ENERGY SOLUTIONS CENTER

Track: Commercial Natural Gas I

Unit # 8: Humidity Control

An overview of Humidity Control Technologies for Commercial Facilities

Mr. Eric Burgis, Energy Solutions Center

Presentation Outline

- Humidity & Health
- Impacts of Poor Humidity Control
- Science & Engineering
- Available Technologies
  - Conventional Cooling Systems
  - Dehumidification Systems
  - Humidification Systems
  - Other Equipment
- Manufacturers
- Associations and Resources

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What is Humidity?

- Amount of water vapor in the air
- Humidity measurements
  - Absolute humidity
    - Mass or density of water vapor in a given volume of air
    - Grams of water per cubic meter of air
  - Relative humidity
    - Ratio of amount of water actually in a particular mass of air to the amount of water vapor the air can hold at a particular temperature
    - Expressed as a percentage
  - Dewpoint
    - Air temperature at which a particular mass of air has as much water vapor as it can hold (in other words, 100% relative humidity)
    - Expressed in degrees of air temperature

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Humidity Impacts

- Warm air can hold more water than cold air, resulting in:
  - Condensation
    - If warm, humid air is cooled, excess water will condense
    - If surfaces are colder than air temperature, air around surfaces will be cooled resulting in condensation
  - Human discomfort
    - People cool by evaporating water from skin
      - Very humid air unable to take up additional moisture
      - Makes people feel hot and sticky
    - Cold winter outdoor air brought in for heating holds insufficient moisture for
      - Optimal respiratory function
      - Warm, comfortable feeling
    - Too little or too much humidity increases
      - Accelerates growth of disease-causing microbes
      - Aggravates health problems

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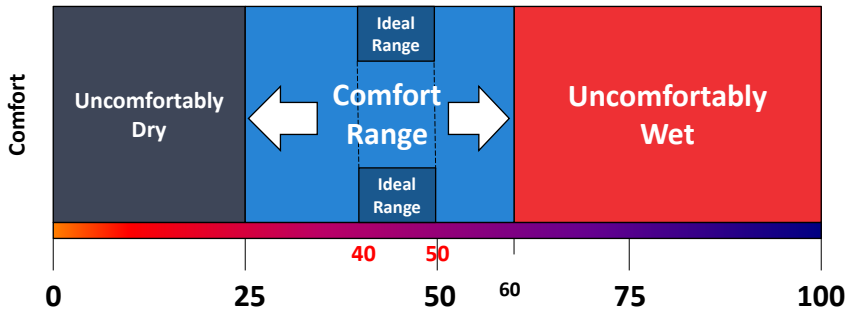
Relative Humidity (RH) Percentage

This chart illustrates the RH comfort level for 80% or more of the occupants in a space.



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How Warm Do You Feel?

- A person's comfort depends on the direct effect of temperature and humidity
- If either are too high or too low they can have a significant effect on comfort level

HEAT INDEX TEMPERATURE

TEMPERATURE F	10	20	30	40	50	60	70	80	90	100
125	123	141								
120	116	130	148							
115	111	120	135	151						
110	105	112	123	137	150					
100	105	113	123	135	149					
95	99	104	110	110	120	132	144			
90	85	87	90	93	96	100	106	113	122	
85	80	82	84	86	88	90	93	97	102	108
80	75	77	78	79	81	82	85	86	88	91
75	70	72	73	74	75	76	77	78	79	80
70	65	66	67	68	69	70	70	71	71	72

PERCENT RELATIVE HUMIDITY

Source: National Oceanic & Atmospheric Administration

The Heat Index (HI) or the "Apparent Temperature" is an accurate measure of how hot it really feels when the Relative Humidity (RH) is added to the actual air temperature.

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Humidity & Health

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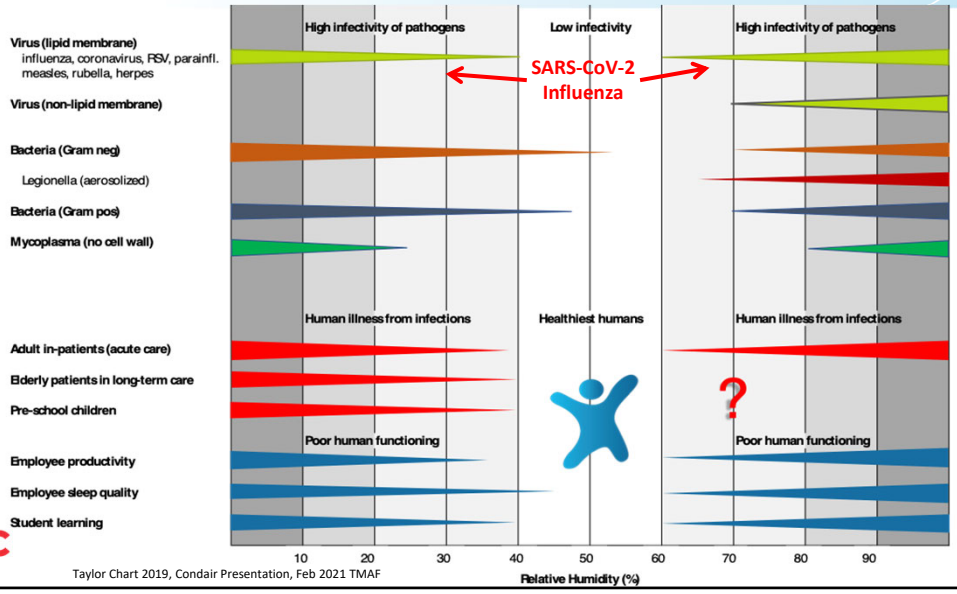
Health Impact of Uncontrolled Humidity



