

●●● POWER ENGINEERING

Fourth Class

Edition 3.5

HVAC Fundamentals for Facility Operators

Part B

Unit B-10



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HVAC FUNDAMENTALS FOR FACILITY OPERATORS

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UNIT INTRODUCTION

Nearly all buildings contain HVAC systems to improve human comfort. As qualified operators, Power Engineers often manage the air conditioning systems in their facility. This unit describes the thermodynamic and operating processes, equipment, and auxiliaries used to condition air for human comfort and health.

Temperature and humidity are two important characteristics of the atmosphere that greatly affect the comfort of building occupants. The relationship of these two properties is called psychrometrics. The information presented in this chapter will lead to a greater understanding of the varied systems in place that control these properties.

Every HVAC system consists of a number of components, the most common of which include fans, filters, ducts, heating coils, cooling coils, and humidification equipment. Adjusting these components optimizes the condition and distribution of air that is suitable to maintain human health and comfort.

UNIT RATIONALE

Human comfort is a critical consideration in regulated facilities with large numbers of occupants. As facility operator, the Power Engineer is responsible for managing those systems that ensure optimal human comfort, in order to provide a healthy workspace.





Conditioning the Air

LEARNING OUTCOME

When you complete this chapter you should be able to:

Explain the methods and techniques for conditioning air in plants and buildings.

LEARNING OBJECTIVES

Here is what you should be able to do when you complete each objective:

- 1. Discuss the process to condition air for human comfort and health.*
- 2. List the categories and functions of HVAC systems.*
- 3. Describe the operation of air handling units.*
- 4. Define the terms humidity, relative humidity, and dew point.*
- 5. Define the terms dry-bulb temperature, wet-bulb temperature, wet-bulb depression, and how they relate to relative humidity.*



CHAPTER INTRODUCTION

Heating, ventilation, and air conditioning (HVAC) systems use mechanical components to treat the air entering the building. Nearly all buildings contain an HVAC system to improve human comfort. The term “air conditioning” is commonly used in place of HVAC.

Power Engineers often manage the air conditioning systems as part of their industrial and facility operating responsibilities. This chapter provides a basic understanding of the processes used to condition air so that it is suitable for human comfort and health.

OBJECTIVE 1

Discuss the process to condition air for human comfort and health.

HVAC SYSTEM OVERVIEW

An **HVAC** system performs many functions to treat the air.

- a) A heating process increases the air temperature.
- b) A cooling process removes heat from the air, which causes the temperature of the air to drop.
- c) A **ventilation** process supplies air or removes air from a space.
- d) A filtration process removes particles from the air.
- e) A humidification process controls the humidity of the air.

Heating, cooling, filtration, ventilation, and humidification are collectively called **air conditioning**.

Fans are typically used to supply fresh air and to exhaust air. The system can mix building return air with the make-up air, and then supply it to the building. Exhausting air is important because the air may contain odors, excess humidity, CO, and other contaminants that may have an adverse effect on people's health.

Each building is required to change the air in the building. This is referred to as “building air changes per hour” and is measured in m³/hour. In a perfect world, make-up air would consist of 100% fresh air, but that would be very costly. To increase building efficiencies, a percentage of the building air is exhausted to the outside, and a percentage is recirculated back into the building. Some air within the building may not be recirculated at all. Local building codes will determine the fresh air make-up requirements for the occupied spaces.

HVAC systems will include:

- Fans
- Filters
- Ducting
- Heating coils
- Cooling coils
- Humidity control

An HVAC system must have a way to distribute the air, and methods to control the flow of air entering and leaving a building.

The purpose of HVAC is to improve the comfort of the people occupying the building space. Factors that influence human comfort are:

- Temperature
- Humidity
- Air quality
- Air movement

Temperature control is important in the operation of a building. There are two common complaints: the temperature is either too hot or too cold; and the **humidity** is either too high or too low. As previously mentioned, air quality refers to odours, particulates, and other conditions that may affect human health. Air movement refers to velocity, noise, drafts, and air circulation in general.



HVAC systems come in various designs, based on the building space and the outside air conditions. Compare the summer design requirements of an HVAC system located in Houston, Texas versus the winter requirements for a building in Edmonton, Alberta.

Consider the air quality outside the Houston building in July. One could imagine that the air would have a very high **relative humidity (RH)**, maybe near 100% RH, and an air temperature above 40°C. The HVAC system would have to be designed to treat high humidity and high temperature air.

In Edmonton, the temperature in January can be below 0°C. For this building, the RH would be very low, near 5%. The HVAC system would have to be designed to treat low temperature and low humidity air.

Obviously, the design of these two systems would be very different. The equipment required to support load capacity and provide acceptable air conditions would differ for each location.

Some of the components found in a basic HVAC system are listed below.

Fixed louvres redirect the airflow. This causes rain or snow to fall out of air suspension.

Dampers control the airflow.

Finned heating coils; some of these may use steam to heat the air. The steam circulates through the coil and heats the air travelling around the coil. The steam condenses inside the coil, and returns to the boiler.

Finned cooling coils; some of these may use chilled water to cool the air. The water circulates through the coil, and removes heat from the air travelling around the coil. The warmed water leaves the coil, and returns to the chiller.

Humidifiers add water to the air; they pump water from a water bath and inject it into the airflow using spray nozzles.

Air diffusers direct the flow of air into the space without creating a draft.

Fans create airflow or air movement.

Return air is a percentage of exhaust air that leaves the building and returns to the HVAC system. The air is recirculated to increase building efficiencies and lower the operating costs. This recirculated air must be retreated in the HVAC system.

Outside air (also known as **make-up air**) is regulated by building codes; it is used to help maintain human health conditions.

Mixed air is a mixture of return air and make-up air. It flows to the HVAC system to be treated.

Supply air is the air treated by the HVAC system that will be supplied to the building.

CONDITIONING AIR FOR HUMAN COMFORT AND HEALTH

The thermal and atmospheric conditions of the air in a space must be controlled. The purpose of controlling the air quality is to increase the comfort of those using the space; this is better for the health of those in the space, and it may also help to improve productivity.

Human health is the key criteria when designing an HVAC system. One must consider the adverse effects air contaminants may have on the health of people who have respiratory issues. High humidity increases the chance for mold to form inside the building. Consider a hospital operating room; the air supplied to that room will be treated with a separate HVAC system to handle that specific type of air.

Using food as a fuel, the human body can be compared to a furnace. To function properly (i.e. for comfort), the body must be kept at a constant internal temperature of 37°C, which is done by a sensitive temperature regulating mechanism within the body. This mechanism allows continuous transfer of heat by conduction, convection, radiation, and evaporation.

The comfort of human beings therefore is affected by the atmospheric conditions surrounding them. This includes temperature, relative humidity, air movement (i.e. velocity), and air cleanliness.

Effective Temperature and Comfort Zone

Because of the many variables which affect comfort, as well as the differences between individuals, it is impossible to find exact conditions that are satisfactory to all people, under all circumstances. A great deal of research has been done on this subject in an attempt to relate the factors of temperature, humidity, and air movement. The outcome of these experiments is **effective temperature (ET)**.

Effective temperature is a measure of comfort which involves the combined effects of the dry-bulb temperature, relative humidity, and air movement. Even though it is expressed in °F or °C, effective temperature is not an actual temperature and it cannot be measured with a thermometer.

During summer and winter, relative humidity needs to be between 30% and 70%. Above 70%, the air feels muggy, regardless of the temperature. Below 30%, the air becomes too dry and affects nasal membranes.

Effect of Air Motion

Air motion has a considerable effect on comfort. An increased airflow increases the heat loss of the body by **conduction**, **convection**, and **evaporation**. This helps the body to remain comfortable when the room temperature is higher than normal.

The use of an electric fan is a good example of cooling by increasing airflow. However, a higher than normal airflow over the body when the room temperature is normal will make a person feel uncomfortable.

An airflow of 4.6 m – 7.6 metres per minute is considered to be relatively still. But, if the air is moving at 19.8 m/min, most people would consider it to be a draft.

CONCLUSION

The following are some of the key points from the above discussion.

- a) The variations in temperature desired by men and women, or by different age groups.
- b) The physical activities of the occupants.
- c) Because of radiant heat, rooms on the sunny side of the building with warm walls or sun shining through the windows should be kept cooler. Rooms on the north side or exposed to the wind should be kept warmer in winter. A full auditorium, meeting room, theatre, or crowded department store should be kept at a lower temperature than a room that is sparsely occupied.
- d) To prevent discomfort, keep the effective air temperature higher when most occupants only spend a short time in the building.



OBJECTIVE 2

List the categories and functions of HVAC systems.

FUNCTIONS OF AN AIR HANDLING SYSTEM

The purpose of an HVAC system is to maintain satisfactory space conditions for the comfort of the occupants and for the intended function of the building. The requirements for system performance vary according to the type and location of each building, but will include some or all of the functions described.

Heating

A source of heat is required to offset the heat loss to the atmosphere surrounding the building through exterior walls, the roof, floor slabs on grade, and basement walls. The heat must be effectively distributed to all rooms and zones to ensure that comfortable conditions are maintained in all areas of the building.

Cooling

A source of cooling is required to offset the heat gain through the building's exterior shell from solar radiation and the atmosphere surrounding the building, as well as from internal sources of heat. The cooling must be effectively distributed to ensure that comfort conditions are maintained throughout the building.

Ventilation

Provision of outside air into the building is required to replenish the oxygen supply for the occupants. Also, outdoor air is necessary to dilute odours that develop in the building and to provide make-up air for rooms with exhaust systems; this maintains an acceptable air balance in the building.

Humidification

When the relative humidity of the outdoor air is low, moisture must be added within the building to maintain acceptable conditions for human comfort. Also, this moisture minimizes the effects of static electricity, which may be important for proper operation of sensitive equipment within the building.

Dehumidification

A method of removing excessive moisture from the building may be required to maintain a relative humidity that is acceptable to occupants and for the operation of sensitive equipment. Also, in colder climates, dehumidification may be required in humid areas, such as swimming pools, to prevent structural damage during winter due to frost formation in exterior walls.

Air Circulation

Air movement is required in each space to dissipate body heat from occupants and prevent a buildup of odours, which may develop in stagnant areas.



Filtration

Air filters must remove contaminants, such as dust, dirt, smoke, pollen, and lint, from recirculated and outside air before the air can be introduced into the building.

It may not be necessary for a system to meet all of these requirements to achieve satisfactory performance. Each application is unique; its requirements vary in accordance with geographical location, local weather conditions, type of occupancy, building layout and construction. For example, a small residence located in a moderate climate may only require a source of heating and ventilation for odour control to maintain acceptable conditions for the occupants. Therefore, installation of electric baseboard heaters along exterior walls in each room and a washroom exhaust fan may be adequate for this application.

For a larger residence, in an area with cold winters and hot summers, a more complex system is required to maintain satisfactory conditions on a year-round basis. A forced air system provides heating, air filtration, air circulation, and ventilation. A humidifier can provide humidification during winter, and cooling coils can provide dehumidification in the summer.

Therefore, to analyze which system is best for a building, it is important to determine the basic requirements that the system must provide to achieve satisfactory conditions in the building, and the requirements that are desirable but not essential. Once this is established, the system that best matches these needs can be selected.

CATEGORIES OF AIR CONDITIONING SYSTEMS

Many types and variations of systems have been developed over the years for use in buildings of various sizes and locations. However, these systems can generally be divided into three main categories.

Unitary Systems

Each individual room or zone has a self-contained air conditioning unit; this unit maintains the desired environmental conditions.

Central Systems

Air is filtered, heated, cooled, and humidified or dehumidified in an air-handling unit located in a central mechanical room in the building. The conditioned air is then distributed through supply ductwork to all rooms and zones in the building. The system is mainly controlled in the mechanical room, but supplementary thermostats in each zone may also be provided for improved individual room temperature control.

Combined Systems

Air is conditioned in an air handling unit located in a central mechanical room and is ducted to all areas of the building. However, this system normally provides only ventilation, preheating and cooling. Supplementary equipment located in each zone provides heating and additional cooling if required. Combined systems are usually complex and more costly than central systems, but they provide superior zone temperature control.



OBJECTIVE 3

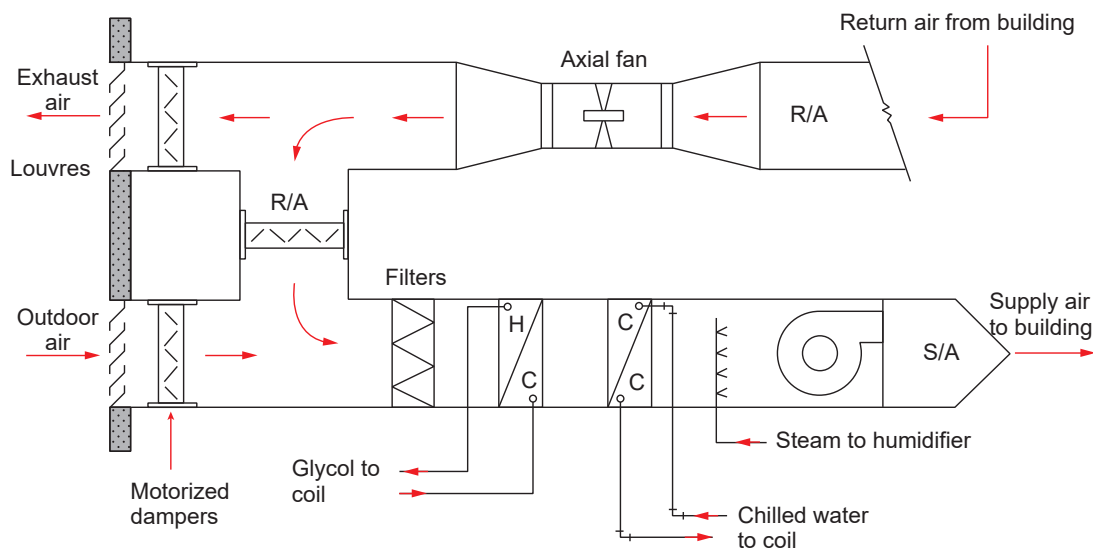
Describe the operation of air handling units.

OPERATION OF AIR HANDLING UNITS

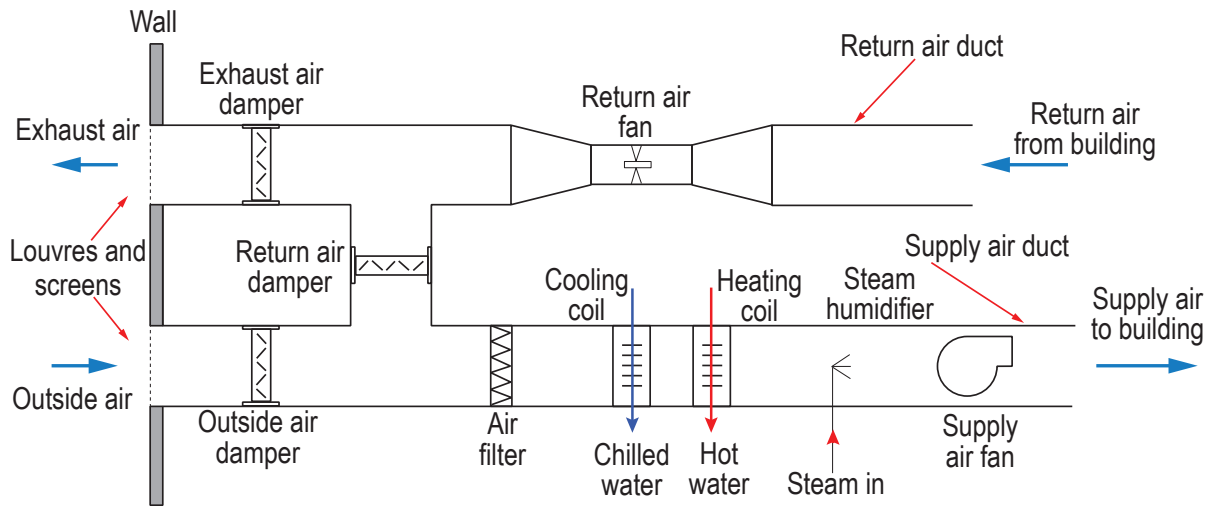
Before analyzing the various types of systems in each category, a discussion of the main components and the operation of air conditioning equipment is required. Regardless of the type of system, the air is mainly conditioned in an [air handling unit](#), such as the one shown in Figure 1. The unit may include a:

- Fan
- Filter
- Humidifier
- Source of heating and cooling
- Motorized dampers for airflow control

Figure 1 – Typical Air Handling Unit



A basic air handling unit consists of a fan, filter, heating coil, cooling coil, and possibly a humidifier or dehumidifier. Many medium to large systems that use return air and mixed air may require an exhaust or return fan to overcome friction losses.

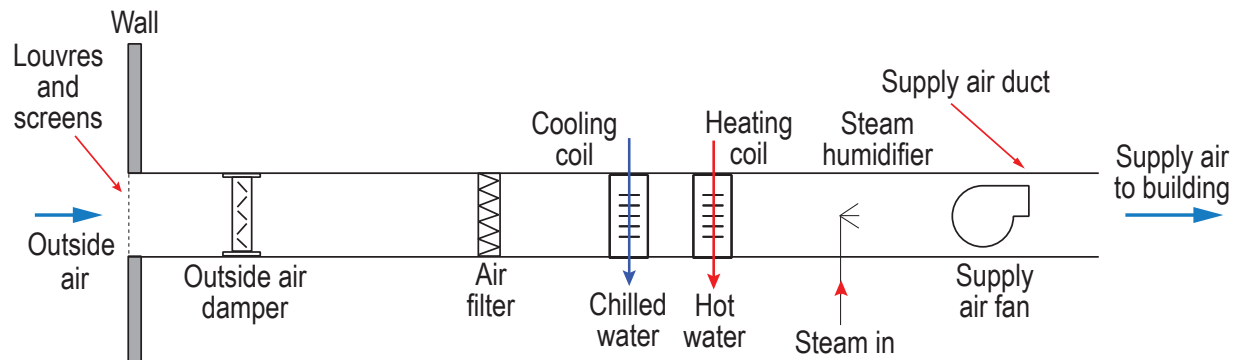
Figure 2 – Basic HVAC Unit


The air first travels through an air filter. Media type filters are most commonly used. Electronic filters are used if the air quality requires higher filtration.

The air needs to be heated or cooled; this is accomplished with heating and cooling coils. Heating coils use steam, hot water, or glycol, though some are electric. Direct and indirect firing are also used. Cooling coils use chilled water or liquid refrigerant to cool and dehumidify the air. After heating or cooling, the air may flow through a humidifier, to bring the air's relative humidity to between 30% and 70%.

A supply air fan forces the air through the system. An exhaust fan draws air from the conditioned spaces. Motorized dampers are used to control airflow through the system.

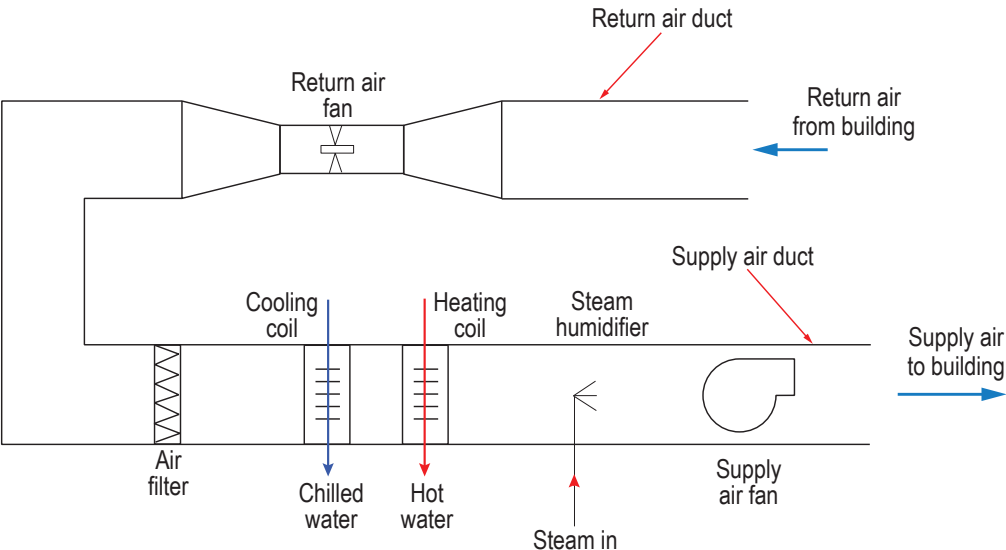
There are many different configurations for air handling units. In some buildings, it is a requirement to draw in 100% make-up air or outdoor air (Figure 3). In this system, the air handling unit will not have any recirculation air. In this building, the operational costs are very high because there is no recirculation at all, but the air will not be muggy, nor will it contain large amounts of odours. Garages, operating rooms, and laboratories usually use this type of system.

Figure 3 – 100% Outdoor Air




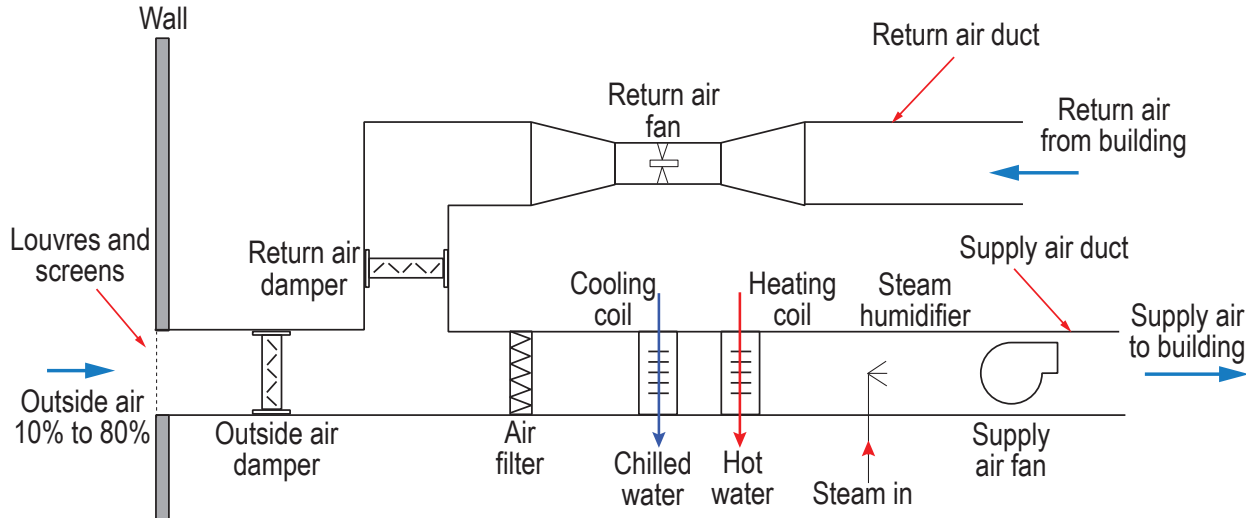
In some buildings, there will be 100% air recirculation (Figure 4). This lowers operating costs because no fresh air needs to be treated. However, over time, the air in the building may feel muggy or stale.

