THERMAL COMFORT & PSYCHROMETRICS – ESSENTIAL TIPS & THUMB RULES

Struggling to design comfortable spaces and efficient HVAC systems? Master the art of creating healthy, comfortable indoor environments with ease!

In this comprehensive 8-hour course, you'll explore the key factors that influence human perception of comfort, including temperature, humidity, air movement, and more.

You'll learn to:

- Define and recognize thermal comfort criteria
- Design efficient and comfortable HVAC systems
- Optimize indoor air quality and occupant well-being
- Apply psychrometric principles for heating, cooling, and humidity control
- Select the right HVAC equipment for any climate zone
- Estimate cooling loads and airflow requirements
- Achieve comfort even in extreme weather conditions.

Key rules of thumb are provided in **Annexure- 1** for easy reference whenever you need them. The thumb rules, metrics, and guidelines are derived from sound engineering practices and author's experience. They can vary depending on operating conditions and other factors. This document is a live resource that will be continuously updated as more information becomes available.

Ready to enhance your HVAC design and analysis skills? Let's get started!

CHAPTER - 1: THERMAL COMFORT

Thermal comfort refers to the heating and cooling requirements necessary to maintain suitable temperature, humidity, and indoor air quality (IAQ). It aims to maintain a comfortable temperature range for building occupants, avoiding conditions of excessive heat or cold.

Table 1. Requirements for Thermal Comfort

	Parameter	Requirements
	Air Quality	Adequate fresh air, filtration and air exchange.
	Temperature Control	Not too hot, not too cold (75±2°F for summers, 68 - 72°F for winters).
	Relative Humidity Control	Not too dry, not too humid (30 – 60%).
	Air Distribution and Velocity	No hot/cold spots, gentle air movement.
	Lighting	Good amount of diffuse light, no excess/glare.
	Noise Level	30-55 dB maximum in occupied spaces, quiet and comfortable.
	Human Dimension	Design spaces with appropriate sizes, shapes, colors, and acoustics for a pleasant environment.

1.1 Comfort Zone

The comfort zone is defined as the range of environmental conditions where at least 80% of people are expected to be satisfied with the thermal environment.

ASHRAE Standard 55: Thermal Environmental Conditions for Human Occupancy provides guidelines for acceptable ranges of temperature and relative humidity (RH) combinations that are considered comfortable for most people.

Similarly, ISO 7730 Standard provides a definition of comfort conditions, as shown in the figure below.

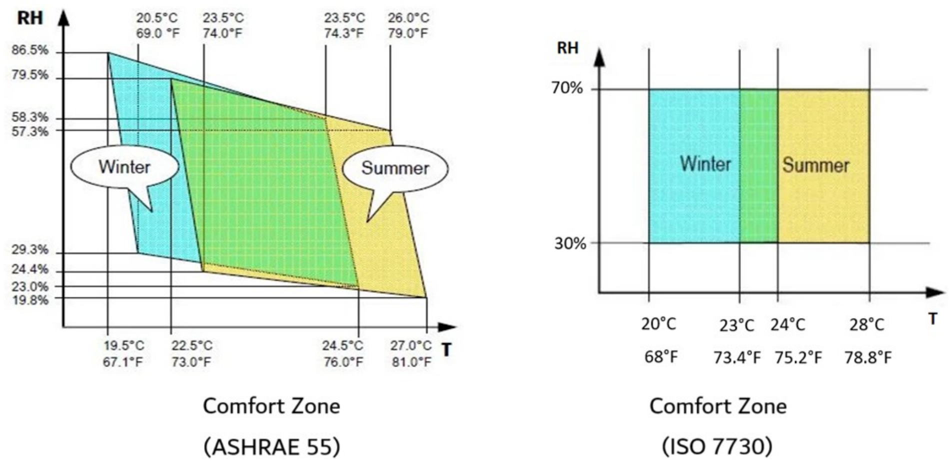

Figure 1. Conditions for Thermal Comfort Zone (ASHRAE 55 & ISO 7730)

Find the intersection of temperature and RH to determine comfort level.

Here are some key points about ASHRAE 55/ISO 7730 charts on RH-Temp. thermal comfort:

a. They define the range of temperature and humidity combinations that are considered comfortable for most people.
b. They are used by HVAC engineers and architects to design buildings that provide comfortable indoor environments.
c. They show the effects of other factors on thermal comfort, such as air velocity, clothing level, and metabolic rate.