Taylor Chart 2019, Condair Presentation, Feb 2021 TMAF

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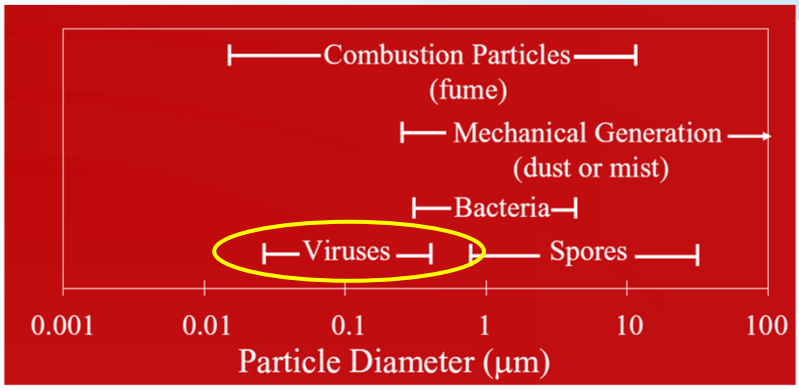
ASHRAE - Design Standards

- Standard 55-2023: Thermal Environmental Conditions for Human Occupancy utilizes the environmental factors of temperature, thermal radiation, **humidity**, and air speed, as well as the personal factors of activity and clothing
  - Read more at the ANSI Blog: ANSI/ASHRAE 55-2023: Thermal Environmental Conditions for Human Occupancy https://blog.ansi.org/?p=8322
- When the Graphical Comfort Zone Method is used, systems must be able to maintain a humidity ratio at or below 0.012 ***(about 65% RH at 75°F),*** which corresponds to a water vapor pressure of 1.910 kPa (0.277 psi) at standard pressure or a dew-point temperature of 16.8°C (62.2°F).
- There are no established lower humidity limits for thermal comfort; consequently, this standard does not specify a minimum humidity level. Nonthermal comfort factors, such as skin drying, irritation of mucus membranes, dryness of the eyes, and static electricity generation, may place limits on the acceptability of very low humidity environments.

Influence of Humidity on Influenza

- Humidity levels influences the influenza virus and other pathogens in four ways:
  - Airborne Longevity of the virus as an aerosol
  - Transmissibility of the virus
  - Depth of pathogen penetration of the body and associated severity of infection
  - The mortality of the virus

Partial Size of Aerosol (Micrometers)



Virus particles are very small and remain airborne for long times

1 µm (Micron) = 1/25,400 of an inch. The diameter of human hair to ranges from 17 to 181 µm.

Study: Generation and behavior of Airborne particles (Aerosols)

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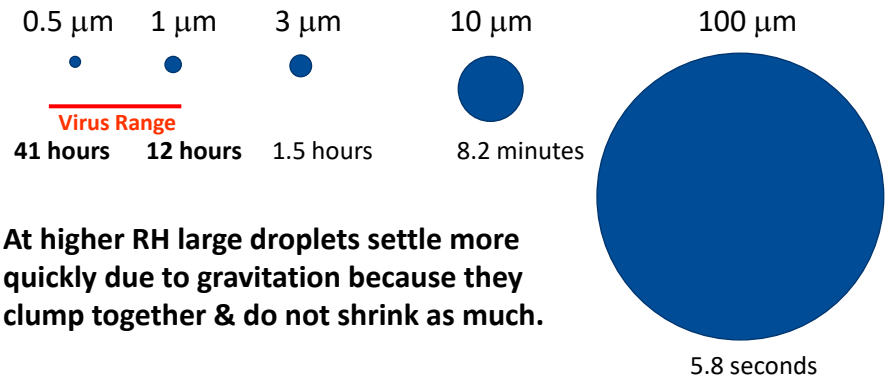
Partial Size of Aerosol

Time to Settle 5 Feet (1.5 meters) by Unit Density Spheres



At higher RH large droplets settle more quickly due to gravitation because they clump together & do not shrink as much.

Study: Generation and behavior of Airborne particles (Aerosols)

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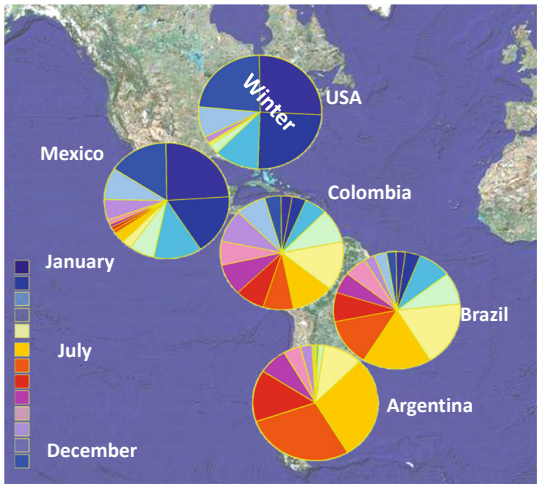
% Seasonal Transmissibility of Influenza by Month



Columbia Univ., 2012

Seasonal Distribution of influenza is shown by region. In the U.S. and Canada influenza is transmitted mostly in the dry Winter months.

This indicates that the direct transmission of influenza by relative humidity alone is sufficient to produce observed seasonality.

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HOW DO WE PROTECT OURSELVES FROM THE BAD MICROBES?

Condair Presentation, Feb 2021 TMAF

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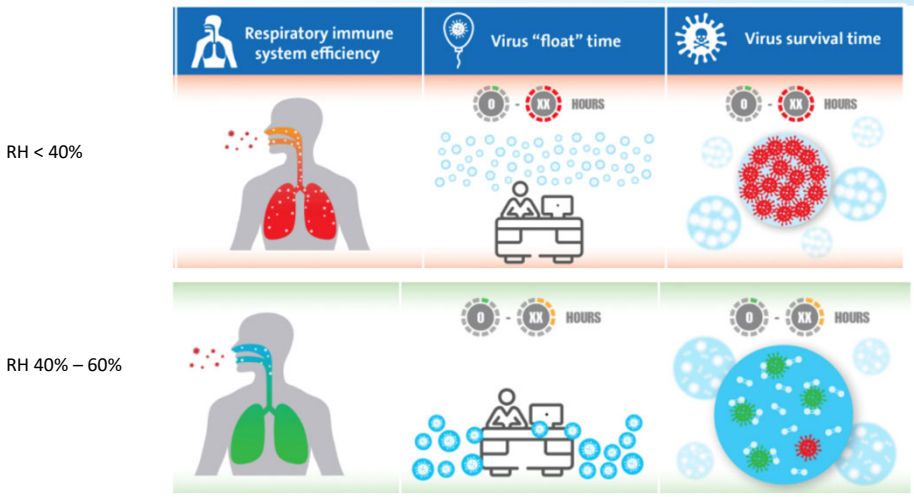
Three Dimensions of Rh 40–60% Protection