Figure 4 – Full Recirculation



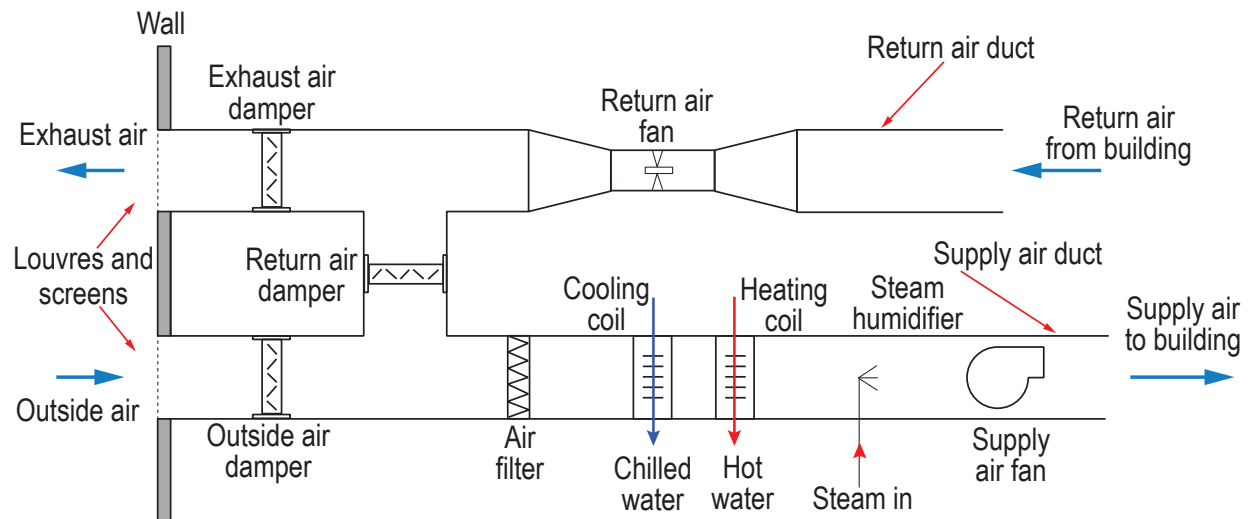
In a fixed outdoor air percentage system, the supply air is drawn through non-modulating dampers. These dampers are affixed to permit anywhere from 10 to 30 percent outdoor air, according to system design. Such a system is shown in Figure 5. These installations are cheaper than those that use variable percentages of outdoor air, because they do not use control systems to modulate the dampers. Fixed outdoor air systems do not respond as well to weather changes as systems that can vary the amount of outside and return air.

Figure 5 – HVAC System with Fixed Outside Air and Return Air Dampers



A variable mixed percentage air handling system will vary the ratio of make-up air to recirculated air based on climate conditions. On a cold winter day, the make-up air percentage is reduced and more air is recirculated. On hot summer days, a higher percentage of outdoor air is drawn into the building. These systems are more costly to install, but they balance human comfort while maintaining reasonable operating costs. These systems are usually installed in many residential, commercial, and industrial buildings.

Figure 6 – Variable Mixed Percentage Air





OBJECTIVE 4

Define the terms humidity, relative humidity, and dew point.

COMPOSITION OF AIR

Pure dry air is an invisible, odourless, and tasteless mixture of gases that surrounds the earth. It consists mainly of oxygen and nitrogen, together with traces of carbon dioxide, hydrogen, argon, helium, and some other gases. However, these trace gases may be ignored. The composition of dry air is generally taken to be 23.2% oxygen and 76.8% nitrogen by mass, and 21% oxygen and 79% nitrogen by volume.

Completely pure and dry air does not exist in nature. Dust, smoke, bacteria, pollen, and fumes are some of the contaminants most commonly found in the air. Atmospheric air also contains moisture, in widely varying amounts. Desert air contains little moisture and is thus very dry. On the other hand, in some coastal areas and in tropical forests, the air is so moist that one can feel the wetness in the atmosphere.

All these factors are of prime concern in air conditioning. Although the control of the air temperature plays a major role in comfort air conditioning, removal of contaminants and control of moisture are of nearly equal importance.

Humidity

Humidity is the term used to describe the presence of moisture in the air. It should be recognized that moisture in the air is not in the form of droplets, but it is water that has been evaporated into vapour, which is thoroughly mixed with the air and occupies the same space. Water vapour in the air is thus actually low-pressure, low-temperature steam.

The question can be asked: “How can there be steam at atmospheric pressure while the temperature is well below the boiling point of water?” The answer is that while the mixture of air and water vapour is at atmospheric pressure, the water vapour itself is not. It is actually at an extremely low pressure. It is known that the temperature at which water vaporizes gets lower when the pressure is reduced, and water will vaporize into steam even at temperatures down to 0°C, provided the pressure is low enough.

Absolute or Specific Humidity

Absolute humidity is the actual mass of moisture present in a specific amount of air. In the SI system, absolute humidity is expressed in kilograms per kilogram of dry air.

Relative Humidity (RH)

Relative humidity is the ratio of the mass of moisture contained in a given amount of air to the maximum amount of moisture this air can contain at that temperature. It is usually expressed as a percentage.

Relative humidity and temperature are inversely related. When the temperature goes up, the relative humidity will drop, and when the temperature drops, the relative humidity will increase. A basic formula for calculating relative humidity is:

$$\frac{\text{actual } m_{H_2O}}{\text{max } m_{H_2O}} \times 100\% = RH$$



Because the amount of water vapour that air can hold depends on the temperature of the air, changes in temperature will result in changes in relative humidity, provided the absolute humidity remains constant (in other words, no moisture is added to or taken away from the air). The relative humidity will decrease when the temperature of the air-water vapour mixture is increased. Conversely, the relative humidity will increase when the temperature is decreased.

Dew Point

If moist air is cooled down to the point where the amount of water vapour it contains equals the maximum amount the air will hold at the lower temperature, the mixture has reached its **dew point**. At this point, the relative humidity becomes 100%, and the mixture is said to be saturated. Any further reduction in temperature will cause some of the water vapour to condense, since the moisture holding capacity of the air decreases as the temperature is reduced.

The dew point can thus be defined as the temperature at which air subjected to cooling becomes saturated, and below which water vapour will condense from the air.



OBJECTIVE 5

Define the terms dry-bulb temperature, wet-bulb temperature, wet-bulb depression, and how they relate to relative humidity.

DRY-BULB TEMPERATURE

When a liquid-in-glass thermometer is used to measure the temperature of the air, the temperature sensitive element of the thermometer (the bulb) is dry. The temperature of the air measured with an ordinary thermometer is called the **dry-bulb temperature**.

WET-BULB TEMPERATURE

Wet-bulb temperature is the temperature indicated by a thermometer that has its bulb covered by a water-wetted wick, which is exposed to a stream of rapidly moving air. The wet-bulb thermometer therefore, measures the dry-bulb temperature, and then subtracts the cooling effect of evaporation.

WET-BULB DEPRESSION

The rate of evaporation of the moisture in the wick depends on the humidity in the air. If the air is dry, and thus has a low relative humidity, evaporation will be fast and the wet-bulb thermometer will show a temperature considerably lower than the dry-bulb temperature. If the air is quite moist, and thus has a high relative humidity, evaporation will be slow and the wet-bulb temperature will only be slightly lower than the dry-bulb temperature.

The difference between the dry-bulb temperature and the wet-bulb temperature is called the **wet-bulb depression**.



CHAPTER SUMMARY

From the above discussion, the learner should be aware that maintaining a comfortable atmosphere that pleases the majority of the occupants in a building is no easy matter. However, a good understanding of the factors that affect comfort and the variations that may be required will put the building operator in a better position to deal with complaints. The following points should be considered.

- a) Consider the impact of effective temperature, air velocity, and relative humidity, on occupant comfort.
- b) Consider the variations between temperature desired by men and women or by different age groups.
- c) Consider the physical activities of the occupants.
- d) Remember the effects of radiant heat.
- e) Keep the effective temperature higher when most occupants only spend a short time in the building.

It is not possible to satisfy everyone. Tests show that 2% of the people will not be satisfied no matter how the conditions are changed; and that satisfaction with the comfort conditions may vary from day to day depending on personal, physical, or psychological changes.

Do not try to satisfy one person in a group occupying a space by raising or lowering the temperature; doing so could upset everybody else. Rather try to satisfy this individual by finding a warmer or cooler spot in the room, or by adjusting an air register to supply more or less air to this person.



CHAPTER 2

Humidification

LEARNING OUTCOME

When you complete this chapter you should be able to:

Explain the equipment and principles of humidification.

LEARNING OBJECTIVES

Here is what you should be able to do when you complete each objective:

- 1. Describe the general purpose and principles of humidification.*
- 2. Describe residential and warm air types of humidifiers.*
- 3. Describe industrial and commercial types of humidifiers.*



CHAPTER INTRODUCTION

The maintenance of human comfort is one of the Power Engineer's key responsibilities. Two of the most important operating parameters directly related to human comfort are temperature and humidity.

OBJECTIVE 1

Describe the general purpose and principles of humidification.

HUMIDIFICATION

To help understand the humidification process, it is important to review the terms humidity, **specific humidity**, and relative humidity (RH). Humidity is the term used to describe the presence of moisture in the air. Specific humidity is the actual mass of moisture present in a specific amount of air. Relative humidity is the ratio of the mass of moisture contained in a given amount of air to the maximum amount of moisture this air can contain at that temperature.

News stations report humidity as relative humidity. For example, the air may be -18°C with an RH of 100%. However, the specific humidity at -18°C is quite low, because cold air does not hold much moisture. Table 1 shows the maximum amount of moisture that the air can hold at various temperatures.

Air temperature affects relative humidity. If specific humidity remains constant and the air temperature increases, then RH decreases. To maintain a constant RH, moisture must be added to the air when its temperature increases.

The opposite is also true. If specific humidity remains constant and the air temperature decreases, then RH increases. To maintain a constant RH, moisture must be removed from the air when its temperature decreases.

In the winter months, if the outside air temperature is low, then the actual mass of water vapour the air can hold is also low. This makes the air feel very dry. The air that is brought into the building must be heated. If only heat is added to the air, the relative humidity of that air will decrease. Therefore, the air will feel drier even though the mass of water vapour remains unchanged.

The purpose of humidification is to increase the relative humidity of the air. The humidification process adds moisture to heated air. In the winter months, this will increase the human comfort.

Effects of Dry Air

Dry indoor air can cause nose and throat membranes to dry, which causes discomfort and dry cracked lips. Dry air also causes a static electric charge to build up on people walking on a wool or nylon carpet. The result may be an electric shock caused by the discharge of this static electrical charge, when any metallic object, or even another person, is touched.

Wood furniture and floors dry out and become squeaky, and plants wither. Dry air also increases the evaporation of moisture on the skin, resulting in a cold and uncomfortable feeling, even if the room temperature is sufficiently high. All these symptoms are caused by lack of humidity in the air.

The word humidity refers to water vapour or moisture in the air. Air absorbs moisture; the amount of moisture depends on the pressure and temperature of the air.

Since only air at atmospheric pressure is dealt with here, the effect of pressure may be ignored, but air temperatures affect the humidity considerably. The higher the temperature of the air, the more moisture it can absorb; conversely the lower the temperature, the less moisture it will hold.



Table 1 – The Effects of Temperature on the Maximum Amount of Moisture Air Can Hold

Temperature of Air (°C)	Max Moisture (kg of water vapour/kg of dry air)
30	0.0273
21	0.0157
5	0.00505
-18	0.0008

It is apparent that as the temperature of the air drops, the maximum amount of moisture the air can hold decreases. The opposite is also true. If the air temperature rises, the maximum amount of moisture it can hold will also rise.

Relative Humidity

Assume a kilogram of air at 21°C contains 0.0075 kg of moisture. This is only 50% of the maximum amount of moisture this air can absorb; thus the relative humidity of this air is 50%. Hence the definition of relative humidity: the amount of moisture contained in the air compared to the maximum amount of moisture the air is capable of holding at the stated temperature. Relative humidity is expressed as a percentage.

For example, consider 1 kg of air at 5°C, saturated with moisture. It holds 0.005 kg of moisture and has a relative humidity of 100%. If this air is heated up to 21°C, but no moisture is added, the relative humidity of the heated air will then become 31.8%.

$$\frac{\text{Actual } m_{H_2O}}{\text{Max } m_{H_2O}} \times 100\% = RH$$

$$\frac{0.005 \text{ kg of water vapour per kg of dry air}}{0.0157 \text{ kg of water vapour per kg of dry air}} \times 100\% = 31.8\%$$

When the air temperature is raised without the addition of moisture, the relative humidity drops. This explains why indoor air can get so dry during cold weather, even though air at the outside temperature is saturated.

Outside air is continually drawn into a building for ventilation purposes, and is heated either directly in the heating system or by mixing with room air. Its relative humidity drops sharply, which causes dryness in the building.

For example, assume the outside temperature is -18°C and the relative humidity is 100%. This air is drawn into the building and heated up to 21°C. Since the air only holds 0.0008 kg of moisture, its relative humidity at 21°C is only 5.1%.

$$\frac{\text{Actual } m_{H_2O}}{\text{Max } m_{H_2O}} \times 100\% = RH$$

$$\frac{0.0008 \text{ kg of water vapour per kg of dry air}}{0.0157 \text{ kg of water vapour per kg of dry air}} \times 100\% = 5.1\%$$

Heating the air made it extremely dry.



In order to maintain comfortable conditions inside a building during the heating season, it is necessary to add humidity to the air. From a health standpoint, relative humidity (RH) between 35% and 50% is desirable. However, in colder climates, these levels of humidity may create a condensation problem on the cool surfaces of windows, walls, and ceilings, which can result in damage to the structure. In order to prevent condensation during cold weather, a compromise is often made by reducing the RH. In newer buildings equipped with good insulation, vapour barriers and double-glazed windows, a higher RH can be carried before condensation occurs.

Each building is different in construction, so there are no set rules for proper relative humidity; however, Table 2 provides some general guidelines. It gives the outdoor air temperature and the recommended indoor relative humidity that can prevent condensation. Keep in mind that some modern buildings are designed to allow a higher RH.



On Track

When a slight condensation appears on the corners of the windowpanes, the RH inside the building has reached its maximum permissible value in relation to the outside temperature. If the outside temperature decreases, lower the set point for the humidity controller. Some building management systems automatically adjust the relative humidity according to the outside air temperature.

Table 2 – Relative Humidity

Outdoor Temperature (°C)	Relative Humidity (%)
-29	20
-23	25
-18	30
-12	35
-6.5	40+



OBJECTIVE 2

Describe residential and warm air types of humidifiers.

RESIDENTIAL AND WARM AIR SYSTEM HUMIDIFIERS

Normal living processes create a certain amount of moisture, such as cooking, washing, and breathing. This amount, though, is usually insufficient to maintain the required relative humidity. Additional moisture needs to be supplied by means of humidifiers.

A residence equipped with a warm air heating system is easy to humidify. Simply install a single humidifier in either the furnace plenum or in the warm air supply duct; this can provide all of the required moisture. However, this type of humidifier does not work in a residence with a non-ducted heating system, such as those that use steam, hot water, or electric radiant heat. For non-ducted systems, each heated area will require its own separate humidifier.

Types of Residential and Warm Air System Humidifiers

There are three types of humidifiers used for residential purposes:

1. Pan
2. Wetted element
3. Atomizing.

Pan Humidifier with Plates

This humidifier consists of a shallow pan (or tray) partially filled with water. Absorbent plates are placed in a vertical position in the tray, and their lower part is immersed in the water. The water is drawn to the surface of the plates by [hygroscopic](#) action. The warm air passing over the plates causes the water to evaporate, and the vapour is carried off by the air. A float valve automatically controls the water level in the tray.

Wetted Element Humidifier

The wetted element humidifier uses a water saturated evaporation pad, through which warm air is forced. The pad can be either flat or cylindrical. The water is supplied to the flat pad either by gravity from a distribution pan above the pad, or by a spray. A solenoid valve controls the water supply to the pad.

Cylindrical pads rotate through a tray partially filled with water. A float valve controls the level of water in this tray.

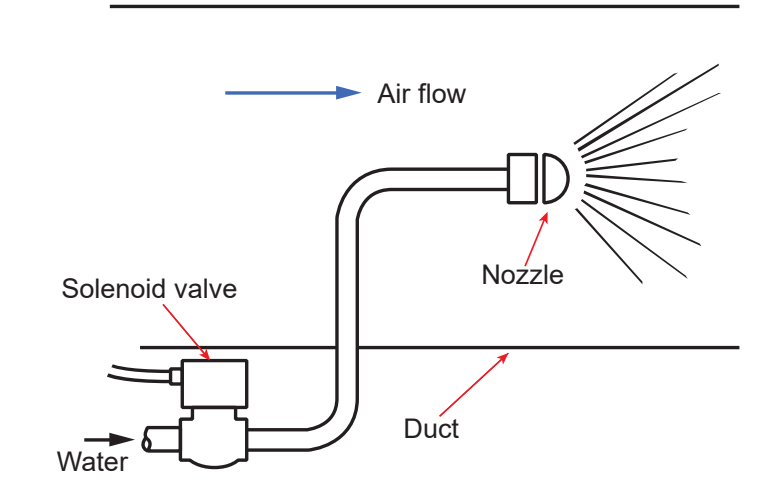
Atomizing (Spray) Humidifier

In an atomizing humidifier, water is broken into small particles by using either a spinning disc or cone, or a spray nozzle.

In a spinning disc humidifier, a rapidly rotating disc atomizes the water into a fine mist. This unit is usually used as a room unit; it can be either portable or stationary.

In a spray humidifier (Figure 1), water is forced through a nozzle at high pressure. The pressure of the water converts to velocity, and the increase in velocity breaks the water up into a fog, which is then absorbed by the air. This is similar to closing the valve on a garden hose to have a fine spray of water. The water is sprayed into the warm air supply duct or directly into the area to be humidified. A humidistat controls the water supply to the spray by means of a solenoid valve.

Figure 1 – Spray Humidifier



Maintenance of Residential and Warm Air System Humidifiers

Most water contains dissolved mineral salts. When the water evaporates in the humidifier, these salts stay behind in the evaporation plates and pads. The salts can build up to such an extent that clogging occurs, and prevents proper evaporation from happening.

The humidifiers need to be cleaned in order to keep them in top condition.

1. To clean the plate units, soak them in a slightly acidic solution, and then wash them in soapy water.
2. Clean the tray or pan to remove salt buildup.
3. Check the float and solenoid valve for leakage.

The spray nozzle of an atomizing humidifier can easily plug if solids are present in the water supply. The use of a fine screen in the supply line is recommended. Check the nozzle regularly for proper atomizing action. Clean the nozzle and screen when necessary.

The disadvantage of an atomizing humidifier is that the water sprayed into the air contains salts in the solution. These salts appear as a fine white dust that settles into ducts and rooms. Regular cleaning is required to remove this dust. If the water is softened by ion exchange, there will be an increase in residue, because the magnesium and calcium salts will be replaced by sodium salt.

On Track

Check the manufacturer manual for the operating, maintenance, installation, and troubleshooting guides.



OBJECTIVE 3

Describe industrial and commercial types of humidifiers.

INDUSTRIAL AND COMMERCIAL HUMIDIFIERS

Humidifiers used in large ventilation or air conditioning systems are more sophisticated than those used in smaller warm air heating systems. This section describes some of the more common humidifiers used in industrial and commercial HVAC systems.

Types of Industrial and Commercial Humidifiers

There are three basic types of humidifiers used for HVAC systems:

1. Air washers
2. Steam grid humidifiers
3. Pan type humidifier

Air Washers

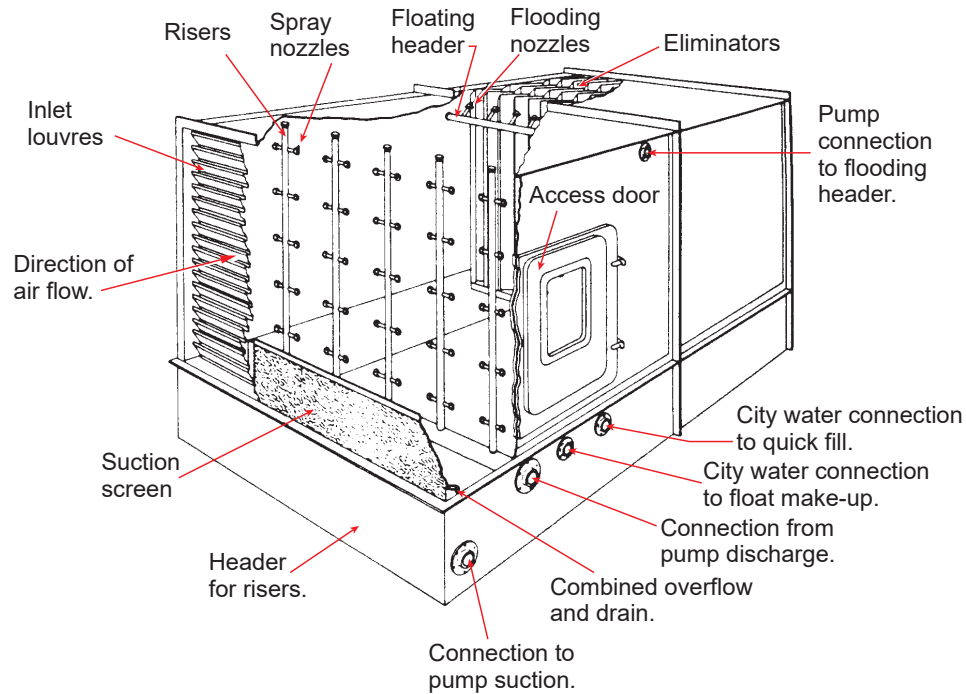
The air washer is one of the most versatile pieces of equipment used in an HVAC system. Its main purpose is to humidify the air, but it also serves to

- Heat
- Cool
- Dehumidify
- Clean the air

A side view of an air washer/humidifier system is shown in Figure 2. It consists primarily of a casing and a spray chamber, in which a bank of spray nozzles is installed. Other washers have two or even three banks of sprays for increased efficiency.

The air flows through the spray chamber and comes in contact with the spray water. The air humidity increases, but the air stream entrains some water droplets. Eliminators, at the outlet of the washer, prevent the air from carrying away droplets of water. These eliminators are designed to change the direction of the airflow several times; this causes the droplets to impinge and run down the surface of the eliminators and into the bottom of the tank.

Dust particles also strike the surface of the eliminators. A continuous stream of water from the flooding nozzles washes the dust down. The air washer also removes some odours, but it is not effective in the removal of greasy particles, soot, or tobacco smoke.

Figure 2 – Single Bank Air Washer Humidification System


The spray water collects in the bottom tank, and a pump usually recirculates the water back to the sprays. A float-controlled make-up valve maintains the water level in the tank.

An air washer should be installed on the suction side of the fan, where it can be maintained at a pressure slightly below that of the atmosphere, in order to avoid leakage of water through the joints.

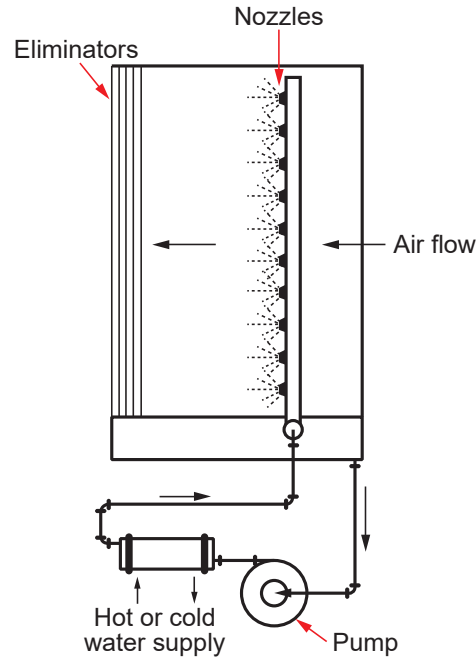
When using the air washer for humidification, the spray water must be heated above the dew point temperature of the entering air. When using the air washer for both heating and humidification, the spray water must be heated above the dry bulb temperature of the entering air.

Conversely, when the air washer uses spray water that is cooled to a temperature below the dew point temperature of the entering air, cooling and dehumidification is achieved.

