaks of "humidity", without out any indication as to what type of humidity metric they are referring, it generally assumed to be Relative Humidity or RH, which is the most common and useful definition in terms of HVAC system design, human comfort and most environmental parameters.

In this white paper, we will be discussing how indoor air relative humidity affects human health and the spread of disease. Are there levels of indoor air RH that are beneficial to humans? Are there levels of RH that are detrimental to humans? What impact does RH have on potentially infectious agents? How do these levels compare?   And finally, how can we use the building's HVAC systems to maintain humidity levels at their optimal levels?

RH Effect on Humans

Numerous studies have shown that human biological processes do not function well in environments with very low RH levels. A relative humidity level of less than 30% can cause dry skin, dry eyes, induce asthma, increase infections, and induce fatigue. Importantly, dry air weakens the body's mucociliary clearance mechanism, which is a biophysical process the body uses to rid the respiratory system of pathogens before they reach the lung tissue.



Mucociliary Clearance Mechanism

Many studies have shown that our natural respiratory defense mechanisms function optimally when the relative humidity level of the air is between 40% and 60%. Studies have also shown that infected subjects have more severe symptoms when the relative humidity is low, as opposed to when the relative humidity is in this desirable 40%-60% range.

Conversely, high humidity also adversely affects many functions of the human body, including its ability to reject heat. The body relies heavily on the heat of vaporization to cool the skin surface and keep the body cool. If indoor RH levels rise above about 60%, this evaporative process slows and requires the body to produce more sweat to maintain its appropriate internal temperature. The body also reacts to high RH levels by increasing the rate of respiration and increasing blood flow to the extremities, resulting in feelings of lethargy and sluggishness.

High RH is also detrimental to those suffering from allergies, asthma and other respiratory illnesses. As the humidity levels rise, human respiration becomes more difficult, increasing the chances of an allergy/asthma attack or other forms of respiratory distress.

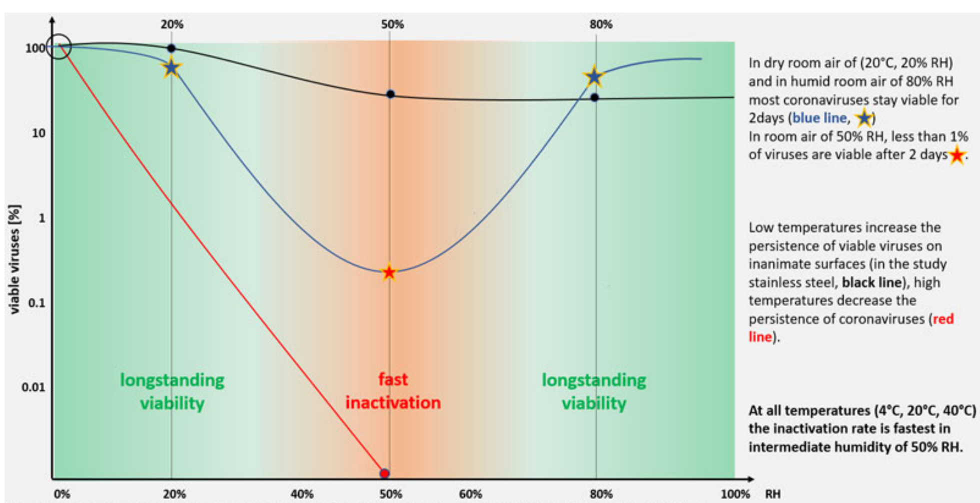
RH Effect on Pathogens

It has long been known that dry air coupled with cold temperature aids viral transmission. The annual patterns of the common cold and seasonal influenza viruses follows this phenomenon religiously. As temperate climates reach dry winter conditions, the incidence of colds and the flu inevitably increase until spring, when outdoor temperature and humidity levels rise and cases taper off. This fact has been known for centuries, but only recently have scientific studies conclusively identified the primary causes of these seasonal fluctuations in virus infections.

A comprehensive review of the most current research on the effects of seasonality on viral infections was recently pre-released by the *Annual of Virology* in an article authored by a team of doctors from Yale University and the University of Zurich (Moriyama, Hugentobler and Iwasaki) titled *Seasonality of Respiratory Viral Infections*. Click here for a link to the full review for an in-depth look at the mechanisms behind the seasonal virus phenomenon.

