Session #2: HVAC Fundamentals
Toward Healthier Buildings: Humidification

Presented by: Dan Hahne
Varitec: Director of High-Performance HVAC Solutions

Introduction

- **Education:**
  - University of Arizona – Chemical Engineering
    - 1974 thru 1976
  - University College London – BFA Degree (Sculpture)
    - 1978 thru 1983
  - Boston University – MFA Degree (Sculpture)
    - 1983 thru 1985

- **Industry:**
  - Norman S. Wright SW: Estimator/Sales
    - 1985 thru 1999
  - Air Specialty Products/ThermAir Systems: Outside Sales
    - 2000 thru 2008
  - Air Specialty Products/ThermAir Systems: Engineering Sales
    - 2009 thru 2016
  - **Varitec Solutions:** Senior Sales Engineer
    - 2016 - 2022
    - 2022 - Director of High-Performance HVAC Solutions/Educator

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Varitec: The HVAC System Solution

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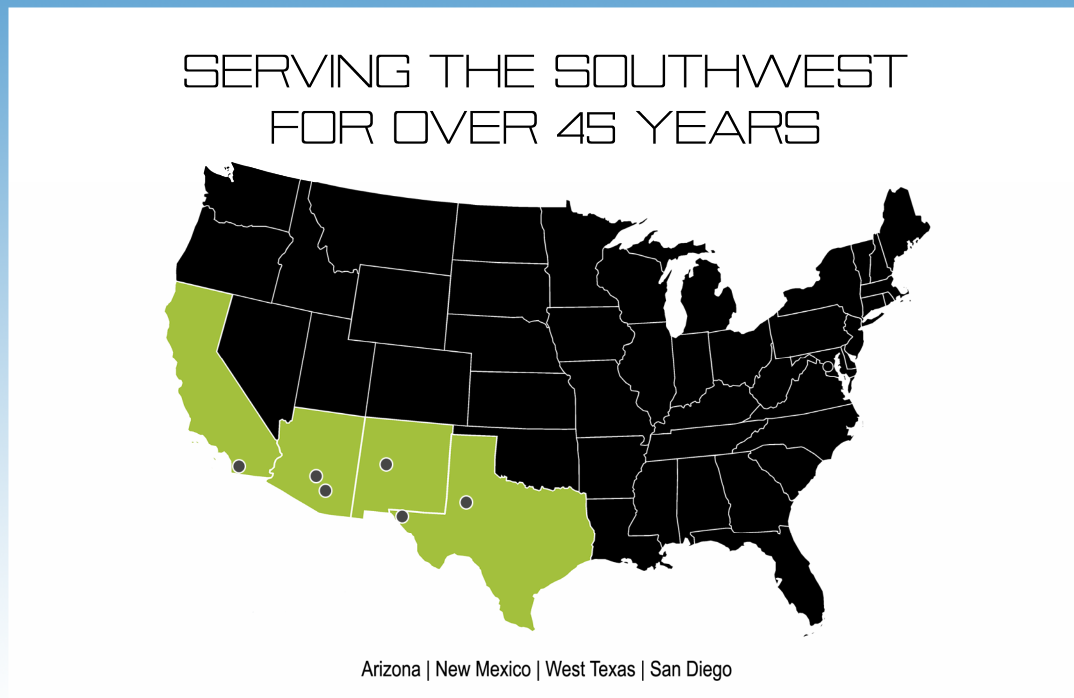
Varitec: The HVAC System Solution



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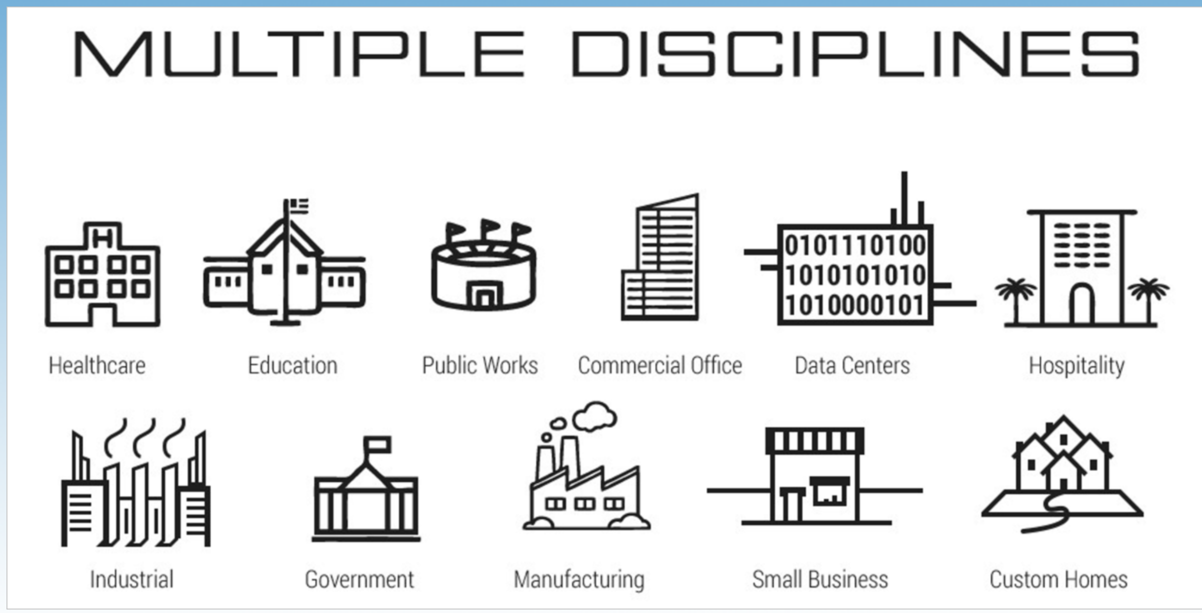

Varitec: The HVAC System Solution

System Solutions:

- Mixed Air VAV Systems
- Package Central Plants for Air & Water Cooled Designs
- Variable Refrigerant Systems
- Underfloor Air Systems
- 100% OSA Systems
    - DOAS Technology
    - Active Chilled Beams
    - Passive Hydronic Cooling & Heating Systems
- Cloud Based Controls
- Humidity Control

Varitec: The HVAC System Solution

Shaping
The Future
Of HVAC

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Varitec Technical Institute

Mission:

To provide an educational platform for continued learning in the HVAC industry with a focus on high performance buildings and innovative technologies for a better built environment.

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February 15th : Market Pressures & Performance

- Health & Well-Being, One Breath at a Time

March 22nd : Fundamentals of HVAC

- Session #1: Fundamentals of HVAC Systems

April 19th: Fundamentals of HVAC

- Session #2: Toward Healthier Buildings, Humidification

May 10th: Fundamentals of HVAC

- **Session #3: Psychrometrics Deconstructed Part 1**

June 14th : Fundamentals of HVAC

- Session #4: Psychrometrics Deconstructed Part 2

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VARITEC™
WEBINAR:
FUNDAMENTALS OF HVAC SYSTEMS

July 12th: Fundamentals of HVAC

- Session #4: The Physics of Air Flow

September 13th: 100% Outside Air Systems

- The Importance of Ventilation & Building Design Considerations

October 11th: Thermally Stratified Environments

November 8th: Underfloor Air Systems

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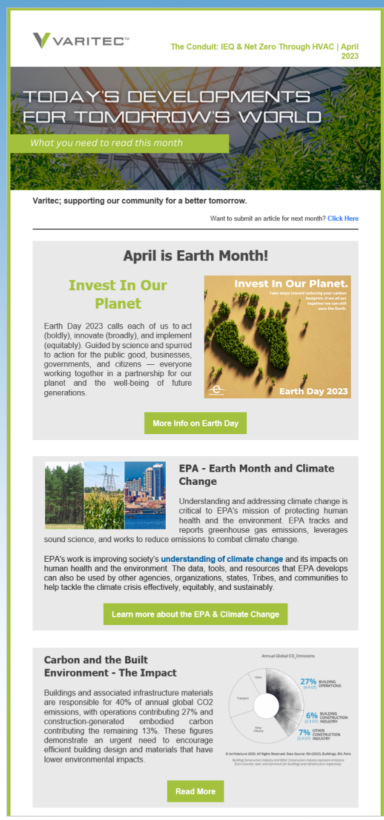

Varitec's Monthly Newsletter:

- Introducing the Inflation Reduction Act Guidebook
- Designing Buildings that Are Both Well-Ventilated and Green
- Newly Released ASHRAE 90.1-2022 Includes Expanded Scope for Building Sites
- Report: Indoor Air Pollution Could be Five Times Worse than Outdoor Air Pollution
- ASHRAE February Podcast: Regulating Contaminants with Benjamin Jones

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Humidification

Agenda:

- **Session #1: HVAC Fundamentals Review**
  - Thermal Comfort, Energy and Heat Transfer
- **The Nature of Water**
  - The States of Water
  - Terms and Definitions
  - The Physics of Water Vapor
    - Dan’s Home Office/Studio
- **ASHRAE:**
  - Position Document on Infectious Aerosols
- **Humidity & The Risk of Infection**

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Session #1: Fundamentals of HVAC Systems Thermal Comfort, Energy, Heat Transfer, and ASHRAE Standards Review

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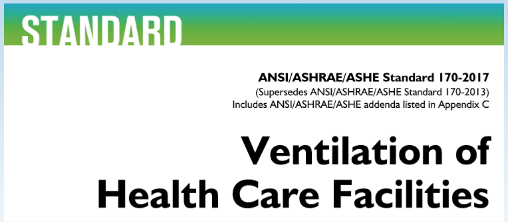
Thermal Comfort

ASHRAE: American Society of Heating Refrigeration & Air Conditioning Engineers

- An American professional association seeking to advance heating, ventilation, air conditioning and refrigeration systems design and construction
- They write the HVAC standards adopted by many state and municipal authorities for HVAC minimum requirements, recommendations and research information
- **www.ashrae.org**



STANDARD

ANSI/ASHRAE/ASHE Standard 170-2017
(Supersedes ANSI/ASHRAE/ASHE Standard 170-2013)
Includes ANSI/ASHRAE/ASHE addenda listed in Appendix C

Ventilation of Health Care Facilities

ASHRAE: Mission Statement

- To serve humanity by advancing the arts and sciences of heating, ventilation, air conditioning refrigeration and their allied fields.

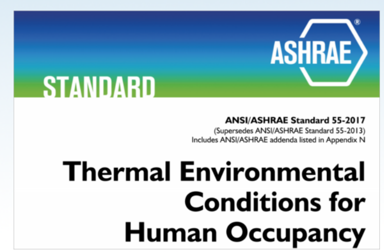
Fundamentals of HVAC: Part 1 - Review

Heating, Ventilating & Air Conditioning Systems: Purpose

- **Thermal Comfort:**
  - **ASHRAE Standard 55: Definition:** "…the condition of mind that expresses satisfaction with the thermal environment and is assessed by subjective evaluation."
- **Indoor Air Quality (IAQ):**
  - ASHRAE Standard 62.1: Create a healthy environment with a reduced risk of infection

Principles of Thermal Comfort

- **ASHRAE Standard 55**
  - Factors for Thermal Comfort



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Fundamentals of HVAC: Part 1 - Review

Heating, Ventilating & Air Conditioning Systems: Purpose

Factors for Thermal Comfort:

- Factor #1: Temperature
- Factor #2: Humidity
- Factor #3: Radiant Heat
- Factor #4: Air Speed
- Factor #5: Occupant Metabolic Rate
- Factor #6: Clothing Insulation

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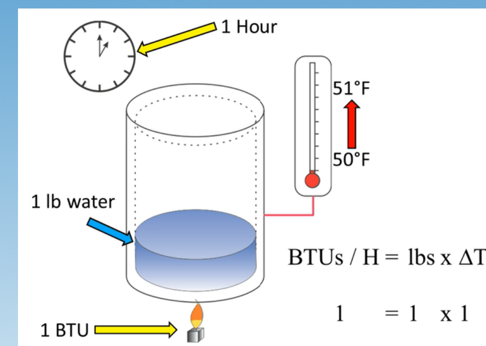
Fundamentals of HVAC: Part 1 - Review

Factor #1: Temperature

- **Definition: Temperature is** a measure of the amount of **thermal energy in the air**



Thermal Energy (Measured in BTUs)

- British Thermal Unit (BTU) – The amount of energy to raise (1) pound of water (1) degree Fahrenheit (F)

- **(1) ton of energy (load) = 12,000 BTUs of energy**
- **Energy in the air measured at a thermostat is SENSIBLE HEAT ENERGY**
- **Dry Bulb Temperature: Fahrenheit (F)**

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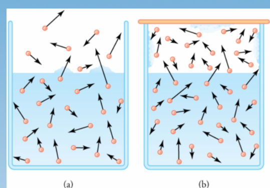
Fundamentals of HVAC: Part 1 - Review

Factor #2: Humidity

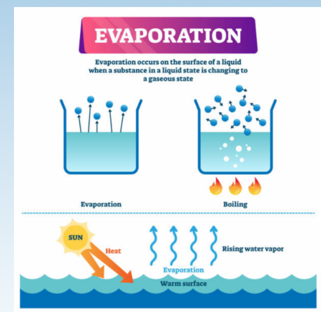


Thermal Energy & Water Relationship:

- The state of water is determined by **the amount of thermal energy** present in a given sample of H_2O

Thermal Energy, Evaporation & Water Vapor:

- Higher fluid temperature = Greater molecular activity
- Greater molecular activity = greater evaporation rate.



- **LATENT ENERGY:** Energy needed to sustain water in a vapor state
- **Wet moves to Dry**

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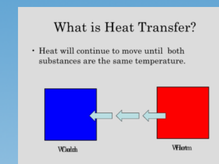
Fundamentals of HVAC: Part 1 - Review

Heat Transfer: Purpose & Modes

- **Energy in regions of high energy states moves to regions of lower energy states (Heat Transfer):**



Cooling: Transfer heat energy from a building and deposit it outdoors

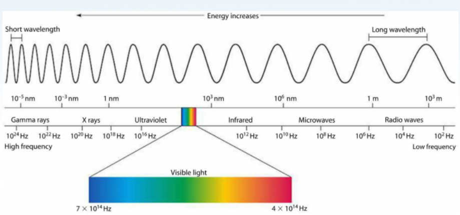
- **Sensible Cooling:** Reduce thermal energy in a building
- **Latent Cooling:** Reduce the amount of water vapor (dehumidification)

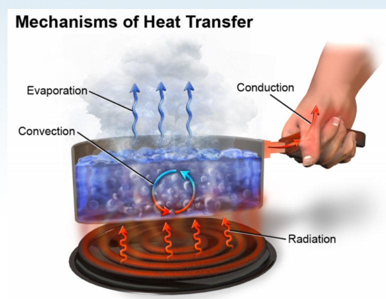
Heating: Add heat energy to a building

- **Sensible Heating:** Add thermal energy
- **Latent "Heating":** Adding moisture to a building (Humidification)

Heat Transfer: Modes

- **Conduction**
- **Convection**
- **Radiation**
- **Evaporation**



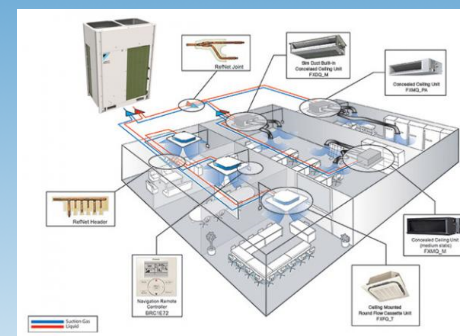


Fundamentals of HVAC: Part 1 - Review

Heat Transfer Mediums:

Heat Transfer Fluid: Definition

- "**..heat transfer fluid is a gas or liquid** that takes part in heat transfer by serving as an intermediary in cooling on one side of a process (i.e. a building), transporting and storing thermal energy and heating on another side of a process". (i.e. outdoors) (Wikipedia)



HVAC: Heat Transfer Mediums

- **Air**
- **Water**
- **Refrigerant**

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The Nature of Water

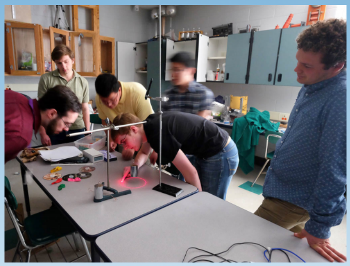
The Nature of Water: Terms & Definitions

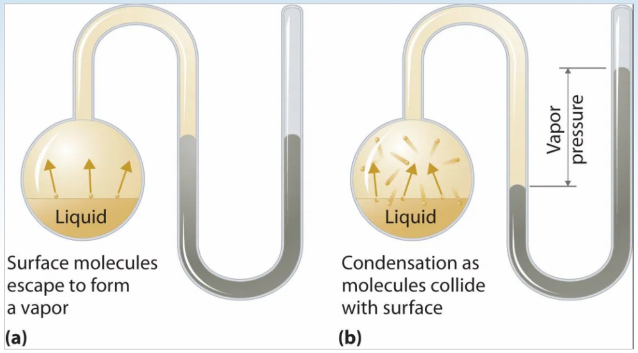
High School Physics Class:

Understanding Phase Change:

Definitions:

- Energy
- Equilibrium
- Force
- Pressure





- Relative Humidity (RH)
- Vapor Pressure (In Hg)
- Dew Point (F)
- Specific Humidity (gr_{water}/lb_{air})
- Absolute Humidity (lbs_{water}/lbs_{air})

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The Nature of Water: Terms & Definitions