When using the air washer, as in the two examples above, the Power Engineer can have considerable control over the air temperature and humidity level.

The following methods are used in order to maintain the spray water at the desired temperature:

- Only part of the spray water is recirculated, hot or cold water is added as required.
- The spray water is recirculated through a heat exchanger and is either heated or cooled by hot or chilled water. Figure 3 illustrates this method.
- A heating or cooling coil is mounted directly in the sump of the washer.

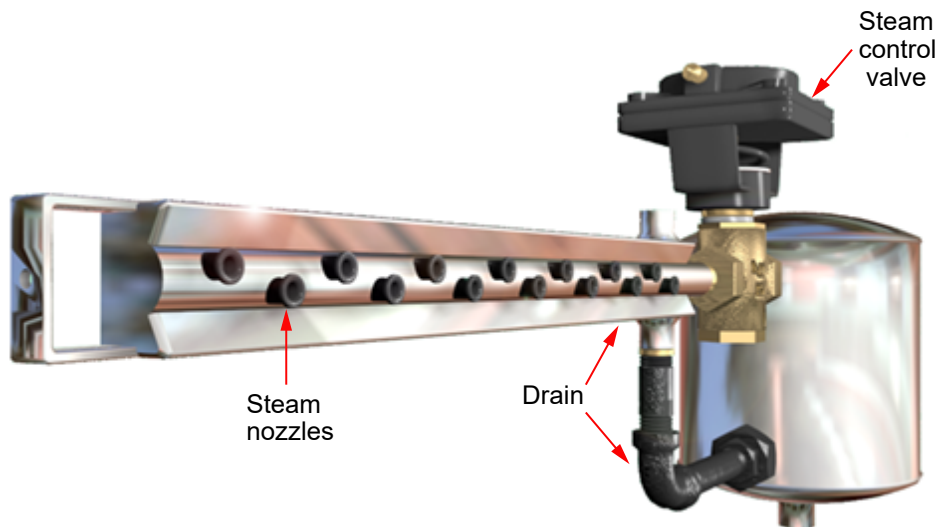

Figure 3 – Single Bank Air Washer with Temperature Controlled Recirculation


Steam Grid Humidifier

When steam is available, humidification can be achieved with a steam grid humidifier by injecting steam into the supply air stream.

The steam grid humidifier, as illustrated in Figure 4, comes complete with a drain pan to catch the condensate droplets.

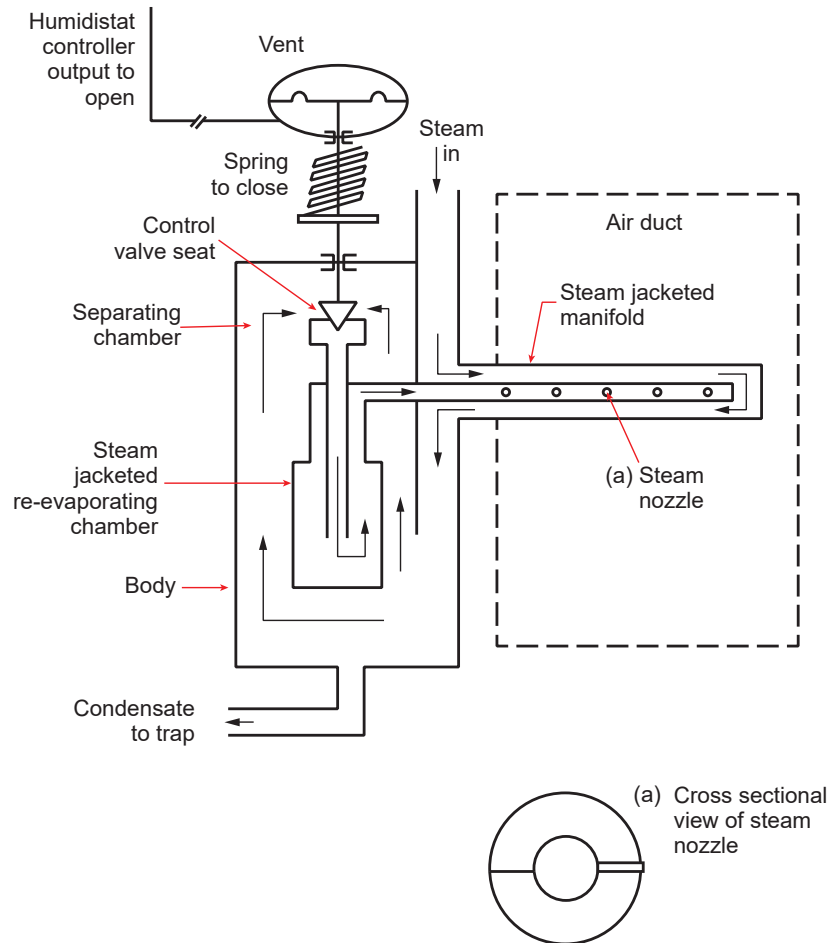
To achieve satisfactory results, the steam pressure should be in the range of 35 kPa to 70 kPa; this will prevent splashing of condensate and an objectionable increase in the temperature of the supply air. A steam modulating control valve, actuated by a humidistat located in the room or in the return air stream, will regulate the humidity.

Figure 4 – Steam Grid Humidifier


Do not use an on-off control with a steam grid humidifier. The control can cause fog, overheating, and wide fluctuations in the relative humidity would occur.

A schematic diagram of a steam grid humidifier is shown in Figure 5.

Figure 5 – Schematic Diagram of a Steam Grid Humidifier



In the steam grid humidifier, steam is supplied to the steam jacket of the distribution manifold at supply pressure and temperature. From there, it flows into the separating chamber. The baffle at the entrance of the chamber knocks down any condensate formed in the supply line or manifold jacket. The drain leg collects the condensate and the trap removes it.

The steam then flows upward to the control valve, which regulates the supply of steam to the manifold at a pressure slightly above atmospheric. The steam is directed downward, to the re-evaporating chamber. Entrained liquid is separated from the steam by the 180° turn the steam must make before it can enter the manifold. The separating chamber has a higher pressure and temperature. Since the re-evaporating chamber is surrounded by the steam in the separating chamber, the separated liquid is re-evaporated.

The dry low-pressure steam then flows into the distribution manifold. The manifold is almost completely surrounded by the supply steam flowing through the jacket; therefore, the steam will exit through the openings in the manifold into the air stream, completely free of any condensation.

The steam is supplied directly by a steam boiler, or by a secondary steam boiler. The latter is referred to as clean steam humidification.

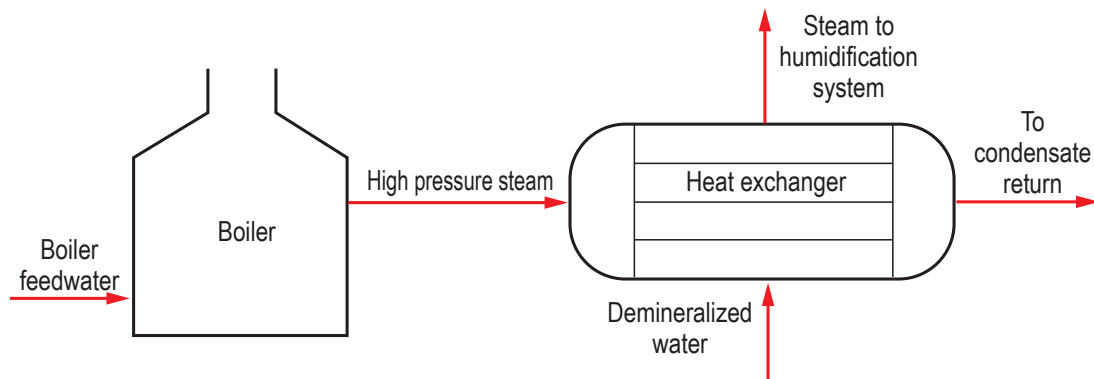


Steam used for humidification can cause health problems, if it contains chemicals such as amines. Neutralizing and filming amines circulate with the steam. If steam that is carrying amines is used for humidification, the amines can be inhaled, which negatively impacts human health. Therefore, humidification steam must be of high purity. Boiler chemical treatment companies can recommend treatment chemicals suitable for humidification systems.

Clean Steam Humidification

Clean steam humidification is replacing the traditional methods of generating steam used to humidify the air. This type of humidification uses a heat exchanger supplied with high- or low-pressure steam as the heat source. This heat is added to demineralized water to cause it to boil into low-pressure clean steam. This steam will have no chemicals and no minerals, so will leave no mineral dust or chemicals in the air it has humidified.

Figure 6 – Schematic Diagram of Clean Steam Humidifier System



Clean steam is an expensive method of humidification. It requires a heat exchanger to be used in conjunction with the steam boiler. The piping or fittings that contact the demineralized water or steam must be made of stainless steel.

Clean steam is used in hospitals, archives, pharmaceutical industry, and museums.

Pan Humidifier

The pan humidifier consists of a water pan equipped with a float valve assembly, overflow and drain connections, as well as a steam or electric heating coil in the pan. Moisture is added to the air stream by vaporizing the water in the pan.

This humidifier offers a broad range of capacity. It can be installed inside the casing of an air handling apparatus, inside the supply air duct, or attached to the underside of a duct. Some models come equipped with a fan, which allows remote mounting.

The electrically heated pan humidifier has a low water cut-off switch to protect the heating element from early failure.

The steam heated pan humidifier offers high capacity and accurate humidity control if used with a modulating control valve and the steam pressure does not exceed 103 kPa.

On Track

A properly operating humidity control system can lower heating costs. When less moisture evaporates from the skin, bodies feel warmer. In this way, temperature set points and fuel consumption can be reduced.





Cleaning the Humidification System

When water is used for humidification, Legionella Pneumophila bacteria can grow. Therefore, the humidifier sumps must be kept clean. Two of the most common methods used for cleaning are mechanical and chemical treatments.

The mechanical method flushes the old water from the system and replaces it with fresh water. With the chemical treatments, a batch of biocides is regularly added to the system. To get the best results, use a combination of both methods.

Perform a regularly scheduled swab test, to ensure the system is clean of bacteria. If a swab tests positive for bacterial growth, take the system off line and drain it. Clean the entire system and spray it with chemicals to kill the bacteria. Do another swab test to ensure that the system has been properly cleaned before placing it back on line.



CHAPTER SUMMARY

Power Engineers must be able to identify the various humidification systems in the plant, in order to operate, troubleshoot, and maintain those systems.

This chapter covered the basic principles of humidification. The content included an overview of various systems, how to operate them, and identified potential operating difficulties.

With these principles, the Power Engineer will be able to operate the humidification systems effectively, in order to maintain human comfort.





Fans for Air Distribution Systems

LEARNING OUTCOME

When you complete this chapter you should be able to:

Describe the airflow behaviour and movement of air through distribution systems.

LEARNING OBJECTIVES

Here is what you should be able to do when you complete each objective:

1. *Discuss the theory of airflow and pressure conversions.*
2. *Describe the major types of air handling fans, their construction, and operation.*
3. *Interpret fan performance curves.*
4. *Describe fan motors, drives, and belt guards.*
5. *Describe fan volume controls.*



CHAPTER INTRODUCTION

An air conditioning system consists of a group of components that operate together in a controlled manner to produce specific conditions of the air within a space or a building.

This chapter will discuss fans, methods of airflow control, fan accessories, and fan performance curves. As well, basic principles of velocity and pressure conversions will be covered.

OBJECTIVE 1

Discuss the theory of airflow and pressure conversions.

AIRFLOW

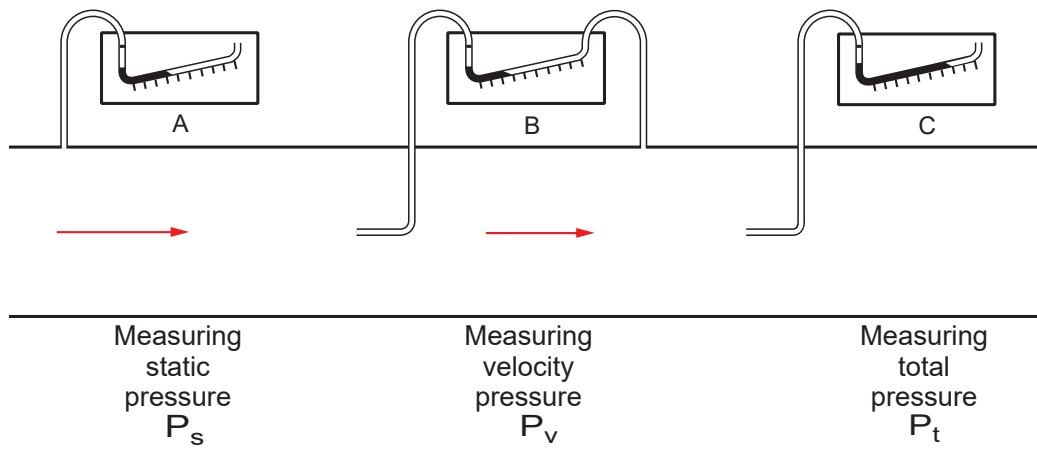
Before taking a look at the various types of fans used in air moving systems, first consider what is involved in air movement.

Fans convert mechanical energy to potential energy, in the form of air pressure. The air pressure at the outlet of the fan will be greater than the air pressure at the outlets of the air handling system. This difference in air pressure will cause the higher-pressure air to flow to regions of lower air pressure. In this case, the air will flow from the fan (high pressure) to the air outlets (low pressure) of the air handling system.

This pressure is normally quite small – slightly above atmospheric pressure. Manometers are used to measure this small pressure. There are three different kinds of pressures developed by a fan: static, velocity, and total pressure. Each can be read separately, depending upon the way the manometer is connected to the outlet duct.

Static pressure (pressure not caused by air movement) is static exerted by the air on duct walls; it is similar to the pressure exerted by steam or water on the interior walls of piping. This pressure can be read by connecting the manometer at right angles to the ducts as shown in Figure 1 (A). It is the static pressure of the air that overcomes the resistance of ducts and filters.

Figure 1 – Measuring Air Pressure in a Duct



Velocity pressure (pressure caused by moving air) is pressure caused by the impact of the air flowing through a duct. It is detected only when it strikes a surface. The velocity pressure will be in addition the static pressure in the system. Assume that the duct in Figure 1 is under pressure but the end is closed off by a damper, so there is no air flow. If a thin metal vane is hung in this duct, the static pressure on either side will be equal, thus the vane will remain in the vertical position. When the damper is opened again, the vane will tip backwards due to the impact of the moving air striking it. This added pressure is velocity pressure.

Velocity pressure can be experienced while driving a car. A hand placed outside an open window will be subject to a force due to velocity pressure. This force varies with the velocity of the vehicle, due to variations in velocity pressure.



By connecting one end of the manometer at right angles to the duct wall and the other end with open facing the airflow, as in Figure 1 (B), the velocity pressure can be measured.

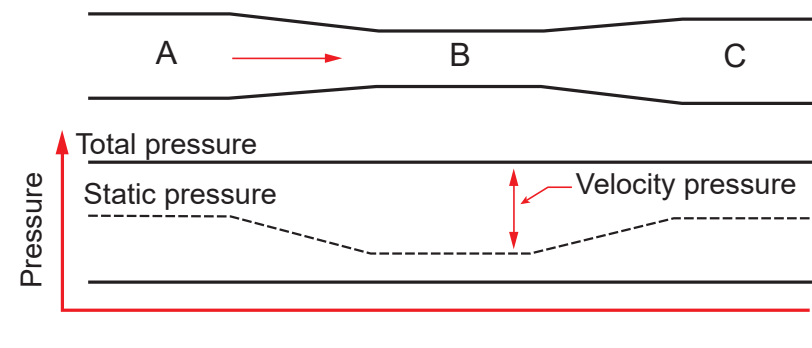
The **total pressure**, the sum of static pressure and velocity pressure can be measured by connecting the manometer, as shown in Figure 1 (C).

$$\text{Total Pressure} = \text{Static Pressure} + \text{Velocity Pressure}$$

PRESSURE CONVERSIONS

The total pressure in the duct shown in Figure 2 remains constant throughout the duct, without losses due to friction or turbulence. Total pressure consists of static pressure plus velocity pressure. Static pressure can be either positive (above atmospheric) on the fan outlet side of the duct, or negative (below atmospheric) on the suction side of the fan.

Figure 2 – Pressure Conversions without Losses



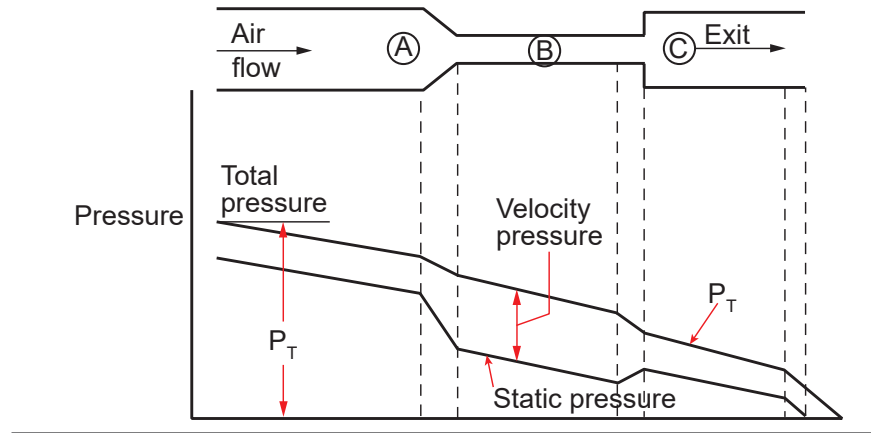
As air passes from A to B in Figure 2, it goes through the converging section which causes the velocity pressure of the air to increase. However, the static pressure drops by an equal amount, so the total pressure remains the same. As the air passes from B to C in the diverging section, both the velocity of air and the velocity pressure will decrease. This loss in velocity pressure converts to a gain in static pressure. Again, the total pressure remains the same. In the diagram, the difference between the total pressure line and the static pressure line is the velocity pressure.

Consider a steam turbine nozzle. In this nozzle, steam pressure and velocity are inversely proportional. When the cross sectional area reduces, the velocity increases, and the pressure decreases. Therefore when the air pressure drops (static pressure) from A to B the velocity and velocity pressure will increase. When the air flows from point B to point C, the cross sectional area increases causing the velocity (velocity pressure) to decrease and the pressure to increase.

In the example shown in Figure 2, frictional losses were ignored. Generally, there will be losses in the converging and diverging sections of the duct since the conversion of pressure and velocity is never 100% efficient, due to the formation of eddy currents. If the transition is gradual enough, eddy currents and turbulence will not form, and pressure recovery will be close to 90%.

Figure 3 shows the actual pressure profile across a duct with an angled converging section (A to B) and an abrupt diverging section (B to C). In the diverging zone, the abrupt angles of the zone cause poor recovery of static pressure, resulting in a loss of total pressure. The pressure lines are generally sloped downward as a result of pressure losses due to friction and turbulence.

Figure 3 – Pressure Conversions with Losses





OBJECTIVE 2

Describe the major types of air handling fans, their construction, and operation.

TYPES OF FANS

Fans are identified into two general groups: centrifugal fans and axial flow fans.

Centrifugal fans: the air flows radially through the impeller. Centrifugal fans are classified according to the shape and design of the fan blades:

1. Backward inclined (BI)
2. Forward curved (FC)
3. Backward inclined with airfoil blades and radial blades (straight)

Axial flow fans: the air flows axially through the impeller. Axial flow fans are not classified by blade shapes, but rather according to the principles on which they are designed. There are three general types:

1. Propeller
2. Tube axial
3. Vane axial

Centrifugal Fans

A centrifugal fan consists of a rotor or wheel, with several radial blades, mounted on a shaft within the fan housing. Another commonly used name for a centrifugal fan is a squirrel cage.

Air enters the fan near the axis of the wheel, and flows to the circumference under the influence of the centrifugal force produced by the rotation. The air discharges through the outlet located tangentially with respect to the fan wheel. The flow of air through the fan is caused by:

- a) The centrifugal force imparted to the air enclosed between the blades.
- b) The tangential velocity imparted to the air as it leaves the tips of the blades.

In order to convert this velocity energy into useful static pressure, the fan housing has a scroll or volute shape, with a gradually increasing cross-sectional area in the direction of the airflow.

The centrifugal fan is somewhat similar to the centrifugal pump in design and operation. The pressure developed by the fan, however, is much lower than that developed by the pump.

Fan Designation (Classes of Construction)

Operating limits have been standardized for centrifugal fans commonly used for heating, ventilating, and air conditioning. Classifications are based on:

- Construction of the fan
- Types of materials used
- Static pressure developed
- Fan speed
- Outlet velocity

Each class number increase represents an increase in the fan speed and air performance capability of the fan. These standards establish the classes of construction outlined in Table 1.

Table 1 – Classes of Construction for Centrifugal Fans	
Class	Construction
Class I	up to 0.94 kPa (9.5 cm/3¾ in W.G.) maximum total pressure
Class II	up to 1.7 kPa (17.1 cm/6¾ in W.G.) maximum total pressure
Class III	up to 3.2 kPa (32.4 cm/12¾ in W.G.) maximum total pressure
Class IV	more than 3.2 kPa

The above classes are based on standard air conditions:

- 21°C
- 101.3 kPa (76 cm Hg) barometric pressure
- A density of 1.2 kg/m³

Any fan duty involving air or gases at other temperatures or altitudes above sea level must be corrected to standard conditions before determining the class of fan required.

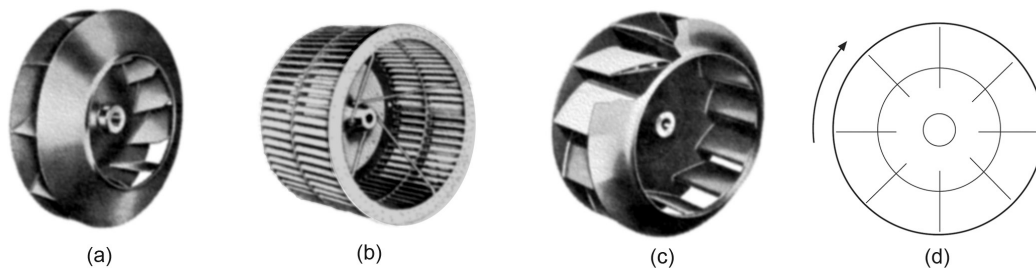
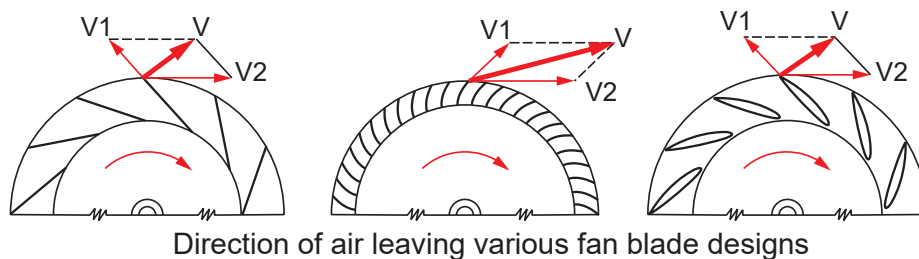
Fan manufacturers must adhere to well-defined standards of construction for each of the above classes of duty in order to obtain certification for their equipment.

Types of Centrifugal Fans

There are four types of centrifugal fans used in air conditioning systems. The main features which distinguish one type of fan from another are the shape of the blades and the way they are inclined.

In Figure 4, the basic blade diagram and an actual view of each type of fan wheel is shown. Figure 4(a) shows a fan wheel with backward inclined (BI) blades; which means that the blades are sloped backward relative to the direction of rotation. Figure 4(b) shows a fan wheel with forward curved (FC) blades. Figure 4(c) shows a wheel with backward inclined airfoil blades. The fourth type of centrifugal fan is the radial blade shown in Figure 4(d).