Condair Presentation, Feb 2021 TMAF

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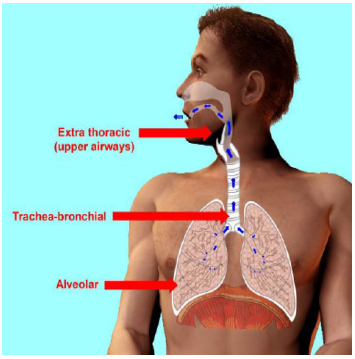
Depth of Pathogen Penetration

Aerosol size and density influences penetration of the respiratory tract. The smaller the particle the more likely it may be absorbed in the body.

Thoracalic fraction:	
Bronchial tubes	2 - 3 µm
Bronchiolic tubes	1 - 2 µm
Alvcolic fraction:	
Alveoles (pulmonary vesicles)	0.1 - 1 µm



http://scienticon.de/index.html, Dr. Rudolf Huester

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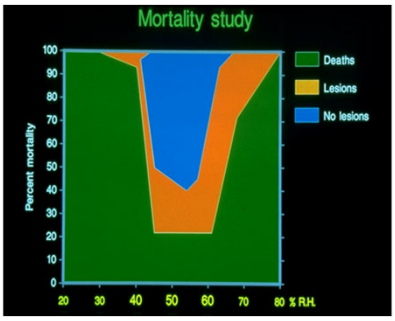
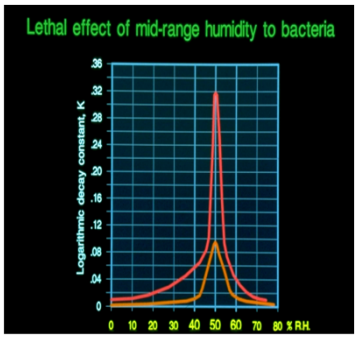
Influence of Humidity on Mortality of Pathogens



The bacteria mortality rate is greatest between 40 and 60% relative humidity.



Research indicates that lab animals inoculated with influenza virus were dramatically effected by RH outside the mid range of 40%-50% RH.

- **Green range: The mice perished**
- **Orange range: Contracted virus and recovered**
- **Blue range: Mice didn't get infected**

http://www.plospathogens.org/article/info%3Adoi%2F10.1371%2Fjournal.ppat.0030151

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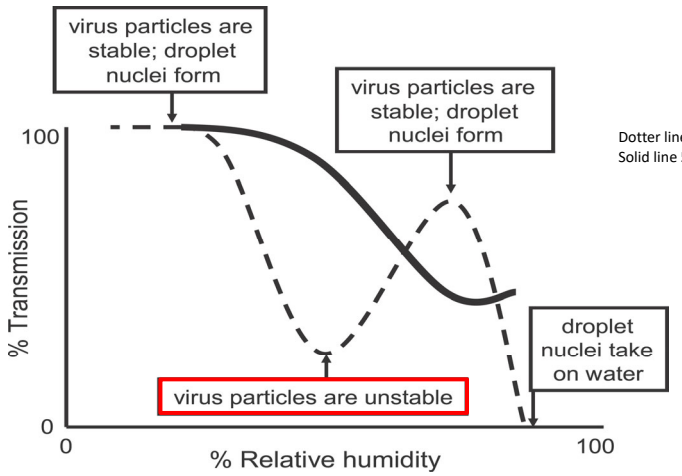
Stability of Virus Particles



Dotter line 20 ° C (68 ° F)
Solid line 5 ° C (41 ° F)

https://journals.plos.org/plospathogens/article?id=10.1371/journal.ppat.0030151#ppat-0030151-b012

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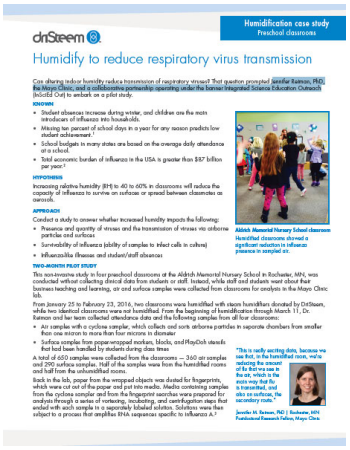
Pre-School Humidification Study

- Conducted by Jennifer Reiman, PhD from the Mayo Clinic, in collaboration with Integrated Science Education Outreach
- Actual Test 2 months
- Location: 4 classrooms at Aldrich Memorial Nursery School classroom in Rochester, MN
  - 2 humidified, 2 not humidified
- **Hypothesis: Increasing relative humidity (RH) to 40 to 60% in classrooms will reduce the capacity of influenza to survive on surfaces or spread between classmates as aerosols.**
- 650 samples from air and surface collected


Humidification case study
Preschool classrooms

driSteem

Humidify to reduce respiratory virus transmission

Can sharing indoor humidity reduce transmission of respiratory viruses? That question prompted Jennifer Reiman, PhD, the Mayo Clinic, and a collaborative partnership operating under the Iterian Integrated Science Education Outreach (InScEd Out) to embark on a pilot study.

KNOWN

- Student absences increase during winter, and children are the main introducers of influenza into households.
- Missing ten percent of school days in a year for any reason predicts low student achievement.[1]
- School budgets in many states are based on the average daily attendance at a school.
- Total economic burden of influenza in the USA is greater than $87 billion per year.[2]

HYPOTHESIS

Increasing relative humidity (RH) to 40 to 60% in classrooms will reduce the capacity of influenza to survive on surfaces or spread between classmates as aerosols.

