Psychrometrics Deconstructed: Part #1

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
  - Director of High-Performance HVAC Solutions/Educator
    - 2022 thru present

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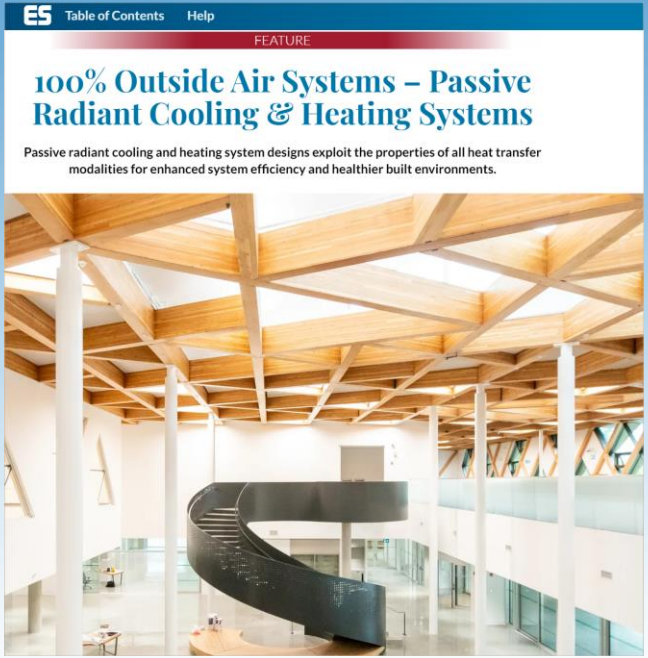
Latest Publication

Engineered Systems Magazine: December 2022 Edition

- *100% Outside Air Systems – Passive Radiant Cooling and Heating Systems*



- **(Co-Author: Darren Alexander, P.E. (Twa Panel Systems, Inc.)**

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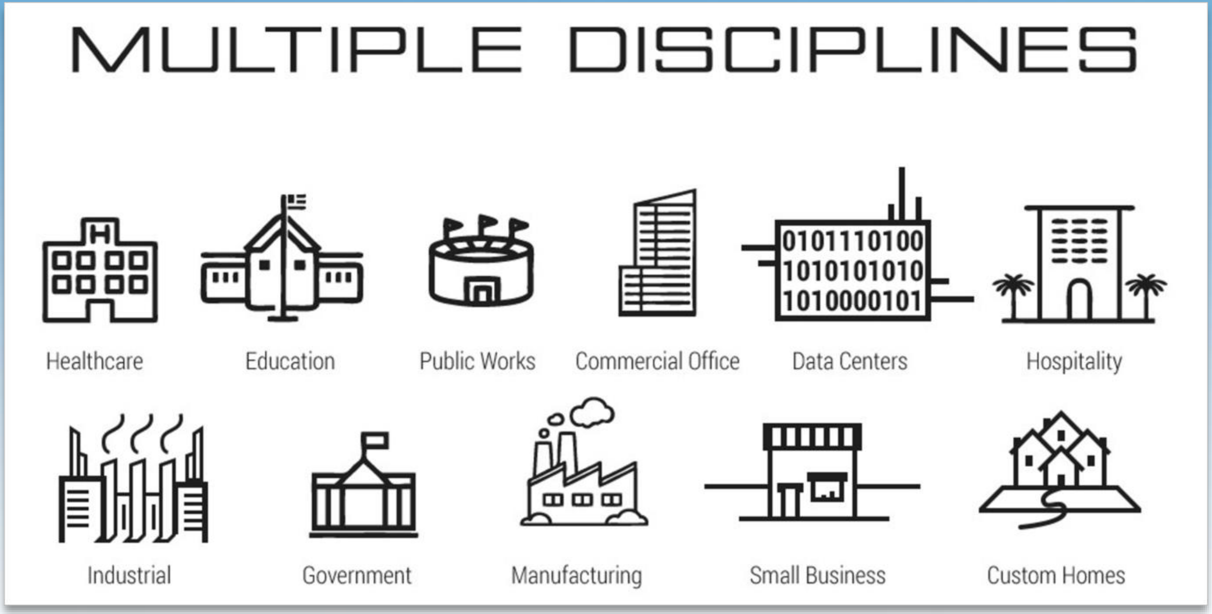
Varitec: The HVAC System Solution

Varitec: The HVAC System Solution



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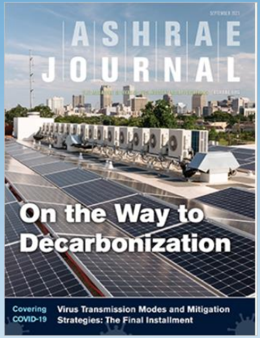
Varitec: The HVAC System Solution

System Solutions:

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

Ventilation: The OSA Challenge

ASHRAE Journal September 2021



- **Recent Development for Standard 90.1;**
  - "…the **U.S. Department of Energy (DOE)** issued a determination that **ANSI/ASHRAE/IES Standard 90.1-2019** for buildings except low-Rise Residential Buildings, improves energy efficiency in commercial buildings…The **final determination** makes the 2019 version of the standard the reference energy-efficiency standard…"

What's Next for Standard 90.1

ATLANTA—In late July, the U.S. Department of Energy (DOE) issued a determination that ANSI/ASHRAE/IES Standard 90.1-2019, *Energy Standard for Buildings Except Low-Rise Residential Buildings*, improves energy efficiency in commercial buildings compared to the 2016 standard.

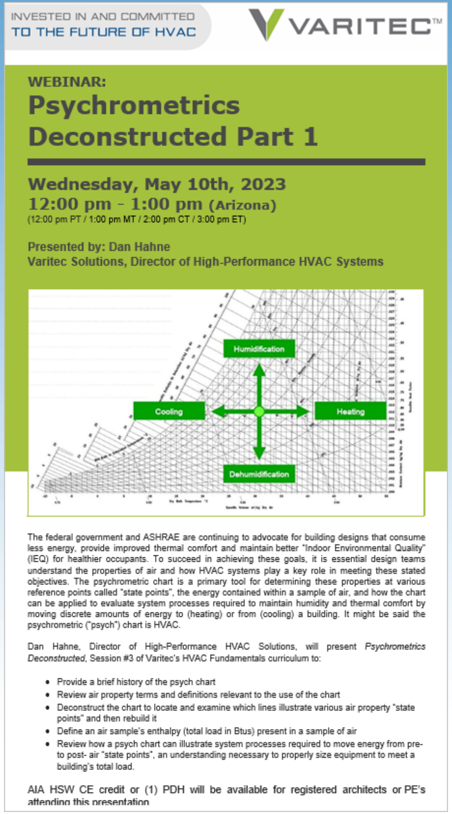
The final determination makes the 2019 version of the standard the reference energy-efficiency standard for buildings other than low-rise residential buildings, said Standing Standard Project Committee 90.1 Chair Don Brundage, P.E., Member ASHRAE; Co-Vice Chair Thomas Culp, Ph.D., Member ASHRAE; and special status as the model energy code for buildings within the 90.1 scope."

Now What?

DOE analysis shows the updated standard could cause national savings in commercial buildings of about 4.7% site energy, 4.3% source energy and 4.3% energy cost. States and other jurisdictions are now required to review their commercial building code regarding energy efficiency and update their codes to meet or exceed Standard 90.1-2019. Each state or jurisdiction has their own process for considering updates

US Department of Energy

Varitec Technical Institute



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WEBINAR:

Psychrometrics Deconstructed Part 1

Wednesday, May 10th, 2023
12:00 pm - 1:00 pm (Arizona)
(12:00 pm PT / 1:00 pm MT / 2:00 pm CT / 3:00 pm ET)

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

The federal government and ASHRAE are continuing to advocate for building designs that consume less energy, provide improved thermal comfort and maintain better "Indoor Environmental Quality" (IEQ) for healthier occupants. To succeed in achieving these goals, it is essential design teams understand the properties of air and how HVAC systems play a key role in meeting these stated objectives. The psychrometric chart is a primary tool for determining these properties at various reference points called "state points", the energy contained within a sample of air, and how the chart can be applied to evaluate system processes required to maintain humidity and thermal comfort by moving discrete amounts of energy to (heating) or from (cooling) a building. It might be said the psychrometric ("psych") chart is HVAC.

Dan Hahne, Director of High-Performance HVAC Solutions, will present *Psychrometrics Deconstructed*, Session #3 of Varitec's HVAC Fundamentals curriculum to:

- Provide a brief history of the psych chart
- Review air property terms and definitions relevant to the use of the chart
- Deconstruct the chart to locate and examine which lines illustrate various air property "state points" and then rebuild it
- Define an air sample's enthalpy (total load in Btus) present in a sample of air
- Review how a psych chart can illustrate system processes required to move energy from pre- to post- air "state points", an understanding necessary to properly size equipment to meet a building's total load.

AIA HSW CE credit or (1) PDH will be available for registered architects or PE's attending this presentation

Varitec Presents: Webinar Wednesday:

- When: May 10th
- Topic: Psychrometrics Deconstructed: Part #1

HVAC Fundamentals

Agenda:

- White House Indoor Air Quality Initiatives
  - IAQ Summit
  - Clean Air in Buildings Website
- Physical Properties of Heat Transfer
- Psychrometrics: The Properties of Air
- The Psychrometric Chart Deconstructed
  - History and Purpose
  - Terms & Definitions: Properties of Air
- Psychrometric Chart: Application
- Presentation Review

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White House Indoor Air Quality Initiatives

White House: Clean Air in Buildings

White House: October 11, 2022 - IAQ Summit

- "…improving indoor air quality within the buildings we use every day is an essential part of the Biden Administration's plan to manage COVID-19 this fall and winter."


THE WHITE HOUSE

Administration Priorities COVID Plan Briefing Room Español

OCTOBER 12, 2022

Readout of the White House Summit on Improving Indoor Air Quality

BRIEFING ROOM › STATEMENTS AND RELEASES

In addition to new, updated COVID-19 vaccines and lifesaving treatments, improving indoor air quality within the buildings we use every day is an

- "Yesterday , the **White House hosted a Summit on Improving Indoor Air Quality,** bringing together public health and ventilation experts…**to highlight the benefits of improved indoor air quality** in mitigating the spread of COVID-19…"
- "Encouraging businesses and organizations around the country in taking the **Clean Air in Buildings** Challenge."

- "Making it easier for schools to improve indoor air quality."
- "Lifting up organizations who are leading the way on indoor air quality in their buildings."

White House: Clean Air in Buildings

White House: Clean Air in Buildings Challenge

- **The Clean Air in Buildings Challenge is a call to action** for organizational leaders and building owners and operators of all types to assess their indoor air quality and make ventilation, air filtration, and air cleaning improvements to help keep building occupants safe.

- “ The quality and cleanliness of the air we breathe everyday has a significant impact on our health and well-being
- Better indoor air quality is a powerful tool in preventing the spread of COVID-19 and other infectious diseases..”

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White House: Clean Air in Buildings

White House: Clean Air in Buildings Challenge

About the Challenge: 4 Key Commitments

- **Commitment #1: Create a Clean Indoor Air Action Plan**:
    - Create a plan for upgrades and improvements, including HVAC inspections and maintenance if applicable
- **Commitment #2: Optimize Fresh Air Ventilation**
    - **Bring clean outdoor air indoors and circulate it when it is safe to do so.**
- **Commitment #3: Enhance Air Filtration and Cleaning**
    - By taking steps such as improving your central HVAC system and/or installing in-room air cleaning devices including HEPA filters
- **Commitment #4: Engage the Building Community**
    - Communicate with building occupants to increase awareness, commitment, and participation.

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ASHRAE, CDC & EPA: Air Quality Statements

CDC Website Subsequent Statement

- *"When indoors, **ventilation mitigation strategies** can help reduce viral particle concentration."*
- *"Open outdoor air damper beyond minimum settings to reduce or **eliminate HVAC air recirculation**."*

CENTERS FOR DISEASE CONTROL AND PREVENTION

EPA: Introduction to Indoor Air Quality

- **Primary Causes of Indoor Air Quality Problems:**
  - "**Inadequate ventilation** can increase indoor pollutant levels by not bringing in enough outdoor air to dilute emissions from indoor sources…"

- ***"An important approach to lowering the concentrations of indoor air pollutants… the amount of outdoor air coming indoors."***

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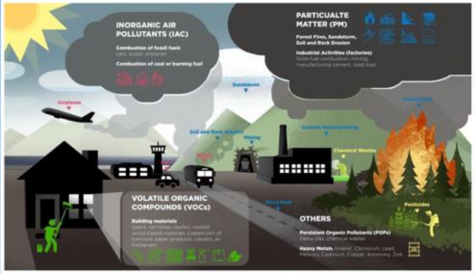
ASHRAE, CDC & EPA: Air Quality Statements

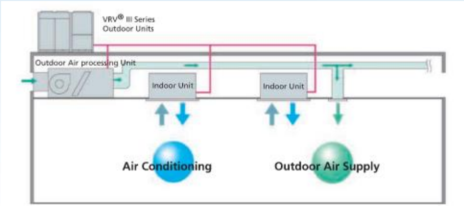
Environmental Protection Agency (EPA):

- Outdoor Air and Indoor Contaminants: Comparison

Indoor Air Pollutant

- Asbestos
- Biological Pollutants
- Carbon Monoxide
- Cook Stoves
- Formaldehyde/Pressed Wood Products
- Lead
- Nitrogen Dioxide
- Pesticides
- Radon
- Particulate Matter (PM)
- Volatile Organic Compounds
- Wood Smoke





Outdoor Air Pollutant

- Carbon Monoxide
- Lead
- Nitrogen Dioxide
- Ozone
- Particulate Matter (PM):Various Sizes
- Sulfur Dioxide)

(Note: Outdoor air contains other pollutants not regularly monitored by the EPA)

Buildings contain both indoor and outdoor air contaminants

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ASHRAE, CDC & EPA: Air Quality Statements

Environmental Protection Agency (EPA):

- *“EPA studies of human exposure to air pollutants indicate the **indoor levels of pollutants may be two to five times** – and occasionally more than 100 times **– higher than outdoor levels.”***

(By: Robert E. Stumm, P.E.)