Definition: Energy

- "Energy, in physics, the capacity for doing work…potential, kinetic, thermal, electrical, chemical, nuclear, or other various forms. (Britannica)"
- **"All forms of energy are associated with motion."**

(Mineral Medix)

Energy is the physical cause (Force) of motion and quantitative or qualitative states: (Change)

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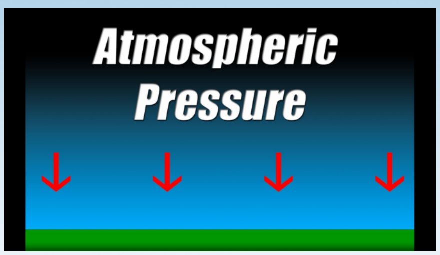
The Nature of Water: Terms & Definitions

Definition: Change

- "…to make different in some particular: ALTER
  (Merriam-Webster Dictionary)
- "The actualizing of potentiality of the subject…"
  (Aristotle)
- HVAC Language: To **create a change of state**



Definition: Force

- "…in mechanics, **any action** that tends to maintain or alter the motion of a body or to distort it." (Britannica)
- HVAC Language: **To Move Energy**

Definition: Pressure

- " …continuous physical **force** exerted on or against an object by something in contact with it" (Oxford Dictionary)

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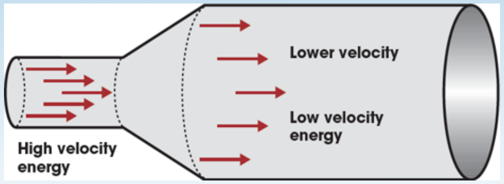
The Nature of Water: Terms & Definitions

Equilibrium: Thermal Energy (Heat Transfer)

- All physical states and/or objects seek to be at rest; i.e. **Equilibrium**
- Heat energy always moves to cold (Heat Transfer):
  - **Conduction**
  - **Convection**
  - **Radiation**



Equilibrium: Pressure

- **Air or moisture** at high pressure states will always tend to lower pressure states **(Pressure Differentials)**

Air Pressure: "Nothing sucks, everything blows" (Dan Int-Hout)

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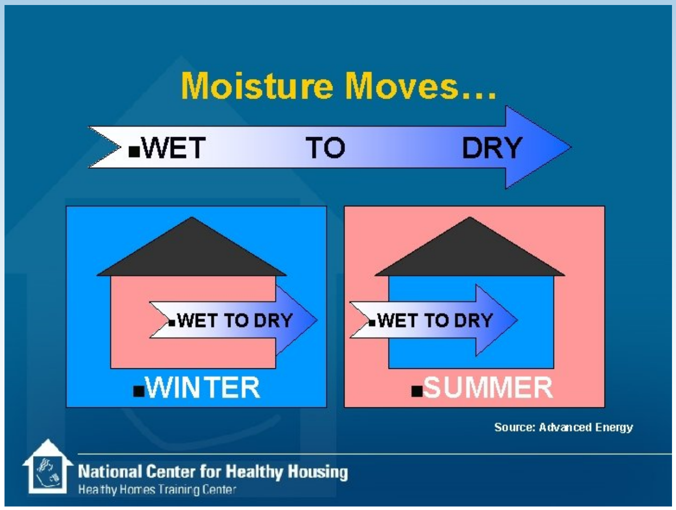
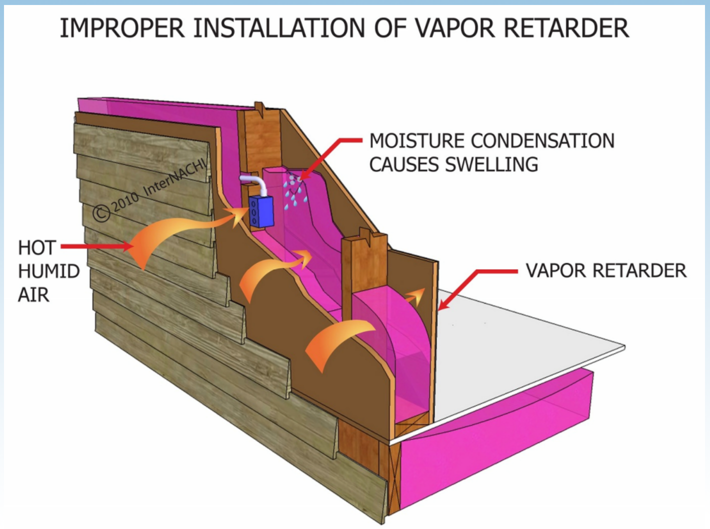
The Nature of Water: Terms & Definitions

Equilibrium: Water Vapor & Vapor Pressure

- Like thermal energy, **moisture will always move from "wet" conditions to "drier" conditions** to achieve a state of **"hydrous equilibrium"**





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The Nature of Water: Terms & Definitions

What is Water?

- "… a substance composed of the chemical elements hydrogen and oxygen and existing in gaseous, liquid, and solid states." (Britannica)

The Three States of Water: (SEA LEVEL)

- **Liquid:**
  - Water as a fluid exists within a range of temperatures between 32F (freezing) and 212F (boiling)
- **Gaseous:**
  - Water in the form of a vapor
- **Solid:**
  - Water in the form of a solid, ice

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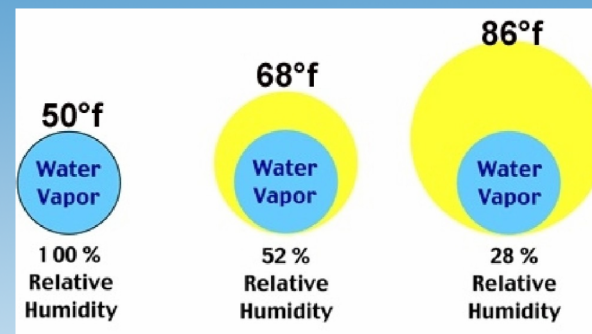
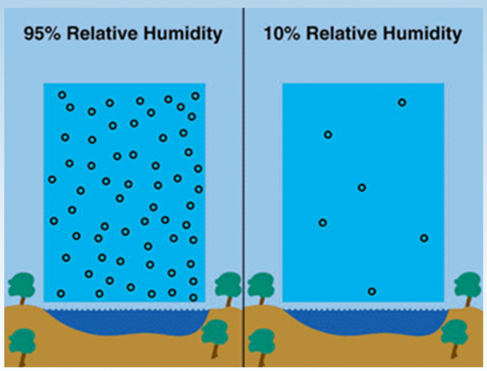
The Nature of Water: Terms & Definitions

Definition: Relative Humidity

- Humidity (water vapor) as a measure of water in the air in respect to the amount of water air can hold (100% RH) at **a given temperature**.





All Three Listed Conditions @ Sea Level:

- **Dew Point = ~ 49.14 F**
- **Specific Humidity = ~ 51.91 gr/lb** (dry air)
- **Vapor Pressure = ~ .351** (inches of mercury)

"Actual" moisture content: the same at three different temperatures

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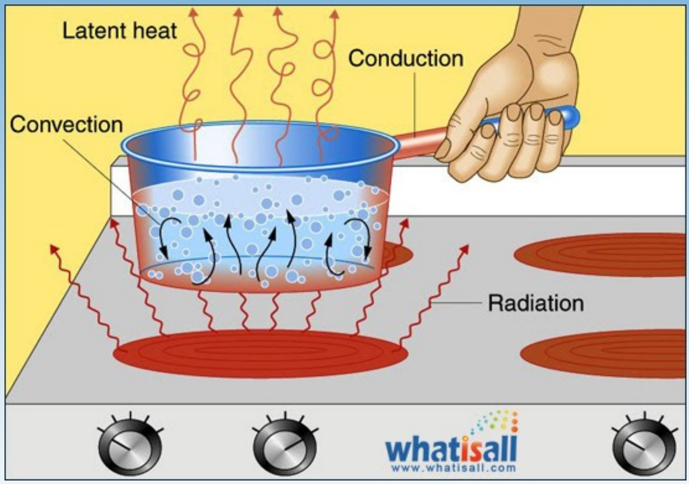
The Nature of Water: Terms & Definitions

What Force Drives Water Vapor from Wet Environments to Dry Environments?



