Humidity and Occupants

What the Latest in Humidity Research Means for You

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Presenters

- **Matt Nowak**
  North American Sales Manager
  Armstrong International

- **Eric Brodsky, PE**
  Director of Technology
  Research Products Inc. / Aprilaire / DriSteem

- **Duncan Curd**
  General Manager
  Nortec Humidity Ltd.

- **Jeremy Wolfe**
  National Sales & Marketing Manager
  CAREL USA

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Agenda

1. **Fundamentals of Humidity**
   - Key Terms and Definitions
   - How indoor humidity changes throughout the year
   - Where humidification matter most

2. **Humidity and People**
   - Historical Research
   - Impacts of moisture to the human body
   - Recent advances in humidity research

3. **Recent Research**
   - Microbiome Study Details
   - Example of Hospital Savings
   - Results and Recommendations

4. **Humidity in Your Building**
   - Technologies for Humidification
   - Cooling and Humidifying with Adiabatic Systems
   - Humidification with Steam
   - Case Studies / Installation Examples

What is Humidity and How Do We Measure It?

Humidity

- The amount of water vapor in the air
- Measured in “Absolute” or “Relative” terms

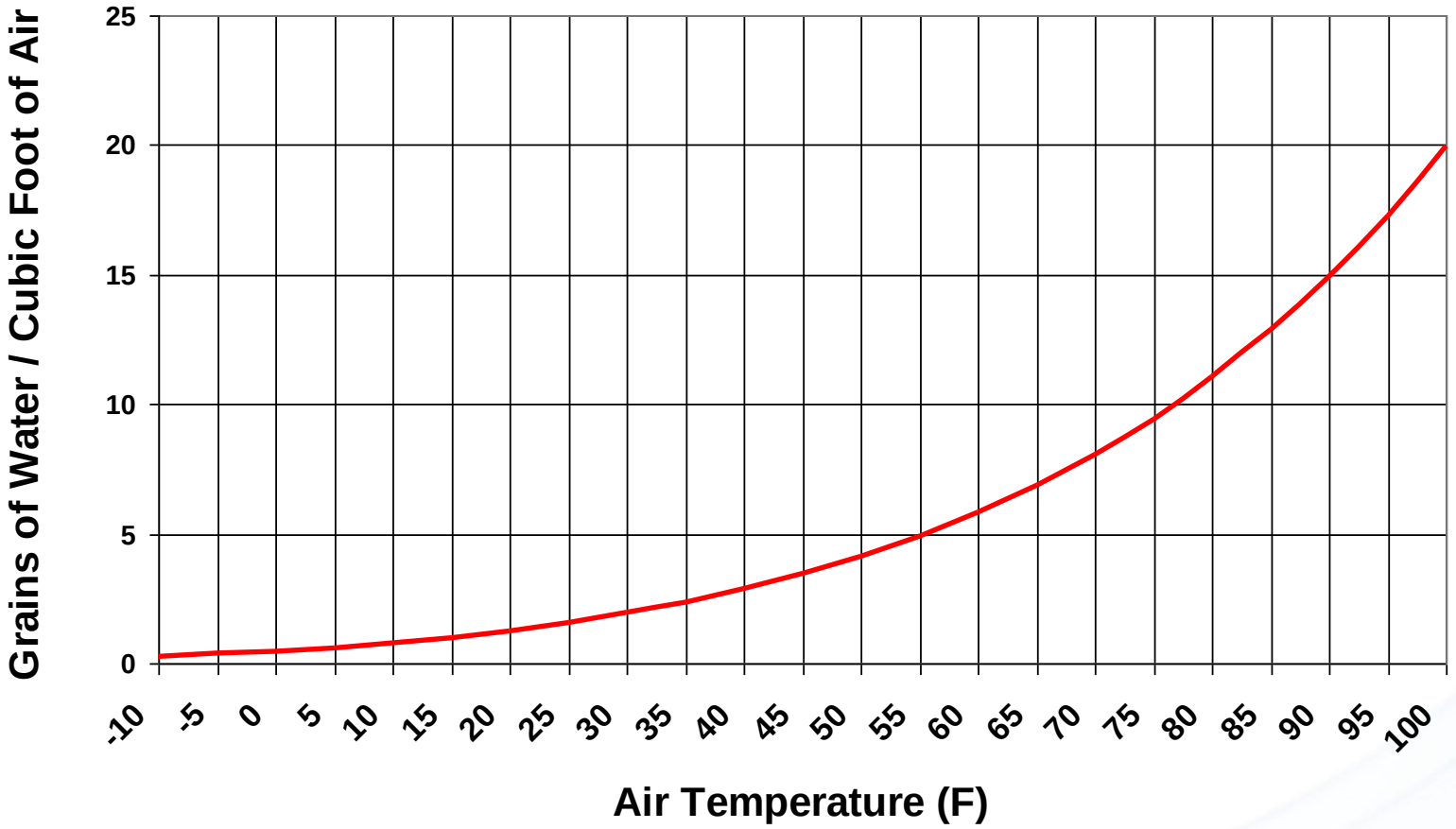
Absolute Humidity

- Mass of water in particular volume of air
- Expressed as mass (grains/lb_{da} or g_w/kg_{da})

Relative Humidity

- Amount of water vapor in the air relative to how much it can hold at a given temperature (%)

Maximum Moisture Content Of Air Depends On Air Temperature



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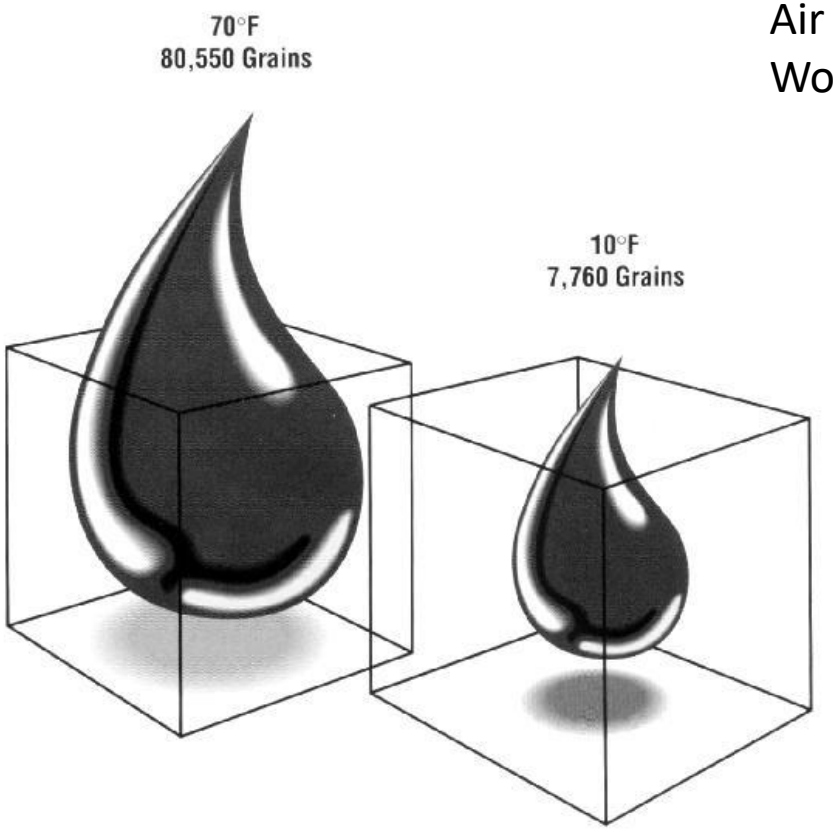
How Much Water Can the Air Hold?



Air Heated From 10°F @ 100% RH to 70 °F
Would Only Be Less Than 10% RH

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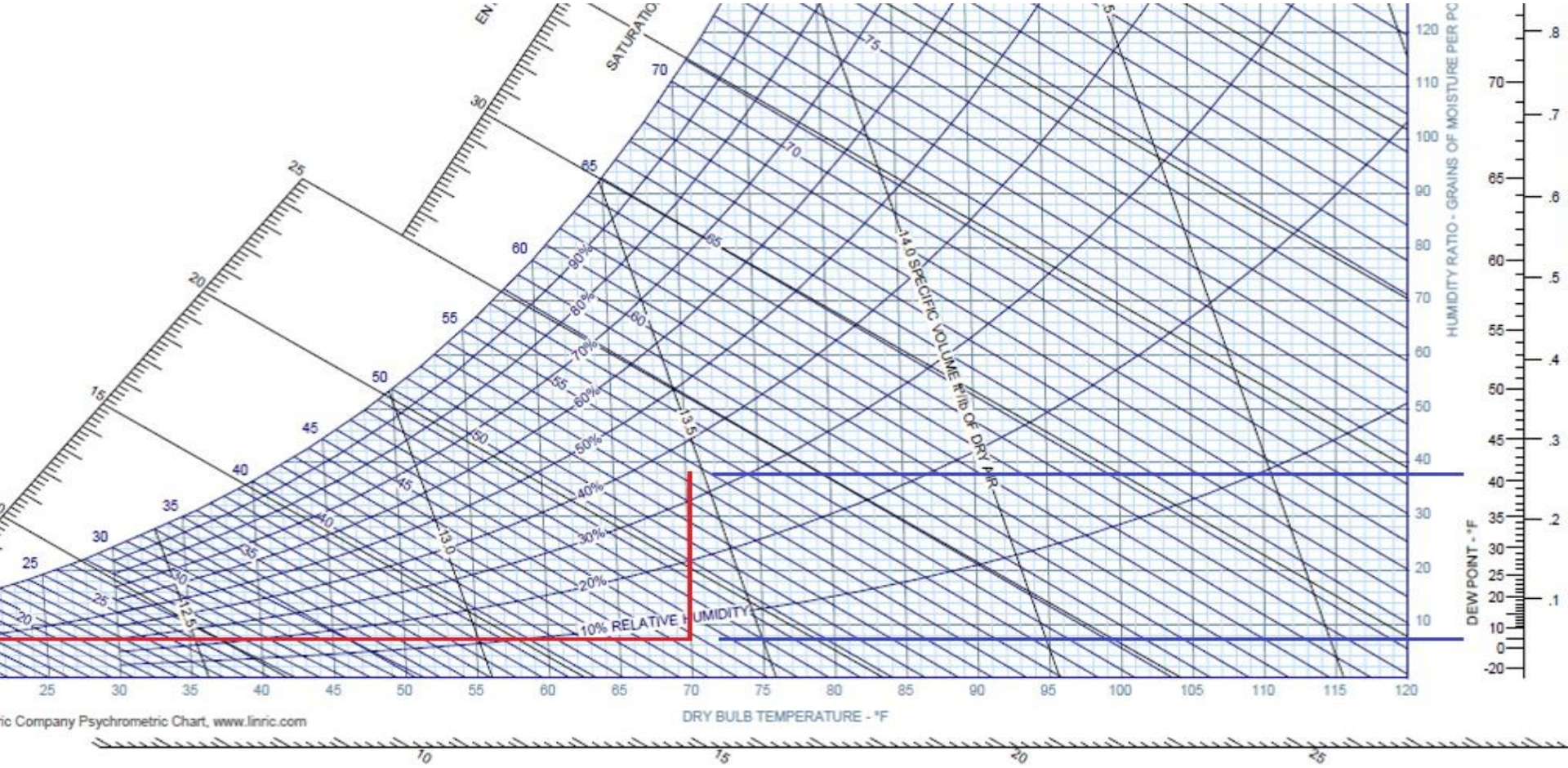
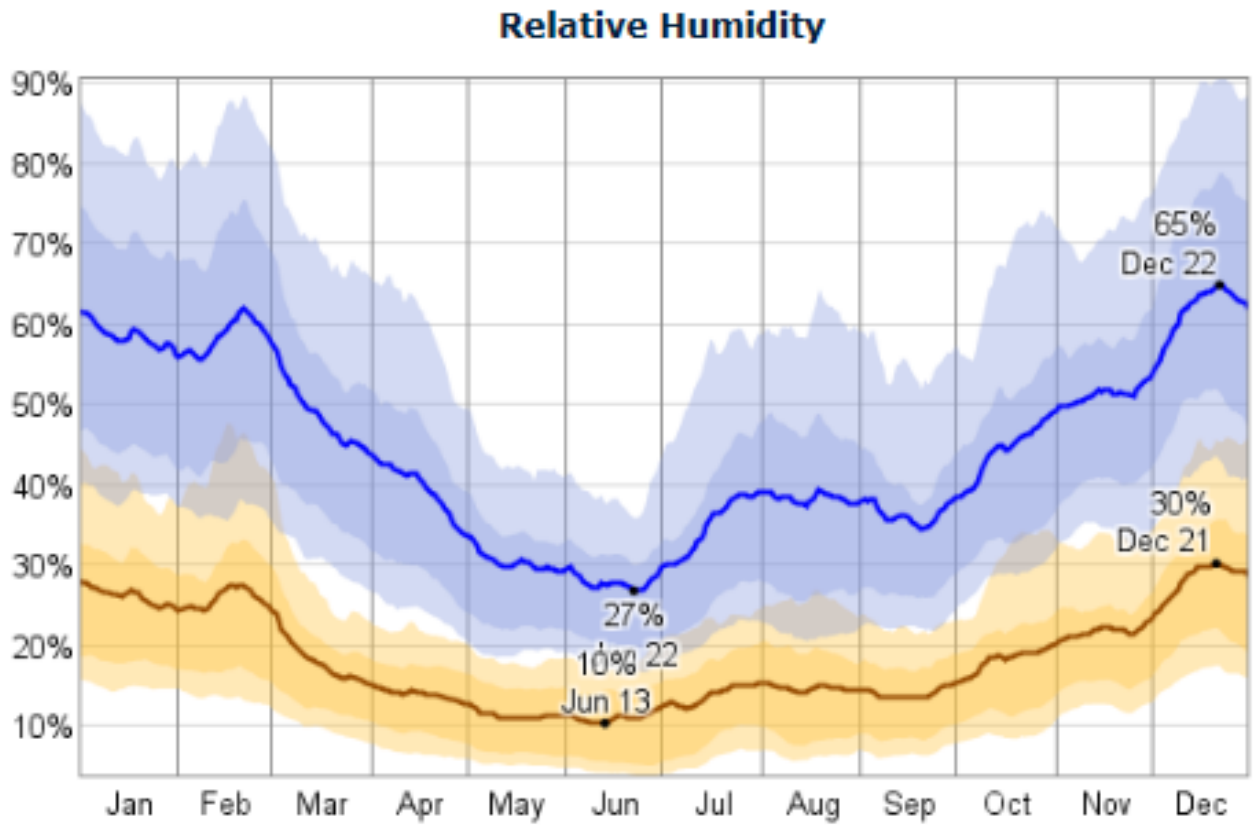
The Psychrometric Chart