APPROACH

Conduct a study to answer whether increased humidity impacts the following:

- Presence and quantity of viruses and the transmission of viruses via airborne particles and surfaces
- Survivability of influenza (ability of samples to infect cells in culture)
- Influenza-like illnesses and student/staff absences

TWO-MONTH PILOT STUDY

This non-invasive study in four preschool classrooms at the Aldrich Memorial Nursery School in Rochester, MN, was conducted without collecting clinical data from students or staff. Instead, while staff and students went about their business teaching and learning, air and surface samples were collected from classrooms for analysis in the Mayo Clinic lab.

From January 25 to February 23, 2016, two classrooms were humidified with steam humidifiers donated by DriSteem, while two identical classrooms were not humidified. From the beginning of humidification through March 11, Dr. Reiman and her team collected attendance data and the following samples from all four classrooms:

- Air samples with a cyclone sampler, which collects and sorts airborne particles in separate chambers from smaller than one micron to more than four microns in diameter
- Surface samples from paper-wrapped markers, blocks, and PlayDoh utensils that had been handled by students during class times

A total of 650 samples were collected from the classrooms — 360 air samples and 290 surface samples. Half of the samples were from the humidified rooms and half from the unhumidified rooms.

Back in the lab, paper from the wrapped objects was dusted for fingerprints, which were cut out of the paper and put into media. Media containing samples from the cyclone sampler and from the fingerprint searches were prepared for analysis through a series of vortexing, incubating, and centrifugation steps that ended with each sample in a separately labeled solution. Solutions were then subject to a process that amplifies RNA sequences specific to influenza A.[3]

Aldrich Memorial Nursery School classroom
Humidified classrooms showed a significant reduction in influenza presence in sampled air.

"This is really exciting data, because we see that, in the humidified room, we're reducing the amount of flu that we see in the air, which is the main way that flu is transmitted, and also on surfaces, the secondary route."

Jennifer M. Reiman, PhD | Rochester, MN
Postdoctoral Research Fellow, Mayo Clinic

Pre-School Study Results

Influenza-positive samples from air and surfaces

Sample type	Humidified rooms percent positive	Unhumidified rooms percent positive	Odds ratio*
Air	11.7	18.3	0.51
Surfaces (paper)	18.0	22.1	0.51

* Odds ratio less than 1 indicates a reduced likelihood of finding influenza-positive samples in humidified rooms compared to unhumidified rooms.

- The % of positive Influenza samples was greater in air and on surfaces in unhumidified rooms.
- 45 of influenza-positive samples were further tested for infectivity
  - **48% from unhumidified room were infectious**
  - **Only 17% from the humidified rooms were infectious**

Humidity Control Applications

- Food Service establishments
- Office buildings
- Retail shopping facilities
- Ice rinks
- Groceries
- Hotels and motels
- Hospitals, healthcare and elder care facilities
- Schools, colleges & universities
- Theaters
- Refrigerated warehouses

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Impacts of Poor Humidity Control

Humidity is a component of indoor air quality.

Uncontrolled humidity negatively affects people, buildings and equipment/supplies.

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Eliminating excess summer humidity

- Effective cooling means controlling temperature and humidity
- Cooling reduces air temperature which increases relative humidity levels
- Desiccant dehumidification will remove excess humidity independently from cooling
  - Frees A/C for cooling air only
  - Focus on cooling only
  - Operate more efficiently
  - Operate with less wear and tear
  - Can install smaller cooling unit at lower capital cost – and further reduce operating costs

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Dehumidification Also Needed in Spring and Fall

- Cooling System do not operate as much in the Spring and Fall Months
- Reduced operation of the cooling system in Spring and Fall results in higher indoor humidity than desired when the outside air is humid
- Desiccant Dehumidification System can remove that humidity without having to run the cooling system

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High Humidity Impacts

- Cooling costs
  - Systems work harder and longer to maintain desirable temperature due to cooling both the air and the water vapor, using more energy and increasing operating costs
- Integrity of building structure and systems
  - Condensation on metal structures contributes to oxidation and early failure
  - Condensation damages windows
- Health of building occupants
  - Contributes to growth of disease-causing microbes – bacteria, mold, fungi
  - Contributes to Sick Building Syndrome – aggravating allergies, asthma, etc.

CONTINUED

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High Humidity Impacts

- Contents of buildings
  - Can damage stored “dry” foods
  - Contributes to growth of mold & mildew
  - Damages furnishings, equipment & supplies
- Comfort of building occupants
  - In Summer you feel hotter
  - In Winter you feel cold & clammy

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Low Humidity Impacts

- Integrity of building structure and systems
  - Static electricity can damage computers and electronics
  - Can dry out wall coverings, floor and ceiling tiles, furniture – leading to shrinking and cracking
- Comfort of building occupants
  - Too little moisture makes occupants feel colder in winter – reducing productivity
- Health of Building Occupants
  - Aggravates asthma, allergies and other respiratory-related illnesses
  - Contributes to incidents of cracked lips, dry skin, and bloody noses
  - Impacts employee productivity and absenteeism

Cost of Illness

- Cost of sick days
  - The IBI (Integrated Benefits Institute) estimates a cost of $260/sick day
  - The Bureau of Labor Statistics estimates 10 sick days per employee per year
  - Humidity only costs ~$10/employee a year
    - Compare this to approx. $2,600 in lost time

Agency for Healthcare Research and Quality, "AHRQ News and Numbers," 8 December 2010. http://www.ahrq.gov/news/newsroom/news-and-numbers/120810.html.

Integrated Benefits Institute, "Absence Cost Estimator," 9 2010., http://ibiweb.org/uploads/general/ACE_Sample_Report_-_U.S._Workforce.pdf.

Cost per employee from Nortec & based on a small office of 100 people with minimum outside air.

Humidity Control

- Humidity is a component of indoor air quality
  - Too much or too little moisture equals uncontrolled humidity in the space
- Uncontrolled humidity negatively affects people, buildings and equipment/supplies

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Proper Humidity Impacts

- Comfort of building occupants
  - Proper humidity helps control unpleasant odors
  - Proper humidity levels help control growth of bacterial and mold and can reduce the spread of viruses such as influenza
  - People feel more comfortable at proper humidity levels
  - Save Energy required for cooling
  - Helps reduce/eliminate the need for sub-cooling & re-heating – reducing capital costs & energy use

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Science and Engineering

Please note that this section of the presentation is meant to be an overview only.

