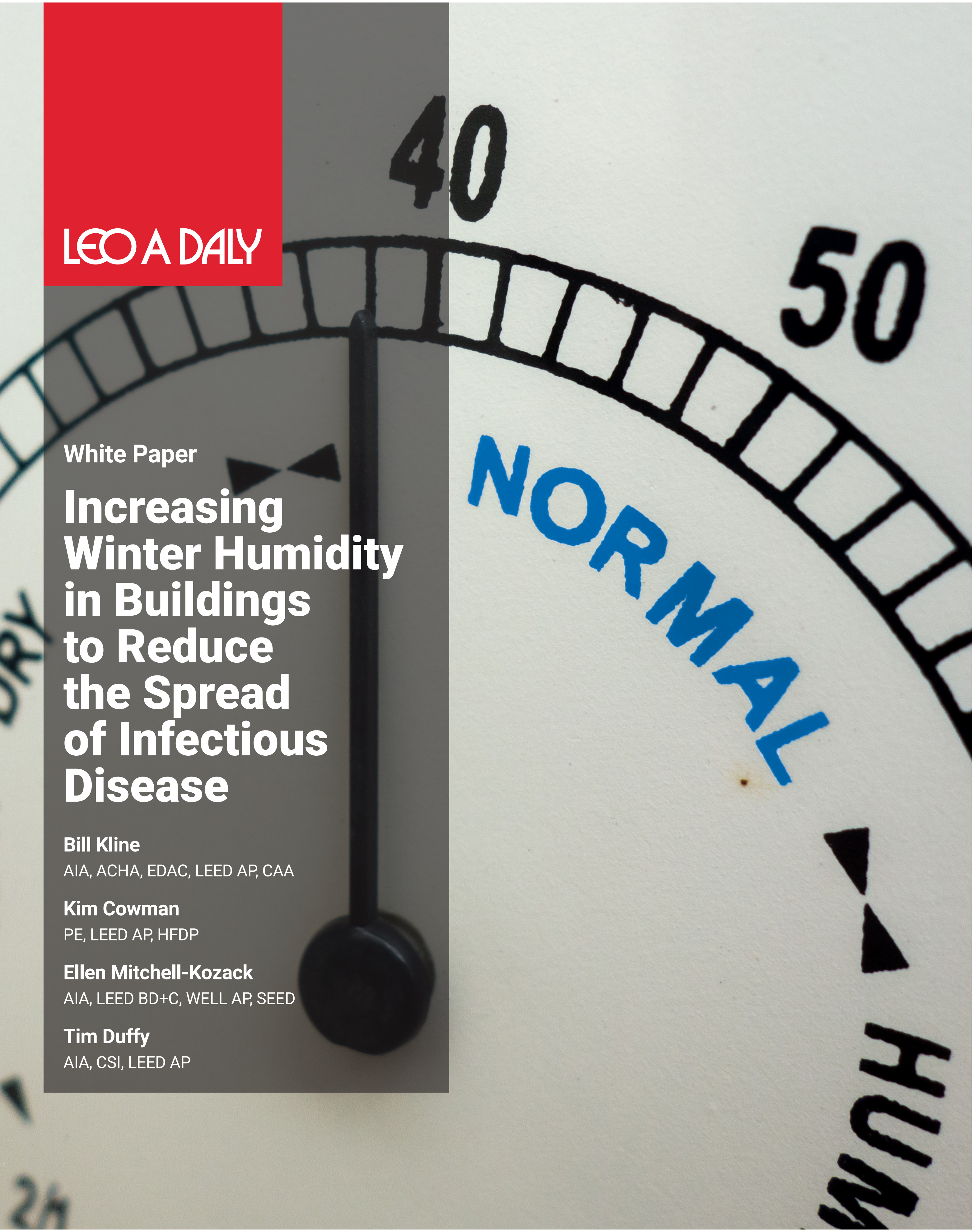

LEO A DALY

White Paper

Increasing Winter Humidity in Buildings to Reduce the Spread of Infectious Disease

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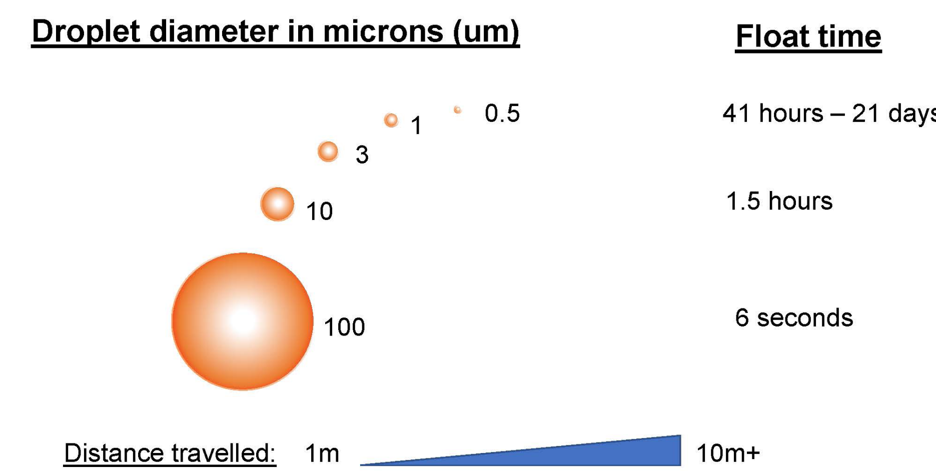
Summary

Interior relative humidity levels of at least 40 percent can substantially suppress all methods of COVID-19 spread, but especially airborne transmission. Yet most American buildings in cold and mixed climates operate at much lower levels of humidity during the winter, usually 20 percent or less. Simply adding humidifiers to raise the levels without a thorough investigation of the building envelope can cause catastrophic damage to the walls, ceilings and floors, reducing the lifespan of the building, increasing maintenance costs and energy consumption, and potentially causing additional health concerns such as mold growth and off-gassing of volatile organic compounds, which are health hazards.

There is a reason flu and colds spread more frequently during winter. Cold air lacks the moisture content of warmer months. Lack of moisture increases the number of infectious particles in the air and creates an atmosphere in which those particles can thrive. At the same time, dry air impairs human respiratory immune functions. This is the science behind a March 2020 report from the Annual Review of Virology and the longtime research of Stephanie Taylor, M.D., a distinguished lecturer for the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE).

