HUMIDIFICATION

NSWC NORMAN S. WRIGHT CLIMATEC MECHANICAL EQUIPMENT

VARITEC™ TECHNICAL INSTITUTE

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/Engineering Sales
    - 2000 thru 2008
  - **Varitec Solutions:**
    - Senior Sales Engineer/Educator (High Performance HVAC)
    - 2016 thru present

Varitec: The HVAC System Solution

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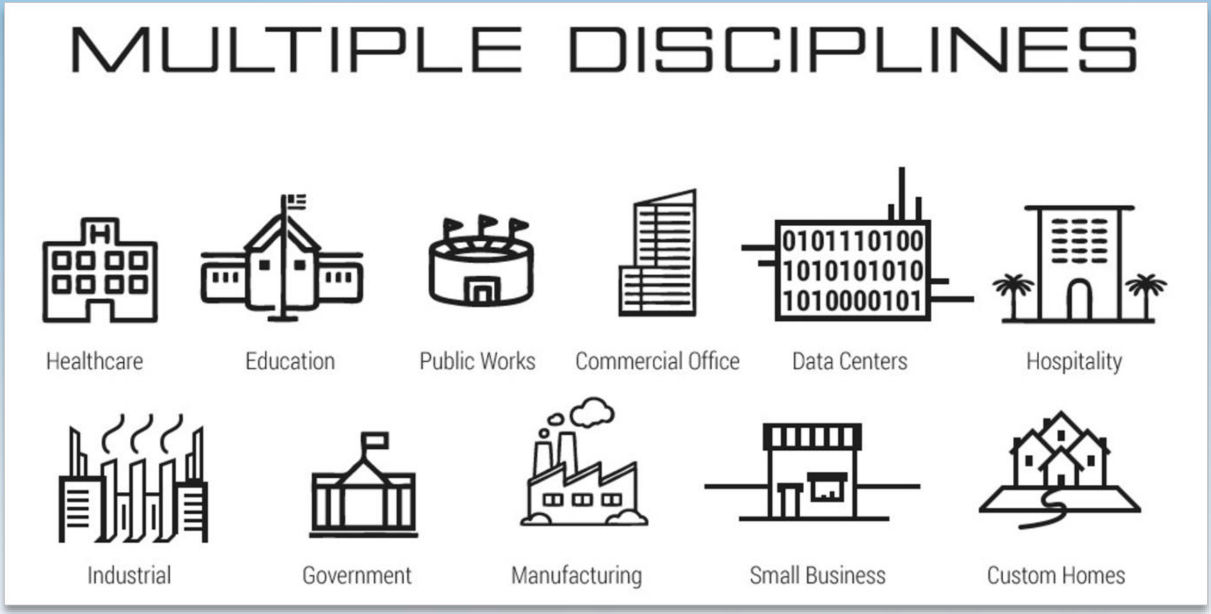
Varitec: The HVAC System Solution



Varitec: The HVAC System Solution

System Solutions:

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

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Varitec: The HVAC System Solution

Shaping
The Future
Of HVAC

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.

Humidification

Agenda:

- ASHRAE: Position Document on Infectious Aerosols
- The Nature of Water
    - The States of Water
    - Terms and Definitions
    - The Physics of Water Vapor
        - Dan’s Home Office/Studio
- The Risk of Infection
- Building Humidification: Solutions

Acknowledgements

Dr. Clifford Ho:
(Senior Scientist Sandia Labs)
Sandia Report:
Modeling Airborne Transmission of SARS-CoV-2 (Covid-19)

Position Document on Infectious Aerosols

Varitec Technical Institute

CDC: Science Brief: COVID-19

Centers for Disease Control and Prevention
CDC 24/7: Saving Lives, Protecting People™

COVID-19 MENU

Science Brief: SARS-CoV-2 and Potential Airborne Transmission

Updated Oct. 5, 2020 Print

The principal mode by which people are infected with SARS-CoV-2 (the virus that causes COVID-19) is through exposure to respiratory droplets carrying infectious virus.

CENTERS FOR DISEASE CONTROL AND PREVENTION

How COVID-19 Spreads:

- Airborne transmission of SARS-CoV-2 can occur under special circumstances
- COVID-19 can sometimes be spread by airborne transmission
- COVID-19 spreads less commonly through contact with contaminated surfaces

ASHRAE: Epidemic Task Force Review

ASHRAE

News

FOR IMMEDIATE RELEASE

Media Contact:
Karen Buckley Washington
Public Relations Specialist
kbwashington@ashrae.org

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.