Psychrometrics can be difficult to explain and comprehend in a short presentation.

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Sensible vs. Latent Cooling

- **Latent Cooling** is the cooling of the water vapor in the air
- **Sensible Cooling** is the cooling of the air itself
- **Total Cooling Load = Latent + Sensible Loads**
  - Gas-fired dehumidification removes moisture before the cooling coils – reducing the Latent Cooling Load
  - Reduction in the Latent Cooling Load reduces the Total Cooling Load

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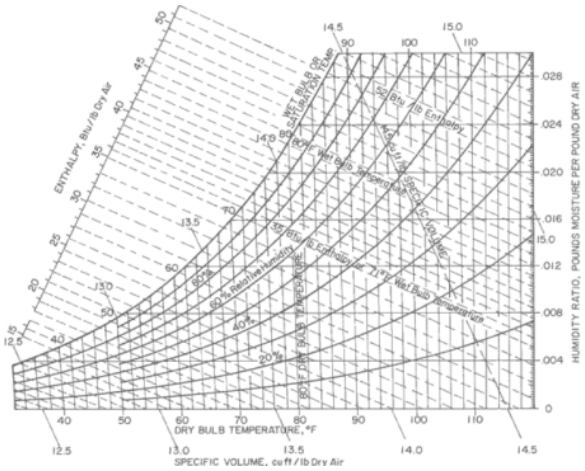
Psychrometric Charts

- Understanding Psychometric charts helps with visualization of environmental control concepts such as why heated air can hold more moisture, and conversely, how allowing moist air to cool will result in condensation



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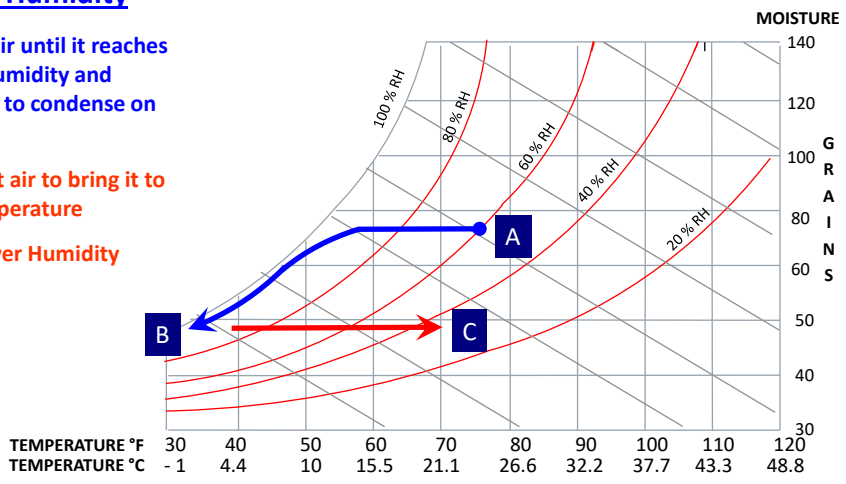
Conventional Cooling Psychrometric Chart

To Decrease Humidity

A to B - Cool Air until it reaches 100% relative humidity and moisture begins to condense on the cooling coils

B to C - Reheat air to bring it to the desired temperature

Net result – Lower Humidity



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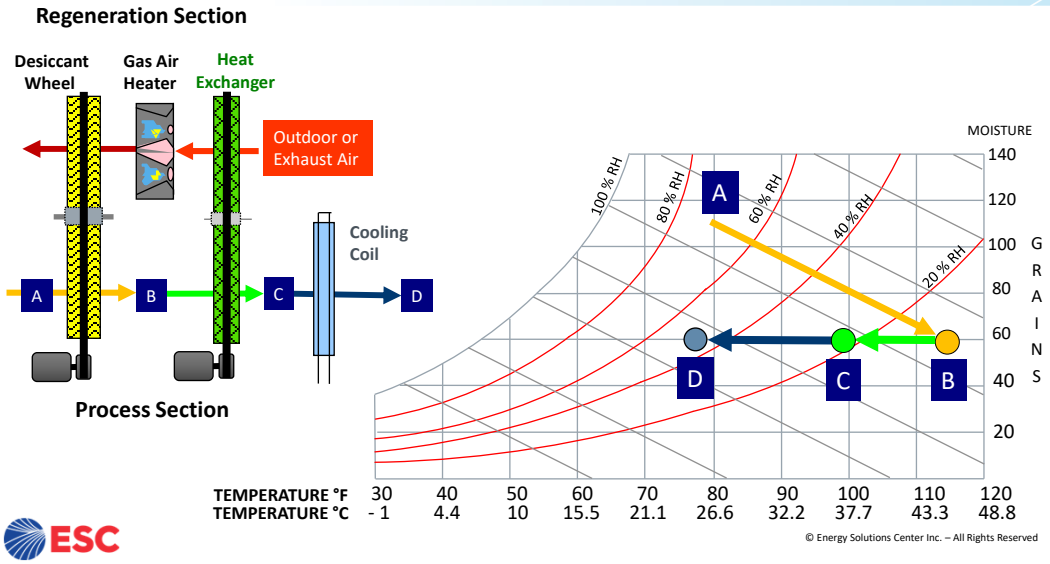
Desiccant Dehumidification Psychrometric Chart



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Humidity Measurement

- There are various devices used to measure and regulate humidity
- Humidity measurement uses a psychrometer or hygrometer
- A humidistat is used to regulate the humidity of a building
- These can be analogous to a thermometer and thermostat for temperature control

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Sling Psychrometer

- Incorporates two bulbs – one wet and one dry
  - This is a basic High School chemistry lab experiment
- After a short time, the water on the wet bulb evaporates and at that time, the temperature is measured of each bulb
- The delta between the temperatures is noted **and** the ambient temperature is noted
- Each is used on a chart to find the relative humidity of that temperature and the space