Figure 4 – Fan Wheels



Each type of blade shown is incorporated in a Fan Wheel



Characteristics

The vector diagrams shown for each fan wheel in Figure 4 indicate that the blades give the air a forward motion in the direction of rotation (horizontal vector V_2), and a motion along the surface of the blades (vector V_1). The direction of vector V_1 is determined by the inclination of the blades and centrifugal force. The resulting vector V shows the forward velocity.

If it is assumed that the wheels in Figure 4 rotate at the same speed, the horizontal vectors V_2 would be of equal lengths, meaning the wheels produce equal forward motion. Since the wheels are rotating at the same speed, the vectors V_1 would also have equal length (because centrifugal forces are equal), but in a direction according to the inclination of the blades. The resulting velocity vector V of the air leaving the forward curved (FC) blades is considerably higher than that of the air leaving the backward inclined (BI) blades.

Because the pressure produced by a fan is proportional to the resulting velocity vector V , it is evident that an FC fan can operate at a much slower speed to produce a pressure equivalent to that of the BI fan. The comparison below illustrates this point.

Consider three centrifugal fans. Each fan is 900 mm in diameter. Each fan delivers 8.166 m³/s of air against 0.625 kPa static pressure (17 303 cfm at 2.5 in. of water pressure). Table 2 compares the power consumed and the rotational speed required.

Table 2 – Centrifugal Fan Comparison

Fan Type	Rotational Speed	Power Consumed
backward inclined fan	810 r/min	6.7 kW (9 hp)
forward curved fan	450 r/min	8.12 kW (10.9 hp)
backward inclined airfoil	815 r/min	6.6 kW (8.8 hp)

This example, with the three fans, illustrates the difference in speed required for each type of fan. It also shows that fans with the backward inclined blades require less power to deliver a specified air volume; therefore, they are more efficient than forward curved fans. Higher efficiencies result in the backward inclined fans being quieter to operate. This conclusion holds true for medium to large sized fans.

In sizes smaller than 600 mm (24 in.) diameter, the high speed of both types of backward inclined fans may require high belt speeds, which cause more noise. Conversely, the lower speed (for the same air volume) of the forward curved design makes them more desirable for small fans.

The above example also illustrates that the backward inclined airfoil fan is more efficient than the backward inclined fan. This is because the aerodynamic shape of the airfoil blades permits smoother airflow through the wheel. However, the magnitude of this difference in efficiency can rarely justify the higher initial cost of the airfoil fan when the system operates in the low-pressure range (lower than 0.75 kPa or 3 in. static pressure). Therefore, the backward inclined airfoil fan is mostly used for high capacity, high-pressure applications, where power savings may outweigh the higher initial cost.

The low rotation speed of the forward curved fan is sometimes highly desirable. For instance, this feature is adaptable to factory-assembled air handling units having two or more fans on a common shaft. The higher speed of the backward inclined fan may require a shaft of excessively large size.

Axial Flow Fans

The flow in axial fans is parallel to the shaft, unlike the centrifugal fan where the air flows radially, away from the shaft.

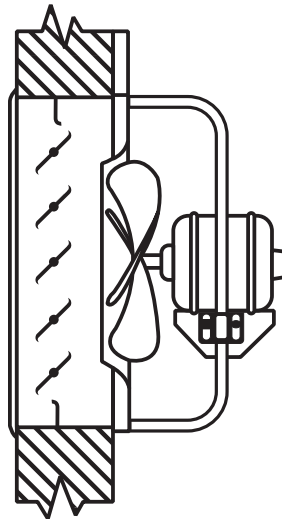
Axial fans are divided into three general types:

1. Propeller Fan
2. Tube Axial Fan
3. Vane Axial Fan

Propeller Fan

Figure 5 shows a shaft-mounted propeller fan driven by a motor, either directly or by a V-belt. The fan is often placed in a mounting ring. The propeller fan has a high air moving capacity, but it is unable to produce high pressures. So this fan is normally selected for pressures in the range of 0.03 to 0.06 kPa (1/8 to 1/4 in. of water). For this reason, it cannot be used in ducted air distribution systems, but it does find widespread application in air-cooled condensers, unit heaters, and as an exhaust fan for ventilation purposes.

Figure 5 – Propeller Fan



The power required by a propeller fan is lowest at maximum air delivery. In contrast, centrifugal fans require maximum power at maximum air delivery. Therefore, the propeller fan is more economical to produce large air movements at low pressures.

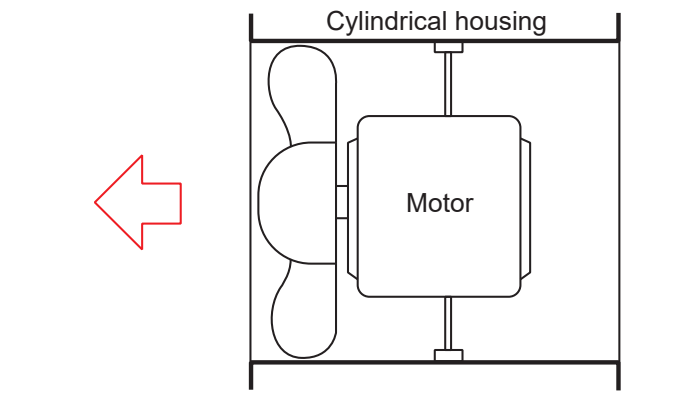


Tube Axial Fan

The **tube axial fan**, as shown in Figure 6, is a heavy-duty propeller fan, suitable to mount on a duct. It will produce pressures up to 0.6 or 0.75 kPa (2 ½ or 3 in. of water). It discharges the air in a spiral motion; therefore, friction losses in the ducts and the system are considerably higher than with the straight airflow produced by the centrifugal fan.

The tube axial fan is also quite noisy; therefore, it is seldom used in commercial air conditioning. This fan is more common for industrial air conditioning applications, where noise is less of an issue. For this reason, this type is often the logical choice for transportation and marine applications.

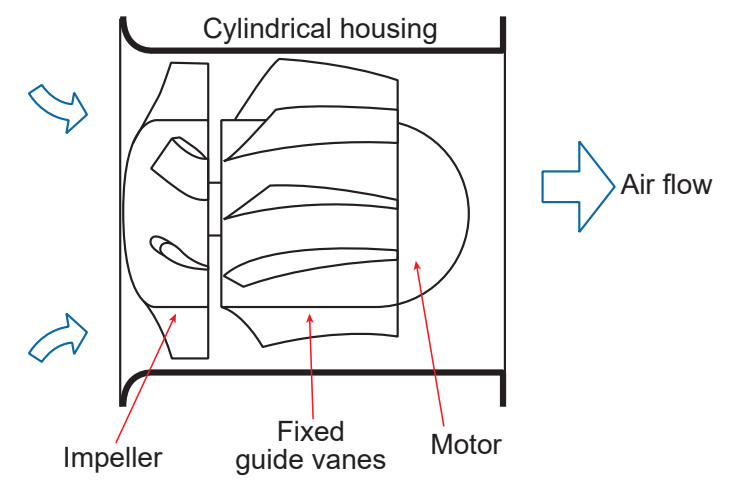
Figure 6 – Tube Axial Fan



Vane Axial Fan

The **vane axial fan**, shown in Figure 7, is a tube axial fan equipped with guide vanes located behind the fan wheel to straighten out the spiral flow of air. This reduces turbulence and friction, and improves efficiency. It is still a relatively noisy fan, so when used in commercial air conditioning, it is necessary to use sound attenuators at strategic locations in the ductwork.

Figure 7 – Vane Axial Fan



Vane axial and tube axial fans are often used when space is a consideration. Both of these fans are usually mounted off the floor; this can present maintenance problems because the fan bearings (and the motor, in the case of direct driven fans) are mounted inside the casing. For this reason, they can be difficult to service or change without the use of ladders or scaffolding.



Troubleshooting

Fan pressure will determine the system operating pressure. If the fan is running normally, at 2 kPa, and the operator finds a pressure of 4 kPa, the operator needs to troubleshoot the system. Closed dampers or some other kind of blockage is likely preventing normal airflow.



OBJECTIVE 3

Interpret fan performance curves.

FAN PERFORMANCE CURVES

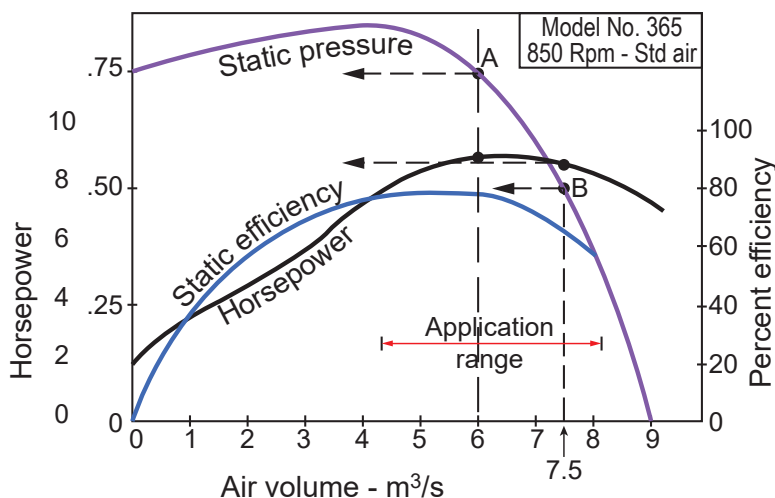
Fan performance curves are obtained from a series of laboratory tests conducted on a fan with various restrictions at the end of the test duct. The test results are illustrated graphically by plotting static pressure, fan power, and static efficiency against the air volume flow rate. Flows vary between full shut-off (closed outlet and zero airflow) and free delivery (fully open outlet and zero fan static pressure). The fan performance curves allow designers to determine the correct fan selection for the system, and allow operators to troubleshoot fan performance issues.

A good understanding of the performance curve characteristics is important when assessing the compatibility of the various fans with different types of applications.

Backward Inclined Fan Curve

The curve shown in Figure 8 is for a BI fan, model #365, operating at 850 r/min, and handling air at standard air density. The pressure-volume curve increases from shut-off, rising to a maximum, after which it decreases sharply to free delivery. Note that in this diagram, the power is measured in horsepower rather than in kW.

Figure 8 – Backward Inclined Fan Curves



The static efficiency curve rises from zero at shut-off, peaks, and then decreases to zero again at free delivery. As indicated, the normal application range for the fan is to the right of the peak of the static efficiency curve.

The power characteristic curve rises from shut-off to a maximum, and then falls off when approaching free delivery, which is why the BI fan is called a non-overloading fan. A non-overloading fan has relatively constant power input requirements for a given speed, and will not change significantly with changing airflow conditions.

Example 1 illustrates this point.

Example 1

Assume that the model 365 BI fan was selected to deliver $6.0 \text{ m}^3/\text{s}$ of air against 0.75 kPa (3 in.) static pressure (point A on the curve in Figure 8). The fan power required is 6.7 kW (9 hp). After the installation was completed, the actual measured static pressure was only 0.5 kPa (2 in.), meaning that the fan was delivering $7.5 \text{ m}^3/\text{s}$ (point B) instead of $6.0 \text{ m}^3/\text{s}$, and the fan power was approximately 6.5 kW (8.8 hp), which is a 3% decrease in power. As will be seen in the following discussion, the results are drastically different when a similar situation occurs with an FC fan.

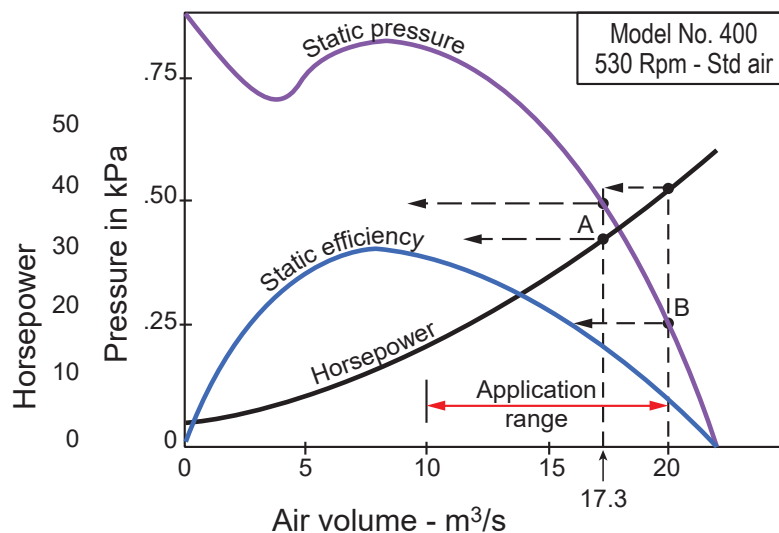
Forward Curved Fan Curve

Figure 9 shows a curve for an FC fan where the static pressure curve falls off slightly as the air volume increases from shut-off; then it rises to a maximum, after which it decreases to free delivery.

The power requirements rise from a minimum at shut-off to a maximum at free delivery. This type of fan is considered overloading. At constant speed, when there are changes to the airflow, the power requirements will increase and cause the fan and motor to overload.

The fan operation can be unstable when operating on the left portion of the curve; therefore, the normal application range for the fan is to the right of the peak of the static efficiency curve.

Figure 9 – Forward Curved Fan Curves



It is interesting to note the difference in the results when an FC fan is subjected to a situation similar to that described in Example 2.

Example 2

A fan is selected to deliver $17.3 \text{ m}^3/\text{s}$ against 0.5 kPa (2 in) static pressure (point A). The corresponding fan power is 26 kW (35 hp).

After installation, the measured system static pressure is 0.25 kPa (1 in.), and the air volume delivered is $20 \text{ m}^3/\text{s}$ (point B). The corresponding fan power is 31.3 kW (42 hp): a 20% increase in power. This example clearly shows the importance of estimating the system pressure accurately.

In order to correct the situation described in these two examples, the fan should be slowed down by adjusting or changing the drive.

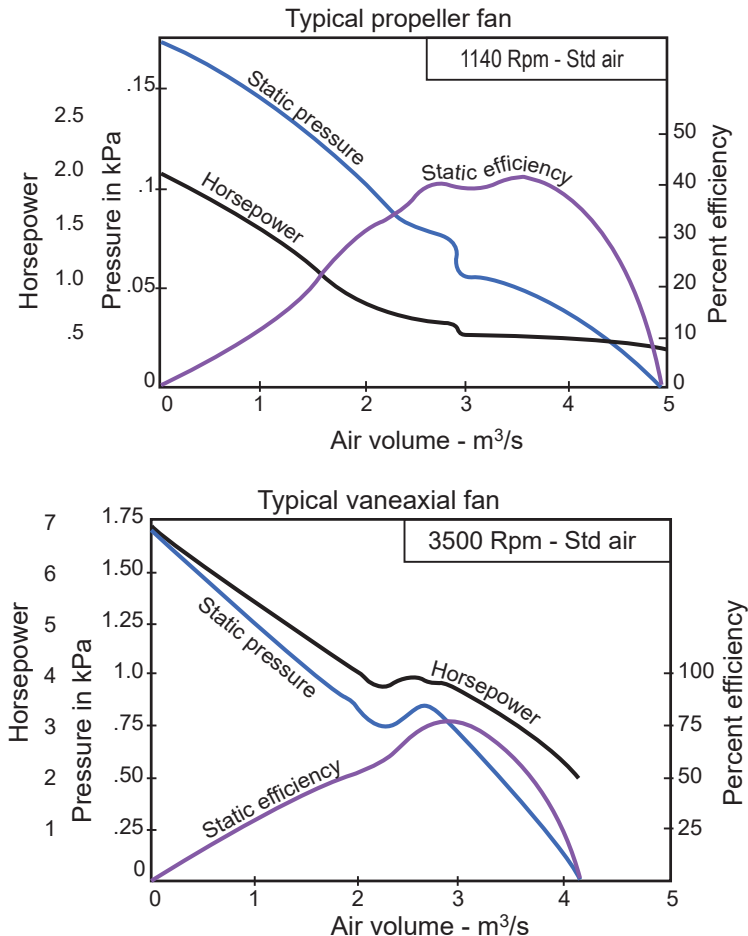


Axial Flow Fan Curves

Figure 10 shows curves for typical propeller fans and vane axial fans. The obvious difference between these curves and the BI and FC curves are the slopes of the horsepower and static pressure curves, which decrease steeply as the static efficiency and volume increase. The propeller and vane axial fans have minimum power requirements at free delivery.

These curve characteristics explain why both of these fans are a logical choice when large volumes of air must be moved at low pressures.

Figure 10 – Axial Flow Fan Curves



Troubleshooting

A building operator will be able to use fan curve data to assist with troubleshooting operational issues. A possible scenario involves a complaint that the building is too hot.

The operator needs to check the heating/cooling system first. If the system is operating properly, check the air delivery system. To check the air delivery system, measure the performance of the fan and motor. Measure the static pressure, fan speed, and motor amperage (to determine power). Verify these values on the fan performance curves to determine if the air delivery system is operating properly. If the actual values do not fit the fan curves, the operator may determine where an adjustment is required to change the air supply to correct the temperature problem.

Performance curves can also assist the operator to determine how changes to the HVAC system may affect air supply to the building.

It is important to determine the characteristics of the building during normal operations. This information will help the operator troubleshoot operational issues that arise.

OBJECTIVE 4

Describe fan motors, drives, and belt guards.

FAN MOTORS, DRIVES, AND BELT GUARDS

Normal torque motors are used for fan duty. The fan motor size must be large enough to handle the maximum brake power of the fan and operate within its rated power. The normal allowable 15% overload factor is reserved for drive losses and reduction in line voltages.

Unless variable speed control (described in the following section) is necessary, the fan drives available are direct drives or V-belt drives.

Direct Drives

A direct drive is normally used on smaller air moving equipment. It is suitable for the following applications:

- a) Systems where the resistance can be determined accurately. For example, in small fan coil units used to heat or cool the perimeter areas of a building.
- b) Systems where exact air quantities are not required; for example, in an installation that uses unit heaters. If there is a shortage of air quantity, it can be counteracted by increasing the amount and pressure of steam, or the amount and temperature of the hot water supply.

V-Belt Drives

The V-belt drive is used on most air conditioning, heating, and ventilation applications. In order to minimize vibration problems and premature wearing of the belts, it is important to use a matched set of belts and good quality balanced sheaves.

It is customary for the manufacturer to supply an adjustable motor sheave and a fixed pitch fan sheave when the motor size is 5.6 kW (7 ½ hp) or smaller. This feature is particularly useful on applications where adjustments may be required to obtain exact air quantities. The adjustable pitch motor sheave is available as an optional feature on drives that use motor sizes 7.5 kW (10 hp) or larger.

Belt Guards

For safety, belt guards are required on all V-belt drives. The guards are made of sheet metal, and have brackets for easy installation. The better quality belt guards have a facing of expanded wire mesh to allow inspection of the belts while they are in motion. These guards also have two tachometer holes which permit measurement of the fan and motor speed without removal of the belt guard. Coupling guards are required for direct drive equipment.



OBJECTIVE 5

Describe fan volume controls.

VOLUME CONTROLS

On large air conditioning and ventilation systems or on large industrial processes (e.g. laboratory exhausts), reducing the air volume handled by the fan during periods of partial loads, such as evenings or weekends, considerably reduces power consumption. Several methods can be used to achieve this goal.

Variable Speed Motor Control

An AC motor can be speed-adjustable by using a variable frequency drive (VFD). The VFD controls the motor input frequency and voltage, which control the motor speed and torque. This is the most efficient method, and the best one from a sound level standpoint; however, it is the most expensive. A careful analysis must be made to determine whether the payback justifies the cost. Although the VFD is expensive, the cost of installation has dropped enough that the payback in energy savings makes the conversion worthwhile.

Fluid Drive

The fluid drive is used mainly on industrial installations (e.g. mechanical draft fans for automatic combustion control). The power savings are comparable to the variable speed motor control, but the initial cost of the fluid drive is equally high. Other advantages of the fluid drive are the simplified starting equipment and the declutching feature, which relieves the driven fan of shock loading during startup.

Outlet Damper Control

The outlet damper control is used on fans with constant speed motors. It is the least expensive method; unfortunately, it is also the least efficient.

Variable Inlet Vane Control

Radial vanes are installed in the fan inlet; the vane shafts are interconnected so all of the vanes rotate in unison and in the same direction. This method reduces energy consumption by controlling the amount of air spin at the fan inlet, thus controlling the static pressure and power requirement at a given speed.



CHAPTER SUMMARY

This chapter introduced the concepts of velocity and pressure conversions, and how pressure is measured in a system.

It showed how to identify the major types of fans used to deliver building air. The performance characteristics of each type of fan were also covered. These characteristics are represented with performance curves that can assist operators to troubleshoot the systems.

This chapter also looked at the various types of fan capacity control methods.



Ventilation and Air Filters

LEARNING OUTCOME

When you complete this chapter you should be able to:

Describe the various ventilation systems, including various types of air filters used in these systems.

LEARNING OBJECTIVES

Here is what you should be able to do when you complete each objective:

- 1. Explain the difference between natural and mechanical ventilation.*
- 2. Describe the various contaminants found in air.*
- 3. Describe the types of air cleaning devices used in industrial/commercial buildings.*



CHAPTER INTRODUCTION

In order to maintain comfortable conditions in a building, it is necessary not only to maintain a reasonable temperature, but to also supply fresh, clean air and remove stale air from occupied areas; this is called ventilation.

Ventilation may also be necessary to prevent condensation on walls and windows when there is excessive moisture in the air, from cooking or showering; or by evaporation in areas such as laundries and swimming pools.

The amount of ventilating air required depends on the number of people occupying a space, their activities, the volume of the space, and the duration of the stay of the occupants in that space. When the space is large with respect to the number of people occupying it, and their stay is relatively short, the ventilation rate can be low. On the other hand, the ventilation rate in a small space occupied by a large number of people should be high, especially when their stay is extended.

Actual ventilation rates vary from 0.14 to 1.5 m³/min per person. However, even if occupancy is low, a minimum of about one air change per hour is recommended for most occupied areas. This means that all of the air in the occupied space is exchanged with fresh air once per hour.

In earlier days when buildings were not built tightly, much of the required air seeped in through door and window openings and the cracks around them. However, since modern buildings are much tighter and air leakage has been reduced to a minimum, other means have to be used to achieve proper ventilation.

This chapter covers the different types of ventilation systems used to provide the proper amount of ventilation to meet the needs of the building users. It also covers how to clean the air that will enter the building and what kind of contaminants will need to be filtered out.

OBJECTIVE 1

Explain the difference between natural and mechanical ventilation.

METHODS OF VENTILATION

Ventilation is the process of supplying a room or building with fresh air, to replace the stale or noxious air that exists in that space. Ventilation is a key component of maintaining a high level of human comfort. When the air becomes stale, contains odours, or is noxious, comfort levels drop, and the occupants of the building will complain.

Power Engineers need to be familiar with different methods of ventilating, and recognize that the system must be able to achieve a certain rate of air change. The ventilation rate is determined by the volume of occupied space over a one hour period of time. Another commonly used term for the ventilation rate is “air changes per hour.”

Each building is required to achieve a minimum number of air changes per hour in order to meet building codes. This value is based on the following factors:

- Number of occupants
- Activities
- Type of contaminants encountered

The Power Engineer must operate the ventilation system in such a way that there is a balance between energy efficiency and human comfort.

The admission of fresh air into a room should be such that:

- The air spreads evenly over the whole area, to prevent stagnant pockets of air.
- The air does not strike directly on the occupants.

Ventilation can be divided into two basic methods:

1. **Natural:** air movement is caused by the effect of temperature difference or wind.
2. **Mechanical:** air movement is caused by a motor-driven fan or blower.