Typical RH in Las Vegas, NV



The average daily high (blue) and low (brown) relative humidity with percentile bands (inner bands from 25th to 75th percentile, outer bands from 10th to 90th percentile).

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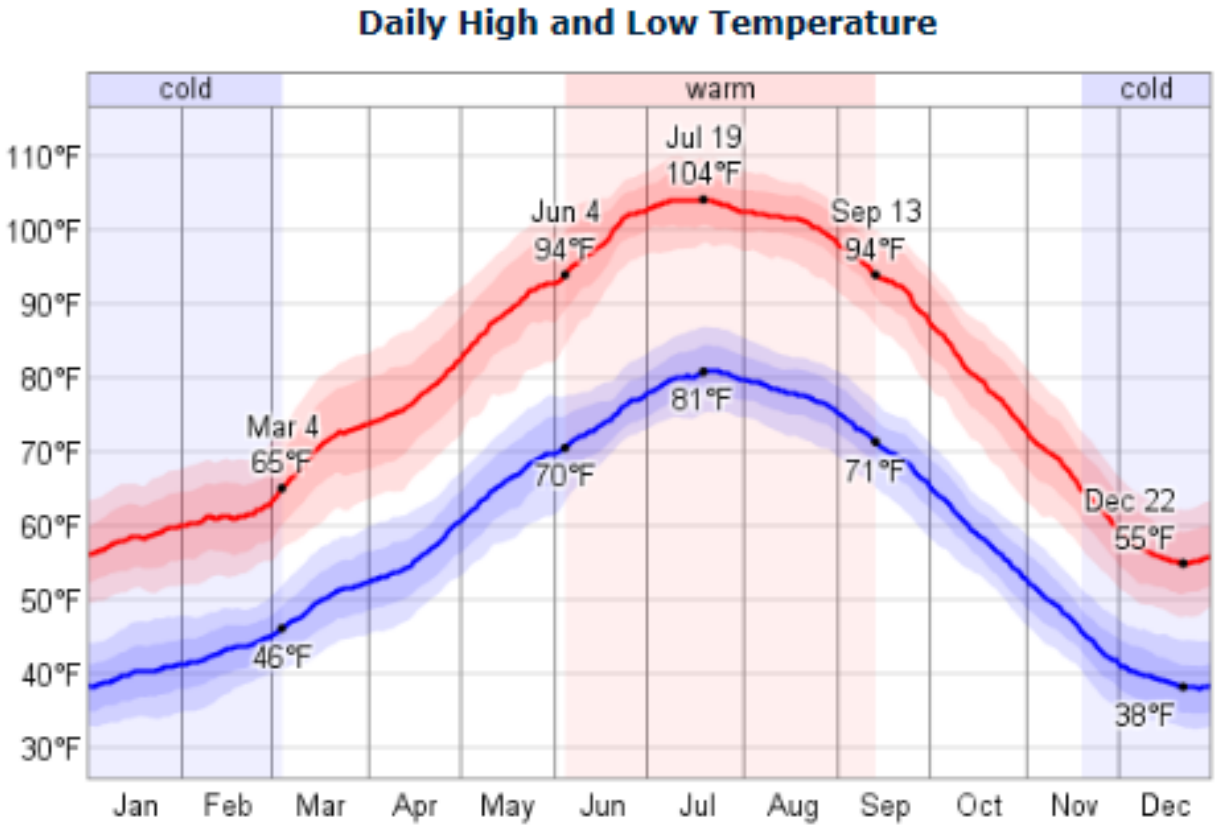
Typical Temps in Las Vegas, NV



The daily average low (blue) and high (red) temperature with percentile bands (inner band from 25th to 75th percentile, outer band from 10th to 90th percentile).

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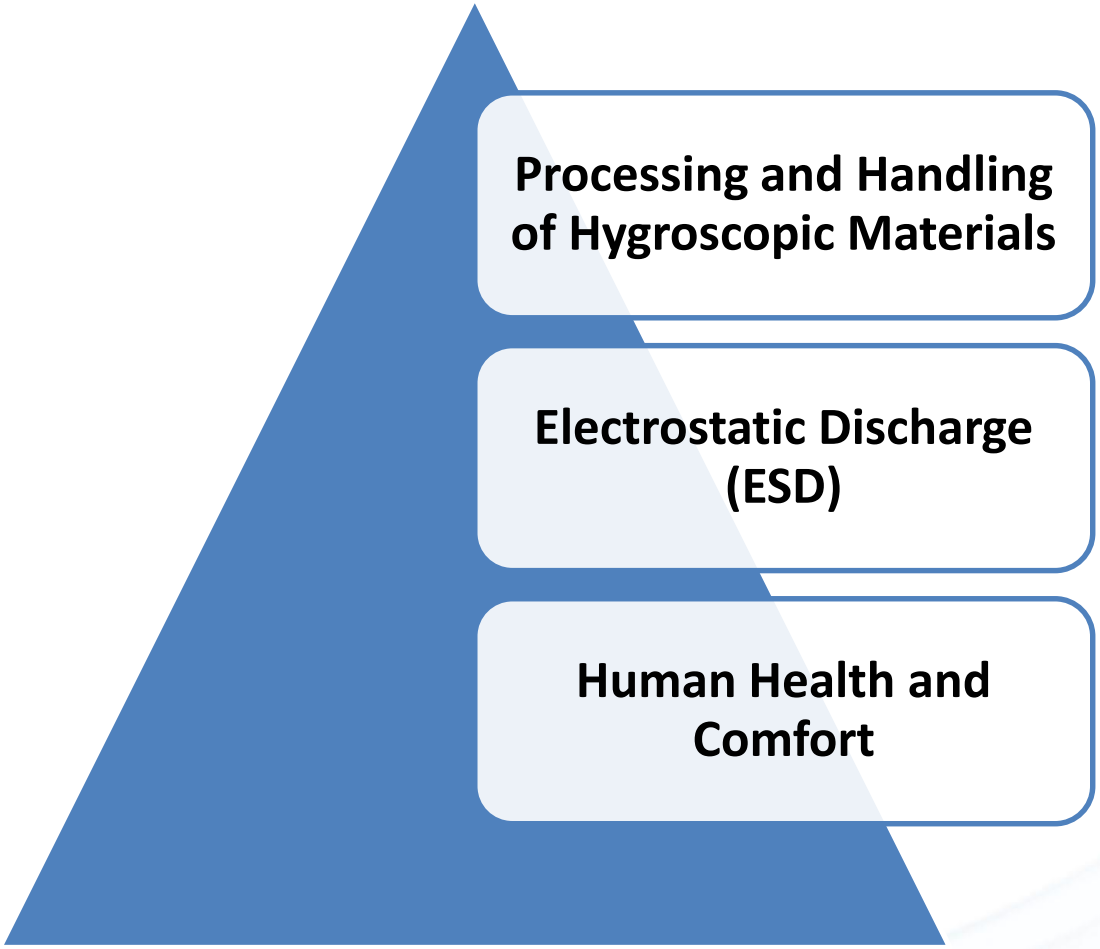
Need for Humidification

- **Summer (July 19th)**
  - 104F @ 10% RH = 72F @ 27.5% RH
- **Winter (Dec. 22nd)**
  - 38F @ 65% RH = 72F @ 19% RH
- **ASHRAE Winter Design Conditions**
  - 30F @ 50%RH = 72F @ 11% RH

