

Air Conditioning and ventilation (TEng2121)

**Wollo university
Kombolcha institute of technology
Target group: 2nd year
Instructor: Hailay K. .
Department :Textile Engineering
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- **Air-conditioning:**

Physical Properties of air; composition of air, air pressure, air temperature, air Humidity, heat contents of air, measurement of humidity. Principles of air conditioning, Comfort and industrial air-conditioning. Basic heat transfer and mass transfer, application to textile industry. Refrigeration equipment, primary and secondary refrigerants, Psychometric chart and its use, calculation of requirements.

Air distribution systems

Duct design, distribution equipment. Design of an air conditioning plant for a textile industry.

- **Humidification:**

Humidity, measurement of humidity, automatic temperature and humidity control; pneumatic, electric and hydraulic systems.

Dehumidification.

Equipment Selection and design, humidifiers, dehumidifiers, fans and diffusers, prevention of noise and vibration, cooling towers.

- **Ventilation:**

Hygienic aspects of ventilation; aims of ventilation, Industrial health hazards (dust, high temperature, high humidity, deleterious gases, and liquids), types of ventilation: general air change ventilation, local ventilation, cleaning air of Suspended matter: dry cleaning, wet cleaning. System of air change in textile mill ventilation: upper-level delivery, low-level delivery, active system of delivery, Dustless system of delivery features of air delivery and removal from windowless buildings. Equipment. Ventilating, humidifying and air conditioning installations employed in textile mills processing different fibres

- **Illumination:**

Introduction, requirement of illumination in the different sections of textile and Leather industries, effect of illumination on working efficiency.

CHAPTER ONE

introduction to air conditioning

Definition

Air Conditioning:

Treatment of air so as to simultaneously control its temperature, moisture content, quality and circulation, as required by occupants, a process, or products in the space.

Refrigeration:

It is used to cool the air and also for removing its moisture content to specific levels.

Related terms

- Environmental control systems (ECS)
- Heating, ventilating, air-conditioning and refrigerating (HVAC&R) systems
- Heating, ventilating and air-conditioning (HVAC)
- Mechanical ventilating and air-conditioning (MVAC or ACMV)
- Air conditioning and refrigeration (AC&R)

HVAC &R

- The term *HVAC&R* is an abbreviation of heating, ventilating, air conditioning, and refrigerating.
- The combination of processes in this commonly adopted term is equivalent to the current definition of air conditioning.
- Because all these individual component processes were developed prior to the more complete concept of air conditioning, the term *HVAC&R* is often used by the industry

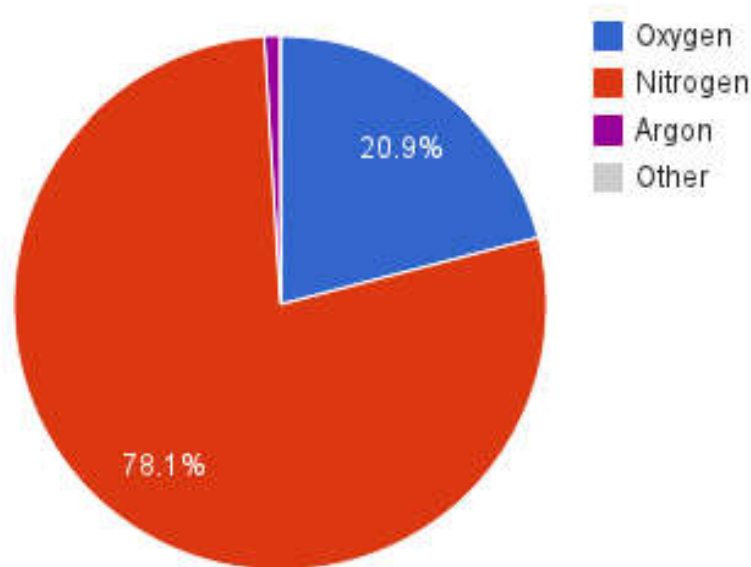
What is air

- Air (or Atmospheric air) is a mixture of (dry) air and water vapor (also known as moisture). Air in the natural state always contains a certain amount of water vapor.

Physical Properties of air

- **Composition of air**

Air Composition (% by volume)



The Engineering ToolBox
www.EngineeringToolBox.com

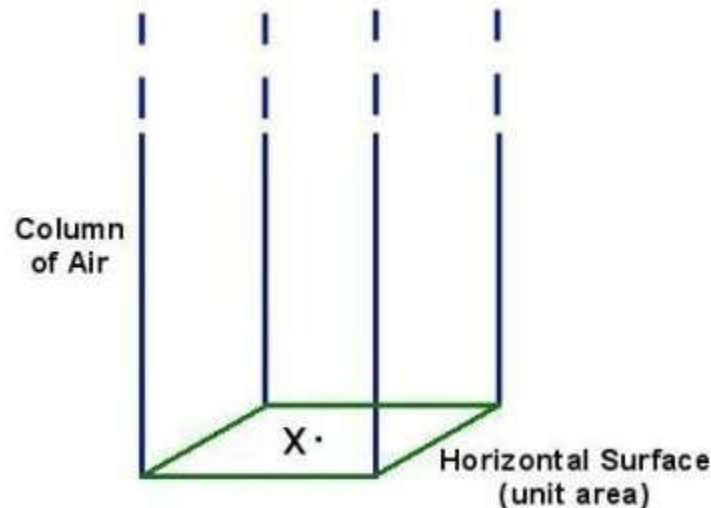
The dry air by itself is a mixture of oxygen about 21% and nitrogen about 78 %. The balance of about 1 % is made up by argon, carbon dioxide, hydrogen etc.

Oxygen is an active agent causing rusting and corrosion of metals. Nitrogen is classified as an inert gas.

Since air consists mostly of the highly superheated oxygen and nitrogen, air is also slightly superheated gas.

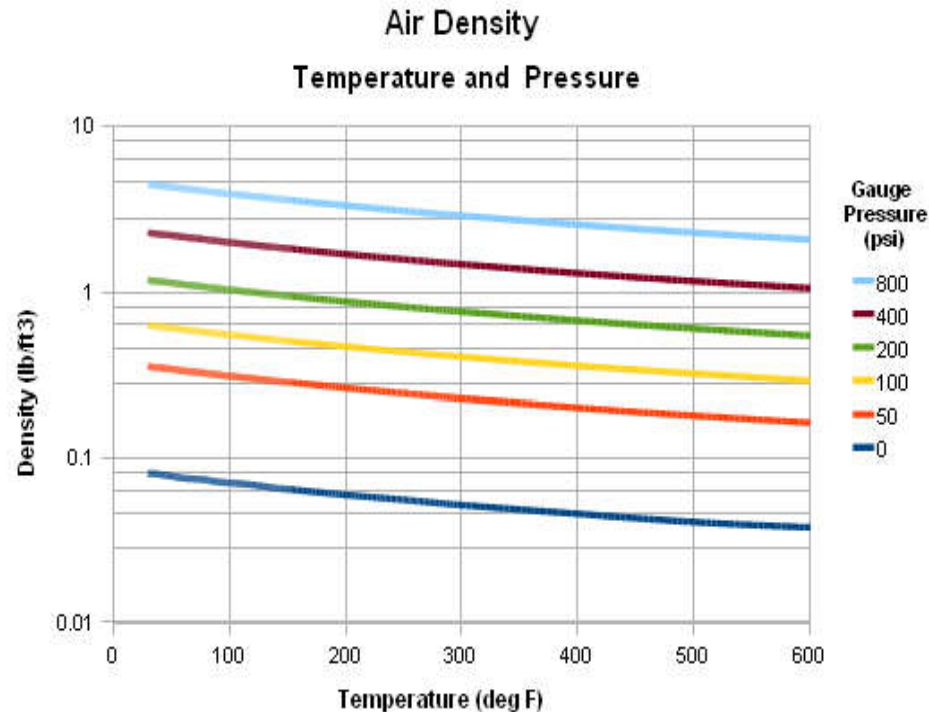
- **Air pressure**

Air has weight. Air pressure is the weight of the column of air above a horizontal surface of unit area (e.g. one square metre). The column of air extends to the top of the atmosphere. As we go up and reach a higher altitude, the pressure is lower because the column of air is reduced.



The pressure at point X is the weight of the column of air above the horizontal surface of unit area.

- Air temperature



Air temperature is a measure of how hot or cold the air is. It is the most commonly measured weather parameter.

More specifically, temperature describes the kinetic energy, or energy of motion, of the gases that make up air.

As gas molecules move more quickly, air temperature increases.

