# 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.

## 1.1 Codes and Standards

| | |
|---|---|
|  | *American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE) Standard 55 is the commonly adopted standard for acceptable indoor thermal environmental conditions for human occupancy.* |
|  | *ISO-7730 is used for Internationally defining thermal comfort.* |

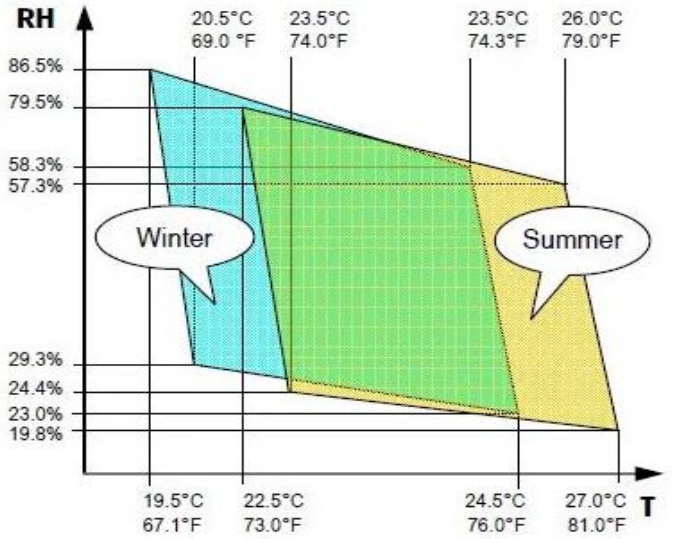
## 1.2 Requirements for Thermal Comfort

| | **Parameter** | ***Requirements*** |
|---|---|---|
|  | Ventilation, fresh air | *Minimum fresh air. Good level of oxygen and air exchange* |
|  | Control of temperature | *Not too hot and not too cold* |
|  | Control of relative humidity | *Not too dry and not too humid* |
|  | Air distribution and velocity | *No hot and cold spots* |
|  | Enough light, preferably diffuse | *Good amount of light, but no excess and no glare* |
|  | Noise level | *30 – 55 dB maximum* |
|  | Human dimension to the context | *Appropriate geometric dimensions, pleasing shapes, colors, and acoustics etc.* |

## 1.3 Conditions for Thermal Comfort

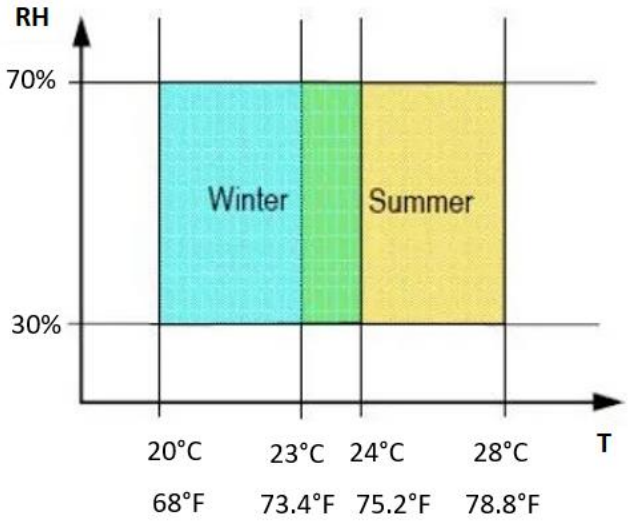
ASHRAE defines human comfort as the state of mind that expresses satisfaction with the thermal environment. Guidelines such as ASHRAE Standard 55 and ISO 7730 provide criteria for thermal comfort based on factors like air temperature, radiant temperature, humidity, and air velocity.

ASHRAE Std. 55 specifies the thermal conditions that are considered comfortable for about 80% of individuals who are sedentary or slightly active. The maximum indoor temperature within the comfort zone depends on the relative humidity levels, as shown in the figure below.




