

# HVACR 101



## Airflow Types and Systems

Module 6 of 10

### LEARNING OBJECTIVES

*On completion of this module, you will be able to:*

1. Recognize the important role that air distribution and ventilation plays in ensuring occupant comfort and satisfaction with a building's HVACR system.
2. Explain what personal comfort means and how it affects air distribution and ventilation system design and operation.
3. Identify basic airflow concepts and science.
4. Recognize the types of equipment and devices that are part of modern air distribution and ventilation systems for home and commercial applications.
5. Identify the major sources of indoor air pollution and contamination.
6. Determine what is involved in measuring airflows and achieving proper air distribution and balance in HVACR systems.
7. Understand the most common issues or questions that HVACR businesses encounter when dealing with airflow and ventilation systems.



## INTRODUCTION

The **Mechanical Service Contractors of America (MSCA)** produced this module on "Airflow Types and Systems." The module reviews air distribution and ventilation systems typically used in HVACR installations. It is part of a ten (10) HVACR 101 series designed to review all aspects of mechanical service operations, including kinds of services provided, types of systems and equipment involved, different ways services are provided to customers, who is responsible for the various service functions, and what resources are available to you in doing your job (see list of modules below).



### IMPORTANT

The MSCA helps contractors with management and marketing skills, training and educational programs, and government and labor relations.

The modules are designed so you will be able to attain knowledge from the comfort of your desk or home. Enhancing knowledge and understanding allows you to become more confident and effective in your job.

#### MSCA HVACR 101 MODULES

- |   |  |
|---|--|
| #1 What is HVACR?                                   | #6 Airflow –Types and Systems              |
| #2 Terminology and Slang Used in the HVACR Industry | #7 Types of Commercial Systems             |
| #3 HVACR Basic Sciences and Formulas                | #8 Fans, Pumps and Miscellaneous Equipment |
| #4 A/C Basic –Small Tonnage                         | #9 Heating Systems                         |
| #5 A/C Basic –Large Tonnage                         | #10 Focus on the Customer                  |

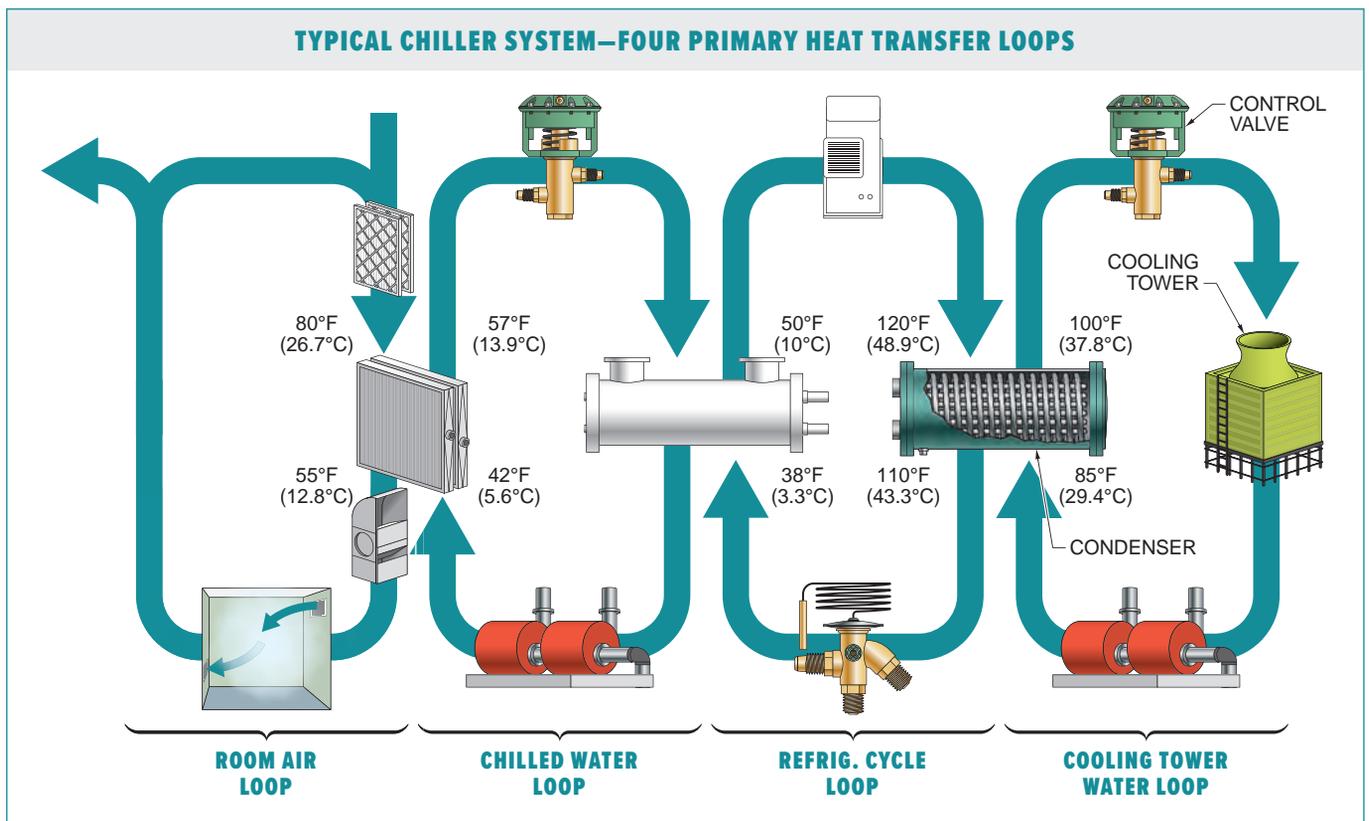
## INTRODUCTION TO AIR DISTRIBUTION AND VENTILATION SYSTEMS

The previous modules in the HVACR 101 series covered fundamental theory and equipment used across a wide range of applications, addressing single room air conditioning systems to large scale commercial environments and processes. The objective of any sized system is to provide an environment which stresses building occupant safety and promotes comfort.

The HVACR equipment discussed in previous modules represents a starting point to providing effective systems. Items such as chillers, condensers, evaporators, cooling towers, etc. are essential equipment. However, cooling capability is not very useful for building occupants unless it can be effectively

delivered to, and precisely controlled within, occupied spaces where it is needed. Effective delivery and precise control of HVACR heating/cooling is the task of the **Air Distribution and Ventilation System**.

As you may recall from Module 5, virtually all large scale air conditioning systems are comprised of four (4) primary heat transfer loops, or subsystems (see diagram below). While all four (4) loops are critical to operation in properly designed systems, three of the four transfer loops do their work in the background, with most building occupants completely unaware of their operation, or even the existence of equipment performing these functions. The same cannot be said of the remaining loop for building air distribution and ventilation ("Room Air Loop").



When things aren't going well with the air distribution and ventilation in a building, this can have a direct and immediate impact on the comfort of people trying to engage in various work activities. Building occupants will definitely notice if the air around them is too hot, too cold, too dry or too humid. Moreover, occu-

pants will sense when the building air seems stale or contains distracting odors, and/or freezing drafts are blowing papers off desks, and/or noisy blowers are making telephone conversations difficult. If these conditions arise, occupants will quickly voice dissatisfaction.

Signs that the air distribution and ventilation system may not be working well include the presence of personal desktop fans to break up stagnated, stale air. Or, air supply grills or registers may be completely shut or blocked off to prevent drafts. Also, electric, plug in space heaters may be used to increase comfort.

## **GOAL OF AN AIR DISTRIBUTION AND VENTILATION SYSTEM**

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While the overall goal is occupant comfort, accomplishing this requires an air distribution and ventilation system to satisfy several closely inter-related objectives, all of which contribute to comfort. They are:

- Effective distribution of temperature-controlled air at proper volume throughout occupied areas to maintain a comfortable temperature range.
- Humidification or dehumidification of air to provide a desirable level of humidity.
- Removal of objectionable contaminants, air pollution, or odors in the air to ensure healthy and pleasant indoor conditions.
- Exchange of excess CO<sub>2</sub> from human respiration with fresh outside air.
- Maintaining acceptable noise levels that contribute to comfort and productivity.
- Blending aesthetically and unobtrusively with the building interior design and work spaces.

These objectives seem straightforward, but effectively accomplishing each one is not simple. It involves substantial complex analysis in system design and maintenance of the associated equipment and components. Operation of a properly configured air distribution and ventilation system will go almost unnoticed by building inhabitants. Conversely, a poorly designed and performing system, failing in one or more of the objectives, will cause constant complaints and service requests from occupants, and may even be hazardous to health. Each of the objectives will be covered in following sections, but it will be useful to first have a better understanding of what is meant by human environmental comfort.

## HUMAN ENVIRONMENTAL COMFORT

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The ultimate performance measure for any air distribution and ventilation system is how well it provides/maintains human environmental comfort. In a typical room or controlled indoor environment, occupant comfort usually refers to satisfaction with thermal conditions, indoor air quality, and environmental noise levels.

### Human environmental comfort generally includes:

- Thermal comfort
- Indoor air quality
- Environmental noise levels

But how is human environmental comfort defined? It turns out that it is very personal. Each person's definition of environmental comfort will depend on how they respond to thermal comfort, air quality and environmental noise factors. Understanding how various air distribution and ventilation system parameters affect these factors is key to proper system design and maintenance.

## THERMAL COMFORT

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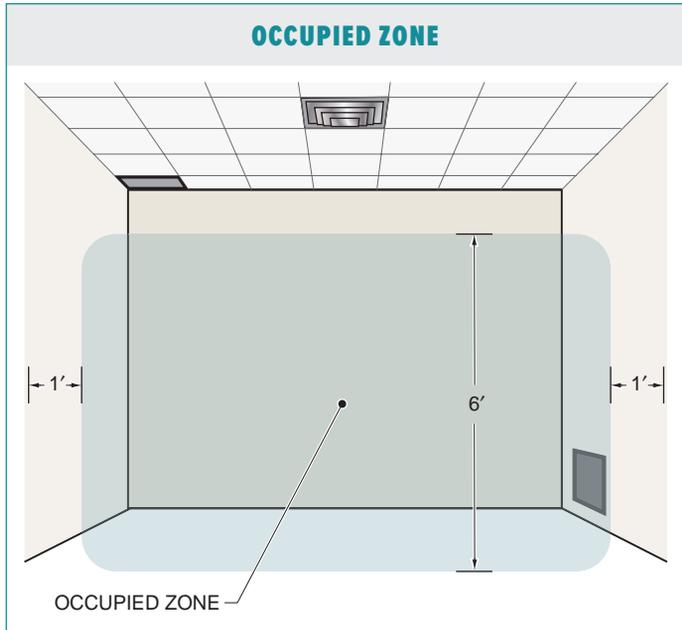
Thermal comfort refers to typical heating or cooling effects on the human body, including air temperature, humidity, and airflow (velocity/speed). It is important to restate that thermal comfort is subjective; meaning it varies from one person to the next. Moreover, there are personal factors and environmental factors which affect thermal comfort. They are:

- Personal—Occupant's metabolic rate (body heat generated by normal activity or body heat generated by physical exertion) and clothing level.
- Environmental—Temperature, humidity and airflow.

Addressing all of these factors, the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) has conducted substantial research to develop helpful guidelines. The ASHRAE 55 standard suggests the following ranges are appropriate design targets which will meet the comfort requirements for 80 percent of typical building occupants.

- Temperature—Ranges from 77°F in summer to 72°F in winter
- Humidity—63% relative humidity for the temperature range above
- Airflow/Air Circulation—30–70 cubic feet per minute (CFM) near occupants

These ranges relate to airflow in the space around the occupant or what is referred to as the **occupied zone**, also defined by the ASHRAE standard. The occupied zone is generally considered to be between the floor and six (6) feet above the floor and more than one (1) foot from internal walls (see diagram below).



Providing desired thermal comfort in the occupied zone is important because it reduces the effort of occupants to maintain a stable normal body temperature which promotes correct functioning of psychological processes. Building occupants which are satisfied with their thermal comfort are more productive and are generally more healthy.

