Design Options for HVAC Distribution Systems

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Overview

The objective of an HVAC (heating, ventilating, and air-conditioning) system is to control the temperature, humidity, air movement, and air cleanliness, normally with mechanical means, to achieve thermal comfort.

Centralized HVAC system installations utilize a number of separate components that are field assembled to serve the specific needs of an individual building.

A central plant has 4 principle elements:

1. Energy Supply (e.g. electricity, fuel);
2. Service Generators (e.g. boilers, chillers);
3. Distribution Components (e.g. air distribution ducts, pipes);
4. Delivery Components (e.g. diffusers, radiators).

Distribution components convey a heating or cooling medium from source-located service generators to portions of a building that require conditioning. Delivery components serve as an interface between the distribution system and occupied spaces.

In this course we will focus on the various design options pertaining to cooling and heating air distribution (item numbers 3 and 4 above).

HVAC systems are of great importance to architectural design efforts for three main reasons.

1. These systems consume substantial floor space and/or building volume for equipment and distribution elements that must be accommodated during the design process.
2. HVAC systems constitute a single major budget item in building projects.
3. The success of a building depends on the ability to provide thermal comfort with the least operating costs (maintenance, energy, or replacement). This depends on the HVAC system design, equipment and controls.

There are several choices for air distribution, each satisfying the HVAC objectives with different degrees of success. The best design will consider the pertinent architectural and financial constraints without sacrificing the performance in terms of reliability, indoor air quality, and energy efficiency.

While HVAC system design is the responsibility of the HVAC designer, an architect must oversee the complete building project on a wider perspective. The type of system selected is determined by the HVAC designer's knowledge of systems. The Architect must also understand the basics, system objectives, the role of key system components, the type of systems that are available and, what such systems can and cannot accomplish.

In selecting a suitable air conditioning system for a particular application, considerations are given to the following:

1. **Architectural Constraints:**

- Details of architecture and building construction;
- Floor space and clear heights to accommodate HVAC equipment and distribution elements;
- Aesthetics;
- Size and appearance of terminal devices;
- Coordination of reflected ceiling plans with lighting, fire sprinklers/detectors;
- Acceptable noise levels;
- Space available to house equipment and its location relative to the conditioned space;
- Shaft spaces available for routing ducts/pipes, etc.
- Climate and shading;
- Indoor and outdoor equipment preferences;
- Acceptability of components projecting into the conditioned space;
- Codes and standards of smoke removal systems;
- Usage patterns;
- Occupancy.

2. System Constraints:

- Type of facility and the indoor conditions required;
- Cooling/heating load;
- Zoning requirements;
- Humidification/dehumidification needs;
- Energy availability and efficiency;
- Redundancy and equipment configuration;
- Type of equipment;
- Reliability of operations;
- Control scheme;
- Zone/individual control.

3. Financial Constraints:

- Capital cost;
- Operating cost;
- Maintenance cost;
- Replacement costs;
- Upgrading costs;
- Equipment failure costs;
- Return of investment (ROI)/Life cycle analysis.

Each of these concerns has a different priority depending on the customer’s goals. Most customers may not understand HVAC design aspects nor their benefits and limitations. It is the responsibility of the Architect and the HVAC Engineer to guide and advise the customer on the best option. For an HVAC Engineer, the customer may be an Architect whose customer may be the building owner.

HVAC DISTRIBUTION SYSTEMS

Based on the fluid media used in the thermal distribution system, air conditioning systems can be classified as:

Centralized systems

- All Air systems (significant ducting)
- Air-Water systems (moderate ducting)
- All Water systems (ductless systems)
- Unitary refrigerant based systems (usually for smaller applications)

Terminal units

- Fan-coils
- Inductors
- Radiators
- Diffusers

Individual (unitary air-conditioning) systems

- Compact
- Split
- Heat pumps

Within the above, there are considerable variations. A building may employ a hybrid combination of these to best satisfy the overall functional objectives.

While there are many options, most conventional centralized systems fall within one of the following three categories: All-Air System, All-Water System, or Air-Water System.