Vapor Pressure: A natural force that drives water vapor from wetter environments to drier environments creating a state of equilibrium

Important: Water vapor requires heat energy (measured in dew point) to remain in a vapor state

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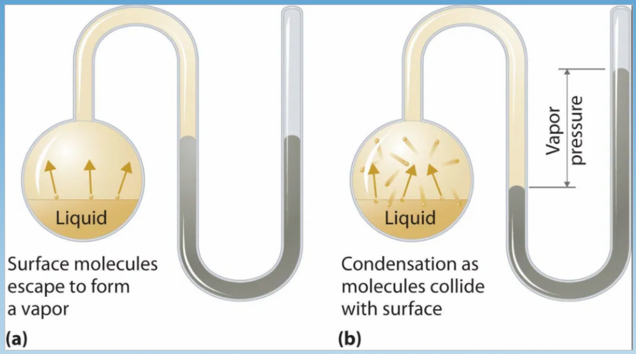
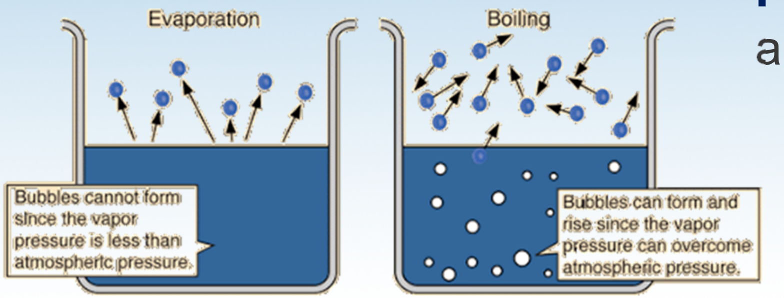
The Nature of Water: Terms & Definitions

Definition: Vapor Pressure

- "…the pressure of the vapor (measured in inches of mercury) resulting from evaporation of a liquid (or solid; off-gassing) above a sample of the liquid or solid…"
- The vapor pressure of a liquid varies with its temperature,





Phase Change: The change of water between any of its three states.

- Adding thermal energy to a liquid increases the phase change rate and vapor pressure.
- **Reducing vapor pressure increases the rate of liquid to vapor phase change**

The Nature of Water: Terms & Definitions

Definition: Dew Point

- The **temperature** a sample of air must be cooled to achieve saturation (100% RH) condensing water vapor into liquid.
- **Dew point** is a measure of the actual moisture content in air

- **Dew point** is not dependent on temperature, or the amount of thermal energy in the air.

ASHRAE Standard 62.1-2019: "Humidity control requirements are now expressed as dew point and not as relative humidity."

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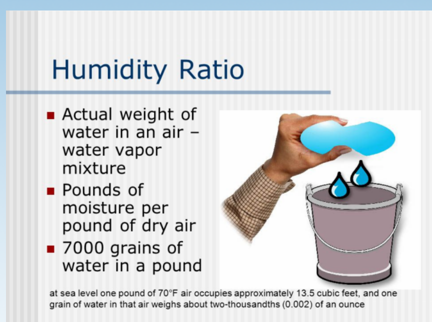
The Nature of Water: Terms & Definitions

Definition: Specific Humidity

- A measure of the **actual amount of water** vapor in a sample of air **regardless of temperature**
- A value representing an absolute amount of water in the air



Specific Humidity:

- **Grains of moisture / lb of dry air**

(1) Grain of water weighs about 0.002 ounces

(1) Pound of water = 7,000 grains

Room air at 75F dry bulb (DB) and 40% RH:

- **Dew Point: 49.08F**
- **Specific Humidity = 51.78 grains$_{(w)}$ / lb $_{(dry\ air)}$**

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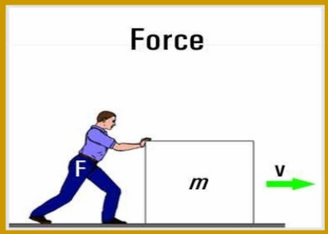
The Nature of Water

(Physics of Water Vapor)

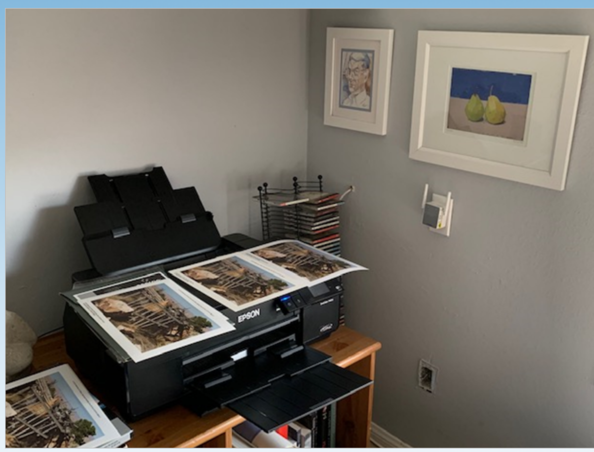
Newton's Laws of Motion



The Nature of Water: Physics of Water Vapor

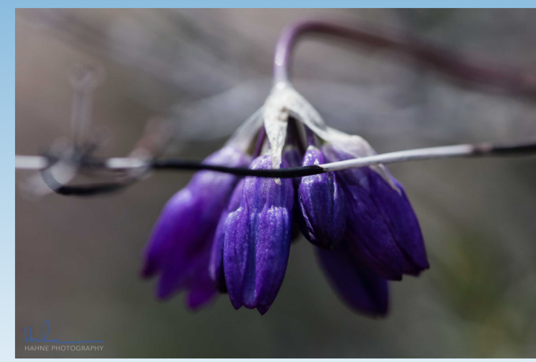
Dan's Office/Study (Elevation: 1100 feet)

- **Photography Studio: Archival grade photo printing and storage**



Studio room set points:

- 75F DB / 40% RH(*)



Room Moisture Conditions @ Setpoint:

- **Dew Point = 49.08 F**
- **Specific Humidity = 53.91 gr/lb** (dry air)
- **Vapor Pressure = .35** (inches of mercury)

(*) ...when the humidistat is working

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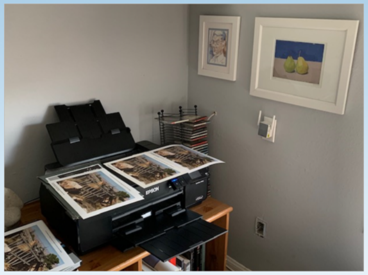
The Nature of Water: Physics of Water Vapor

Phoenix Winter Day (Raining), Arizona

- **Outdoor Conditions:**
  - Temperature: 45F DB (dry bulb)
  - Relative Humidity: 92% RH

- **Dew Point = 42.83 F**
- **Specific Humidity = 42.44 gr/lb (dry air)**
- **Vapor Pressure = .27 in HG**



Dan's Studio set points:
- Temperature: 75F DB
- Humidity: 40% RH

- **Dew Point = 49.08 F**
- **Specific Humidity = 53.91 gr/lb**
- **Vapor Pressure = .35 in HG**

Dan's office is humidifying the outdoors.

Why? Moisture content = Vapor Pressure.

Wet moves to dry!

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The Nature of Water: Physics of Water Vapor

Phoenix Summer "Monsoon" Day:

- Outdoor Conditions:
  - Dry Bulb: 97F / Wet Bulb: 78F
  - Relative Humidity: 43.75%

Outdoor Conditions:

- Dew Point = 71.31 F
- Specific Humidity = 120.82 gr/lb (dry air)
- Vapor Pressure = .773 (in Hg)

Dan's Office:

- Dew Point = 49.08 F
- Specific Humidity = 53.91 gr/lb
- Vapor Pressure = .35 in HG

Double the vapor pressure and moisture than Dan's office at 75F / 40% RH

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The Nature of Water: Physics of Water Vapor

Phoenix Summer "DRY" Day:

- **Outdoor Conditions:**
  - Dry Bulb: 115F
  - Relative Humidity: 15%

- Dew Point = 55.9 F
- Specific Humidity = 55.9 gr/lb (dry air)
- Vapor Pressure = .45 (in Hg)

Dan's Office:

- Dew Point = 49.08 F
- Specific Humidity = 53.91 gr/lb
- Vapor Pressure = .35 in HG

More grains of moisture in (1) lb of 115F / 15% RH air than Dan's office at 75F / 40% RH

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The Nature of Water: Physics of Water Vapor

What about the Total Energy: Enthalpy?