**Temperature** (Ranges from 77°F in summer to 72°F in winter)

Comfort within an occupied area is heavily dependent on the ability of the air distribution and ventilation system to distribute conditioned air in volumes adequate to achieve desired temperatures. In designing a HVACR system, the capacity

and components must be sized to ensure that adequate heating or cooling and airflow are available to meet the total building needs.

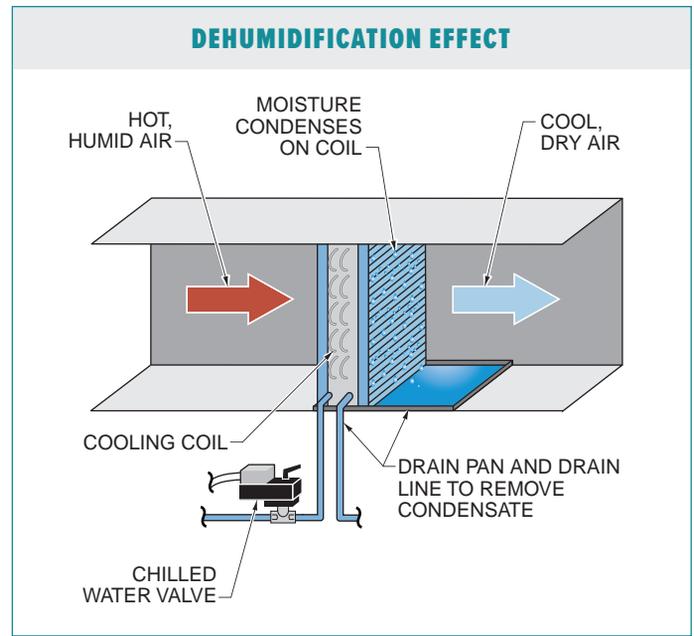
**Humidity** (63% relative humidity for the temperature range above)

Humidification and dehumidification capability are necessary in an HVACR system to raise or lower the level of humidity in occupied spaces. This may mean reducing humidity in hot, humid climates and summer seasons, and adding humidity in cold dry climates or winter months.

The amount of humidity is commonly monitored with a measure called **relative humidity**, which refers to the percentage of water vapor air contains in relation to the maximum amount it can hold when 100 percent saturated. The higher the relative humidity, the high the percentage of water in the air relative to 100 percent saturation. Air can hold only a very small amount of water vapor, 0.01578 lb (about one-fourth ounce) of water per pound of 70°F air. Even so, occupants can become uncomfortable with only minor changes in relative humidity.

HVACR systems may typically change relative humidity in occupied spaces by dehumidification and humidification processes.

- **Dehumidification**—There are several ways to accomplish this, including use of desiccant (water attracting) wheels. More commonly, dehumidification is done by cooling the air to its dew point temperature—the point where the water in air starts to condense on colder surfaces—and then collecting the condensation in a pan to discard. In air distribution and ventilation systems, this is done by passing the air over chilled cooling coils or finned collectors. This is the same basic effect that occurs when water collects on the outside of a glass of ice water; the water condensed out of room air drips down the side of the glass and forms annoying puddles.



In HVACR systems, large amounts of condensate may be removed from circulating air. It is important that condensate pans and drain lines are kept clean and in proper working order.

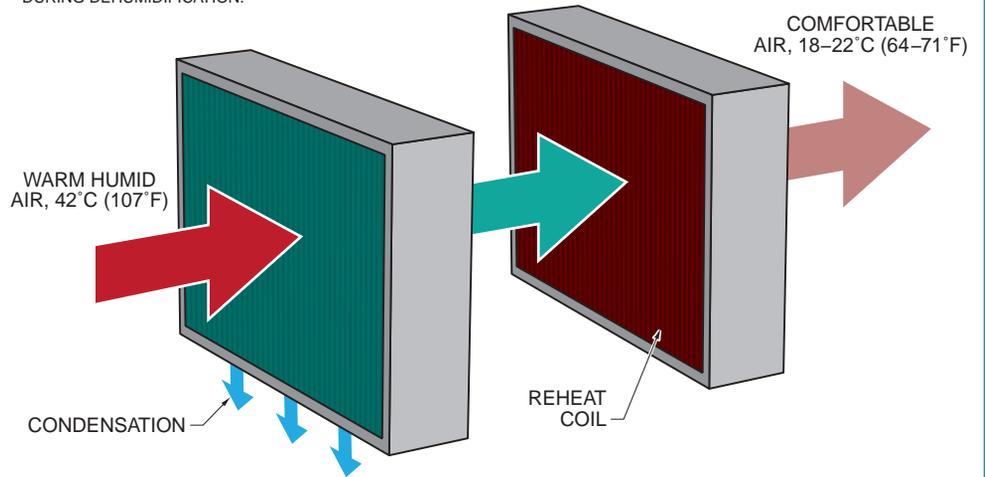
Some dehumidification occurs naturally as an integral part of any air conditioning process. With direct refrigeration air conditioning systems, any air that passes over the cold evaporator coils will dehumidify as significant condensation collects and drips off the coils into a drain pan. For water cooled chiller systems, this effect also occurs at cooling coils, but with less condensation effect, since the chilled water is somewhat warmer than refrigerant.

When dehumidification from the normal air conditioning process is inadequate, additional dehumidification may be needed. It can be accomplished by using a separate system of refrigerated coils located at the AHU or at another appropriate location.

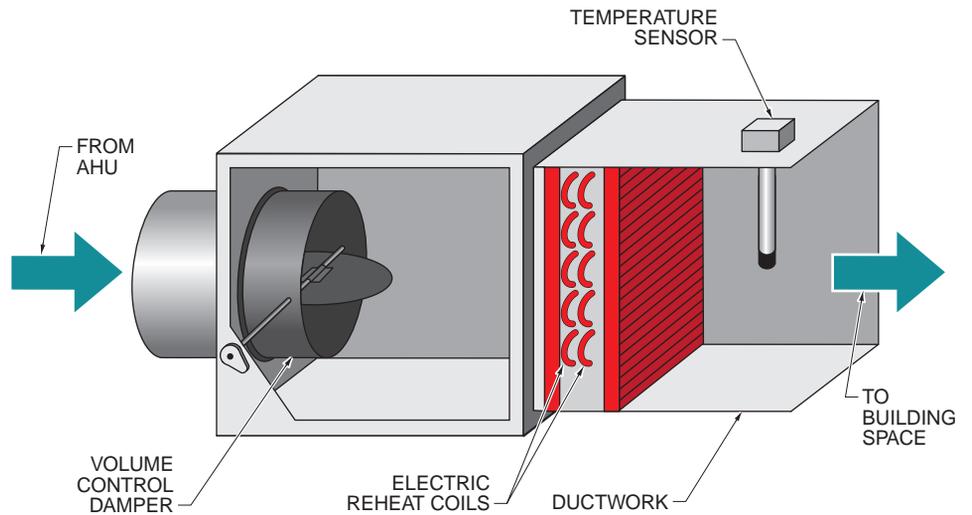
Effective dehumidification requires cooling the airflow to a temperature that may be lower than acceptable for occupant comfort. In this case a reheat coil may be required following the dehumidification stage, to raise the supply air temperature to a level more suitable for the user environment.

### REHEAT FOLLOWING DEHUMIDIFICATION STAGE

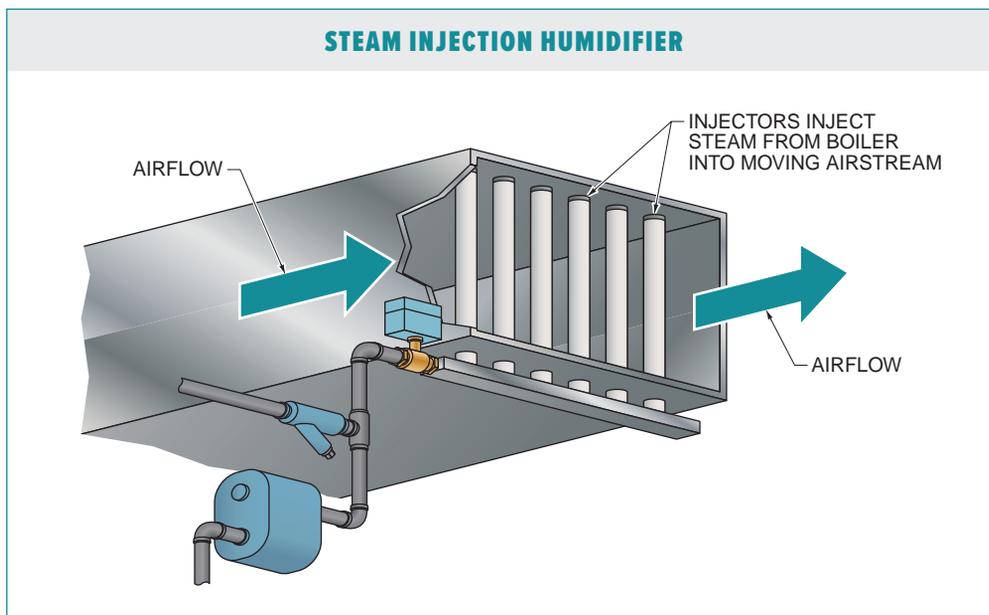
NOTE: GENERALLY, AIR IS OVERCOOLED DURING DEHUMIDIFICATION.



### ELECTRIC REHEAT COILS MOUNTED IN DUCTWORK FOLLOWING DEHUMIDIFICATION STAGE



- **Humidification** is accomplished by adding moisture (water) to the circulating air. This is done by various methods, which include:
  - **Evaporative humidifiers** rely on normal evaporation of water from saturated media on a rotating wheel to add moisture to the air stream.
  - **Direct injection steam** humidifiers use steam from a boiler to inject large volumes of moisture as steam into the airflow at or near the AHU. Using steam ensures that the injected moisture is sterile and bacteria free, but requires an existing source of steam and adds additional heat to the airflow, which increases loading on the air conditioning system when cool air is desired.



- **Atomizing spray** humidification is another approach that uses a fine water spray, or water and air mix, to inject water directly into the moving air stream. This is a simpler method which takes less energy as it only requires insertion of humidifier spray nozzles in the supply duct, along with associated valves and controller.

Regardless of what process is involved, the overall level of humidity is monitored by one or more **humidistats**, similar in operation to thermostats. Humidistats sense relative humidity and are used to call for adding or removing moisture to the circulating air when the humidity falls outside the desirable range.

### Airflow/Air Circulation (30–70 cubic feet per minute (CFM) near occupants)

Proper air circulation provided by the air distribution and ventilation system is required to prevent temperature stratification and drafts. Moreover, insufficient airflow causes stagnant, stale air resulting in individuals becoming uncomfortable. Stratification means that layers of different temperature air exist in the occupied space. For example, during heating periods hot air normally rises toward the ceiling and stratification occurs when air circulation does not push the hot air down into the occupied zone (see definition of Occupied Zone above). Also, drafts created by an improperly designed air distribution and ventilating system may cause an unwanted high rate of evaporation of skin perspiration which can lead to occupants feeling uncomfortable. Air drafts are a common complaint and may cause occupants to cover or plug air supply diffusers/vents.

Airflow rates measure the volume (in cubic feet) of air that passes a given point in one minute (CFM). For example, 30 CFM means that 30 cubic feet of air is moving past a certain point in one (1) minute. The higher the CFM, the more air movement.

In older buildings if walls are added, eliminated or moved, airflow to occupants may be impacted which creates unintended stagnated or drafty spaces. Efforts must be made to ensure proper airflow after renovations.

## **INDOOR AIR QUALITY (IAQ)**

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Indoor air quality refers to the characteristics of air inside buildings that may affect the health and comfort of building occupants. IAQ generally refers to the cleanliness of air; which may be described as good or adequate when cleanliness is high. Poor IAQ typically refers to the degradation of clean air caused by contaminants. Common contaminants are discussed in more detail in later sections, but in general, air quality degradation is attributable to the following factors:

- Dust or other contaminants in the indoor air or introduced from outside air.
- CO<sub>2</sub> accumulation from human respiration.
- Undesirable gases that may come from the outside air, the indoor environment, or processes that take place near the occupied spaces.
- Airborne mold or bacteria from people and interior surfaces.