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Hygrometer

- An instrument used for measuring the moisture content in the environmental air or humidity
- Devices use temperature of condensation, or changes in electrical capacitance or resistance to measure humidity changes.
- Used in Humidistats to control equipment that dehumidifies or humidifies the air

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Types of Hygrometers

- Metal Coil Type
  - Provides a dial indication of humidity changes
- Hair Tension
  - Uses a human or animal hair under tension
  - The length of the hair changes with humidity and the length change may be magnified by a mechanism and/or indicated on a dial or scale

CONTINUED

Types of Hygrometers

- Electronic
  - Chilled mirror dew point hygrometers – use a chilled mirror and optoelectronic mechanism to detect condensation on the mirror
  - Capacitive humidity sensors - sense the effect of humidity on the dielectric constant of a polymer or metal oxide material
  - Resistive humidity sensors - sense the change in electrical resistance of a material due to humidity

Hygrometers

Metal Coil Type

Hair Tension Type

Chilled Mirror Type

Capacitive Humidity Sensor

Resistive Humidity Sensor

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Everyday Hygrometers

Typically $5 to $25 at your local department or hardware store

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A Last Bit of Engineering

- Latent Cooling
  - Cooling the moisture in the air which leads to condensation of moisture on the cooling coils
  - Gas-fired desiccants remove moisture before the cooling coils reducing the latent cooling load
- Sensible Cooling
  - Cooling the air itself to reasonable ambient temperature
  - Removal of moisture with desiccant means sensible cooling becomes primary load
  - Overall reduction in total cooling load

Components of Cooling

- Space cooling accomplished by maintaining both components of cooling:
  - Temperature (sensible cooling)
  - Humidity (latent cooling)
- With dry air, it is very easy to regulate temperature

Available Technologies

- Conventional systems
- Dehumidification Equipment
- Humidification Equipment
- Electric & Hybrid Systems

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Conventional Cooling Systems

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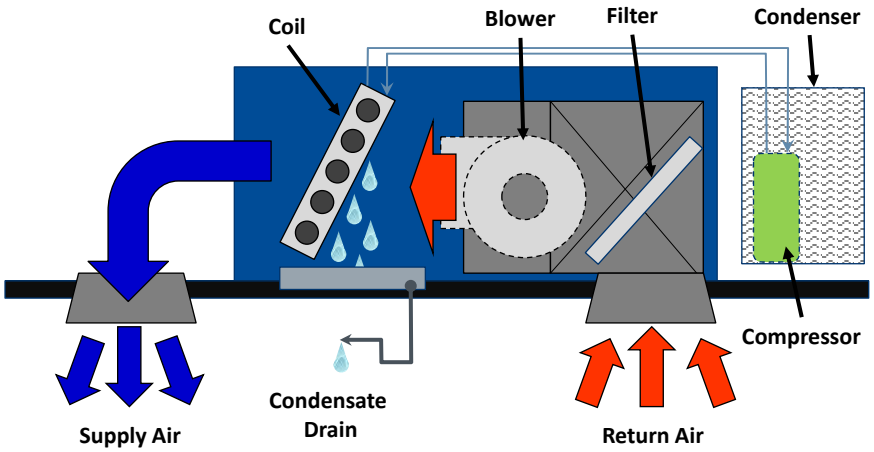
Conventional Cooling System



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Problem with Using Conventional Air Conditioning to Dehumidify

- Cool the air to the temperature required to remove the excess humidity to achieve the desired absolute humidity. This will be at a temperature lower than the final desired temperature.
- Reheat the air to the desired temperature. The absolute humidity will remain constant as the air is reheated. Relative humidity will drop.
- Sub-Cooling and Reheating is not very energy efficient, but is a normal practice in commercial buildings
- Cooling coils and condensate drain system are constantly wet and are an ideal breeding ground for bacteria, mold, etc.

Dehumidification removes the moisture from the air so there is none to condense onto the cooling coils

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Dehumidification Systems

Desiccant Wheel (Dry)

Liquid Desiccant

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Dry Desiccant Dehumidification Wheel Type

Commercial
&
Industrial sizes

300 cfm – 120,000 cfm

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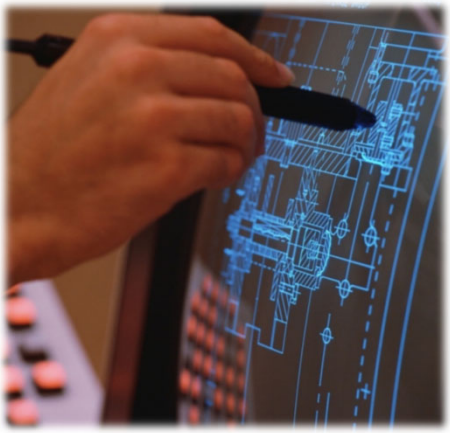
Dry Desiccant Dehumidification Design Considerations

- Desiccant process is a function of:
  - Moisture of space or process air
  - Temperature of air
  - Temperature of reactivation air
  - Velocity of air
  - Speed of desiccant wheel
  - Depth of wheel
  - Desiccant material used



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Basic Desiccant Wheel Process

- Porous wheels are coated with a special humidity-absorbing desiccant material
  - Silica Gel often used as the desiccant
- Desiccant absorbs the moisture from the air
- Humidity-saturated section of the wheel is then rotated to a position where it is "regenerated" to drive off the humidity, typically by heating it
- "Regenerated" section of the wheel is rotated so that it can absorb more moisture upon again being exposed to air