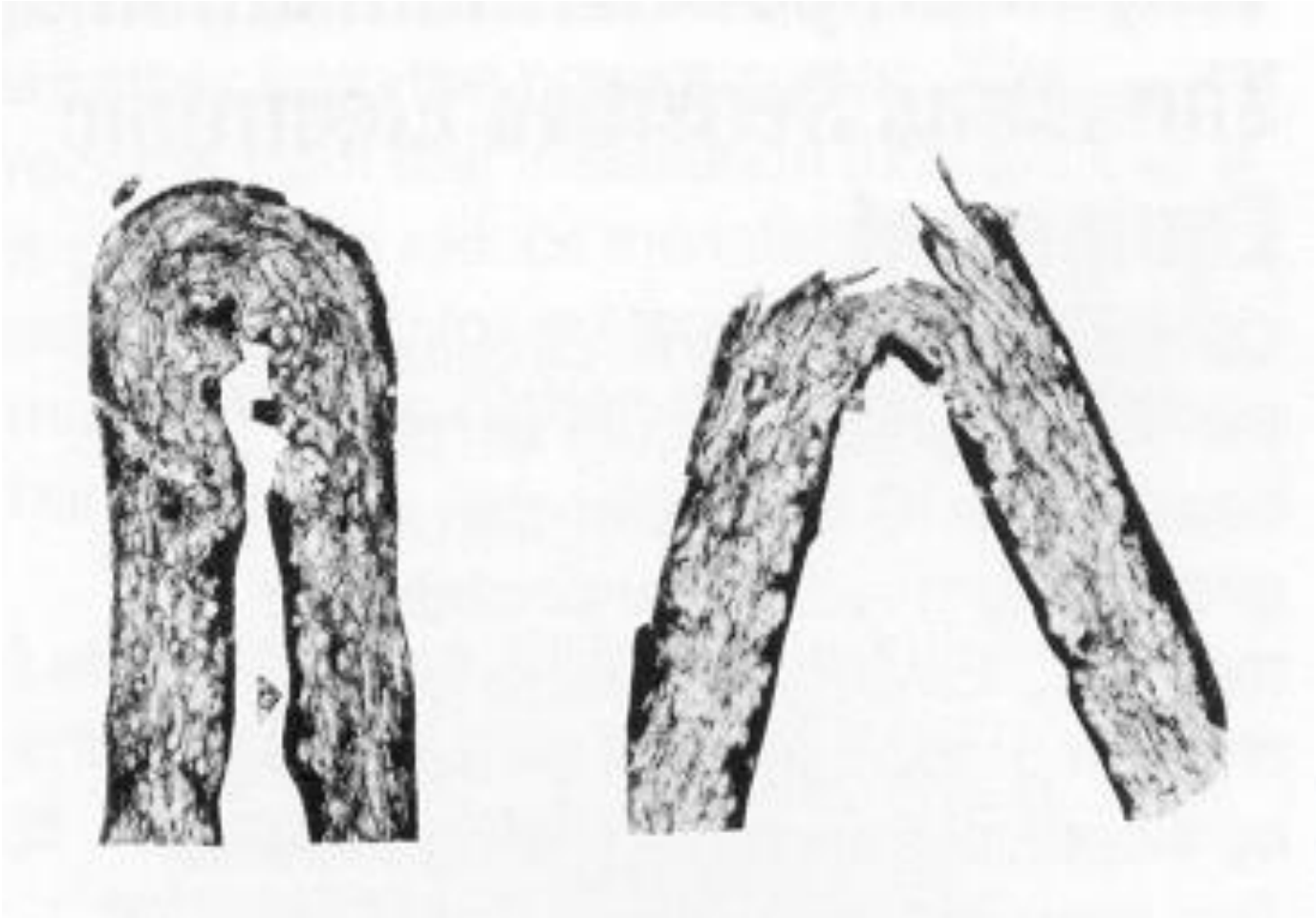
Problems Associated with Dry Air



Hygroscopic Materials

- **Most Common**
  - Paper / Leather / Books / Paintings / Wood Products
- **Common Effects**
  - Curling of Stock
  - Cracking or Breaking at Creases
  - Loss of Package Strength
  - Production Delays
  - Gluing Failures
  - Warping
  - Cracking
  - Dry Rot
- **Also applications in Food Storage / Concrete Curing / Ect.**

Effects of Humidity on Paper



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Electrostatic Discharge

- Electronic Office Equipment including Data Centers
- Manufacturing Facilities for Electronics
- Handling of Flammable Materials

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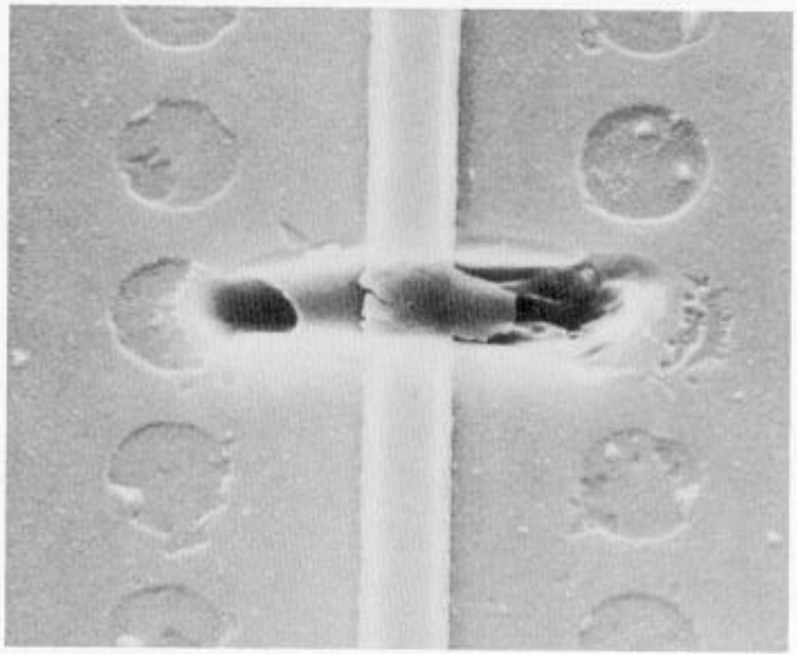
Humidity and ESD

	Electrostatic Voltages	
	10%-20% RH	65%-90% RH
Walking Across Carpet	35,000	1,500
Walking Over Vinyl Floor	12,000	250
Worker at Bench	6,000	100
Vinyl Envelopes for Work Instructions	7,000	600
Common Poly Bag Picked Up From Bench	20,000	1,200
Common Chair Padded with Polyurethane Foam	18,000	1,500

Lonnie Brown and Dan Burns, "The ESD Control Process is a Tool for Managing Quality," Electronic Packaging and Production, April 1990, pp 50-53

IC Damage from ESD

Figure 7-1.
Effect of humidity on electrostatic voltages



Integrated circuit damaged by ESD.
(Photo courtesy of Motorola Semiconductor, Inc.)

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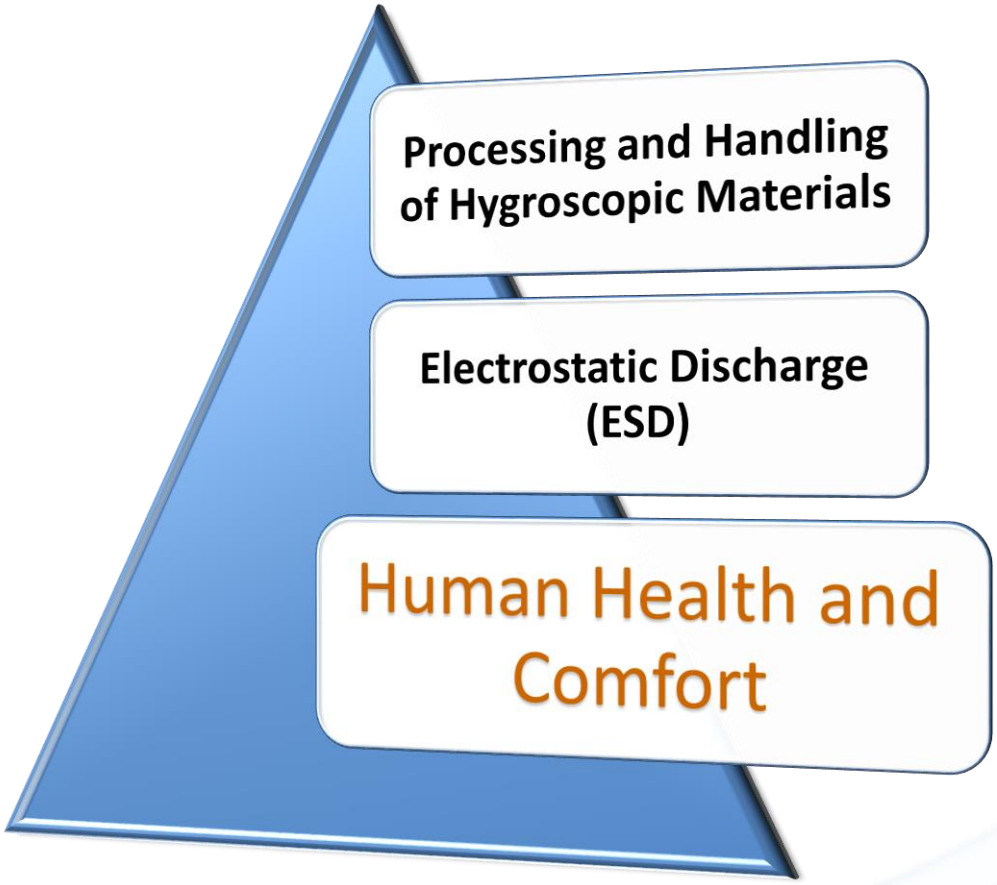
Problems Associated with Dry Air



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Humidity and People

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Humidity and People

- Historical humidity and health research
- Impacts of moisture on the human body
- Recent advances in humidity research

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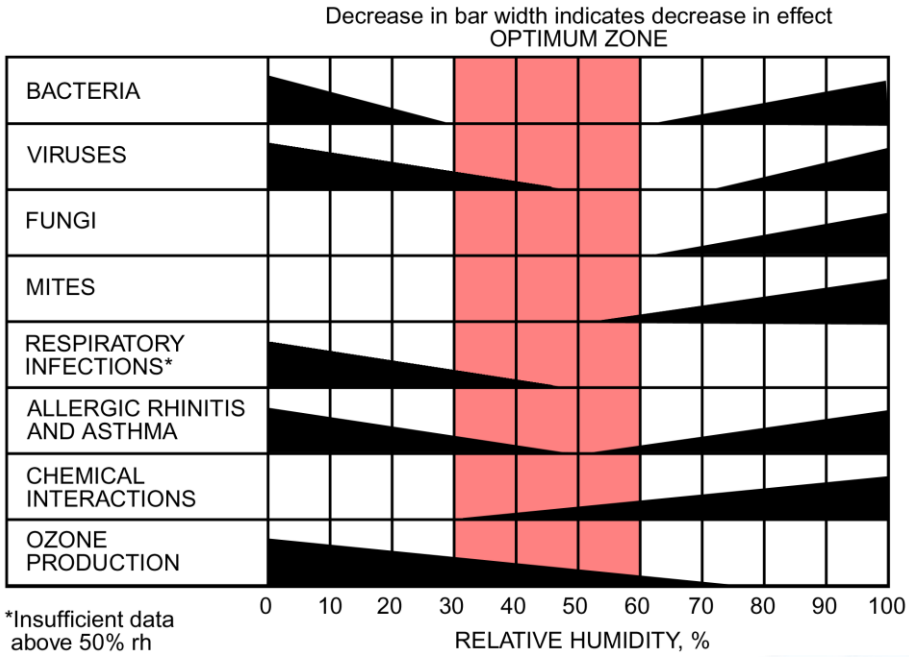
Historical Humidity and Health Research

- **Research primarily started in 1960s with a focus on allergies**
- **The Sterling Chart was first published in 1985[1]**
  - Focus is allergens, pathogens, chemicals and ozone
- **Updated by ASHRAE [2]**
  - Common reference for building design criteria
  - Mid-range humidity 30-60% is optimal for occupancy