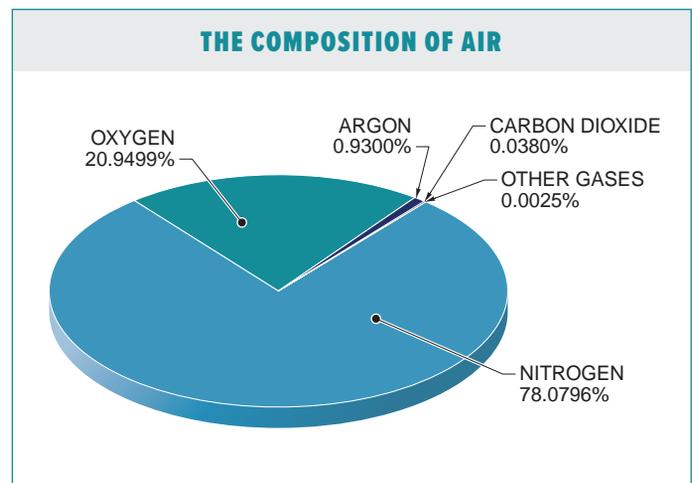
A properly functioning air distribution system can address air quality in two ways by: 1) using appropriate filtering of the supply air to trap contaminants; and/or 2) by introducing additional fresh outside air into the circulating airflow (reducing contaminant concentrations as outside air continually replaces degraded indoor air). The methods will be covered later in the module. First, the composition of air and typical pollution sources will be discussed.

When determining indoor air quality (IAQ), the presence and concentration of contaminants in the air are factors which define poor air quality.

## COMPOSITION OF AIR

What we call fresh, clean, or pure air usually means air that contains a mix of atmospheric gasses and little else except water vapor. Fresh air is a mix of about nine (9) different atmospheric gasses in concentrations which are high enough to be measurable. The mix is described as the percent of total volume of air that each compound represents and is often indicated as a ratio known as **parts per million (ppm)**. The ppm measure is useful for clarity when the percentages of some compounds are a very small part of the total volume. The primary components of air are shown in this chart.

Note that contrary to popular opinion, the air we breathe is not mainly oxygen; the largest component is nitrogen which comprises 78% of the total by volume. Carbon dioxide makes up only .038% or 380 ppm of the total; however, it is a key element in maintaining indoor air quality, which is covered below.



## INDOOR AIR QUALITY (IAQ) AND POLLUTION SOURCES

In practice, clean air is degraded as various contaminants or pollutants from a variety of sources are elevated or added to the normal composition of air. Regardless of their nature or potential hazard, pollutants alter the

natural makeup of clean air. Testing is often required to determine actual air quality and presence of pollutants, many of which have no odors or visible indicators. For technicians installing and troubleshooting air distribution and ventilation systems, it is important to be aware of common pollutants and their sources in order to mitigate harmful effects and reduce their impact on occupant comfort.

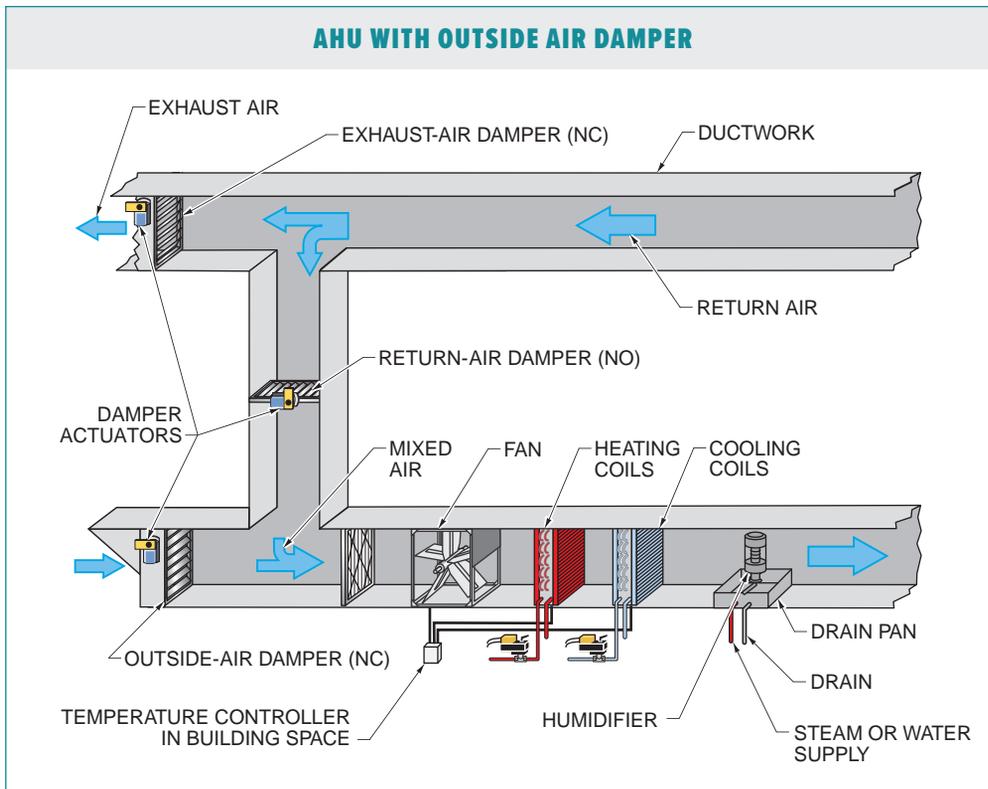
- **Carbon dioxide (CO<sub>2</sub>)** is probably the most common indoor pollutant, as this gas comes from normal respiration. It will always be present in indoor spaces where living, breathing people and animals are present. CO<sub>2</sub> is not toxic to humans, but an accumulation causing high levels indoors may cause occupants to become drowsy, incur headaches, or have trouble concentrating on tasks.

There are different recommendations for acceptable levels of CO<sub>2</sub> depending on the application. The National Institute of Occupational Safety and Health (**NIOSH**) suggests that indoor air concentrations of CO<sub>2</sub> exceeding 1,000 parts per million (ppm) indicate inadequate ventilation or airflow levels. ASHRAE recommends that CO<sub>2</sub> levels not exceed 700 ppm above outdoor ambient levels. The federal Occupational Safety and Health Administration (OSHA) safety standards limit CO<sub>2</sub> concentrations in the workplace to 5,000 ppm for prolonged periods, and 35,000 ppm for exceptions lasting less than 15 minutes.

Carbon dioxide is odorless at normally encountered concentrations. However, at high concentrations it has a sharp and acidic odor.

The most common way to reduce CO<sub>2</sub> levels is to introduce outside air through the air distribution and ventilation system. This is usually accomplished by opening (setting) outside air dampers in air handling units (AHUs) or by increasing the supply of outside air provided by a dedicated air handler.

Carbon dioxide is easily monitored with simple measuring devices or room monitors, and some AHUs may even include CO<sub>2</sub> occupancy monitors that allow the ventilation system to automatically adjust the outside air mix to reduce CO<sub>2</sub> levels when building occupancy increases.



- Dust and Particulates** are one of the more visible and annoying sources of air contamination. Dust is made up of fine airborne soil, pollen, fibers from paper or other material, and small particles from various decomposition processes. Most dust is large enough for conventional filters to provide an effective defense in reducing this pollution source for particles down to as small as 0.3 micron size (microscopic). This range (down to 0.3 microns) allows effective filtering of most pollen, dust, mold, and even smoke particles that may be contaminating indoor air.

A micron is a unit of measure in the metric system equal to one (1) millionth of a meter in length (one micron is about .00004 inches). The average cross-section of human hair is 50 microns and the human eye cannot see anything smaller than 40 microns in size.

- **Undesirable Gasses** are chemical pollutants readily emitted from certain solids or liquids. **Volatile organic compounds (VOCs)** often make up the most common type of undesirable gases. VOCs can cause IAQ complaints, and they can be potentially harmful alone or after reaction with other airborne compounds if allowed to accumulate in high enough concentrations in indoor environments.

VOCs are produced by a wide variety of commonly used products such as paints, glues, cleaning supplies, pesticides, ink or toner cartridges, and whiteboard markers. VOCs from building construction or installation processes also tend to be released or outgassed for some time from many plastics, furniture, office equipment, building materials, carpeting, and other furnishings. The famous “new car smell” you may be familiar with is likely due to VOCs which are released over several months from the vinyl, plastic, carpeting, and seat covering materials in the newly manufactured car.

There are standards in place to effectively ban VOC content in many products, and VOC emission testing of building materials used indoors has become increasingly common for carpeting, paints, and other items which have traditionally been sources for VOC contamination. VOC problems are declining in response as high VOC emitting products are phased out. When VOC contamination is detected or suspected as a source of occupant IAQ complaints, the normal mitigation approach is to identify and move VOC sources to another location, provide a separate exhaust vent, and in many cases, increase outside air mixture and airflow levels to affected zones.

- **Molds and related allergens** are various biological substances which can grow when excessive moisture is allowed to accumulate over time on various building surfaces. While some varieties of mold contain toxic compounds called mycotoxins, the primary hazard possessed by mold growth is its allergenic properties, similar to dander or pollen.

Dampness is the main problem because moisture supports mold growth. Growth can be inhibited by lowering humidity levels or correcting water leaks and condensation in localized trouble spots to prevent reoccurrence. Plaster wall board is a common breeding ground for mold when it is subjected to continued moisture exposure or is not properly dried out after water leaks or condensation problems are not corrected.

Mold remediation means cleaning, sanitizing or demolition to remove mold or mold-contaminated matter, as well as treatment or other preventive activities to abate the reoccurrence of mold growth.

- **Radon** is an invisible, radioactive gas that results from the atomic decay of radium, which is contained in many natural rock or stone building materials, including cement. Also, natural occurring radon can be discharged from soil/rock found under building foundations. Radon is considered hazardous and is a potential contributor to lung cancer. Radon is a heavy gas, and thus, will tend to accumulate in basements or lower levels of buildings, where its concentration can be easily measured with simple test kits or monitors.

Radon concentrations can be reduced to acceptable levels by sealing emitting surfaces, by proper venting areas of natural concentration, and by increasing ventilation airflow or using exhaust fans to remove the collected gas. Radioactive radon gas has a half-life of approximately four days, so residual radon will rapidly decay to a non-hazardous state over several weeks time, once the radioactivity has been mitigated.

- **Carbon monoxide (CO)** is a colorless, odorless gas which is generated as a combustion byproduct from burning fossil fuels. Quite a different compound than carbon dioxide (CO<sub>2</sub>), carbon monoxide (CO) is one of the most toxic and potentially lethal indoor air contaminants. Common sources of CO are tobacco smoke, kerosene space heaters, and automobile exhausts. Moreover, defective furnaces or boilers can also be a source.

High levels of carbon monoxide can rapidly lead to nausea, unconsciousness and death. The presence of CO is easily detected using readily available monitors, which should be installed in areas that are at risk due to combustion activity (furnaces, gas hot heaters, etc.). Because of its potential lethal effect, as well as it may be generated by defective combustion equipment, it is important that technicians check for, and be alert for, CO pollution in occupied spaces.

- **Ozone (O<sub>3</sub>)** is a potentially harmful pollutant gas produced naturally by ultraviolet light in the atmosphere. Ozone also is created at ground level by electrical discharge such as lightning or from certain electrical devices including laser printers, air ionizers, UV anti-bacterial filters, and even brush-type electric motors.

Ozone is irritating to lung tissue and harmful to human health. It can cause sore or scratchy throat, shortness of breath, coughing, and inflamed or damaged airways. Moreover, it can aggravate lung diseases such as asthma, emphysema and chronic bronchitis.