Natural Ventilation

In many small buildings with low occupancy rates, such as older residences, small offices, and shops, ventilation is achieved mainly by opening windows. This method is not very efficient because it often creates cold drafts on the floor, and it does not effectively remove the stale, warmer air in the upper part of the room, especially when the window is at a low level.

Another disadvantage of **natural ventilation** is that the building using such a system will not be able to achieve a number of air changes per hour easily. Most buildings today do not rely on this method of ventilation.

Mechanical Ventilation

New building codes require that a main or principal exhaust fan be installed to ensure proper ventilation. **Mechanical ventilation** systems can be divided into three groups, according to the way the fan or blower is used to move the air:

- Natural Air Intake, Mechanical Exhaust
- Mechanical Air Intake, Natural Exhaust
- Mechanical Air Intake, Mechanical Exhaust



Natural Air Intake, Mechanical Exhaust

A motor driven fan draws stale air out of rooms. Fresh air comes into the rooms through windows or air intakes.

The disadvantage of this ventilation system is that the fresh air drawn into the building through windows is neither filtered nor heated. The exhaust fan creates a pressure in the building slightly lower than the atmospheric pressure when air cannot freely enter the building. This will result in infiltration of outside air around doors and windows, and may cause cold drafts in winter. There is also the risk of back venting gas-fired appliances if the exhaust fan overpowers the natural chimney effect. This can cause products of combustion to enter the space.

In larger buildings, bathroom and kitchen exhaust outlets are often connected to a common duct system. A roof-mounted centrifugal fan draws the exhaust air into the ducts and discharges it above the roof.

The advantages of a common exhaust duct system are its simple design, relatively low cost, ease of maintenance (there is only one fan), and fume disposal is away from windows and air intakes. This system also allows for installation of an air-to-air heat exchanger, to recover heat from the exhaust air stream and warm up the fresh intake air.

The disadvantage is low energy efficiency. The one fan must run continuously, and will continually draw air from the building, even if there are no requirements to exhaust the air from the building. In recent improvements, the main exhaust only runs when one or more other fans have started. As the exhaust system draws the air from the building, the make-up air system is required to add more air to the building. This increases the volume of air that requires treatment, and adds to the operational costs for the building.

Mechanical Air Intake, Natural Exhaust

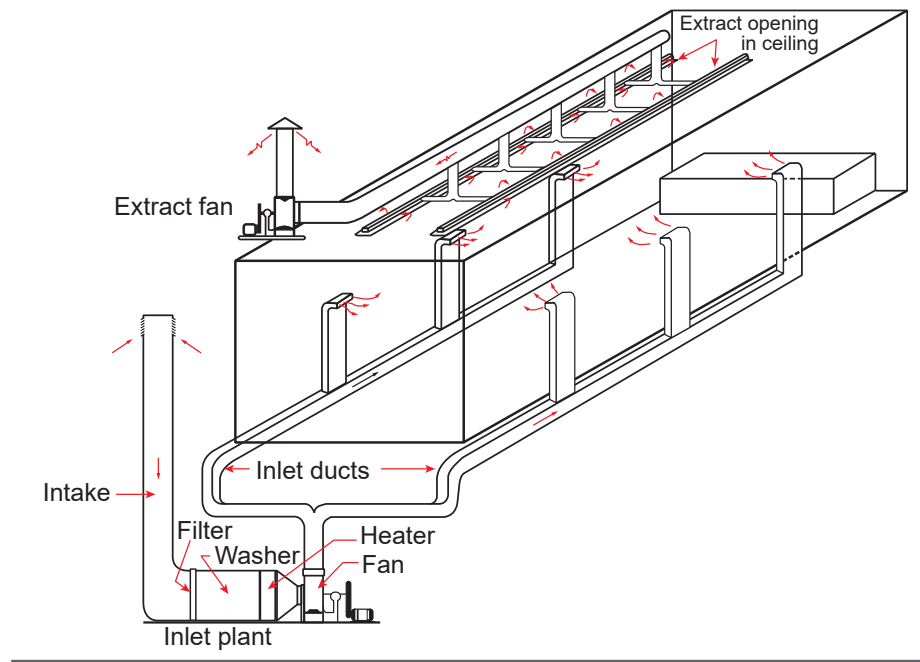
A fan or blower forces fresh air into the building and moves the stale air out through the windows or air outlets in outside walls or the roof. This system keeps the pressure in the building slightly higher than atmospheric pressure, to prevent infiltration. The fresh air can be supplied by:

- a) A propeller fan mounted in the outside wall. The air blown into the building by this type of fan is usually neither filtered nor heated.
- b) A fresh air supply duct installed in a warm air heating system. This duct is connected to the return air duct or plenum. The blower draws in a controlled amount of fresh air and mixes it with the return air. The mixed air passes through the filter, and then is heated and distributed through the building.
- c) A unit ventilator, which circulates, filters, and heats the room air. It also draws in a controlled amount of outside air.
- d) A make-up air heater connected to a duct system. In buildings heated by steam or hot water heating systems, ventilating air is often supplied by a make-up air heater, which takes air via a duct system to the various areas. The air can be heated by natural gas, propane, or oil; or the air heater may have a heated glycol coil.

Mechanical Air Intake, Mechanical Exhaust

In larger buildings, fans or blowers supply fresh air into and remove stale air from the building. A great number of combinations of supply and exhaust methods is possible with different types of fans, with or without ducts, to suit various purposes. An example of a ducted ventilation system is shown in Figure 1.

Figure 1 – Mechanical Ventilation System with Supply and Exhaust Fan



The HVAC unit (inlet plant) has a fan to supply fresh air to the building, and ducts to distribute the air throughout the entire building. The duct outlets are designed to promote air movement in each area. The exhaust fan (extract fan) draws air through the exhaust ducting. In the ceiling, there are return air registers (extract openings) through which air is removed via the exhaust duct.

This installation is designed to maximize the movement of air, to increase human comfort. Yet, it does not create drafts that reduce comfort.

The advantage of a mechanical ventilation system is that, if properly designed, it supplies a controlled amount of filtered and heated air. It then distributes the air in such a way that it avoids any discomfort to the occupants.

When using a mechanical ventilation system, the operator must maintain positive static air pressure in the building. A slightly positive building pressure keeps contaminants out of the building. If the building pressure is negative, contaminants may enter the building through small openings such as cracks around windows and doors.

If an operator knows that people are having trouble opening or closing exterior doors, one possible cause will be incorrect building static pressure. Another indicator is a sudden rush of air when moving from one area to another. The operator should check the operation of the system to ensure that air pressure controls are functioning.

Another operational concern is uneven air movement. If there are uneven air temperatures, or if the airflow varies from one register to another, there could be an air balancing issue. This refers to balancing the air supply in all parts of the building, to support the required number of air changes, while providing an even distribution of air over the occupied spaces.



The operator should contact an air balancing company to test the system and correct any air imbalances. Without the proper tools and knowledge, the operator may cause greater system imbalance by adjusting the air registers without fully understanding the root cause of the problem.

One disadvantage of a mechanical system is higher costs for maintenance and operation. The more complicated the system, the greater the maintenance costs.



OBJECTIVE 2

Describe the various contaminants found in air.

FILTERS

Filters are a necessary part of all ventilation systems. They range from simple, throwaway types used in a residential furnace, to the sophisticated filtering mechanisms used in medical laboratories.

Air Cleaning

The air supplied by an air handling system must be as clean as possible in order to maintain a clean atmosphere in the conditioned spaces. The recirculated building air, as well as the outside ventilation air, usually contain a considerable amount of contaminants. It is therefore necessary to clean all air passing through an HVAC system.

The contaminants suspended in the air are divided into five general classes:

Solid particles of visible size: dust, dirt, lint, pollen, insects, and others.

Solid particles of microscopic size: fine dust, fumes, and smoke.

Liquid impurities: mist and fog that consist of extremely small droplets of chemicals.

Vapours and gases: cooking odours, and odours produced by human and animal occupancy.

Living organisms: bacteria and spores.

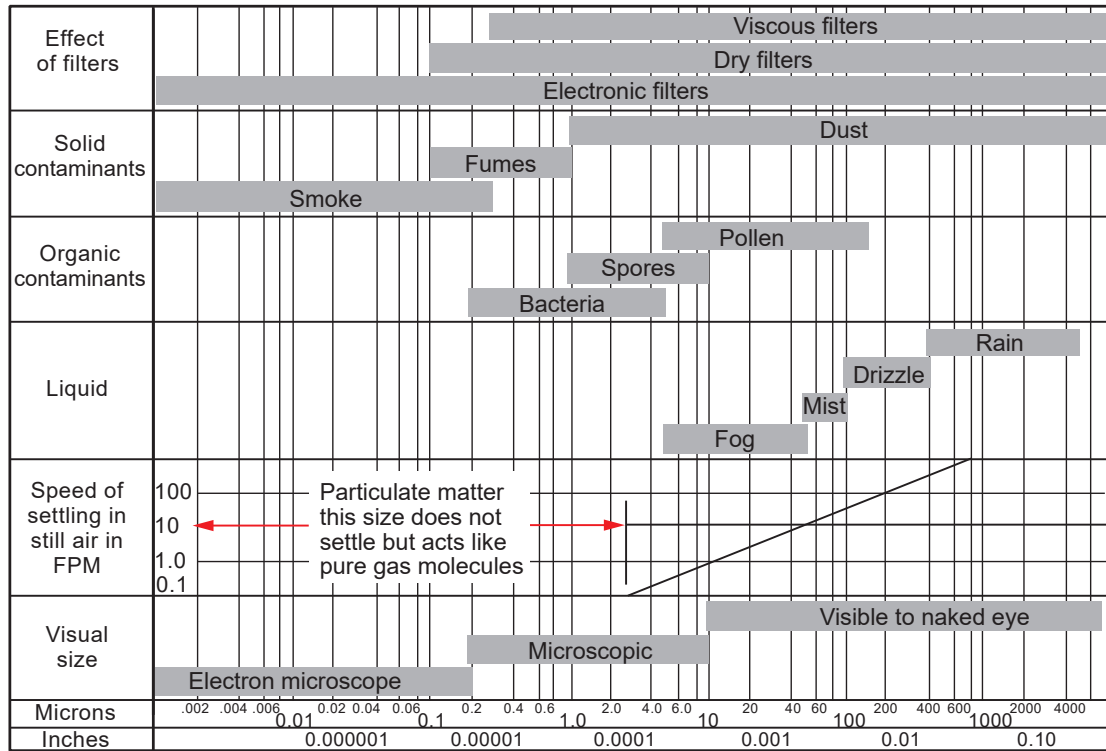
Contaminants in the air vary tremendously in size. Their size is measured in microns (one micron is one-thousandth of a millimetre). Smaller particles, such as tobacco smoke, are only 0.2 microns in diameter. Bacteria vary from 0.2 to 5 microns. Pollens range from 5 to 150 microns. Dust particles vary from 1 micron to well over 1000 microns.



Figure 2 shows the size and characteristics of the various contaminants in the air.

This variety in sizes has made it impossible to design a single air cleaner which will remove all contaminants. As a result, many different types of air cleaners have been designed to meet the needs of various applications. The type of air cleaner to use in an air conditioning system will depend on the type and concentration of the contaminants, and the desired degree of cleanliness.

Figure 2 – Size of Contaminants



OBJECTIVE 3

Describe the types of air cleaning devices used in industrial/commercial buildings.

AIR CLEANING DEVICES

Air cleaning devices are an essential part of any well-designed HVAC system. They provide a method of removing many of the contaminants that are in the air. A perfect air filter would operate at 100% efficiency on the target contaminants, require zero energy input, and last forever. However, a filter of this type has not yet been invented.

Filters plug up over time with contaminants. This has a negative effect on airflow. It causes an increase in fan power to maintain the air volumes necessary to meet the required air changes per hour. It is essential to select both a filter and filtering process that will save energy and maximize filter life span. The greatest cost of a filter is usually not the filter itself; rather, it is the energy cost to move the air through the filter. The cost of overcoming the pressure drop that is created across the filter increases the energy requirements to operate the fan.

Air cleaning devices are divided into six general classifications:

- a) Mechanical air filters (removal of solid and liquid particles)
- b) Electronic air cleaners
- c) Air washers
- d) Charcoal absorbers (removal of gases and vapours)
- e) Activated alumina chemisorbant media, for the removal of corrosive gases such as H₂S, SO₂, Cl₂
- f) Devices, such as ultraviolet or germicidal lamps, for the removal of bacteria

Mechanical Air Filters

Mechanical air filters for industrial applications can be divided into two broad classes:

Throwaway filters: which use a filtering medium cheap enough to be disposed of when it becomes dust laden. These can be cellulose based pleated filters or fibreglass based, either dry or coated with an adhesive (a viscous oil like material), to attract and hold the dirt particles.

Cleanable or renewable filters: which can be cleaned and reused. They can also be classified as dry or viscous filters. As well, they can be grouped according to the various shapes and sizes, filtering efficiencies, and materials.

Within these two classifications, there are dry, viscous, and high efficiency particle air (HEPA) filters. These filters may use a similar media like fibreglass for the viscous type. The cellulose dry type are not usually coated with any viscous material, and may be manufactured to HEPA standards.

Dry Filters

Dry air filters consist of a matting of fine tangled filter material held in a frame placed across an air duct or plenum. When the air flows through the filter, dust and dirt particles contained in the air become entangled and stay behind.

Dry filters are efficient when screening dust, but their dust-holding capacity is relatively small. These are the best filters available for lint removal, but are ineffective for removing smoke and other fine particles. Air must be moved through dry filters at a fairly low speed, usually at no more than 0.25 m/s. These filters are therefore designed with corrugations in order to expose as large a surface area as possible.



The majority of dry filters use a relatively inexpensive filter medium, such as fibreglass or cellulose, which is placed in an inexpensive wire frame for throwaway applications. Some filters, however, use a sturdier permanent frame. When it becomes loaded with dust, only the filter medium is changed. Other dry filters use a more durable filter medium, such as wool felt, which can be vacuum cleaned, air blown, or dry cleaned, allowing reuse of frame and filter medium.

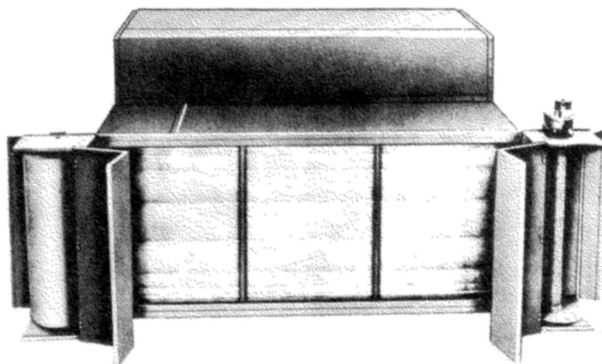
Figure 3 illustrates a dry filter with a permanent frame which can be used either with disposable or reusable filter media.

Figure 3 – Dry Filter



In larger air conditioning systems, dry filter media is sometimes used in a rotating air filter, also called a roller or curtain filter (Figure 4).

Figure 4 – Rotating Filter

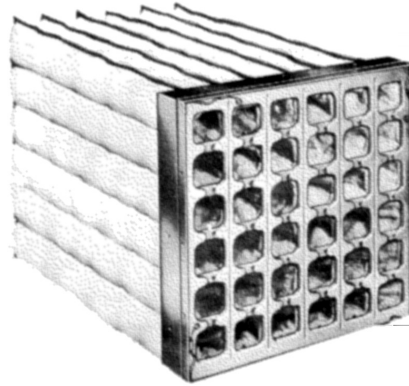


This filter consists of a frame placed across the air duct or plenum and two rolls, one on either side (or above and below) of the frame. The clean filter mat comes in a large roll placed on one side. The free end of this roll stretches across the air stream and attaches to a second roller. An automatic mechanism rotates this second roller, which rolls up a short section of filter mat at regular intervals. This operating period is usually controlled by an adjustable time clock, or by a pressurestat actuated by the static pressure drop across the filter (the pressure drop increases when the filter becomes dirty).

When the entire clean roll is used up, a new roll is installed, and the dirty roll is either cleaned or disposed of. These filters are less expensive than other filters and would therefore be used to capture the larger particles that would plug up the more expensive filters used downstream.

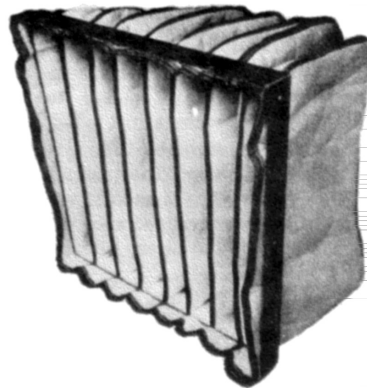
Dry filters with high dust removal efficiency and low air resistance are the replaceable bag type and wedge type filters illustrated in Figures 5 and 6. These filters have a very large filtering area, a large dirt holding capacity, and a longer service life than pad type filters. The filter medium for both types is made from a special modacrylic fibre.

Figure 5 – Bag Type Filter



(Courtesy of American Air Filter)

Figure 6 – Multi-Wedge Type Filter



(Courtesy of Union Carbide Corp.)

It is important to install a pad type pre-filter, prior to the bag or multi-wedge filter, to protect the more expensive filter. Failure to provide pre-filtering will result in having to change the expensive filters more often.

Viscous Impingement Filters

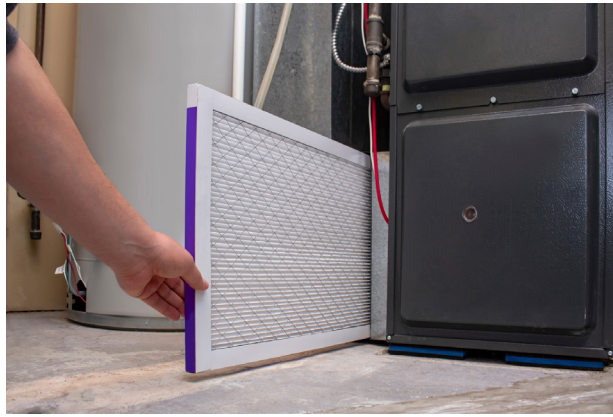
Viscous impingement filters are the most common type of filter used in ordinary air conditioning systems. They contain filter media of tightly packed glass fibre, copper or aluminum wool, or crimped metal.

The filter medium is coated with a viscous, sticky fluid. Dust particles in the air passing through the filter impinge on the viscous surfaces and adhere. In most designs, the filtering material is packed tighter in the direction of airflow, so air passages become progressively smaller. The air velocity through a viscous filter can be much higher than with the use of dry filters; 2.5 metres per second is common. Dry filters have a finer weave and will filter smaller particles than viscous filters.



The viscous filter in Figure 7 is highly efficient in the removal of coarser dust and pollen. Lint, however, will pack on the entering face and quickly clog it. The filter is available in throwaway filter frames, filter media, cleanable, and roll types.

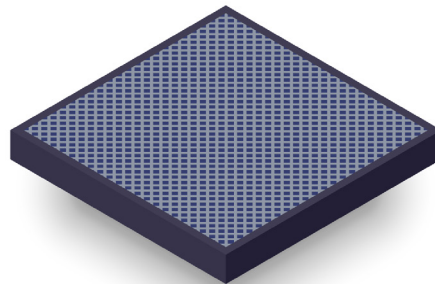
Figure 7 – Disposable Viscous Filter



The throwaway type is often mounted in a cardboard frame 25, 50, 75, or 100 mm thick, with the faces wire-reinforced to prevent bulging. They are available in various sizes to fit air ducts, or to build a large area filter bank in a plenum.

The cleanable type in Figure 8 is usually constructed in much the same manner as the throwaway type. However, the frames and screens are made of metal. When the filtering media becomes dust laden, it can be removed from service and replaced by a clean unit. The dirty filter is then washed in cleaning solution, dried, and given a bath of viscous oil. Excess oil is drained off, and the filter is stored for future use.

Figure 8 – Cleanable Viscous Filter



The roll type viscous filter is similar in construction to the dry type rotating filter illustrated in Figure 4. The viscous filter media is of the disposable type. The rolls may be mounted vertically with the filter media moving horizontally across the path of the air, or they are mounted horizontally with the media moving vertically across the air channel.

HEPA Filters

The **high efficiency particle air (HEPA)** filter uses a material similar to felt or paper, and it will filter much finer particles than either dry or viscous. HEPA filters are very efficient, but very expensive. These filters will filter down to 0.3 micron with 99% efficiency, but require a pre-filter to remove larger particulate.

When a HEPA filter is used, multistage filtering should also be used. Less expensive and higher capacity pre-filters should be used to filter out the larger particulate, so as not to fill the expensive HEPA filters too quickly. HEPA filtration systems are commonly found in hospitals, laboratories, and other facilities that require small particle filtering.

Electronic Air Cleaners

Electronic air cleaners are divided into the two following classes:

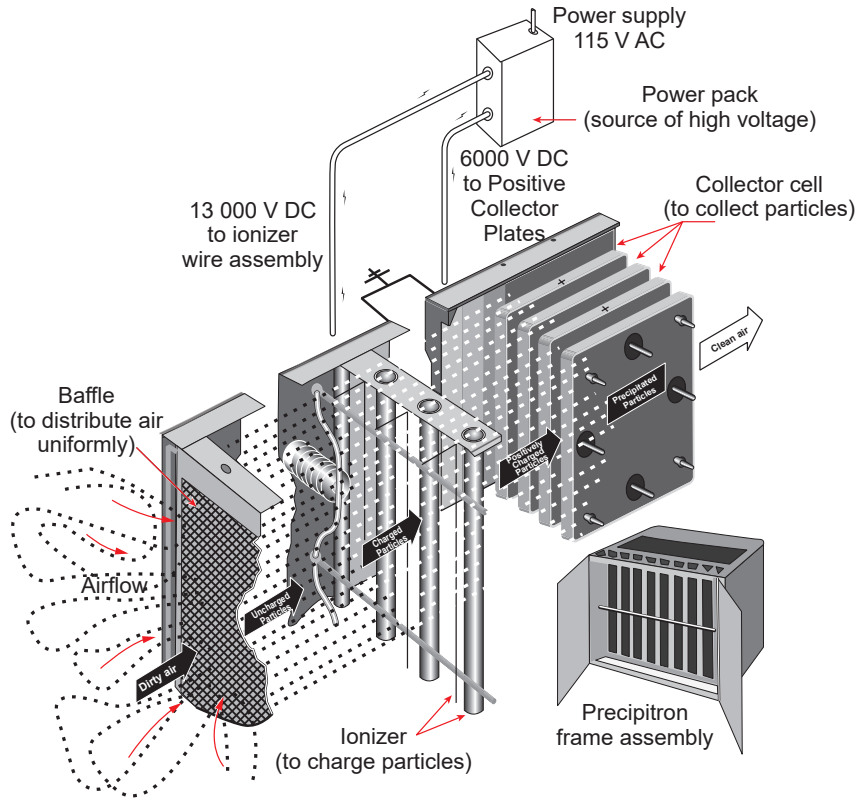
1. Electrostatic precipitators
2. Charged-media electronic air cleaners

Electrostatic Precipitators

In an electrostatic air cleaner, shown in Figure 9, the air and dust particles first pass through a coarse filter or baffle to eliminate any large particles. These dust particles become negatively charged when passing the contaminated airflow through an ionizing zone. The airflow, which now contains negatively charged particles, then flows through a bank of metal collector plates arranged parallel to the airflow. Alternate plates are positively charged with 6000 VDC. The others plates (the collectors) are grounded. The negatively charged particles adhere to the grounded collector plates. The contaminants are removed from the plates at regular intervals by washing.

The filter offers practically no resistance to the airflow. However, if the power supply fails, filtration ceases. It is common practice to place dry filters of the throwaway type ahead of the electronic filter to prevent large dirt particles from entering.