Heat content of air

- The total heat content of air is made up of sensible heat and latent heat.
- The sensible heat is mainly from the dry air. The water vapor also has sensible heat, but since this is extremely small. It is generally not taken into account.
- The latent heat content is due to the water vapour present in the air. The latent heat content of air depends upon its dew point.

Air Humidity

- It is the amount of water vapor in the air. Water vapor is the gaseous state of water and is invisible.
- There are three main measurements of humidity:
 - Absolute,
 - Relative and
 - Specific.

Absolute humidity is the water content of air.

Absolute humidity is the mass of the water vapor (m_w), divided by the volume of the air and water vapor mixture (P_{net}), which can be expressed as:

$$AH = \frac{m_w}{P_{net}}.$$

- SI unit of absolute humidity is kg/m³.

Relative humidity,

Relative humidity of air φ is the ratio of absolute humidity Φ to its maximal value $\Phi_{\max}$

Relative humidity is typically expressed in percents as

$$\varphi_{\%} = \frac{\Phi}{\Phi_{\max}} \cdot 100$$

Specific humidity is a ratio of the water vapor content of the mixture to the total air content on a mass basis.

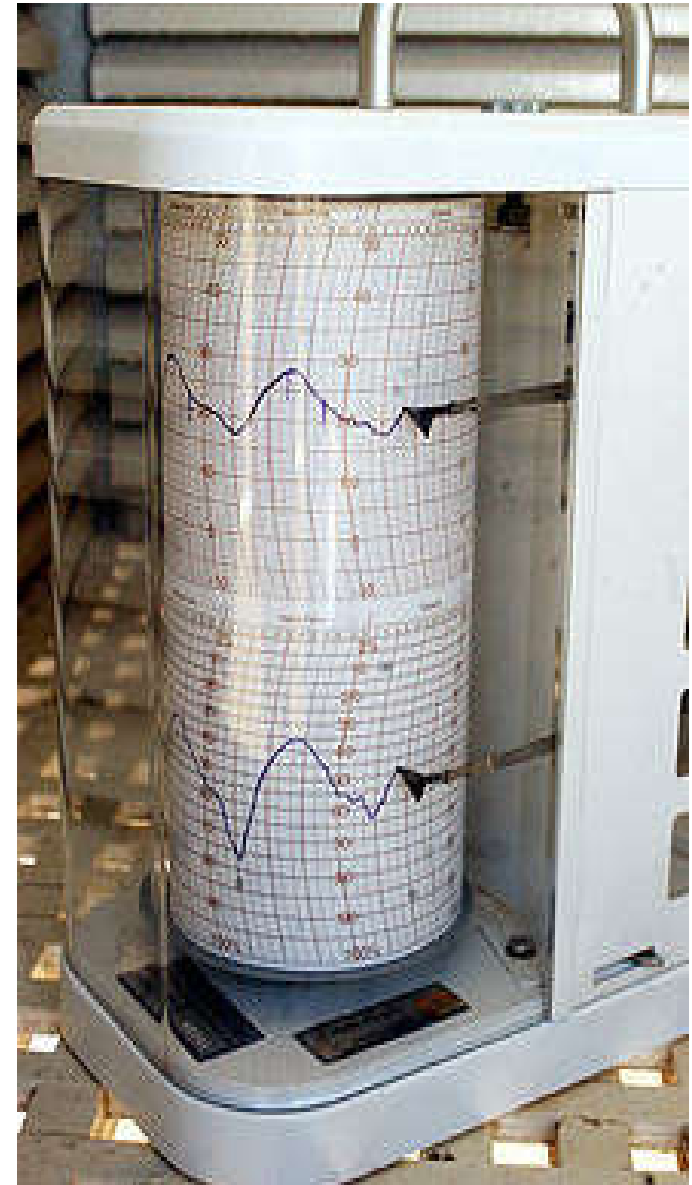
$$SH = \frac{m_v}{m_a}.$$

- Sometimes referred to as the humidity ratio.

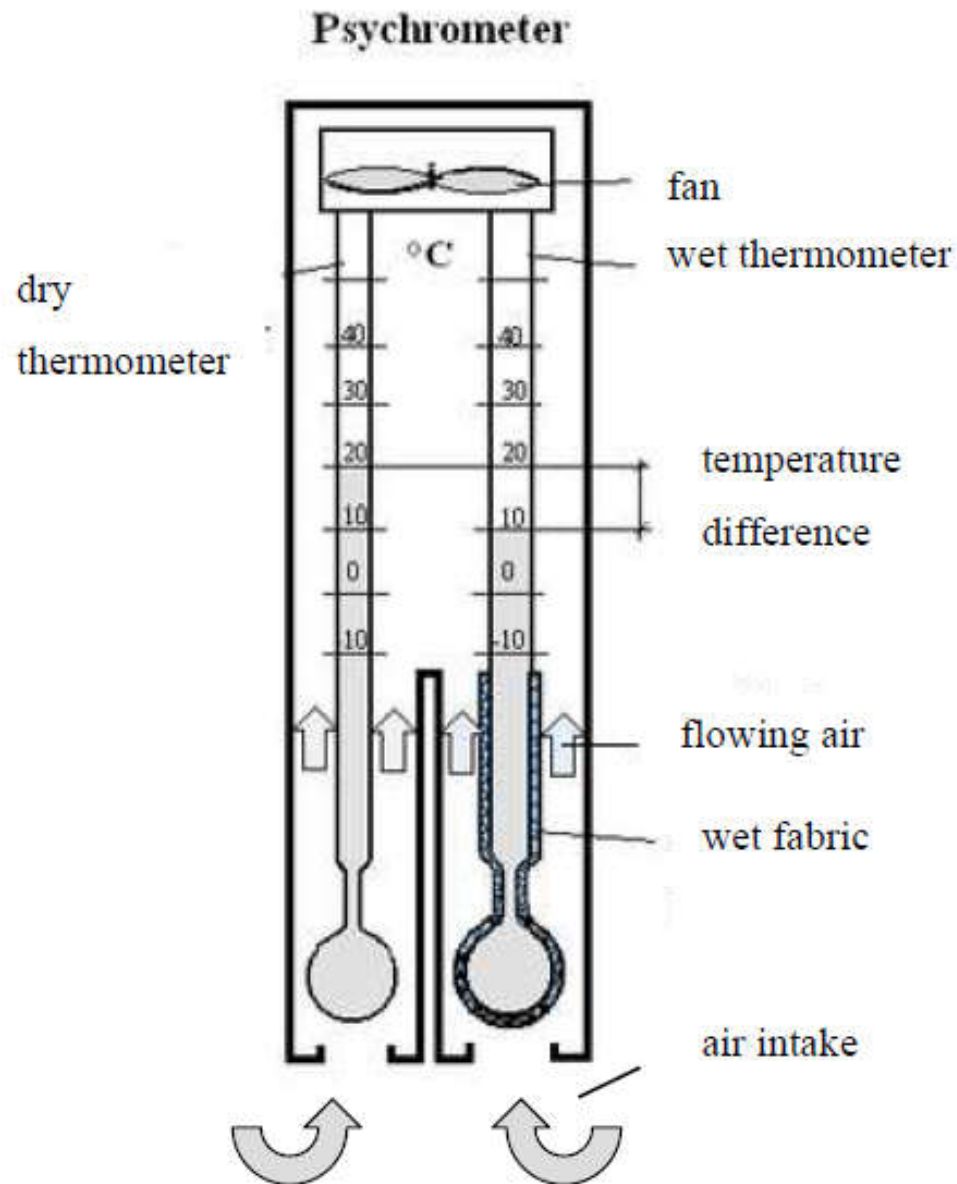
Measurement of humidity

There are various devices used to measure and regulate humidity.

A device used to measure humidity is called a psychrometer or [hygrometer](#)



Assmann's psychrometer



- It consists of two mercury thermometers; first of them is called dry thermometer and it is used to measure the temperature of surrounding environment t_1 .
- The bulb of second thermometer, called the wet thermometer, is covered with a wet fabric.
- Evaporation from the wet thermometer lowers the temperature of surrounding air t_2 (i.e. $t_2 < t_1$) by the latent heat of liquid-to-vapor phase transition.
- Difference between the two temperatures ($t_1 - t_2$), psychrometric difference, therefore depends on the air humidity.
- Evaporation increases with decreasing humidity, which causes an increase in temperature difference.