It is not typical to find ozone contributing to IAQ problems except in urban areas with high outdoor air pollution or in localized indoor areas where specialized equipment is located and may be malfunctioning. Ozone's unique odor makes it readily detectable so technicians should be alert to IAQ complaints that suggest ozone pollution. Mitigation may involve relocating ozone sources within the building. Also, increasing airflow, or providing separate exhaust systems can be effective.

When higher levels of ozone are coming from outside air, it may be desirable to reduce fresh air intake to the AHU (when other parameters allow it) to reduce ozone being introduced into the building environment. It is possible to filter ozone out of circulating air using beds of activated carbon, but it would be unusual to find need for this in most building environments.

It is not typical to find ozone contributing to IAQ problems except in urban areas with high outdoor air pollution or in localized indoor areas where specialized equipment is located and may be malfunctioning.

Ozone has some useful purposes when handled properly. Ozone in high concentrations is effective against bacteria, so it is widely used for water purification. In some hospitals, ozone also is used to sterilize sealed operating rooms between surgeries.

## ENVIRONMENTAL NOISE LEVELS

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Noise is another element of human comfort that is often overlooked in design and servicing of air distribution and ventilation systems, but in many cases noise control can be just as important to building occupants as other comfort factors.

In normal air distribution and ventilation systems, sound is transmitted through the system from mechanical operations, airflow, and various system components. So, what is the difference between these sounds and noise? Noise is somewhat subjective but is generally defined simply as annoying or undesirable sounds.

For an air distribution and ventilation system, the objective is usually to reduce or attenuate (reduce) excess noise created by system operation. However, in some cases, a certain level of noise may be desirable. This is because low levels of noise can be beneficial to help mask other more objectionable noises from a busy office environment such as call center conversations, ringing telephones or office copiers. In these situations, the relatively low level of constant noise from the air distribution and ventilation system can increase productivity in the office environment.

To assess noise, sound can be measured with a sound level meter. The sound level meter responds to changes in sound pressure which is converted by the meter to decibels (dB) readings.

Decibel readings may range from zero (0) dB (threshold of hearing) up to 140 dB (Jet Engine at 100'). Some typical levels which may be encountered are shown in the table below. Note that a normal business office will be about 60–65 dB.



ENVIRONMENTAL NOISE	dB
Jet Engine at 100'	140
<i>Pain Begins</i>	125
Chain Saw at 3'	110
Power Mower	107
<i>Level at which sustained exposure may result in hearing loss</i>	80–90
City Traffic	85
Vacuum Cleaner	75
Normal Conversation	60–70
Business Office	60–65
Household Refrigerator	55
<i>Threshold of Hearing</i>	0

A technician may use a sound level meter to determine if occupied spaces are too noisy or to locate the source of objectionable sound. Remember each individual's response to sound is different, but generally, 60–65 dB is considered the threshold of acceptable office conditions. Remediating annoying or undesirable sounds is a lengthy subject which will not be covered in this module.

With regard to the selection and installation of new equipment, to simplify noise related equipment/component design choices, a **Noise Criteria (NC)** rating methodology has been developed by the Air-Conditioning, Heating, and Refrigeration Institute (AHRI). This allows manufacturers to test and generate an NC rating for different system components which can predict how much noise they will generate when operating in an air distribution and ventilation system. The objective is to select components (such as chillers, condensing units, AHUs and GRDs) that have a favorable NC rating.

The proper selection and maintenance of air distribution and ventilation system components contributing to thermal comfort, indoor air quality and acceptable environmental noise levels will promote building occupant maximum utility and satisfaction in occupied spaces.

## AIR AND AIRFLOW BASICS

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Air distribution and ventilation systems are designed to move conditioned air to the occupied spaces in a building. Basic principles of air and airflow are covered below which are important to designing air distribution and ventilation systems. Specifically, air volume and density, static pressure, and Bernoulli's Law of system pressure relationships.

### Volume and Density

In Module 3 it was noted that air is not actually weightless. It has a measurable weight, even if quite small. For the purposes of calculation, **air has a specific volume of 13.35 pounds per cubic foot per pound (ft<sup>3</sup>/lb), and a density of 0.074906 pounds per cubic foot**, at *standard conditions* (clean, dry, 70°F air at sea level). A typical 12 by 12 foot office with approximately 1,200 cubic feet of space would contain about 90 pounds of air. So if we wanted to

replace all the air in this office once each hour, the air distribution and ventilation system would have to move 2,160 pounds, or over a ton of air every 24 hours. In an airflow system, it is important that equipment is properly sized to move large quantities of air effectively and efficiently (low energy consumption).

There are recommendations for the amount air that should be replaced in various occupied spaces. Guidelines are usually expressed as "air changes per hour" for a defined space. Accounting for the satisfactory amount of air changes is primarily a design function/responsibility. However, proper HVACR system operation and maintenance is important to ensuring that desired air changes are obtained.

## Static Pressure

Since air has molecular density, it will encounter resistance when coming up against obstacles to airflow in a HVACR system. In every HVACR system there will be resistance which results from system air passing through heating and cooling coils, filters, terminal boxes, etc.; any component that is placed in the airstream which restricts flow. Also, ductwork may affect airflow. Ductwork with many elbows and/or transitions restricts flow. Even the length of ductwork impacts airflow. For this reason, it is important to design and maintain air distribution and ventilation systems to provide the shortest and smoothest possible path for airflow to reduce the energy required to move air around a building.

Static pressure is the force required to move air. It is a key factor in overcoming airflow resistance. Simply stated, the push of air must be greater than the resistance to the flow or no air will flow through the system. In air distribution and ventilation systems, increases in static pressure are used to overcome the resistance to airflow in HVACR components and ductwork.

Dirty coils and filters can increase resistance and cause loss of static pressure and result in low airflow. A routine maintenance program to clean coils and change filters, among other tasks, is essential to provide optimal performance and occupant comfort.

## Bernoulli's Law

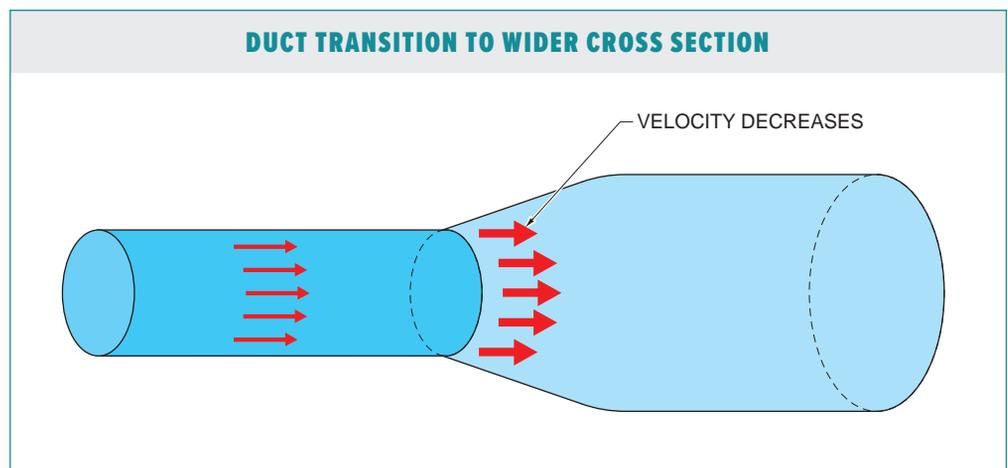
Air movement in a ventilation system is defined by the physics of **Bernoulli's law**, which explains how airflow and pressure are interrelated.

BERNOULLI'S LAW		
<b>Static Pressure</b>	The force required to move air through ducts and other components	$P_s$
<b>Velocity Pressure</b>	The force exerted by a moving air stream along the axis of movement	$+ P_v$
<b>Total Pressure</b>	The sum of static and velocity pressures	$= P_t$

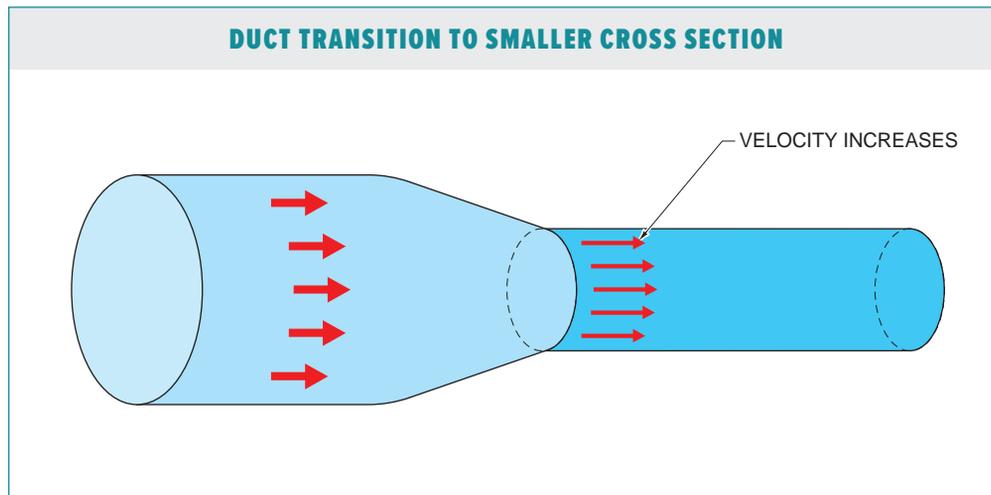
When describing airflow in Bernoulli's Law there are several measures of pressure. They are:

- **Static Pressure ( $P_s$ )** is the pressure applied to the walls of a tube or duct by the air contained within (Like the air inside a balloon).
- **Velocity Pressure ( $P_v$ )** is the pressure exerted by moving air along the axis of airflow.
- **Total Pressure ( $P_t$ )** will always equal  $P_s + P_v$ . Bernoulli's law says that the combination of static pressure and velocity pressure in a given volume of airflow will always be constant ( $P_t = P_s + P_v$ ).

This means that if air is flowing through a cross section of pipe or duct and transitions to a wider cross section of pipe, Velocity Pressure ( $P_v$ ) will drop, but Static Pressure ( $P_s$ ) will increase such that Total Pressure ( $P_t$ ) will stay the same.



The reverse is also true for the opposite transition. If air is flowing through a cross section of pipe or duct and transitions to a smaller cross section of pipe, Velocity Pressure ( $P_v$ ) will increase, but Static Pressure ( $P_s$ ) will decrease such that Total Pressure ( $P_t$ ) will stay the same.