- All-Air Systems deliver heated/cooled air to each space through ducts;
- All-Water Systems deliver chilled/hot water to each space and rely on indoor terminal units;
- Air-Water Systems deliver a combination of heated/cooled air and hot/chilled water to control aspects of comfort.

The obvious difference between the above systems is the fluid that is used to heat/cool a space: air for All-Air, water for All-Water, and air and water for Air-Water.

Why are there so many variations in system design?

An air conditioning system may have several requirements that must be accommodated during the design process:

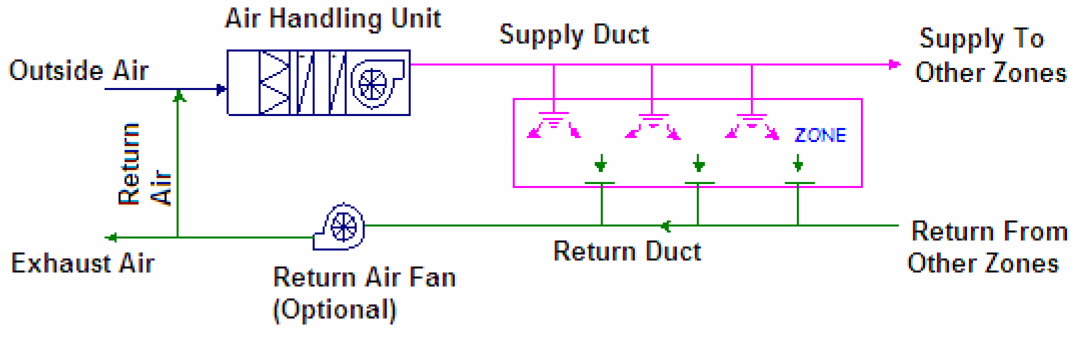
1. The cooling, heating, and moisture control provides the foundation for key HVAC system design and components;
2. The additional functions of air circulation and air quality control establish further component requirements;
3. In specific building situations, supplemental functions such as noise and smoke control and the interlocking of security and fire protection functions, can be imposed on an HVAC system;
4. Automation and control of an HVAC system is critical to its successful operation. The subject of system control leads to the concept of HVAC zoning. During the design process, a zone is defined as a region of a building that requires separate control if comfort is to be provided for occupants. Numerous air distribution systems are available ranging from uni-zone systems (the indoor space constitutes a unique conditioned zone), to multi-zone systems (separate specifically conditioned indoor spaces), with or without reheat design options.
5. An air conditioning system must satisfy both humidity and temperature requirements. Humidity control generally takes precedence over temperature control and as such, the air is cooled much lower (equal to the apparatus dewpoint of the coil) to remove moisture over the coil surface. The resultant air becomes too cold and is reheated before it is delivered to the indoor spaces.
6. The modern HVAC design relies on energy efficient variable air volume (VAV) systems and variable air volume and temperature (VVT) systems. Many other options are highlighted in the course.

PART 1 ALL - AIR SYSTEMS

As the name implies, in an “all – air” system air is used as the media that transports energy from the conditioned space to the A/C plant. In these systems air is processed in the A/C plant and this processed air is then conveyed to the conditioned space through insulated ducts using blowers and fans. This air extracts (or supplies in case of winter) the required amount of sensible and latent heat from the conditioned space. The return air from the conditioned space is conveyed back to the plant, where it again undergoes the required processing thus completing the cycle. No additional processing of air is required in the conditioned space.

The system is categorized by the use of air-handling units (AHU) or roof top packages (RTP) to condition air. The conditioned air is sent through ductwork to the occupied space where it will heat or cool the space as required, and return via return air ducts back to the AHU or RTP. Air Handling Units contain a cooling coil (connected to a chiller or condensing unit), a heating coil (connected to boilers or electric heaters), filters, and one or more circulating fans. Roof Top Packages contain a refrigerant cooling cycle, heating coils (connected to boilers or electric heaters), filters, and one or more circulating fans.

A schematic arrangement of an All-Air system with its major components is shown below.



All - Air System

All-air systems require the majority of air supplied to a space be returned to the air-handling unit for reconditioning, or exhausted from the building. This "return" air may be conveyed in a return air duct system or through plenums formed by various elements of a building, such as a suspended ceiling or the building structure.