In this whitepaper, LEO A DALY design experts offer solutions for building owners and operators who want to attain healthier levels of interior humidity to reduce the spread of COVID-19 and other illness. Every building has its unique characterisitics, but building modifications hinge primarily on mechanical systems, building enclosures and local climactic conditions.

Infectious droplets shrink, travel far and evade surface cleaning when the air is dry.



Credit: Dr. Stephanie Taylor

Below 40 percent relative humidity, there are an increased number of pathogens such as SARS-CoV-2 in the air, and increased viability (infectivity) of those particles.

"The state of vapor equilibrium in room air, expressed as saturation ratio or RH, affects all infectious droplets with respiratory viruses, independent of their source (respiratory tract or aerosolized from any fluid) and location (in air or settled on surfaces). RH therefore affects all transmission ways but has the most pronounced effect on airborne transmission."

Annual Review of Virology. "Seasonality of Respiratory Viral Infections." March 20, 2020

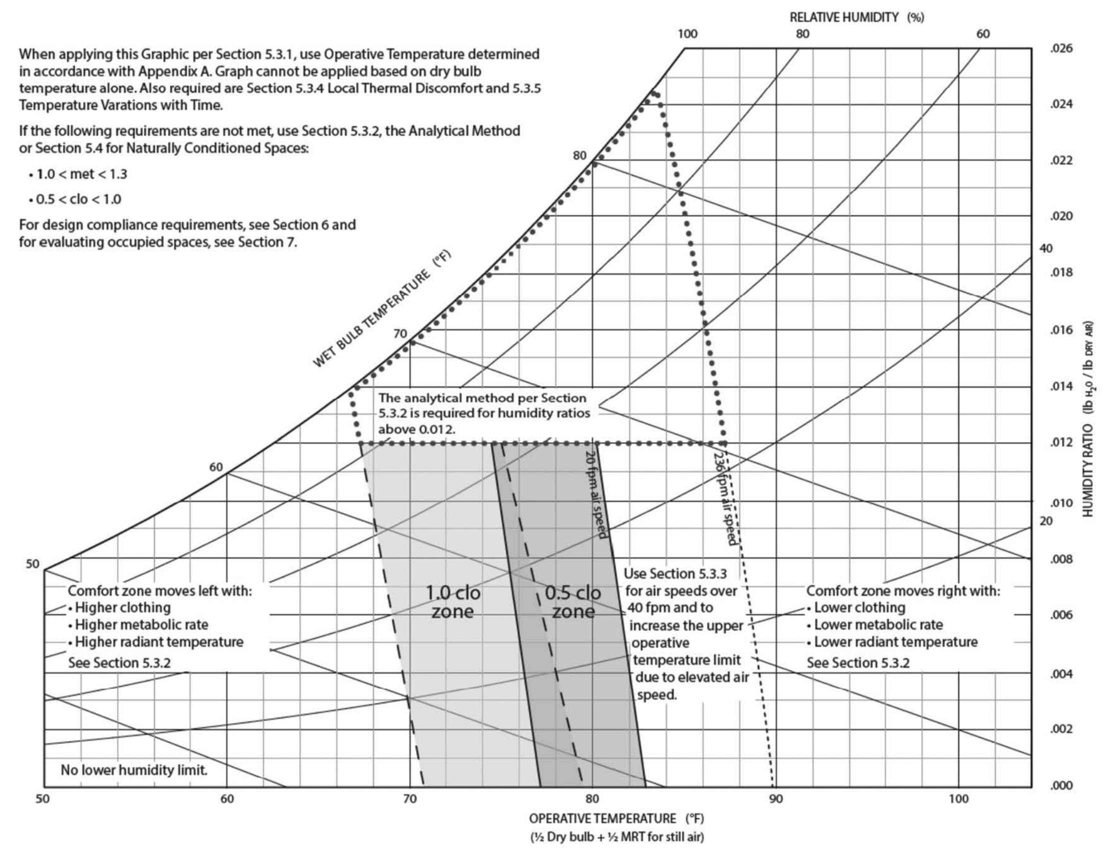
"Low ambient humidity impairs barrier function and innate resistance against influenza infection."

Proceedings of the National Academy of Sciences, USA. May 19, 2019

The RH “Sweet Spot”

Recent research from Yale University School of Medicine, the University of Zurich and Harvard School of Medicine, among others, identifies 40 to 60 percent relative humidity (RH) as ideal for human health. This “sweet spot” is the theme of the website 40to60rh.com. Above 60 percent, indoor humidity can initiate growth of bacteria, mold and fungi, and it can degrade the building itself, initiating rot, rust and off-gassing from building components on the interior.

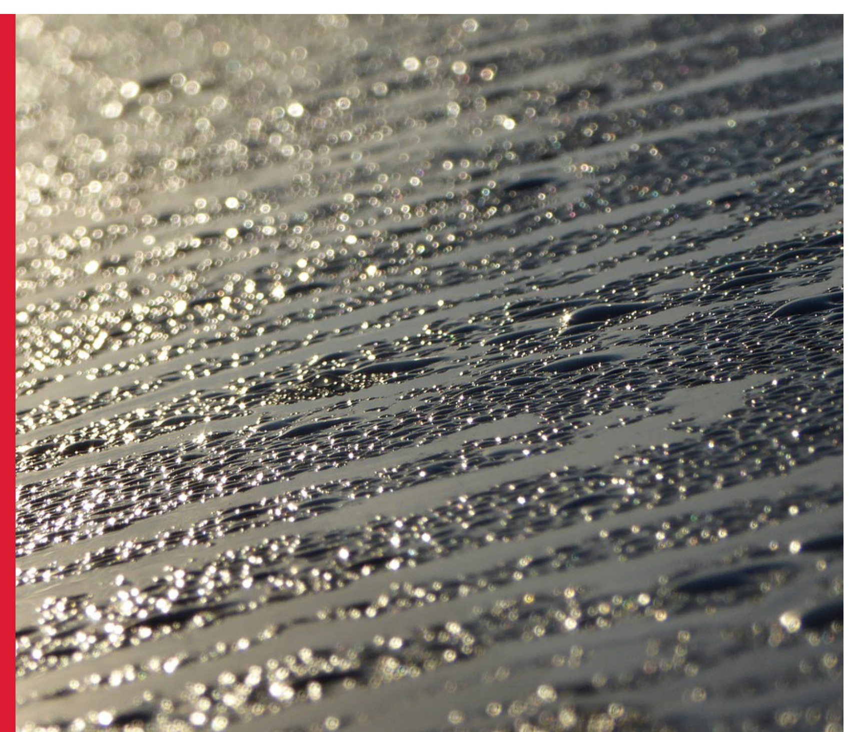
On the low end of the spectrum, RH below 40 percent allows pathogens to thrive, floating freely from person to person. It increases the number of pathogens in the air and increases each pathogen’s infectivity at the same time. These pathogens include flu and colds as well as SARS-CoV-2, which causes COVID-19. Research shows that the drier air also impairs our bodies’ natural respiratory immunity functions.