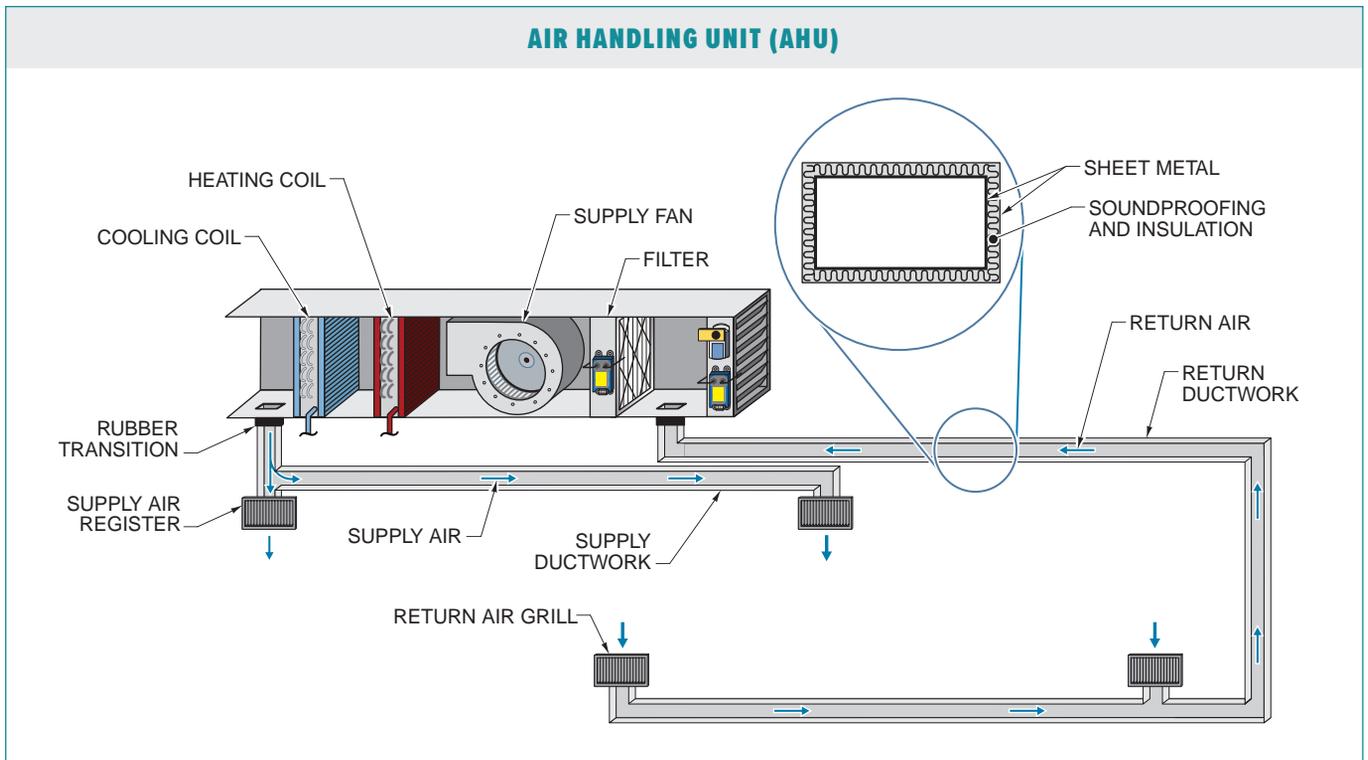
The concepts above are established relationships that are applied often with air distribution and ventilation systems to properly size components and to make sure that air is effectively distributed as needed to all zones in a building.

## COMPONENTS OF AIR DISTRIBUTION SYSTEMS

The major components of an air distribution and ventilation system include equipment and devices which are used to circulate air throughout a building in order to control heat transfer, maintain air quality, and regulate airflow based on demands of the various occupied spaces. Each component performs a task critical to the proper operation of the system in supporting building users. The key components of a typical air distribution and ventilation system are covered below.

### Air Handling Unit

The Air Handling Unit (AHU) is the heart of an HVACR air distribution and ventilation system. The AHU is generally a self-contained, centralized unit which is used to condition and circulate air as part of the building's HVAC system.



While the air handler in a small commercial or residential HVAC installation is often nothing more than a small blower included with the integrated furnace and air conditioning system, the AHUs in larger commercial installations incorporate a number of key components that are critical to the AHU's ability to re-circulate environmental air combined with an appropriate mix of fresh outside air.

Since many buildings operate with a slight positive pressure to discourage infiltration of outside contaminants or unconditioned air, the AHU must also be capable of maintaining a small positive pressure for the entire building.

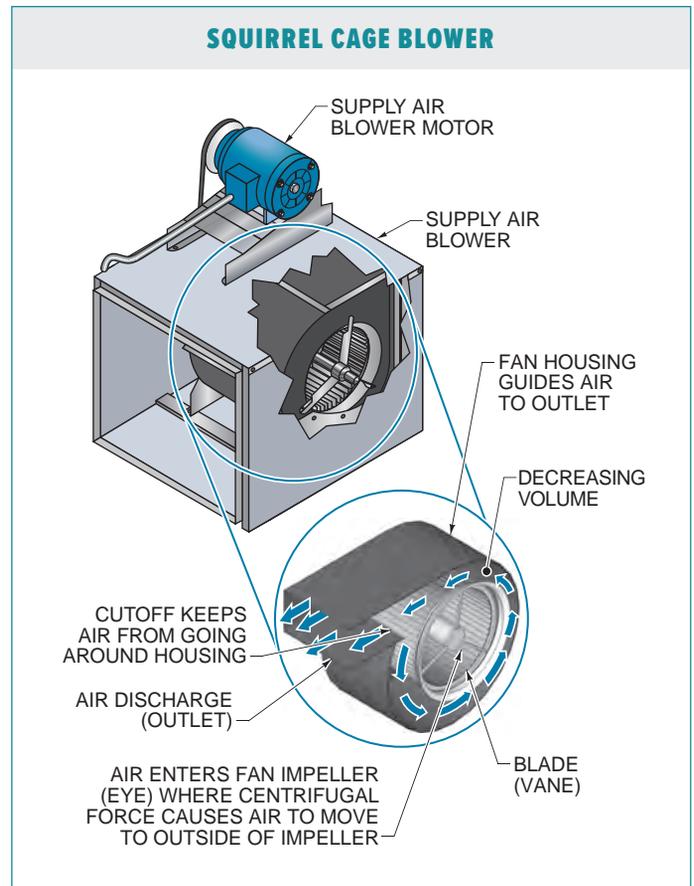
### Fans and Blowers

Fans and blowers are an integral part of any AHU. One or more high capacity fans or blowers are usually incorporated in an AHU, and these fans are the air distribution workhorses for the system, doing most of the work needed to move large volumes of air throughout the building.

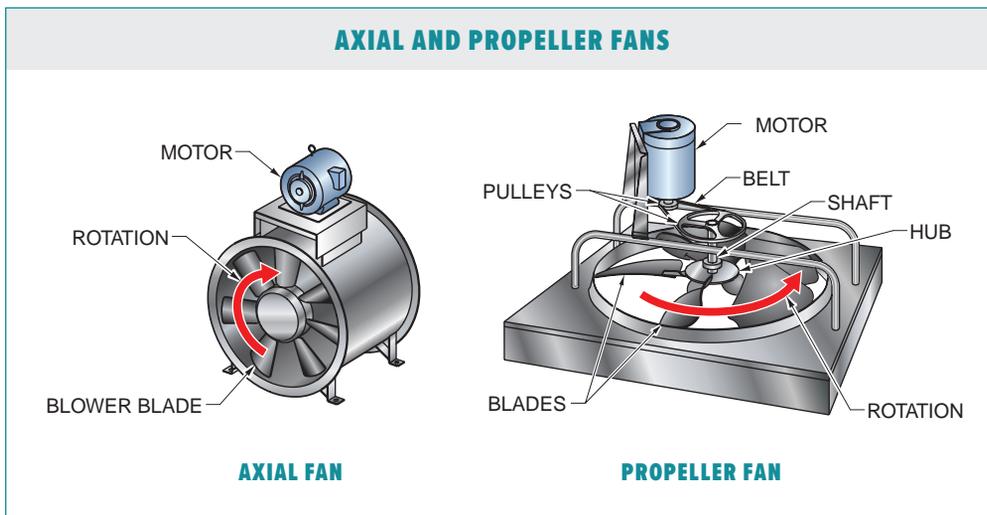
Fans must move large volumes of air and also provide the necessary pressure to move air to where it is needed by overcoming the resistance of system components which may be obstacles to airflow. There are two main types of fans used in HVACR systems – **centrifugal** and **axial**.

- **Centrifugal fans** are probably the most common type encountered in AHUs. Centrifugal fans consist of a rotating wheel, or impeller, mounted inside a round housing. The impeller is driven by a motor, which is usually connected via a belt drive. These fans are often referred to as **squirrel cage blowers**—so called because the appearance of the impeller vanes is similar to that of a pet rodent’s exercise wheel.

Centrifugal fans are particularly well suited to air distribution and ventilation systems because they can generate relatively high pressures and airflow volumes with a quiet, cost effective design. The airflow through centrifugal fans can be easily modulated by closing off the air intake to restrict flow. The fan load or electrical power required will also drop proportionately as airflow is reduced, providing an energy efficient way to regulate airflow from a single speed motor. Centrifugal fans represent a good cost and performance choice for many AHU applications.

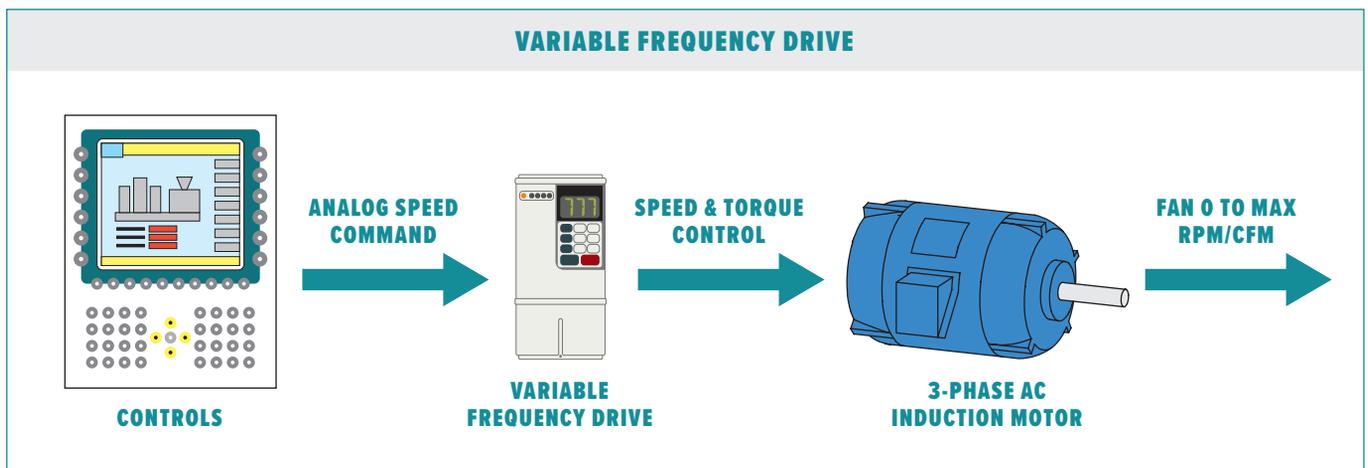


- **Axial or Propeller fans** consist of a cylindrical housing (or venturi) with a fan blade mounted on a motor or drive shaft along the axis of the housing. The fan blades take the place of the impeller used in centrifugal fans with the blades providing the force needed to create airflow.



The axial fan is capable of moving high volumes of air but at relatively low pressures. These fans tend to generate somewhat high levels of noise, so larger axial fans are more likely to be used in air exhaust or outside condenser applications, where noise will not be a factor.

Regardless of the type of fan used, there are various methods used to control the airflow generated. Fans may be single speed, offer a range of pre-set speeds, or allow continuously variable speed using **variable frequency drives (VFDs)**. A VFD is an electrical/electronic device which controls the speed and torque of motors by varying motor input frequency and voltage.



Another alternative primarily used in larger AHUs is multiple blowers. Multiple blowers may be located at the end of the AHU, at the beginning of a long supply duct, or in the return air duct where the fans will help push return air back into the AHU.

### Heating and Cooling Coils

Heating and cooling coils are normally included in a centralized AHU to provide temperature control for the distributed supply air. Larger AHUs utilize heat exchanger coils that can circulate hot water or steam from a central boiler for heating, and/or chilled water from a central chiller system for cooling.

AHUs for smaller buildings without chiller and boiler systems may contain a localized gas or electric heat source for heating, along with a split system AC evaporator finned coil for cooling.