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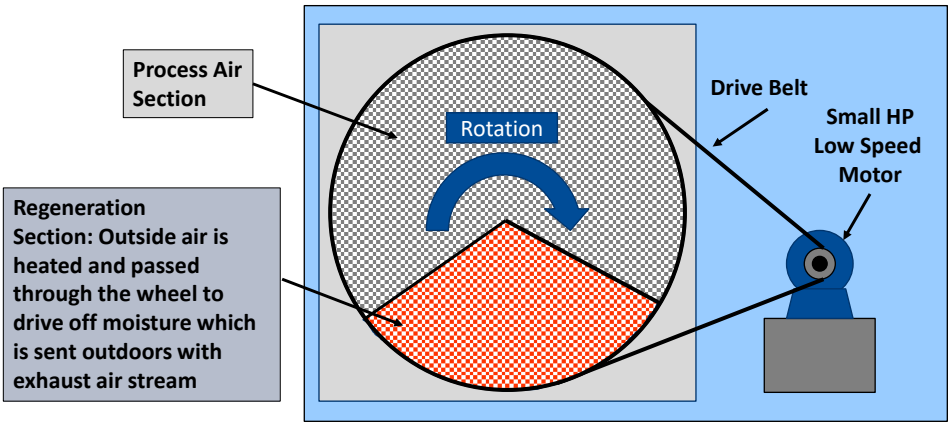
Wheel Technology



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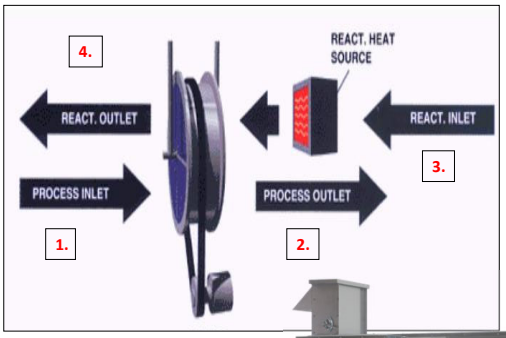
Dry Desiccant Dehumidification How It Works



1. **Process Inlet**—Air to be dried.
2. **Process Outlet**—Air dried by desiccant wheel.
3. **Reactivation Inlet**—Air flow used to drive moisture off wheel.
4. **Reactivation Outlet**—Hot, wet air from wheel exhausted outside. May be passed through an air-to-air heat exchanger before exiting the building to recover the heat.

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Reactivation of Desiccant Wheel

- Reactivation of the desiccant wheel is accomplished between 120-190°F (48.8-87.7°C)
- Available sources of heat
  - Natural gas heater
  - Hot water / steam
  - Electric element
  - Waste heat

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Desiccant Dehumidification
Dry System Maintenance

- Filters - Filters - Filters (90% of reported problems)
- Wheel - no regular scheduled maintenance
- Wheel drive assembly - check belt tension and wear
  - Larger wheels - change oil on speed reducer once per year
- Fan belts and bearings - check belt tension and oil bearing at recommended maintenance intervals
- Cooling components
  - cooling coil, standard maintenance
  - evaporative, flush pad & add water treatment

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Liquid Desiccant Dehumidification

- For larger Commercial and Industrial Applications
- Chemical adsorption process
- Size range
  - 1000 CFM to 84,000 CFM

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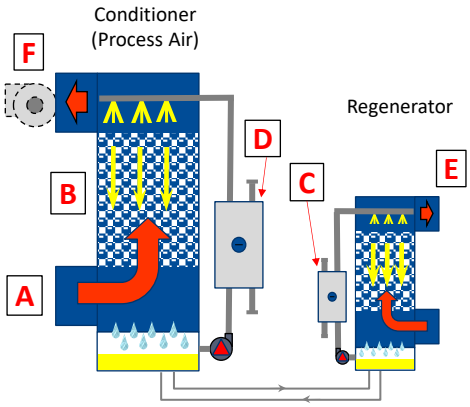
Liquid Type – How it Works

A. **Process Air In**
B. **Packing Blocks** – Provide greater contact area for desiccant to absorb moisture from the air
C. **Heater -** Gas-fired burner heats the liquid to drive off absorbed moisture
D. **Cooler** – Cool liquid to help it absorb moisture
E. **Hot Moist Air Out** – Hot, wet air from liquid exhausted outside
F. **Air Out** – Dried air out



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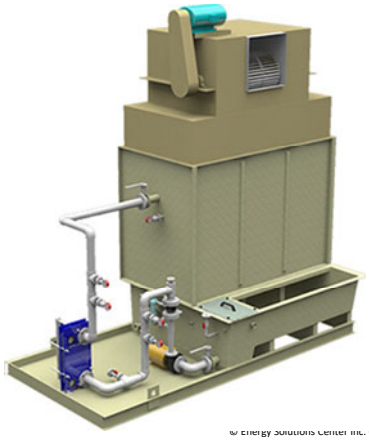
Desiccant Dehumidification Liquid System Maintenance

- Lithium Chloride (LiCl)
  - Corrosive solution
  - Mist eliminators
  - Pumps



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Advantages of Natural Gas Desiccant Dehumidification

- Reduces growth of disease-causing microbes
- Controls odors, mold and mildew
- Eliminates condensation
- Increases comfort of building occupants
- Prevents damage to furnishings, carpeting, tiles, and other building materials
- Saves energy for cooling – don't have to cool as much in summer
- Reduces overall operating costs
- Reduces conventional cooling requirements – *smaller system(s) can be installed*
- Improves efficiency of chillers
- Ensures more precise temperature and humidity control

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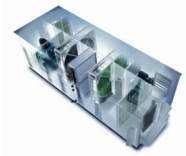
Difference between Desiccant Wheels and Liquid Desiccant Systems



Provides warm dry air

Commercial & industrial sizes

Provides cool dry air

Typically large commercial and industrial sizes

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Humidification Systems

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Adding humidity in cold winter months

- Traditional approach – space or process boiler
- Alternative – dedicated boiler
- Better alternative – direct-fired gas humidification
- Gas humidifiers are atmospheric steam generators: Steam is generated at atmospheric pressure and 212°F (100°C)

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Natural Gas Humidifiers

- Natural Gas Humidification
  - Natural gas humidifiers add moisture to dry air
  - Natural gas burners boil water to steam and deliver humidity via air handler or blower
  - Minimizes steam pressure
  - Eliminates boiler chemicals
  - Can be used in conjunction with existing boiler

Gas Humidifiers are designed to handle scale build up with daily cleaning and purge cycles