The current research repeatedly points to the impact that indoor relative humidity has on not only the human respiratory system's ability to fight off viral infections, but also the survivability and efficacy of the viruses' spread through airborne transmission. Low relative humidity has a very significant effect on airborne droplet transmission and the ability of the viruses to survive outside of a host carrier. This survivability applies to *all* droplet sizes, independent of their source, size or location. Even droplets located on contact surfaces (fomites) are impacted by the RH in the space, with conclusive evidence that midrange RH levels are the most effective at neutralizing the virus's ability to survive long enough to infect another host (person).

Nearly all recent studies have shown that a relative humidity range of 40% to 60% diminishes the ability of the virus to remain viable within a droplet, aerosol or fomite particle, minimizing the chances of a transmission dramatically. The impact of RH on aerosol particles is the most pronounced as shown in the graph below. Viability of the virus drops to 1% after 2 days in a 50% RH environment. This compares to over 80% virus viability



Graph 2 Inactivation of SARS Coronavirus–Surrogate TGEV after 2 days, at different temperatures and humidities. Outdoor temp. 4°C, room temp. 20°C und desert temp. 40 °C. Fastest inactivation at all temperatures in intermediate humidity.

Casanova LM et al, Effects of Air Temperature and Relative Humidity on Coronavirus Survival on Surfaces, APPLIED AND ENVIRONMENTAL MICROBIOLOGY, May 2010, p. 2712–2717 at 20% or 80% RH. A number of animal studies have confirmed that aerosol viral infection rates decrease significantly at midrange RH levels, while infection rates are *enhanced* at both low and high RH levels.

The research is conclusive: Relative humidity is one of the most influential variables in the fight against airborne and contact transmission of viruses, including the SARS-CoV-2 virus. This is particularly true for tight indoor environments. The current research also indicates similar humidity impacts on other microbiological organisms (primarily molds and bacteria), with even more pronounced results, particularly at high relative humidity levels.

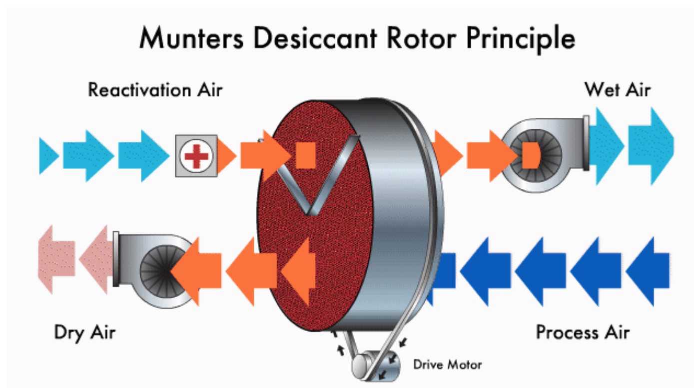
Summer Control of Humidity

A building's HVAC system can have a very dramatic impact on the relative humidity levels in the occupied spaces, provided the proper equipment and controls are implemented to monitor and control humidity levels directly. Unfortunately, most traditional HVAC systems are set up to only passively control humidity in the summer, through the natural condensation of humidity on cold cooling coils in the system.

Air conditioning systems are an extremely effective means of removing high summer humidity levels and most HVAC systems are *designed* to maintain indoor RH levels at or about 50-55% under summer design conditions. However, there is usually no active monitoring or direct control of the humidity levels, except in the most sophisticated buildings. Most often, summer humidity control only becomes a priority when excessively high humidity levels become apparent due to either light loading of the space, operational problems with the air conditioning equipment or defects in the design of the systems.

A thorough evaluation of the anticipated loading conditions, outdoor air ventilation rates, occupancy levels and the diversity of occupancy levels is essential to ensure that the air conditioning systems are properly designed and configured to address summer humidity levels independent of temperature control. With proper design, monitoring and control, a buildings' HVAC system provides the most economical and powerful means of keeping humidity levels within the desired 40% to 60% range that is ideal for infection control.

Under certain conditions, air conditioning systems alone may not be able to maintain acceptable indoor humidity levels during periods of high outdoor humidity. This can occur when the cooling equipment is oversized for the cooling load presented, or when outdoor air ventilation rates and outdoor air humidity conditions are too high for the air conditioning system to maintain acceptable RH levels. Under those conditions, other technologies can be applied, including reheat (hot gas, electric, hot water, etc.) or desiccant solutions to keep the indoor relative humidity levels below 60% at all times.