- Relative humidity of air determined by the Assmann's psychrometer can be then calculated from the partial pressure of water vapor p_1 (at the temperature t_1) and partial pressure p_2 (at the temperature t_2) via relation

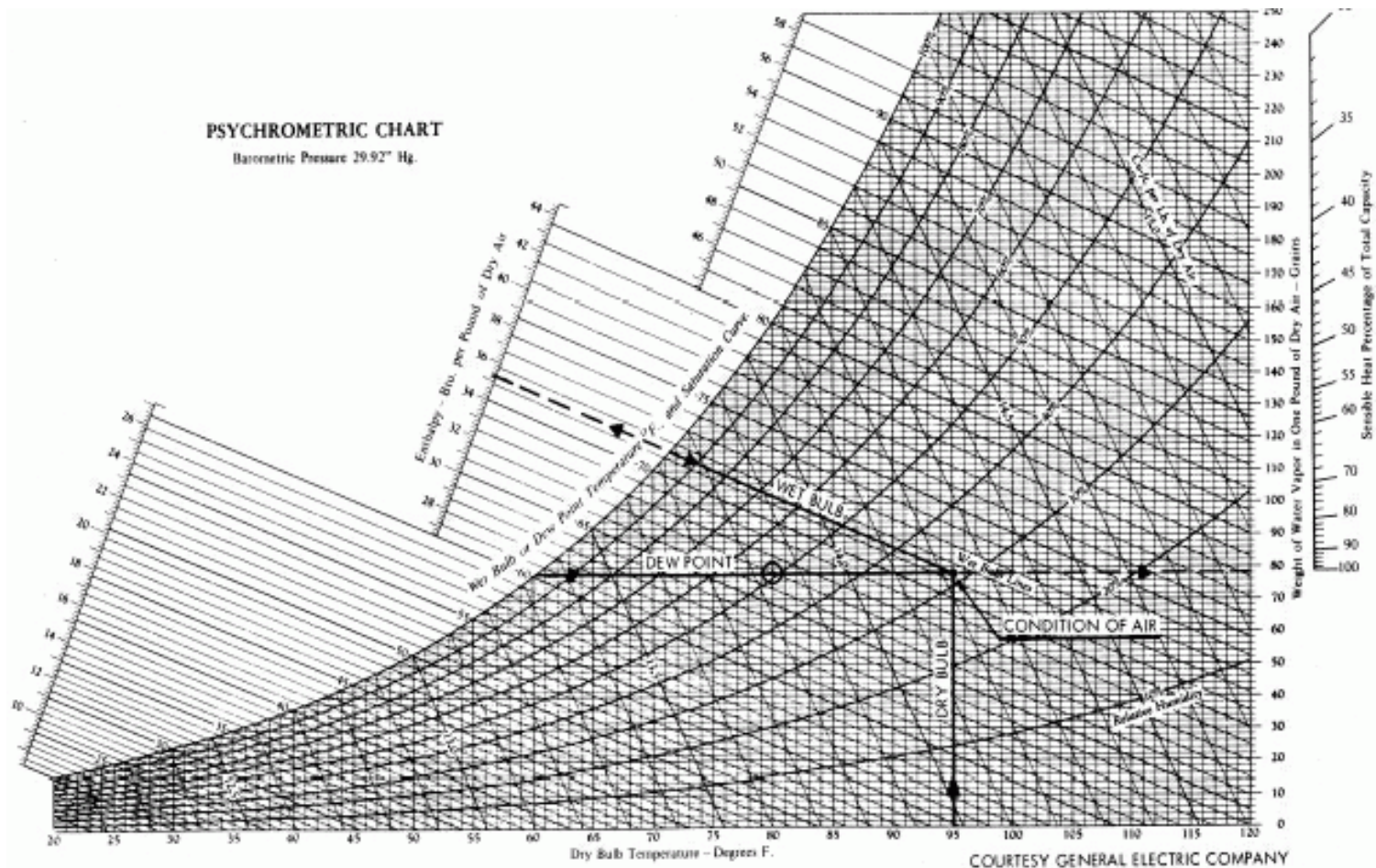
$$\phi = \frac{p_2 - Ab(t_1 - t_2)}{p_1}$$

- where b is an atmospheric pressure in pascals (Pa) and A is a psychrometric constant.
- Its value for psychrometer used in our laboratory is $A=0,00066 \text{ K}^{-1}$.

Psychometric chart and its use

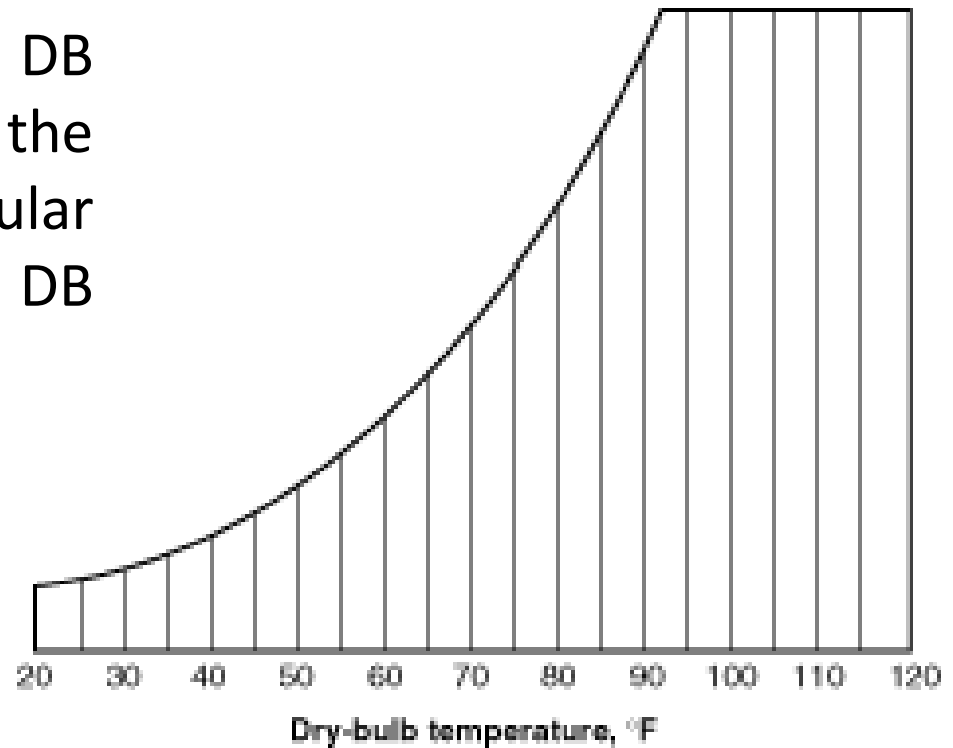
- Psychrometry is an impressive word which is defined as the measurement of the moisture content of air.
- it is the science and practice associated with atmospheric air, method of control of its temperature/ moisture content and its effect on material and human comfort.
- This can be accomplished through use of psychrometric tables or a psychrometric chart.
- The psychrometric chart looks like a shoe

Psychrometric chart



Dry Bulb (DB) Temperature Lines

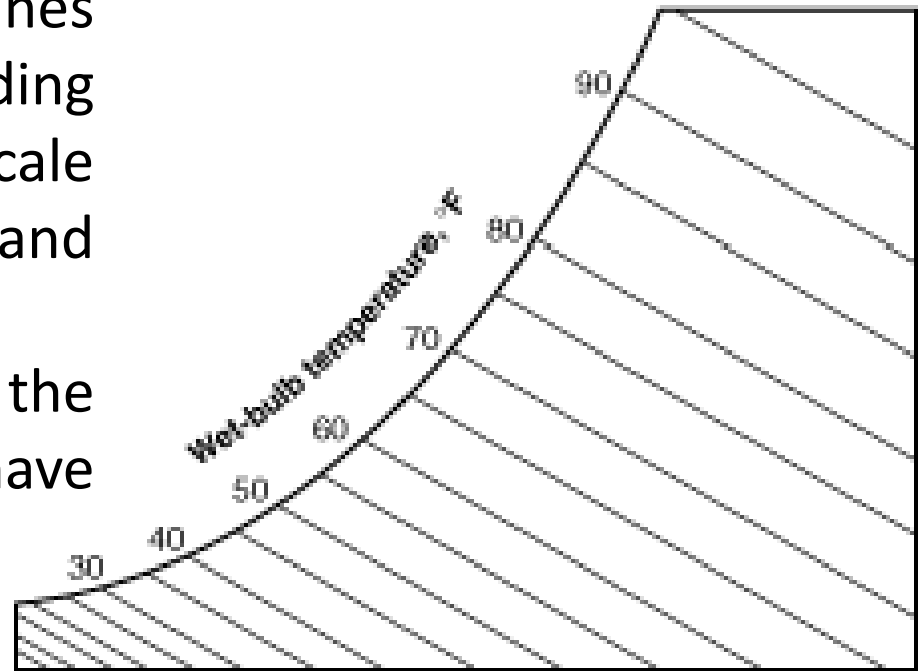
The vertical lines shown in the chart are the constant DB temperature lines and all the points located along a particular vertical line have same DB temperature.