The electrostatic filter is the best filter available for the removal of fine dust, smoke, and fumes. Therefore, it is used extensively in buildings where the air supply must be as clean as possible, as in hospitals. However, since this filter is much more expensive than other types of filters, its use in ordinary buildings, such as offices and apartments, is limited.


Figure 9 – Electrostatic Air Cleaner


(Courtesy of Westinghouse)

Charged-Media Electronic Air Cleaners

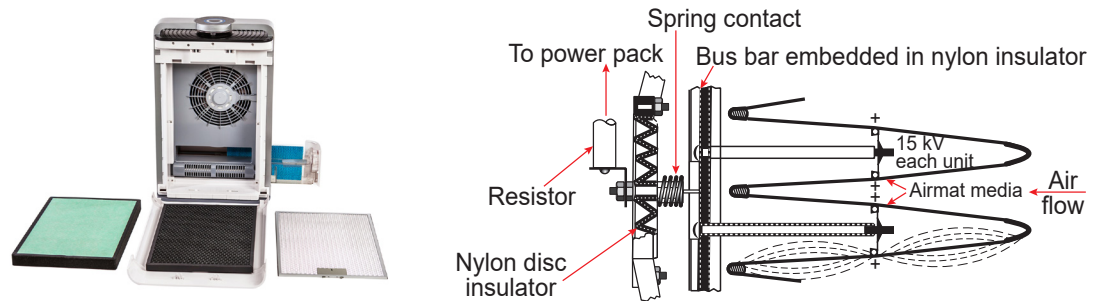
The **charged-media air cleaner**, shown in Figure 10, consists of a glass fibre or cellulose filter mat installed in a V-shaped bank across the air duct and mounted in nonconductive frames.

The filter mat is supported by a grid, which consists of alternately grounded and charged members. The charged members are held at a potential of 12 000 VDC. This sets up an intense and non-uniform electrostatic field through the filter mat. The contaminants carried in the airflow become polarized when they approach the filter mat, and they are then attracted by the filter media.

Another type is the static charge media filter. A charge is induced in the filter media, similar to the static charge induced by rubbing a balloon with wool. These filters are charged at the factory, and last for a set period before losing their charge. They are made with high efficiency filter media, so even after the charge is gone, the filter will still trap particulate matter.

The advantage of this type of filter over the electrostatic precipitator is that, in case the power supply fails, the filter media will still act as an impingement filter and clean the air. The disadvantages of this filter are:

- It offers resistance to the airflow, which will rise when the mat becomes loaded with contaminants.
- The filter medium needs to be replaced at regular intervals.

Figure 10 – Charged-Media Electronic Air Cleaner


(Courtesy of Aerocam Air Filter Company)

Although electronic air filters are proven particulate filtration systems, they are expensive and require maintenance by qualified persons. An electrician may be required to assist with de-energizing the filter for operations to perform maintenance.

Air Washers

Air washers can be used for air cleaning; however, their efficiency is rather low in dust removal, and practically negligible in the removal of small particles, especially greasy ones. In general, filters give better results than air washers do, and they are less expensive. Even when air washers are used for humidification, dehumidification, or cooling, they are usually preceded by filters to remove the impurities from the air.

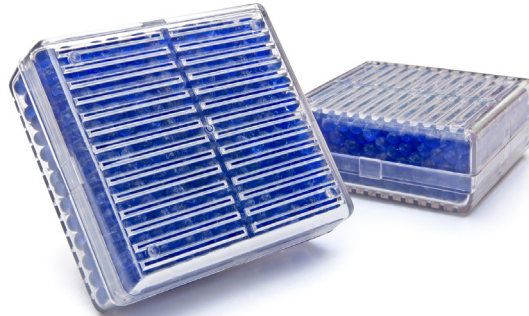
Odour Adsorbers

The most common and successful way of removing odours and other objectionable vapours in an air conditioning system is by means of an **odour adsorber**. This takes the form of cylindrical canisters, flat plates, or accordion-pleated frames that contain activated carbon or activated potassium permanganate. These canisters are placed in the ductwork behind the regular air filters. The carbon or potassium permanganate adsorbs odour-causing gases up to about 20% of its own weight after which it has to be replaced. Sometimes it may be reactivated by heating it to 540°C (1000°F) to drive out the adsorbed gases.



Figure 11 shows an activated carbon filter designed for a duct system. It consists of a removable cell formed by a steel frame with several horizontal perforated trays. Each tray contains a bed of granular, activated carbon. The trays are placed in a V-pattern to maximize the adsorbing area within a limited space.

Figure 11 – Activated Carbon Filter



(Courtesy of Conner Engineering)

Air Sterilizers

The control or removal of airborne bacteria and mould spores is vitally important in certain buildings such as:

- Hospitals
- Nurseries
- Food processing and storage plants
- Pharmaceutical and cosmetic plants

Improper control may cause diseases to spread, and it may also cause food and manufactured products to spoil.

The majority of airborne diseases are spread indoors where people gather. This can be partially prevented by good ventilation. However, in winter, ventilation is often considerably reduced to conserve heat. Bacteria attach to fine dust particles; therefore, good air filtration is very important. Even with the best filter system, it is not possible to eliminate all bacteria.

In buildings where it is necessary to provide an atmosphere free of bacteria and mould spores, the air is often sterilized using germicidal lamps. These lamps emit ultraviolet light that effectively destroys bacteria and spores in the air. These lamps must be located so that the UV rays cannot come in contact with persons. Mounting methods depend on the manufacturer and the style of UV filter.

In-Duct Air Sterilizers

To keep the bacterial content of certain conditioned spaces as low as possible, such as in hospital operating rooms, supply air must be sterile. In other words, bacteria must be destroyed before the air enters these spaces. This is often accomplished by passing the filter supply air through an air sterilizer placed in the supply duct.

The sterilizer consists of a large number of circular channels placed in the direction of the airflow. Each channel contains a tubular ultraviolet lamp, placed in the centre of the channel. The air, now divided into several smaller flows, passes through the channels and is subjected to the ultraviolet radiation. The air leaves the channels in absolutely sterile condition, and continues through the supply duct to the various outlets in the conditioned spaces.



CHAPTER SUMMARY

This chapter covered topics related to ventilation and the importance of meeting building code requirements for air changes. Ventilation rates will vary for each building, application, and occupancy. Consider the number of air changes per hour required for a florist as compared to a gym. The gym will have a higher number people using it, and will have increased odour in the air; its ventilation system will require more air changes per hour.

Air cleanliness is also important for achieving human comfort. Factors such as the type of contaminants to remove and the quality of air to supply, will determine the air cleaning process used.



HVAC Duct Systems

LEARNING OUTCOME

When you complete this chapter you should be able to:

Describe the designs and components of duct systems used in HVAC applications.

LEARNING OBJECTIVES

Here is what you should be able to do when you complete each objective:

- 1. Explain how air duct systems are classified.*
- 2. Describe air duct materials, system layout, fabrication, and installation.*
- 3. Describe air duct leakage.*
- 4. List and describe the types of liners, dampers, and louvres used in air duct systems.*
- 5. Discuss terminal air distribution devices, and the principles of diffusion, induction, entrainment, and aspiration.*



CHAPTER INTRODUCTION

The main function of the duct system is to transmit supply and return air between the air handling apparatus and the conditioned space. Duct systems are designed with consideration of initial cost, operating cost, available space, and noise.

When designing ductwork, there are a few considerations that need be taken into account. Air that flows through a duct will lose some pressure because of friction and turbulence. The greater the air flow velocity through a duct of a given size, the greater the pressure loss. When the size of a duct is reduced, due to an increase of friction losses, the power required to deliver certain quantities of air rapidly rises.

The designer must carefully consider the choice of duct size. Even though smaller ducts will reduce the initial cost of a system, the resulting increase in power consumption, operating cost, and system noise often offset the initial savings. Therefore, the choice of duct size depends upon balancing the first cost against the operating cost of a system.

OBJECTIVE 1

Explain how air duct systems are classified.

CLASSIFICATIONS

A common way to classify **duct systems** is by pressure and velocity. By changing the operating pressure or velocity of the system, the design and operations of the system will change. Power Engineers must recognize the limits of the system they are operating, and be aware of how alterations may affect overall system performance.

The supply and return duct systems are classified with respect to the velocity and pressure of the air within the ductwork. Table 1 summarizes the classifications of HVAC duct systems.

Table 1 – HVAC Duct System Categories

Category	Air Velocity	Duct Static Pressure
Low pressure	less than 11 m/s	not exceeding 0.50 kPa (5 cm of water)
Medium pressure	from 11 m/s to 25 m/s	up to 1.50 kPa (15 cm of water)
High pressure	greater than 25 m/s	from 1.50 kPa to 2.5 kPa (25 cm of water)

Based on the material used and the intended service, the information in Table 1 can vary. For example, fiberglass duct may also be classified for construction service at pressures below 0.50 kPa, as well as for positive and negative pressure service.

A low-pressure system is more conventional for small and medium sized buildings. The main advantages of low-pressure systems are the relative silence of air movement, lower installation costs, and lower operating costs.

The larger the building, the larger the duct work must be to support the volumes of air the system needs to move. Therefore, duct sizing may be considered a disadvantage in large and medium sized buildings. By increasing the size of the ducts, the air friction and resistance to airflow will decrease, and therefore will reduce the power requirements for the fan.

In large buildings, the space required by the low-pressure class of ductwork to move large amounts of air would be excessive. Therefore, to conserve space, medium- and high-pressure duct systems should be used in large buildings. The space saved by medium- and high-pressure duct systems would then be available to clients.

The space saving feature of systems is partly offset by the following factors, which result from the higher static pressures and air velocities:

- Higher operating cost
- Higher initial cost of air handling apparatus
- Higher initial cost for special equipment required reducing the air velocity before distribution to the air space
- Special control devices
- More careful and costly fabrication and installation of ductwork
- Costly noise suppressing devices required (acoustical duct lining or sound attenuators)

An operator needs to know these factors to competently operate and troubleshoot the system, and also to find ways to increase overall building efficiencies.

To help operate and troubleshoot problems, the operator should consider leaks and duct strength as functions of pressure, whereas noise, vibration, and friction losses are functions of velocity.



OBJECTIVE 2

Describe air duct materials, system layout, fabrication, and installation.

To safely operate, troubleshoot, and improve overall efficiencies of HVAC systems and duct systems, it is important to:

- Know the system layout.
- Understand the design limits of the system.
- Know the methods used for fabrication and installation.

DUCT MATERIALS

Sheet metal ducts use the following materials:

- Galvanized steel
- Black steel
- Aluminum
- Stainless steel
- Copper

Galvanized steel has the advantage of corrosion resistance, but has a higher cost. It is used mainly in ventilating and air conditioning systems where the normal service involves only:

- Atmospheric contaminants
- Localized water carryover from cooling coils, humidifiers, air washers, or outdoor air intakes

Black steel is carbon steel with a thin layer of oxidized iron on the surface. It has the advantage of being durable and of high strength. Heavy gauge black steel sheets are used for:

- Kitchen exhaust ducts
- Ducting protected with waterproofing mastic coatings
- Drain pans

Aluminum, stainless steel, and copper are used where the cost is justified by the need for maximum resistance to moisture.

Lined cement ducts are used for buried (underground) exhaust of corrosive material, such as from laboratory fume hoods. The older cement asbestos ducts that were used should have been removed by now.

Fibreglass ducts are used in some low-pressure systems. These ducts are very lightweight, have a low initial cost, are naturally silencing, and they can be fitted on site. However, they have low strength, are easily punctured, and they cannot be used to handle air with high moisture levels, or oil and grease, such as found in kitchen exhausts.

TYPICAL DUCTWORK LAYOUT

A well-designed duct layout is essential for a system to be efficient, and to maintain the highest levels of human comfort, while minimizing sound.

Considerations for ductwork layout:

- The air volume delivered to each zone
- The type, number, and location of outlets and returns
- Duct routing
- Initial cost
- Operational costs

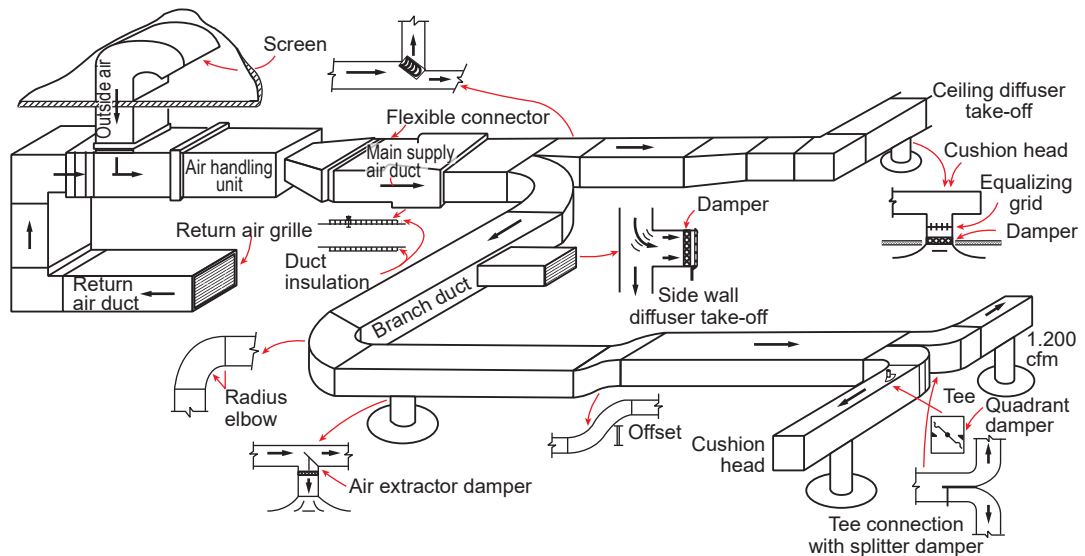
Ducts are fabricated in sections, which are fastened together with special seams, slips, and locks. Figure 1 shows a sketch of a low-velocity air distribution system showing the main components, ductwork details, and some of the commonly used fittings.

The air handling unit conditions the air entering the building. The unit is connected to the ductwork with a flexible connector, which reduces vibration and sound transmission to the air duct. The main trunk (main supply air duct) has many branch ducts, which distribute the air. Figure 1 shows only one branch, but in reality, there can be many.

A take-off duct reroutes air from the main trunk to supply air to specific zones or areas of the building. In order to maintain duct pressure and velocity, reducers are used to compensate for the reduction of air volume.

The return air duct brings air from the occupied spaces to be reconditioned in the air handling unit. In order to increase occupant comfort, fresh make-up air comes in from the outside and mixes with the return air. The duct is standard metal, and is either rectangular or round.

Figure 1 – Low-Velocity Air Distribution System





DUCTWORK FABRICATION AND INSTALLATION

Construction methods for various classes of ductwork are too involved to cover them fully in this chapter. Construction details are found in the **Sheet Metal and Air Conditioning Contractors' National Association (SMACNA) Standards**.

The following are some of the points this standard makes:

- a) Ducts must be constructed of approved gauges (metal thickness) for the size of duct. Ducts of large dimensions must be provided with stiffeners or be diagonally creased to provide stiffness.
- b) Ducts must be well supported and properly braced.
- c) Ducts passing through non-conditioned spaces must be insulated to prevent excessive heat loss or gain and to prevent condensation.
- d) Ducts must be made as tight as possible to prevent air losses due to leakage.
- e) Changes in duct size should be gradual with a slope of 1 in 7.
- f) Flexible connections made of heavy canvas or neoprene coated glass fibre cloth must be provided at fan discharge and suction openings.
- g) Adequate access openings must be provided for cleaning and inspection of components or controls concealed inside ducts.
- h) Mitre elbows which have legs of equal length may increase velocity.
- i) Short radius elbows should be provided with turning vanes.
- j) Supply and return air branch ducts should contain dampers to permit satisfactory air balancing of the system.
- k) Splitters and positive lock dampers should be used in all branch ducts.
- l) Fire dampers with fusible links set for about 70°C must be installed in ducts, which pass through firewalls. See local codes for specific details. An access opening is required in the ductwork to inspect the fire damper, replace the fusible link, or ascertain there is no blockage, which could prevent the damper from closing.

A Power Engineer in charge of a building or HVAC system must have basic knowledge of installation methods, and may be required to accept the construction or upgrades to a duct system. A lack of knowledge can increase operational costs or create a system that no longer meets air quality requirements.

In some installations, it may appear to be a great idea to use an elephant trunk style air duct in lieu of standard metal round ducts to lower installation costs and ease the install. The disadvantage of this method may lead to a high-pressure drop in that system. In some cases, the pressure drop can be so large that the fan and HVAC system can no longer meet the minimum air changes for that particular space.

During installation, the Power Engineer may want to inspect the work. Did the installer use too many elbows when a straight run would create far less of a system pressure drop? Did the installer make every effort to prevent air leakage at joints?

OBJECTIVE 3

Describe air duct leakage.

DUCT LEAKAGE AND LOSSES

Air duct leakage is a transmission loss, just like with an oil or gas pipeline. Although the environmental consequences are different, leaks add costs to the operating budget. The leakage of treated air represents a loss of money spent on filtering, cooling, heating, humidifying, dehumidifying, sanitizing, and pressurizing the air. The factors below will affect leakage:

- Static pressure
- Total length of installed duct
- Number of joints, seams, and openings
- Method used to seal openings and joints
- Quality of work

Air leakage from ducts varies from 5% to 30%, depending on the quality of the work. These significant losses indicate the importance of doing a thorough inspection of the duct system before it is covered with insulation, or wall or ceiling material. The longer a run of duct work, the more leaks that will occur.

The effects of air leakage in supply air ducts differ from those in the return air ducts.

Supply Air Duct Leakage Loss

Air leakage from the supply duct creates a loss of cooling or heating effect. This loss must be carefully evaluated based on the following criteria:

- a) When the entire supply air duct is outside the conditioned space, assume 10% leakage. When only part of the supply air duct is outside the conditioned space, include only that fraction of 10% as the leakage. The fraction can be determined by the ratio of length outside the conditioned space to total length of supply duct.
- b) Losses due to air leakage from insulated supply air ducts within the conditioned space must be evaluated based on judgement. This evaluation will depend on whether the leaked air actually gets into the conditioned space or whether it is lost.
- c) Losses from bare supply air ducts within the conditioned space do not need be considered in loss calculations.

Return Air Duct Leakage

In return air ducts, the process is the opposite of the one just described for the supply air ducts: there is inward gain of air instead.

To evaluate the effects of return air duct leakage, use the following guide:

- a) If the return air duct is outside the conditioned space, assume 3% seepage. When only part of the return air duct is outside the conditioned space, apply judgement to evaluate what portion of the seepage above 3% should be considered.
- b) Seepage in return air ducts covered within the conditioned space or in a covered space used as a return air path may increase the load on the air system in terms of volumes of air. However, it will not have to be added to the amount of air needed to supply the occupied space.

The Power Engineer must be able to identify leaks in the system to reduce operational costs. Air leaks are difficult to find in HVAC systems. With a basic understanding of possible leak sources, a Power Engineer can become more successful in system troubleshooting.



OBJECTIVE 4

List and describe the types of liners, dampers, and louvres used in air duct systems.

DUCT LINERS

Unless properly designed, duct systems will transmit noise throughout the entire building. The direction of airflow has little or no effect on the transmission of noise. This noise can be controlled if a duct system is designed using basic noise control principles.

Metal ducts are often lined with sound absorbent materials that reduce airborne noises. Duct liners consist of flexible or semi-rigid fibreglass blankets. These blankets have a special surface coating on the side facing the air stream to help withstand the erosive air velocities without deteriorating. To restrict the spread of smoke and fire through duct systems, and to minimize ignition sources, the duct lining materials must satisfy local building codes and requirements of the **National Fire Protection Association Standard 90A**.

In some instances, the liner can also function as thermal insulation. If so, the metal duct wall may serve as the vapour barrier. Acoustical liners should not be used for the additional function of thermal insulation, where the duct wall temperature can fall below the dew point of the air flowing inside the duct, which can occur if the duct is installed outside of the building or in unheated areas. In this case, properly apply insulation to the exterior of the duct.

DAMPERS

The general function of dampers in an air handling system is to control the flow of air. This may be achieved by manual operation or with damper operators, which can provide either modulating, multi-position, or two-position control. Dampers in air duct systems have a similar function as valves do in steam systems.

Manual Dampers

Manual dampers are used to balance the airflow of an air handling system, in accordance with the specified design quantities. They are also used in smaller systems to close the outdoor air intake, to prevent freezing when the system is switched off.

Modulating Dampers

Modulating dampers are used to produce changes in the volume of an airflow proportional to a control signal. Modulating dampers are used in many applications. Mixing boxes, and face and bypass dampers are two common applications.

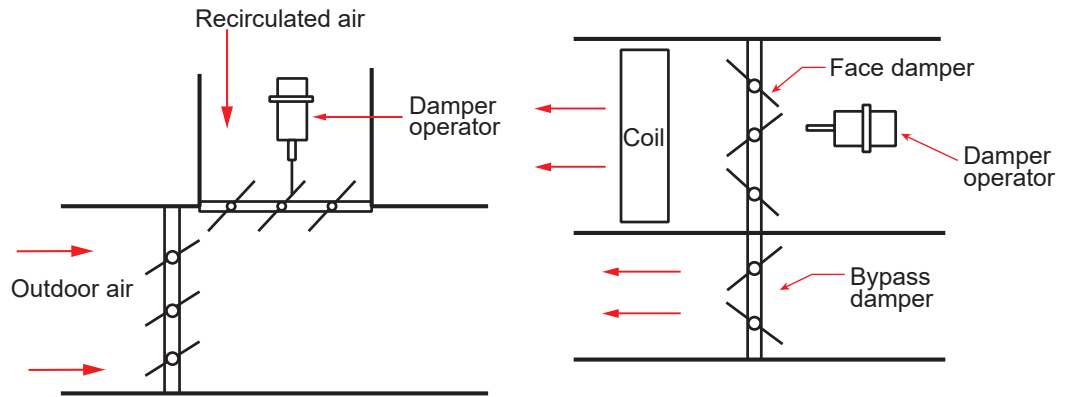
Mixing boxes use modulating dampers to regulate the amounts of different airflows. For example, a mixing box can be used to regulate the outdoor air and recirculated air in correct proportion. The box will maintain a mixed air temperature set point, and a constant volume of air for an air handling system (Figure 2(a)).

Face and bypass dampers (Figure 2(b)) modulate the volume of air passing through a heating or cooling coil. As the face damper opens, the bypass damper closes, and vice versa. Modulating dampers are also used in variable volume control systems to modulate the volume of conditioned air necessary to meet the load requirements of a particular space (Figure 2(c)).

Two-Position Dampers

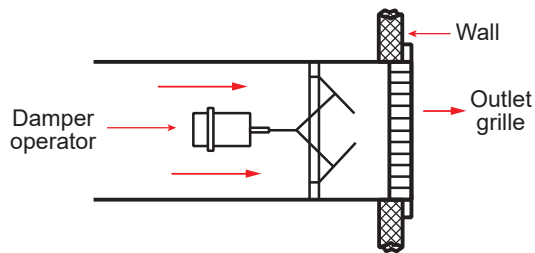
Two-position dampers are controlled in such a way that they are either fully open or fully closed. For example, the two-position dampers installed in a fresh air intake will move to the fully open position when the fan starts, and will return to the fully closed position when the fan stops (Figure 2(d)).