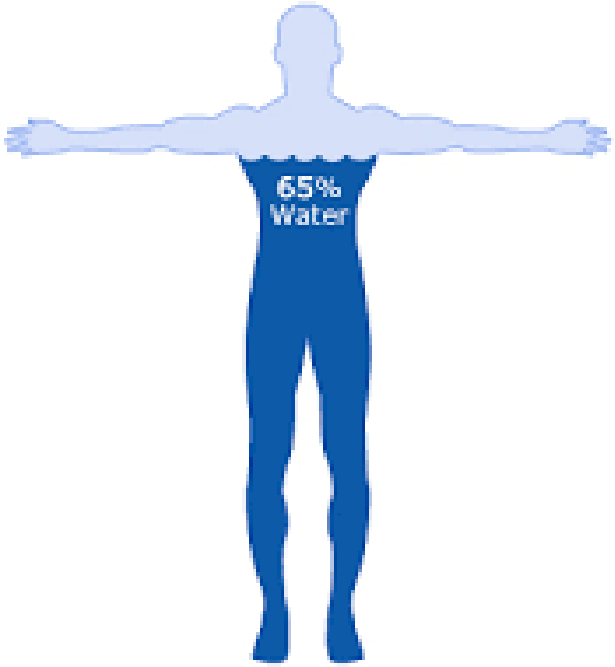
[2]2016 ASHRAE HVAC Systems and Equipment Handbook – Ch 22

[1] E.M. Sterling, A. Arundel, and T.D. Sterling, *Criteria for Human Exposure to Humidity in Occupied Buildings* (ASHRAE Transactions, 1985), Vol. 91, Part 1

Humidification for People

Human Body Response

- Human body is ~65% water
- The prevention of dehydration is critically important. Many human mechanisms exist to maintain overall fluid balance.
- Health and comfort (wellness) is significantly impacted by building humidity

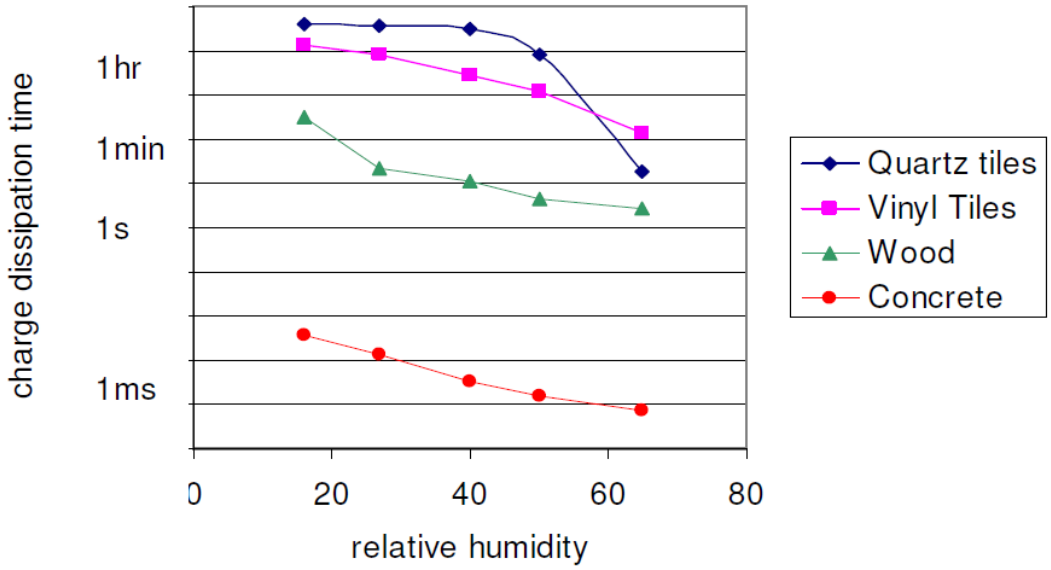


http://www.passmyexams.co.uk

Humidification for People

Static Electricity

- Is a build-up of electric charges within or on the surface of a material
- Can be a nuisance or a hazard
- Static issues decrease from ~20% to ~45% RH[1]



[1] Graham Hearn, Wolfson Electrostatics, *Controlling Static Electricity in Modern Buildings*

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Importance of Proper Humidification for Wellness

Skin

Maintaining healthy skin as a barrier is critical to wellness

Water content of innermost skin cells is ~70%

Below ~30% RH conditions, the skin becomes dry[1]

Dry skin symptoms include:

Itching, cracking and chapping

Skin conditions such as psoriasis

may become aggravated at lower RH

[1] Sunwoo Y, *Physiological and Subjective Responses to Low Relative Humidity in Young and Elderly Men*, (J Physio Anthropol, 2006 May), 25(3):229-38.

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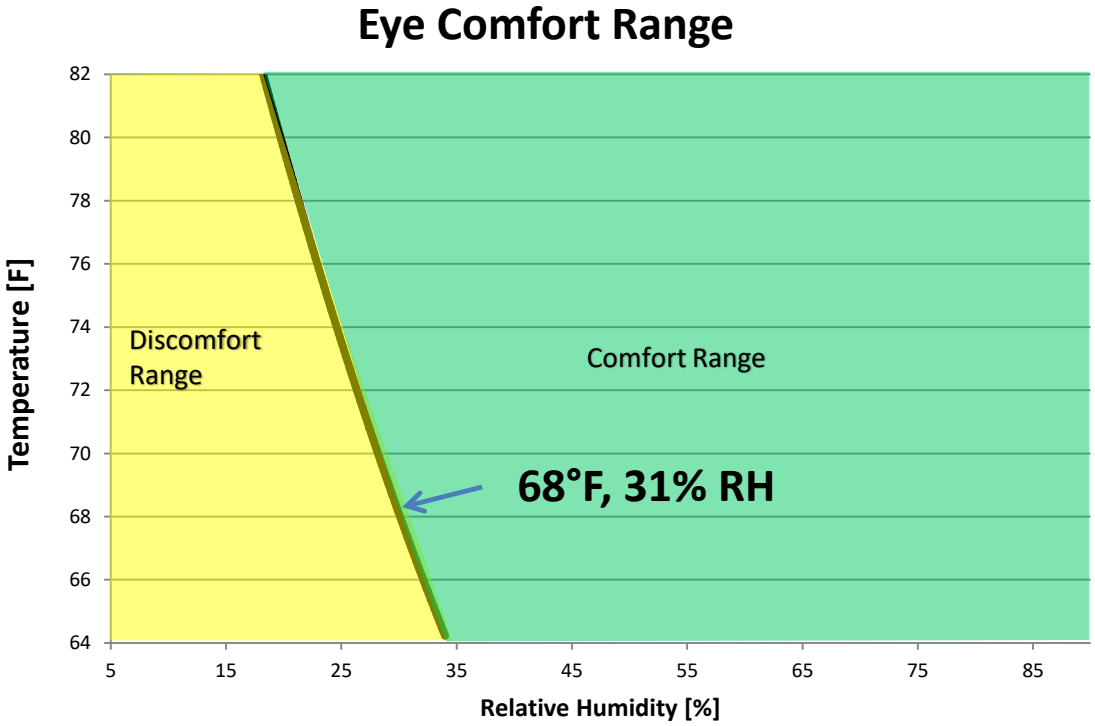
Importance of Proper Humidification for Wellness

Eyes

Low humidity causes a breakdown of the tear film

Discomfort to the eye increases with time if the dew point is below 26°F[1]



[1] J.E. Laviana, F.H. Rohles, Jr. and P.E. Bullock, *Humidity Comfort and Contact Lenses* (ASHRAE, 1988) 94(1), 3-11.

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Importance of Proper Humidification on Wellness

Throat

Humidity below 30% RH can irritate vocal chords [1]

- Dryness of throat
- Increased hoarseness or laryngitis
- National Institute for Health (NIH) recommends:
  - Drink water, six to eight glasses a day
  - Use a humidifier
  - Keep relative humidity > 30% RH

[1] National Institute on Deafness and Other Communication Disorders, *Taking Care of Your Voice*, https://www.nidcd.nih.gov/health/taking-care-your-voice (December 14, 2016)

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Importance of Proper Humidification on Wellness

Nasal Passages

- **Membranes in the nose dry out quicker in low humidity** [1]
  - Humidity above 30% RH is needed for the mucous membranes in the nose to properly filter the air we breathe
  - More significant impact on the elderly or health compromised

[1] J.P. Guggenbichler, R. Huster and S. Geiger, *Luftfeuchtigkeit und Immunabwehr Die Rolle der Schleimhaut und Auswirkungen auf die Klimatechnik* (2007) Tab Technik AM, Vol. 38, No. 9

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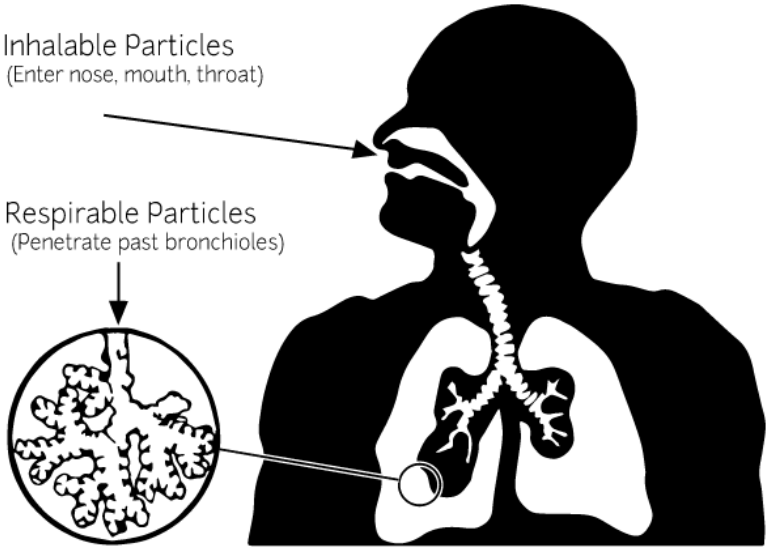
Importance of Proper Humidification for Wellness

- **Lungs – Low humidity results in breathing smaller particles** [1]
  - Low humidity can increase creation of smaller exhaled breathe aerosols that can retransmit microbes
  - Greater likelihood of particles being inhaled deeply



particles in the nose, throat, and lungs
an edited version of Figure 4-1 EPA/600/R-95/115

[1] ASHRAE Guideline 10-2016, *Interactions Affecting the Achievement of Acceptable Indoor Environments*

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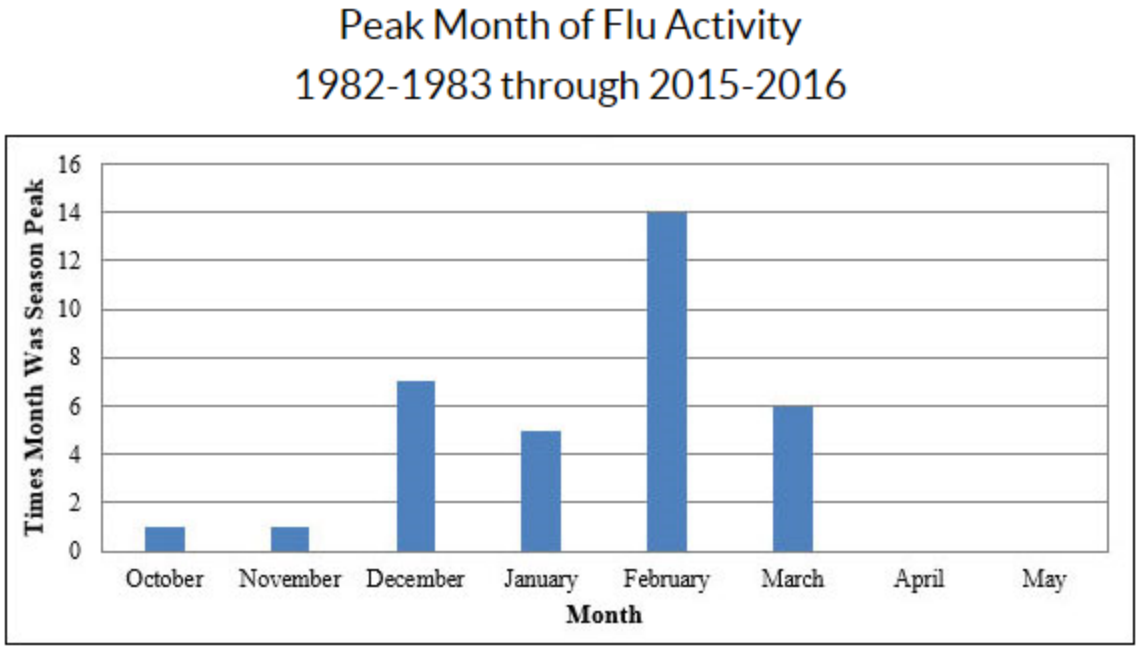
Recent Humidification Research