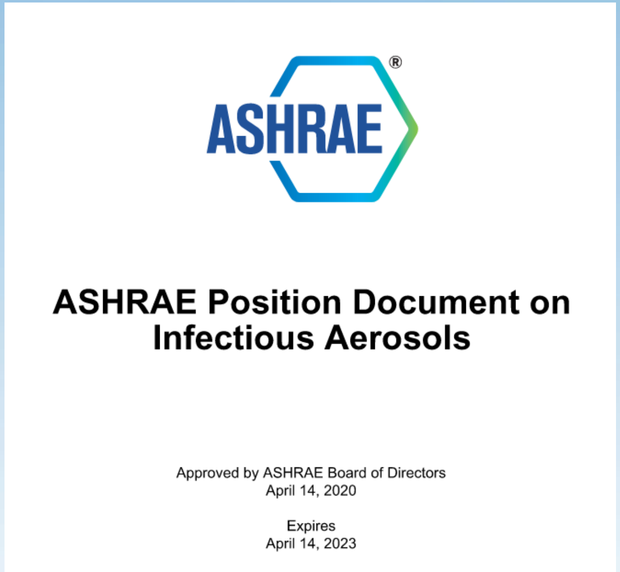
Changes to building operations, including the operation of heating, ventilating, and air-conditioning systems, can reduce airborne exposures.

It replaces the April 2020 statement…”

ASHRAE Position Document on Infectious Aerosols

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%."

ASHRAE Position Document on Infectious Aerosols

Paragraph 3.3: Temperature & Humidity


ASHRAE

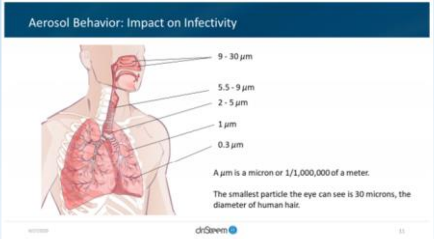
ASHRAE Position Document on Infectious Aerosols

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."

ASHRAE Position Document on Infectious Aerosols

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."

The Nature of Water

The Nature of Water

What is the definition of Dry?
The absence of moisture

The Nature of Water: States of Water

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)

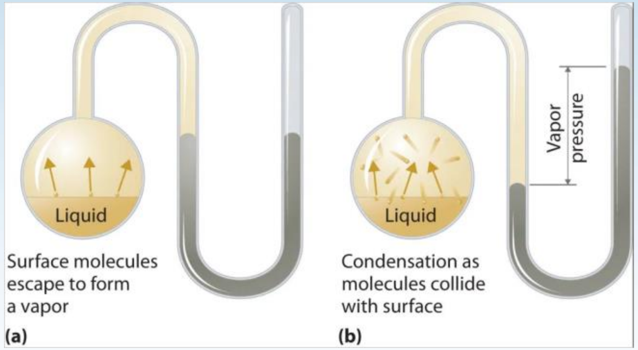
- Liquid:
  - Water as a fluid exists within a range of temperatures between 32F (freezing) and 212F (boiling)
- Gaseous:
  - Water in the form of a vapor
- Solid:
  - Water in the form of a solid, ice

The Nature of Water: Terms & Definitions

Understanding Phase Change:

Definitions:

- Energy
- Force
- Equilibrium
- Pressure



- Vapor Pressure
- Humidity Ratio
- Dew Point
- Absolute Humidity
- Relative Humidity

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."**

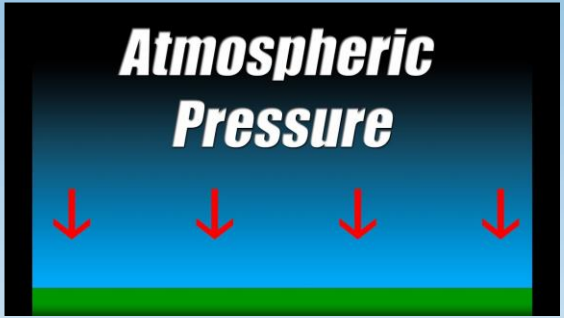
(Mineral Medix)

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

The Nature of Water: Terms & Definitions

Definition: Force

- "…in mechanics, any action that tends to maintain or alter the motion of a body or to distort it." (Britannica)



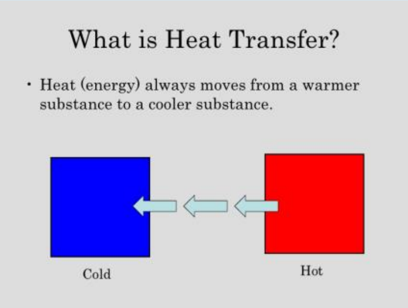
Definition: Pressure

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

The Nature of Water: Terms & Definitions

Equilibrium: Thermal Energy

- All physical states and/or objects seek to be at rest; i.e. **Equilibrium**
- **Thermal energy** is the measured value at a room thermostat **(Dry Bulb (DB) temperature)**
- Heat energy always moves to cold (Heat Transfer):
  - **Conduction**
  - **Convection**