What is RH?

Relative humidity is a way of describing how much water vapor is present in the air, as a percent of the maximum at a given temperature and pressure.

The lower the air temperature, the lower the capacity to hold moisture.

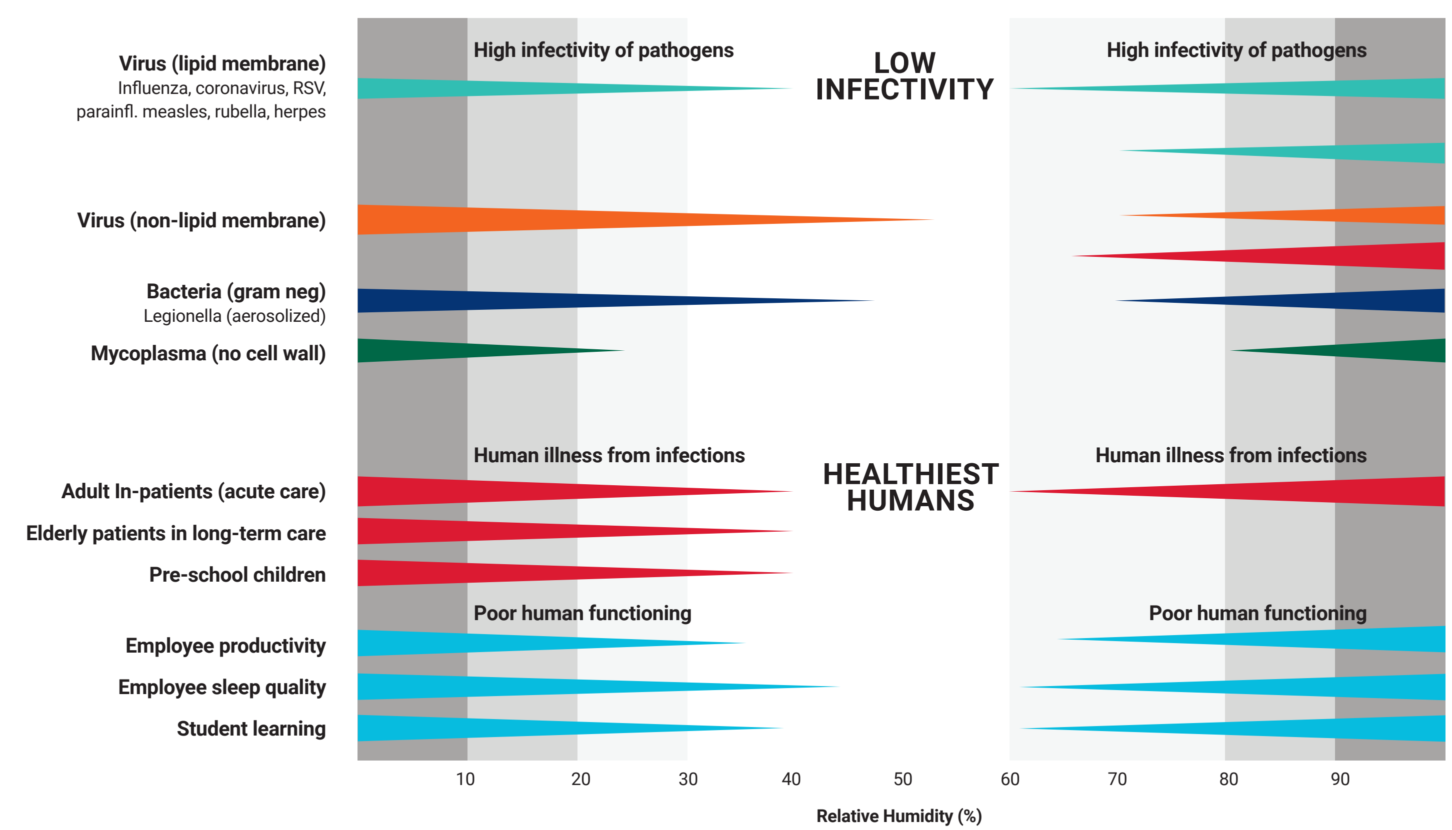


Thermal Comfort and Human Health

The typical standard governing relative humidity in buildings comes from the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE). ASHRAE Standard 55 addresses “thermal comfort.” For typical commercial building occupancies, the standard sets an upper humidity ratio limit to control the impact of high humidity on thermal comfort. In the summer months, in many climates, a building’s mechanical systems actually remove humidity to keep RH below 60-65 percent. The challenge comes with **winter**, when cold, dry air is warmed to temperatures adequate for thermal comfort. The result is an RH level around 20 percent or less, well below the 40 percent needed to minimize the spread of pathogens.

Left: ASHRAE Standard 55 — Thermal Environmental Conditions for Human Occupancy *Standard 55 indicates a range of indoor environmental conditions to achieve occupant thermal comfort. Factors include humidity and temperature, as well as thermal radiation, air speed, activity level (metabolic rate), and occupant clothing (degree of insulation).*

Below: The Taylor Chart *Credit: Dr. Stephanie Taylor, M.D., M Arch. 2019*



Mechanical Systems

It is very uncommon for mechanical systems to actively humidify space in buildings. Notable exceptions include healthcare uses, museums and specialized storage facilities.

Winter's colder air is inherently dry and most mechanical systems warm the outside air to achieve thermal comfort within a building, effectively reducing RH in the occupied space.

Consequently, it is not uncommon in climates with cold winters to see relative humidity levels dip below 20 percent into the teens or even single digits. This includes mixed climates with roughly equal annual heating and cooling requirements. The only humidity supplied inside these buildings would come from occupants respirating or from some other process taking place inside such as cooking or industrial processes involving steam or large bodies of water such as a whirlpool.

Adding humidity to achieve 40 percent or better RH during winter will require adding equipment to supply the humidity.

The Right Humidification System for the Building

Most people are familiar with home humidifying systems. For example, a small, stand-alone unit used in certain rooms of your home. This concept is also applied on a commercial scale. This implementation would make sense in a more process-oriented space such as a warehouse or manufacturing facility, where limiting the extent of humidified areas is desirable.

