UNIT-5

Air Conditioning Systems

Air Conditioning Systems

Air-conditioning systems are classified according to how outdoor (fresh) air and return (recirculated) air are handled.

1. All Fresh Air System

Definition

In an all-fresh-air system, 100% outdoor air is supplied to the conditioned space and exhausted after use.

Features

- No recirculation of room air.
- Provides maximum ventilation.
- Higher energy consumption because all incoming air must be conditioned.

Applications

- Hospitals
- Laboratories
- Clean rooms
- Operation theaters

Schematic

Outdoor Air → Filter → Cooling/Heating Coil → Room → Exhaust

2. RecirculatedAir System

Definition

A portion or all of the room air is returned, conditioned, and supplied again to the room.

Features

- Energy efficient.
- Lower operating cost.
- Reduced fresh air requirement.

Applications

- Offices
- Theaters
- Shopping malls

Schematic

Room Air → Return Duct → Air Conditioner → Room

3. Recirculated Air System with Bypass

Definition

A portion of air bypasses the cooling coil and mixes with cooled air after the coil.

Purpose

- Better temperature control.
- Prevents overcooling.
- Saves energy.

Bypass Factor (BPF)

The bypass factor represents the fraction of air that passes through the coil without being effectively cooled or heated.

$$BPF=\frac{T_2-T_c}{T_1-T_c}$$

Where:

- T_1 = Entering air temperature
- T_2 = Leaving air temperature
- T_c = Coil surface temperature (ADP)

Coil Efficiency

$$\text{Coil Efficiency}=1-BPF$$

4. Reheat System

Definition

Air is first cooled below the desired condition to remove moisture and then reheated.

Advantages

- Precise humidity control.
- Better comfort conditions.

Applications

- Textile industries
- Hospitals
- Pharmaceutical plants

Process

Outdoor Air → Cooling Coil → Reheat Coil → Room

Apparatus Dew Point (ADP)

Definition

The effective surface temperature of a cooling coil.

On the psychrometric chart, the cooling process line extended meets the saturation curve at the ADP.

Formula

BPF=T2−ADPT1−ADPBPF=\frac{T_2-ADP}{T_1-ADP}BPF=T1−ADPT2−ADP

Hence,

ADP=T2−BPF×T11−BPFADP=\frac{T_2-BPF\times T_1}{1-BPF}ADP=1−BPFT2−BPF×T1

Room Sensible HeatFactor (RSHF)

Definition

Ratio of room sensible heat to total room heat.

RSHF=RSHRSH+RLHRSHF=\frac{RSH}{RSH+RLH}RSHF=RSH+RLHRSH

Where:

- RSH = Room Sensible Heat
- RLH = Room Latent Heat

Effective Sensible Heat Factor (ESHF)

Definition

Ratio of effective sensible heat to effective total heat.

It includes outdoor air load.

ESHF=RSH+OASHRSH+RLH+OASH+OALHESHF=\frac{RSH+OASH}{RSH+RLH+OASH+OALH}ESHF=RSH+RLH+OASH+OALHRSH+OASH

Where:

- OASH = Outdoor Air Sensible Heat
- OALH = Outdoor Air Latent Heat

Grand Sensible Heat Factor (GSHF)

Definition

Ratio of grand sensible heat to grand total heat.

GSHF=GSHGTHGSHF=\frac{GSH}{GTH}GSHF=GTHGSH

or

GSHF=RSH+OASHRSH+RLH+OASH+OALHGSHF=\frac{RSH+OASH}{RSH+RLH+OASH+OALH}GSHF=RSH+RLH+OASH+OALHRSH+OASH

It is numerically the same expression as ESHF but used in overall system analysis.

Example

Given:

- Room Sensible Heat = 25 kW
- Room Latent Heat = 8 kW
- Outdoor Sensible Heat = 4 kW
- Outdoor Latent Heat = 3 kW

GSHF=25+425+8+4+3GSHF=\frac{25+4}{25+8+4+3}GSHF=25+8+4+325+4 GSHF=2940GSHF=\frac{29}{40}GSHF=4029GSHF=0.725GSHF=0.725GSHF=0.725

Answer: 0.725

Ventilation and Infiltration

1. Ventilation

Definition

Ventilation is the intentional supply of fresh outdoor air to a conditioned space and removal of stale indoor air to maintain acceptable indoor air quality.

Requirements of Ventilation Air

Ventilation is required to:

- Supply oxygen for occupants.
- Remove carbon dioxide.
- Remove odors and smoke.
- Remove excess heat and moisture.

- Dilute airborne contaminants and microorganisms.
- Maintain indoor air quality standards.

Methods of Ventilation

1. **Natural Ventilation**
   - Through doors, windows, ventilators.
   - Caused by wind and temperature differences.
2. **Mechanical Ventilation**
   - Using fans and blowers.
   - More reliable and controllable.