ASHRAE Journal: June 2022

- “Of particular interest are several studies providing substantial evidence of **acute exposure to CO_2 at levels as low as 1,000 ppm** inducing significant reductions in cognition and decision-making abilities…”
- **To reduce indoor CO_2, increase a building’s outside air.**

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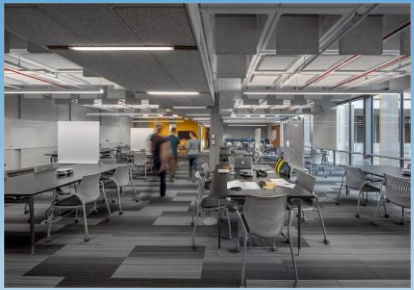
Physical Properties of Heat Transfer

Physical Properties of Heat Transfer



- **Heating and Ventilating Systems (HVAC): Purpose**
  - Promote personal comfort, a sense of well being and good IAQ while reducing the risk of germicidal (colds, flu & coronavirus) infection for building occupants

- **Thermal Comfort:**
  - To Maintain building thermal comfort, occupants should feel neither too hot nor too cold
  - To maintain a comfortable environment, **ENERGY (Heat) needs to be transferred** from a building to outdoors (cooling) or added to a building (heating)
- **What is Heat Transfer?**
  - **Definition:** "…any or all of several types of **phenomena** … that convey energy and entropy from one location to another" **(Britannica)**

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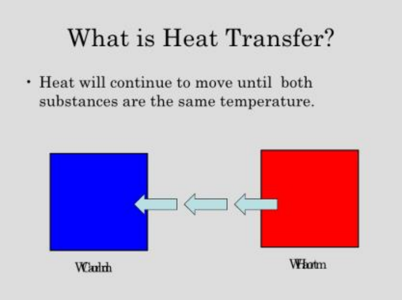
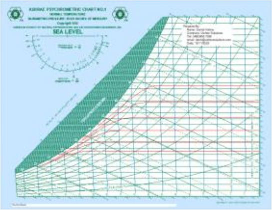
Physical Properties of Heat Transfer

Heat Transfer: Energy Moved in "Controlled" Amounts

- **Cooling: Remove heat energy and deposit it outdoors**
  - Remove energy added to a building
  - **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: How Much Heat?



- **Calculate the amount of building energy (total load) gained or lost** and the amount to be moved to maintain constant design temperature.
- How to calculate the amount of energy to be moved?
- **The Psychrometric Chart** references the **energy (enthalpy)** amount (load) to be moved to maintain space design conditions.

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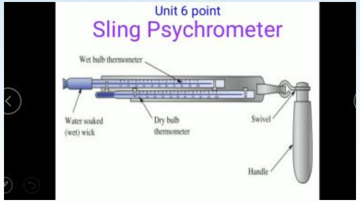
Physical Properties of Heat Transfer

Heat Transfer: Psychrometric Chart

- **Psychrometric Chart Celebrates 100th Anniversary:**
  - "Prior to 1900, tables of empirical psychrometric property values were used by meteorologists."
  - "**In 1847 (James) Glaisher's Hygrometrical Tables** were the first reliable tables listing water-vapor pressure; barometric pressure, stationary wet-bulb, dry-bulb, and dew-point temperature; relative humidity…" **(ASHRAE Journal November 2004)**

(Hygrodeik Wet & Dry-Bulb Hygrometer)



- "In 1886 the **American meteorologist William Ferrel** developed an improved empirical formula for computing water vapor pressure from dry-bulb and sling-psychrometer-wet-bulb temperature and barometric pressure…" **(ASHRAE Journal November 2004)**

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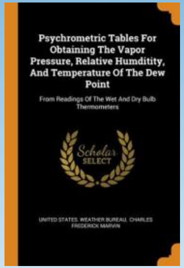
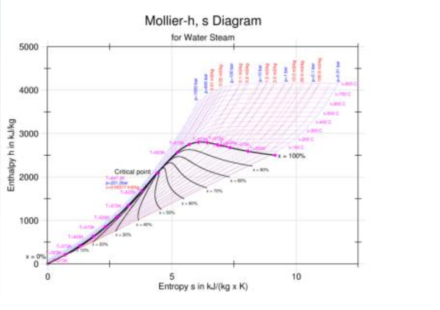
Physical Properties of Heat Transfer

Heat Transfer: Psychrometrics

- **Psychrometric Chart Celebrates 100th Anniversary:**
  - “Improved tables were prepared in 1900 by **Professor (Charles) Marvin**.” **(ASHRAE Journal November 2004)**



(Mollier Diagram)



- **Richard Mollier: (1863 – 1935):**
  - A German professor of Applied Physics and pioneer of experimental research in thermodynamics
  - Created in 1904 the **Mollier diagrams** illustrating the relationship between moist air and **enthalpy (Total Energy)**

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Physical Properties of Heat Transfer

Heat Transfer: Psychrometric Chart

Willis H. Carrier
President ASRE 1927
President ASHVE 1931

- **Psychrometric Chart Celebrates 100th Anniversary:**
  - In response to an air quality problem at Wilhelms Lithographing & Publishing Company in Brooklyn. Willis Carrier submitted drawings for what became recognized as the world's first modern air conditioning system
  - By 1903 **Willis Carrier (1876 – 1950)** completed the world's first scientifically based air-conditioning system specifically designed to control humidity.
- In 1904, **to simplify the task of** air-conditioning design, he (Carrier) graphed the data from Marvin's tables. This resulted in **the basic psychrometric chart** shape as we know it today." **(ASHRAE Journal November 2004)**

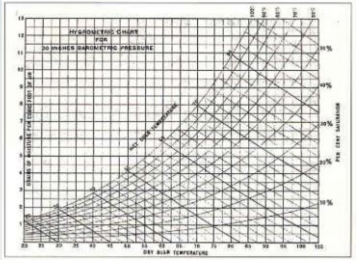

Figure 1: Willis H. Carrier hygrometric chart, circa 1904–1906.

"The installation marked the birth of air conditioning"

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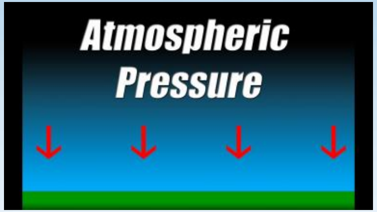
Physical Properties of Heat Transfer

Heat Transfer: Terms & Definitions

- **Psychrometric Chart: Terminology Review**
- **Definition: Change**
  - "…to make different in some particular: TO ALTER (Merriam-Webster Dictionary)
  - Bring about a **"CHANGE"** in state



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)

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Physical Properties of Heat Transfer

Heat Transfer: 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 forces associated with motion."**

(Mineral Medix)

- **Energy** is directly or indirectly the agent for motion, quantitative or qualitative **change**
- **Energy** is a **Force**
- **Energy (electrical load)** is required **to move heat (thermal energy) mechanically**

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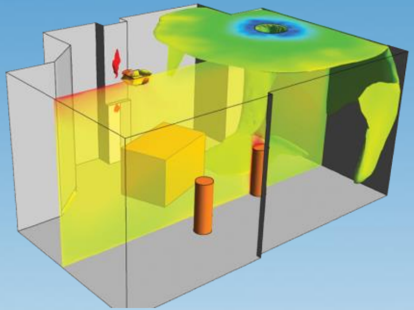
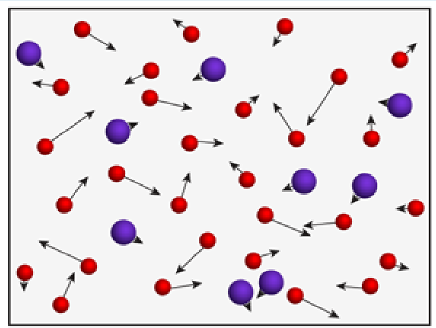
Physical Properties of Heat Transfer

Heat Transfer: Terms & Definitions



- **Definition: Thermal Energy - Temperature**
  - The value assigned to the amount of **thermal energy present in a sample of air**
- **Thermal Energy = Sensible Heat, F (Dry Bulb)**
  - "The temperature of the air is a measure of **the rate of molecular movement**." (American Geosciences Institute)



- "The higher the **molecular energy (Kinetic Energy)** the higher the temperature you feel in the air."

(American Geosciences Institute)

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Physical Properties of Heat Transfer

Heat Transfer: Terms & Definitions

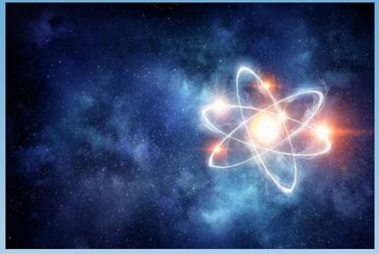
Water & Heat Energy: Energy & States of Water

- Freezing: Liquid becomes a solid (Below 32F degrees)
- Melting: Solid becomes a liquid (Above 32F degrees)
- Evaporation: **Liquid becomes a gas, “heat of vaporization**”
- Condensation: Gas becomes a liquid **(Dew point)**

- **ASHRAE Standard 55: Definition**
  - **Humidity:** “…the moisture content of the air…”
  - Common measure of humidity is **Relative Humidity**
  - **Absolute measure** of moisture content is **Dew Point (°F)** or **Specific Humidity (grains (water) / LB (air))**
  - **Water requires thermal (LATENT) energy to remain in a vapor state**
  - **Latent Cooling:** Remove enough **thermal energy** so water vapor cannot remain in a gaseous state

Physical Properties of Heat Transfer

Heat Transfer: Terms & Definitions



- **Definition: Thermodynamics**
  - "…the study of the **relations** between **heat**, work, temperature, and **energy** **(Britannica)**
- **Definition: Enthalpy**
  - An air samples **Total Energy Energy (Sensible Btus + Latent Btus)** and the product of the pressure and volume of a thermodynamic system

- **Definition: Psychrometrics:**
  - "…the study of the **thermodynamic** properties of **air-vapor** mixtures, partial **pressures** and **enthalpy**." **(Science Direct)**

- **Psychrometrics (Psychrometry):**
  - **Derivation: Greek words *psuchron*** (ψυχρόν), ***meaning cold*** and *metron* (μέτρον), a means of measurement

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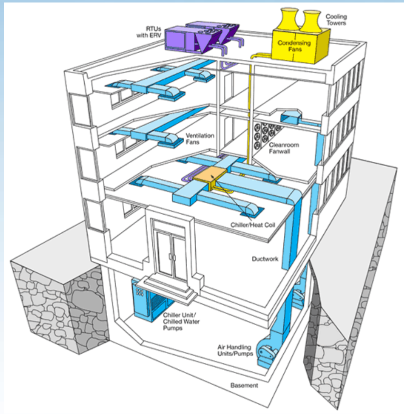
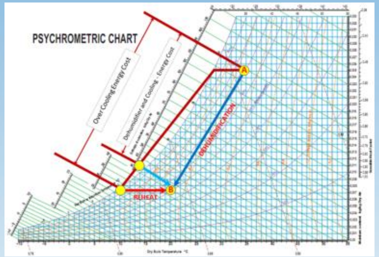
Psychrometrics: The Properties of Air

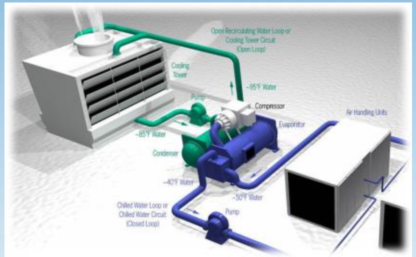
Psychrometrics: The Properties of Air

Heat Transfer: Controlled Amounts of Energy

- Determine amount of energy to be moved to maintain building **temperature** set points and humidity levels







Cooling:

- Calculate **total load (sensible energy + latent energy)**
- **Sensible energy:** measured at a building thermostat
- **Latent energy:** energy removed to condense water vapor
- **How? Apply the Psychrometric Chart**

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Psychrometrics: The Properties of Air

Properties of Air: Terms and Definitions

- To calculate **total load**, understanding implicit terms and definitions is of fundamental importance

- **Dry-Bulb Temperature (DB) Temperature:**
  - The amount of energy in the space as **measured by a room thermostat** or "dry" thermometer.
  - Also called **"sensible temperature"** – the heat sensed by an occupant and read by a **dry thermometer**.