Figure 2 – Control Dampers

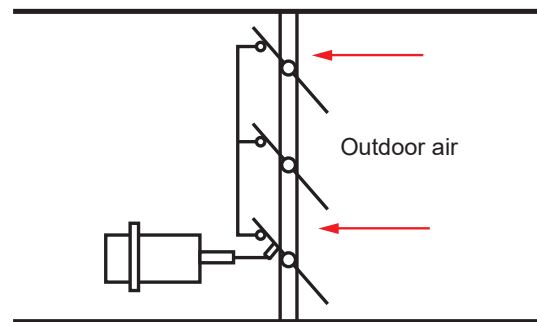


a) Outdoor and recirculated air mixing with parallel operating blades

b) Face and bypass damper type with opposed blades



c) Variable volume control



d) Two-position dampers

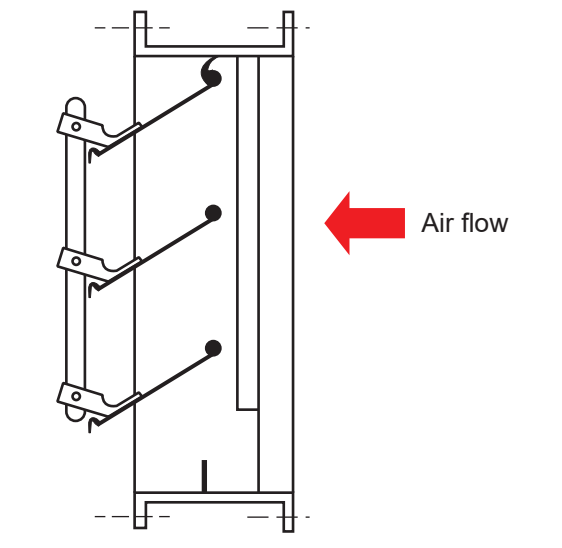


Relief Dampers

As shown in Figure 3, the function of a **relief damper** is similar to that of a check valve. It will allow the air to flow in only one direction.

A relief damper consists of a series of blades mounted in a frame; each blade pivots freely on its shaft. The blades are interconnected with a linkage, which causes them to open or close simultaneously. The relief damper is used as a check damper on exhaust systems, to relieve excess pressure from a building, and prevent backdraft of cold air when there is a negative building static pressure. Depending on its application, this type of damper can be referred to as a **backdraft damper**, gravity shutter, or an atmospheric damper.

Figure 3 – Relief Dampers



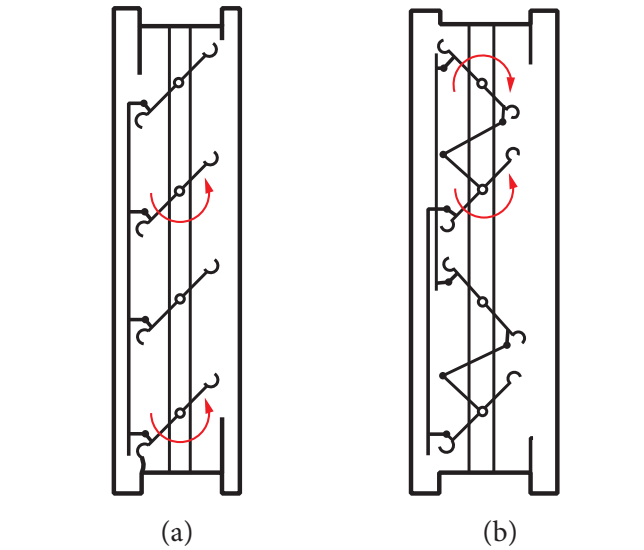
DAMPER DESIGNS

The damper types most commonly used are single blade, **parallel blade**, and **opposed blade dampers**.

Single blade dampers are generally restricted to small sizes because of the difficulty of securing proper operation with high velocity air.

Parallel blade dampers consist of two or more blades linked together in such a way that all blades rotate in the same direction (Figure 4(a)). This type is often used on mixing boxes where the two sets of dampers are mounted with the blades directing the two air flows toward each other for good mixing, thus minimizing the hazard of coil freeze-up due to cold air stratification (Figure 4(a)). Parallel blade dampers are best suited for two position damper operation, such as fresh air intake, where no throttling of the airflow is required.

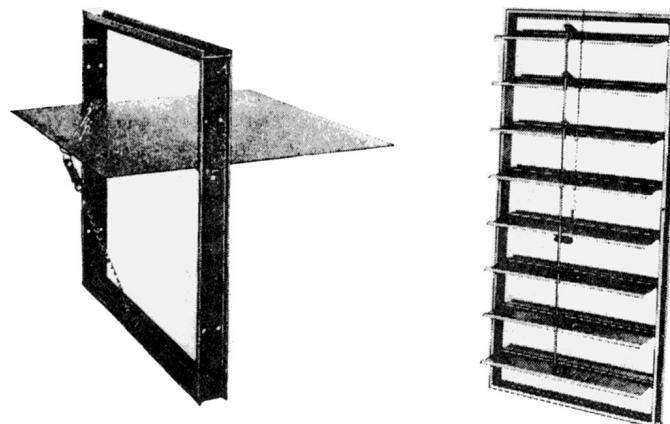
Opposed blade dampers have linked blades, so the adjacent blades rotate in opposite directions (Figure 4(b)). Opposed blade arrangements are superior when modulation of airflow is required, since the airflow is more in proportion to the blade position. Parallel blade dampers tend to divert the air, but do little throttling or modulating until the blades are nearly closed. The linkage allows the opposed blade dampers to move in unison.

Figure 4 – Automatic Dampers


Fire Dampers

To prevent the spreading of fire and smoke, the **National Building Code** requires supply and return ducts of air conditioning systems be equipped with **fire dampers** at the point where they pass from one area, or fire zone, to another. This rule applies to horizontal as well as vertical ducts.

A fire damper consists of a steel casing equipped with a single or multiple blade steel dampers that fit tightly in the casing when closed. Normally, the damper is kept open by a chain and fusible link. In the event of fire, the link melts and the damper shuts. Fire dampers of the single and multiple blade design are shown in Figure 5. They are installed to close in the same direction as the moving air streams, so the air pressure will help close them, not open them.

Figure 5 – Fire Dampers


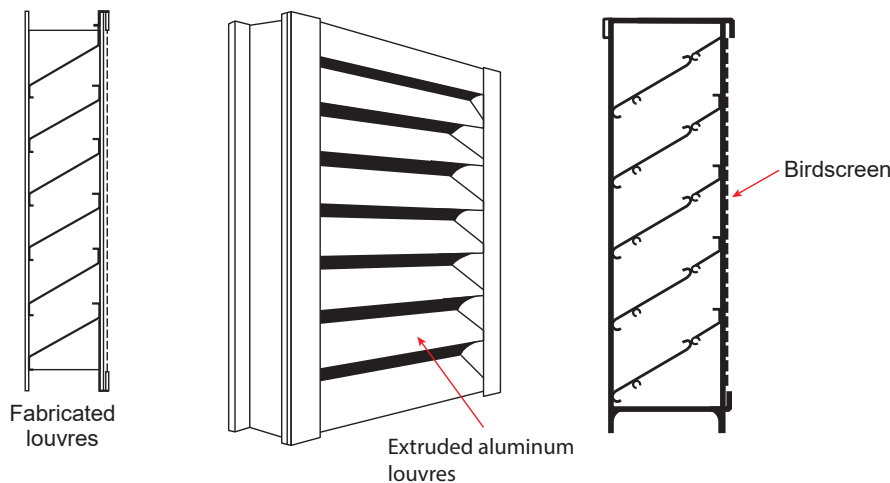
A smoke damper is a device that resists the passage of smoke. The damper operates automatically, and it is controlled by a smoke detector. A fire damper or a damper serving other functions may be used for this purpose, if its location lends itself to the multiple functions. A combination of a fire and smoke damper will meet the requirements of both.



Louvres

Stationary air louvres are used in fresh air intake openings to minimize the amount of water and snow entering an air handling system. The extent to which this prevention is achieved depends on the design of the louvres, face velocity of airflow, wind velocity, and other factors. It is seldom possible to eliminate all the water or snow, nor is it necessary. Figure 6 illustrates two types of louvres: fabricated and extruded aluminum.

Figure 6 – Louvres



Fabricated Louvres

Fabricated louvres are available in standard metals:

- Galvanized steel
- Painted steel
- Aluminum
- Copper
- Stainless steel

A 2 cm screen (mesh) is added to the louvres, to stop most foreign materials, such as paper, trash, and birds. In some locations, an insect screen must be used to cope with the presence of mosquitoes. The insect screen must be accessible for easy cleaning, and it is usually removed during the winter season to prevent clogging with frost or wet snow. The type of screen and mesh required are often specified by codes.

Extruded Aluminum Louvres

Extruded aluminum louvres offer a wide variety of blade designs and sturdy construction. Various attractive architectural effects can be achieved to meet the aesthetic requirements of a building. The requirements for bird and insect screens also apply for this type of louvre.

Louvre Location

It is important to locate air intake louvres away from exhaust air streams, especially toilet, laboratory, or kitchen exhausts, so that the exhaust air does not enter the louvres. In addition, when an air intake louvre is located near a roof, it must be mounted sufficiently above the roof to minimize the pickup of roof dust and high temperature air during the summer. It is also important to consider that snow may pile up and subsequently enter the louvres. The height is determined by the annual snowfall, with a minimum of one metre recommended as a mounting height for most areas.

OBJECTIVE 5

Discuss terminal air distribution devices, and the principles of diffusion, induction, entrainment, and aspiration.

TERMINAL AIR DISTRIBUTION DEVICES

The main objective of an air distribution device is to introduce the supply air into the conditioned space, in order to produce and maintain comfortable conditions within the occupied zone of these spaces. The occupied zone is normally considered to be up to the two-metre level, and to within a metre of the walls. Usually, no attempt is made to maintain design conditions in the upper part of these areas or close to the outside walls. These spaces are often used to mix the conditioned supply air with the room air.

Terminal devices:

- a) Distribute the air to the spaces.
- b) Provide uniform temperatures in the space.
- c) Control or counteract the effects of conduction, radiation, and convection.
- d) Provide adequate air motion to prevent local still pockets of air without excess drafts.

A terminal distribution device accomplishes the above functions by using diffusion, induction, entrainment, and aspiration.

In diffusion, the air is introduced through the outlet into the space in a manner designed to result in rapid mixing of supply air with room air, which reduces both the temperature difference and the velocity before the air enters the occupied zone. A diffuser is the most common method used to introduce air to an occupied space. The diffuser creates turbulence for the conditioned air, reduces its velocity, and causes rapid mixing with the room air.

In induction, entrainment, or aspiration, the supply air and room air are mixed either before the conditioned air leaves the outlet or immediately after. In these designs, the conditioned air flows through a nozzle or outlet to create a slight vacuum. This vacuum draws in room air and causes the two air streams to mix. Supply air outlets of air conditioning systems can be located in the ceiling, inside wall, or outside perimeter of the conditioned space.

NOISE ATTENUATION

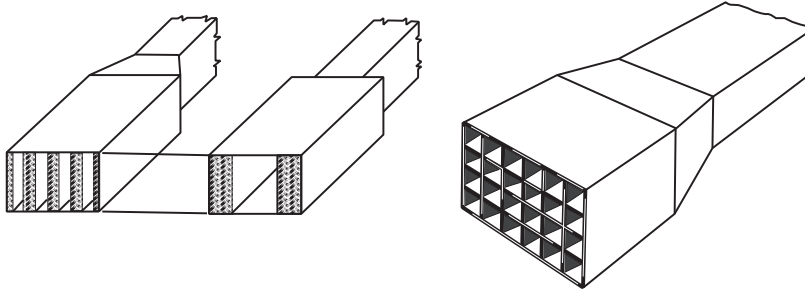
Air conditioning system noise may be due to fans, air turbulence, and high velocity mixing valves. Even when temperature, humidity, and air movement in a building are carefully controlled, the comfort of the occupants can be seriously affected when the noise level created and transmitted by HVAC equipment exceeds the background noise level of these spaces. Since it is usually not possible to eliminate all the sources of noise, other means must be used to dampen (attenuate) noise before it can reach the occupied spaces.

Normally, ductwork will attenuate some of the noise produced by fans, but it is usually insufficient. By lining the ducts with porous sound absorbing material, further attenuation can be achieved. One of the most effective locations for sound absorbing lining is in the suction and discharge plenum of the fan. Additional attenuation can be provided by lined straight ducts, which also give the additional advantage of thermal insulation.



Where available duct length is insufficient to provide the required attenuation, prefabricated in-duct sound absorbers or duct splitters can be used. Some of these absorbers are shown in Figure 7. These units split the air duct into several smaller air passages. They are constructed with an outer shell of perforated sheet metal, and the channels are formed by sound absorbing material. Their sound dampening ability is excellent over the entire sound frequency range. However, their additional resistance to airflow will increase operating costs.

Figure 7 – Sound Absorbers





CHAPTER SUMMARY

This chapter introduced many considerations for duct system designs that will condition the air spaces within the limits of initial cost, operating costs, available space, and noise.

In order to design an effective system, some operating factors must be defined. Will the pressure drops, velocities, quantity of air, and power requirements be in the tolerable range? Will a system be excessively noisy? Will the duct encroach excessively on the occupied space? Are there more effective ways of routing the ductwork? Is the material suitable for the service conditions?

These and other considerations must be made during the initial design and subsequent retrofit stages, to ensure code compliance and the comfort of building occupants.



Types of Coils and Operation

LEARNING OUTCOME

When you complete this chapter you should be able to:

Describe the various types and operation of coils used in HVAC systems.

LEARNING OBJECTIVES

Here is what you should be able to do when you complete each objective:

1. *Explain how steam, hot water, and glycol coils are sized, configured, and operated to reduce the chance of freezing.*
2. *Describe the installation recommendations for coils, piping, steam traps, control valves, air vents, and vacuum relief devices.*



CHAPTER INTRODUCTION

Atmospheric air may be heated or cooled with coils installed in ductwork or in air handling units. The earliest such coils consisted of banks of bare tubes, which were quite inefficient. To address this, fins were installed to increase the contact surface area between the air stream and the tubes, hence increasing the heat transfer efficiency. These are often referred to as extended surface tubes. The external surface of the tube is the primary surface and the fin surface is the secondary surface.

In contrast to bare tube coils of the same capacity, finned tube coils are much more compact, lighter, and usually less expensive. A finned tube coil may have a heat transfer area from 10 to 30 times that of bare tubes.

This chapter explains the operation of various heating coils used in HVAC systems.

Before reading this material, review the basic heat exchanger theory in **Part A, Unit 2, Chapter 3: Introduction to Heat Transfer and Heat Exchangers**.

OBJECTIVE 1

Explain how steam, hot water, and glycol coils are sized, configured, and operated to reduce the chance of freezing.

COIL FREEZE-UP

There are three main media used to supply heat to a heating coil:

1. Steam
2. Hot water
3. Glycol

A glycol system requires the installation of an additional heating circuit; steam and hot water systems do not. Steam and hot water systems pose no additional environmental concerns, but the glycol system does. However, a glycol system will eliminate concerns surrounding coil freeze-up.

To reduce the risk of freeze-up in steam and hot water heating coils, it is important to consider the following:

- Size of the heating coils.
- Configuration of the heating coils.
- The way the coil operates.

Steam Coils

Steam coils are sized according to the tube length. Short length coils are 1.1 m or less. Long tube coils are greater than 1.1 m. Most freeze-up problems occur in steam coils handling 100% outside air. Freeze-up can also occur when outside and return air are incorrectly blended. These conditions result in air temperature stratification ahead of the coil.

Coils with Short Tube Length

The danger of freezing a steam coil is minimal with short tube coils, as long as the:

- Steam trap is properly chosen and functioning.
- Coil is properly piped.
- Coil is sloped to ensure drainage of the condensate.

Coils with Long Tube Length

In steam coils with longer tube lengths, freezing problems do not occur when the incoming air is extremely cold (say -35°C). Rather, freeze-up occurs when the incoming air is just below freezing, and modulating steam flow control valves are used. With most coils, the control valve is fully open when the incoming air temperature is quite low. However, if the air temperature approaches -2°C , the control valve can be nearly closed. As a result, the flow of condensate will be very sluggish, which can cause the condensate to freeze in the last few centimetres of a long tube coil.

A two-position control valve provides enough steam pressure to clear the condensate whenever there is a call for heat. However, from the standpoint of control, overheating and poor set point tracking will occur during milder weather.



When steam heating coils handle subfreezing air, the limitations of the modulating steam flow control valve and the two-position steam flow control valve present an interesting challenge. There are several methods used to minimize the hazard of freeze-up while controlling the output of steam heating coils:

- Use a preheat coil
- Use a preheat coil with a reheat coil

Preheat coils heat outdoor air to prevent the equipment that is downstream from freezing. The preheat coil should not increase the air temperature more than 18°C. This kind of heating arrangement is used when there is a 35% to 100% fresh air make-up.

When an increase in temperature is greater than 18°C, an arrangement using preheat coils with a reheat coil will minimize chances of freeze up issues.

In either arrangement, if the steam supply pressure at the coil inlet drops below a minimum specified level (for example, 35 kPa), provisions must be made to close the outdoor air dampers and stop the fan. The damper motor or actuator must be a spring return type, and the damper blades must overlap and be tight fitting, preferably with a neoprene seal at the edges. The control system must delay the opening of outdoor air dampers for at least 10 minutes at the startup of the air handling unit and after the steam has been turned on.

Correct Steam Coil Selection

The initial selection of the steam coil must be done with care to avoid oversizing. It is good design practice to select steam coils so that at least 40% of the coil capacity is used when the air temperature entering the coil is at -1°C. Under such conditions, the valve will throttle, but will supply enough steam to prevent condensate freeze-up. This rule applies for ordinary coils as well as steam distributing coils. It is important to keep the tube lengths as short as possible.

Steam Flow Control Valves

Correct control valve sizing is also very important. Here again, it is best to not oversize the valve. A high-pressure drop across the valve is desirable for good control. However, this pressure drop may itself become a source of trouble if the initial steam pressure is not sufficiently high ahead of the valve. It is common practice to select a control valve for a pressure drop corresponding to 50% of its initial steam pressure.

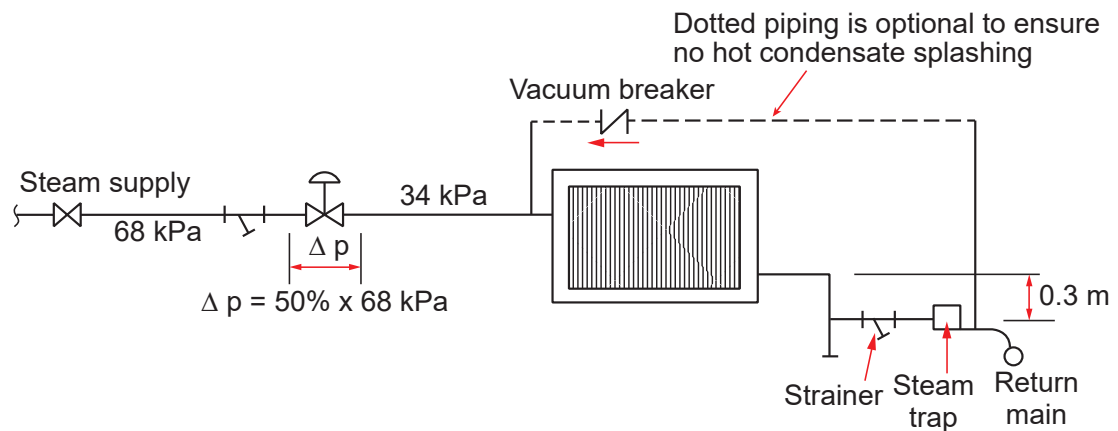
Effects of an Oversized Coil and Control Valve

With an oversized coil and air entering at -1°C, the steam flow control valve may be cracked open, or it may be hunting (opening and closing). Little or no steam reaches the outlet of the coil. If the valve closes for any length of time (which is the case with an oversized valve), it is possible for a vacuum to develop in the coil. Since the return main is normally at atmospheric or higher pressure, this vacuum could cause condensate to remain trapped in the coil. A great many freeze-ups are caused by this problem.

On Track

A vacuum develops in a coil when the steam flow control valve fills the coil with steam, and then shuts off. As it gives off heat, the initial volume of steam in the coil condenses to 1/1600 of its original volume.



Figure 1 – Vacuum Breaker Installation

The vacuum occurs whenever the steam admission valve remains closed for an appreciable length of time. This problem can be solved by installing a vacuum breaker.

Vacuum Breaker

The vacuum breaker allows air to enter the coil. The coil then operates at a pressure slightly greater than the condensate return line. The condensed steam can then flow into the condensate return line.

To prevent possible freeze-ups caused by a vacuum in the coil, a vacuum breaker must be installed, as shown in Figure 1. As an alternative, a DN 12 (½ in. NPS) swing check valve may also be used for this purpose.

For best results, the vacuum breaker must be installed after the steam flow control valve, and as close as possible to the inlet connection to the coil.

When a check valve is used as a vacuum breaker, it may be left open to the atmosphere, or it may be connected to the return header, as indicated by the dotted line in Figure 1. This last alternative is preferred where intermittent splashing of hot condensate may present a hazard. This type of connection is necessary when the pressure in the return main is above atmospheric.

It must be emphasized that no matter how capable a steam trap might be, it will not function satisfactorily without a vacuum breaker.

HOT WATER COILS

There is always some apprehension about using water coils to heat air at subfreezing temperatures. However, when there is no alternative, the following points provide a reliable guideline for the correct application of such a system with minimal possibility of freeze-up:

- A constant flow of water should be fed to the coil. A minimum water velocity of 0.9 m/s should be established inside the tubes, and the water temperature should be maintained at a reasonable level.
- The air velocity through the coil should not exceed 3.55 m/s.
- Positive air venting of the coil is essential.
- A control system must be selected to ensure reliable operation. The greatest fears in hot water coil installations that handle subfreezing air are:
 - Failure of the circulating pump
 - Failure of the heat source



In order to protect the hot water system from freeze-ups, safety control devices are used, such as freeze stats and flow switches.

A freeze stat temperature controller will stop the fan, close the outside air dampers, and open the return air dampers, if excessively low hot water temperature is detected. The temperature of the hot water is determined by measuring the temperature of the air discharging from the hot water coil.

A flow switch (or sail switch) stops the fan and closes the outside air dampers, if the hot water flow is interrupted due to pump failure or the accidental closure of hand valves.

A parallel flow arrangement offers better protection against freeze-ups; therefore, it is preferable to use this arrangement for hot water coils used to heat subfreezing air. In the parallel flow, the cold air enters the coil where the hottest water is flowing. Even though parallel flow is not as efficient as a counter flow arrangement, this is one instance where safety against freeze-up has priority over heat transfer efficiency.

GLYCOL COILS

Trouble-free steam or hot water coil performance depends on the proper functioning of associated equipment. A failure of one component can result in coil freeze-up and expensive repairs. It is therefore understandable that many designers, building operators, and plant engineers prefer using a solution of ethylene glycol mixed with water for better protection against freezing.

However, the use of ethylene glycol solution will result in the following:

- a) Lower heat transfer rate, hence lower efficiency.
- b) Increased friction losses in the coil and piping.
- c) Larger pumps and higher power consumption.

Because it is slightly toxic, ethylene glycol is not recommended for use in heating and air conditioning systems in the food industry. For these applications, a solution of propylene glycol may be used, because it is nontoxic. It is important to remember, however, that propylene glycol has different heat transfer characteristics and much higher pressure drops.