For most other buildings, there is a more holistic approach. Humidification would be injected directly into the building's central air-handling systems. This method would constantly supply humidified air throughout a building.

Implementation and Energy

Looking at a representative, existing, 120,000-square-foot building, with packaged rooftop air-handling equipment, we caclulated estimates of adding the required humidification infrastructure.

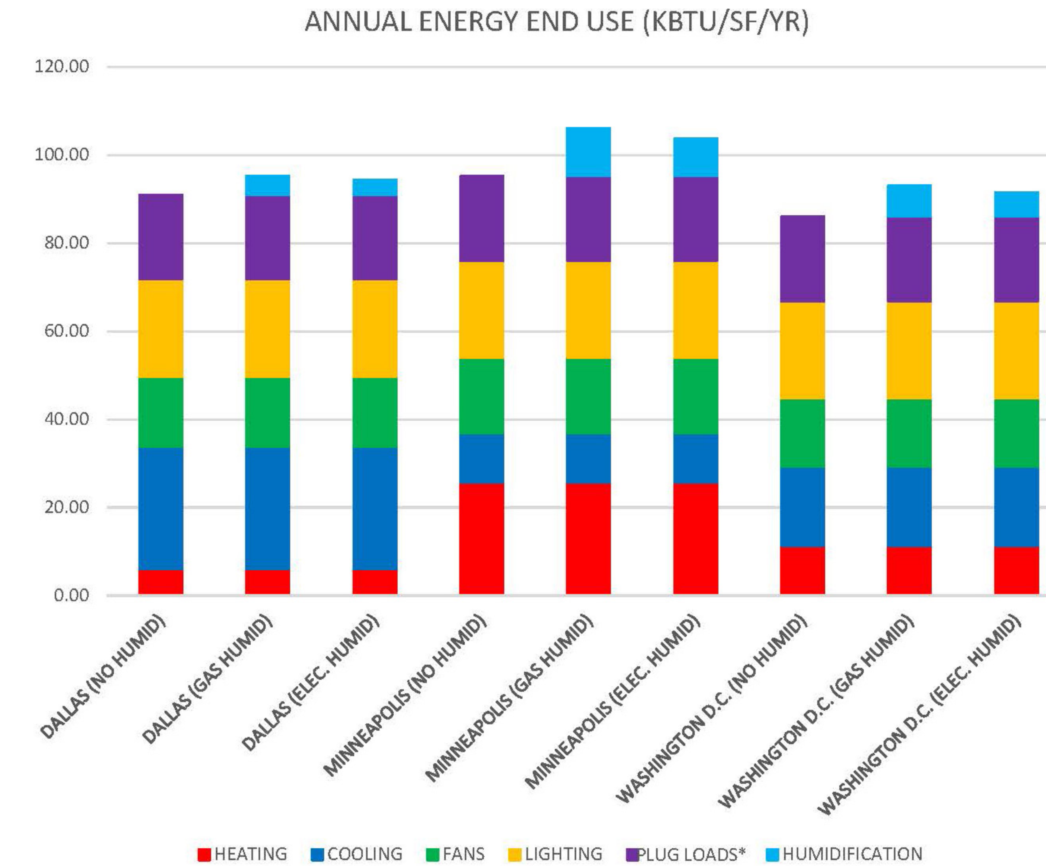
Equipment required would include either natural gas or electric steam generators, steam dispersion grids located in the supply ductwork, appropriate steam supply and condensate piping and some level of water treatment such as water softeners or reverse osmosis systems.

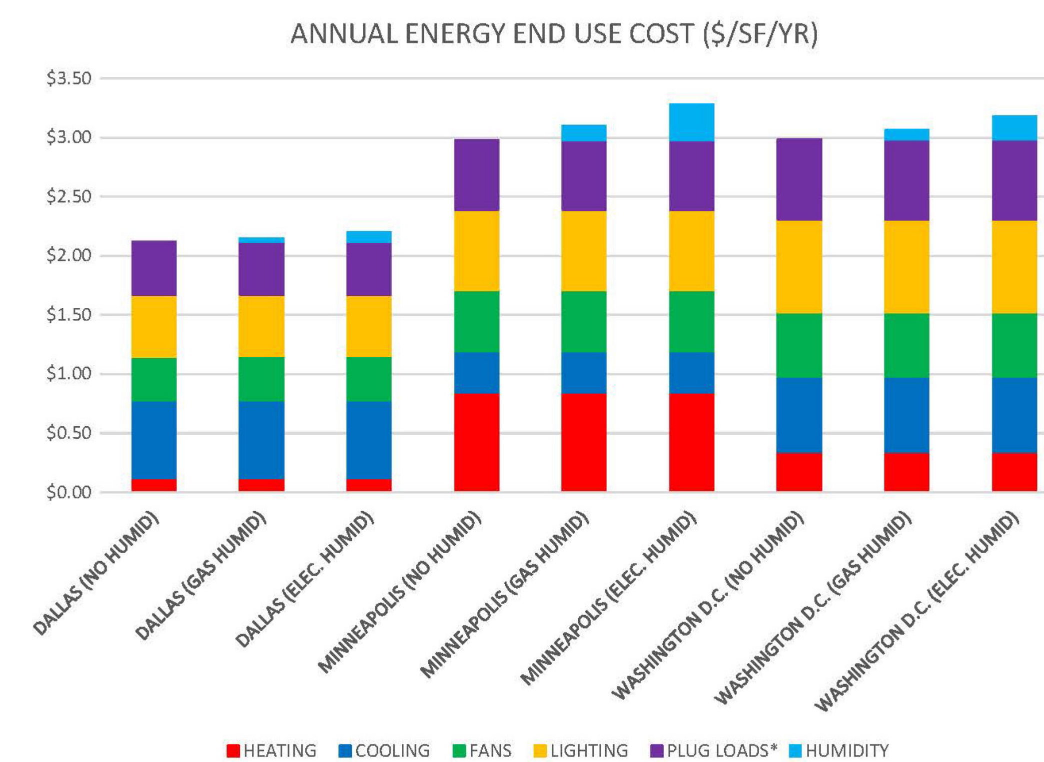
The results range from about $2.50 to about $3 per square foot.

Furthermore, additional energy will be required to generate and inject the humidity into a building. If the building enclosure is upgraded at the same time, including more efficient insulation, energy savings would then offset a portion of the humidification cost.