Phoenix Summer "DRY" Day:

- Outdoor Conditions:
  - Dry Bulb: 115F / Wet Bulb: 74.6F
  - Relative Humidity: 15%
  - Enthalpy = 38.69 Btus/lb (Air)

Phoenix Summer "Monsoon" Day:

- Outdoor Conditions:
  - Dry Bulb: 97F / Wet Bulb: 78F
  - Relative Humidity: 43.75%
  - Enthalpy = 42.36 Btus / lb (Air)

Greater amount of energy in a sample of summer Monsoon air than summer "hot dry" conditions

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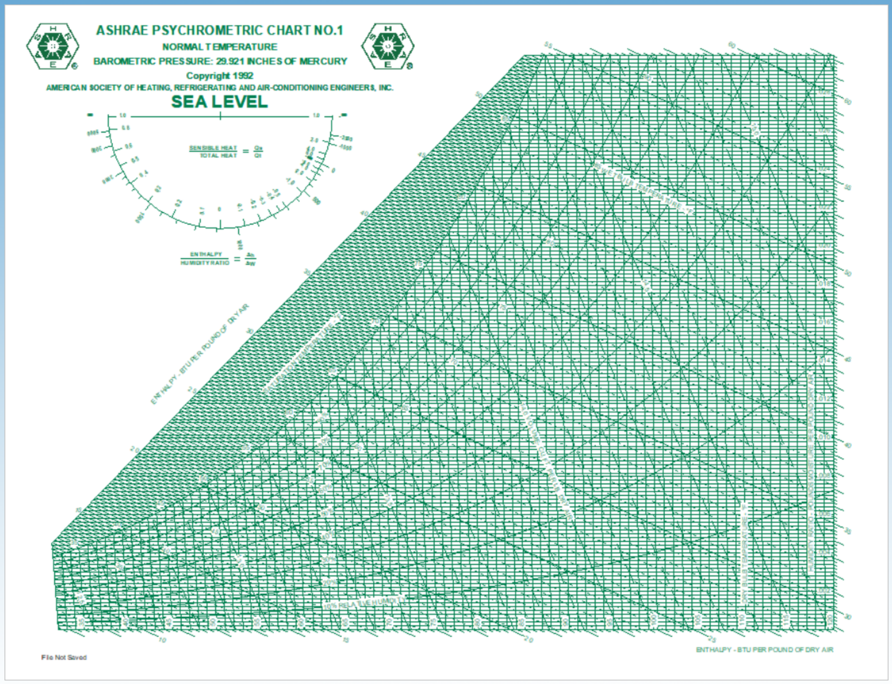
The Nature of Water: Physics of Water Vapor

Congratulations!

Psychrometrics 101

(The foundation of heating and ventilating system design)



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Humidity and Condensation

Humidity and Condensation

Building Condensation:

- **THE PROBLEM: Water Vapor Condenses. When?**
- Lack of **room dew point (latent energy) CONTROL**
- Room wall, window or wall register temperature is **equal to or below room dew point**
- **Water Vapor Condenses to a Liquid**

ASHRAE®

Room Design Conditions:

- **ASHRAE Standard 55**
  - **75F (Dry Bulb) / 50% RH**
  - **Room dew point = 55.13F**
  - **Vapor Pressure = .438 (in Hg)**

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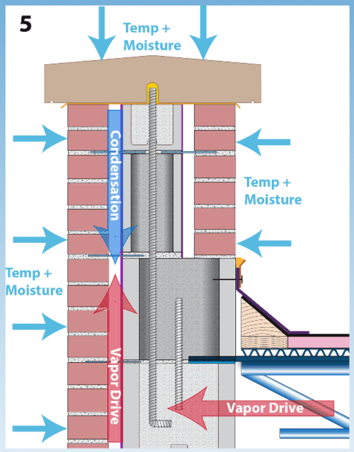
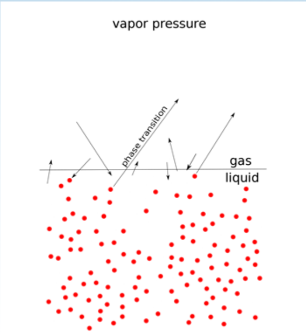
Humidity and Condensation

Building Condensation:

- **Moisture Imbalance: PRESSURE EQUILIBRIUM**
- Indoor moisture gain: Occupants, sinks, toilets…
- Outdoor **Vapor Pressure** greater than indoor vapor pressure = **moisture transfer / increased humidity**





WET MOVES TO DRY = LOSS OF ROOM HUMIDITY (DEW POINT) CONTROL

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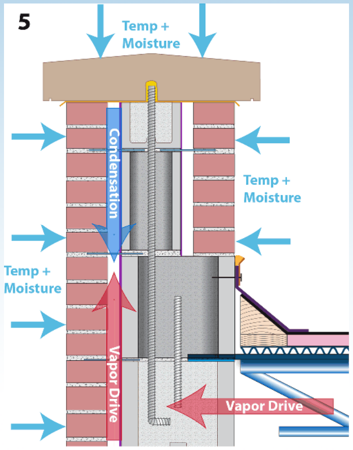
Humidity and Condensation

Building Condensation: Summer Monsoon

Monsoon Outdoor Air Conditions:

- OSA: 97F DB / 78F WB = 71F Dew Point
- Vapor Pressure = .77.3 (in Hg)



Room Design Conditions:

- ASHRAE Standard 55
  - 75F (Dry Bulb) / 50% RH
  - Room dew point = 55.13F
  - Vapor Pressure = .438 (in Hg)

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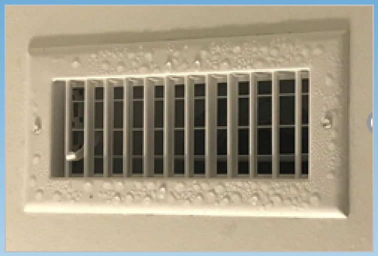
Humidity and Condensation

Building Humidity Challenge



Monsoon Day: Supply Air Condition

- Supply Air: 55F DB / 54F WB = **53.32F Dew Point**
- Vapor Pressure = **0.41 (in Hg)**

Room Design Conditions:

- Room Design Condition at 1100 FT elevation
- 75F (Dry Bulb) / 50% RH
- **Room dew point = 55.13F**
- **Room Vapor Pressure = 0.438 (in Hg)**

DEW POINT DEPRESSION = 1.81F = MINIMUM HUMIDITY CONTROL

INSUFFICIENT DEW POINT CONTROL

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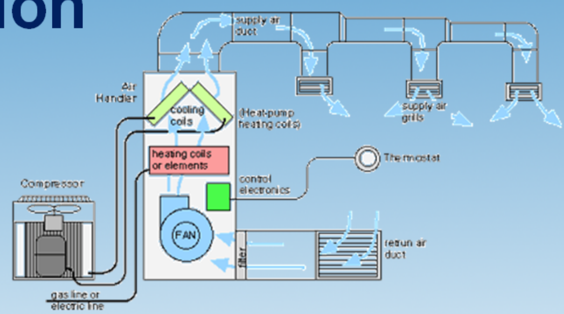
Humidity and Condensation

Building Humidity: Diffuser Condensation

Supply Air Condition: Monsoon

- Supply Air: **55F DB / 54F WB**
- Supply Air Dew Point = **53.32F Dew Point**
- **Diffuser Temperature = 55F (DB)**



Room Design Conditions:

- 75F (Dry Bulb) / 50% RH
- **Room dew point = 55.13F**
- **DIFFUSER TEMPERATURE = 55F**
- **ROOM DEW POINT = 55.13**

CONDENSATION OCCURS

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Humidity and Condensation

Building Humidity Control:

Revise Supply Air Conditions

- Change to 52F (DB) / 50F (WB)
- **Supply Air Dew Point = 48.44F**

Room Design Conditions:

- Room Design Condition at 1100 FT elevation
- 75F (Dry Bulb) / 50% RH
- **Room dew point = 55.13F**
- **Room Vapor Pressure = 0.438 (in Hg)**

DEW POINT DEPRESSION = 6.69F Dew Point

DEW POINT CONTROL = HUMIDITY CONTROL

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Humidity and Condensation

Operating Room: Humidity Control

ANSI/ASHRAE/ASHE Standard 170-2017

Table 7.1 Design Parameters—Hospital Spaces

Function of Space	Pressure Relationship to Adjacent Areas (n)	Minimum Outdoor ach	Minimum Total ach	All Room Air Exhausted Directly to Outdoors (j)	Air Recirculated by Means of Room Units (a)	Design Relative Humidity (k), %	Design Temperature (l), °F/°C
SURGERY AND CRITICAL CARE							
Critical and intensive care	NR	2	6	NR	No	30–60	70–75/21–24
Delivery room (Caesarean) (m), (o)	Positive	4	20	NR	No	20–60	68–75/20–24
Emergency department decontamination	Negative	2	12	Yes	No	NR	NR
Emergency department exam/treatment room (p)	NR	2	6	NR	NR	Max 60	70–75/21–24
Emergency department public waiting area	Negative	2	12	Yes (q)	NR	Max 65	70–75/21–24
Intermediate care (s)	NR	2	6	NR	NR	Max 60	70–75/21–24
Laser eye room	Positive	3	15	NR	No	20–60	70–75/21–24
Medical/anesthesia gas storage (r)	Negative	NR	8	Yes	NR	NR	NR
Newborn intensive care	Positive	2	6	NR	No	30–60	72–78/22–26
Operating room (m), (o)	Positive	4	20	NR	No	20–60	68–75/20–24
Operating/surgical cystoscopic rooms (m), (o)	Positive	4	20	NR	No	20–60	68–75/20–24

ASHRAE Standard 170-2017

- Operating Room Design Conditions
- Design Temperature: 68-75 F @ 20-60% RH

Banner OR Design Guidelines:

- Room Condition: 68F DB / 50% RH = 48.7F Dew Point

CAN YOU SEE THE PROBLEM???