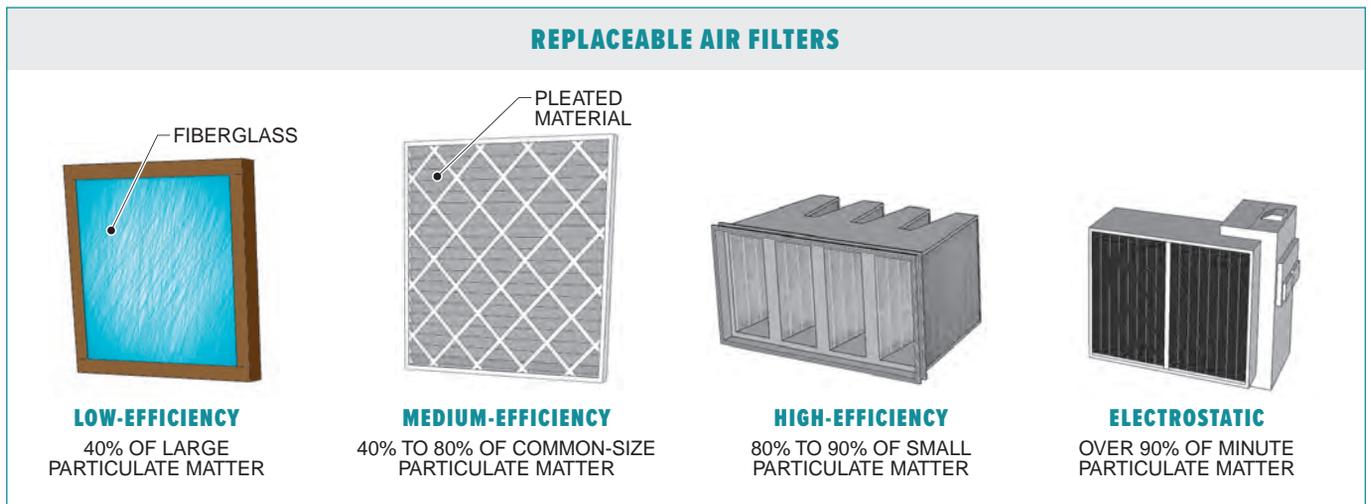
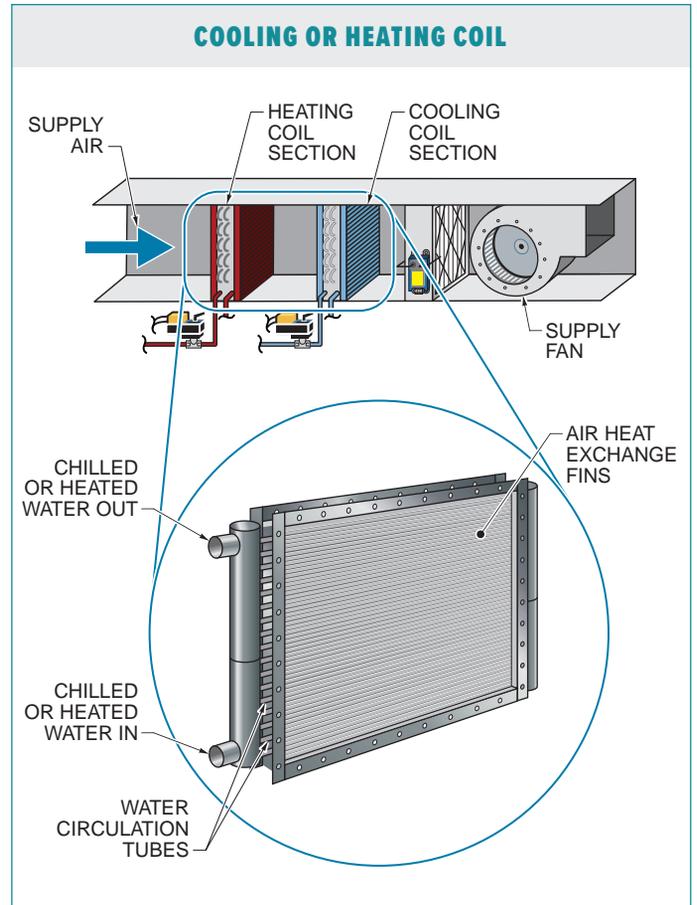
Heating and cooling elements may also be included locally as part of the duct system. They may be in addition to, or instead of, heating and cooling

coils provided in the AHU. Local heating and/or cooling coils are helpful when specific zones are a long way from the AHU heating or cooling source, or when higher levels of cooling or heating are needed for specific zones than are normally supplied for the rest of the building.

## Air Filters

Air filters are typically included in AHUs in order to provide filtered, contaminant-free air to the building occupants. Replaceable media filters are typically located at the intake side of the AHU, in order to keep the downstream air distribution components as clean and uncontaminated as possible. By cleaning the air, filters are primarily responsible for promoting occupant health, inhibiting bacteria and mold growth, and keeping internal airflow surfaces clean.

With today's ever-increasing emphasis on indoor air quality, filtering has become an important factor in the design and operation of air distribution systems. A range of filtering techniques may be used individually or in combination, including basic replaceable media dust filters, high filtration (HEPA) filters, or electrostatic filtering systems. For critical environments such as hospitals, ultraviolet air treatment may also be included to reduce bacterial contaminants in the air supply.



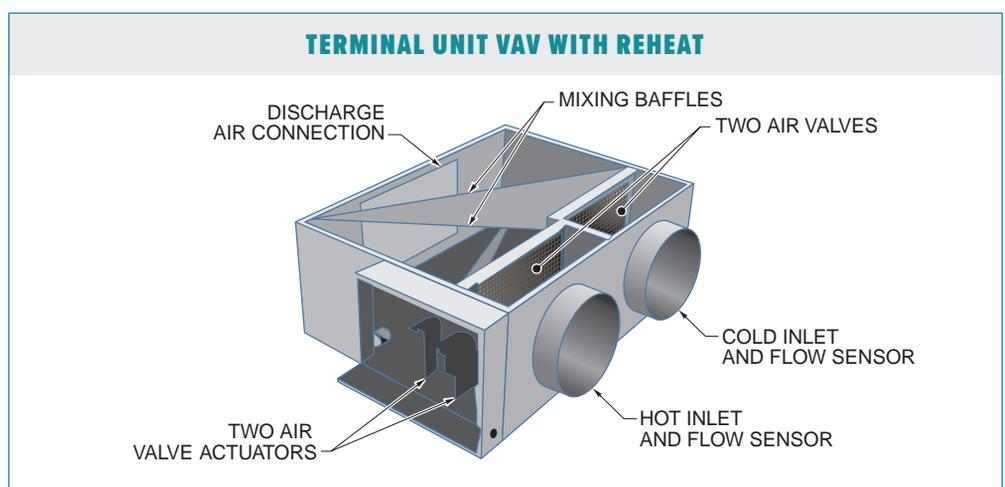
Filters are rated for their overall particle removal effectiveness using a measure developed by the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) called **minimum efficiency reporting value (MERV)**. A MERV rating is an indication of how effectively a filter can trap particles in the tested range of 0.3 to 10.0 microns in diameter. A higher MERV value translates to better filtration, so a MERV-11 filter works better than a MERV-8 filter.

Filter selection, sizing and maintenance is especially critical, because air filtration directly affects air quality, and overcoming filter resistance often represents a large part of the power consumed in air distribution. Virtually all filters require replacement or service at specific intervals. Incorrect or poorly maintained filters cause dramatically reduced airflows, increased operating costs, or premature failure of system components. But most importantly, poorly maintained filters can be dangerous to occupant health.

### Other Types of AHUs

Although the term AHU usually refers to large centralized air handlers responsible for primary building airflow, there are other kinds of specialized components also referred to as AHUs that can be found in a typical air distribution and ventilation system.

- **Terminal units** are small self-contained air handlers for local use in a single zone. These devices may include an air filter, cooling or heating coil and a small blower. Terminal units are sometimes referred to as blower coils, variable air volume (VAV) boxes, or fan coil units.
- A **makeup air unit (MAU)** is a larger air handler that conditions 100 percent outside air, and no re-circulated air. This type of air handler is often used in conjunction with a main AHU with dampers controlling the amount of air that comes from the MAU into the main AHU.



## Ductwork

The AHU may be the heart of an air distribution system, but it takes ductwork to carry the conditioned air to all points throughout the building where it is needed. Ductwork is the network of air pathways that route the conditioned air through the building and return it to the AHU in order to meet the demands of different spaces or zones throughout the building. Ducts are usually airtight channels for air distribution with round or rectangular shapes that have traditionally been fabricated from galvanized sheet metal and insulated to prevent excessive energy losses when routed over long distances.

### SHEET METAL DUCTWORK



With rising labor and material costs, newer materials are now widely used for ductwork systems, including aluminum, spiral metal duct, sheet fiberglass assembled duct, and prefabricated flexible duct.

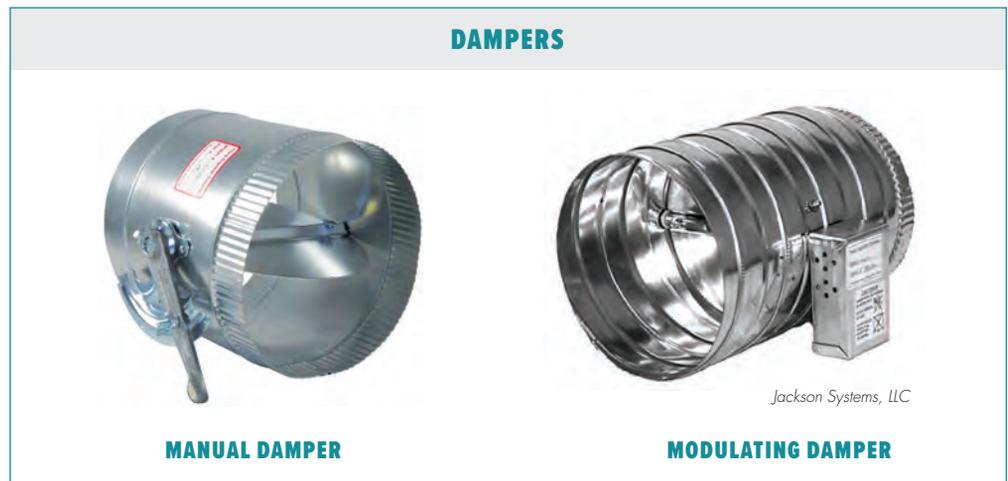
### FLEXIBLE DUCT



## Dampers

Dampers are airflow regulators with one or more vanes or shutters that can be manually or automatically adjusted to open or close off the flow of air passing through. Dampers provide a way to adjust air volumes across the system so that the AHU can meet the specific air distribution and ventilation demands of different zones while balancing airflow to all areas of the building.

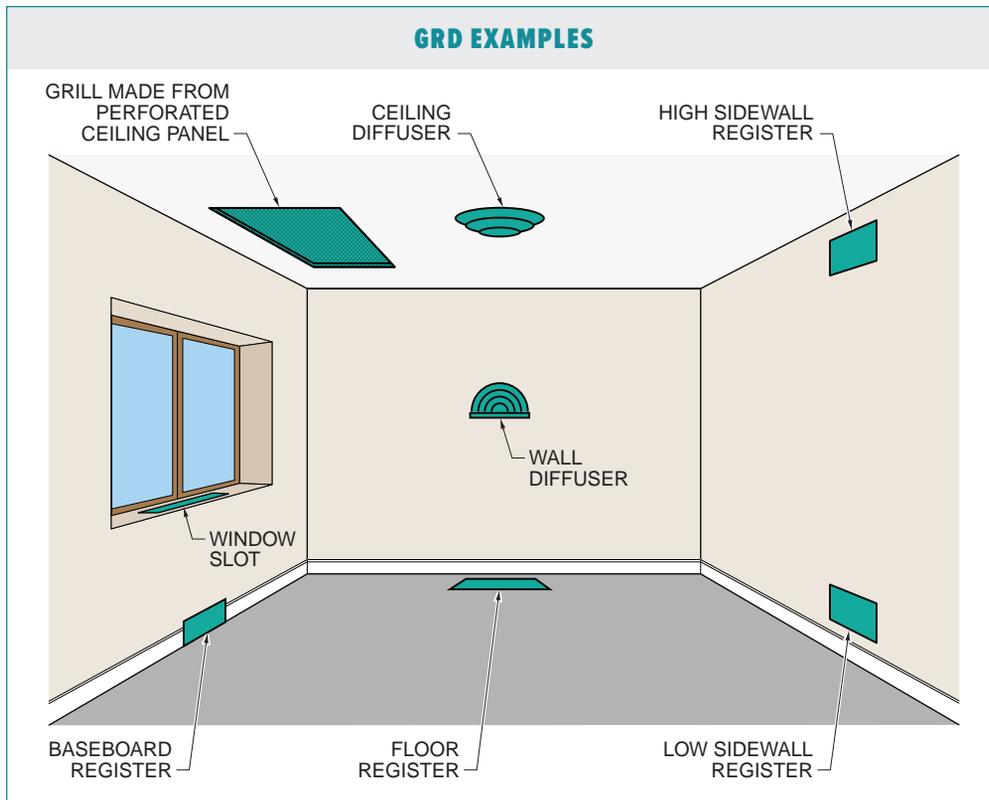
A typical HVAC system may have numerous dampers throughout the system to regulate the flow of outside air, return air, exhaust air, and supply air. Dampers used to balance airflow in ducts can be manually adjusted to set the volume of air passing through the damper. Modulating dampers have a motor operated damper blade which can be adjusted (opened and closed) based on signals sent from a HVACR control system. There also are special purpose fire dampers in many systems which close automatically when high temperatures are sensed in an area and stay closed until manually reset.