Buildings typically use electricity or natural gas energy to generate humidity. Which one is used will influence the cost. As demonstrated on the following pages, extreme winter climates will see a bigger impact to the energy costs.

For natural gas systems in a very cold climate like Minneapolis, humidification may result in a 2.5 percent increase in your overall energy costs, and electric systems might require an overall cost increase of around 8 percent. In a more termperate climate like Dallas, lower costs of 1.5 percent to about 3.5 percent are more likely.





The graphs at left illustrate the impact on energy use and cost for adding humidification to an existing 120,000 square-foot commercial building.

These calculations are based on real-world scenarios but every building and location will have its own unique circumstances.

Building Enclosures

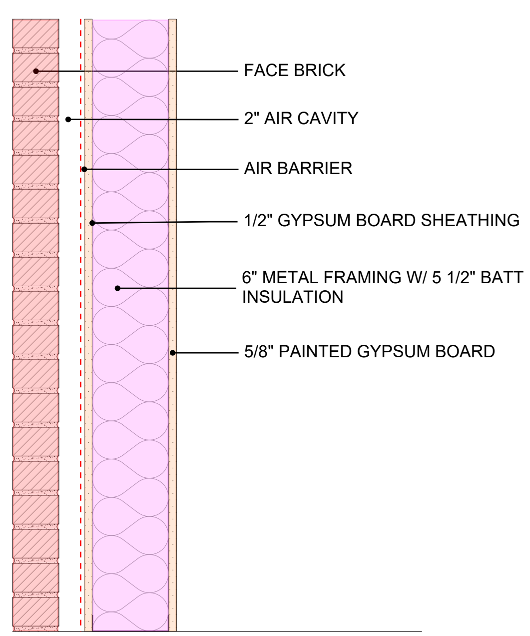
Architecture will determine whether a building can safely perform at 40 percent RH.

Increasing humidity is not simply a matter of adding the mechanical infrastructure needed to generate and distribute it throughout a building.

While some newer buildings' envelopes may be able to accomodate a higher humidity level without incident, for many buildings, the enclosure may be inadequate to contain higher levels of water vapor. The enclosure, or envelope, comprises the walls, window systems, roof assemblies and sub-grade infrastructure.

With higher RH comes increased potential for condensation, the droplets that form on a cold glass in a warm environment. Imagine that the warm environment is your workplace, school or hotel, and the cold surface is a surface within the walls.

During winter, the temperature of the wall is very cold on one side and warm on the other. Air with RH50 on the warm inside will condense on surfaces that reach approximately 53 degrees, the dew point. If this dew point is within the wall assembly, damage to the envelope may occur.



Wall Assembly Types

The exterior walls of a building are made of several layers. For the purposes of this discussion, the dividing line between interior and exterior will be defined as the air/vapor barrier, a layer within the wall assembly. If condensation occurs inside the air barrier, negative outcomes could result.

Depending on the makeup of the wall assembly, condensation inside it could lead to corrosion, mold, mildew and off-gassing of poisonous fumes. While it is a good practice to reduce volatile organic compounds in construction, many materials in existing buildings contain chemicals susceptible to these outcomes if humidity is increased and condensation forms inside the air barrier.

Wall assemblies for buildings have evolved over decades. Energy efficiency has driven code changes progressively, aiming to increase the amount of insulation. Specifically, to increase "continuous insulation." An adequately insulated wall will push the dew point outside the air barrier and allow for the building to safely perform with RH at 40 to 60 percent.

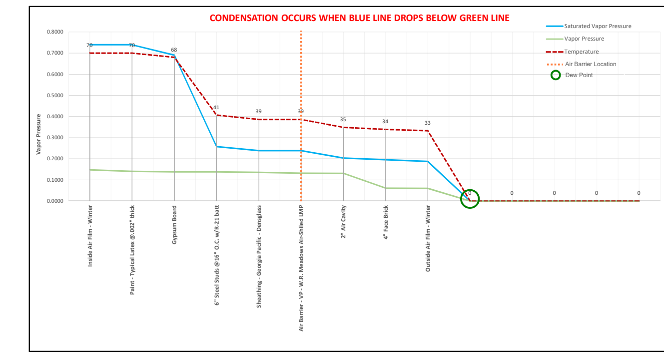
The Vapor Drive

LEO A DALY has developed a Vapor Drive tool, whose output measures the performance of a wall assembly (input) and level of relative humidity (input).

It uses ASHRAE climate data for **winter** temperatures, and is effective for cities across the full range of climactic conditions.

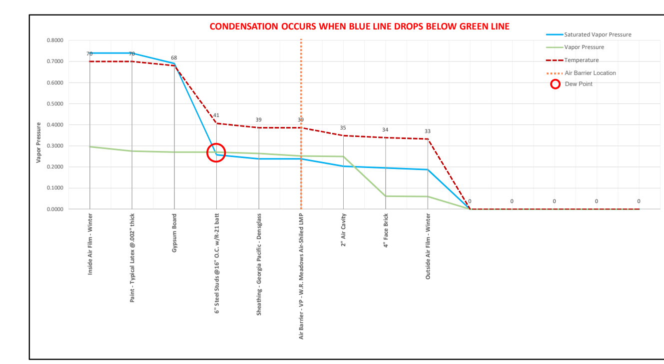
Every building is unique, and its enclosure is influenced by location, building type, and codes and standards in effect when the building was built. The Vapor Drive tool can be used on any building. For illustration, we have utilized representative assemblies for buildings approximately 30 years old, and working forward as energy codes became more stringent over time and required more insulation.

To the right are examples of Vapor Drive results for a typical wall assembly on a 30-year-old building, the first at RH 20 and the second at RH 40.