Health – Viruses and Seasonal Influenza

- **Influenza is more common in the fall and winter months[1]**



[1] https://www.cdc.gov/flu/about/season/flu-season.htm

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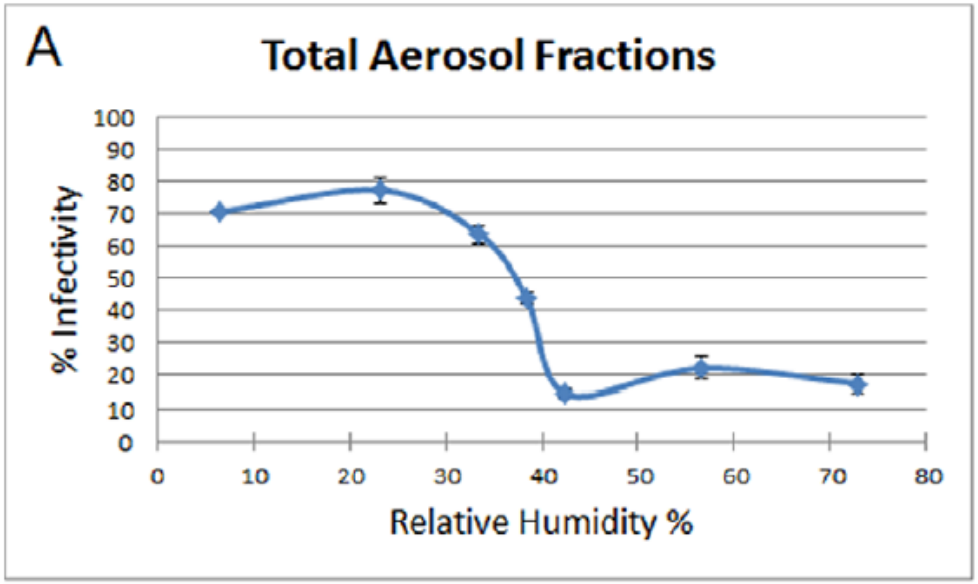
Recent Humidification Research

Influenza Virus

- **Studies show that higher humidity reduces infectivity of influenza**



Research indicates that 1 hour after coughing, the influenza virus is ~5 times more infectious at 7-23% than at > 43% RH

[1] John Noti, et al, *Humidity Leads to Loss of Infectious Influenza Virus from Simulated Coughs* (February 27, 2013)

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Recent Humidification Research

Health – Viruses and Seasonal Influenza

- **Possible reasons for increased winter influenza include[1] :**
  - People spend more time indoors in proximity of others
  - Exhaled aerosols can dry out and become smaller in lower humidity and have longer settling times
  - Drying of nasal mucous membrane weakens respiratory system
  - Virus is most stable at lower RH

Data suggests that humidifiers may be adequate to raise humidity to levels associated with a significant reduction in influenza virus survival[2]

[1] Anice Lowen, et al, *Influenza Virus Transmission Is Dependent on Relative Humidity and Temperature* (October 19, 2007)
[2] J. Metz, et al, *Influenza and Humidity – Why a bit more damp may be good for you!* (June 2015)

Recent Humidification Research

ASHRAE Research Project 1630 completed in 2016

Title - Update of the Scientific Evidence for Specifying Lower Limit Relative Humidity Levels for Comfort, Health and IEQ in Occupied Spaces

Authors - Melanie M. Derby, Maryam Hamehkasi, Steven Eckels, Grace M. Hwang, Byron Jones, Ronaldo Maghirang

About 600 articles were identified and 70 articles were reviewed in detail concerning effects of humidity on comfort, health, and indoor environmental quality

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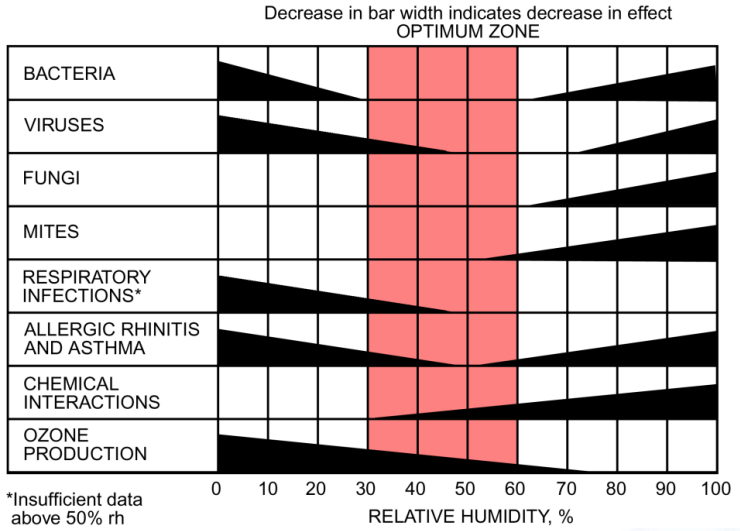
Recent Humidification Research

Findings include:

- Lower humidity decreased house dust mite allergens
- Lower humidity increased virus survival for influenza
- Health, comfort, skin dryness, eye irritation, and static electricity increased as humidity decreased

RP 1630 results are consistent with the updated Sterling Chart in the ASHRAE Handbook



Low and High humidity control is important for wellness, health and comfort

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Summary

- Humidity plays an important role in health and comfort
  - Our bodies are 65% water
  - Our skin, eyes, and respiratory system all need proper humidity

- Research shows a link between low humidity and the likelihood of flu
  - Our body defenses are stronger above 30% RH
  - There is less infectious flu virus in the air at higher RH levels
  - The likelihood of flu infectivity decreases at higher humidity levels

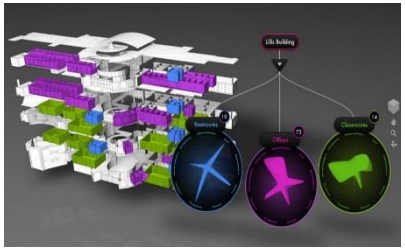
Updates in Humidity Research

With Contributions from Dr. Stephanie Taylor
And Dr. Med. Walter Hugentobler

What is the Microbiome ?

- **Microbiomes are communities of microbes – bacteria, viruses and fungi-that live in, on and around every living thing**
- **Microbiome of:**
  - the gut
  - the skin
  - the built environment
  - the air, etc

We send our microbes into buildings



Buildings send their microbes into us

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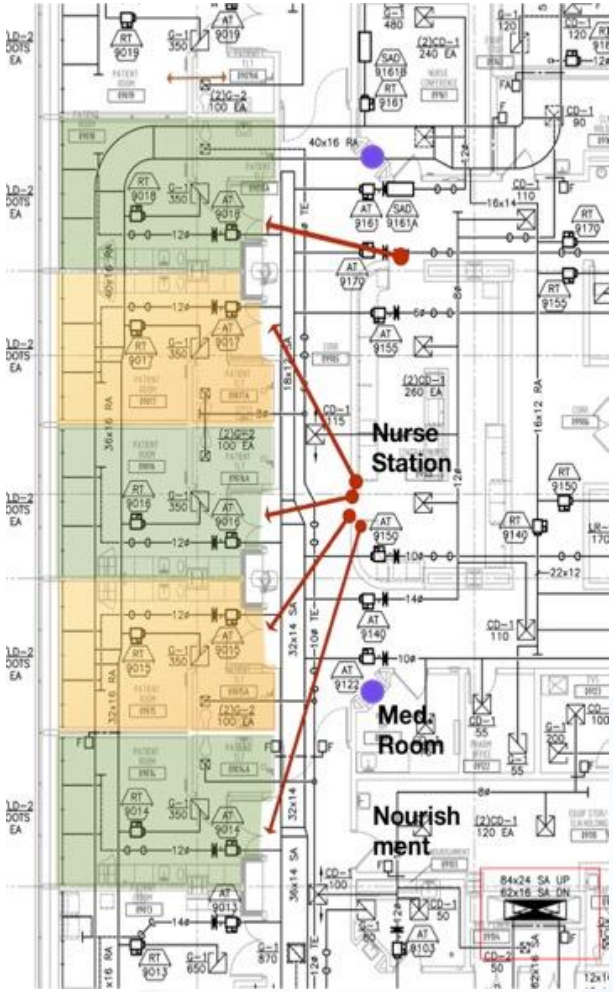
Microbiome Research in a New Hospital

- Constructed in 2013 to LEED Silver
- 1.2 million square feet, 12 story
- 240 single occupancy rooms



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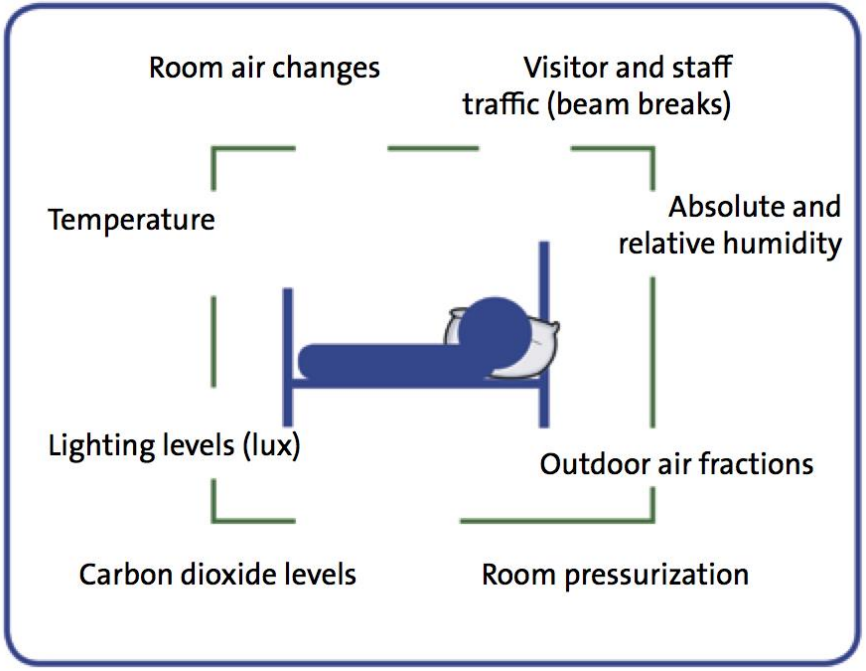
Research Goals: Patient Room vs. Patient Outcome

- Monitor the physical environment (10 rooms, 2 RN stations)
- Measure microbial footprint
- Determine Healthcare Associated Infections (HAI's)