- **Relative Humidity (RH):** is the moisture content in a sample air as a percent of the total amount of moisture air can hold when it is fully saturated **(100% RH)** at a dry bulb temperature.
- **Relative** to what? **Temperature** **(RH values vary per dry bulb temperature)**

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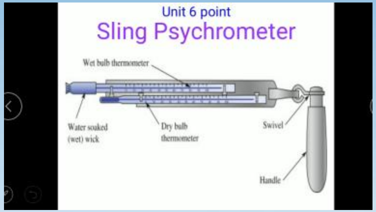
Psychrometrics: The Properties of Air

Properties of Air: Terms and Definitions

- **Wet-Bulb Temperature (WB)**: Lowest **temperature air is cooled** to by water evaporating into a vapor at a constant pressure.
    - Measured by wrapping a **wet wick around the bulb of a thermometer.** The **measured temperature** is the **wet bulb temperature. (Latent Energy)**
    - **Lower WB = drier air (more evaporation), higher WB = more humid air (less evaporation)**



- **Dew Point Temperature (DP):** The temperature (°F) at which **insufficient energy** is present to maintain water in a vapor state thereby condenses and becomes liquid
- **Higher dew point = greater moisture content & humidity**
- **Lower dew point = lesser moisture content & humidity.**

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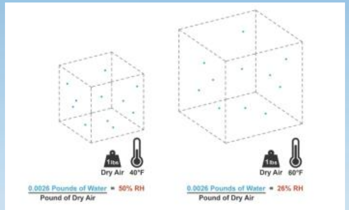
Psychrometrics: The Properties of Air

Properties of Air: Terms and Definitions

- **Specific Humidity (Humidity Ratio *W*):**
  - The **mass of water vapor** in dry air measured in grains of moisture per pound of dry air (gr/lb).
  - **7,000 grains = 1 LB of water vapor**



- **Enthalpy (*h*) = Total Load**
  - **Total Load = (sensible + latent) energy** measured in (*Btu/lb* $_{air}$)
    - ***Btu = British Thermal Unit***
    - *Energy required to raise one pound of water one degree (°F)*
    - *12,000 Btus = 1 ton of load*

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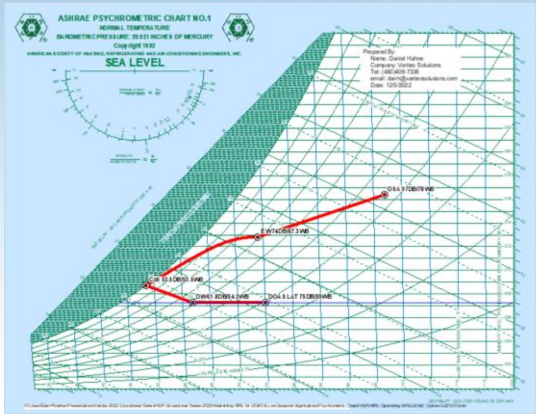
Psychrometrics: The Properties of Air

Psychrometric Chart: Purpose

- References the **relationship** between **sensible energy** **(temperature)**, **latent energy** **(humidity)** and **enthalpy** **(total energy)**
- **Psychrometric chart simply put is a REFERENCE CHART/ graph**



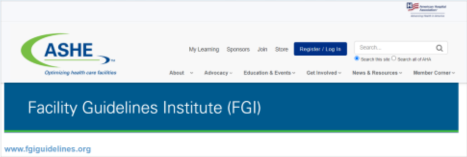
- **Psychrometric Chart Use:**
  - Any two air property values will reveal any other psychrometric value
  - Example: Knowing the dry bulb temperature and RH; dew point, specific humidity and enthalpy can be determined
  - **The chart illustrates total process load of a system, the total heat energy (enthalpy) to be transferred**

The Psychrometric Chart Deconstructed

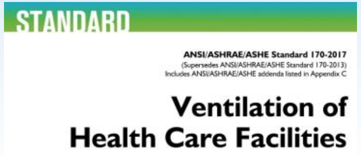
The Psychrometric Chart Deconstructed

American Society for Health Care Engineering (ASHE): Facility Guidelines Institute (FGI) www.fgiguidelines.org

- “**In 2018, FGI incorporated (ASHRAE) Standard 170-2008** as part three of its ***Guidelines for Design and Construction of Hospitals.***
- …The joint commission, federal agencies, and authorities in 39 states use the FGI guidelines either as a code or a reference standard when reviewing, approving, and financing projects…” **(ES Engineered Systems Magazine October 11, 2018)**



“The new **ANSI/ASHRAE/ASHE Standard 170-2017**… can be adopted in part or as a whole by authorities for health care facility construction and private organizations…”
(ES Engineered Systems Magazine
October 11, 2018)



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PREMIER PERFORMANCE THROUGH EDUCATION, DESIGN & INNOVATION

The Psychrometric Chart Deconstructed

ASHRAE Standard 170-2017: Healthcare Standards

- Patient Room Air Design Conditions

Table 7.1 Design Parameters—Hospital Spaces *(Continued)*

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
Continued care nursery	N/R	2	6	N/R	No	30–60	72–78/22–26
Labor/delivery/recovery (LDR) (s)	NR	2	6	NR	NR	Max 60	70–75/21–24
Labor/delivery/recovery/postpartum (LDRP) (s)	NR	2	6	NR	NR	Max 60	70–75/21–24
Newborn nursery suite	NR	2	6	NR	No	30–60	72–78/22–26
Nourishment area or room	NR	NR	2	NR	NR	NR	NR
Patient corridor	NR	NR	2	NR	NR	NR	NR
Patient room	NR	2	4 (y)	NR	NR	Max 60	70–75/21–24
PE anteroom (t)	(e)	NR	10	NR	No	NR	NR
Protective environment room (t)	Positive	2	12	NR	No	Max 60	70–75/21–24
Toilet room	Negative	NR	10	Yes	No	NR	NR

Patient Room – Temperature Range 70F DB to 75F DB @ Max 60% RH

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The Psychrometric Chart Deconstructed

Psychrometric Chart: Use & Application

Patient Room Design Set Points:
(72F at 40% RH)

Operating Room Design Set Points:
(72F at 40% RH)

Conditions to be maintained throughout the year.

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The Psychrometric Chart Deconstructed

Psychrometric Chart and Application:

General Design Conditions: Phoenix, Arizona

- **Example of Construction Standards 4 11 14 rev3**

Design Criteria

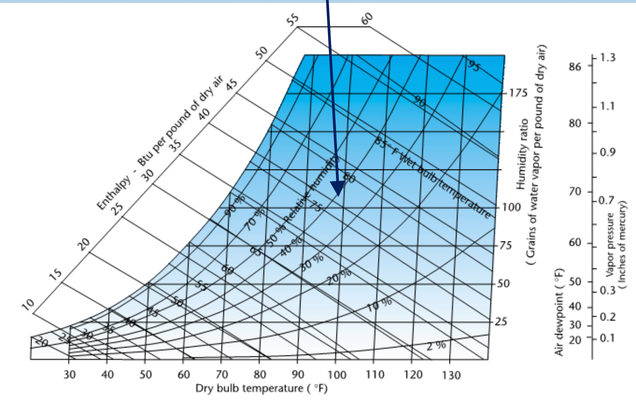
(Temperatures shown are for Arizona Region. All others use ASHRAE 1% or local best practice.)

Summer Design Dry Bulb Temperature (For Outside Air/Mixed Air)	115 deg F
Summer Design Wet Bulb Temperature For Outside Air/Mixed Air)	72 deg F
Summer Design Dry Bulb Temperature (For Coil Sizing)	97 deg F
Summer Design Wet Bulb Temperature (For Coil Sizing)	76 deg F
Winter Design Dry Bulb Temperature	31 deg F
Indoor Design Temperature Range for Conditioned Space	66-78 deg F
Indoor Design Temperature for Unconditioned Space	85 deg F

All air handler cooling coils shall be selected for a chilled water temperature range of 50 to 60 degrees F to maximize waterside economizer use.

Note: Individual spaces may require temperatures outside the ranges indicated above. The design team shall account for acceptable temperatures in each individual space and consider input from the users when selecting the appropriate temperature for each space.

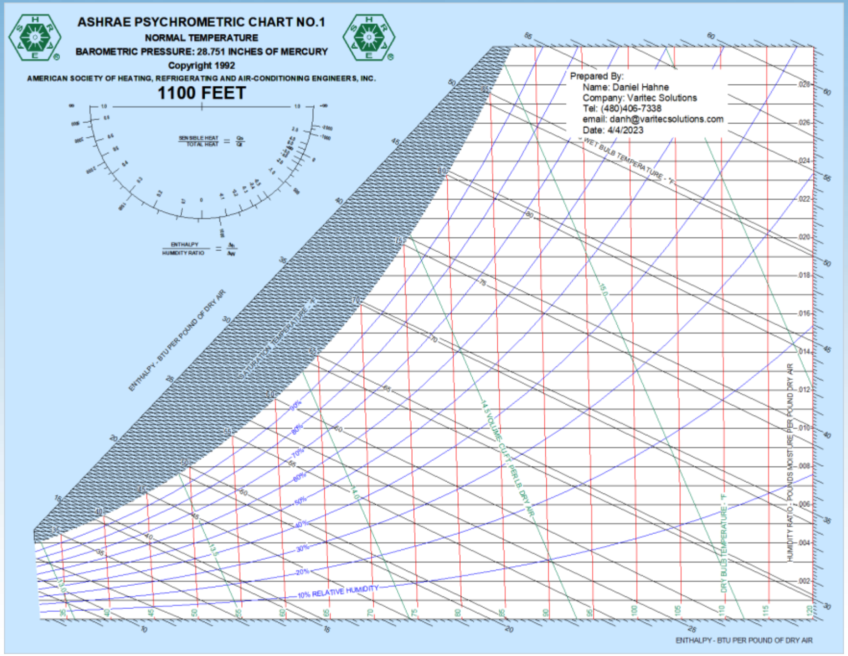
97D DB / 76F WB



The Psychrometric Chart Deconstructed

Psychrometric Chart: Use & Application

- Imagine a container filled with (1) LB of air from a hospital located in Phoenix.
- Phoenix site elevation = 1100 ft.
- **Elevation affects air properties**
- **Room air condition 72F dry bulb (DB) and 40% relative humidity (RH)**
- **Outdoor air condition 97F DB / 76F WB = (39% RH)**
- Knowing two air sample properties all other properties can be determined referencing the psychrometric chart.



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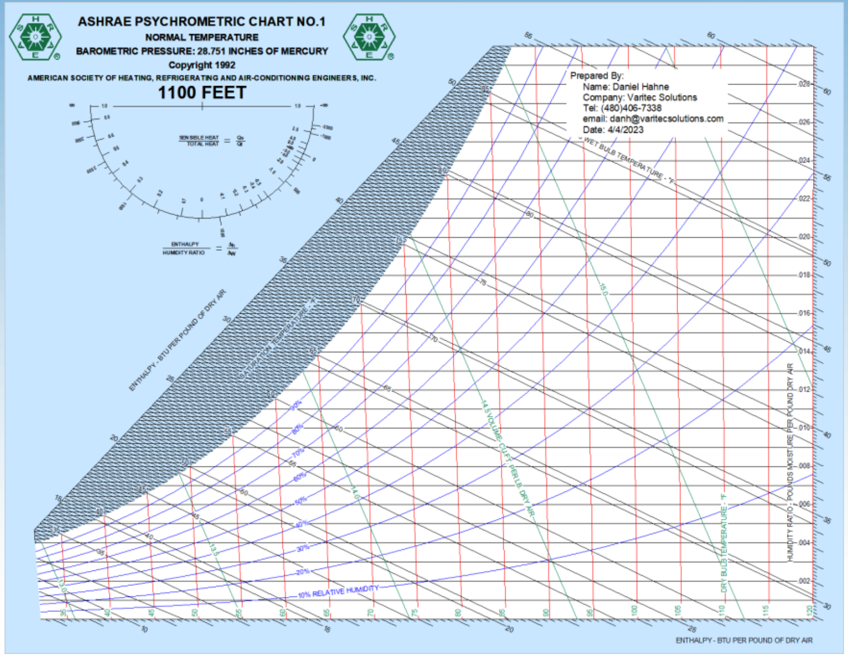
The Psychrometric Chart Deconstructed

Psychrometric Chart: Use & Application

- “X-Axis: Dry Bulb Temperature (°F)
- “Y-Axis: Dew Point Temperature (°F)
- “Y-Axis: Humidity Ratio (grains/lb)
- “Y-Axis: Absolute Humidity (lb (water) /lb (air))
- Parabolic Lines: Relative Humidity
- Furthest Left Parabolic Curve: Saturation Curve
- Top-Right to Lower Left: Enthalpy (Btus/lb)



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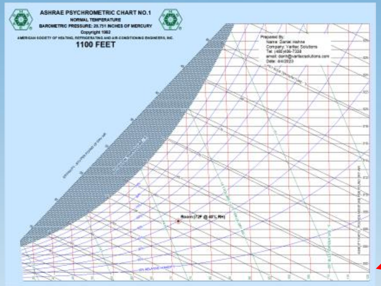
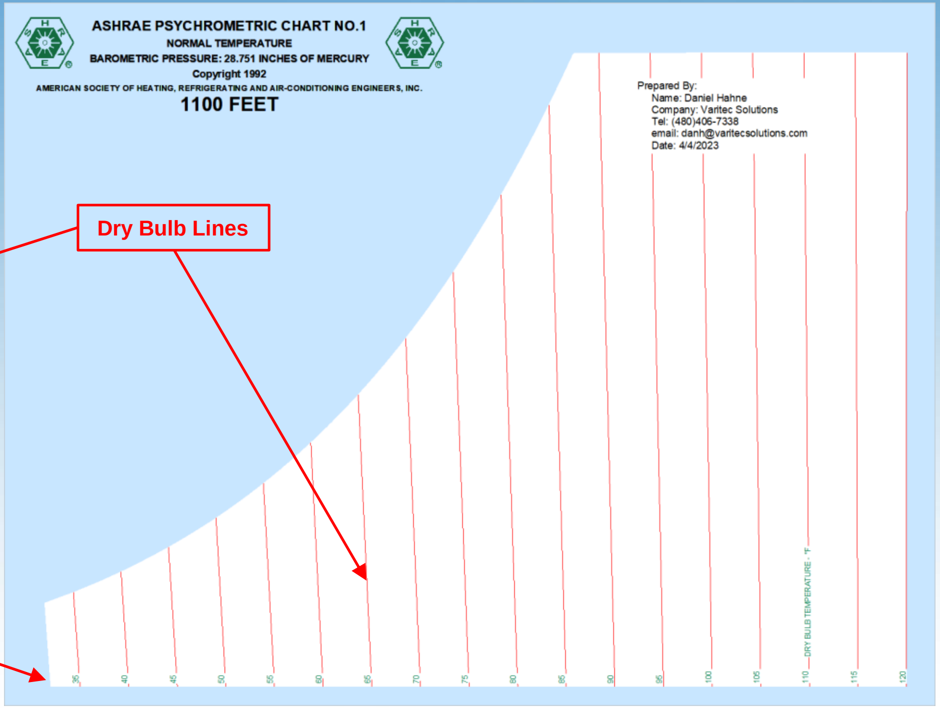
The Psychrometric Chart Deconstructed

How to Read & Use the Chart:

- **DECONSTRUCTING the "Psych Chart"**





Hospital Patient Room:

- **Dry Bulb (DB):** Air temperature measured at a thermometer. (sensible energy)
- **Psychrometric chart:** Dry bulb temperature referenced along the "X-axis" of the chart

