HVAC Hacks #2: Thermal Comfort & Psychometrics – Essential Tips & Thumb Rules

An Online Continuing Education Course for Engineers

Course Number: HV-6026

Credit: 6 Hours / 6 PDH / 6 CPD

HVAC Hacks #2: Thermal Comfort & Psychometrics – Essential Tips & Thumb Rules

A. Bhatia, Mechanical Engineer

Struggling to design a comfortable space and efficient HVAC systems? Discover the secrets to creating happy and healthy buildings.

This course explores the science behind thermal comfort. We'll delve into the space temperature, humidity, air movement, and even factors like activity level and clothing. These elements combine to shape how we feel in our environment. In this 6-hour course, you will gain a solid understanding of:

a. The Comfort Zone: Understand the factors impacting how people perceive comfort.
b. Beyond Temperature: Understand how humidity, air movement, and indoor air quality impact comfort.
c. Properties of Air: Grasp air properties for effective comfort control.
d. Psychrometry: Use psychrometric analysis to solve real-world HVAC challenges.
e. Smart Equipment: Analyze HVAC equipment selection based on climate zones, ensuring your system functions efficiently in any location.
f. Controls: Optimize temperature and humidity control for any climate.
g. Ventilation: Design effective ventilation systems and calculate required airflow (CFM) to maintain healthy indoor air quality.
h. Managing Extreme Conditions: Achieve comfort in hot, cold, dry, and humid environments.

Embedded within the course are essential metrics, practical tips, and handy rules of thumb to accelerate your learning journey and help you to make well-informed decisions.

Let's get started with essential metrics and rules of thumb.

THERMAL COMFORT

Thermal comfort is when an individual feels neither too hot nor too cold. It's the state where the body's heat generation and heat loss are in balance, and the person experiences a sense of well-being regarding the surrounding temperature and humidity.

	Description	*Rules of Thumb*
	Thermal Comfort Standards	*ASHRAE Standard 55 defines thermal comfort criteria.*
	Temperature	*68°F and 78°F. The preferred range is 72°F to 75°F*
	Relative Humidity	*30% and 60%. Preferred range is 40% to 60%*
	Air Velocity	*Winter: 30 ft/min and summer: 50 ft/min*
	Clothing Insulation	*0.5 and 1.0 CLO (1 CLO = 0.88 $ft^2h°F/Btu$)*
	Metabolic Rate	*1.0 and 1.2 met. (1 MET = 18.4 Btu/h ft^2)* *An average adult at rest generates around 340 Btu/h (100 W) heat.*
	Air Quality	*Ensure adequate ventilation – fresh air intake.* *a. 15 -20 CFM of outside air per person. ASHRAE Std. 62.1 recommends the minimum outdoor air ventilation rate of 5 CFM per person plus 0.06 cfm per square foot of occupied floor area.* *b. CO_2 levels less than 600 ppm.* *c. Minimum MERV 8 filtration and preferred MERV 13. MERV stands for Minimum Efficiency Reporting Value.*
	Acoustic Comfort	*Adapt to the following criteria:* *a. 30 to 50 NC for occupied room* *b. Less than 80 dba for equipment noise*
	Air Velocity	*Limit air velocities.* *a. Less than 1500 ft/min* in main ducts *b. Less than 800 ft/min in branch ducts near diffusers* *c. Less than 500 ft/min in intake and exhaust louvers*
	Thermal gradients	*A range of +/- 2°F to avoid fluctuations*
	Thermal Comfort Indices	*a. Predicted Mean Vote (PMV) between -0.5 and +0.5*

	Description	*Rules of Thumb*
		b. Standard Effective Temperature (SET): The SET value accounts for all comfort variables and has an acceptable range of 71.6°F to 78.8°F. *c. Heat Index (HI): The "apparent temperature" that includes the influence of outdoor temperature and relative humidity.* • *HI between 80°F-90°F: Caution* • *HI between 90°F-103°F: Extreme caution.* • *HI between 103°F-124°F: Danger* • *HI ≥125°F: Extreme danger*

PSYCHROMETRIC CHART AND AIR PROPERTIES

A psychrometric chart is a graphical representation of the properties of air-water vapor mixtures. It focuses on understanding the behavior of air as it interacts with moisture, heat, and other variables. This chart shows the relationship between 7 thermodynamic properties:

1. Dry bulb temperature (DBT)
2. Wet bulb temperature (WBT)
3. Relative humidity (RH)
4. Dewpoint temperature (DPT)
5. Enthalpy (H)
6. Humidity ratio (w)
7. Specific volume (v)

These parameters help HVAC engineers analyze and manipulate air properties. The rules governing the relationship of these properties are tabulated below:

	Description	*Rules of Thumb*
	**Standard Air**	*The volumetric airflow rates are based on standard air conditions: 70°F temperature, sea-level atmospheric pressure of 14.7 psi (29.92 inches of mercury), and 0% relative humidity.*
	**Standard Air Characteristics**	*Standard air is assumed to have a density of 0.075 lbs/ft³, an enthalpy of approximately 16.8 Btu/lb, and a specific heat of about 0.24 Btu/lb °F.*
	**DBT and WBT**	*DBT measures sensible heat, while WBT measures latent heat or moisture.*

	Description	*Rules of Thumb*
	**DBT and WBT**	*A large difference between DBT and WBT indicates dry air, low RH, and a high evaporation rate. In such locations, a cooling tower is justified.*
	**DBT and WBT**	*A small difference between DBT and WBT indicates high RH and low evaporation rate. In such locations, an air-cooled condensing unit is the preferred option.*
	**DBT and RH**	*Warm air has a higher capacity to hold moisture than cold air. Air's moisture-holding capacity doubles for every 20°F rise in temperature.*
	**DBT and RH**	*If DBT and RH are both high, it indicates hot and humid conditions.*
	**DBT and RH**	*If DBT is high and RH is low, it indicates hot and dry conditions.*
	**DBT and RH**	*If DBT and RH are both low, it indicates cold and dry conditions.*
	**DBT and RH**	*If DBT is low and RH is high, it indicates cold and moist conditions.*
	**WBT and RH**	*High WBT indicates higher RH. This means air is saturated with moisture.*
	**WBT and RH**	*Low WBT means the air is drier and can hold more water vapor.*
	**Saturated air**	*Air is saturated when its relative humidity reaches 100%. In this condition, the DBT = WBT = DPT.*
	**Condensation**	*Cooling saturated air leads to dew, fog, rain, or snow formation.*
	**DPT**	*Dewpoint measures moisture in the air regardless of temperature. A higher dewpoint means air can hold more moisture, while a lower dewpoint means air is drier.*
	**Moisture control**	*Removing moisture from the air in a heat exchange cooling process is impossible without bringing the air near the saturation line. However, moisture may be removed by desiccants without approaching saturation.*
	**Insulation and vapor barrier**	*Insulation and vapor barriers prevent condensation or frost on indoor walls and ceilings caused by high outdoor air dewpoints. This is particularly important during cold weather when indoor moisture levels are typically higher than outside.*
	**Fog**	*Fog is water droplets suspended in the air. It can be prevented by heating or blending with unsaturated air.*

	Description	***Rules of Thumb***
	**Specific volume**	*Air's specific volume increases with higher temperature. The high specific volume also means the air is less dense.*
	**Enthalpy**	*Enthalpy is the air's heat content. It indicates how much heat needs to be removed from the air to change its temperature and humidity.*

PSYCHROMETRIC PROCESSES

Psychrometric processes are fundamental in understanding how air changes thermodynamic properties to achieve thermal comfort via HVAC systems. Engineers rely on psychrometric charts for manipulating air properties, estimating the necessary heating or cooling capacities, sizing essential equipment such as cooling coils and dehumidifiers, and evaluating the effects of various treatment processes. Here are some key psychrometric processes:

	Description	***Rules of Thumb***
	**Sensible Heating**	*Adding heat increases the air temperature without changing its moisture content (humidity ratio). The process characteristics are:* *a. DBT, WBT, enthalpy increases.* *b. RH decreases* *c. The humidity ratio and dewpoint are constant.*
	**Sensible Cooling**	*Removing heat lowers the air temperature without changing its moisture content (humidity ratio). The process characteristics are:* *a. DBT, WBT, enthalpy decreases.* *b. RH increases* *c. The humidity ratio and dewpoint are constant.*
	**Latent Heating**	*Latent heating occurs when moisture is added to the air, typically through evaporation, causing the air's humidity ratio to increase. There is no change in temperature.*
	**Latent Cooling**	*Latent cooling occurs when moisture is removed from the air, decreasing the humidity ratio. There is no change in temperature.*
	**Humidification**	*Humidification adds moisture to dry air, increasing its relative humidity (RH). This process is essential in spaces where the air is*

	Description	*Rules of Thumb*
		too dry, often during winter when heating systems can deplete indoor humidity. *Humidification is often necessary to prevent discomfort, static electricity, and health issues associated with overly dry air.* *The process characteristics are:* *a. DBT remains constant.* *b. WBT, RH, humidity ratio, and dewpoint temperature incre*
	**Dehumidification**	*Dehu moisture from the nd humid climates ch as swimming cteristics are:* *emperature* *ir ed below.*
	**Cooling and Dehumidificatio**	*ss* *a. DBT, WBT, enthalpy, humidity ratio, and dewpoint temperature decreases.* *b. RH increases* *Cooling and dehumidification occur when the air is cooled below its DEWPOINT temperature, at which point it becomes saturated. If cooled further, the excess moisture will condense out of the air.*
	**Heating and humidification**	*Adding heat and moisture to the air. The process characteristics are:*