Damper malfunction and/or maladjustment can dramatically affect air distribution and ventilation system efficiency and occupant comfort. Maladjustment is often caused by changes in building space requirements, creating the need for more or less airflow in zones or individual spaces. Rebalancing airflows to zones and individual spaces may be required to restore acceptable comfort levels.

## Room Air Distribution Fixtures

After conditioned and filtered air has been routed to a desired space through appropriate ductwork, the circulation of air throughout a room is determined by fixtures that take the form of **Grills, Registers, and Diffusers**, a class of devices similar in design and sometimes referred to generally as **GRDs**.



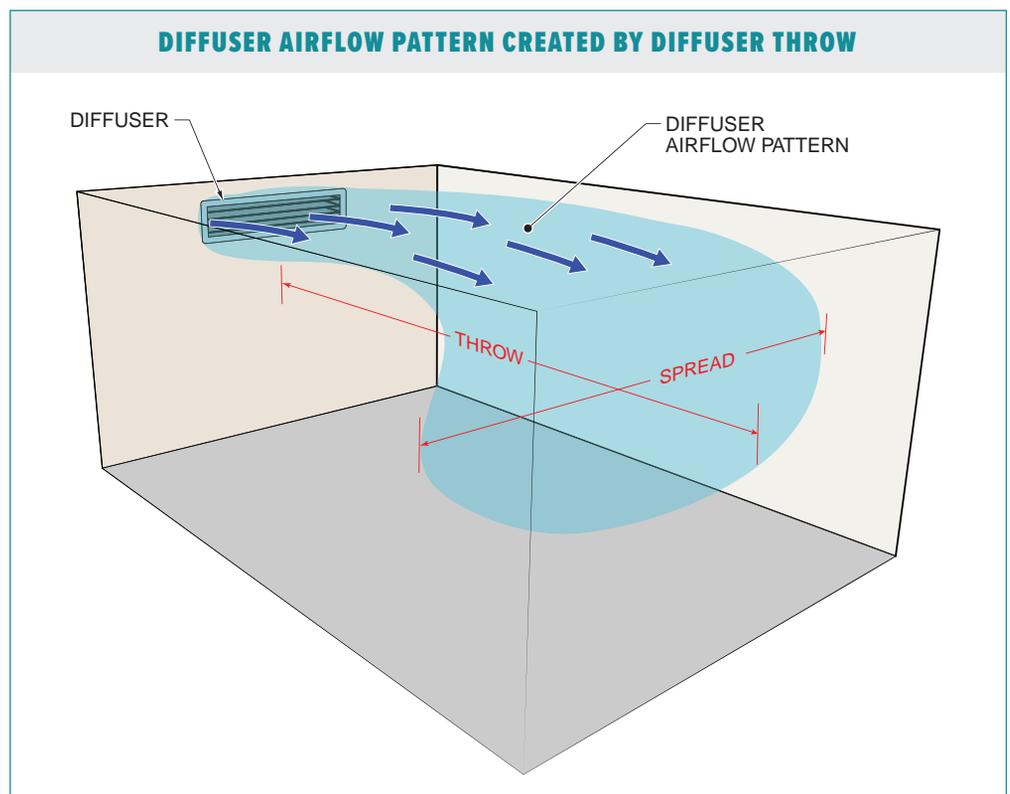
- **Grills** are duct terminating fixtures in square or rectangular shapes with fixed vanes that permit free airflow. The vanes are angled in such a way as to better disperse air in one or more directions. The vanes also provide an optical and physical barrier, blocking inadvertent access to the duct opening, and providing a more aesthetically pleasing appearance to room occupants. Moreover, grills are often used as return air duct fixtures where their purpose is mainly to cover the duct opening without restricting air flowing into it.
- **Registers** are similar to grills, but they add a second set of movable louvers which allow manually adjusting the air flow out of the fixture.
- **Diffusers** are more sophisticated air outlet fixtures incorporating a range of vanes, louvers, and other structures designed to more effectively disperse air over a wider area in a room. Diffusers can come in many different shapes and may allow for manual or automatic adjustment of the airflow. They are most often used in ceilings to disperse supply air uniformly over a relatively wide area.

For maximum design flexibility GRDs come in an almost unlimited variety of configurations to meet space constraints while blending with the interior design features of the building.

## GRD SELECTION GUIDELINES

For supply air to properly mix or diffuse with the air in a room, the selection of GRDs is important. Improper ventilation system design or operation can result in excessive air velocities (drafts), air not mixing properly, or **stratification** effects (where supply air stays in a layer and is prevented from combining well with existing room air). Guidelines include selecting/using proper GRD to:

- Handle air duct velocity which includes GRD size. (Note: undersized GRDs may cause noise problems).
- Provide desired "throw" pattern to distribute air in direction or directions required. Typically, the GRD style will dictate throw pattern.
- Incorporate (or not) damper or register adjustments.

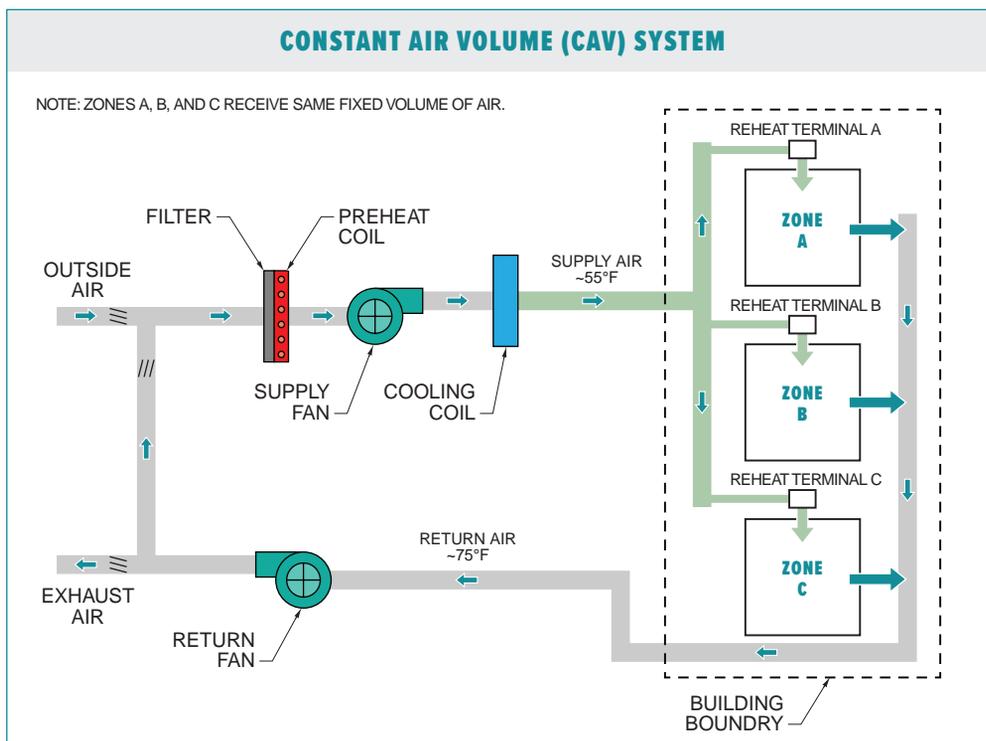


GRDs make sure that the conditioned air reaching occupants is dispersed properly in the occupied space.

## DIFFERENT TYPES OF AIR DISTRIBUTION SYSTEMS

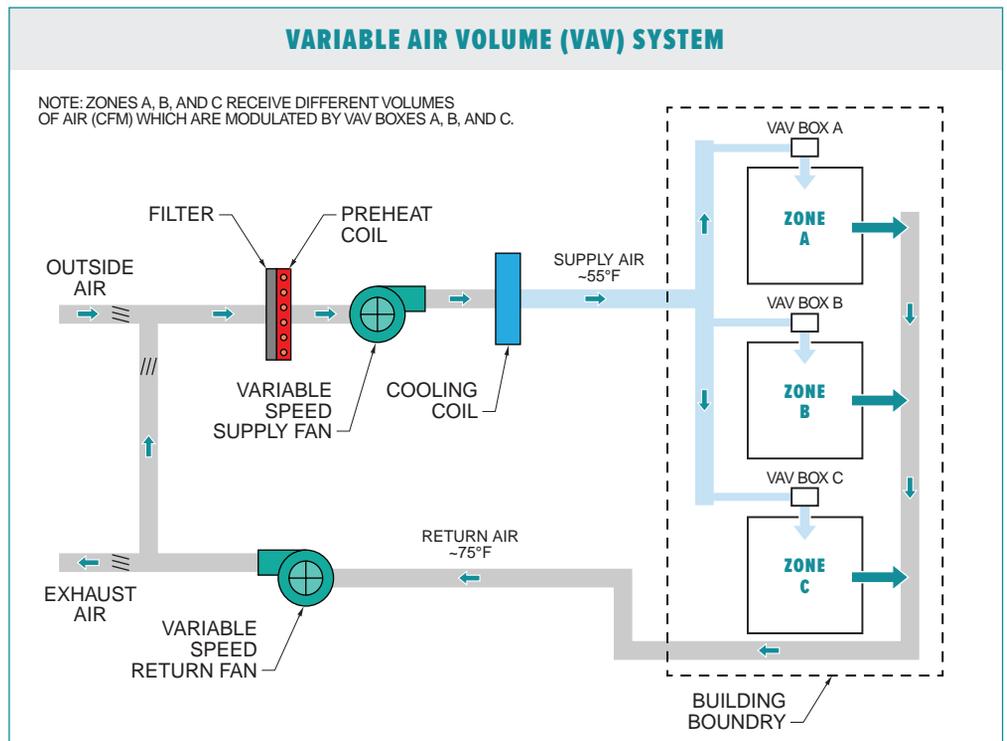
There are different types of air distribution systems in use and the approach employed will definitely affect the overall performance as well as the specific components required for each system. While there are a number of air distribution design variants, the most commonly encountered configurations are described below.

- **Constant-Volume Systems (CV)** are the simplest type of air distribution system and are typically found in residences and many older commercial buildings. In a CV system, a constant amount of air flows through the system whenever the AHU fan is on, so there is no modulation of airflow based on demand. In its simplest configuration, a CV system supports a single zone, with a thermostat sensing zone temperature and signaling the AHU to provide heating or cooling based on the thermostat control. CV systems are relatively energy inefficient, especially when local zone reheat is used, so they are not typically used in new installations. In fact, basic CV systems without some form of temperature control are now prohibited by many building codes.



A variant of the CV system is the **constant volume variable temperature (CVVT)** system, which does allow control of the supply air temperature (referred to as temperature reset) in response to thermostat feedback.