5 minute samples for 1 year = 8 million data points

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Study Results

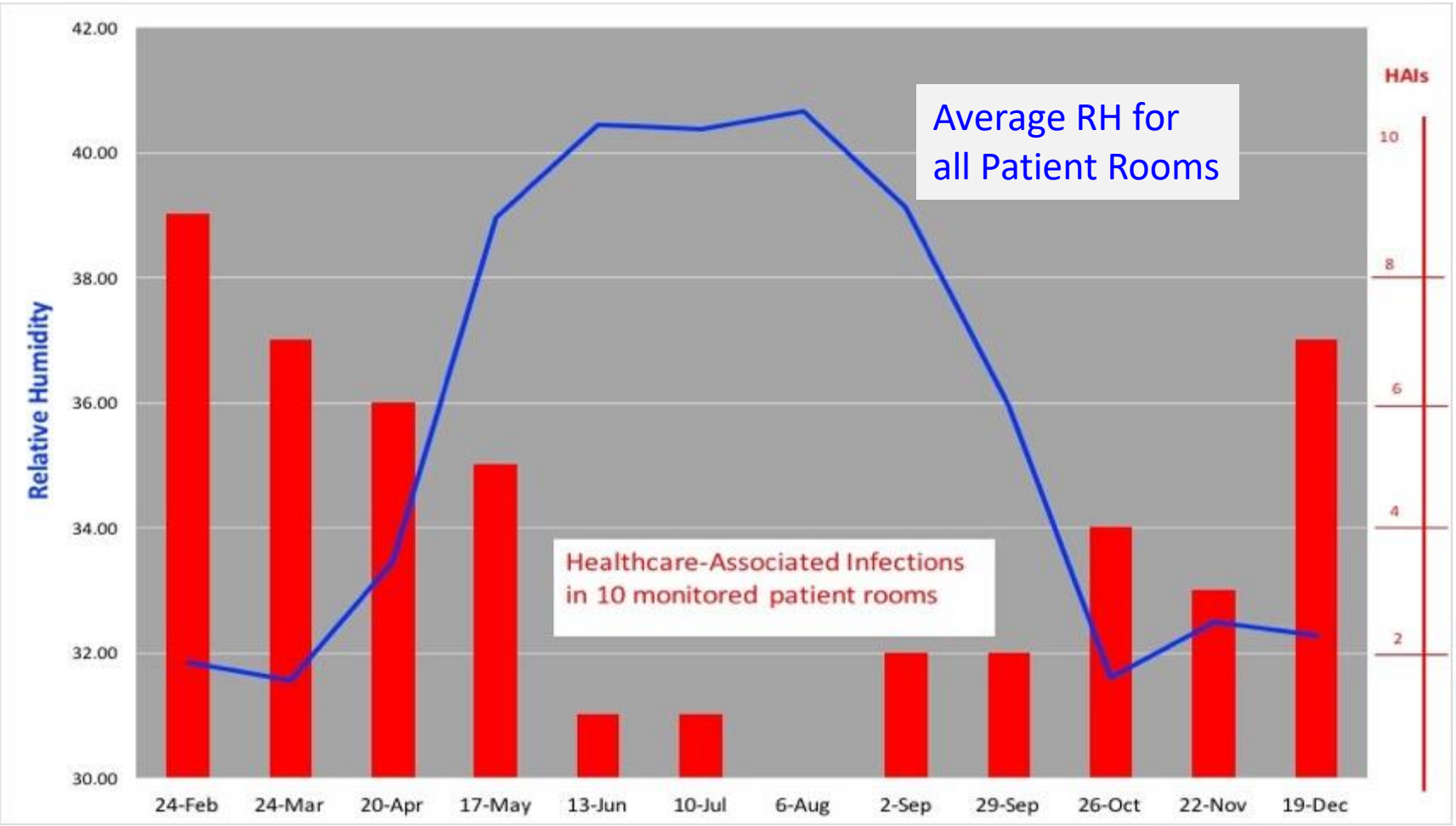
- **15% of patients contract HAI's**

Rate	Symptom	HAI Organism
1	Unspecified infection	Citrobacter infection
6	Colitis and Diarrhea	Clostridium difficile
6	Post-surgical Wound Infection	OIrganism Unspecified
2	Pneumonia	Cytomegalovirus, Pseudomonas, Epstein-Barr
5	Urosepsis	Organism unspecified, E-Coli
3	Infection with Joint Prosthesis	MRSA
6	Central Line with Blood Stream Infection	Bacteria Unspecified
4	Pneumonia	Organism Unspecified
1	Gastritis, Enteritis	Cytomegalovirus , Salmonella
4	Bacteremia	Organism Unspecified
2	Pneumonia	MRSA

Why?

- **Likely several reasons**
- **Most factors did not show strong correlation…**

Study Results: Indoor RH vs. Patient HAI's



Source: ***Colonization and Succession of Hospital-Associated Microbiota, in Press 2016***

Simon Lax, Daniel Smith, Naseer Sangwan, Kim Handley, Peter Larsen, Miles Richardson, Stephanie Taylor, Emily Landon, John Alverdy, Jeffrey Siegel, Brent Stephens, Rob Knight, Jack A Gilbert

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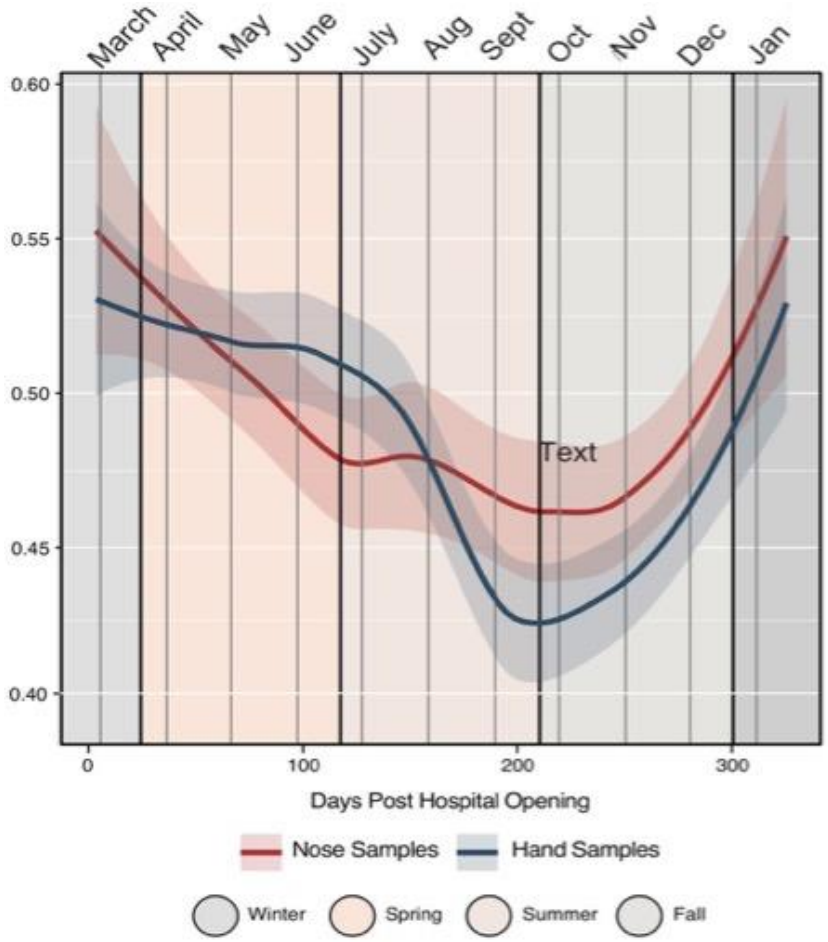
Study Results: Indoor RH vs. Bacteria Spread

Spread of skin bacteria from clinical staff



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Study Conclusions

As Relative Humidity goes ↓

Infections and bacterial spread goes ↑

$t < 0.02$ $t < 0.01$

How Costly Is This?

Summary of Total Excess Costs and Hospital Days Due to Hospital Acquired Infections

	Total Infections	Total Excess Costs	Total Excess Hospital Days
Urinary Tract Infections	1,296	$1,435,968	2592.0
Surgical Wound Infections	365	$7,042,464	4378.0
CRBSI	148	$4,990,636	2509.0
VAP	15	$401,369	170.0
MRSA	120	$927,162	646.0
CDIFF	122	$500,200	733.0
TOTAL	**2,066**	**$15,297,799**	**11,028.0**

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Mechanics of Infections: Droplets in Air

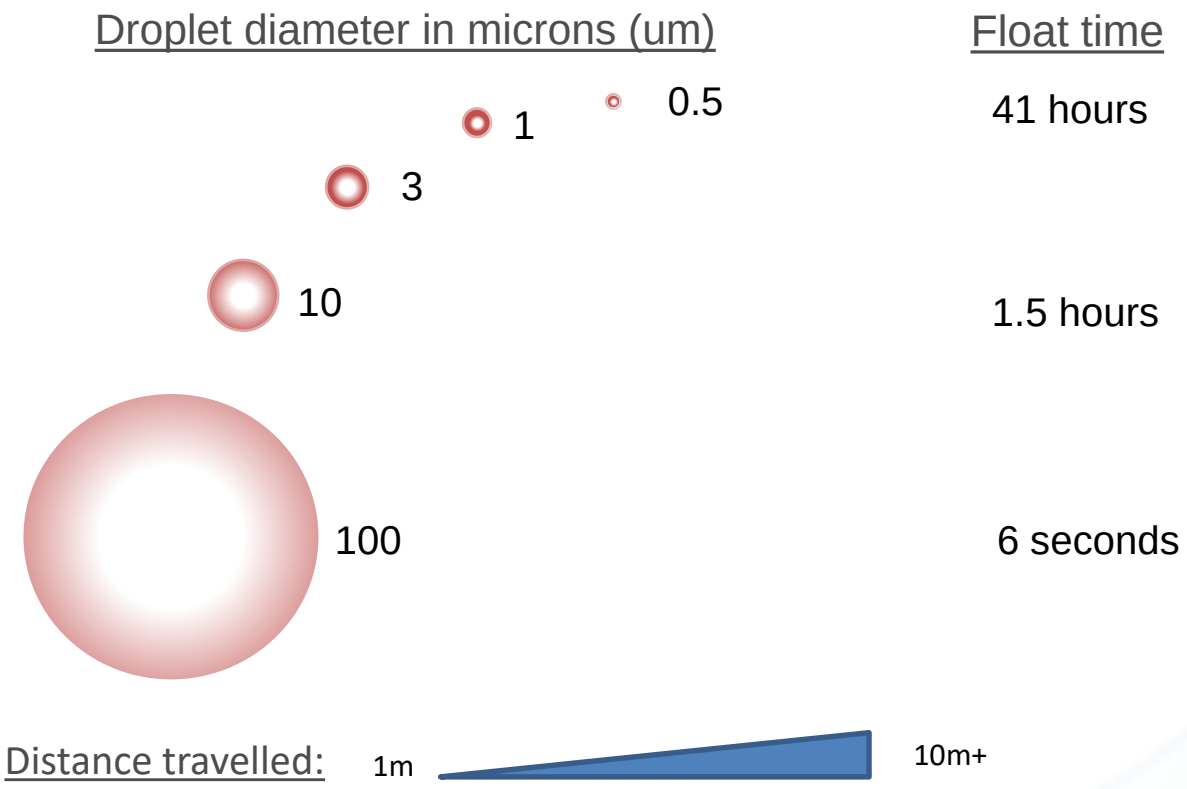
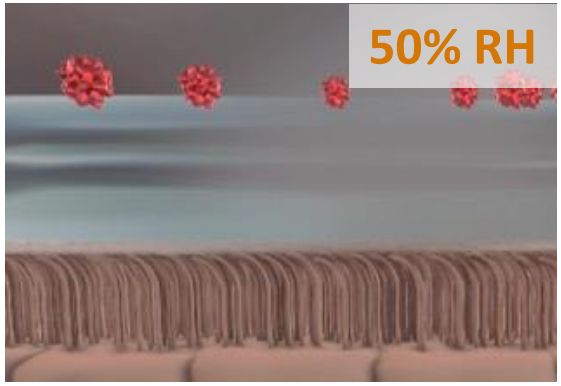