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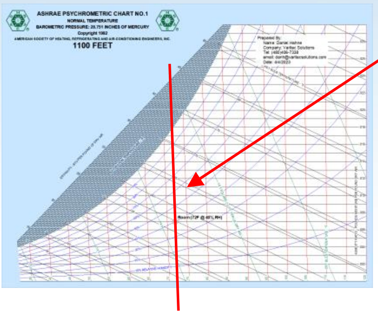
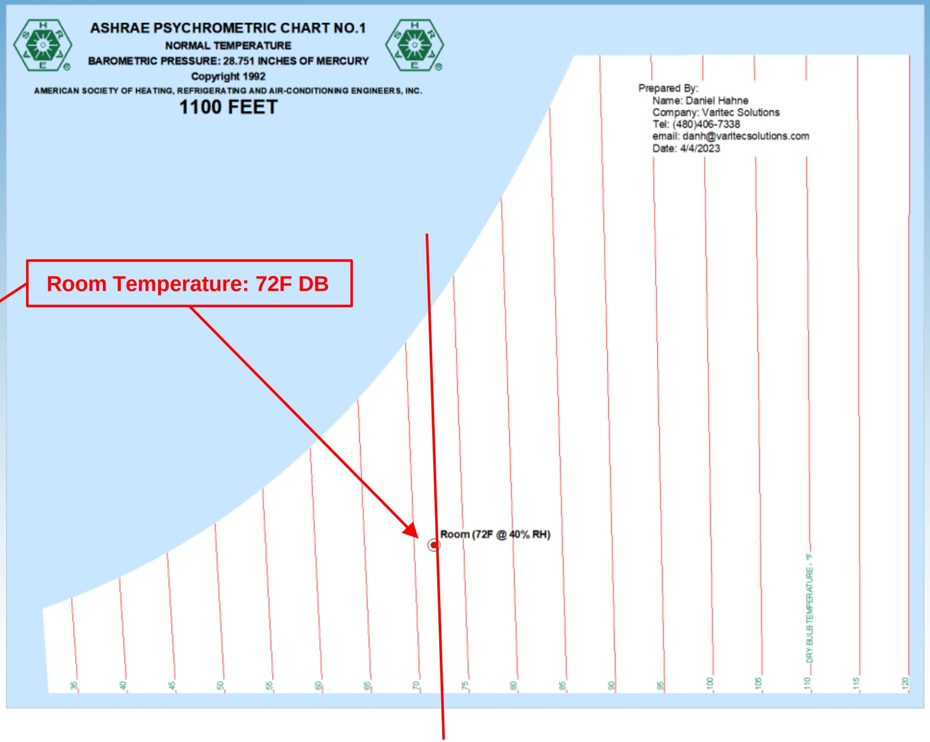
The Psychrometric Chart Deconstructed

How to Read & Use the Chart:

Hospital Patient Room:

- **Dry Bulb (DB) Temperature:**
  - **72F Dry Bulb (DB)**
- Dry bulb lines span upward from “X-axis”
- State point DB line **parallel** to other DB lines



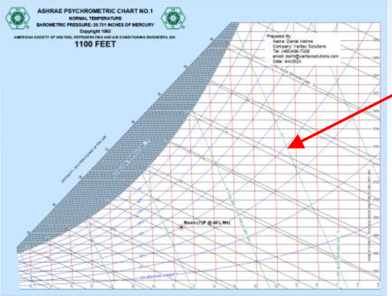


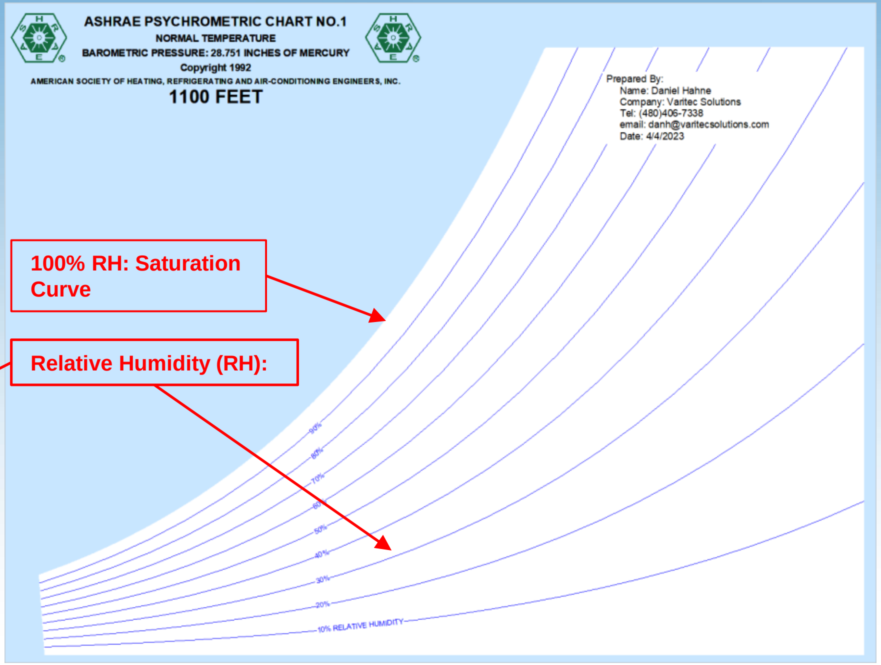
The Psychrometric Chart Deconstructed

How to Read & Use the Chart:

Hospital Patient Room:

- **Relative Humidity (RH)**
- Air sample's actual moisture content **as a percentage** in relation to the amount of moisture air can hold when saturated at a given temperature, 100% RH.
  - **Temperature related, not absolute**
  - RH illustrated by upward, "semi-hyperbolic" curvilinear lines





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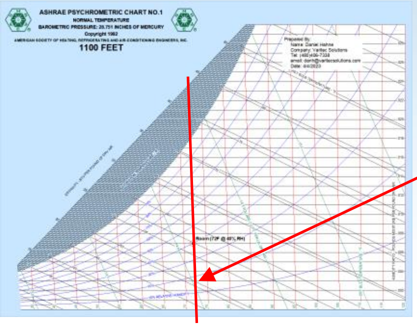
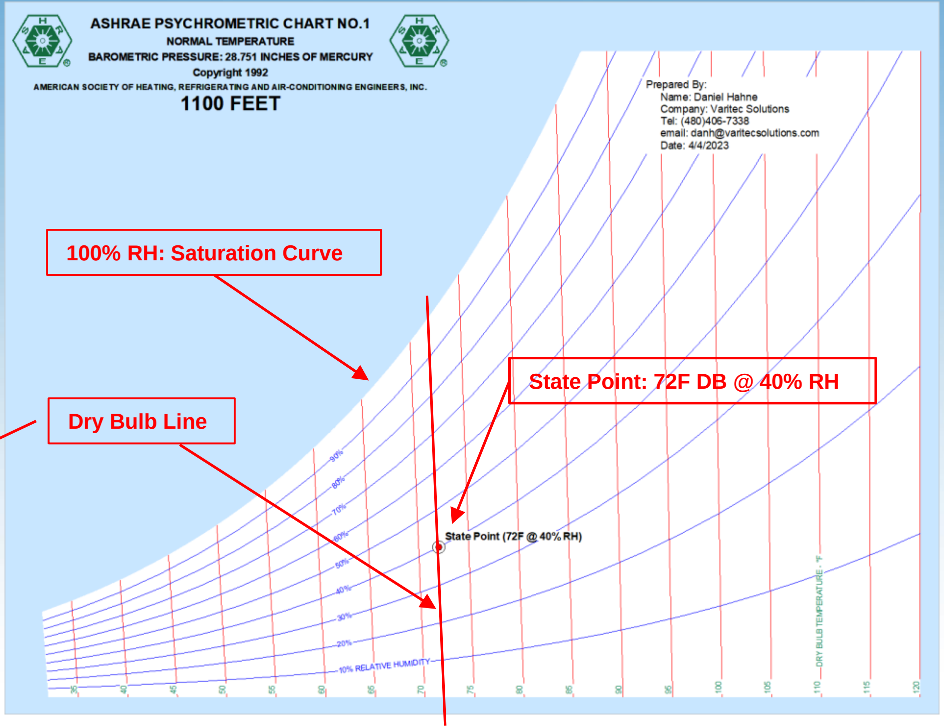
The Psychrometric Chart Deconstructed

How to Read & Use the Chart:

Hospital Patient Room:

- **Dry Bulb (DB) / Relative Humidity (RH)**
  - 72F Dry Bulb (DB)
  - 40% Relative Humidity (RH)
- Where RH line and dry bulb temperature intersect a **"state point"** is created





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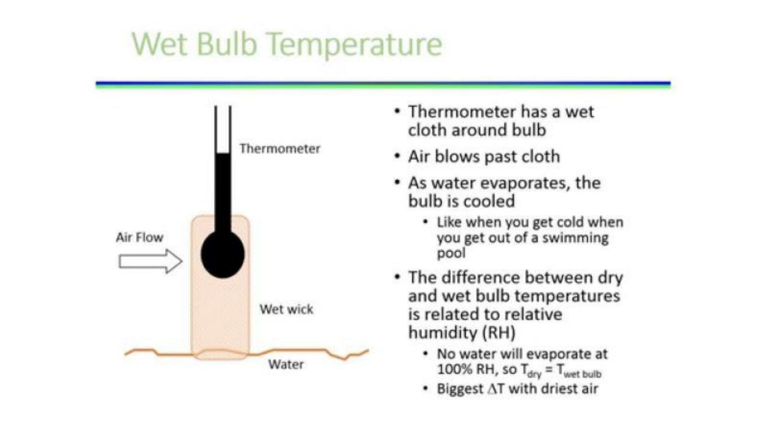
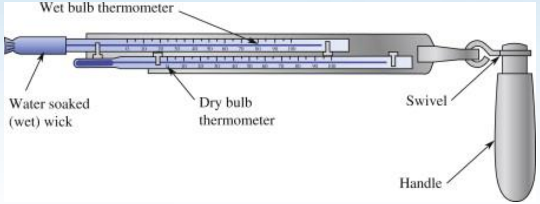
The Psychrometric Chart Deconstructed

How to Read & Use the Chart:

Hospital Patient Room:

- **Wet Bulb (WB):** Temperature measured by a thermometer covered by a wetted “wick”.
- Water evaporates from a moistened wick (phase change from water to vapor) drawing heat energy from the thermometer reducing its temperature.
- **Evaporation rate** affects the thermometer temperature
- **Evaporation rate is directly related to room humidity levels.**





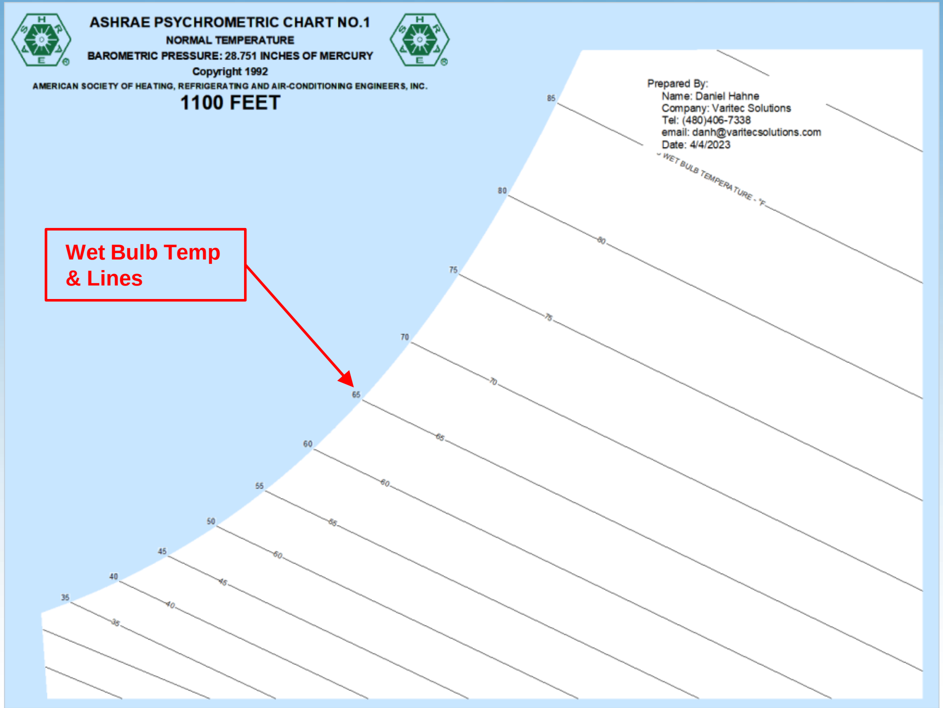
(Wet-Bulb Psychrometer)

The Psychrometric Chart Deconstructed

How to Read & Use the Chart:

Hospital Patient Room:

- **Wet Bulb (WB):**
  - Room design condition:
    - 72F DB @ 40% RH = 57F WB
  - Wet bulb values are located along the **Saturation Curve (100% RH)** of the chart
  - Wet bulb lines run upper left to lower right diagonally



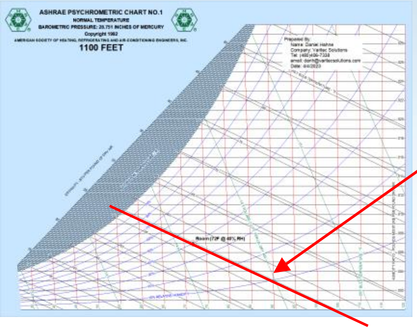
How can you reference wet bulb temperatures? Measure it or plot it.