WALL TYPE B IN DALLAS IN WINTER, RH = 20

- *Status-quo*
- *Condensation occurs where the blue line (saturated vapor pressure) crosses the green line (vapor pressure), indicated by a green circle*
- *Note that condensation safely occurs far to the right (exterior) of the air barrier (vertical orange line) with current average levels of relative humidity (20 percent)*



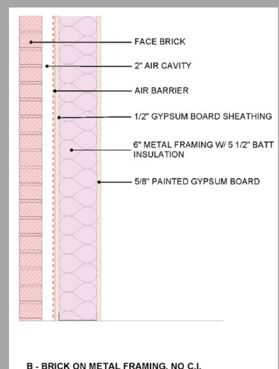
WALL TYPE B IN DALLAS IN WINTER, RH = 40

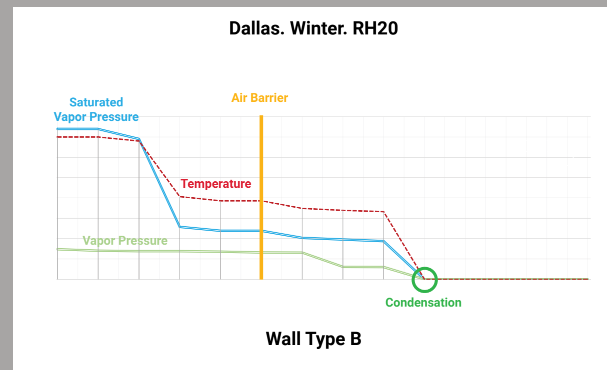
- *Modified to 40 percent RH*
- *This shows the same performance analysis as above, this time with RH raised to a healthier 40 percent*
- *Note that condensation has moved far left of the air barrier, indicated by a red circle*
- *Condensation occuring in this location could innitiate material degradation, shortening the life of the building and initiating mold, rot, and poisonous fumes*

Wall assemblies have increased in efficiency as energy codes have changed over time.

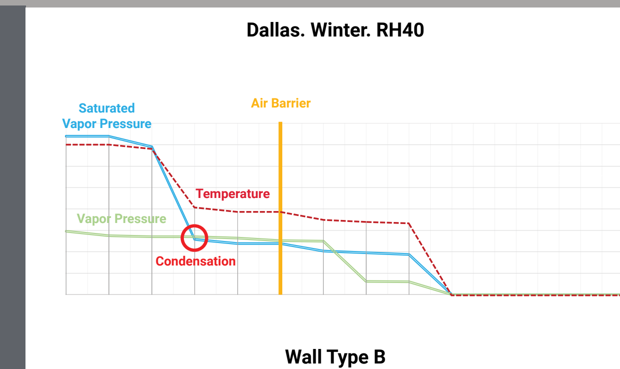
RH 20

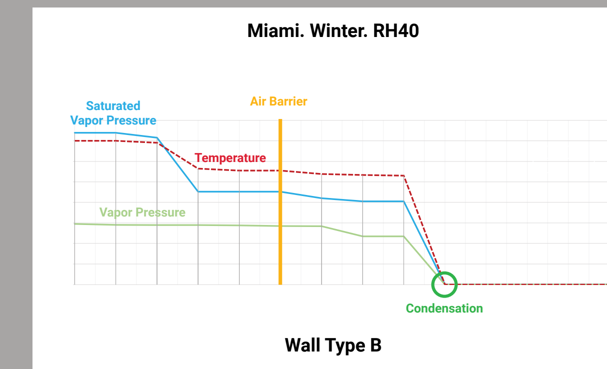
RH 40





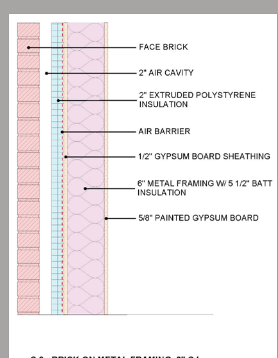
Vapor analysis for Wall Type B with no exterior continuous insulation, using winter temperatures for Dallas, demonstrates how condensation moves inward with increased interior RH, even in a relatively warm climate. Colder climates will have worse effects. A building enclosure of this type would require modifications to raise RH to 40.

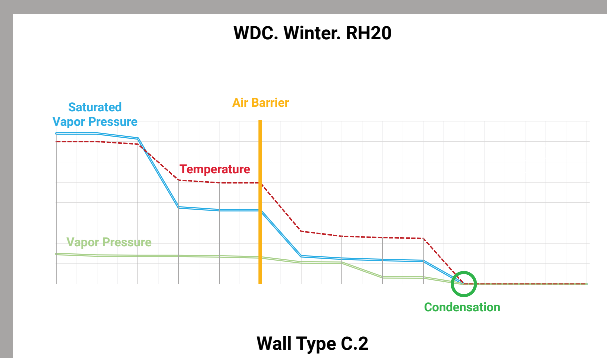




Miami's mild winters make this wall type suitable for increasing RH to 40 percent without condensation moving inside the walls.

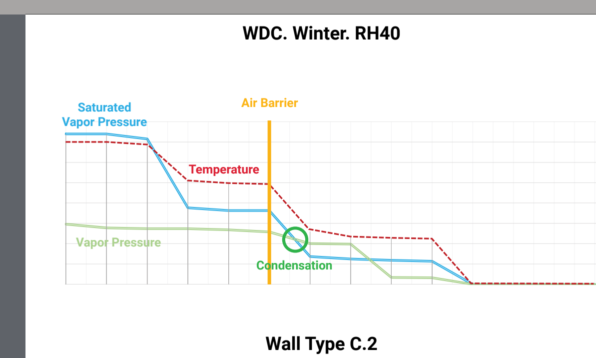
Early 1990's



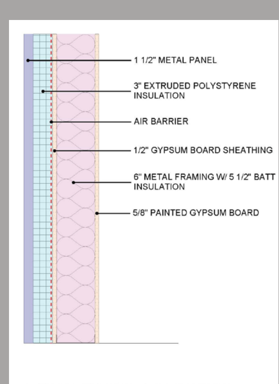


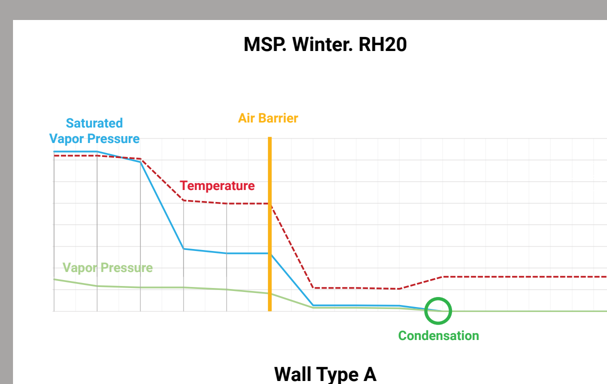
Wall Type C.2 is representative of a building built in the early 2000s, as energy codes began to require exterior continuous insulation.

Vapor analysis at RH 20 and 40 in Washington, D.C.,'s mixed climate demonstrates movement of condensation inward, although it remains safely outside the air barrier. A building enclosure of this type would probably not require envelope modifications to raise RH to 40 percent.