"All-Air" systems are classified by two main categories:

1. Single duct;
2. Dual or double duct.

The single duct systems can provide either cooling or heating using the same duct, but not both heating and cooling simultaneously. Dual duct and multi zone systems can provide both heating and cooling simultaneously. These systems can be further classified as:

- Single duct, constant volume, single zone system;
- Single duct, constant volume, multiple zone system with terminal reheat;
- Variable air volume system.

SINGLE DUCT, CONSTANT VOLUME, SINGLE ZONE SYSTEMS

The simplest and most common of the "All-Air" central systems is a single duct, constant volume, single zone system. This system is so called as there is only one supply duct, through which either hot air or cold air flows, but not both simultaneously. It is called as a constant volume system as the volumetric flow rate of supply air is always maintained constant. It is a single zone system as the control is based on temperature and humidity ratio measured at a single point. Here a zone refers to a space controlled by one thermostat. However, the single zone may consist of a single room or one floor or whole of a building consisting of several rooms.

A single zone system consists of an air-handling unit, a heat source, cooling source, distribution ductwork, and appropriate delivery devices. The figure below is a general arrangement of a single zone HVAC system.

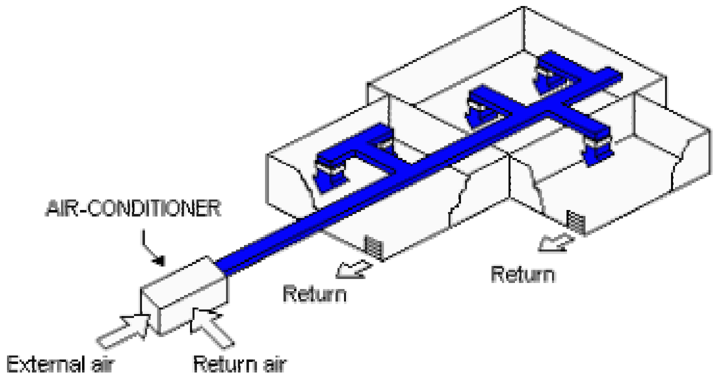
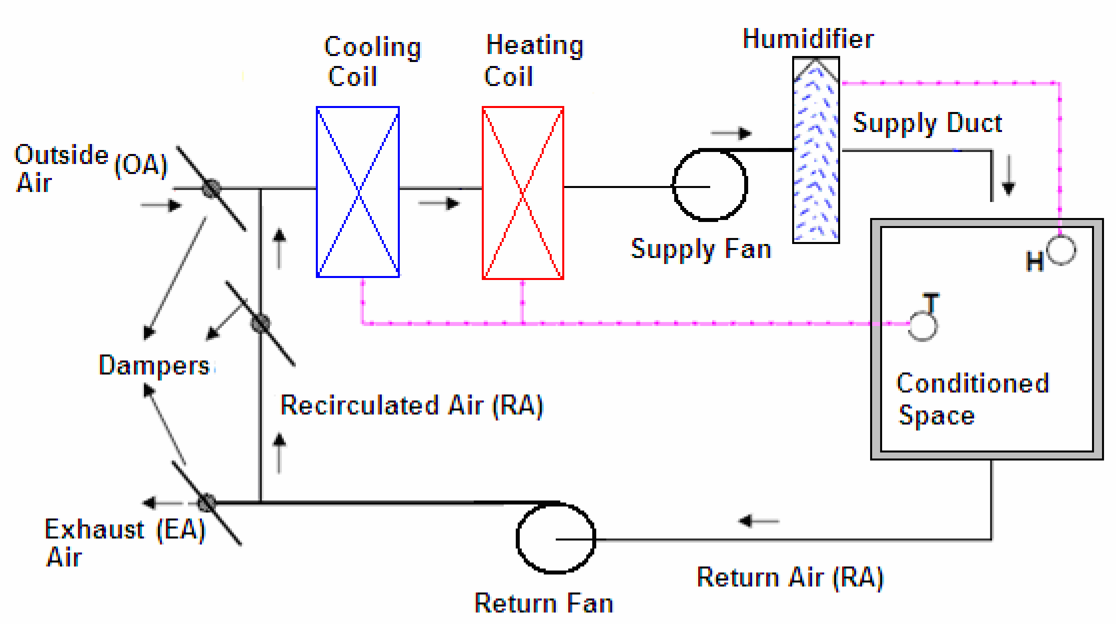


Figure below shows a schematic arrangement of a single duct, constant volume, single zone system. It consists of the main heating and cooling coils in a series flow air path using a common duct distribution system that feeds all terminal apparatus.