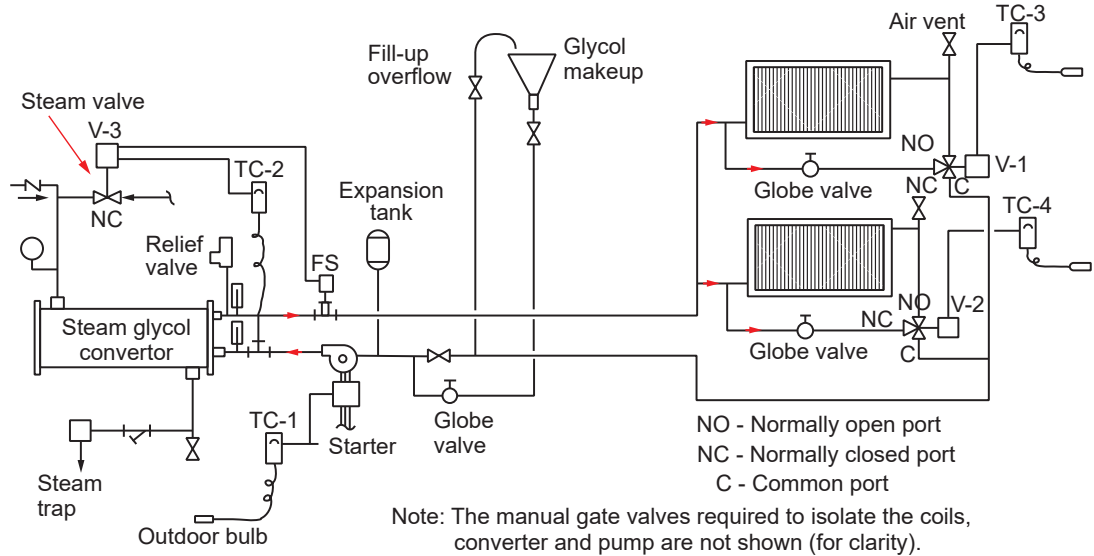
A glycol velocity of 1.2 to 1.8 m/s is recommended to ensure a turbulent flow and reasonable heat transfer efficiency.

The use of a direct-fired boiler is not recommended for heating glycol because the heat transfer surface should not exceed 140°C. Temperatures exceeding this level will cause a breakdown of the inhibitor, which must be added to the glycol to prevent corrosion in the system. To transfer heat to glycol heating loops, steam or hot water heat exchangers can be used.



Figure 2 shows a system for heating glycol. Controls must be installed to prevent overheating of the glycol, if the glycol circulation pumps fail. When hot water is the heat source, the water should not exceed 100°C.

Figure 2 – Glycol System for Coils Handling Subfreezing Air (Using Steam as Heat Source)





OBJECTIVE 2

Describe the installation recommendations for coils, piping, steam traps, control valves, air vents, and vacuum relief devices.

STEAM COIL PIPING AND TRAPPING

Steam coil piping differs from other systems because it usually carries four fluids: steam, water, air, and non-condensable gases. For this reason, satisfactory steam coil operation is dependent on proper piping, trapping, venting, and vacuum relief.

Accepted methods for piping steam coils in low-, medium-, and high-pressure systems are shown in Figures 3 to 5, at the end of the chapter. These piping diagrams and the following recommendations must be followed closely to assure satisfactory operation.

Steam Coil Installation

- a) Whenever possible, install steam coils with the tubes in a vertical position, as shown in Figures 3 and 4. The vertical position will ensure more positive condensate drainage out of the coils.
- b) When steam coils must be installed with tubes in a horizontal position (as in Figure 5), the pitch of the coil toward the return connection must be sufficient to ensure the condensate is able to flow freely at all times out of the coil. This is very important in order to prevent physical damage, water hammer, unequal thermal stresses, freeze-up, and corrosion.
- c) Ensure the types of steam coils used to heat subfreezing air are completely drainable when the steam supply is off.

Piping Installation

- a) Support the piping independently of the coils.
- b) Provide swing joints or flexible fittings in all piping connections adjacent to the heating coils, to absorb expansion and contraction. Provide the necessary flanges or unions and manual shut-off valves to facilitate coil removal.
- c) Pitch the condensate piping from the trap to the return header 21 mm/m ($\frac{1}{4}$ in. per ft.).
- d) Do not modify or add to the coil connections. The coil connections as provided by the manufacturer are sized according to the coil. Use the pipe size that corresponds to the full size of the coil connections.
- e) Use the pipe size at the inlet and outlet of the steam trap that corresponds to the full tapping connection size on the trap.
- f) Pitch the steam supply and condensate return piping down a minimum of 10 mm/m ($\frac{1}{8}$ in. per ft.).

Steam Trap Installation

- a) Steam trap selection must be based on the pressure difference across the trap and a minimum capacity corresponding to three times the coil condensate rate. Refer to the trap manufacturer data for recommendations regarding specific applications.
- b) Locate the steam trap so its outlet is at least 300 mm below the coil return connection. This positioning provides sufficient hydrostatic head to overcome trap losses, and assures complete condensate removal from the coil.
- c) Always trap each coil separately to prevent condensate holdback in one or more coils. The float and thermostatic (F&T) trap is preferred because it offers a continuous discharge of condensate and air. It is really two traps in one. The float will pass condensate regardless of temperature, since the float handles all condensate. The thermostatic bellows handles air and non-condensable gases. The float is modulating in its action. For example, if the condensate load is low, the float rises only a small amount. As the condensate load increases, the float rises until its discharge port is wide open.

The F&T trap is recommended for systems that have:

- Coils controlled by modulating control valves.
 - Condensate that flows by gravity into a return main at atmospheric pressure.
 - Coils operating with low or medium pressure steam (i.e. up to 172 kPa). Beyond that pressure range, the cost of F&T traps increases considerably.
- d) Use the inverted bucket (IB) trap when the steam pressure is higher than 172 kPa and the flow is not modulated. IB traps also cost less than F&T traps. The IB trap is also used with overhead returns, as shown in Figure 4, or with pressurized returns.
 - e) Overhead returns require 7 kPa of available pressure at the trap discharge for each 610 mm rise in elevation, to ensure continuous condensate removal. Therefore, do not use a modulating valve to control the steam coil; use a two-position control valve instead.

On Track

The term “available pressure” means pressure over and above the pressure in the condensate return main.

- f) Always install a strainer near the inlet of each trap.
- g) As indicated in Figure 4, use the same pipe size as the main for the drip leg. Never drip the steam supply main through coils. Drip the steam supply main through a steam trap into the return condensate main.

Control Valve Installation

- a) Do not oversize the modulating control valve.
- b) Do not use a modulating valve to control a steam coil when the entering air temperature is below 1.5°C.
- c) Refer to Figures 1 and 2 for recommended methods to control steam coils that handle subfreezing air.
- d) Do not use a modulating valve for the steam coil where the condensate must be lifted to an overhead return, as shown in Figure 4. For the arrangement shown, both V_1 and V_2 can be two-position control valves with slow opening characteristics to prevent coil damage, or they can be manual valves. However, when the modulating feature is necessary, arrange for the steam traps to drain the condensate by gravity into a vented receiver with a condensate pump that will lift the condensate to the overhead return.
- e) When using a modulating control valve, select a valve with V-port trim, to obtain a gradual modulating action.



- f) Control each coil bank separately when installing coils for series airflow, as in Figure 4, because each coil has equal loading and pressure drop.
- g) Use a single control valve on a bank of coils connected in parallel (Figures 3 and 5), since each coil has equal loading and pressure drop.
- h) Size the steam control valve for the steam load, not for the supply connection size.

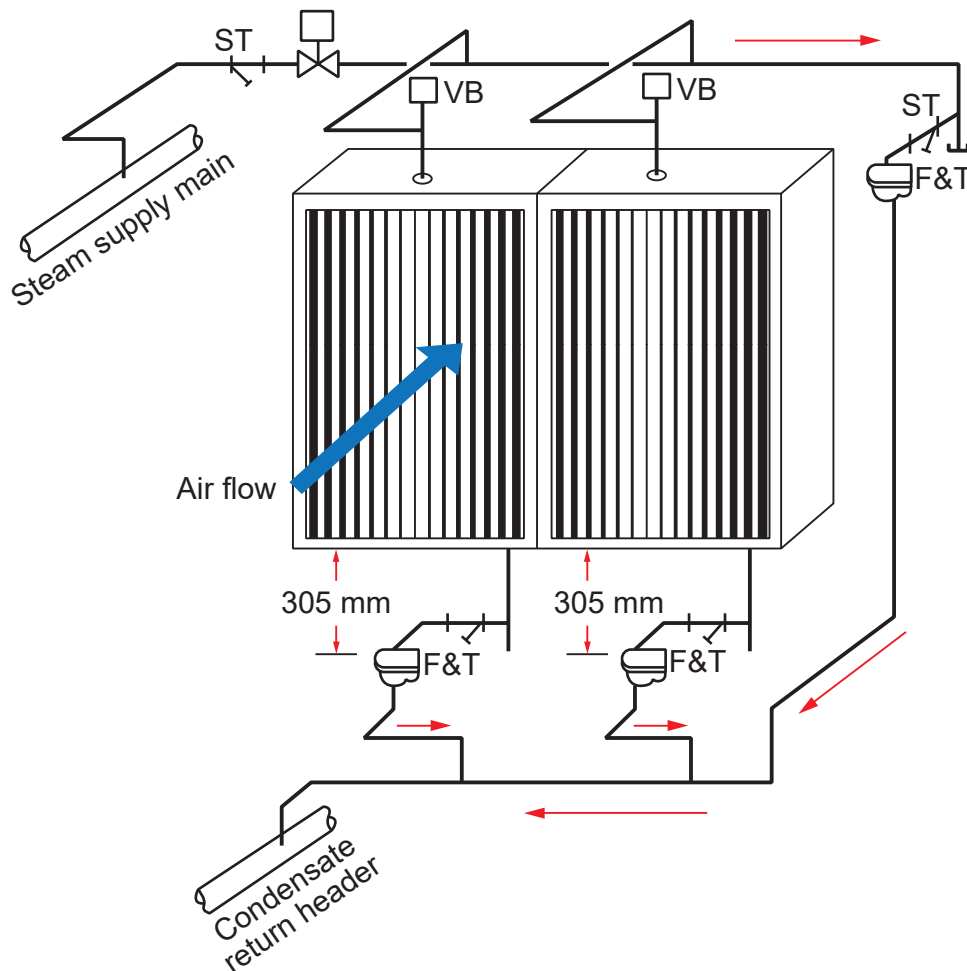
Air Vent Installation

- a) Provide air vents as required to eliminate non-condensable gases in the steam supply main and coils.
- b) Install the air vent at the inlet of an inverted bucket trap, as shown in Figure 4. The vent is installed this way because the IB trap has a slow venting rate which could cause the condensate to back up into the lower part of the coil and result in coil freeze-up.
- c) When the steam main is adequately vented, omit the air vent at the coil if the F&T trap is used with atmospheric return, as shown in Figures 3 and 5, because this type of trap is continuously venting.

Vacuum Relief

When a modulating valve or a two-position control valve controls the steam coil, it is important to have a vacuum breaker fitting in order to provide vacuum relief. Refer to the previous discussion on vacuum breakers (Figure 1) for the available types and the recommended location for the installation.

Figure 3 – Medium- and Low-Pressure Steam Coil Bank with Vertical Tubes, Horizontal Air Flow, and Atmospheric Gravity Return



**Notes:**

- a) The manual shutoff valves, unions, and flanges are not shown for clarity.
- b) The pressure classification as referred to in Figures 3, 4, and 5 is as follows:
 - Low pressure: up to 103.4 kPa
 - Medium pressure: 103.4 to 690 kPa
 - High pressure: above 690 kPa

Legend:

F&T: float and thermostatic trap

IBT: inverted bucket trap

ST: strainer

CV: check valve

VC or VB: vacuum breaker

AV: air vent



CHAPTER SUMMARY

Potential for coil freeze-up exists when heating cold air. Coil design and installation are important for preventing freeze-up.

Cold air can be heated with steam, hot water, or glycol. Coils may have long or short tubes, with short tube designs best suited for steam use. Proper coil and control valve sizing are important for preventing freeze-up, which is most likely to occur at temperatures just below freezing.

Glycol coils can be used where freeze-up concerns are paramount. Fittings, such as vacuum breakers and air vents, help prevent freeze-up of steam and hot water coils. Freeze-stats and flow switches shut down the air handler and close off the outside air dampers if freeze-up is imminent.

Building operators must understand system design, installation, and component selection to successfully operate and troubleshoot heating equipment.



UNIT SUMMARY

Maintaining a comfortable environment for the majority of the occupants in a building is challenging. As a qualified building operator, a Power Engineer must understand the factors that affect comfort. This understanding, and the variations it may require, puts the Power Engineer in a better position to deal with complaints or issues.

This unit discussed how temperature, pressure, and humidity relate to HVAC systems in order to provide human comfort. In addition, this unit presented an overview of the various components, systems, and operating controls used in a typical HVAC system.

The building operator must understand the design, limitations, and normal operating parameters of an HVAC system. It is also essential for the operator to know how to select the components for that system. With this knowledge, the Power Engineer will be able to successfully operate and troubleshoot HVAC systems.

A self-assessment tool is available on MyPower LMS. Login using the unique user ID and password found on the inside front cover of Unit 1.



KNOWLEDGE EXERCISES AND UNIT GLOSSARY

Chapter 1	Conditioning the Air	U10-9
Chapter 2	Humidification	U10-13
Chapter 3	Fans for Air Distribution Systems	U10-15
Chapter 4	Ventilation and Air Filters	U10-17
Chapter 5	HVAC Duct Systems	U10-19
Chapter 6	Types of Coils and Operation	U10-21
Unit B-10	Unit Glossary	U10-23



KNOWLEDGE EXERCISES – CHAPTER 1

Name: _____ Date: _____

Instructor: _____ Course: _____

Objective 1

1. List the factors that contribute to effective temperature.

2. Explain why most buildings recirculate air instead of using 100% make-up.

3. Explain why relative humidity should be kept within a recommended range.

Objective 2

4. List some equipment considerations for a building located in Winnipeg, Manitoba (geographical location with cold dry winters, hot humid summers).

5. Air entering a building has a relative humidity of 80% and a temperature of 30°C. List the equipment required to treat the air.



Chapter 1 (Cont.)

Objective 3

6. What are the basic components of air handling unit?

7. Describe the following types of HVAC systems. Identify where and why they would be used.

a) Systems with 100% recirculated air.

b) Systems with 100% outside air.

c) Systems with fixed outside air percentage.

Objective 4

8. What is humidity? How can moisture exist in vapour form at room temperature?



Chapter 1 (Cont.)

9. How does absolute humidity change with the Canadian seasons?

Objective 5

10. Describe wet-bulb depression.





KNOWLEDGE EXERCISES – CHAPTER 2

Name: _____ Date: _____

Instructor: _____ Course: _____

Objective 1

1. Describe the relationship between temperature, specific humidity, and relative humidity.

2. List the effects of low humidity.

3. What is the recommended range for relative humidity for human comfort?

Objective 2

4. What is a primary problem when using untreated water for a humidifier?

5. Describe how water may turn into a fog when the water flows through a spray humidifier.



Chapter 2 (Cont.)

6. What is the primary issue relating to humidification when using a non-ducted heating system?

Objective 3

7. Explain how an air washer can be used to dehumidify the air.

8. Explain how clean steam humidification is safer for human health than using steam directly from boilers.

9. Explain what must be done if a humidification system swab test is positive.

10. Describe the advantages of using the steam grid humidifier.



KNOWLEDGE EXERCISES – CHAPTER 3

Name: _____ Date: _____

Instructor: _____ Course: _____

Objective 1

1. Discuss what causes air to flow in the HVAC system.

2. Explain why the conversion of velocity to pressure, or pressure to velocity, is never 100% efficient.

Objective 2

3. List the types of centrifugal fans that are commonly used.

4. Describe the airflow as the air passes through the axial flow fans.

Objective 3

5. Describe the purpose of a fan performance curve.



KNOWLEDGE EXERCISES – CHAPTER 4

Name: _____ Date: _____

Instructor: _____ Course: _____

Objective 1

1. The air velocity through a viscous filter can be _____ higher than with dry filters.
 - a) 2.5 m/s
 - b) 4.0 m/s
 - c) 4.5 m/s
 - d) 7.5 m/s

2. What is the purpose of keeping the building static pressure slightly above atmospheric?

3. What is a possible cause of uneven temperatures in a building?

Objective 2

4. What are the factors for determining the type of air cleaning system to use?

5. Living organisms that must be removed from the air are:

- a) Insects and pollen
- b) Bacteria and insects
- c) Bacteria and spores
- d) Pollen and spores



Chapter 4 (Cont.)

Objective 3

6. The best filters available for ventilation system lint removal are:
 - a) Charged-media electronic
 - b) Dry
 - c) Viscous impingement
 - d) Activated alumina chemisorbant

7. The filter that utilizes both the electric charge and a filtering media is the
_____.



KNOWLEDGE EXERCISES – CHAPTER 5

Name: _____ Date: _____

Instructor: _____ Course: _____

Objective 1

1. Explain how the duct system pressure affects the initial cost and the overall operating costs of an HVAC system.

2. Explain why a low-pressure system requires more space to move the same air as a medium - or high-pressure system.

Objective 2

3. Describe why access openings are necessary near fire dampers.

4. Explain why flexible connectors are used on the outlet of the air handling unit.



Chapter 5 (Cont.)

Objective 3

5. List three factors that affect the quantity of air leakage from a treated air duct.

Objective 4

6. Explain why opposed dampers are better for control than parallel dampers.

7. Describe the difference between louvres and dampers.

8. Explain why a mixing box is a good fit for parallel blade dampers.

Objective 5

9. True or False: Induction or aspiration causes a slight vacuum that draws air towards the HVAC outlet and causes supply air and room air to mix.

10. List the functions of terminal air devices.



KNOWLEDGE EXERCISES – CHAPTER 6

Name: _____ Date: _____

Instructor: _____ Course: _____

Objective 1

1. Explain how the installation of a vacuum breaker can prevent steam coil freeze-up.

2. Explain why oversized steam coils are susceptible to freezing.

3. Explain how freeze stats protect hot water coils.

Objective 2

4. Explain why the float and thermostatic trap is the preferred steam trap for steam coils.



Chapter 6 (Cont.)

5. Explain why a coil must have drains.

6. Draw a simple sketch of a medium pressure steam coil bank with vertical tubes, horizontal airflow, and atmospheric gravity return. Show all necessary fittings.



UNIT B-10 GLOSSARY

Term	Definition
Absolute humidity	The mass of moisture (i.e. water vapour) present in one kilogram of an air/moisture mixture. The measurement unit for absolute humidity is kg/kg.
Air conditioning	The simultaneous control of the physical and the chemical conditions of the atmosphere within a structure. This is achieved by affecting some or all of the following air conditions: temperature, humidity, motion, distribution, pressure, and filtration (dust, bacteria, odours, toxic gases, and ionization.)
Air diffusers	Air distribution outlet or grille designed to direct airflow into desired patterns.
Air handling unit	A machine comprised of a fan, a filter, a heater, a cooler, and a humidifier, used to supply conditioned air in an HVAC system.
Air washers	A mechanical device placed in an air stream to cool, clean, humidify, or dehumidify the air.
Axial flow fans	A fan that supplies air parallel to the direction of the fan shaft.
Backdraft damper	See <i>relief damper</i> .
Centrifugal fans	A fan that supplies air perpendicular to the fan shaft. Centrifugal fans are classified according to the shape and design of the fan blades: backward inclined, forward curved, backward inclined with airfoil blades, and radial blades.
Charged-media air cleaner	An electrically charged fibreglass or cellulose filter mat, installed in an air stream, which efficiently removes particulate matter.
Conduction	The transmission of heat through and by means of matter unaccompanied by any obvious motion of the matter.
Convection	Transfer of heat by means of movement or flow of a liquid or gas.
Dampers	Device for controlling airflow.
Dew point (wet bulb temperature)	The temperature at which air subjected to cooling becomes saturated and below which the water vapour will begin to condense out of the moist air.
Dry air filters	A matting of fine tangled fibrous material, placed across an air duct or plenum, to remove particulate from an air stream.
Dry-bulb temperature	The temperature of a gas or mixture of gases indicated by an accurate thermometer when there is no latent heat flow from the thermometer.
Duct systems	In HVAC systems, a collection of large interconnected ducts, fans, filters, coils, dampers, and louvres for moving air to and from conditioned spaces
Effective temperature (ET)	The overall effect of air temperature, humidity, and air movement on human comfort.
Electronic air cleaners	An air purification device that imparts an electrical charge to particles in an air stream causing them to collect on an oppositely charged plate.
Evaporation	Term applied to the changing of a liquid to a gas. Heat is absorbed in this process.
Fire dampers	A steel frame equipped with steel dampers, which fit tightly in the casing when closed. The damper is activated by the melting of a fusible link.
Fixed louvres	A non-adjustable assembly of blades that direct airflow.
HEPA	See <i>high efficiency particle air (HEPA)</i> .
High efficiency particle air (HEPA)	An air filter capable of removing particles as small as 0.3 micron in diameter with 99% efficiency. They are commonly used in hospitals, laboratories, and other facilities requiring supply air nearly free of particles.



Term	Definition
Humidity	The presence of moisture in the air.
HVAC	Acronym for heating, ventilating, and air conditioning.
Hygroscopic	Having an affinity for moisture.
Make-up air	In an HVAC system, the fresh air supplied to an occupied space to replace stale, oxygen depleted, and possibly smelly air in the building or system.
Mechanical ventilation	The use of fans to recirculate, exhaust, and supply fresh air to occupied spaces.
Mixed air	In an HVAC system, a mixture of make-up air and return air that is to be recirculated in a building or system.
Natural ventilation	Passive ventilation achieved by permitting airflow through building openings, such as windows and doors, without the use of fans.
Odour adsorber	A method of removing objectionable vapours in an air conditioning system, by exposing the air stream to activated carbon or activated potassium permanganate.
Opposed blade damper	Dampers with blades linked so that adjacent blades rotate in opposite directions. Opposed blade arrangements are superior when modulation of airflow is required.
Parallel blade damper	Dampers consisting of two or more blades linked together in such a way that all blades rotate in the same direction. This type is often used on mixing boxes where sets of dampers are used to direct airflows toward each other for good mixing.
Preheat coils	In an HVAC system, a device for raising the temperature of extremely cold outside air to prevent freezing of downstream equipment.
Relative humidity (RH)	The ratio of the amount of water vapour in the air to the amount water vapour that the air can hold at a given temperature.
Relief damper (backdraft damper)	A passive damper comprised of a series of interconnected, weighted blades that open and close simultaneously, due to differences in static pressure across the blades. Relief dampers are used to relieve excess building static pressure and prevent cold air from entering a building.
Return air	In an HVAC system, the air returning from a ventilated space, to be reheated, recooled, filtered, humidified, or exhausted.
SMACNA	Sheet Metal and Air Conditioning Contractors' National Association (SMACNA).
Specific humidity	The mass of moisture (i.e. water vapour) present in one kilogram of an air/moisture mixture. The measurement unit for absolute humidity is kg/kg. Also called absolute humidity.
Static pressure (duct)	The pressure exerted by the air on duct, pipe, or vessel walls.
Stationary air louvres	Louvres used in fresh air intake openings to minimize the amount of water and snow entering an air handling system.
Supply air	In an HVAC system, conditioned air that is delivered to an occupied space.
Total pressure	The sum of static pressure and velocity pressure.
Tube axial fan	A heavy-duty propeller fan suitable for duct mounting.
Vane axial fan	A tube axial fan equipped with guide vanes located behind the fan wheel to straighten out the spiral flow of air.
Velocity pressure	The pressure caused by the impact of the air flowing through a duct or pipe.
Ventilation	An HVAC process that supplies or removes air from an occupied space.
Viscous	Thick and sticky.



Term	Definition
Wet-bulb depression	The difference between the wet-bulb and dry-bulb temperatures as measured with a psychrometer, for the calculation of relative humidity.
Wet-bulb temperature	See <i>dew point</i> .