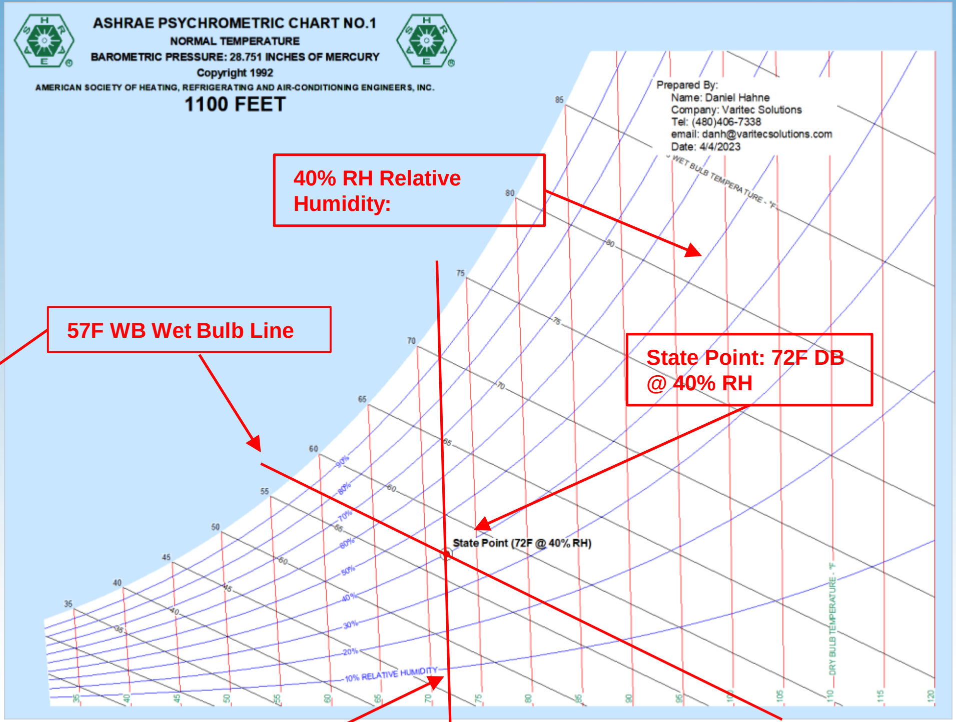
The Psychrometric Chart Deconstructed

How to Read & Use the Chart:

Hospital Patient Room:

- **Determine Wet Bulb (WB)**
  - Room design condition:
    - 72F DB @ 40% RH
    - **Wet Bulb Temp = 57F (WB)**





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The Psychrometric Chart Deconstructed

How to Read & Use the Chart:

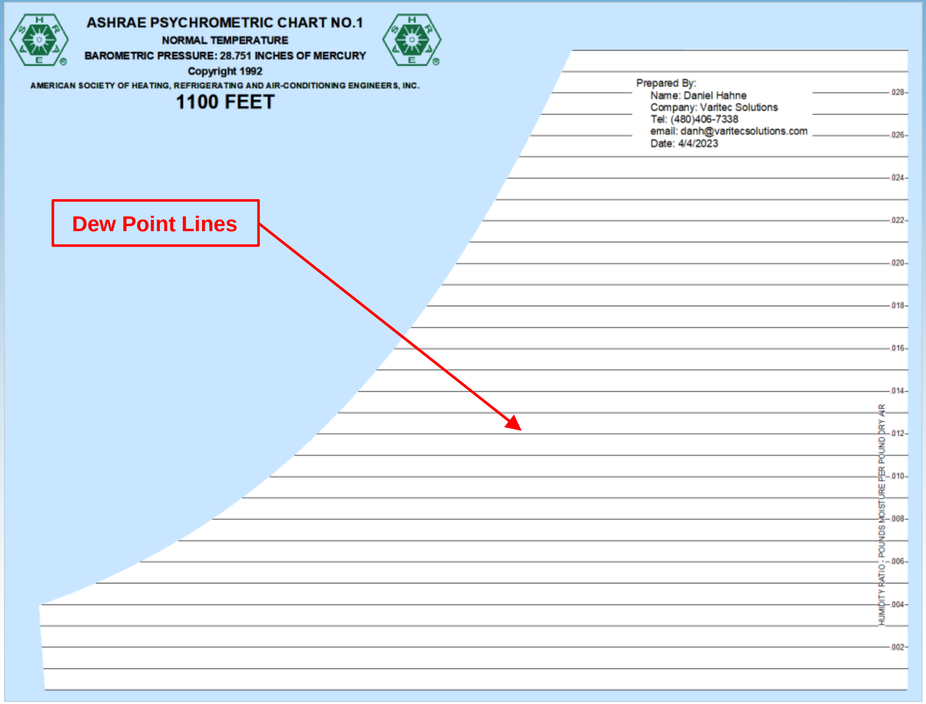
Hospital Patient Room:

- **Dew Point (DP):** The temperature (°F) **water vapor condenses** to a liquid state (dew) or forms on cooler surfaces.

- **Absolute measure of air moisture content.** Not related to temperature

- Dew point lines run **parallel** to “X-axis”

- Dew point values lie along the chart’s “Y-axis” (parallel to humidity ratio lines) or along the saturation curve, depending on the chart manufacturer.
- Why, **dew point is the wet bulb value when dry bulb and wet bulb are equal**

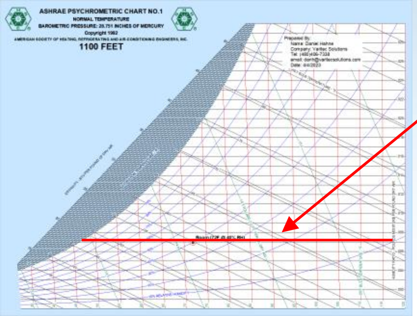


The Psychrometric Chart Deconstructed

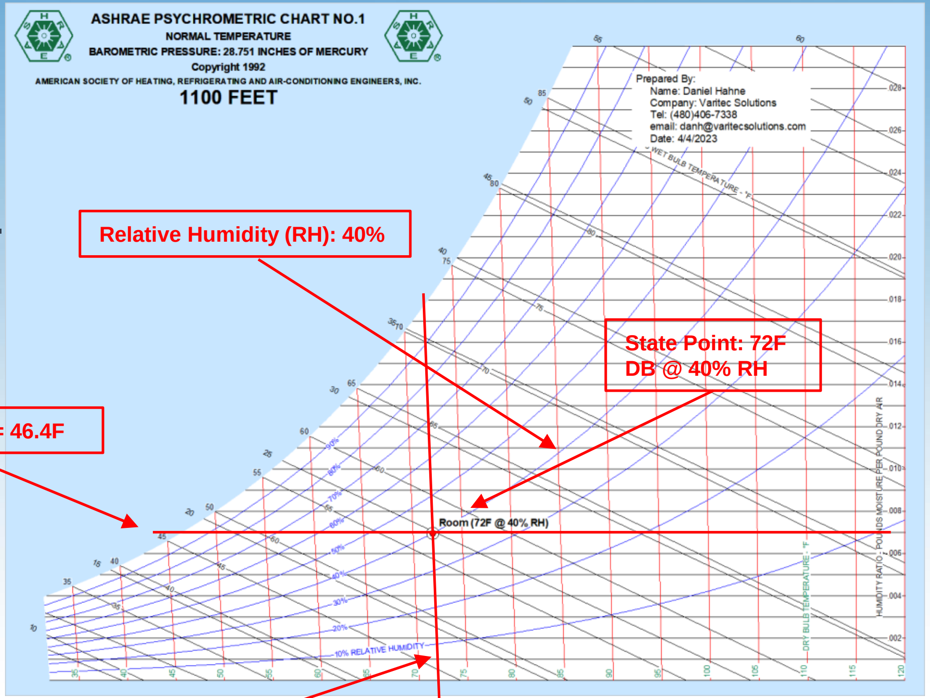
How to Read & Use the Chart:

Hospital Patient Rooms:

- **Determine Dew Point (DP):**
  - The temperature water under goes a phase change from vapor (gas) to liquid.
  - 72F DB and 40% RH
  - **Dew Point = 46.4F degrees.**



Dew Point (DP) = 46.4F



72F DB Dry Bulb Line

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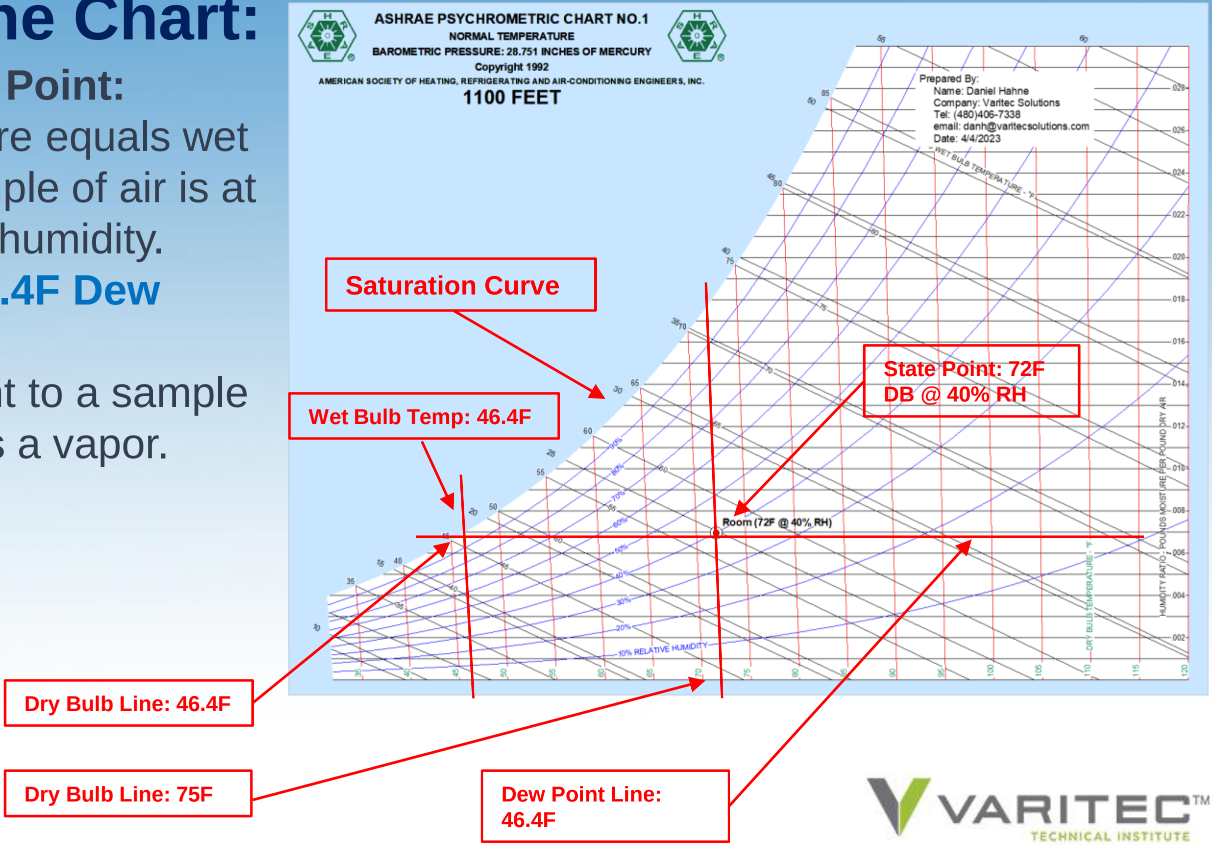
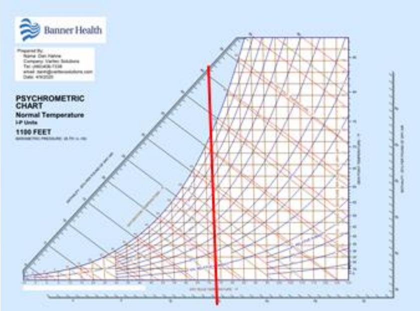
The Psychrometric Chart Deconstructed

How to Read & Use the Chart:

- **Dry Bulb, Wet Bulb and Dew Point:**
  - When dry bulb temperature equals wet bulb temperature the sample of air is at saturation, 100% relative humidity.
  - **46.4F DB/46.4F WB = 46.4F Dew Point**
  - Insufficient energy present to a sample of air to maintain water as a vapor.





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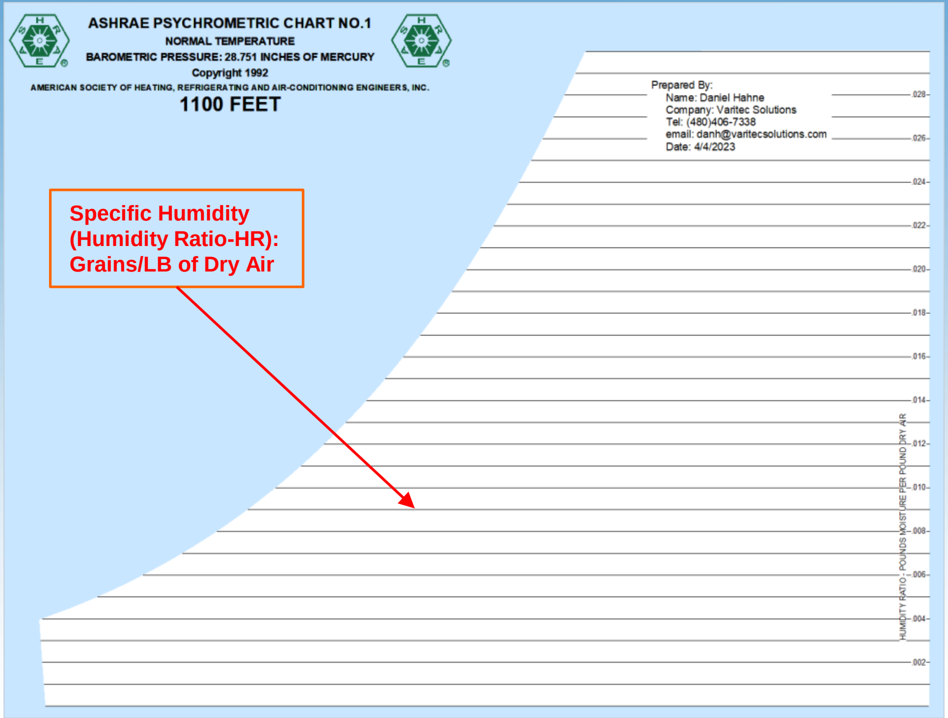
The Psychrometric Chart Deconstructed

How to Read & Use the Chart:

Hospital Patient Room:

- **Specific Humidity (Grains of water vapor per pound of dry air):** Absolute moisture amount in the air by **weight** (grains – 7,000 grains of moisture per pound of water) compared to the weight of the air sample.
- Specific Humidity line parallel to the “X” axis.
- 72F DB and 40% RH
- **Specific humidity = 48.68 gr/lb (air)**



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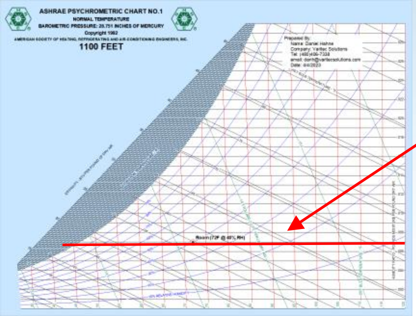
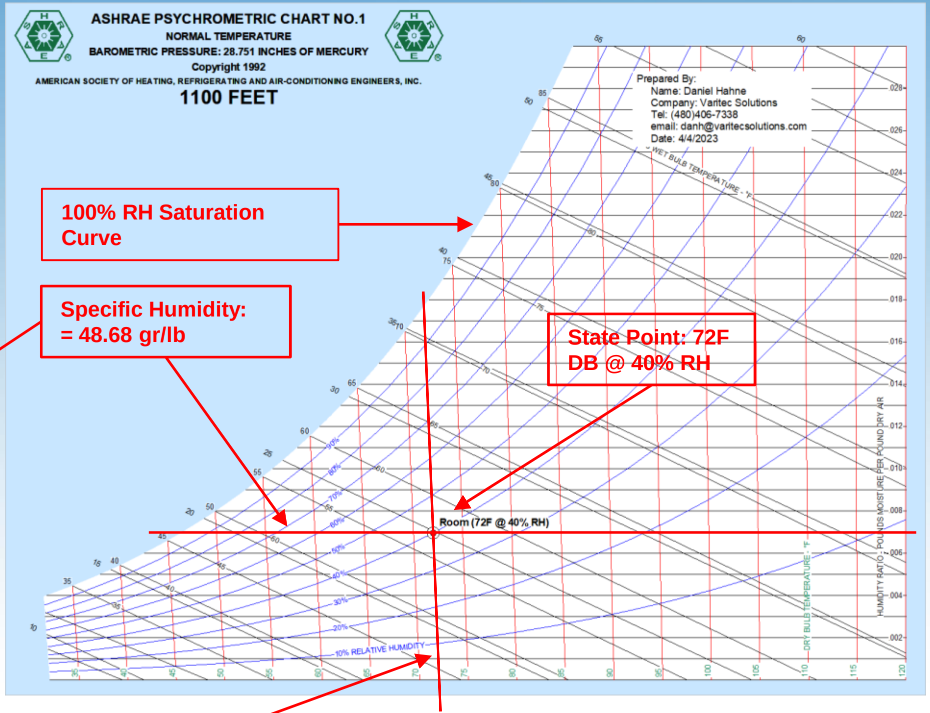
The Psychrometric Chart Deconstructed

How to Read & Use the Chart:

Hospital Patient Room

- **Determine Specific Humidity**
  - Room design condition:
    - 72F DB @ 40% RH
    - **Specific Humidity = 48.68 gr/lb**





72F DB Dry Bulb Line

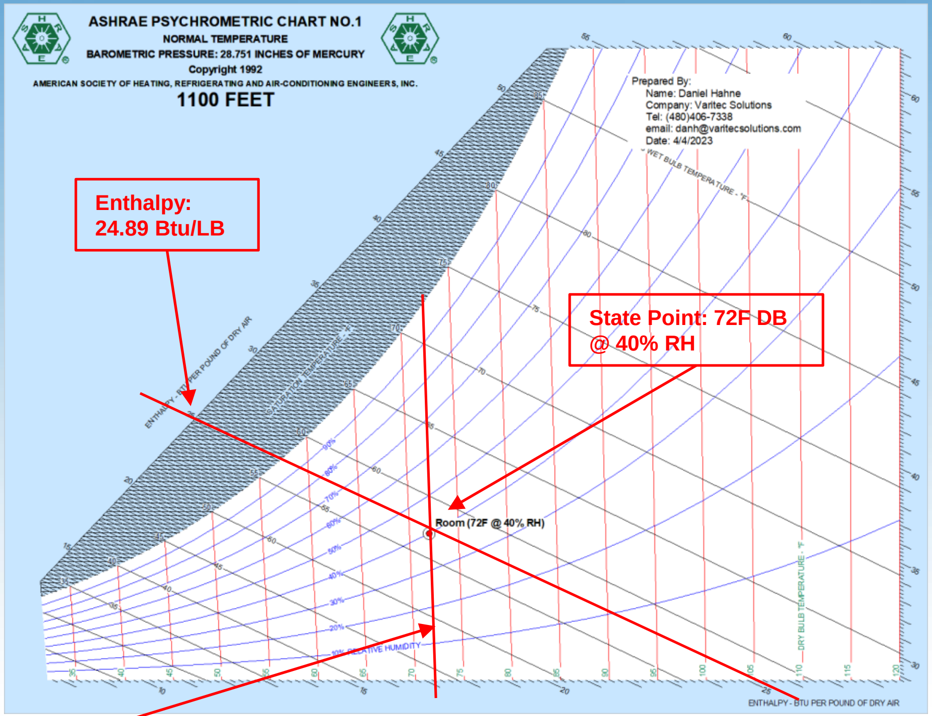
The Psychrometric Chart Deconstructed

How to Read & Use the Chart:

Hospital Patient Room:

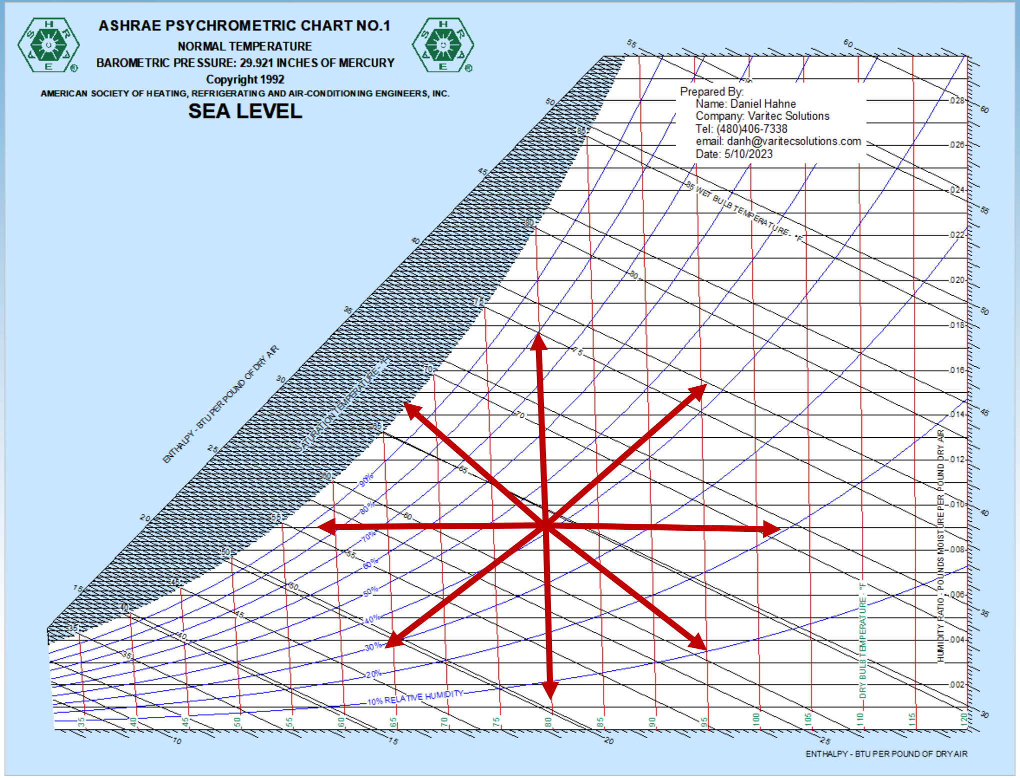
Determine Enthalpy:

- Plot a **"state" point** on the psych chart at 72F DB at 40% RH.
- Draw a diagonal line parallel to the WB line through state point to enthalpy line
- Air at 72F DB and 40% RH contains 24.89 BTUs per pound of dry air
- **Enthalpy = Total Load = (sensible energy + latent energy)**



The Psychrometric Chart Deconstructed

Psychrometric Chart: Processes



Process Types

- Sensible Heating
- Sensible Cooling
- Humidification
- Dehumidification
- Evaporation
- Chemical Dehumidification
- Heating Humidification
- Cooling Dehumidification

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The Psychrometric Chart Deconstructed

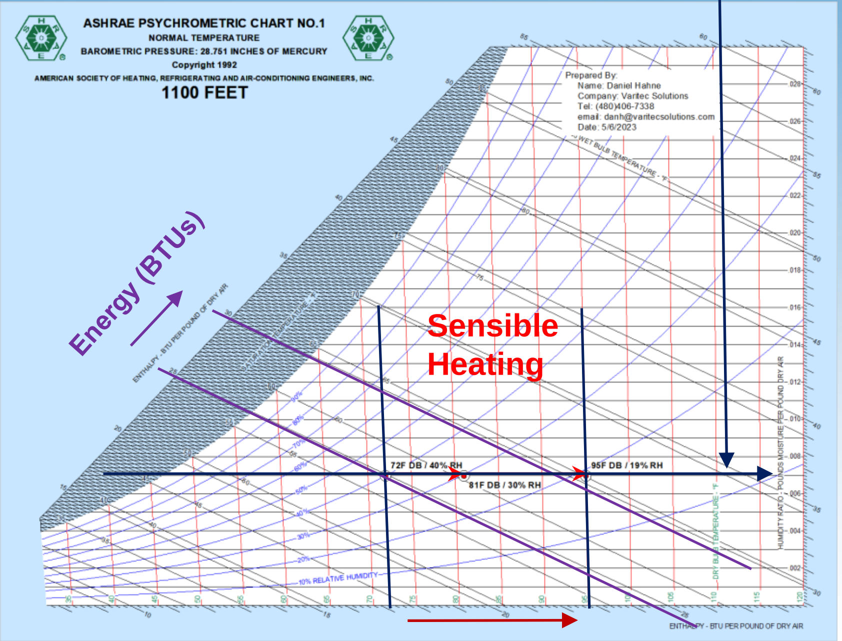
How to Read & Use the Chart:

Process: Sensible Heating

- **State Point #1: 72F DB / 40% RH**
  - Dew Point = 46.39F, Specific Humidity = **46.7 grains**
- **State Point #2: 81F DB / 30% RH**
  - Dew Point = 46.39F, Specific Humidity = **46.7 grains**
- **State Point #3: 95F DB / 19% RH**
  - Dew Point = 46.39F, Specific Humidity = **46.7 grains**

Temperature Increases, Relative Humidity Decreases, Dew Point Remains Constant = ENTHALPY INCREASE

Specific Humidity / Dew Point Line



Temperature Increases

Mass of Water (Grains) Remains Constant

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The Psychrometric Chart Deconstructed

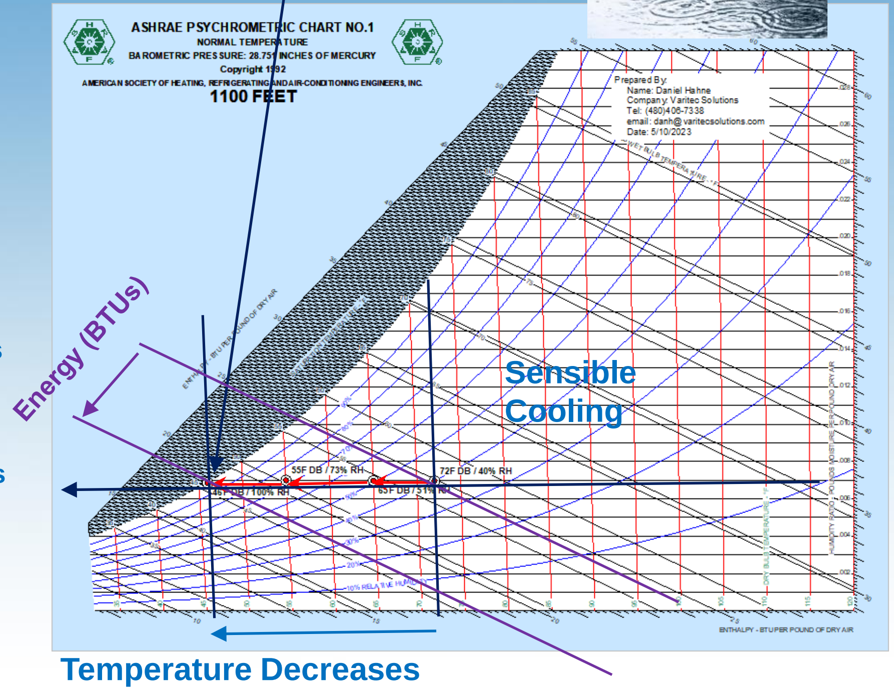
How to Read & Use the Chart:

Process: Sensible Cooling

- **State Point #1: 72F DB / 40% RH**
  - Dew Point = 46.39F, Specific Humidity = **46.7 grains**
- **State Point #2: 65F DB / 51% RH**
  - Dew Point = 46.39F, Specific Humidity = **46.7 grains**
- **State Point #3: 55F DB / 73% RH**
  - Dew Point = 46.39F Specific, Humidity = **46.7 grains**
- **State Point #4: 46F DB / 100% RH**
  - Dew Point = 46.39F Specific, Humidity = **46.7 grains**

Temperature Decreases, Relative Humidity Increases, Dew Point Remains Constant = ENTHALPY DECREASE