Wet Bulb (WB) Temperature Lines

The constant WB temperature lines are the diagonal lines extending from WB temperature curved scale downwards towards the right hand side of the chart.

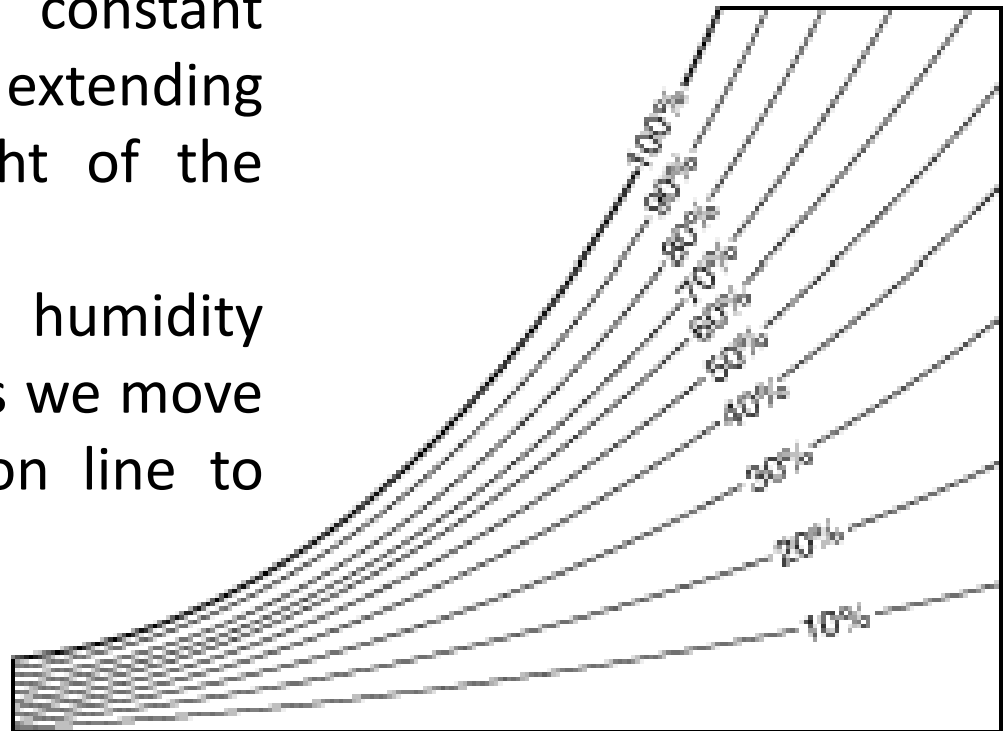
All the points located along the constant WB temperature line have the same temperature.



Relative humidity lines

Chart with the curved constant relative humidity lines extending upward and to the right of the chart

The constant relative humidity lines decrease in value as we move away from the saturation line to the right and downward.



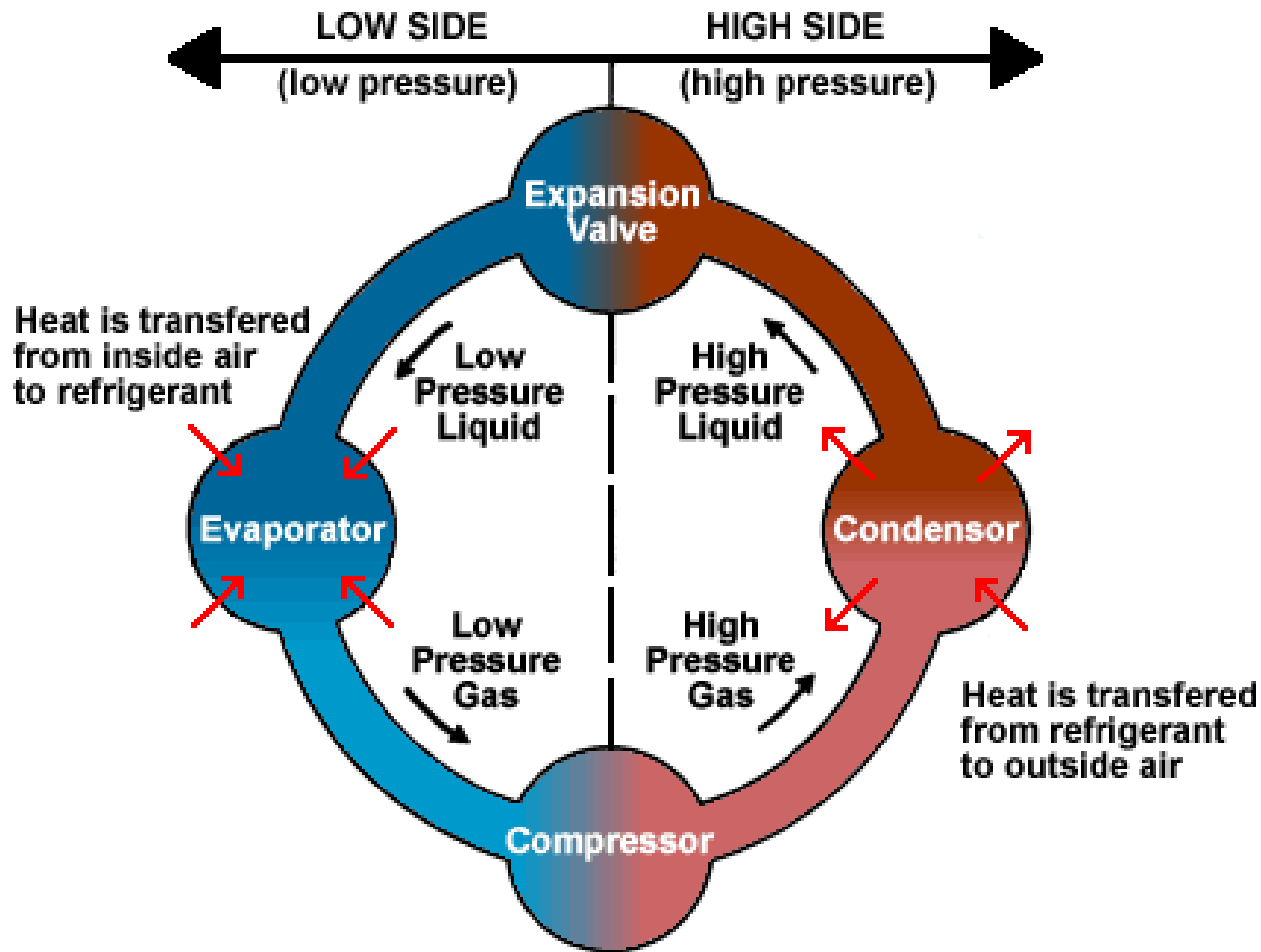
Principles of air conditioning

- All air conditioning systems must have four basic elements:
 - [Compressor](#)
 - [condenser](#)
 - [Expansion Valve](#)
 - [Evaporator](#)

From the compressor, high-pressure gas is sent to the condenser, where the heat is dissipated and condensed to liquid.

The high-pressure liquid flows on to the expansion valve, where it is metered and its pressure is reduced.

At the evaporator, the liquid absorbs heat from the air and evaporates to gas. The cycle is then repeated, starting at the compressor.



Liquids absorb heat when changed from liquid to gas
Gases give off heat when changed from gas to liquid.

Application of air conditioning

1. Comfort air conditioning systems
2. Process air conditioning systems

Comfort Air Conditioning Systems

Comfort air conditioning systems provide occupants with a comfortable and healthy indoor environment in which to carry out their activities.

The various sectors of the economy using comfort air conditioning systems are as follows:

1. The commercial sector includes office buildings, supermarkets, department stores, shopping centers, restaurants, and others.

air conditioning systems to satisfy multiple-tenant requirements. In light commercial buildings.

For shopping malls and restaurants, air conditioning is necessary to attract customers.

2. The institutional sector includes such applications as schools, colleges, universities, libraries, museums, indoor stadiums, cinemas, theaters, concert halls, and recreation centers.

one of the large indoor stadiums, the Superdome in New Orleans, Louisiana, can seat 78,000 people.

3. The residential and lodging sector consists of hotels, apartment houses, and private homes.

Many systems serving the lodging industry and apartment houses are operated continuously, on a 24-hour, 7-day-a-week schedule, since they can be occupied at any time.