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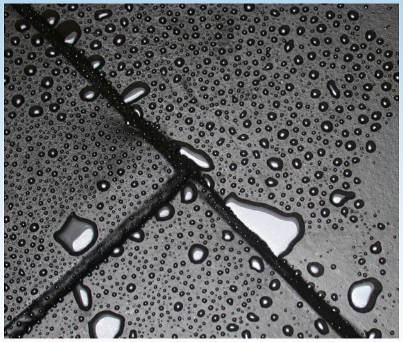
Humidity and Condensation

Operating Room: Humidity Control

Humidity Control: Conventional Design

- **OR Supply Air Condition** @ 55F DB/54F WB or 94.06% RH or **53.32F Dew Point**



Humidity Control: Better Design

- OR Supply Air Condition @ 52F DB/50F WB or 87.6% RH or **48.44F Dew Point**
- **Better, but what about the moisture gain within the OR?**

Humidity Control: Supply air dew point to be a minimum 4-6F below space dew point!!!

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Position Document on Infectious Aerosols

ASHRAE: Epidemic Task Force Review

ASHRAE **News**

FOR IMMEDIATE RELEASE

Media Contact:
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ASHRAE Epidemic Task Force Releases Updated Airborne Transmission Guidance

Clarified guidance for evaluating and mitigating the spread of SARS-CoV-2

ATLANTA (April 5, 2021) – The ASHRAE Epidemic Task Force released an updated, unequivocal statement on the airborne transmission of SARS-CoV-2 in buildings.

ASHRAE has released the following statement:

> *"Airborne transmission of SARS-CoV-2 is significant and should be controlled. Changes to building operations, including the operation of heating, ventilating, and air-conditioning systems, can reduce airborne exposures."*

It replaces the April 2020 statement that said airborne transmission was "sufficiently likely" that airborne precautions should be taken. At that time both, the World Health Organization (WHO) and the Centers for Diseases Control (CDC), contended that transmission of SARS-CoV2 was by droplet and fomite modes, not airborne. Subsequently, both have acknowledged the risk of airborne transmission indoors.

ASHRAE NEWS: (April 5, 2021)

Updated Airborne Transmission Guidance

"Airborne transmission of SARS-CoV-2 is significant and should be controlled.

Changes to building operations, including the operation of heating, ventilating, and air-conditioning systems, can reduce airborne exposures.

It replaces the April 2020 statement…"

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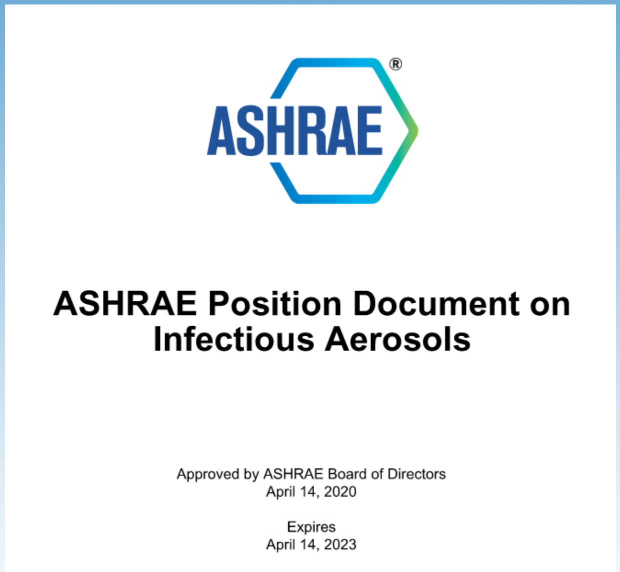
ASHRAE: Epidemic Task Force Review

Paragraph 3.3: Temperature & Humidity

- "HVAC systems are typically designed to control temperature and humidity, which can in turn influence transmissibility of infectious agents.
- "…the weight of the evidence…suggests that controlling RH reduces transmission of certain airborne infectious organisms, including some strains of influenza…"


ASHRAE

ASHRAE Position Document on Infectious Aerosols

Approved by ASHRAE Board of Directors
April 14, 2020

Expires
April 14, 2023

(Mousavi et al. 2019):

- "…scientific literature generally reflects the most unfavorable survival for microorganisms when the RH is between 40% and 60%."

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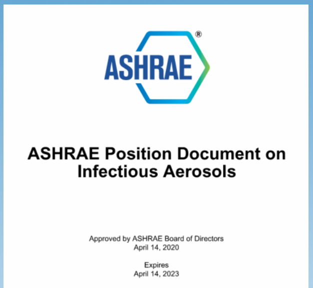
ASHRAE: Epidemic Task Force Review

Paragraph 3.3: Temperature & Humidity


ASHRAE

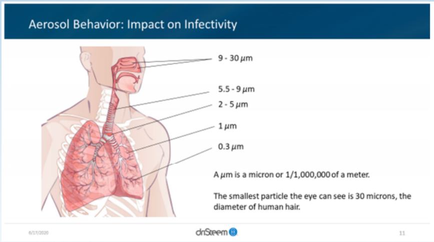
ASHRAE Position Document on Infectious Aerosols

Approved by ASHRAE Board of Directors
April 14, 2020

Expires
April 14, 2023

(Taylor & Tasi 2018):

- **Regarding dry environments,** "…infectious aerosols emitted from a primary host shrink rapidly to become droplet nuclei, and these dormant infectious pathogens remain suspended in the air and are capable of traveling great distances."



(Kudo et al. 2019):

- "…mechanisms through which ambient RH below 40% impairs mucus membrane barriers and other steps in immune system protection

(Goffau et al. 2009; Stone et al. 2016)

- "…many viruses and bacteria are anhydrous resistant and actually have increased viability in low-RH conditions."

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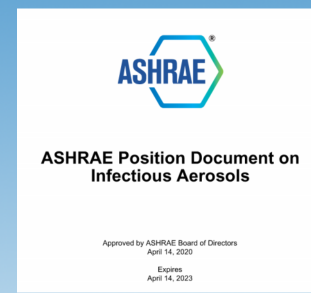
ASHRAE: Epidemic Task Force Review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Approved by ASHRAE Board of Directors
April 14, 2020

Expires
April 14, 2023

ASHRAE: Building Readiness Guidelines

Schools and Universities

New/Modified Facility Design Recommendations

- "…The underlying effort of the designer should be to increase outside air to the spaces, treat return air and or supply air to space via mechanical filtration and **maintain indoor comfort as defined by the design temperature and relative humidity**."

Designer Guidelines:

General School: Temperature and Humidity Design Criteria

- "…Winter classroom design guidelines 72F/40-50% RH…"
- "Summer classroom design guidelines 75F/50%-60% RH."

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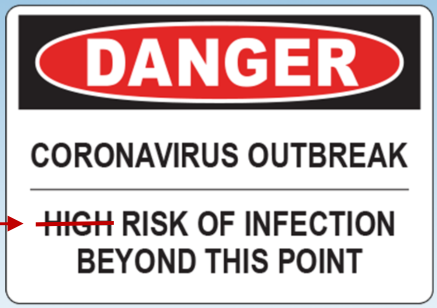
Humidity & The Risk of Infection

Reduced



The Risk of Infection

Cold and flu season?

Late Autumn, Winter & Early Spring

(The driest time of the year)

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The Risk of Infection

Expiration Events: Velocity, Momentum & Distance

- **Expiratory Event:**
  - Breathing
  - Talking
  - Coughing
  - Sneezing

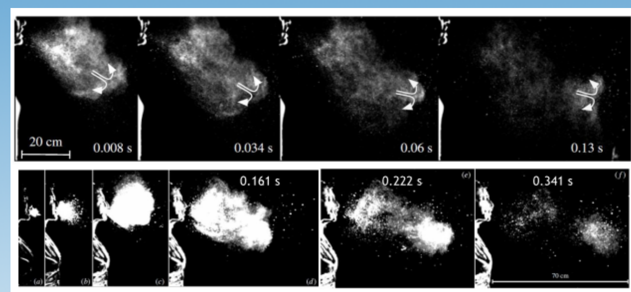
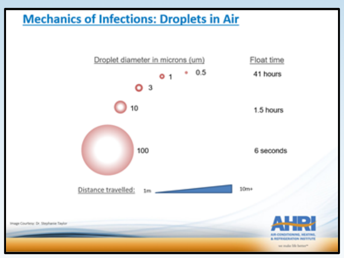


Figure 7. High-speed camera images of a sneeze illustrating salient processes of counter-rotating flow at the leading edge and bifurcation of the droplet plume (Bourouiba et al. [6]).