1.2 Variables affecting Thermal Comfort

Thermal comfort is a complex, multi-factorial concept that extends beyond temperature and humidity control. While HVAC systems primarily focus on regulating these two factors, several other variables such as air velocity, clothing type, person's age and activity level significantly influence occupants' comfort levels Accurately quantifying these variables can be challenging due to individual differences. For instance, faster air movement may increase comfort in warmer conditions, while clothing choices and metabolic rates can drastically alter a person's perception of temperature. Below are recommended values for temperature, humidity, and other parameters that help create a comfortable indoor environment, keeping in mind the variability in individual preferences.

Table 2. Variables Affecting Thermal Comfort

	ASHRAE 55 Guidelines	**Thermal Comfort Criteria**
	Comfort Zone	Comfort Zone: 73°F-79°F and 30%-60% RH Acceptable Zone: 68°F-82°F and 20%-80% RH Warning Zone: Outside acceptable zone, potential discomfort. Note: Check comfort zone w.r.t temperatures and RH together.
	Temperature	68°F to 79°F. Comfort zone for most people.
	Relative Humidity	30%-60%. Optimal humidity range
	Air Velocity	30 to 50 ft/min. Avoids drafts and discomfort.
	Radiant Temperature	Ranges from 65°F to 78°F for optimum comfort. ±5°F of air temperature.
	Clothing Insulation	0.5 to 1.0 CLO (1 CLO = 0.88 ft²h°F/Btu).
	Metabolic Rate	1.0 to 1.2 met (1 MET = 18.4 Btu/h ft²).
	Air Quality	Ensure adequate ventilation – fresh air intake. • 15-20 CFM/person (ASHRAE 62, old standards) • 5 CFM/person + 0.06 CFM/ft² for office area (ASHRAE 62.1) • MERV 8+ (MERV 13 preferred for new installations) • CO_2 < 1000 ppm (absolute reading considering 400 ppm outside ambient air).

	ASHRAE 55 Guidelines	Thermal Comfort Criteria
	Acoustic Comfort	Room NC levels of 30 to 55 for occupied areas. Equipment noise levels < 80 dBA.
	Air distribution	Avoid drafts, Minimize floor-to-ceiling temp difference to ≤ 4°F.
	Air stratification	Minimize. Air stratification refers to the temperature gradient from floor to ceiling due to air movement.
	Thermal gradients	±2°F between different areas of the space.
	Thermal Comfort Standards	ASHRAE Standard 55 (US) and ISO-7730 (International)

Air temperature significantly impacts thermal comfort, but achieving the ideal temperature alone isn't enough. Other factors like air velocity, radiant temperature, clothing, metabolism, and activity level also matter. The Standard Effective Temperature (SET) or comfort index combines these factors into a single metric.

1.3 Standard Effective Temperature (SET)

Humidity significantly impacts a person's tolerance for high or low air temperatures. Even at a low temperature, high humidity can cause discomfort. The SET is a single value expressed in Fahrenheit or Celsius that considers the combined effects of multiple factors affecting human comfort. Two key parameters that are crucial for thermal comfort are:

a. Dry bulb temperature (DBT)
b. Relative humidity (RH)

Using SET values, we can compare how comfortable it feels in different cities with varying temperature and humidity conditions.

Example:

NOAA* data shows Phoenix summers (June-Aug) average 104°F with 20-30% humidity, while Miami averages 89°F with 70-75% humidity. Using the Standard Effective Temperature (SET) metric, Phoenix's heat is more bearable (SET: 95-100°F) due to low humidity, whereas Miami's high humidity makes its temperature feel equally hot (SET: 98-102°F) despite being 15°F lower.

*NOAA: National Oceanic and Atmospheric Administration (NOAA)

Table 3. SET Number and Thermal Comfort

	Activity Level/Context	SET Number Range
	Sedentary (office work)	71.6°F - 78.8°F is generally considered comfortable.
	Active tasks/warmer environment	71.6°F - 75.2°F. Lower end of the range may be preferred.
	Cooler environment	75.2°F - 78.8°F.

Notes:

a. SET (Standard Effective Temperature) measures thermal comfort.
b. These ranges are general guidelines and may vary based on individual preferences.
c. Adjust SET values according to specific contexts, clothing, humidity, air velocity, and activities for optimal comfort.

1.4 Air Velocity and Air Movement

Air velocity enhances heat loss, making us feel cooler in warm or humid conditions. Fans work by increasing air movement, not temperature, to speed up evaporation and creating a cooling sensation on the skin.

Air movement can be achieved either through natural means, such as gravity, or through mechanical methods.

Table 4. Ideal Air Velocity & Air Movement

	Factors	Rules of Thumb
	Air velocity: Winters	Around 30 ft/min.