Single Duct, Constant Volume, Single Zone System

As shown in the figure, outdoor air (OA air) for ventilation and recirculated air (RA air) are mixed in the required proportions using the dampers and the mixed air is made to flow through a cooling and dehumidifying coil, a heating coil and a humidifier using a an insulated ducting and a supply fan. As the air flows through these coils the temperature and moisture content of the air are brought to the required values. Then this air is supplied to the conditioned space, where it meets the building cooling or heating requirements. The return air leaves the conditioned space, a part of it is recirculated and the remaining part is vented to the atmosphere. A thermostat senses the temperature of air in the conditioned space and controls the amount of cooling or heating provided in the coils so that the supply air temperature can be controlled as per requirement. A humidistat measures the humidity ratio in the conditioned space and controls the amount of water vapor added in the humidifier and hence the supply air humidity ratio as per requirement.

Control Philosophy

The cooling/ heating capacity in the single zone, constant volume systems is regulated by either coil control or face-and-bypass control.

1. In coil control, supply air temperature and humidity ratio is controlled by varying the flow rate of cold and hot water in the cooling and heating coils, respectively. As the cooling season gradually changes to heating season, the cooling coil valve is gradually closed and heating coil valve is opened. Though coil control is simpler, using this type of control it is not possible to control the zone humidity precisely as the dehumidification rate in the cooling coil decreases with cold water flow rate. Thus at low cold water flow rates, the humidity ratio of the conditioned space is likely to be higher than required.
2. In face-and-bypass control, the cold and hot water flow rates are maintained constant, but the amount of air flowing over the coils are decreased or increased by opening or closing the by-pass dampers, respectively. By this method it is possible to control the zone humidity more precisely, however, this type of control occupies more space physically and is also expensive compared to coil control.

Because this type of system serves only one zone, control is normally affected at the air-handling unit (AHU) by a single thermostat and humidistat, it is important to locate these sensors in a proper location, so that they are indicative of zone conditions.

Advantages of Single Duct, Single Zone, Constant Volume Systems:

1. The primary advantage of a single zone central system is simplicity of design;
2. Single zone systems are the most basic and least complex of central all-air systems;
3. Low first cost among all types of systems;
4. Easiest to maintain.

Disadvantages of Single Duct, Single Zone, Constant Volume Systems:

1. It can effectively condition only one zone. This is only a disadvantage when improperly applied.
2. Because control is achieved at the air-handling unit, single zone systems are not easily modified to serve multiple zones, should building usage change with time.

Applications of Single Duct, Single Zone, Constant Volume Systems:

The all-air single-zone air conditioning system is the basic central system, which can supply a constant air volume or a variable air volume at low, medium, or high pressure. Normally the air-handling unit is located outside the conditioned space. But if conditions permit, it can also be installed within conditioned areas.

In a true sense, very few buildings fall under a single thermal zone. Single zone systems find many applications because of simplicity. Most central HVAC systems serving one-family residential units are single zone systems. In larger residences, two or more single zone systems may be used to provide thermal zoning. In low-rise apartments, each apartment unit may be conditioned by a separate single zone system. Many large single-story buildings such as supermarkets, discount stores, and the like, can be effectively conditioned by a series of single zone systems with each system serving a loosely defined region of the building. The central or interior zones of large office buildings are usually conditioned by a single or a series of separate single zone systems.