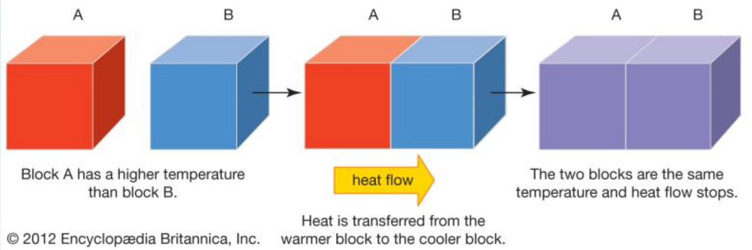
Equilibrium: Pressure

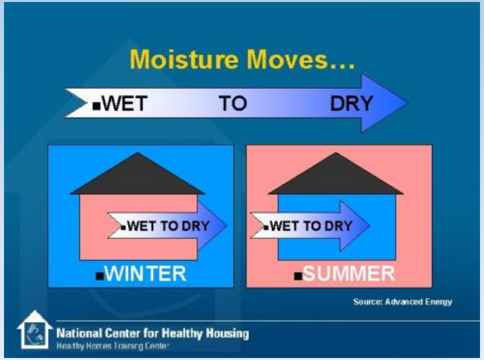
- **Air or moisture** at a high pressure state will always tend to a lower pressure state (Pressure differential)

The Nature of Water: Terms & Definitions

Thermal Energy (Heat)

- Heat added to a body or to a discrete volume of air will disperse to create a state of equilibrium with adjacent areas.

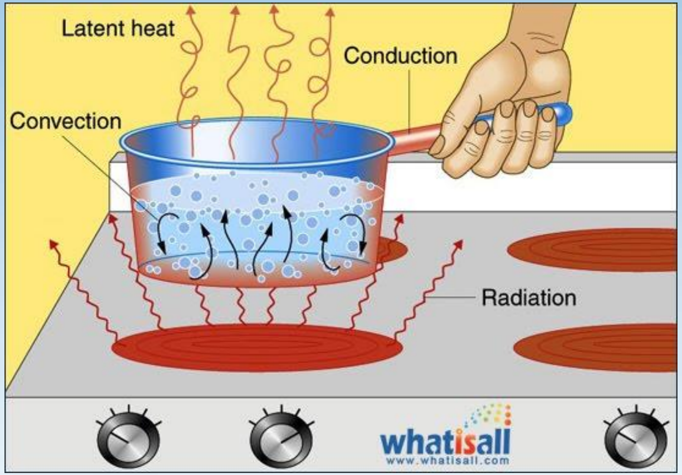




Moisture, like thermal energy, will always move from **"wet"** conditions **to "drier"** conditions to achieve a state of equilibrium

The Nature of Water: Terms & Definitions

What force moves moisture from wet to dry?



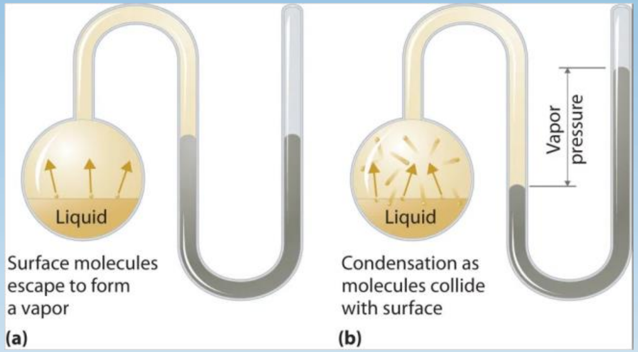
Vapor Pressure – the force that drives moisture from wet areas to drier areas

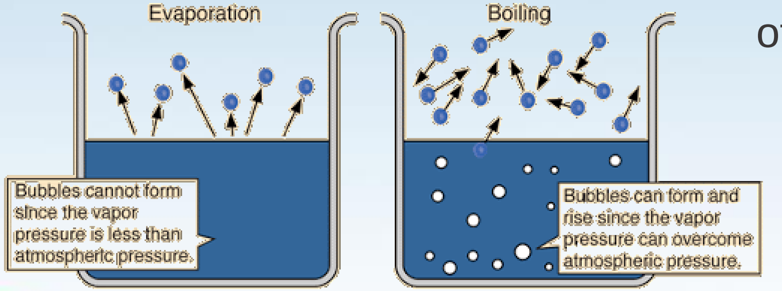
Important: Water vapor requires heat energy (measured as temperature) to remain in a vapor state

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-gasing) above a sample of the liquid or solid…"
- The vapor pressure of a liquid varies with its temperature,





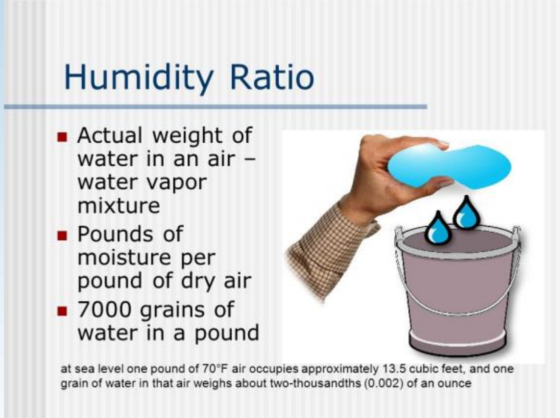
Phase Change: The change of water between any of its three states.