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Gas-Fired Humidifiers

- Combustion efficiency typically 80% to 83.7% (non condensing)
- H.E. Unit 92% - 94% efficiency (Condensing, Modulating)
- Venting as Class I or III gas appliance
- Units ranging from 50-600 lbs./hr. of steam
- Units modulate down to 25 lbs/hr. of steam
- Natural gas pressures
  - 4.5 – 9.0 inches WC (0.16 – 0.33 psi)

	Steam Output (lbs/hr)	Maximum Input (BTU/hr)
Condensing	50	62,000
	100	124,000
Non-Condensing	100	140 000
	200	280 000
	300	420 000
	400	560 000
	500	700 000
	600	840 000

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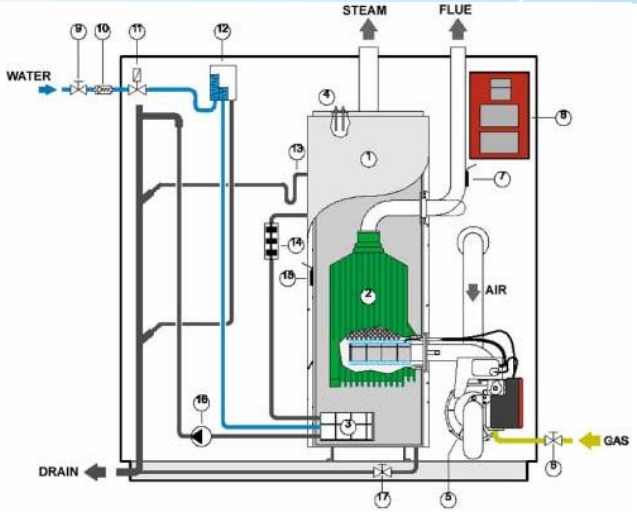
Standard Steam Humidifier

1. Stainless steel boiler
2. Heat exchanger
3. Clean-out cover
4. High level foam probes
5. Forced draft gas burner
6. Gas inlet
7. Flue temperature sensor
8. Controller
9. 10. 11. Water inlet assembly
12. Fill cup - conductivity probes
13. Boiler overflows
14. Triple float level control
15. Boiler temperature sensor
16. Drain pump



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Humidification – How It Works

- Gas burner fires into heat exchanger
- Heat exchanger submerged in tank of water
- Water heated to steam which is distributed via air handling system or remote blower

Remote Blower System

Steam Distributor Pipe

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Natural Gas Humidification Advantages

- Reduces incidents of respiratory infections and allergy-related illnesses related to dry air
- Contributes to health and comfort of building occupants – reducing employee absenteeism and thereby increasing productivity
- Eliminates dangers of static electricity – helping protect expensive computer equipment
- Protects equipment, furnishings and supplies
- Ensures more precise temperature and humidity control – reducing energy costs

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Cost of Humidity

- 900 lbs/person/year
- 1,050,000 Btu/person/year
- ~ $10 /person/year

Based on a small office of 100 people with minimum outside air. & $9.33/MCF natural gas.

Humidification Economics

Energy Operating Cost Comparaison (92% efficient unit)
Total humidification load: **50 & 100 lbs/hr** (60% correction factor)
Average operating period: 2200 hrs

Systems Compared:
Electric Humidifier (EL) Electricity @ $0.14 / kWh
Gas Humidifier (GS) Natural Gas @ $9.33 / 1000 ft^3

Series	Size	System Cost	Installation Cost	Operating Cost	1st year cost	Energy Savings/Yr	Payback in years
Electric	50 #/Hr	$4,300	$4,500	$5,500	$14,300	N/A	N/A
Gas	50 #/Hr	$13,000	$6,000	$1,900	$20,900	**$3,600**	**1.8**
Electric	100 #/Hr	$5400	$4,500	$10,300	$20,200	N/A	N/A
Gas	100 #/Hr	$16,000	$6,000	$2,650	$24,650	**$7,650**	**.6**

Notes: Based on Condair EL electric model and Condair GS natural gas model. Payback based on incremental cost.

Electric & Hybrid Systems

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Electric & Hybrid Equipment

Electric Equipment

- Electric heating elements are available for desiccant wheel regeneration
  - Newer products use the waste heat from conventional cooling systems to reactivate a desiccant wheel for 'free' dehumidification

Hybrid Systems

- Hybrid products have gas reactivated desiccants and electric cooling in the same package
- Provides humidity control with the gas fired desiccant then cools the warm air with the electric cooling system before the dry air enters the building

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Manufacturers

Numerous manufacturers exist for each humidity control technology.

Listed on the following slides are some of the major manufactures by technology type

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Dry Wheel Desiccant Systems

- Bry-Air – www.bry-air.com
- Climate by Design– www.cdihvac.com
- Munters – www.munters.com
- Novelaire – www.novelaire.com
- Seasons4 – www.seasons4.net
- FlaktGroup - SEMCO – www.semcohvac.com

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Liquid Desiccant Systems

- AIL Research Inc. – www.ailr.com
- Alfa Laval Inc. - https://www.alfalaval.us/ (formerly Kathabar)

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Humidifiers

- Condair – www.condair.com
- Armstrong – www.armstronginternational.com
- driSteem – www.dristeem.com
- Carel USA – www.carelusa.com
- Pure Humidifier – www.purehumidifier.com

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Associations and Resources

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Associations & Resources

- ESC – Energy Solutions Center
  - Located in Washington, DC
  - www.gasairconditioning.com

ENERGY SOLUTIONS CENTER

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Associations & Resources

- ASHRAE - American Society of Heating, Refrigerating and Air-Conditioning Engineers – Atlanta, GA
  - Advances heating, ventilation, air conditioning and refrigeration through research, standards writing, publishing and continuing education
  - Membership – 51,000
  - www.ashrae.org

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Associations & Resources

- AEE - Association of Energy Engineers
  - Source for energy engineering and energy management, renewable and alternative energy, power generation, energy services and sustainability
  - Membership
    - 13,000 in 81 countries – 71 chapters
  - www.aeecenter.org

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