Winter Control of Humidity

Generally speaking, there is little to no control of winter humidity levels in most commercial and industrial buildings. Residential occupancies are more likely to include winter humidity controls, however these systems are usually aftermarket additions made by the occupants of the building as a result of the noticeable detrimental health effects of low humidity.

The lack of winter humidification in commercial and industrial buildings is primarily due to the fact that, until recently, the impact of low humidity levels on biological and viral efficacy was not well understood. Recent concerns over the rapid spread of the SARS-CoV-2 virus, particularly in the “super-spreader” events that have been widely publicized, along with the concern for reopening plans in the face of no proven vaccine therapy, has brought these concerns to the forefront.

Fortunately, there are a large number of time-tested, proven technologies that can be readily applied to both existing and new build situations without breaking the bank due to a high cost of implementation. Air humidification equipment has been around for over a century and is very effective and safe if properly designed, maintained and operated.

The best method of uniformly distributing humidity throughout the occupied spaces is with add-on systems for the central heating and ventilating systems that are already provided in the building. These systems generally rely on the generation of “clean” steam, which is injected into the airstream in the supply air ducts or HVAC equipment through in duct distributor units.

In Duct Steam Distributor

Steam-to-Steam Humidifier

The “clean” steam can be generated by a number of methods including small electric steam generators (electrodes), gas fired steam generators for larger systems or steam-to-steam humidifiers in large buildings that have available steam used for the building heating systems. The most common central humidifiers, particularly for retrofit applications, are electrode steam humidifiers, due to their versatility and ease of installation.

The selection of the best central humidification strategy should be the result of a through engineering study of the options available for a specific building in order to optimize the initial cost vs. the long term operating and maintenance cost of the system selected.

Humidifiers can also be stand-alone units, where the application of “clean” steam is not possible or practical at the heating and ventilating units. The stand-alone units are typically applied in a room by room basis and can be residential or commercial rated. The technologies are similar to the HVAC equipment based systems, however the steam is injected directly into the space rather than into the duct for distribution with the air ventilation system.

There is one type of humidifier system that should be avoided due to its potential to generate additional biological hazards at the source of the humidity being introduced into the airstream. Humidifiers relying on evaporation or evaporative pads tend to be very attractive due to their low initial cost, however unless they are meticulously maintained and periodically disinfected, they can become a significant potential source of hazards including Legionella, mold and other airborne biological contaminates.

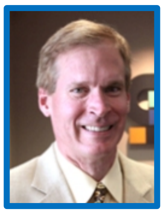
Summary

It seems that nature has laid out a relative humidity range in which humans are best able to defend themselves against viruses and that same range appears to be the range in which viruses are at their weakest. That optimal range is 40% to 60% RH. In the fight against SARS-CoV-2, as well as other biological hazards, it is important to maintain the indoor relative humidity within that ideal range, regardless of the season.

Indoor relative humidity plays a very important role in preventing the spread of respiratory infections. Pathogens literally thrive in air with less than 40% RH, however more importantly, they are not nearly as infectious in the 40% to 60% RH range. HVAC systems can be effectively used to maintain the indoor relative humidity levels in the desired range with the addition of the appropriate sensors and controls and, in temperate climates, the addition of humidification equipment.

About Pedro:

Pedro Ferrer, P.E., has been involved in the design of mechanical systems for malls, mixed-use developments, corporate offices, national retail roll-outs, commercial and institutional buildings for over 26 years with Schnackel Engineers.



About Gregory:

Gregory Schnackel, P.E., LEED AP has been involved in the design of mechanical, electrical, plumbing, fire protections and information technology systems for malls, mixed-use developments, corporate offices, national retail roll-outs, schools, hospitals, medical facilities, commercial and institutional buildings for over 40 years with Schnackel Engineers.

RESOURCES	
ASHRAE	https://www.ashrae.org/
Occupant Health, Building Energy Performance and Humidity - Stephanie Taylor, M.D., M. Arch.	https://www.ashrae.org/professional-development/tech-hour-videos
Low ambient humidity impairs barrier function and innate resistance against influenza infection	https://www.pnas.org/content/pnas/116/22/10905.full.pdf
Annual of Virology, Seasonality of Respiratory Viral Infections	https://www.annualreviews.org/doi/pdf/10.1146/annurev-virology-012420-022445
Influenza Virus Transmission Is Dependent on Relative Humidity and Temperature, National Institutes of Health	https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2034399/#:~:text=The%20stability%20of%20influenza%20virions,60%25%E2%80%9380%25).
Engineering Toolbox	https://www.engineeringtoolbox.com
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