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

The Nature of Water: Terms & Definitions

Absolute Humidity:

- A measure of the **actual amount of water** vapor (moisture) in the air **regardless of temperature**
- Pounds (lbs) water per pound of dry air **($lb_{H_2O}/lb_{Dry\ Air}$)**



Absolute Humidity (Specific Humidity) = grains of moisture / lb of dry air

(1) Grain of water weighs about 0.002 ounces

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

- **Specific Humidity = 51.78 grains/$lb_{dry\ air}$**
- **Dew Point: 49.08F**

The Nature of Water: Terms & Definitions

Dew Point:

- The temperature air must be cooled to be saturated and water vapor condenses. **(Thermal energy removed)**
- **Dew point** is a measure of the actual moisture content in air

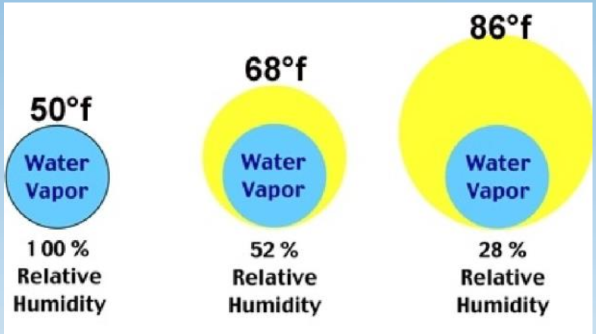
- **Dew point** is not dependent on temperature, or the amount of thermal energy in the air.

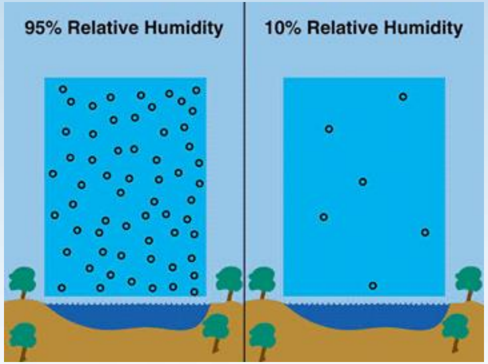
ASHRAE Standard 62.1-2019: "Humidity control requirements are now expressed as dew point and not as relative humidity."

The Nature of Water: Terms & Definitions

Relative Humidity:

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





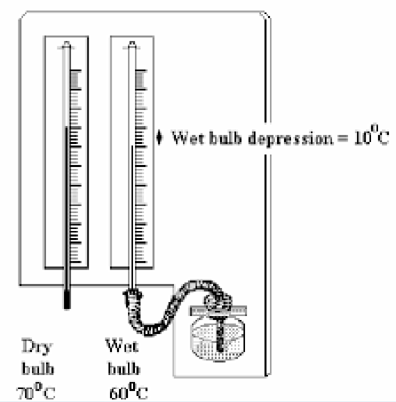
All Three Conditions (Sea Level):

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

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

The Nature of Water: Terms & Definitions

How do you measure Humidity?

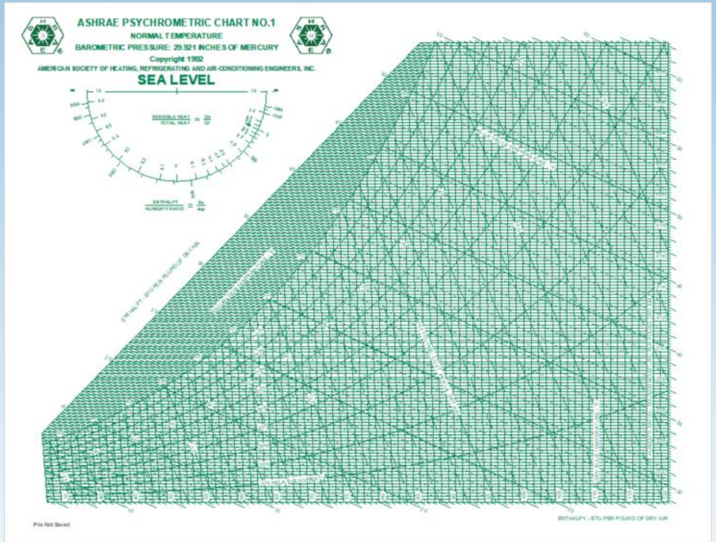


Old Technology: Wet Bulb Thermometer

- A wick wetted by water covers the bottom of a thermostat.
- Evaporation draws heat from the sounding air and cools it
- The resulting temperature is the **wet bulb (WB) temperature**
- The differential between dry bulb and wet bulb temperature is the **wet bulb depression**
- **The greater the wet bulb depression, the higher the evaporation rate, more humid the environment**

The Nature of Water: Terms & Definitions

How To Determine Moisture Conditions?



Know Two Points:

- Dry Bulb Temperature
- Absolute Humidity
- Dew Point
- Relative Humidity
- Vapor Pressure
- Wet Bulb Temperature

All points can be defined with two know conditions!