2. Infiltration

Definition

Infiltration is the uncontrolled entry of outside air into a building through cracks, gaps, doors, and windows.

Sources of Infiltration

- Cracks around windows and doors.
- Openings in walls.
- Elevator shafts.
- Stairwells.
- Utility penetrations.
- Frequent door opening.
- Poor building construction.

Infiltration as Part of Cooling Load

When warm outdoor air enters:

1. **Sensible Heat Load**
   - Due to higher outdoor temperature.
2. **Latent Heat Load**
   - Due to moisture carried by infiltrated air.

Total infiltration load:

Qtotal=Qs+QlQ_{total}=Q_s+Q_lQtotal=Qs+Ql

where:

- QsQ_sQs = Sensible heat load
- QlQ_lQl = Latent heat load

Fans and Blowers

Definition

Devices used to move air through HVAC systems.

Difference

Fan	Blower
pressure rise	er pressure rise
e air volume	erate air volume
ure ratio < 1.1	ure ratio 1.1–1.2

Types of Fans

1. Centrifugal Fan

- Forward curved
- Backward curved
- Radial blade

Features

- High pressure capability.
- Widely used in HVAC systems.

2. Axial Fan

- Propeller fan
- Tube axial fan
- Vane axial fan

Features

- High airflow.
- Low pressure rise.

Applications:

- Ventilation systems
- Cooling towers

Fan Performance Characteristics

The important characteristics are:

1. Air Flow Rate (Q)

Volume of air delivered.

2. Pressure Rise (ΔP)

Pressure developed by fan.

3. Power Consumption

Power=Q×ΔPηPower = \frac{Q \times \Delta P}{\eta}Power=ηQ×ΔP

4. Efficiency

η=Output PowerInput Power\eta=\frac{\text{Output Power}}{\text{Input Power}}η=Input PowerOutput Power

Fan Characteristic Curves

- Pressure vs Flow
- Power vs Flow
- Efficiency vs Flow

Series and Parallel Arrangement of Fans

Fans in Series

Purpose

Increase pressure.

Characteristics

- Same airflow.
- Pressure adds.

Ptotal=P1+P2P_{total}=P_1+P_2Ptotal=P1+P2

Applications:

- Long duct systems.
- High resistance systems.

Fans in Parallel

Purpose

Increase airflow.

Characteristics

- Same pressure.
- Airflow adds.

Qtotal=Q1+Q2Q_{total}=Q_1+Q_2Qtotal=Q1+Q2

Applications:

- Large ventilation systems.

Fan Selection Procedure

Step 1

Determine required airflow.

Step 2

Calculate system pressure loss.

Step 3

Select suitable fan type.

Step 4

Locate operating point on fan curve.

Step 5

Check efficiency.

Step 6

Select motor size.

Step 7

Verify noise level.

HVAC Equipment and Controls

Purpose

Maintain desired:

- Temperature
- Humidity
- Air quality
- Pressure

Common Controls

- Thermostats
- Humidistats
- Pressure switches
- Sensors
- Controllers
- Variable frequency drives (VFD)

Chillers

Definition

A chiller removes heat from water and supplies chilled water to cooling coils.

Types

1. Vapor Compression Chiller

- Compressor
- Condenser
- Expansion valve
- Evaporator

2. Absorption Chiller

Uses heat energy instead of mechanical compression.

Applications:

- Large commercial buildings
- Industries

Condensing Units

Definition

Combination of:

- Compressor
- Condenser
- Condenser fan

Function

Reject heat absorbed by refrigerant.

Applications:

- Split AC systems
- Refrigeration plants

Cooling Coils
Definition

Heat exchangers used to cool and dehumidify air.

Types

1. Direct Expansion (DX) Coil
2. Chilled Water Coil

Functions

- Sensible cooling
- Latent cooling (dehumidification)

Bypass Factor (BPF)

Definition

Fraction of air passing through the coil without effective contact.

BPF=T2−ADPT1−ADPBPF=\frac{T_2-ADP}{T_1-ADP}BPF=T1−ADPT2−ADP

Where:

- T1T_1T1 = Entering air temperature
- T2T_2T2 = Leaving air temperature
- ADP = Apparatus Dew Point

Definition

Devices that add moisture to air.

Types

1. Spray Humidifier

Water sprayed into airflow.

2. Steam Humidifier

Steam injected into air.

3. Ultrasonic Humidifier

Uses ultrasonic vibrations.

Applications

- Textile industries
- Hospitals
- Printing industries

Dehumidifiers

Definition

Devices used to remove moisture from air.

Types

1. Refrigeration Dehumidifier

Air cooled below dew point; moisture condenses.

2. Desiccant Dehumidifier

Uses moisture-absorbing materials such as silica gel.

Applications

- Pharmaceutical industries
- Food storage
- Museums
- Data centers