4. The health care sector encompasses hospitals, nursing homes, and convalescent care facilities.

Special air filters are generally used in hospitals to remove bacteria. The relative humidity in a general clinical area is often maintained at a minimum of 30 percent in winter.

5. The transportation sector includes aircraft, automobiles, railroad cars, buses, and cruising ships.

Passengers increasingly demand ease and environmental comfort, especially for long distance travel.

Modern airplanes flying at high altitudes may require a pressure differential of about 5 psi between the cabin and the outside atmosphere

Process Air Conditioning Systems

Process air conditioning systems provide needed indoor environmental control for manufacturing, product storage, or other research and development processes.

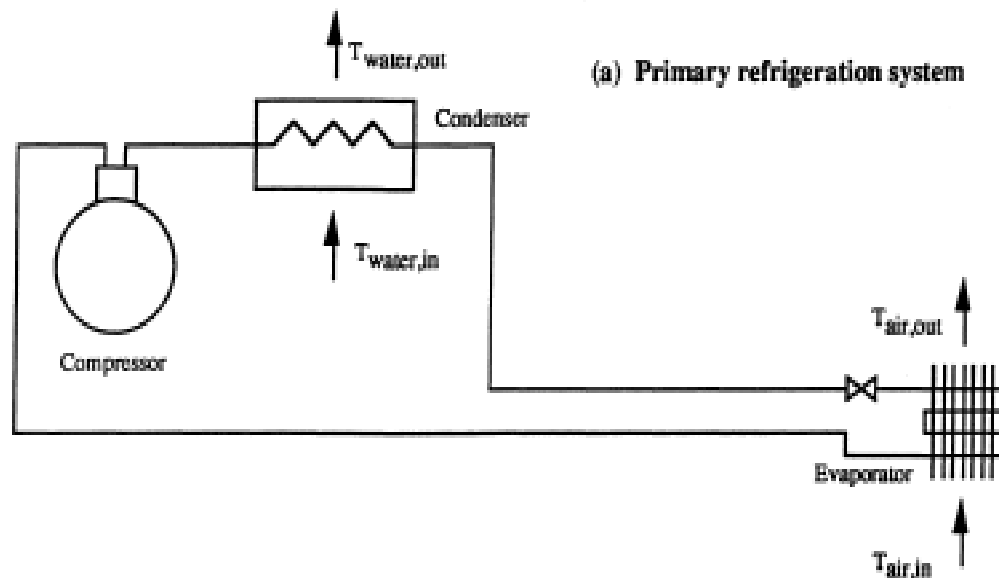
- 1. In textile mills** proper control of humidity increases the strength of the yarn and fabric during processing. For many textile manufacturing processes, too high a value for the space RH% can cause problems in the spinning process. On the other hand, a lower RH% may induce static electricity that is harmful for the production processes.
- 2. *Clean rooms. Many electronic products require clean rooms*** for manufacturing such things as integrated circuits, since their quality is adversely affected by airborne particles. RH% control is also needed to prevent corrosion and condensation and to eliminate static electricity. Temperature control maintains materials and instruments at stable condition and is also required for workers who wear dustfree garments.

3. **Precision manufacturers** always need precise temperature control during production of precision instruments, tools and equipment. Bausch and Lomb successfully constructed a constant-temperature control room of $68 \pm 0.1^{\circ}\text{F}$ ($20 \pm 0.56^{\circ}\text{C}$) to produce light grating products in the 1950s.
4. **Pharmaceutical products** require temperature, humidity, and air cleanliness control. If the temperature or humidity crosses certain limits, there are chances of deterioration of the products. High efficiency air filters must be installed for most of the areas in pharmaceutical factories to prevent contamination.
5. **Ware houses.** Modern refrigerated warehouses not only store commodities in coolers at temperatures of $27\text{--}32^{\circ}\text{F}$ (-2.8 to 0°C) and frozen foods at -10 to -20°F (-23 to -29°C), but also provide RH control for perishable foods between 90% and 100%. Refrigerated storage is used to prevent deterioration. Temperature control can be performed by refrigeration systems, but the simultaneous control of both temperature and RH in the space can only be performed by process air-conditioning systems.

Refrigeration equipment

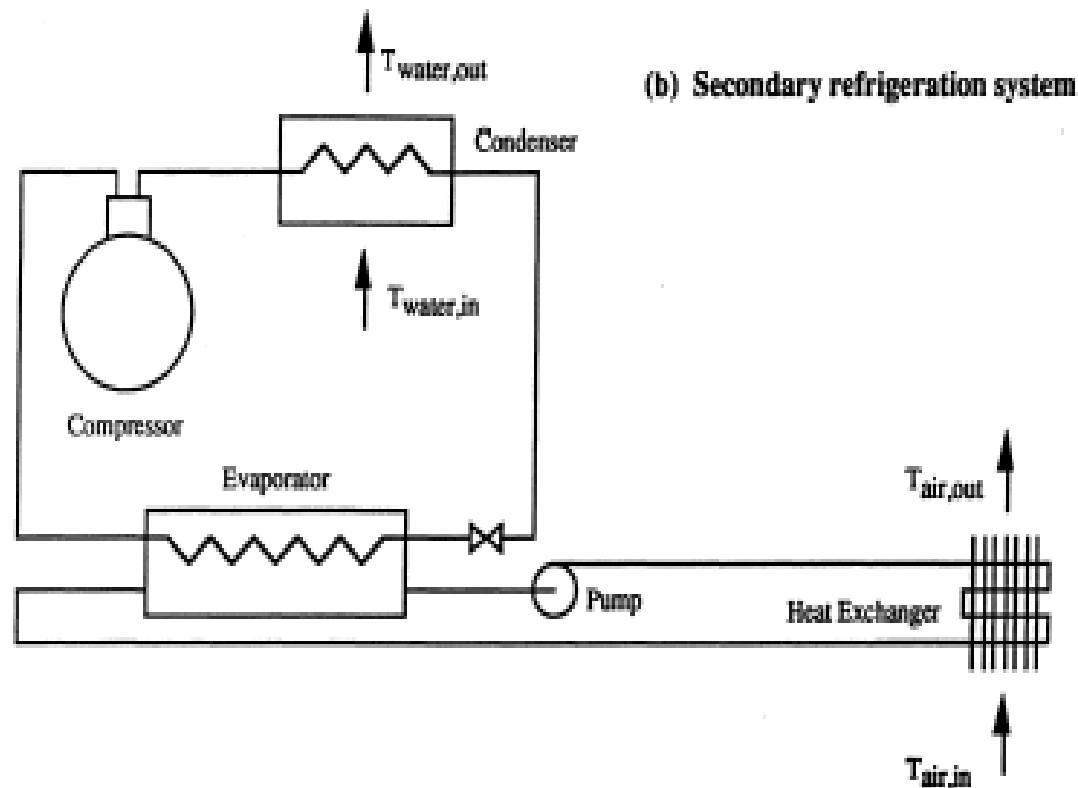
- Based upon the working principle, the refrigerants maybe classified in to
 - Primary and
 - Secondary refrigeration
- **Primary refrigerants** It is a conventional system, a single fluid is circulated throughout the system to cool off the air. The substances that produce refrigeration effect or absorb heat by evaporating at low temperatures and pressures.