Dr. Clifford Ho:
(Senior Scientist Sandia Labs)

Sandia Report:
Modeling Airborne Transmission of SARS-CoV-2 (Covid-19)

Sandia National Laboratories



Smaller the Particle: Longer Float Time

- **Droplets: Size and Count Variations**
  - Droplet Sizes: ~ <1.0 – 100 microns
  - Droplet Count: ~10s to 40,000 droplets
  - **Discharge Velocities: 2.2 to 44 mph @ 0.25 sec**
  - Ballistic Trajectory = Bifurcated discharge plume

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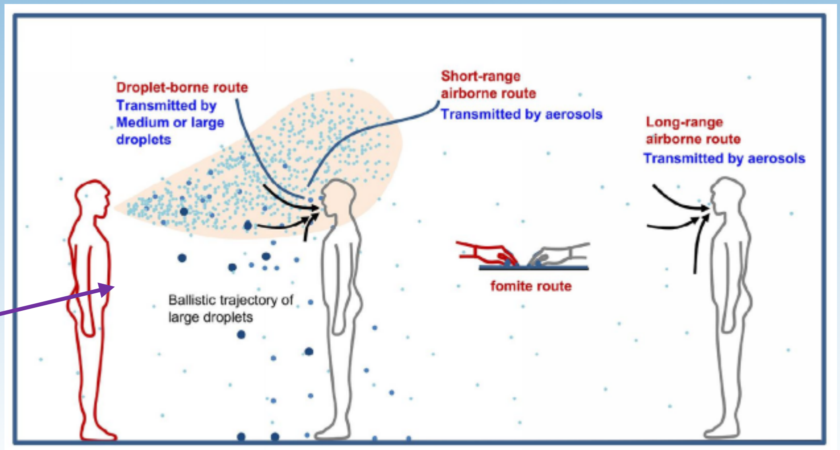
The Risk of Infection

REVIEW - Expiratory Events: Pathogen Routes

Event type affects shape of discharge plume

- **Breathing** = Small droplets / aerosols
- **Talking** = Small to medium droplets
- **Coughing** = Medium to large droplets
- **Sneezing** = Large droplets



Ballistic Trajectory - large droplets

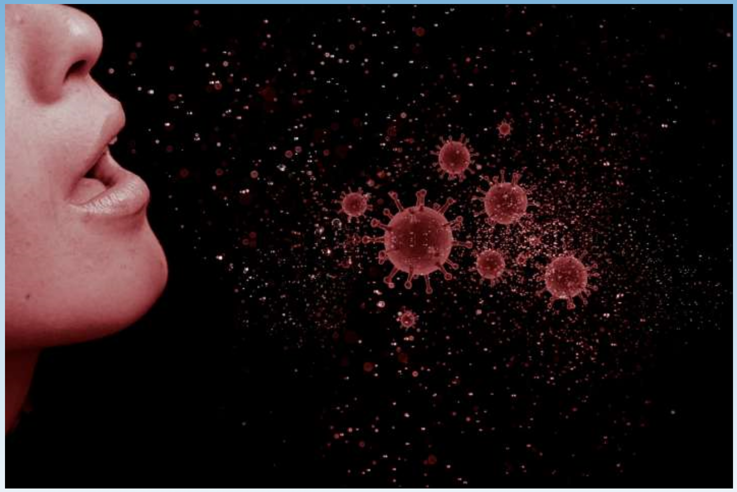
(Wei J and Li Y (2016)

The Risk of Infection

Evaporation: Droplets & Small Aerosolized Particles

Expressed Droplets:

- **Saliva Droplets:**
  - 98% - 99.5% water
  - Electrolytes, mucus, white blood cells, enzymes, etc.
- **Mucus Droplets:**
  - 95% water
  - 2% - 3% mucin secretions
  - Proteoglycans, lipids, proteins, etc.



Cause of droplets shrinking in size after an expiratory event? Evaporation

Aerosolized pathogens pose a greater risk of infection.

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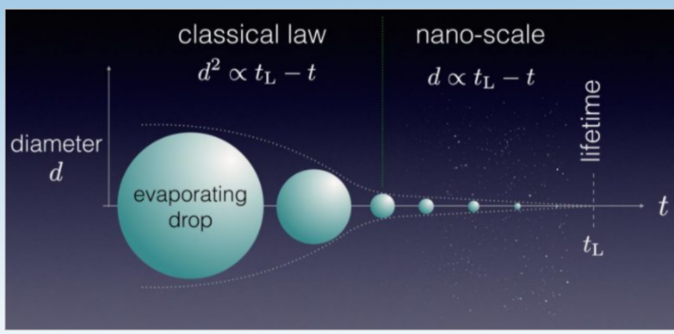
The Risk of Infection

Droplet Size and Desiccation

- How to **Reduce** aerosolization rate of expiratory droplets
  - Reduce expressed droplet **evaporation rate** in the space, **increase humidity**



Droplet Fall Time before Complete Evaporation

- 0% RH: 125 microns
- 50% RH: 100 microns
- 70% RH: 85 microns
- 90% RH: 60 microns

(Xie, X., Y. Li, A.T. Chwang, P.L. Ho, et al. 2007
“How far droplets can move in indoor environments…)

Higher room RH = Higher Vapor Pressure
Higher room Vapor Pressure = Longer Evaporation Rate

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The Risk of Infection

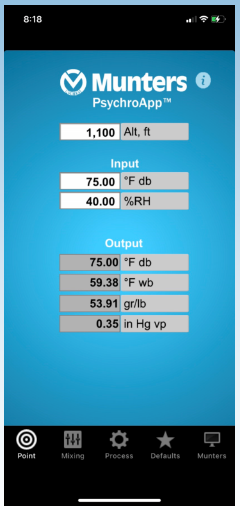
Droplet Size and Desiccation

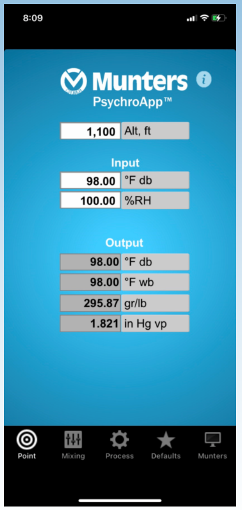
- Increase Room Vapor Pressure, Decrease Evaporation Rate

Vapor Pressure Differential

- Room Condition: 75F DB @ 40% RH
  - Vapor Pressure = 0.35 in Hg
- Discharge plume: 98F DB @ 100% RH
  - Vapor Pressure = 1.821 in Hg

Discharge droplets evaporate in less than or up to several seconds depending on droplet size





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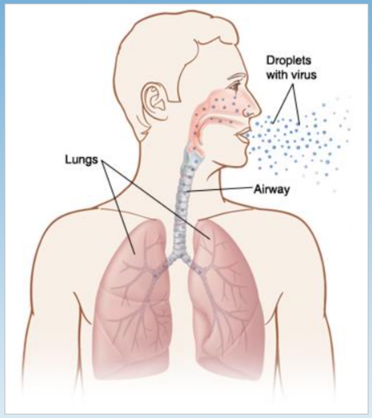
The Risk of Infection

Review - Expiration, Velocity, Momentum & Distance

- Expiratory Event:
  - Dr. Clifford Ho (2020):
    - "…because the size of the droplets that are emitted during tidal breathing are small, the exhaled aerosol plume can remain suspended for long periods."

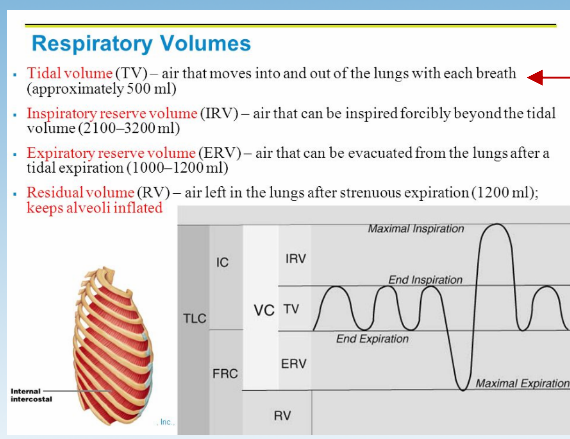


"Thus, despite the lower viral load per exhalation event relative to coughs or sneezes, the persistence of the small aerosolized droplets and continuous nature of breathing and/or talking can increase the potential for transmission, especially in enclosed spaces with low fresh-air exchange."

The Risk of Infection

Tidal Breathing:

- **Continual doses of aerosolize pathogen released into space**



Tidal breathing exhales approximately 500 ml (0.5 liter) of air each breath.

Do the Math!