Dew Point = Condensation



Mass of Water (Grains) Remains Constant

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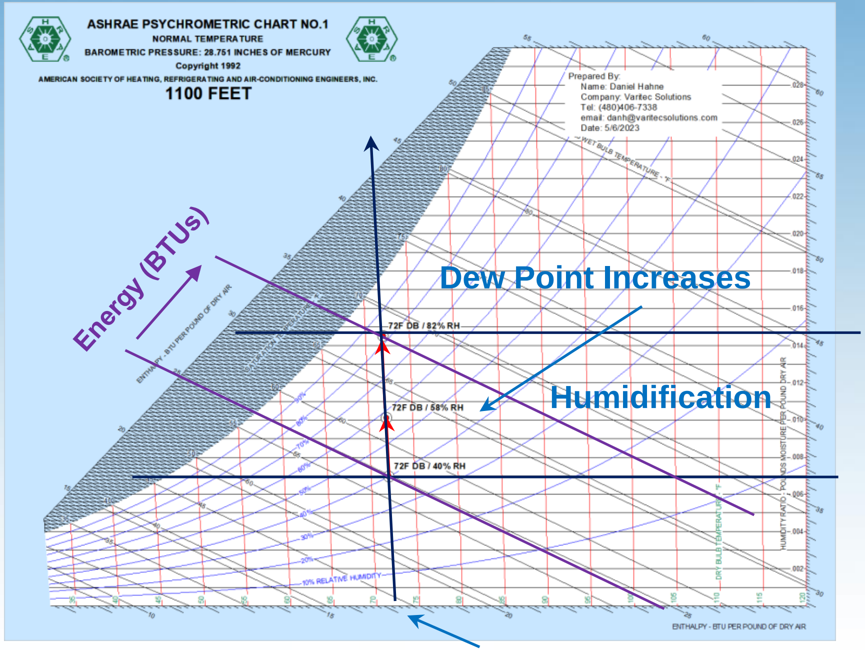
The Psychrometric Chart Deconstructed

How to Read & Use the Chart:

Process: Humidification

- **State Point #1: 72F DB / 40% RH**
  - Dew Point = 46.39F, Specific Humidity = **46.7 grains**
- **State Point #2: 72F DB / 58% RH**
  - Dew Point = 56.39F, Specific Humidity = **70.82 grains**
- **State Point #3: 72F DB / 82% RH**
  - Dew Point = 66.39F Specific, Humidity = **101.6 grains**

Moisture Grains Increase, Relative Humidity Increases, Dew Point Increases, Temperature Constant = ENTHALPY INCREASE



Temperature Remains the Same

Mass of Water (Grains) Increases

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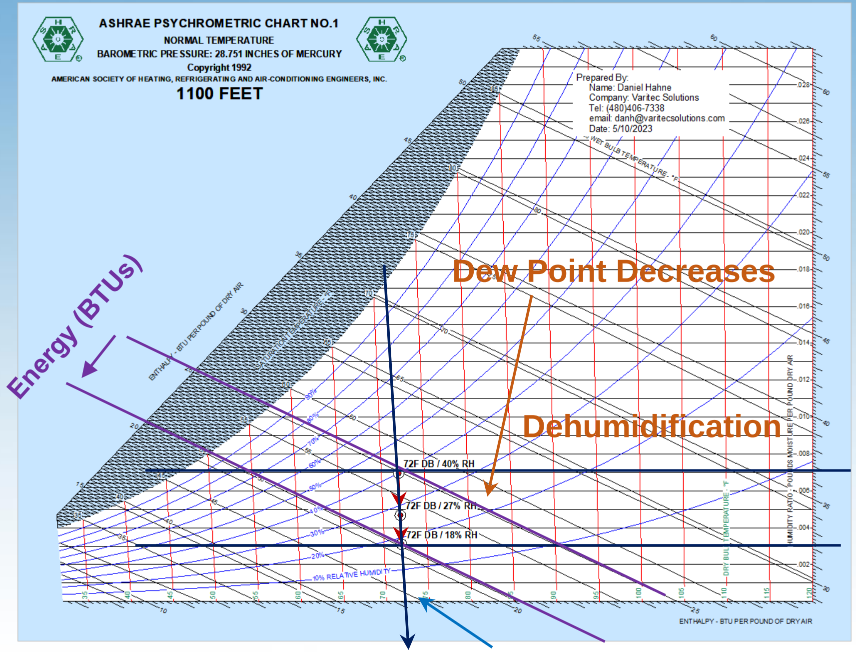
The Psychrometric Chart Deconstructed

How to Read & Use the Chart:

Process: Dehumidification

- **State Point #1: 72F DB / 40% RH**
  - Dew Point = 46.39F, Specific Humidity = **46.7 grains**
- **State Point #2: 72F DB / 27% RH**
  - Dew Point = 36.39F, Specific Humidity = **32.9 grains**
- **State Point #3: 72F DB / 18% RH**
  - Dew Point = 26.39F Specific, Humidity = **21.26 grains**



Temperature Remains the Same

Moisture Grains Decreases, Relative Humidity Decreases, Dew Point Decreases = ENTHALPY DECREASE

Mass of Water (Grains) Decreases

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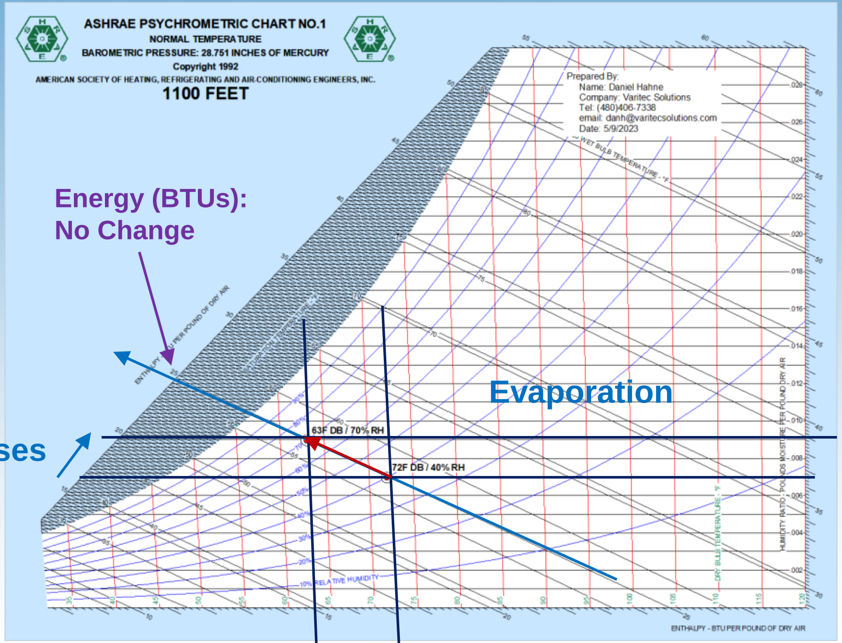
The Psychrometric Chart Deconstructed

How to Read & Use the Chart:

Process: Evaporation

- **State Point #1: 72F DB / 40% RH**
  - Dew Point = 46.39F, Specific Humidity = **46.7 grains**
- **State Point #2: 63F DB / 70% RH**
  - Dew Point = 53.1F, Specific Humidity = **62.7 grains**

Dew Point Increases



Temperature Decreases

Latent energy increases (humidity), sensible energy decreases (dry bulb temperature); Peter robbed to pay Paul = NO ENTHALPY GAIN

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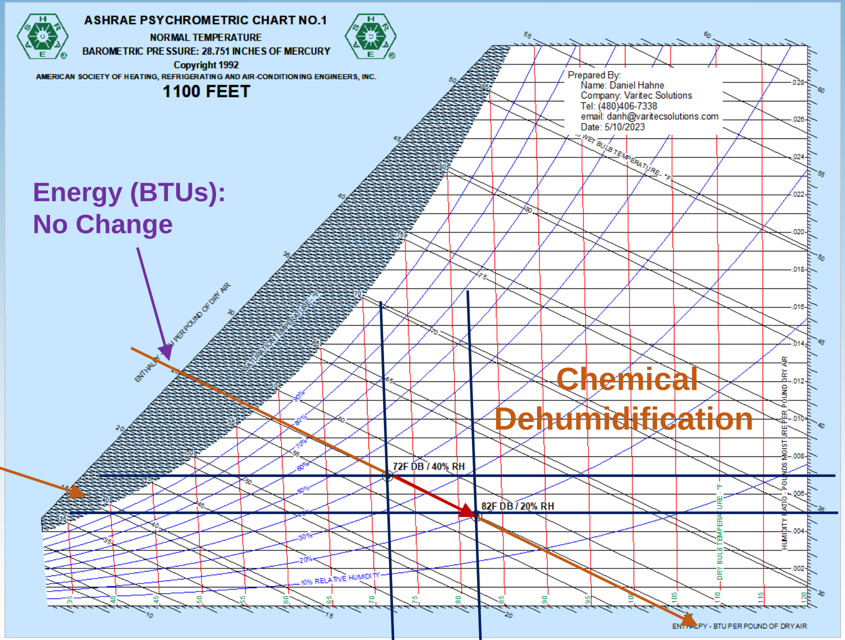
The Psychrometric Chart Deconstructed

How to Read & Use the Chart:

Process: Chemical Dehumidification

- **State Point #1: 72F DB / 40% RH =**
  - Dew Point = 46.39F, Specific Humidity = **46.7 grains**
- **State Point #2: 82F DB / 20% RH**
  - Dew Point = 37.03F, Specific Humidity = **33.79 grains**



Dew Point Decreases

Temperature Increases

Latent energy decreases (humidity), sensible energy increases (dry bulb temperature), Paul robbed to pay Peter =

NO ENTHALPY LOSS

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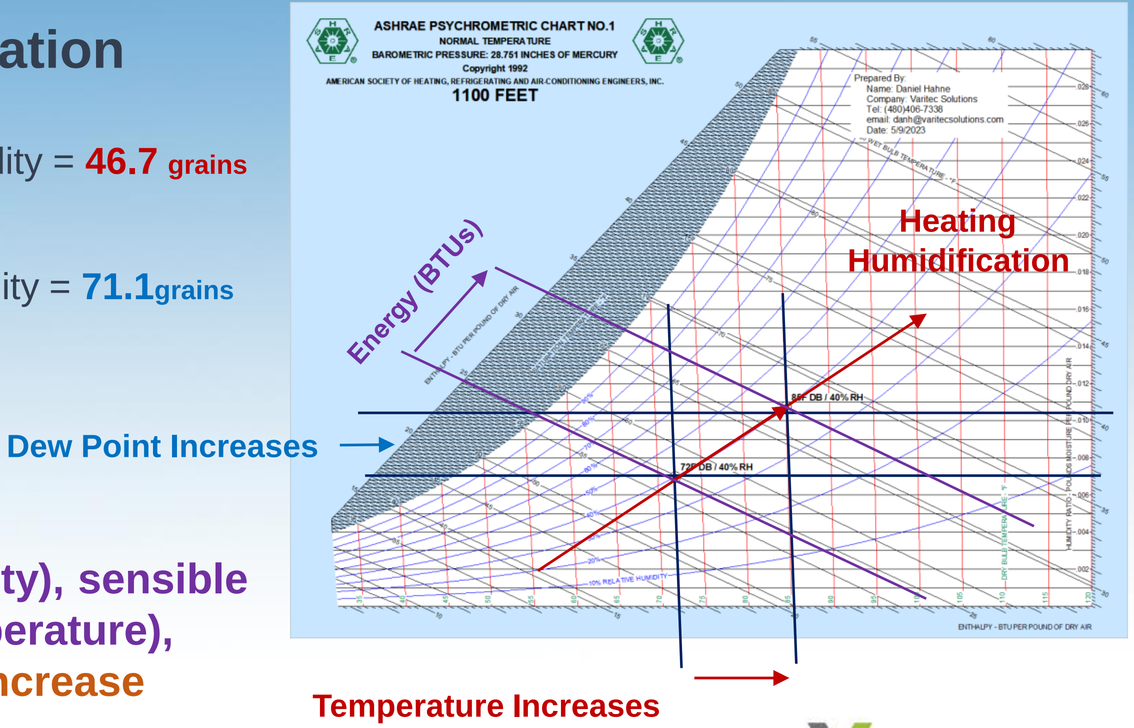
The Psychrometric Chart Deconstructed

How to Read & Use the Chart:

Process: Heating Humidification

- **State Point #1: 72F DB / 40% RH**
    - Dew Point = 46.39F, Specific Humidity = **46.7 grains**
- **State Point #2: 85F / 40% RH**
    - Dew Point = 58F, Specific Humidity = **71.1grains**

Latent energy increases (humidity), sensible energy increases (dry bulb temperature), enthalpy increases = Enthalpy Increase



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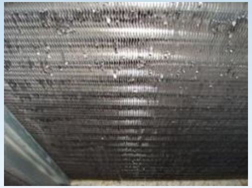
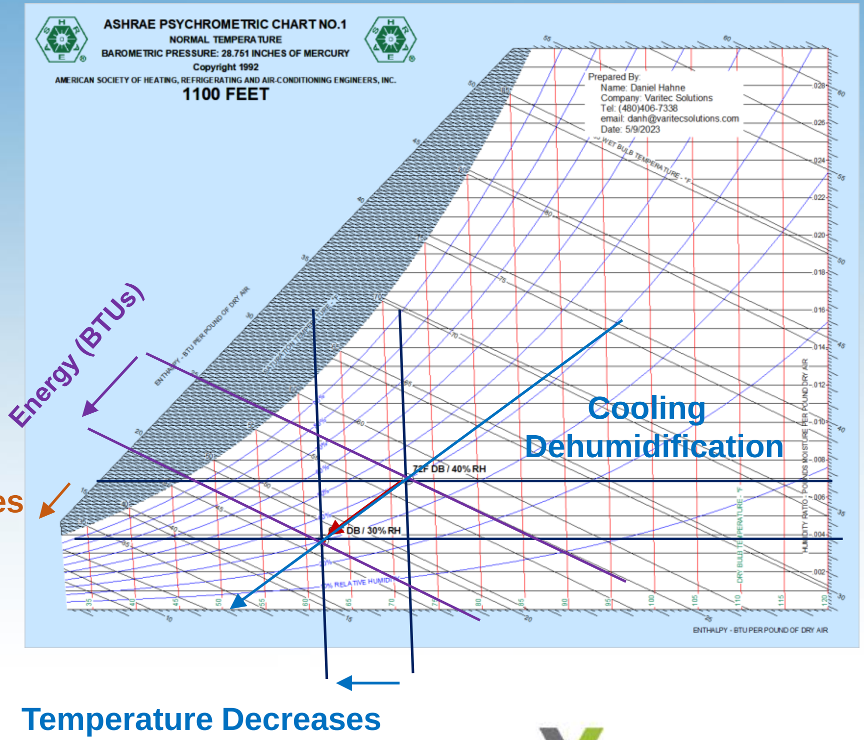
The Psychrometric Chart Deconstructed