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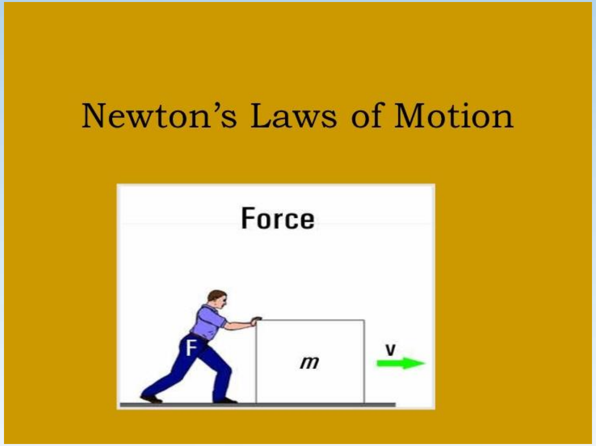
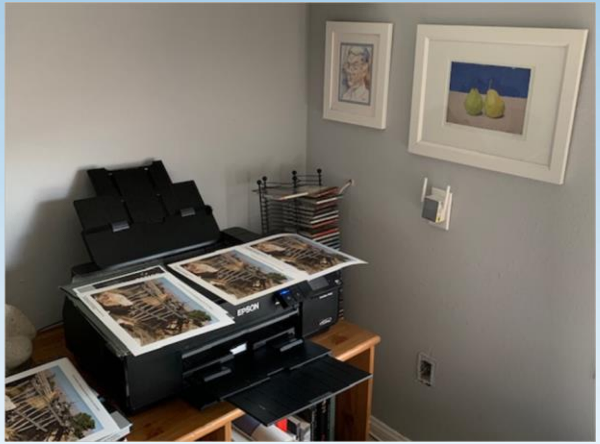
The Nature of Water
(Physics of Water Vapor)



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

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

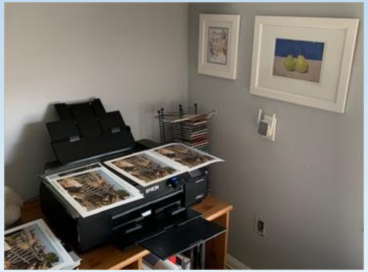
The Nature of Water: Physics of Water Vapor

Rainy Winter Day in Phoenix, Arizona.

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

Dan's Studio set points:

- Temperature: 75F DB
- Humidity: 40% RH



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

- **Dew Point = 42.83 F**
- **Humidity Ratio = 42.44 gr/lb (dry air)**
- **Vapor Pressure = .27 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" Months:

- **Outdoor Conditions:**
  - Dry Bulb: 98F
  - Relative Humidity: 40.59%

- Dew Point = 70 F
- Humidity Ratio = 115.42 gr/lb (dry air)
- Vapor Pressure = .74 (in Hg)

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

The Nature of Water: Physics of Water Vapor

Phoenix Summer "DRY" Months:

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

- Dew Point = 55.9 F
- Humidity Ratio = 69.55 gr/lb (dry air)
- Vapor Pressure = .45 (in Hg)

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

The Nature of Water: Physics of Water Vapor

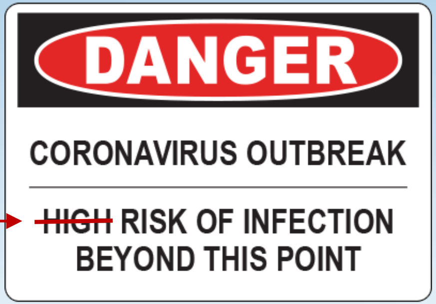
Congratulations!

Psychrometrics 101
(The foundation of heating and ventilating system design)

What is the definition of Dry?
The absence of moisture

REMEMBER
WET DRIVES TO DRY

The Risk of Infection



Reduced

The Risk of Infection

Cold and flu season?

Late Autumn, Winter & Early Spring

(The driest time of the year)

The Risk of Infection

REVIEW - Expiratory Events:

Active Pathogen Ejected into a Space:

- Breathing
- Talking
- Singing
- Coughing
- Sneezing

(Scharfman, Techet, Bush, Bourouiba)

The Risk of Infection

Expiration Events: Velocity, Momentum & Distance

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

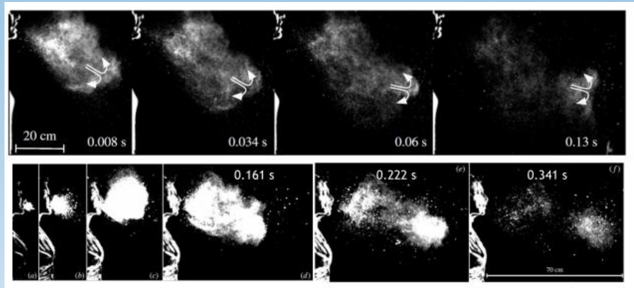
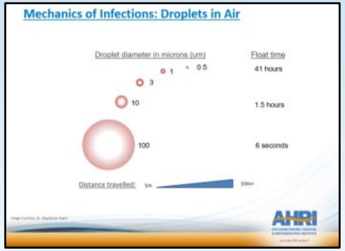


Figure 7. High-speed camera images of a sneeze illustrating salient processes of counter-rotating flow at the leading edge and bifurcation of the droplet plume (Bourouiba et al. [6]).