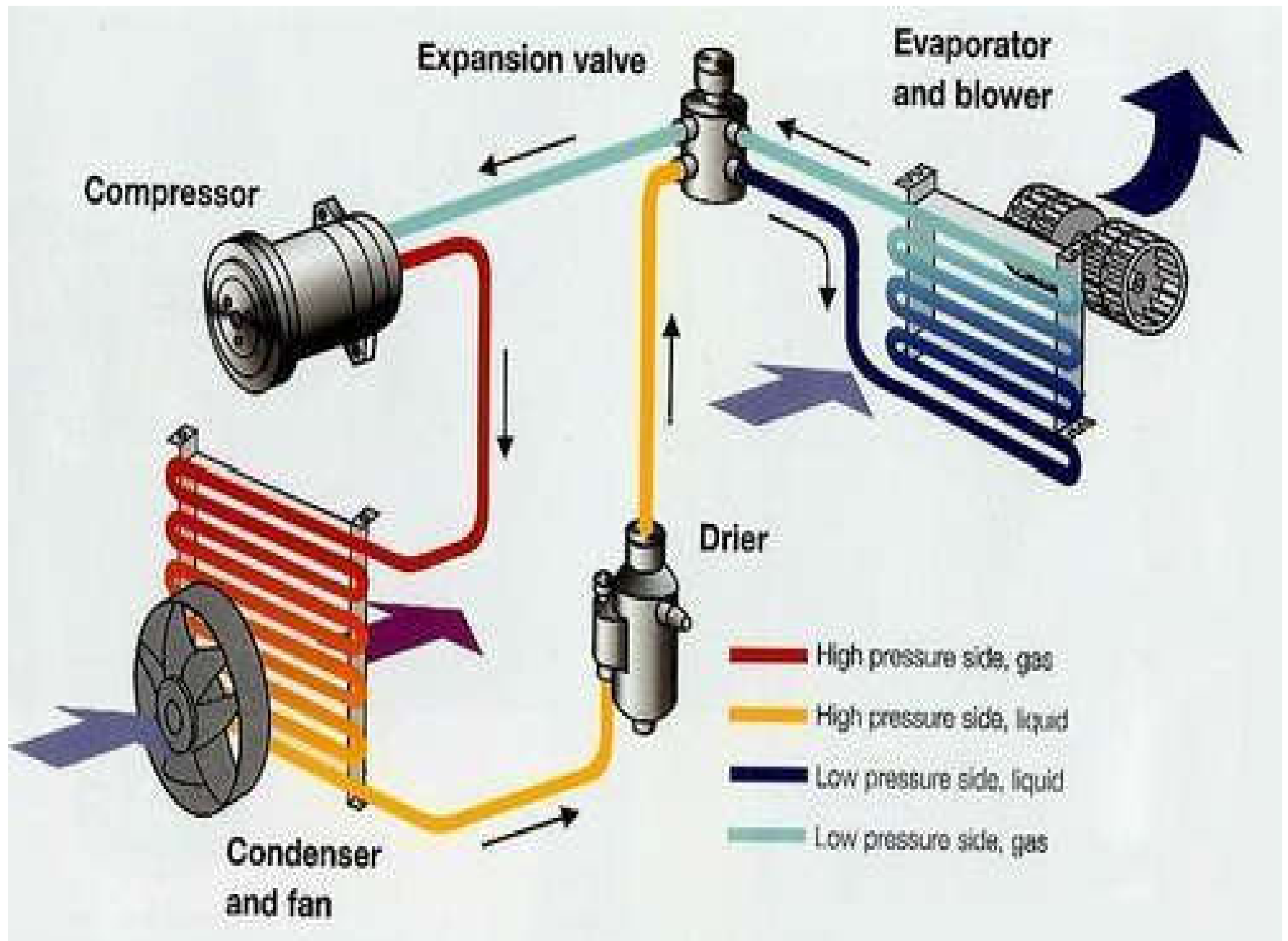
Examples of primary refrigerants are : air, water, ammonia, hydrocarbons, chlorofluorocarbons etc,



- **Secondary refrigerants** are substances that are cooled in the refrigeration plant and transported to produce refrigeration effect at a location away from the refrigeration plant. These do not go through the cyclic processes of evaporation and condensation in a refrigeration system.

Examples. Chilled water, brines and glycols, etc





Air distribution systems

- An air distribution system is a subsystem of an air system which consists of ductwork, terminals, space diffusion devices, and **controls to transport and distribute the conditioned air to the occupied zone as well as to control the indoor environment** within required limits.

Type of Air distribution systems

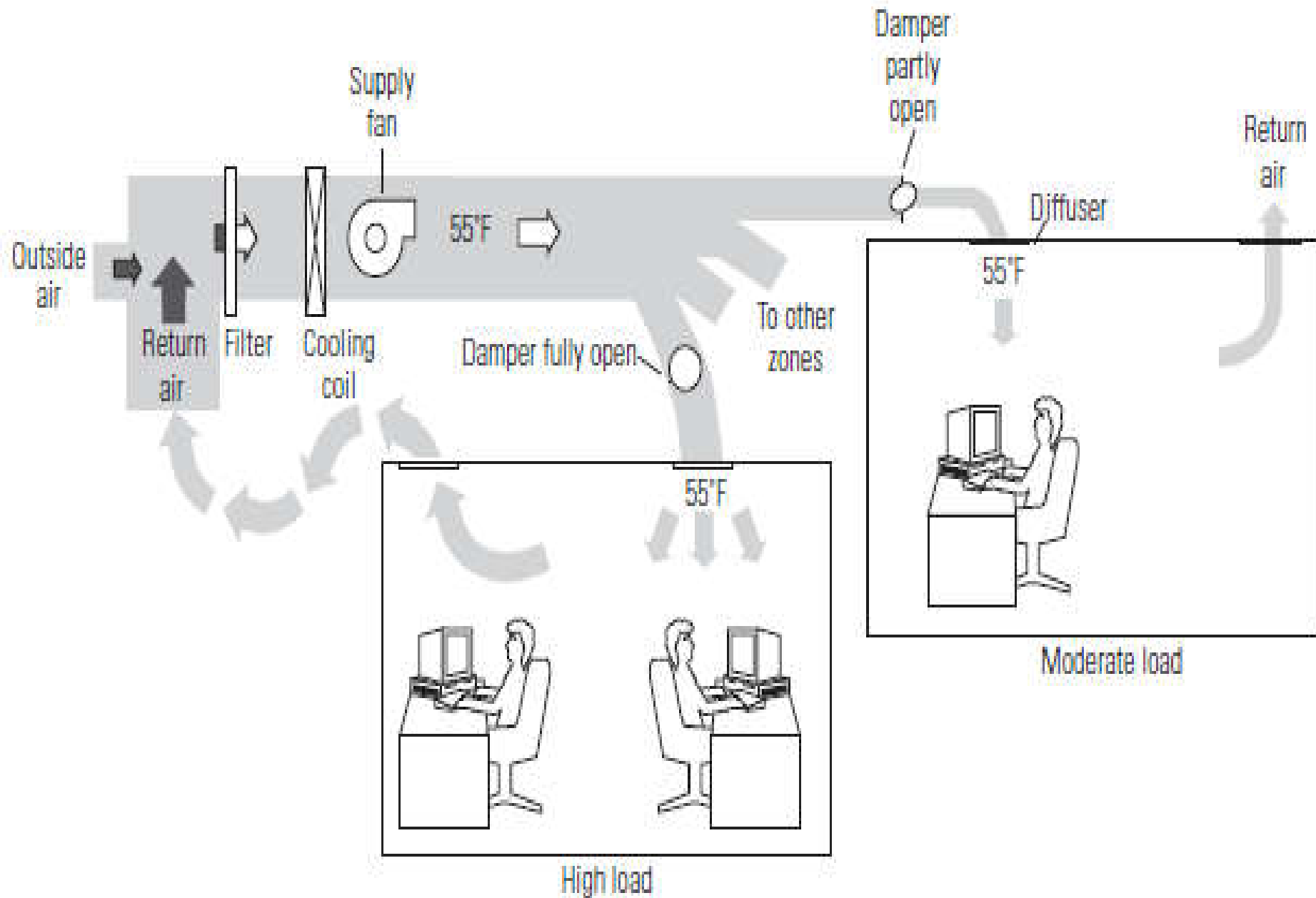
- There are two types of air-handling systems:
 - **constant volume (CV)**
 - **and variable air volume (VAV)**
- In a CV system, a **constant amount of air flows** through the system whenever it is on.
- A VAV system **changes the amount of airflow in response to changes in the heating and cooling load**. VAV systems offer substantial energy savings and are becoming more widespread.

Constant-Volume Systems

- Constant-volume *systems are the simplest type* of air distribution system and are installed in a large percentage of existing commercial buildings.
- In a CV system, when the supply fan is on, a constant amount of air flows through; there is no modulation of the fan power, no discharge dampering at the fan, and no dampering at the terminal ends of the duct runs.
- Its simplest configuration, a CV system serves a **single space (also called a zone)**.
- A thermostat is located in the zone that senses space temperature and sends signals to the air-handling unit to provide heating or cooling based on the thermostat setting.

Variable air volume

- Today's VAV systems can handle **changing load requirements by varying the amount of heated or cooled air** circulated to the conditioned space in response to varying heating or cooling loads.
- This **reduces fan power requirements**, which saves energy and costs.
- VAV systems work either by **opening or closing dampers** or by modulating the airflow through mixing boxes powered by VAV fans as loads in various zones of the building change



Distribution Equipment.