- Variable Air Volume Systems (VAV)** are more typical of modern air distribution installations and promise much higher operating efficiency and effectiveness than possible with CV systems. A VAV system meets changing load requirements by varying the amount of airflow in response to varying heating or cooling loads. VAV systems work by opening or closing dampers to modulate the airflow going to various zones of the building as the loads change. Used in combination with **variable-frequency-drives (VFDs)** to modulate fan speed and CFM, this reduction in flow results in a reduction in the fan power needed, saving energy while more effectively meeting the air distribution demands of the building.



A VAV system may be more commonly configured as a **variable volume variable temperature (VAVT)** system, where supply air temperature can be reset if loads change thus reducing chiller load as well as fan power requirements. This offers the greatest possible efficiency improvement when loads vary significantly. Due to the complexity of the controls and automatic components utilized with VAVT systems, a high level of technical expertise is required for technicians installing and servicing these systems.

Many, if not all, of the components described in the preceding sections can be found in almost every HVACR air distribution and ventilation system, regardless of building size. These components must all properly function both individually and in conjunction with other components to ensure efficient system operation and occupant comfort.

## TESTING, ADJUSTING AND BALANCING SYSTEMS

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Usually upon initial installation of a new system, an engineer or contractor will put the entire system through a series of tests and gather performance information. This includes measuring various performance aspects of all HVACR equipment (such as chillers, AHUs, exhaust fans, etc.) as well as distribution and ventilation airflows. Moreover, the engineer or contractor will make adjustments to equipment and system dynamics with the goal of making the entire system perform as called for in building design specifications. The performance data acquired and various equipment settings are documented in a report which is kept on record. This process is often called a **Testing, Adjusting, and Balancing (TAB) Certification**.

When modifications or significant changes are made to an HVACR system, and particularly a large-scale air distribution and ventilation system, those changes are likely to alter the operating characteristics of a building's entire system, not just the air distribution and ventilation portion. In these cases, it is advisable to perform another TAB certification. This re-adjustment (re-certification) should be done as an effective audit of current performance and to document resulting equipment settings.

## TAB CERTIFICATION PROFESSIONALS

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If a company/organization is not equipped to perform TAB certification, it may be advisable to bring in an independent TAB contractor who is expert in this type of work. Professional contractors experienced in this area are usually certified by a recognized professional society such as the **National Environmental Balancing Bureau** or the **Associated Air Balance Council**.



## AIRFLOW MEASUREMENT AND TROUBLESHOOTING

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Even if a company/organization is not prepared to do a full scale TAB certification, it may want to have the capability to troubleshoot problems or perform certain analysis of air distribution and ventilation performance. This could include measuring airflow produced by an AHU to verify that overall airflow volume is adequate for building needs, as well as measuring airflows to determine proper balance across different zones, so the demands of every zone can be met. Or it could be localized to a specific occupied area where building usage changes (movement of people, office partitions, and office equipment) may cause the original airflow needs to change dramatically.

It also may be useful to compare any sample airflow measurements to the original design specifications and the balancing certification (report) conducted when the building was new. Usually, building management will keep such information on file. The sample data may indicate that a partial or total re-balance may be the solution to many various problems. Or in other cases, system modifications or equipment updates may be required to meet current building needs or realize the greater operating efficiency possible with newer components such as variable speed fans controlled by variable frequency drives (VFDs).

The cause of certain thermal comfort, IAQ and noise problems will often be obvious once airflow measurement and analysis is undertaken.

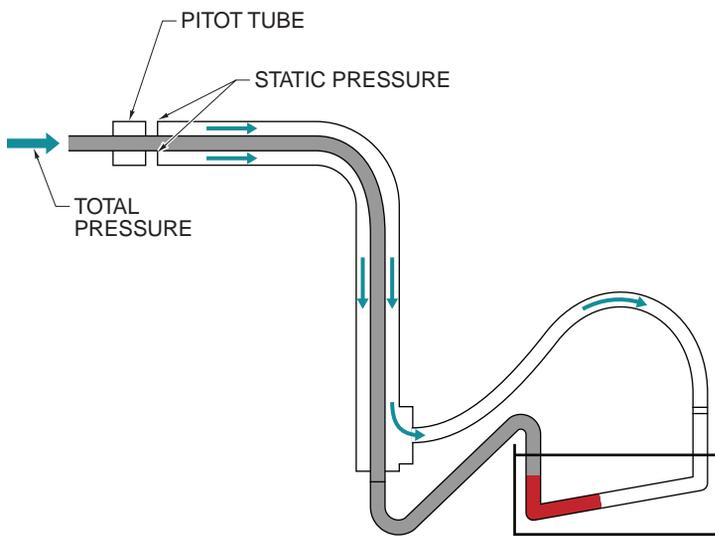
Airflow measurement can be done in several ways using the instruments described below.

### **Pitot Tube**

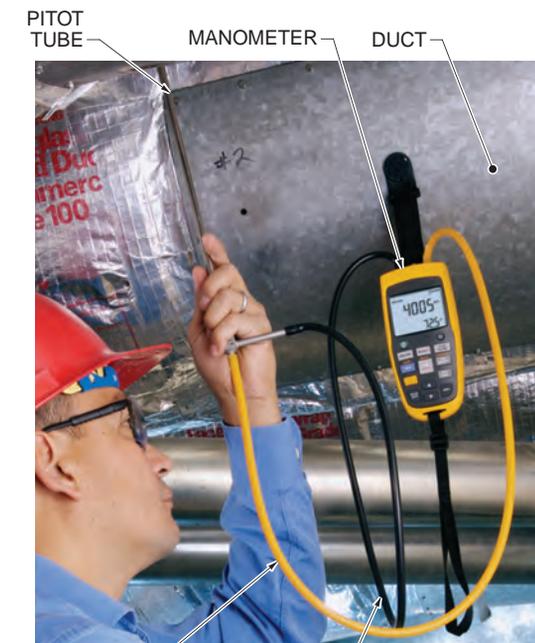
A long-established approach involves measuring duct pressures at different points using a pitot tube. Pitot tubes are typically used to determine CFM in large ductwork (such as at an AHU) using a procedure called a pitot tube traverse. This procedure requires sampling airflow in multiple locations inside the duct using ports (holes) made in the bottom or sides of the ductwork. Existing ducts may already have access ports at appropriate measurement points which were created when the initial system was installed.

The pitot tube is a specially designed tube with separate air channels that allow measurement of both static and velocity pressures at the same time. Typically, it is connected to a manometer which is a pressure measuring device. From the pressure measurements, airflow (CFM) may be calculated. Modern digital manometers used with pitot tubes automatically calculate CFM and show readings directly on a display.

### PITOT TUBE TRAVERSE USING DIGITAL MANOMETER



**PITOT TUBES**



**MEASURING AIR PRESSURE**

Troubleshooting problems or performing maintenance on air distribution systems may require measurement of airflow through large ductwork from the AHU to different zones. A pitot tube traverse is one way to measure AHU and zone CFM.

## Digital Velometer

A digital velometer may be used in smaller ductwork. Typically, it is inserted into one (1) hole made in the bottom or side of a duct. The velometer probe inserted in the duct sends an electronic signal to a hand-held digital readout indicating air velocity (speed). From measurements taken by a velometer, the actual airflow in CFM may be calculated by simply multiplying the air velocity by the duct cross section.

### AIR VELOCITY READING USING VELOMETER



## Anemometer

An anemometer may be used to determine air velocity (speed). Because of its design and size it is typically not used to determine velocity inside ducts. It is most often used to determine air velocity at the face of GRDs. One design of the anemometer uses an enclosed fan which is placed in the airstream. The force of the airstream causes the fan to rotate and the speed of rotation is converted into a velocity measurement. The actual airflow in CFM can be calculated by simply multiplying the air velocity by the GRD outlet size.

## AIR VELOCITY READING USING ANEMOMETER



**DIGITAL ANEMOMETER**

## Flow Hood

A flow hood is the very convenient (time saving) tool used to directly measure CFM at the face of various GRDs. It is most often used at ceiling and wall diffusers which are found predominately (great numbers) in modern air distribution and ventilation systems. The flow hood -- open on the bottom and top -- uses a series of fixed pitot tubes in its base and a fabric hood which flares to fit over the outside of a diffuser. Various size fabric hoods may be attached to the base to accommodate different size diffusers. The fabric top is pressed against the ceiling or walls surrounding the diffuser making an air tight seal. This allows air from the diffuser to pass through the flow hood. Air passing through the flow hood is measured by the fixed pitot tubes and digitally converted to a direct CFM reading.

## CFM READING USING FLOW HOOD



## TOP SERVICE ISSUES FOR AIR DISTRIBUTION AND VENTILATION SYSTEMS

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The following are the **top issues** which HVACR businesses are most likely to encounter in selling or servicing air distribution and ventilation systems.

1. Air distribution is uneven throughout rooms and from zone to zone due to poor duct design and installation or incorrect GRDs for the area.
2. Air stratification (“dead zones”) are noticeable causing hot and cold spots in a room.
3. The AHU blower is sized or sheaved incorrectly for the building demands (normally, need to increase blower/fan speed to increase air quantity (CFM)).
4. Excessive noise is being generated by an AHU or other equipment and also from excessively high or partially restricted airflows from ducts.
5. Annoying vibration coming from fans and other air handling equipment.
6. Maintenance is not frequent enough to keep filters clean and the system operating efficiently.
7. Many GRDs appear to have their airflow obstructed by building features, office fixtures or furniture.
8. Comfort is not maintained well as demand varies over the course of the day.
9. Service accessibility for various types of equipment is poor.
10. The system was not tested, adjusted, and balanced properly at start-up to ensure (certify) correct operation to specifications, so may not be operating at optimum efficiency.

## SUMMARY

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This module (Module 6—Airflow Types and Systems) covers HVACR air distribution and ventilation systems. While all functional areas in a HVACR installation must operate effectively to satisfy the environmental comfort needs of occupants, the air distribution and ventilation system is especially important because it delivers HVACR heating, cooling, and humidity control capabilities directly to the occupied zone where people live and work. The air distribution and ventilation system also provides the critical function of promoting indoor air quality. Air distribution and ventilation systems use appropriate filtering of the supply air to trap contaminants. They also introduce outside air to offset the possible buildup of CO<sub>2</sub> levels and reduce possible

contaminant concentrations. Every HVACR installation designed for human environmental comfort includes similar air distribution and ventilation capabilities, equally critical for building occupants, regardless of the size of the building supported.

In this and previous modules, we have reviewed in detail the important functions performed by HVACR systems. While there are several other areas yet to be covered, in the next module (Module 7—Commercial System Applications) will depart from discussing the internal workings of HVACR technology and look at some of the real world applications for commercial HVACR systems.

## Airflow Types and Systems

Name \_\_\_\_\_

Company \_\_\_\_\_

1. What compound makes up the largest component of air?
  - a. Oxygen
  - b. Nitrogen
  - c. Ozone
  - d. Argon
  - e. Pollution
  
2. Squirrel cage refers to:
  - a. Damper
  - b. Centrifugal blower
  - c. Axial fan
  - d. Diffuser
  
3. A goal of an air distribution and ventilation system is:
  - a. Maintain temperature and humidity within desired ranges
  - b. Reduce contaminants
  - c. Control noise
  - d. Blend with the interior design
  - e. All of the above
  
4. Which of the following is not a toxic pollutant?
  - a.  $O_3$
  - b. Radon
  - c.  $CO_2$
  - d. CO
  - e. None of the above

5. A term for rating filter effectiveness is:
- NC
  - NIOSH
  - MERV
  - dB
6. Human environmental comfort is concerned with which of the following?
- Thermal effects
  - IAQ
  - Noise levels
  - All of the above
7. Which of the following is not a type of air distribution system?
- CV
  - CFC
  - VAV
  - VVVT
8. Failure of room ventilation air to mix well due to layering is called:
- Zone effect
  - Diffusion
  - Stratification
  - Induction
  - Settling
9. GRD refers to:
- Duct termination fixtures
  - Registers
  - Diffusers
  - Grills
  - All of the above
10. Which of the following is used to simultaneously measure static pressure and velocity pressure?
- Anemometer
  - Hydrostat
  - Pitot tube
  - Velometer

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