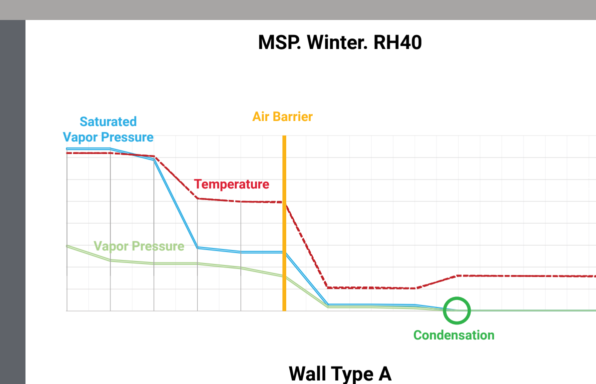
Early 2000's





Wall Type A is representative of a newer building, its walls assemblies meeting current standards.

Even in the coldest climate we tested (Minneapolis), the enclosure performs well at RH of 40 percent.



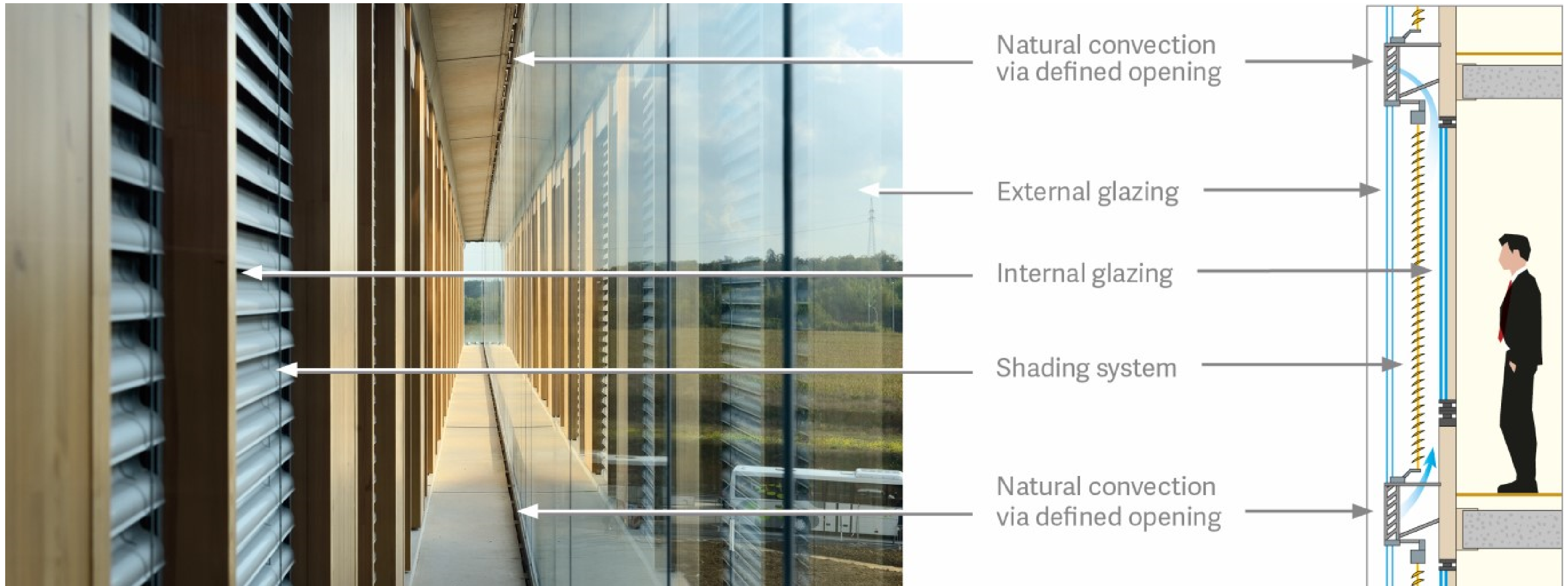
Today

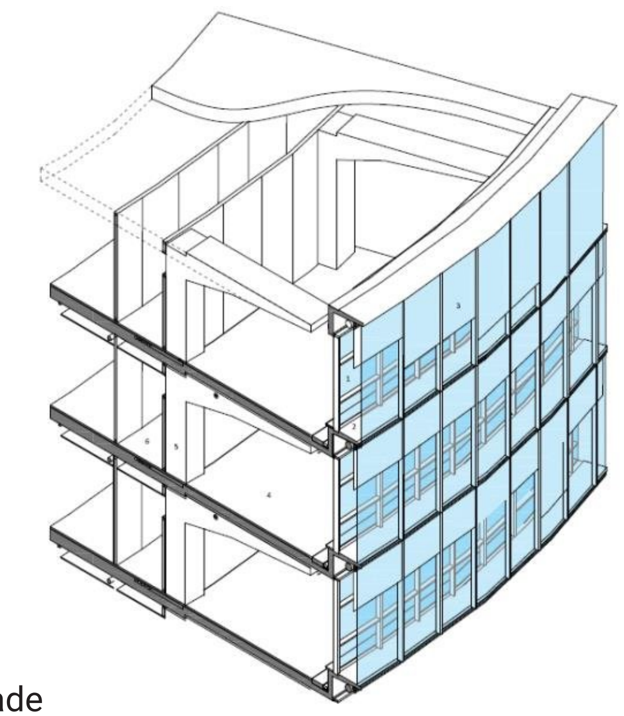
Exterior Continuous Insulation

Why It Matters

To maintain elevated interior relative humidity in cold winter climates, thermal bridges must be minimized, and the insulation and air/ vapor barrier must be continuous. In some colder climates, insulation is also required at foundation walls and under slabs on grade at the perimeter of the building.

Discontinuity of the air/vapor barrier allows warm, moist air to leak and condense, while discontinuity of the insulation allows the dewpoint to move inside the building, resulting in a constant source of condensation within the wall assembly.





Double Facade

Retrofit Solutions for Existing Buildings

Modifications to allow an existing building enclosure to perform safely at a healthier 40 percent RH.

Once designers perform vapor analysis on a building's roof, wall, glazing and sub-slab assemblies, they will have a better understanding of its ability to perform at RH 40. In cases where analysis shows condensation forming inside the wall, there are several choices regarding modification to the building enclosure.