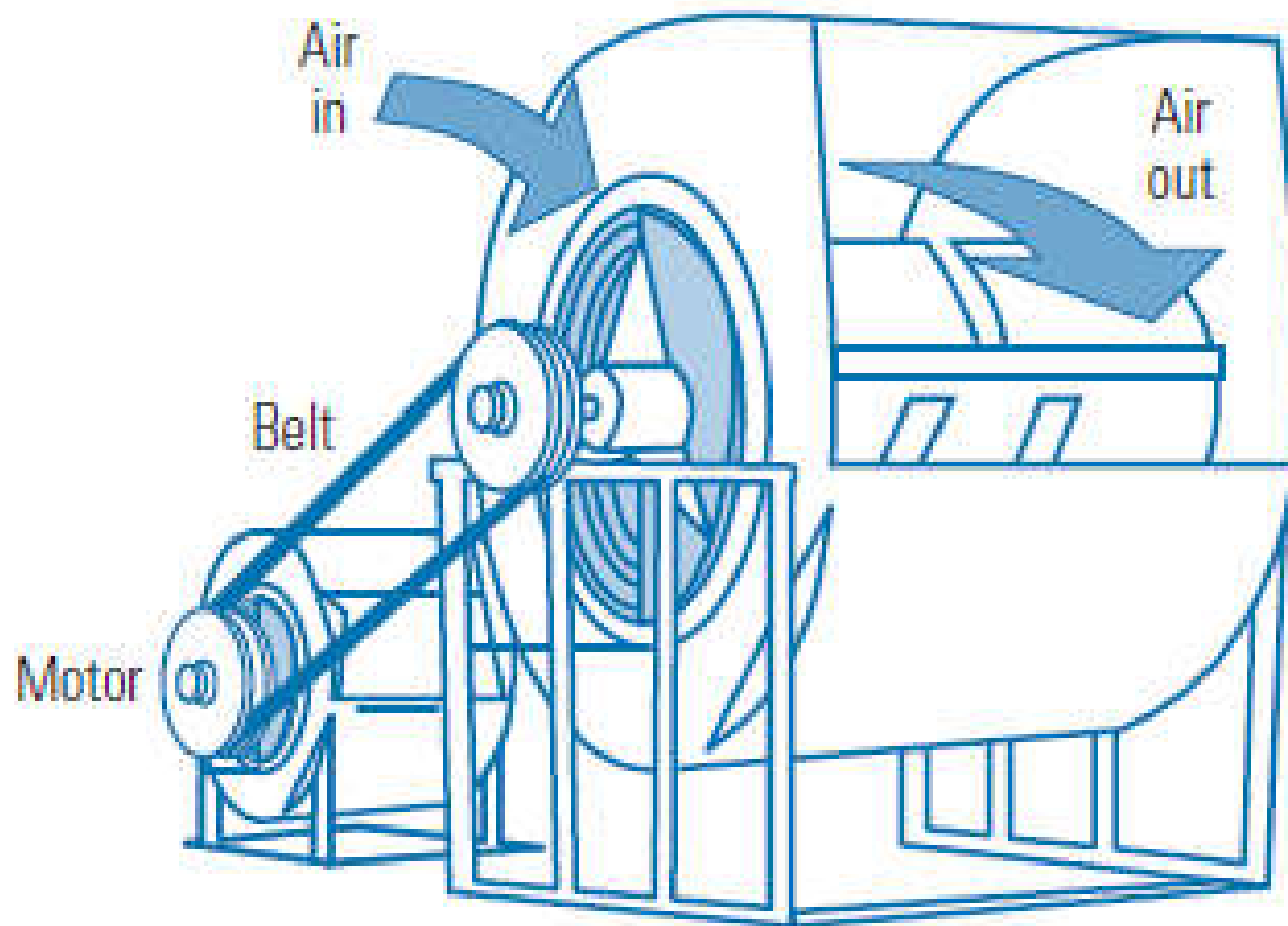
The major components in an air-handling systems: fans, filters, ducts and dampers.

- Fan:** circulate the air and provide the pressure required to push it through filters, coils, ducts, transitions, fittings, dampers, and diffusers.
- Fans are the heart of a building's air-handling system. Like a heart that pumps blood through a body, they distribute the conditioned (heated or cooled) air throughout the building.
 - There are two main types of fans:
 - Centrifugal
 - and axial

Centrifugal fans

- Centrifugal fans are by far the **most prevalent type** of fan used in the HVAC industry today.
- They are usually **cheaper than axial fans** and **simpler in construction**, but they generally do **not achieve the same efficiency**.
- Centrifugal fans consist of a rotating wheel, or impeller, mounted inside a round housing. The impeller is driven by a motor, which is usually connected via a belt drive.

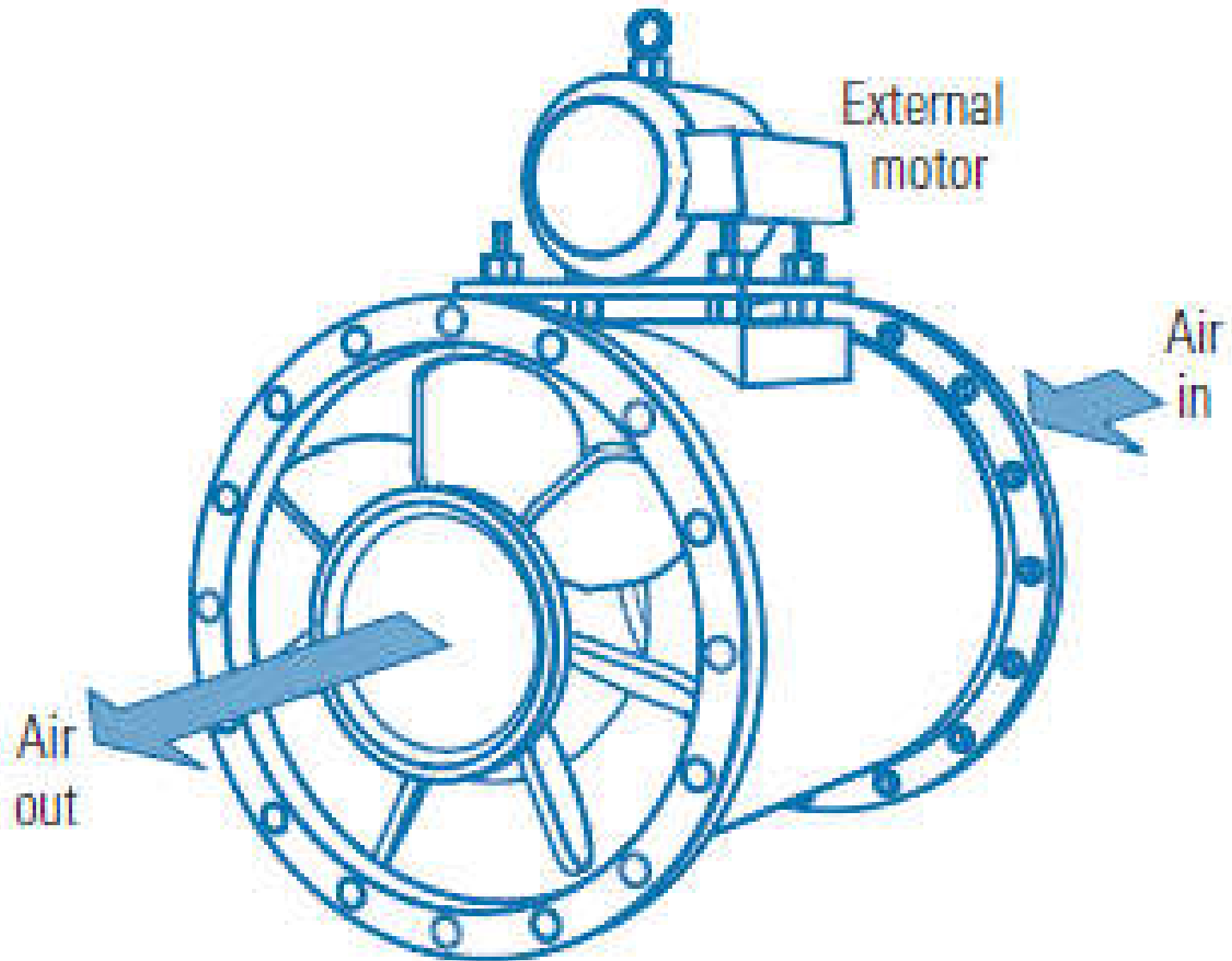
A. Centrifugal fan



Axial fans

- Axial fans consist of a cylindrical housing with the **impeller mounted inside along the axis** of the housing.
- In an axial fan, the impeller **consists of blades mounted** around a central hub similar to an airplane propeller. As with an airplane, the spinning blades force the air through the fan.
- Axial fans are **typically used for higher-pressure** applications (over 5 inches total static pressure) and are **more efficient than centrifugal fans**.
- The motor of an axial fan can be mounted externally and connected to the fan by a belt.
- However, axial fans are often driven by a motor that is directly coupled to the impeller that is mounted within the central hub.