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
  - Pathogen Count: ~10s to 40,000 droplets
  - **Discharge Velocities: 2.2 to 44 mph @ 0.25 sec**
  - Bifurcated plume

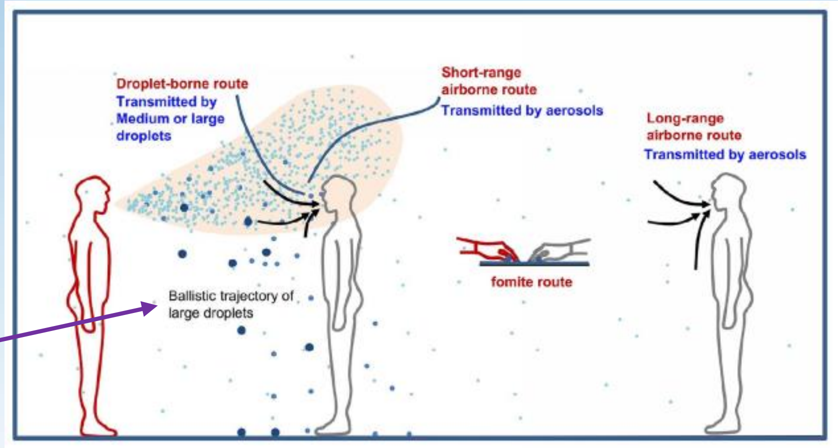
The Risk of Infection

REVIEW - Expiratory Events: Pathogen Routes

Expiratory 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

"Persistence of Small Aerosolized Particles…"

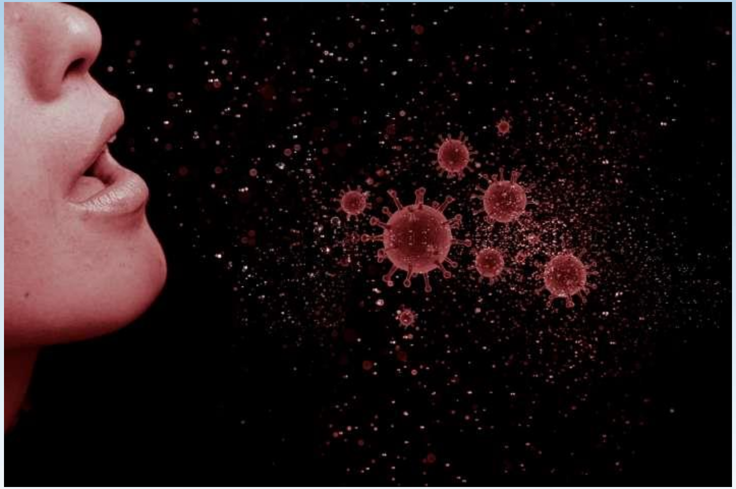
Evaporation causes droplets to shrink in size after an expiratory event

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.



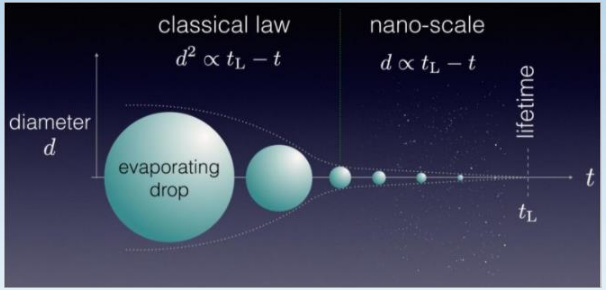
The Risk of Infection

Droplet Size and Desiccation

- Goal: Reduce aerosolization rate of expiratory droplets by reducing evaporation rate in the space

Droplet desiccation rates:

- Size of droplets
- Room relative humidity



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

The Risk of Infection

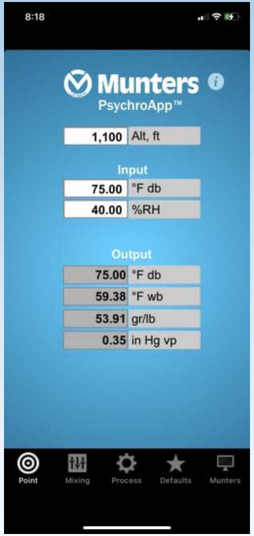
Droplet Size and Desiccation

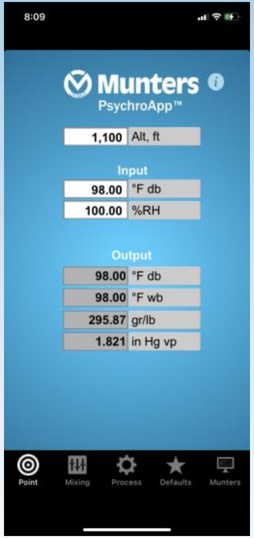
- Increase Vapor Pressure, Decrease Evaporation Rate

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 fractions of a second to several seconds!!!

