Psychrometry and Air Conditioning Systems

1. Classification of Air-Conditioning Systems

Air-conditioning systems are classified based on their **function**, **cycle type**, and **application**:

A. By Function

- **Comfort Air-Conditioning**: Maintains suitable temperature, humidity, and air quality for human comfort.
- **Industrial Air-Conditioning**: Maintains conditions required for processes, equipment, or storage (e.g., textile, pharmaceuticals).

B. By Season

- **Summer AC System**: Removes heat and humidity (cooling and dehumidification).
- **Winter AC System**: Adds heat and humidity (heating and humidification).
- **Year-Round System**: Automatically switches between cooling and heating modes.

C. By Cycle Type

- **Direct Expansion (DX) Systems**: Refrigerant directly cools the air via coils and recirculation fans.
- **Chilled Water AC Systems**: Air is cooled with chilled water produced by refrigeration equipment.

D. By Equipment Distribution

- **Central AC System**: Air is conditioned at a central plant and distributed.
- **Unitary (Room) AC System**: Self-contained units provide localized cooling.

2. ASHRAE Nomenclature

ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers) provides standardized terminology and definitions for HVAC systems.

Common Terms:

- **DBT**: Dry Bulb Temperature (°C/°F) — actual air temperature.
- **WBT**: Wet Bulb Temperature — represents evaporative cooling potential.
- **RH**: Relative Humidity (%) — moisture content relative to saturation level.

- **HR**: Humidity Ratio (kg of water/kg of dry air).
- **Enthalpy (h)**: Total heat content per kg of dry air (kJ/kg).
- **DPT**: Dew Point Temperature — at which air becomes saturated and moisture condenses.

ASHRAE sets guidelines for:

- Thermal comfort standards (e.g. ASHRAE Standard 55),
- Ventilation rates (e.g. ASHRAE Standard 62.1),
- HVAC energy efficiency (ASHRAE 90.1).

3. Applications of Air-Conditioning

A. Comfort Applications

- Homes, offices, malls, cinema halls
- Large-scale buildings: airports, hospitals, data centers

B. Industrial Applications

- Textile mills: Humidity control for fiber processing
- Pharmaceuticals: Precise temperature and humidity for production
- Clean rooms: Electronics and food packaging
- Cold storage: Preserving perishables like food, flowers, medicine

4. Psychrometry – Air-Water Vapor Mixtures

Psychrometry is the study of properties of moist air (mixture of dry air and water vapor). All air-conditioning systems deal with such mixtures.

Assumptions:

- Mixture behaves as an ideal gas mixture.
- Water vapor is in gaseous phase (unsaturated).
- Air is taken at atmospheric pressure (≈1 atm).

5. Psychrometric Properties of Air

Property	Symbol	Description
Dry Bulb Temperature	DBT	Actual air temperature measured by a normal thermometer
Wet Bulb Temperature	WBT	Temperature measured by a thermometer with a wet wick
Relative Humidity	RH	Percentage of actual to saturated vapor pressure
Dew Point Temperature	DPT	Temperature at which air becomes saturated and moisture condenses

Property	Symbol	Description
Humidity Ratio (Specific Humidity)	ω	Ratio of mass of water vapor to mass of dry air
Enthalpy	h	Total heat content (sensible + latent) per kg of dry air
Specific Volume	v	Volume occupied per kg of dry air

6. Psychrometric or Air-Conditioning Processes

Key air-conditioning processes represented on a **psychrometric chart**:

Process	Description	Chart Representation
Sensible Heating	Temperature ↑, moisture same	Horizontal move right
Sensible Cooling	Temperature ↓, moisture same	Horizontal move left
Latent Heating	Moisture ↑, temperature constant	Vertical move up
Dehumidification	Moisture ↓ (e.g. by cooling below dew point)	Down and left
Humidification	Moisture ↑ (e.g. spraying water/mist)	Up and right
Cooling and Dehumidifying	Combination during summer AC	Diagonal down-left
Heating and Humidifying	Combination during winter AC	Diagonal up-right
Evaporative Cooling	DBT ↓, WBT same; adds moisture	Slanted towards saturation curve (constant WBT)
Mixing of Air Streams	Mixing 2 air streams forms a point linearly between two states	Straight line connecting two air states

7. Psychrometric Chart

A **Psychrometric Chart** is a graphical representation of moist air properties at constant pressure (usually at sea level pressure ≈ 1 atm).

Key Features:

- **Horizontal Axis**: Dry Bulb Temperature (DBT)
- **Vertical/Curved Lines**: Constant RH, Wet Bulb Temp., DPT, Specific volume
- **Curved Top Boundary**: Saturation line (100% RH)
- **Slanted Lines**: Constant Wet-Bulb Temperatures and Enthalpy lines

Usage:

- Determine properties if two are known.
- Trace air-conditioning processes (cooling, humidification, mixing).
- Calculate energy needs (enthalpy change × mass flow rate).

Summary Table

Topic	Key Points
Classification of AC Systems	Comfort, Industrial, Seasonal, DX/Central/Chilled Water
ASHRAE Terminology	Standardized psychrometric and HVAC terms (DBT, RH, WBT, h, ω)
Applications	Residential, commercial, electronics, pharmaceutical, industrial
Psychrometric Properties	Temperature, humidity, enthalpy, dew point
AC Processes	Heating, cooling, humidification, dehumidification, evaporative cooling
Psychrometric Chart	Visual tool for analyzing and designing air conditioning systems

Understanding psychrometry is essential for accurate design, control, and analysis of air-conditioning processes that impact comfort, product quality, and energy efficiency.