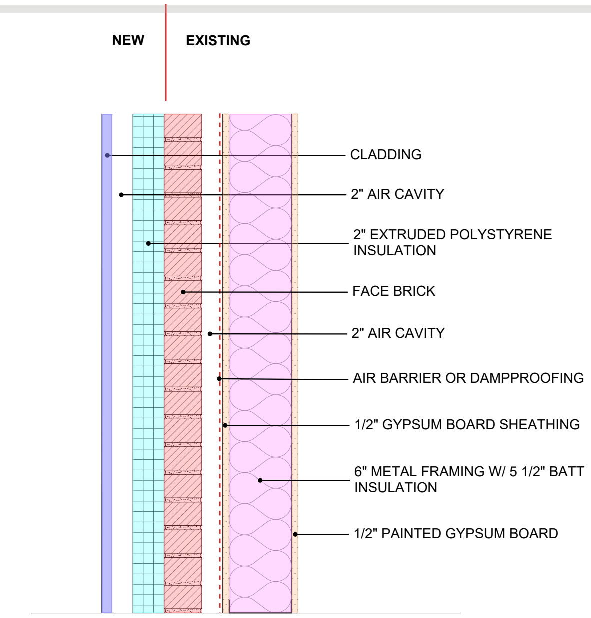
The most involved and costly modification would be a **complete reskin** of the building, bringing it up to current state of the art. This option offers all the advantages of an efficient, modern building envelope – greater efficiency and lower maintenance.

This option preserves the original building, and is a more sustainable option compared to demolition, because the building's embodied energy is maintained and less additional carbon is produced. By preserving the original building, this option is also advantageous from an environmental perspective because it minimizes embodied carbon emissions associated with concrete, steel and aluminum production.

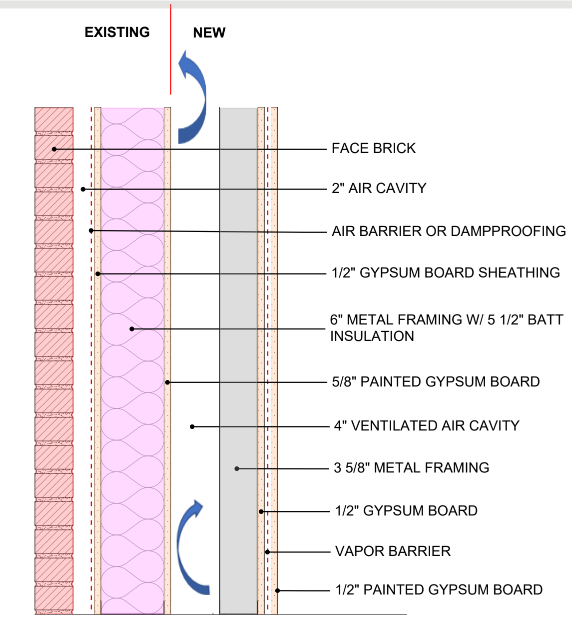
An **envelope retrofit,** which utilizes the existing envelope as a subsurface, and provides a new exterior finish, insulation, and air/vapor barrier, may provide a cost effective solution for buildings with precast or tilt-up concrete facades. Insulated metal panels often prove to be the best alternative for this approach.

Providing **perimeter reheat** is another solution which, while energy intensive, may be an effective alternative to architectural solutions for controlling condensate at large areas of exterior glazing.

Another alternative, appropriate for use, for example, in archival storage spaces in very old historic buildings, is creating a **"Box within a Box."** A new interior enclosure is added inside the building, creating a ventilated cavity between the internal wall and the existing external enclosure. These walls have their own vapor barrier to contain the increased humidity and keep it from condensing on cold surfaces in the original, exterior wall.



Y - DOUBLE FAÇADE RETROFIT



X - "BOX WITHIN A BOX" RETROFIT

In the **double-facade** scenario above, the existing assembly is to the right of the red line. Designers would add new cladding outside the existing exterior wall and then new exterior insulation in an air barrier. Precise decisions would depend on the construction of the existing assembly. The benefit of a **double facade** retrofit is that it moves the dewpoint (condensation) out to a safe location within basically the exterior insulation. This would also have the added benefit of improving the building's energy performance, thanks largely to the additional insulation.

Other Considerations

Priority Buildings

As a strategy, raising relative humiditiy to reduce the spread of pathogens which cause COVID-19 may be more critical in some buildings than others. Long-term care facilities, for example, have accounted for about 42 percent of all COVID-19 cases, according to a May 11 New York Times article. Priorities for renovation should consider the occupants and their interactions, whether they are in healthcare spaces, assisted-living facilities or nursing homes, high occupant-density assembly spaces and auditoria, lobbies, restaurants, and perhaps less critically, office buildings.

Return on Investment

In the post-pandemic landscape, building occupants of all kinds are more likely to feel safer, and thus spend more time in spaces that reduce the threat of infection.

Providing healthier spaces can be a differentiator for employers seeking to attract and retain talent, and for property owners who wish to create a safer, healthier indoor environment.

While envelope upgrades will not provide a return on investment in energy savings, the marginal costs to create better, humidified indoor air quality may provide ROI for certain renovation projects.

There may be modest additional costs to operate and maintain these new humidification systems, but costs will be mitigated by buildings being more desirable, leasing at a higher rate and with fewer vacancies.

Conclusion

Raising relative humidity in existing buildings presents an opportunity for building owners and developers. It offers the potential to enhance the safety and wellness inside buildings at a time when occupants are increasingly aware of infectious disease.

The potential return on investment, health benefits and environmental advantages will diminish risks of outbreaks. Increasing RH is a technically feasible, evidence-based and reliable way to enhance occupant wellness, and mitigate the spread of pathogens of all types.

For new buildings, adding humidification during initial design, and designinig high-performance envelopes beyond code requirements, come at marginal cost increases well worth the health benefits provided, which presents an opportunity to support safer, healthier occupancy, lower infection rates and a diminished risk of outbreaks.

According to the EPA, Americans spend 90 percent of their lives indoors. Maintaining healthier levels of humidity indoors will enhance occupant health and wellness while reducing absenteeism and adding resilience to the post-pandemic economic landscape. It is our opinion that building codes will be adopted in the future mandating higher relative humidity in some facility types and perhaps in all buildings, for all of the reasons discussed in this white paper and the research supporting it (see references).

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Special thank you to Dr. Stephanie Taylor for graphics on pages 3 and 5.

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About LEO A DALY

LEO A DALY is a leader in the design of the built environment. With more than 800 design and engineering professionals in 29 offices worldwide, we are one of the largest planning, architecture, engineering, interior design, and program management firms in the world. Since 1915, we have had an unyielding focus on design excellence to create exceptional spaces that enhance and enrich the human experience. Our award-winning, diverse portfolio includes projects in more than 91 countries, all 50 US states, and the District of Columbia. For more information, visit www.leoadaly.com.

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