**Comfort Zone according to ASHRAE 55**

ISO 7730 Standard defines the comfort conditions as shown in figure below:




**Comfort Zone according to ISO7730**

### 1.4 Variables affecting Thermal Comfort

Typically, HVAC systems are primarily designed to regulate temperature consistently and humidity levels as needed. Nonetheless, factors such as air velocity, clothing type, and activity level also play a role in determining comfort. Quantifying the precise impact of these variables can be challenging, as they vary significantly among individuals. Below are the recommended values to strive for to achieve overall comfort.

| **Parameter** | ***Comfort Conditions*** |
|---|---|
| Temperature | *The temperature range for the comfort zone is typically between 68°F and 78°F.*<br><br>*Most used design condition (summers): 75°F/50% R.H*<br><br>*Most used design condition (winters): 72°F DB.* |
| Relative Humidity | *Humidity control is crucial for maintaining occupant comfort, preventing condensation, and mitigating moisture-related issues such as mold growth.*<br><br>*The relative humidity range for the comfort zone is typically between 30% and 60%, with a preferred relative humidity range of 40% to 60%.* |
| Air Velocity | *The air velocity range for the comfort zone is typically between 30 feet per minute (ft/min) and 50 ft/min.*<br><br>*Air velocity exceeding 100 ft/min is generally not preferred by most individuals. Certain hot industrial settings may require a higher airflow rate at workstations for necessary cooling purposes.* |
| Radiant Temperature | *Discomfort can be caused by cold or hot objects in a room. The mean radiant temperature should be within 5°F of air temperature and range from 65-78°F for optimum comfort.* |
| Clothing Insulation | *The clothing insulation value for the comfort zone is typically between 0.5 and 1.0 CLO (1 CLO = 0.88 $ft^2h°F/Btu$).* |
| Metabolic Rate | *The metabolic rate for the comfort zone is typically between 1.0 and 1.2 met. (1 MET = 18.4 Btu/h $ft^2$).* |

| **Parameter** | ***Comfort Conditions*** |
|---|---|
| Air Quality | *Provide at least 15 -20 CFM of outside air per person.*<br><br>*Provide filtration, minimum MERV 8 and preferred MERV 13.*<br><br>*Maintain $CO_2$ levels less than 1000 ppm (indoor-outdoor differential).* |
| Acoustic Comfort | *The acoustic environment in the comfort zone should be designed to minimize unwanted noise and provide appropriate levels of speech privacy. Maintain room NC levels of 30 to 40. Equipment noise levels shall be less than 80 dba.* |
| Air distribution | *The air distribution in the comfort zone should be designed to avoid drafts and provide consistent air temperatures throughout the space. A temperature difference of 4°F or more between the floor and ceiling of a space can create discomfort for occupants.* |
| Air stratification | *The movement of the air to produce the temperature gradient from floor to ceiling is termed as air stratification. To achieve comfortable conditions in the occupied space, the air conditioning system must be designed to reduce the air stratification to a minimum.* |
| Thermal gradients | *The comfort zone should be designed to minimize thermal gradients, or temperature differences, between different areas of the space. Maintain indoor temperature within a range of +/- 2°F to avoid fluctuations that can cause discomfort.* |

The impact of air temperature on thermal comfort is significant, yet achieving the design air temperature in an air conditioning system alone does not guarantee occupant comfort as other factors such as air velocity, radiant temperature, clothing, metabolic rate, and activity level also play a significant role in determining thermal comfort. Efforts have been made to consolidate these factors into a single numerical index known as the “Standard Effective Temperature (SET) or comfort index.

### 1.4.1 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:**

According to the National Oceanic and Atmospheric Administration (NOAA), the average temperature in Phoenix during the summer months (June to August) is around 104°F, with a relative humidity of around 20-30%. In contrast, Miami's average temperature during the same period is around 89°F, with a relative humidity of around 70-75%. Using the SET metric, we can estimate the perceived thermal comfort levels in these two cities. For example, an air temperature of 104°F with a relative humidity of 20-30% in Phoenix might correspond to an SET value of 95-100°F for sedentary activities, while an air temperature of 89°F with a relative humidity of 70-75% in Miami might correspond to an SET value of 98-102°F for the same activity level. Therefore, while the temperature in Phoenix is higher than in Miami, the low humidity in Phoenix makes it more comfortable for individuals than the high humidity levels in Miami.

| | ***SET Number*** |
|---|---|
|  | *The SET number corresponding to thermal comfort can vary depending on individual preferences and the specific context, but generally, for typical indoor conditions:*<br><br>*a. For a sedentary activity level (e.g., office work), a SET value between 22°C to 26°C (71.6°F to 78.8°F) is often considered comfortable.*<br>*b. For more active tasks or warmer indoor environments, a SET value closer to the lower end of this range may be preferred.*<br>*c. In cooler indoor settings or for individuals who are more sensitive to cold, a SET value closer to the higher end of this range may be more comfortable.* |