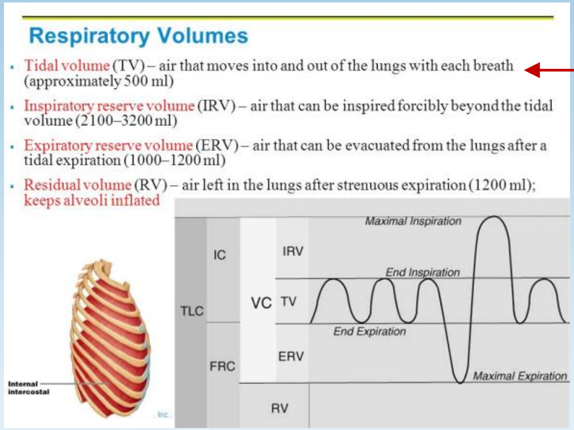




The Risk of Infection

Tidal Breathing:

- Continual doses of aerosolize pathogen into a 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**)

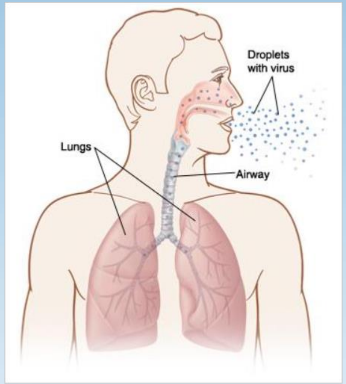
(Respiratory Rate Chart by Damba)

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."

Sandia National Laboratories

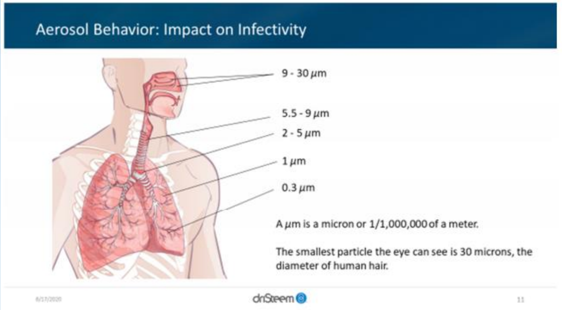


"Thus, despite the lower viral load per exhalation event relative to coughs or sneezes, the persistence of the small aerosolized droplets and continuous nature of breathing and/or talking can increase the potential for transmission, especially in enclosed spaces with low fresh-air exchange."

The Risk of Infection

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

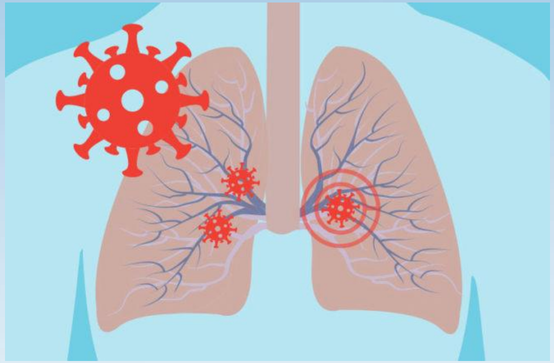
- **(Kudo 35 al. 2019)** "…imunobiologists have now clarified the mechanisms through which ambient **RH below 40% impairs mucus membrane barriers** and other steps in immune system protection."

The Risk of Infection

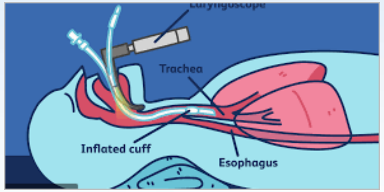
Aerosolized Pathogens: Human Immune System

- 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

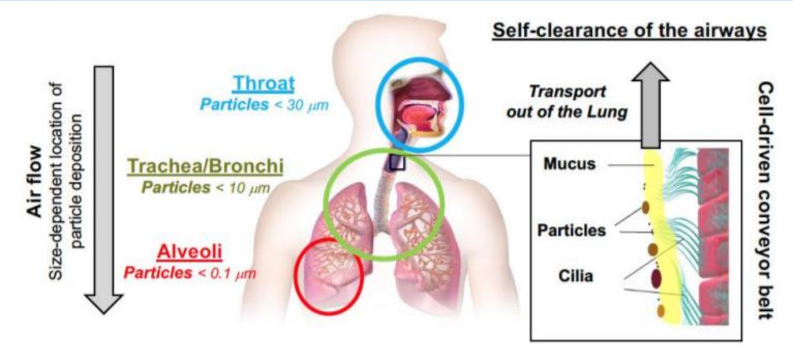


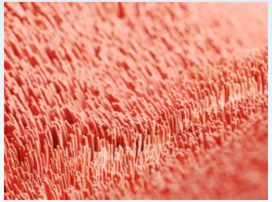
The Risk of Infection

Aerosolized Pathogens: Human Immune System

Self-Clearance Mechanism of the Lung

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





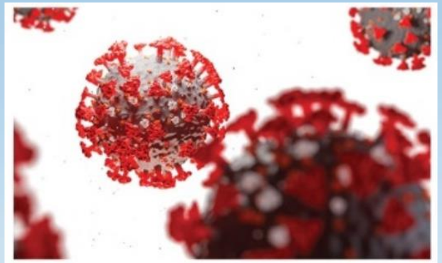
- The particle-enriched slime, including virus particles, is transported towards the mouth through **synchronized circular movements of cilia.**