16 breaths/min * 0.5 Liters

= 8 Liters / Min / Person

Age	Respiratory rate (breaths per minute)
Newborns	44
Infants	20-40
Preschool children	20-30
Older children	16-25
Adults	12-20
Adults during strenuous exercise	35-45
Athletes	60-70(**Peak**)

(Respiratory Rate Chart by Damba)

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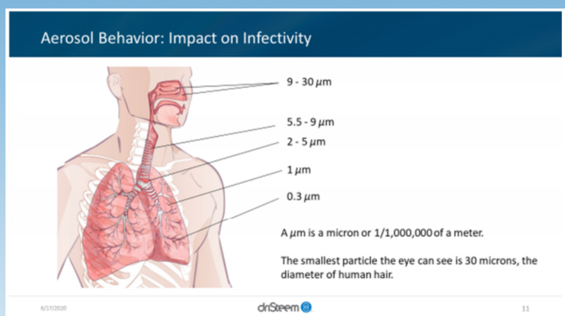
The Risk of Infection

Aerosolized Pathogens: Human Immune System

- **Aerosolized droplets become droplet and viral nuclei**



- **Aerosolized pathogens** more readily bypass the body's natural defense systems and travel deep into the lungs
- Immune system's chances of fighting the virus reduced

ASHRAE Position Document on Infectious Aerosols

- **(Kudo 35 al. 2019)** "…imunobiologists have now clarified the mechanisms through which ambient **RH below 40% impairs mucus membrane barriers** and other steps in immune system protection."

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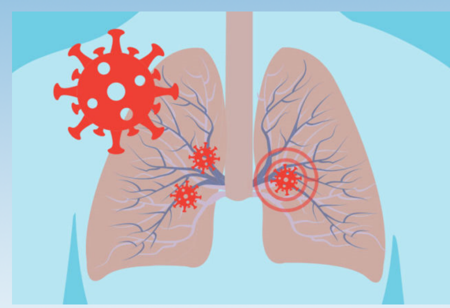
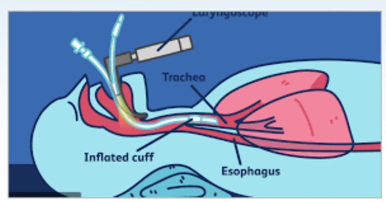
The Risk of Infection

Aerosolized Pathogens: Human Immune System

- Aerosolized droplets become droplet and viral nuclei

- Ingested **"wet" droplets** are more likely to be captured by nasal membranes, wet walls of the mouth and esophagus
- Virus expelled more readily by **immune system activity**





- Pathogens shed from **saliva/mucus droplets** become aerosolized
- **Viral nuclei** are smaller and **travel deep into the lungs**
- Potential for acute respiratory symptoms

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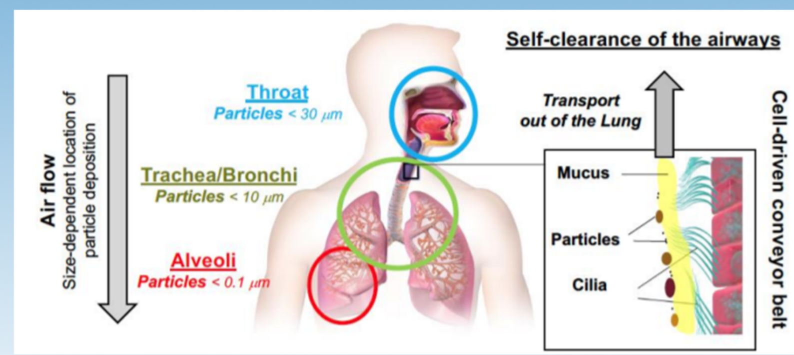
The Risk of Infection

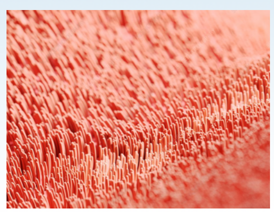
Aerosolized Pathogens: Human Immune System

Self-Clearance Mechanism of the Lung

- Nature developed a powerful mechanism to self-clean the airways: their **cellular linings operate as conveyor belts.**
- Inhaled particles collide with the airway walls where they get stuck on **slimy surfaces.**
- The location where inhaled particles get deposited along the airways depends on **particle wetness and size**.



(Mucociliary Clearance)



- The particle-enriched slime, including virus particles, is transported towards the mouth through **synchronized circular movements of cilia**.

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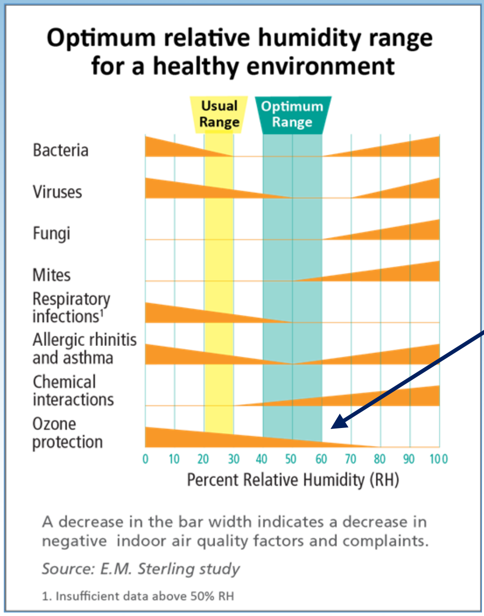
The Risk of Infection

The Sterling Study (1986): 013 ASHRAE Paper

Optimum range for health, wellness and comfort:
40 - 60% RH

- Lower humidity increases survival for viruses that cause respiratory infections
- Lower humidity increases allergens that cause seasonal allergies and asthma
- Indoor environments are usually 20 - 30% RH, which is inadequate for protection



RH Range: 40-60%

The Risk of Infection

Steven Welty: 2013 ASHRAE Paper

2013 (2009) - Airborne Influenza in Dry Wintertime Indoor Air: Is 50% RH Indoor Humidity One Cure for "Flu Season"?

- In 2013, Steven Welty presented a paper to ASHRAE based on his earlier research for the EPA/CDC in 2009 following the H1N1 Flu Pandemic.
- Yes, **H1N1 was classified as a Pandemic** back then by the CDC
- The report referenced airborne spread influenced by RH levels.

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The Risk of Infection

Steven Welty: 2013 ASHRAE Paper

- Raise humidity to 45% +
- Increase air changes to 12 per hour
- In-duct UV
  Upper room UV
- Toilet seat lowered
  Exhaust behind & below toilet
- MERV 13
  +URV 13 UV lights
  MERV 17 HEPA (best)

ASHRAE®

FLU SEASON MITIGATED!

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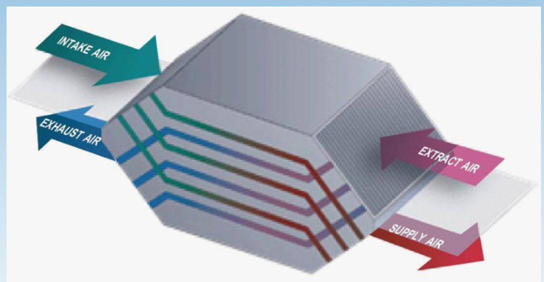
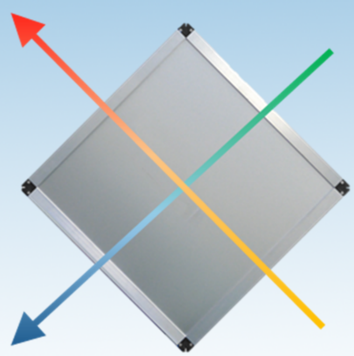
The Risk of Infection

HVAC Design Solution: Heat Recovery

- New Enthalpy Plate and Frame Heat Exchangers
- Pre-treat OSA for enhanced system efficiency
- Latent Cooling (Dehumidification): Monsoon
- Latent Heating (Humidification): Dry Winter

Cross-flow





Cross-flow

ERV/HRV with Plate Heat Exchangers
30 – 10,000 CFM

Counter-flow = approx. 15% higher recovery efficiency

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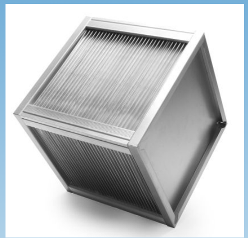
The Risk of Infection

HVAC Design Solution: Heat Recovery

Latent Transfer Efficiency



- High Performance / Low Profile
- Polymer Membrane Core Material
- 65% recovery means

Cross-Flow		Counter-Flow	
Efficiency	Sensible Recovery	Latent Recovery	Total Recovery
Cross-Flow ERV	~63%	~47%	~53%
Counter-Flow ERV	**~75%**	**~65%**	**~70%**
Counter-Flow HRV	**~83%**	--	--

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The Risk of Infection

Recovery Efficiency
Example with High Efficiency Counterflow Core

Calculate Moisture Gain:

- 65% Enthalpy Recovery Efficiency example

- Means **65% of the moisture content (grains) difference between OA and RA is recovered**

- Space (return air): 70 db, 50% RH, 57 gr
- Outdoor air: 71 db, 18% RH, 21.1 gr

- **Difference: 35.9 grains. 65% * 35.9 grains = 23.35 gains**
- **So 23.35 grains of moisture is removed from the return air and added to the incoming outdoor air.**
- Supply air moisture content is now 44.45 grains.

Counter-Flow

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  - The States of Water
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  - The Physics of Water Vapor
    - Dan's Home Office/Studio
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Questions?

Thank you.

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