B. Axial fan



Filters

- Clean the air, protecting occupant health, **inhibiting bacteria** and **mold growth**, and keeping **coil surfaces clean**.
- Commonly found filter types in commercial buildings include
 - dry filters,
 - bag filters,
 - high efficiency particulate air (HEPA) filters,
 - electrostatic precipitators,
 - and carbon filters.

Dry filters

- Dry filters have fine strands of fabric or fiber that intercept smaller particles of about **0.5 to 5.0 micrometers**.
- The pleats in these filters give them greater surface area, but the additional surface also lowers their face velocity.
- The media **is contained in a cardboard frame** that is generally thrown away with the fabric when it becomes dirty.
- These are often used **as pre-filters** for bag or HEPA filters.

Bag filters

- Bag filters use dry media that is arranged in a **long stocking shape to extend their surface area** or to allow recovery of the collected material.
- Although commonly used in HVAC systems, bag filters are generally being replaced by **rigid dry filters**.

HEPA filters

- It has **thin, dry media** (such as paper or glass-fiber mats) with very small pores that trap superfine particulates down to **0.01 micrometer in diameter**.
- They are heavily pleated to reduce face velocity but still **contribute pressure drops of up to 0.072 psi**.
- HEPA filters are used mostly for the **demanding applications** of production facilities
- HEPA filters should be coupled with a coarser pre-filter to extend their lifetime

Electrostatic precipitators

- It use a **high voltage to ionize particles** suspended in the air, then pass the airstream between charged plates that attract and accrete the **charged particles**.
- Because there is no physical impediment to the air, these filters have **very low pressure drops**.
- However, the power equipment used to create the voltage differences continuously consumes about **20 to 40 watts per 1,000 cubic feet per minute (cfm) of airflow**

Duct

- Ducts **convey the conditioned air** from the air-handling unit out through the building and return it back to be conditioned again (or exhausted from the building).
- They are usually constructed of **sheet metal and are insulated.**
- Ductwork can either be **round or rectangular.** **Rectangular duct material used to be cheaper and more common** than round, but the trend these days is to use a spiral version that is fabricated

Types of Air Duct

Air ducts can be classified into four types according to their transporting functions:

- **Supply duct**

Conditioned air is supplied to the conditioned space.

- **Return duct.**

Space air is returned

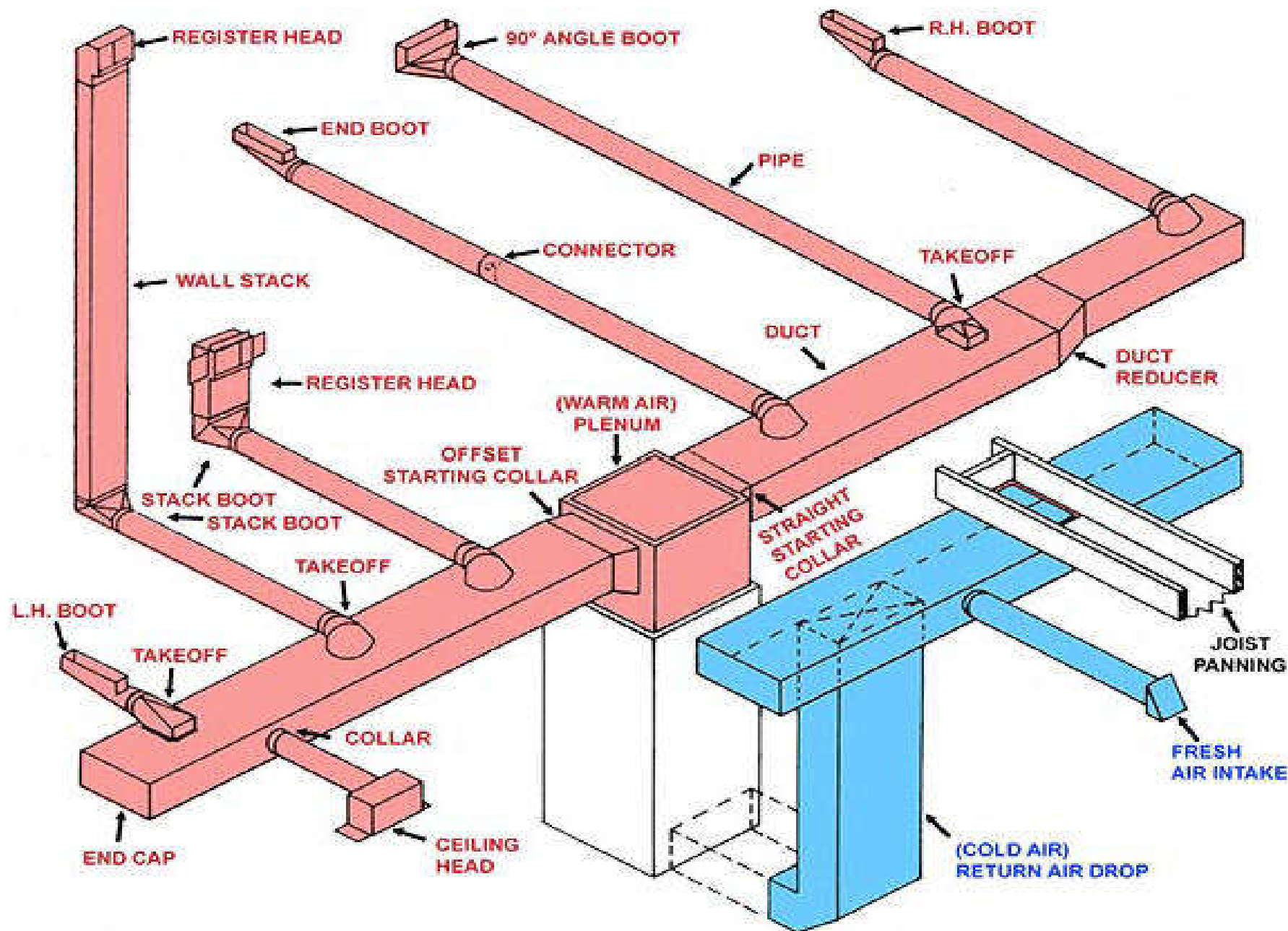
- to the fan room where the air-handling unit is installed or
- to the packaged unit.

- **Outdoor air duct.**

Outdoor air is transported to the air-handling unit, to the fan room, or to the space directly.

- **Exhaust duct.**

Space air or contaminated air is exhausted from the space, equipment, fan room, or localized area.



Each of these four types of duct may also subdivide into

- Headers,
- Main ducts,
- Vertical Duct
- and branch ducts or runouts.

A header is that part of a duct that **connects directly to the supply** or exhaust fan before air is supplied to the main ducts in a large duct system.

Main ducts have comparatively **greater flow rates and size**, serve a greater conditioned area, and, therefore, allow higher air velocities.

A vertical duct is called **a riser**. Sometimes, a header or a main duct is also called a **trunk**.

Branch ducts are usually connected to the terminals, hoods, supply outlets, return grilles, and exhaust hoods.

Duct design

The objectives of good duct design are

- occupant comfort,
- proper air distribution,
- economical heating and cooling system operation,
- and economical duct installation.

The outcome of the duct design process will be a duct system (supply and return plenums, ducts, fittings, boots, grilles, and registers) that

- It provides conditioned air to meet all room heating and cooling loads.
- It is properly sized so that the pressure drop across the air handler is within manufacturer and design specifications.
- It is sealed to provide proper air flow and to prevent air from entering the house or duct system from polluted zones.
- Has balanced supply and return air flows to maintain a neutral pressure in the house.
- Minimizes duct air temperature gains or losses between the air handler and supply outlets, and between the return register and air handler.

- **Rough-surfaced duct material makes a fan work harder than smooth duct materials do.**
- In engineering terms, **the pressure loss of a duct** is **proportional to the friction factor** of its inside skin and to the square of the air speed.
- The **friction factor depends on surface roughness** (the average height of protrusions from the surface) and, to a much lesser extent, on duct diameter, air speed, and air density.
- **Smooth sheet metal, usually steel or aluminum, is the best material For ductwork:** Rigid fiberglass ductwork suffers nearly 30 percent more pressure drop than sheet metal.
- The **acoustic fiber lining used** in many supply ducts (especially just downstream of the fan) has 40 percent more frictional resistance than smooth sheet metal.