(Cilia)

The Risk of Infection

Aerosolized Pathogens: Human Immune System

Droplet Size, Buoyancy & Float Time



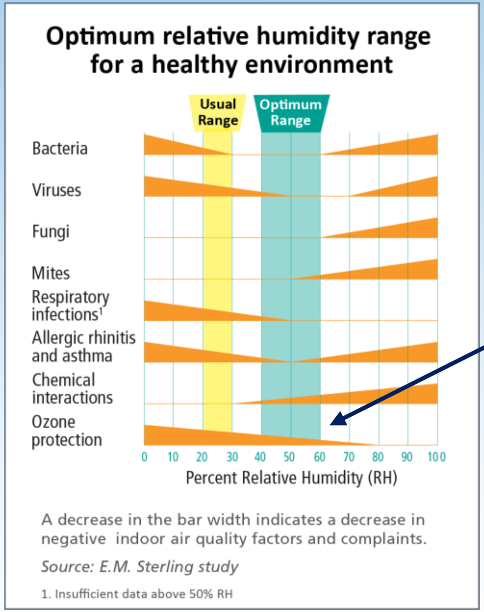
- **COVID-19** behaves similarly to **SARS (SARS Cov-1), MERS and H1N1 (Influenza)** as an aerosol
- Length of time virus is airborne and distance traveled affects spread and severity of infection.
- Respiratory viruses are most harmful when inhaled deep into the lungs.
- Low ambient humidity causes aerosols to desiccate into virus nuclei that can travel long distances (beyond our 6 ft. social distancing guidelines).

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.

The Risk of Infection

Steven Welty: 2013 ASHRAE Paper

ASHRAE®

- 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)

FLU SEASON MITIGATED!

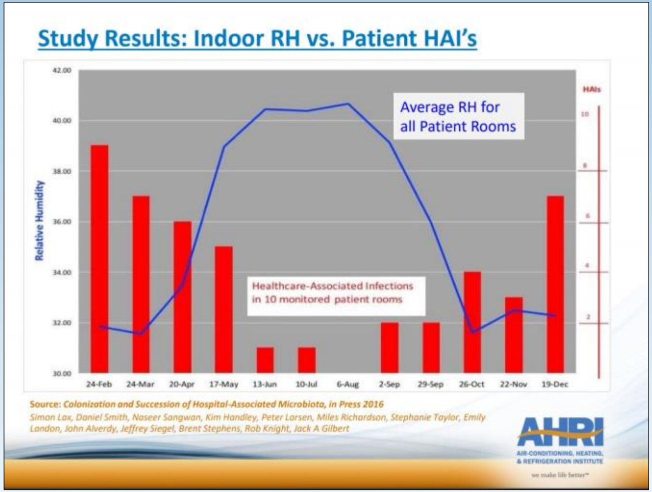
The Risk of Infection

Yale, AHRI and Mayo Clinic Studies:

Yale

**Our study provides mechanistic insights for the seasonality of the influenza virus epidemics, whereby inhalation of dry air compromises
the host’s ability to restrict influenza virus infection.**

https://www.pnas.org/content/116/22/10905



www.ahrinet.org/App_Content/ahri/files
/Humidity_Occupants_Presentation.pdf

MAYO CLINIC

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

https://www.biorxiv.org/content/10.1101/273870v2

NSWC NORMAN S. WRIGHT CLIMATEC MECHANICAL EQUIPMENT

VARITEC™ TECHNICAL INSTITUTE

Building Humidification

Building Humidification: Solutions

Humidifier Generators for all Building Applications

- How much moisture is required to maintain building Relative Humidity set point?

- **Retrofit Opportunities**
- **New Construction**

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VARITEC™ TECHNICAL INSTITUTE

Building Humidification: Solutions

Steam Generation	Electric		Gas-to-steam		Steam exchange	
Steam Dispersion	Pressurized (boiler steam)		Non-pressurized (Generator steam)			
Evaporative Cooling & Humidification	High-pressure system		Wetted media system			
Water Treatment	Reverse-osmosis water treatment		Low-maintenance humidification system			
Controls	Vapor-logic® controller					

Types of Humidification Solutions

NSWC NORMAN S. WRIGHT CLIMATEC MECHANICAL EQUIPMENT

VARITEC™ TECHNICAL INSTITUTE

Building Humidification: Solutions

Humidifier Products

- How much moisture is required to maintain building Relative Humidity set point?

High Pressure Adiabatic

- **National Average: 3 lbs water per 100 CFM of Outside Air**

Isothermal

Questions?

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Thank you.