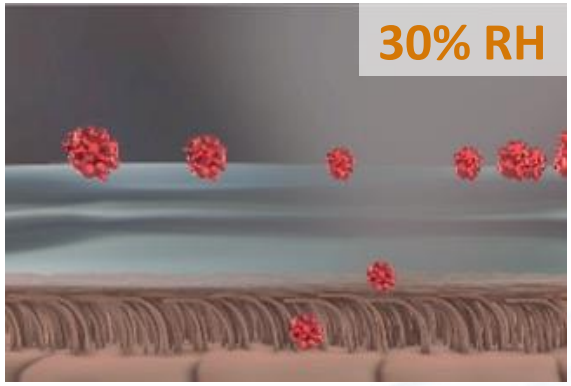
Image Courtesy: Dr. Stephanie Taylor

Mechanics of Infections

- Infectious particles survive longer in dry air

- Bodily defenses less effective in dry air





Images Courtesy: Condair AG

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Not Just Hospitals! Offices, Schools, Homes

- **Results of study apply more broadly**
  - Infectious organisms found everywhere
  - Controlling humidity is essential
- **Healthy employees pay dividends**
  - Fewer sick days
  - Reduced healthcare costs
  - Increased productivity
- **Costs and Incentives**
  - Hospitals penalized monetarily by HAI rates
  - Schools incentives for performance
  - What does illness cost your organization?

Image Courtesy: N. Lea

Unintended Consequences of Optimal Humidity

Image Courtesy: iStock Photo | Photo ID 173250244

Improved productivity through well being [1]

- Reduced eye strain
- Reduced vocal strain
- Reduced allergy and asthma impact
- Increased employee performance
- Mental acuity
- Improved perceived comfort (“humidex”)

[1] **Rief S and Juric M**, Air Humidity in the Office Workplace, Fraunhofer IAO, 2014

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Summary

- **Research shows humidity plays important role in health**
  - Low humidity levels promote infections and bacterial spread
  - Mid-range humidity is ideal target
- **Illness and sick occupants cost money!**
  - Healthcare costs
  - Penalties and lost incentives
  - Lost productivity
- **You Hold the Key!**

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Humidity in Your Building (Practical Applications)

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Technologies for Humidification

Steam vs. Atomizing

	Isothermals	Adiabatics
ASEPTIC HUMIDIFICATION	Steam doesn't carry bacteria	Water droplets introduced in the air: no recirculation Treated water
CAPACITY	Small - **Medium** sized loads (100's)	Small to **Large** sized loads (1000's)
POWER CONSUMPTION	High	Very Low
REQUIRED FREE SPACE	Steam is easily and quickly absorbed by the air	Minimum evaporation space (> 36" - **60"** typ.)
TEMPERATURE CHANGE	Temperature doesn't change significantly	Yes **COOLING EFFECT**
WATER	Tap and treated (maintenance)	Tap and treated (maintenance)

***Typical for the industry**

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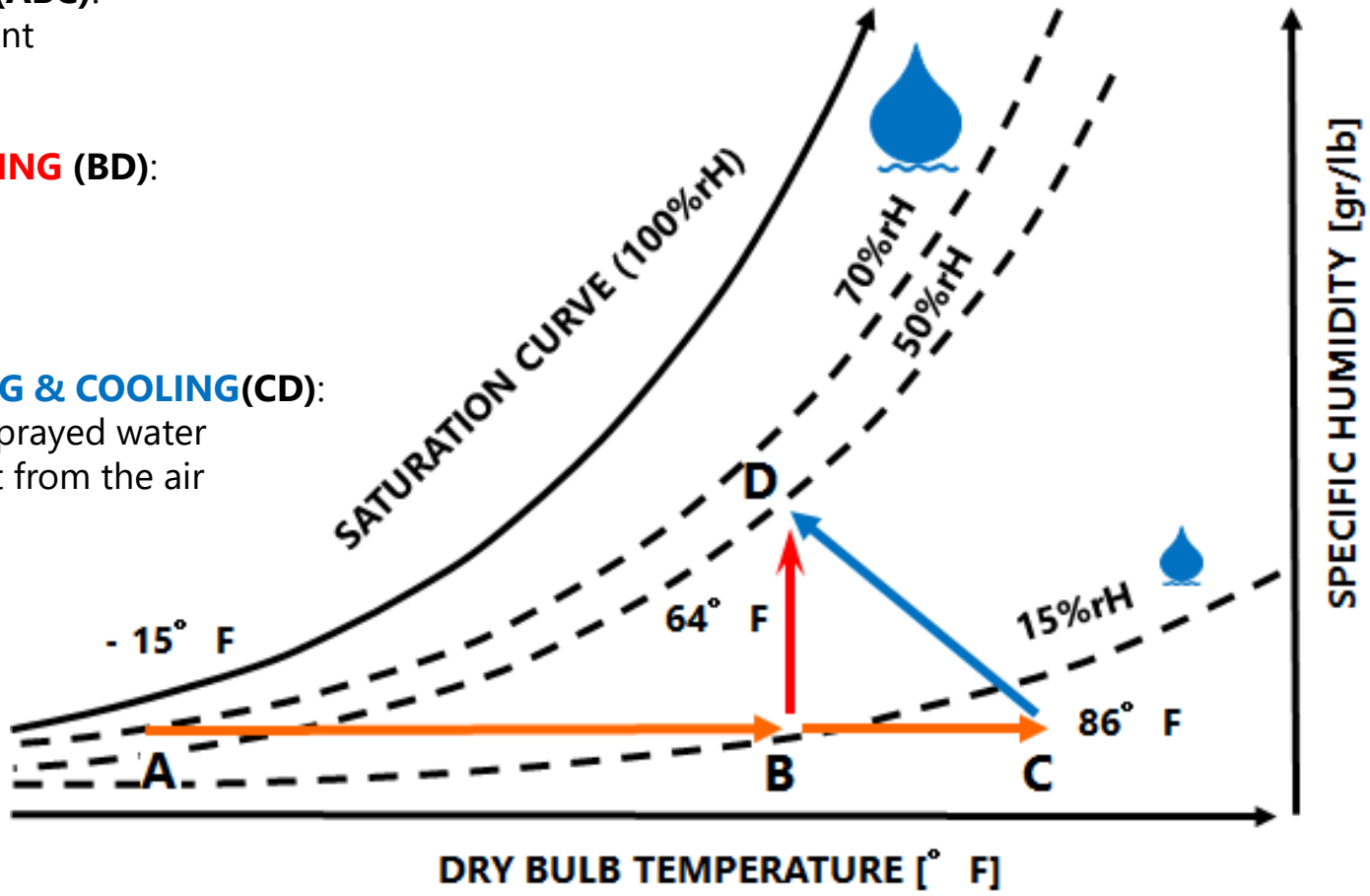
Humidifying with Isothermal & Adiabatic Systems

MECHANICAL HEATING (ABC):
moisture content = constant

ISOTHERMAL HUMIDIFYING (BD):
temp = constant
(i.e. excepted steam baths)

ADIABATIC HUMIDIFYING & COOLING(CD):
temp decreases because sprayed water evaporates absorbing heat from the air



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Technologies for Humidification

Steam Technologies

Gas Fired

Gas

Electric

Electrode

Resistive

Building Steam

Centralized Steam

Steam to Steam

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Technologies for Humidification

Adiabatic Technologies

Wetted Media

Centrifugal

Ultrasonic

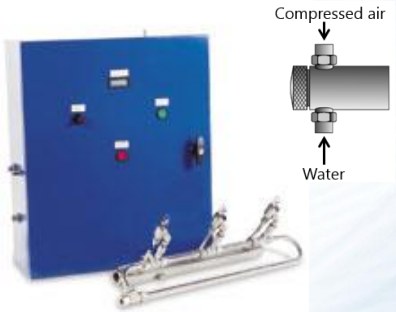
Medium Pressure

High Pressure

Room

Duct

Compressed Air



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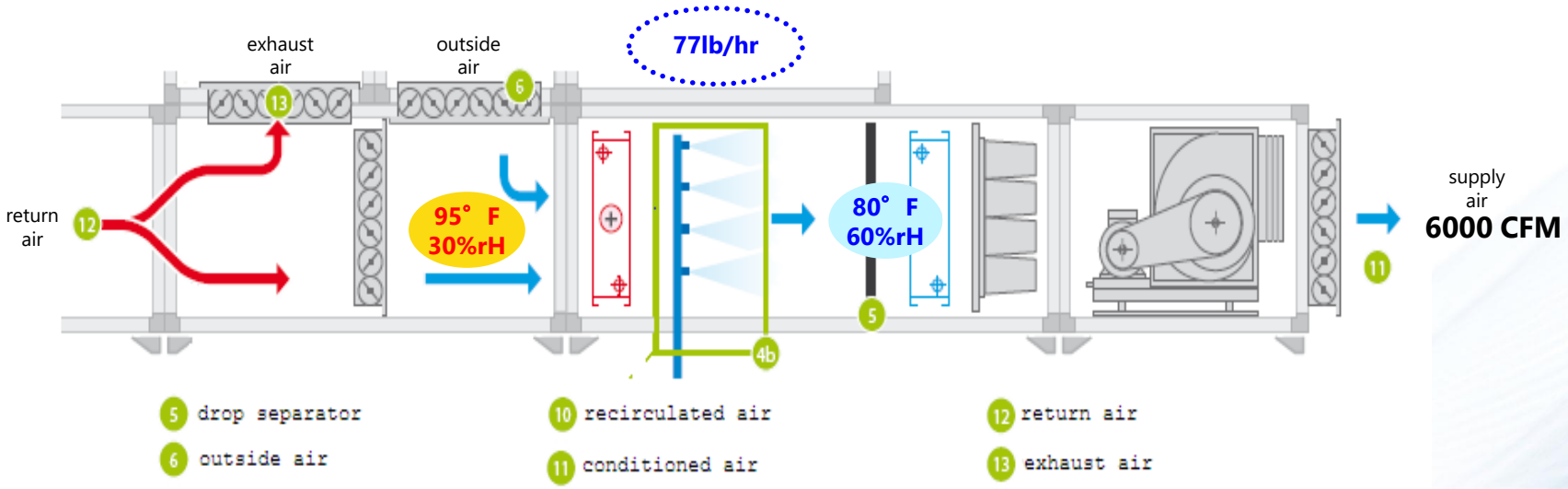
Cooling & Humidifying with Adiabatic Systems

Cooling the air by water evaporation directly in the supply air:

1058 btu/hr of cooling capacity per **1lb/hr** of evaporated water

77lb/hr
+
1kW electric power
=
82k BTU/hr cooling
≈
8.5kW electric saving

THE AIR IS COOLED AND HUMIDIFIED



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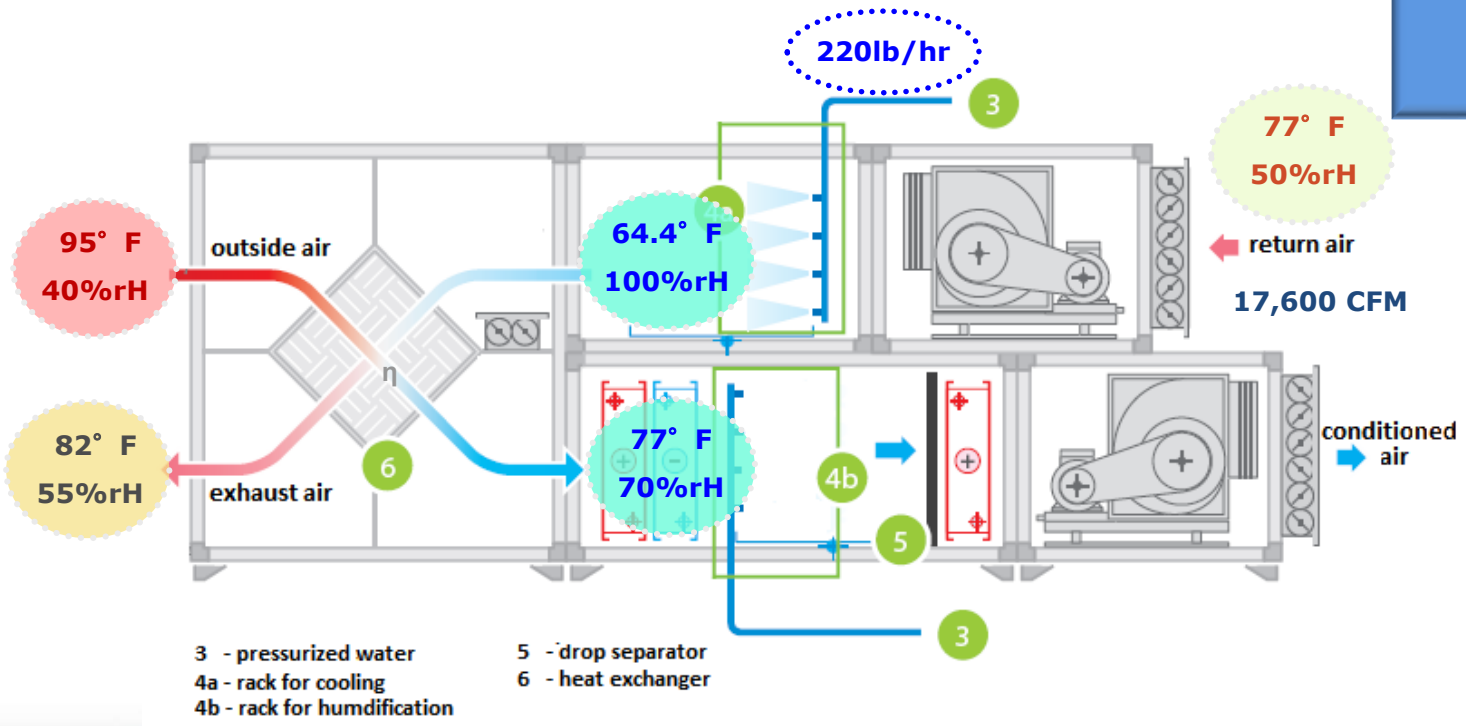
Cooling & Humidifying with Adiabatic Systems

The exhaust air is cooled before entering the heat recovery unit: it sensibly cools the outdoor air thus reducing the load at the cooling coil.

Smaller coil, smaller chiller, lower running costs

IEC does not add moisture on supply air:
SENSIBLE COOLING ONLY

220 lb/h
+
1kW electric power
+
heat recovery ϵ=58%
=
144k BTU/h cooling
(12 tons)
≈
15 kW electric saving



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Application: Hospital

Details:

Location: Santorso (VI), Italy
Technology: High Pressure Atomizers

Image Courtesy: AHRI Member Company

Installation Notes

- 66 units ranging 220 – 2200 lb/hr
- Humidification during cooling mode
- Multiple zones from a single system
- Minimal maintenance required

Image Courtesy: AHRI Member Company

Benefits:

- Evap cooling reduces mechanical needs
- Reduced mechanical energy costs
- Building constructed using Green principals

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Application: Residential Home

Details:

Location: Madison, WI

Technology: Evaporative and Steam

Installation Notes

- Multiple HVAC Systems
- Automatic humidistat control
- Outdoor temperature sensor
- Closet Installation

Benefits:

- Improved homeowner comfort
- Potential energy savings
- Preservation of wood furnishings
- Potential of improved wellness

Image Courtesy: AHRI Member Company

Application: Bikram Yoga Studio

Details:

Location: Phoenix, AZ

Technology: Resistive Element

Installation Notes

- Humidity added directly to room
- Humidifier installed in closet
- Oversized to enable quick startup

Benefits:

- Rapid startup reduces time to open studio
- Operates on standard tap water
- Clean steam reduces odor potential
- Health and wellness of occupants

Images Courtesy :N. Lea

Application: Assisted Living Facility

Details:

Technology: Natural Gas Fired Steam
Short Absorption Manifold

Image Courtesy: AHRI Member Company

Installation Notes

- Short distance for steam absorption
- No indoor space available

Benefits:

- Saved valuable indoor space
- Reduced electrical load by using gas
- Able to absorb in a relatively short distance saving space in the AHU
- Created comfortable environment for not only the elderly but for the health and wellness of all occupants

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Application: Office Building

Details:

Location: Bratislava, Slovakia

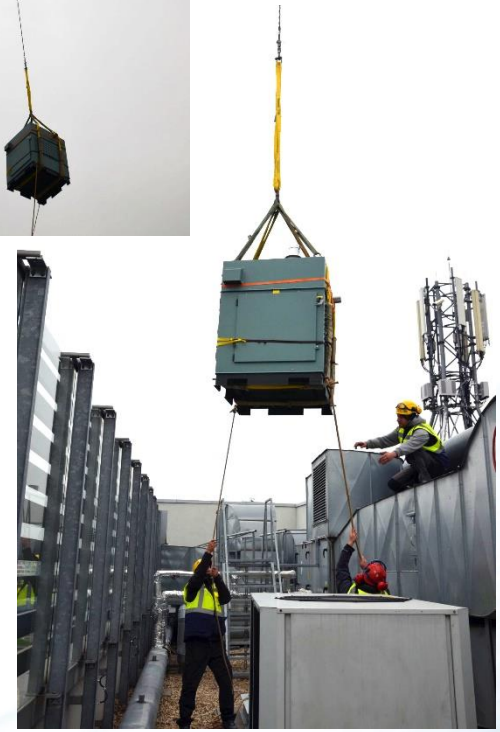
Technology: Natural Gas Fired Steam

Installation Notes

- Tight space was impossible for crane
- Outdoor model saved mechanical space
- Gas selected for capacity and energy cost

Benefits:

- Improved employee eye, skin, and vocal health
- Potential reductions in absenteeism
- Potential improved productivity through well being
- Preservation of building finishes



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Application: Cleanroom Manufacturing

Details:

Location: Dallas, Tx

Technology: High Pressure Fogging

Installation Notes

- Multiple 60,000 cfm rooftop units
- Precision +/-1% control sequence
- Modular design facilitates service
- Process water avoids mineral dust

Benefits:

- Maintains humidity within process spec
- Reduces potential for static electricity
- Evaporative effect reduces mechanical cooling

Images Courtesy: N. Lea

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Application: Social Media Data Center

Details:

Location: Northern Sweden

Technology: Evaporative Media

Installation Notes

- Fans and filters run length of building
- 78 side by side evaporative coolers
- 50,000 lbs of water evaporate per hour

Benefits:

- 4,500 tons of evaporative cooling
- Low energy input and cost
- Stable server environment
- Reduced potential for static electricity

Image Courtesy: AHRI Member Company

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Application: Cancer Research Data Center

Details:

Location: Seattle, WA

Technology: Evaporative Media

Installation Notes

- 750 kW “Tier II” Datacenter
- 106,000 cfm ventilation
- Humidity added in unique “AHU corridor”
- Economizer + Evap proves 90% cooling

Benefits:

- Evap cooling offsets mechanical needs
- Optimal environment for servers
- Helped achieve low overall energy consumption

Image Source: http://www.aeieng.com/index.php/10729-00

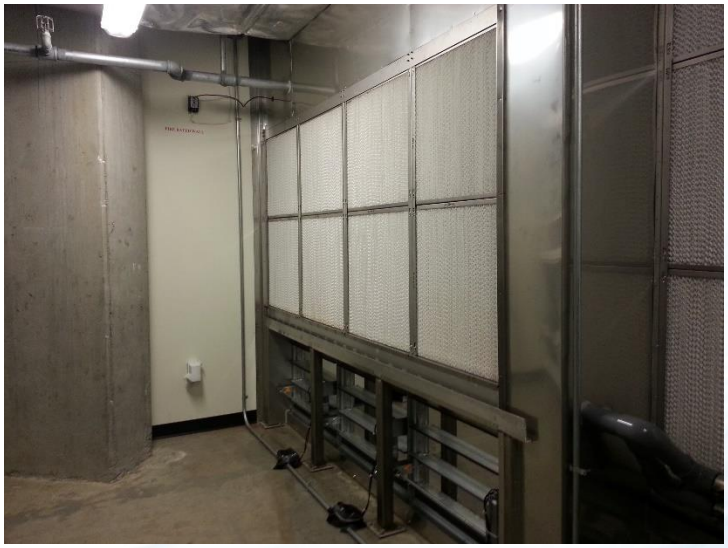

Image Courtesy: N. Lea

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Application: Printing Facility

Details:

Location: Kaukauna, WI

Technology: Natural Gas Fired Steam

Image Courtesy: AHRI Member Company

Installation Notes

- Excessive electrostatic charges
  (folding, packaging, delivery of finished products)
- No existing provisions for duct mounting
- Precision +/-2% control sequence
- Minimal maintenance required

Image Courtesy: AHRI Member Company

Benefits:

- Reduced potential for static electricity
- Direct to space without interrupting existing mech. systems
- Reduced energy cost over traditional electric humidifier

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Humidity Design Resources: More Information

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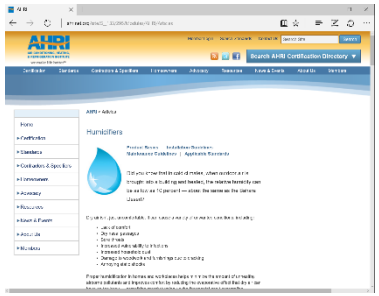
ASHRAE Handbooks

- 2016 Systems and Equipment Chapter 22
- 2015 HVAC Applications



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AHRI Humidifiers Section

- www.ahrinet.org
- Click Contractors and Specifiers

Photo Credit: N. Lea

Local Standards and Norms

- Codes, Federal Standards, etc.
- Euro Standard EN 15251:2007

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Summary

- When outdoor air is cooler than indoor air you are generally going to see a drying effect in buildings
- Air that is too dry has negative health effects for occupants. Target 30 – 60% RH for optimal occupant wellness (eyes, skin, nasal)
- Research shows the relative humidity is in controlling the spread of illness and in particular Hospital Acquired Infections (HAI's). There is a clear payback in Hospitals, which can be easily extrapolated to many building types
- Todays humidifiers are considerably more advanced that old generations and there are types and technologies to match any applications humidity needs, and potentially even contribute to cooling.

Questions

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