How to Read & Use the Chart:

Process: Cooling Dehumidification

- **State Point #1: 72F DB / 40% RH**
  - Dew Point = 46.39F, Specific Humidity = **46.7 grains**
- **State Point #2: 62F DB / 30% RH**
  - Dew Point = 30.45F, Specific Humidity = **25.71 grains**





Latent energy decreases (humidity), sensible energy decreases (dry bulb temperature) = Enthalpy Decrease

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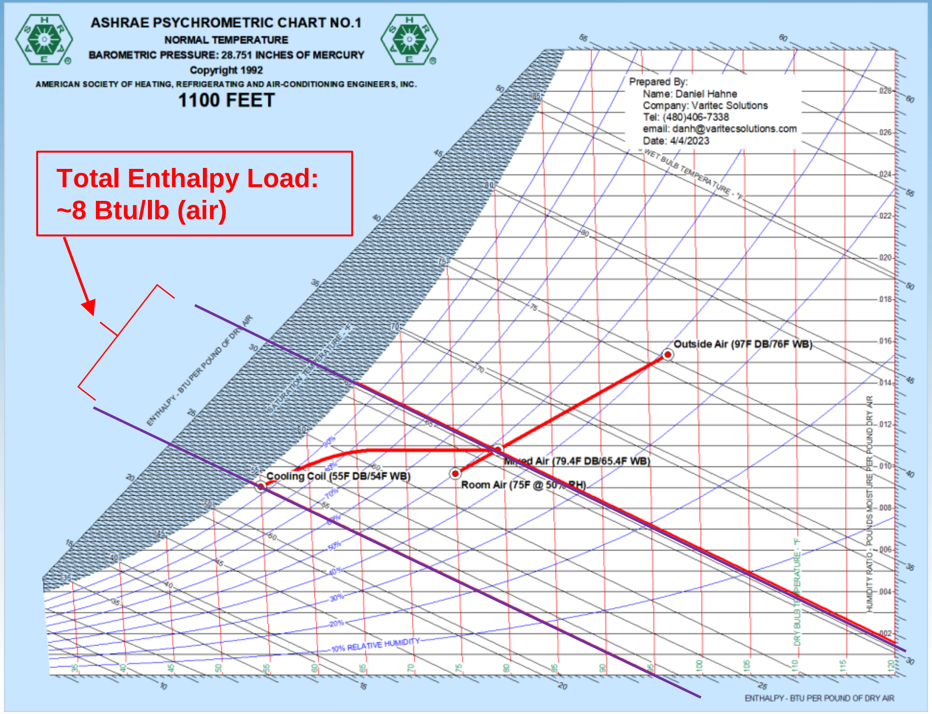
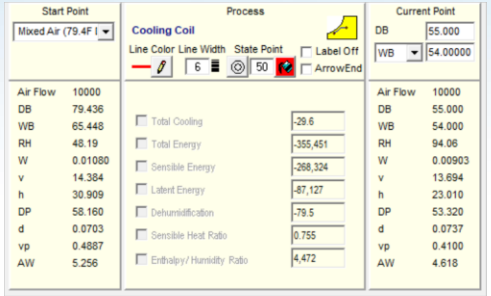
The Psychrometric Chart Deconstructed

How to Read & Use the Chart:

Office Building: (1100ft elevation)

- **System Process Chart:**
  - Total AHU Air Flow: 10,000 CFM
    - OSA: 2,000 CFM
    - Return Air: 8,000 CFM
  - Outside Air: 97F DB / 76F WB
  - Return Air: 75F DB / 50% RH
  - Mixed-Air Condition: 76.8F DB / 61.4F WB
  - Cooling Coil LAT: 55F DB / 54F WB





System Process: Total Heat Transfer Load = ~8 Btu/lb (air)

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The Psychrometric Chart Deconstructed

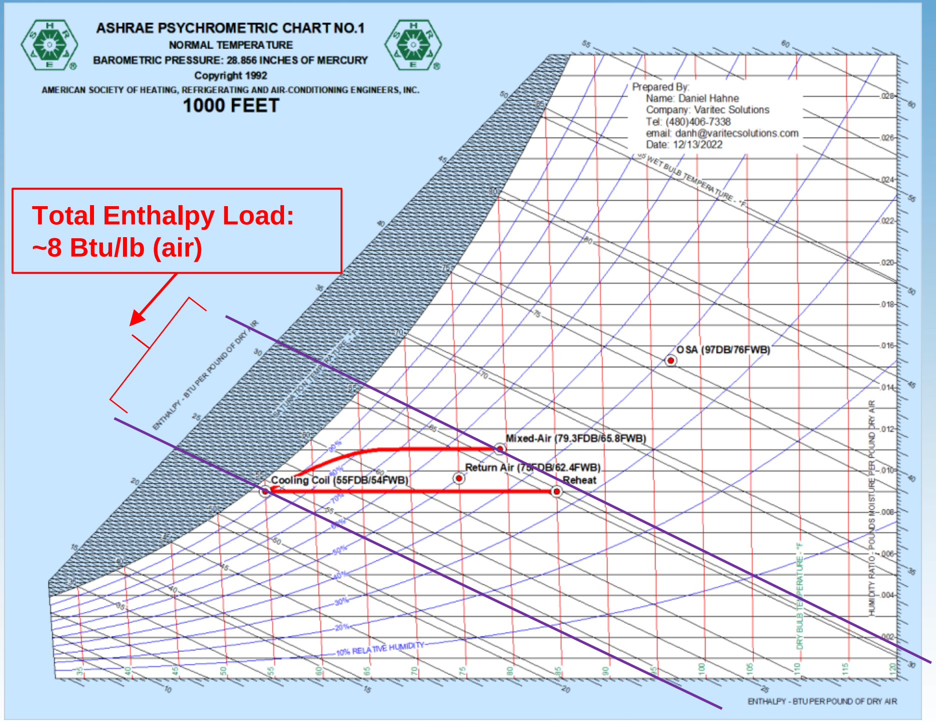
How to Read & Use the Chart:

Office Building: (1100ft elevation)

- **System Process Chart:**
  - Total AHU Air Flow: 10,000 CFM
    - OSA: 2,000 CFM
    - Return Air: 8,000 CFM
  - Elevation: 1100 feet
  - Outside Air: 97F DB / 76F WB
  - Return Air: 75F DB / 62.4F WB
  - Mixed-Air Condition: 79.3F DB / 69.8F WB
  - Cooling Coil LAT: 55F DB / 54F WB
  - **Reheat LAT: 85F DB / 64.8F WB**

System Process:

Total Heat Transfer Load = ~8 Btu/lb (air)



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Psychrometric Chart: Application

Psychrometric Chart: Application

Phoenix Hospital Lobby:

- **Monsoon Challenge: Space Humidity Control**
    - **THE PROBLEM:**
        - Ceiling diffusers condense moisture during monsoon months
        - Hospital doors open and close throughout the day?

- **The Psychrometric Chart:**
    - How to resolve the problem?
    - Identify psychrometric points on chart to evaluate

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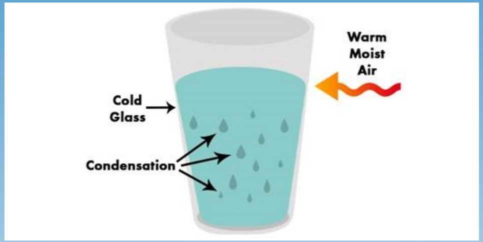
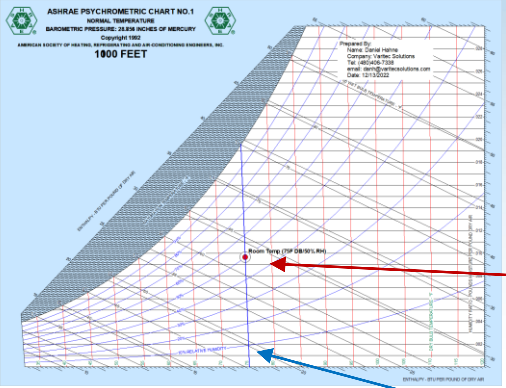
Psychrometric Chart: Application

Phoenix Hospital Lobby:

- **Monsoon Challenge: Space Humidity Control**
  - **Question: When does condensation occur?**
    - When a surface temperature falls below space dew point. (Think of a glass of ice tea during the summer months)





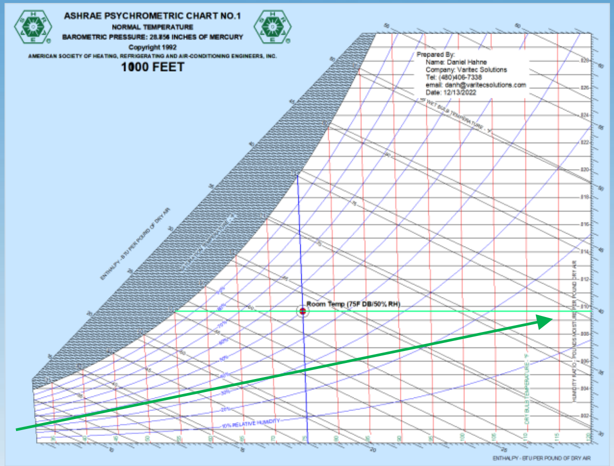
- **Apply Psychrometric Chart:**
  - Identify chart "state point" to evaluate other conditions
  - State point = **75F DB @ 50% RH**

(Dry Bulb Temperature Line)

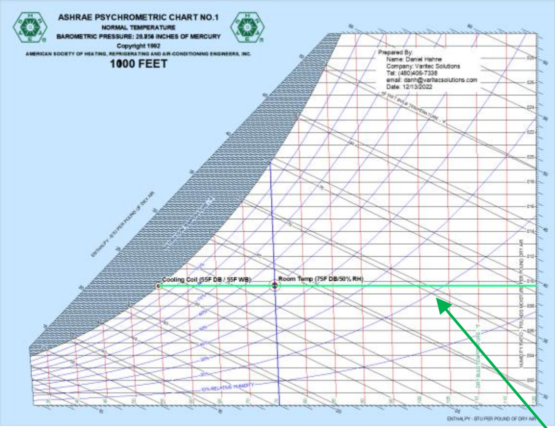
Psychrometric Chart: Application

Phoenix Hospital Lobby:

- **Lobby Conditions:**
  - **Design Room Condition:**
    - 75F DB @ 50% RH
  - **Calculate Space Dew Point:**
    - Lobby dew point = 55.12F



(Space Dew Point Line: 55.12F)



Ceiling Diffuser:

- **Supply Air Condition:**
  - 55F DB / 55F WB
- **Can you see the problem?** The diffuser temperature is at dew point, the temperature at which water vapor condenses into a liquid.

(Supply Air Dew Point Line: 55.00)

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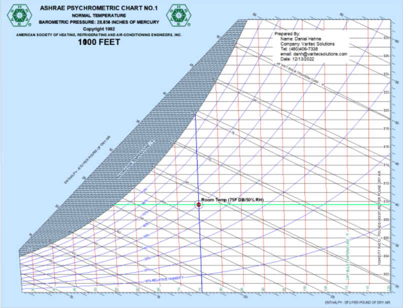
Psychrometric Chart: Application

Phoenix Hospital Lobby:

- **Lobby Problem:**
    - **Condensation:**
        - The diffuser temperature is at dew point
        - Water vapor in the air will condense on the diffuser



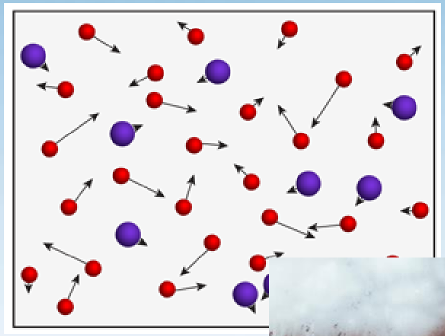
- **Variable Air Volume System (VAV):**
    - Reset the VAV reheat coil leaving air temperature (LAT) to 3F° above space dew point or 58F°.
    - Diffuser will warm to above dew point, condensation will stop

Psychrometrics Deconstructed: Review

Psychrometrics Deconstructed: Review

White House Indoor Air Quality Initiatives

- **IAQ Summit**
- **Clean Air in Buildings Website**

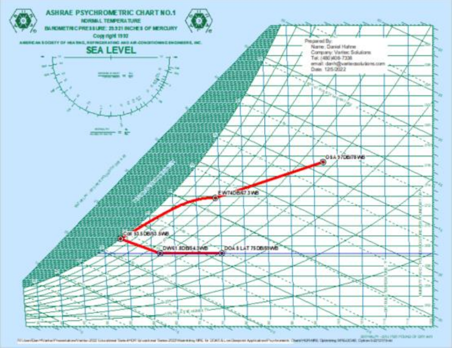


- **Physical Properties of Heat Transfer**
  - History of the Psychrometric Chart
  - Properties of Air Definitions
    - Energy: Sensible & Latent Energy
    - Total Load / Enthalpy
    - Defined Thermodynamics

Psychrometrics Deconstructed: Review

Psychrometrics: The Properties of Air

- Dry bulb
- Wet Bulb
- Dew Point
- Specific Humidity



- **The Psychrometric Chart Exposed**
  - Deconstructed the “Psych Chart” into air properties
- **Psychrometric Chart: Application**
  - Applied the chart to a condensation problem

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Questions?

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