Typically applications of single duct, constant volume, single zone systems include: -

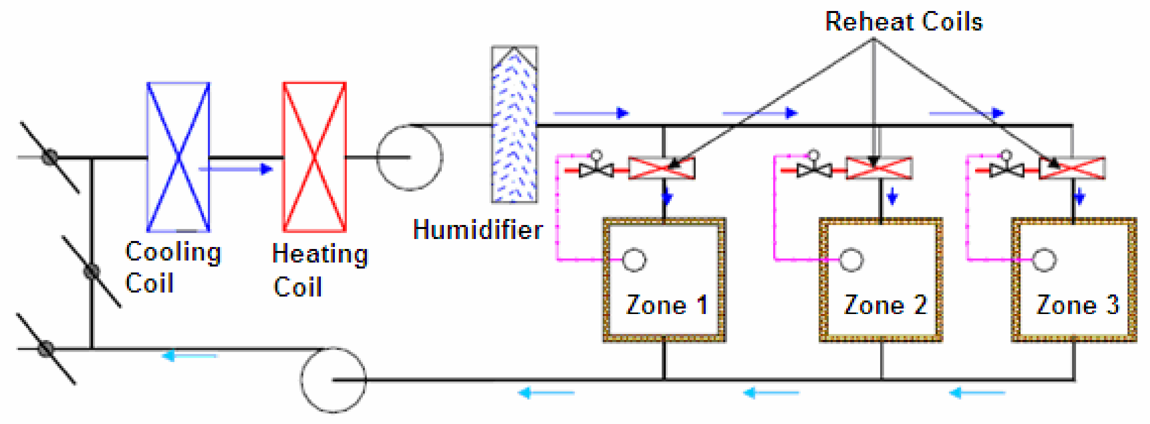
1. Space with uniform loads such as large open areas with small external loads e.g. theatres, auditoria, departmental stores;
2. Small spaces requiring precision control such as laboratories;
3. Multiple single zone systems for large areas.

SINGLE DUCT, MULTI-ZONE SYSTEMS WITH TERMINAL REHEAT

For very large buildings such as office buildings etc. with several zones of different cooling/heating requirements, it is economically not feasible to provide separate duct for each zone. For such cases, multiple zone systems are suitable that uses “reheat” to control the comfort conditions in each zone.

Reheat system consists of some type of heating device, usually an electric strip heater (or it could be hot water or steam), that is located downstream of the air handling unit near each zone. A thermostat in each zone controls the heat output of the reheat coil to produce comfortable conditions. The supply air leaving the central air-handling unit is conditioned to cool the requirement of the greatest cooling load in any of the zones. Any zone that requires less than maximum cooling will have its supply air temperature increased by its terminal reheat device.

Figure below shows a single duct, multiple zone system with terminal reheat coils. In these systems all the air is cooled and dehumidified (for summer) or heated and humidified (for winter) to a given minimum or maximum temperature and humidity ratio. A constant volume of this air is supplied to the reheat coil of each zone. In the reheat coil the supply air temperature is increased further to a required level depending upon the load on that particular zone. This is achieved by a zone thermostat, which controls the amount of reheat, and hence the supply air temperature.



Single Duct, Constant Volume System with Multiple Zones and Reheat

The reheat system can be adapted for single zone applications where the dehumidification of air necessitates the air to be cooled too low. It then requires reheating to satisfy the indoor temperature requirements before it is delivered. Such a system is capable of providing excellent control of thermal conditions. Were it not for this restriction, terminal reheat systems would likely find application in most multiple zone buildings where an all-air approach is chosen.

Advantages of Single Duct, Multi-zone Systems:

- Relatively small space requirement;
- Excellent temperature and humidity control over a wide range of zone loads;

- Proper ventilation and air quality in each zone is maintained as the supply air amount is kept constant under all conditions

Disadvantages of Single Duct, Multi-zone Systems:

- Expensive to operate.
- These systems are energy inefficient as the system involve simultaneous use of cooling and reheat. For this reason, use of reheat systems is strictly regulated by most energy codes and standards. Many state and local regulations restrict the use of reheat (see ASHRAE Standard 90.1).

The preferred way for such situations is to consider a "Variable Air Volume (VAV)" system. More information on VAV systems is provided in the following section.

Applications of Single Duct, Multi-zone Systems:

- Zone or space control for areas of unequal loading;
- Heating or cooling of perimeter areas with different exposures;
- Where close control of both temperature and humidity is desired in process or comfort applications;
- Areas with high latent loads;
- It is flexible and reheat can be added or removed to accommodate changes in zoning.

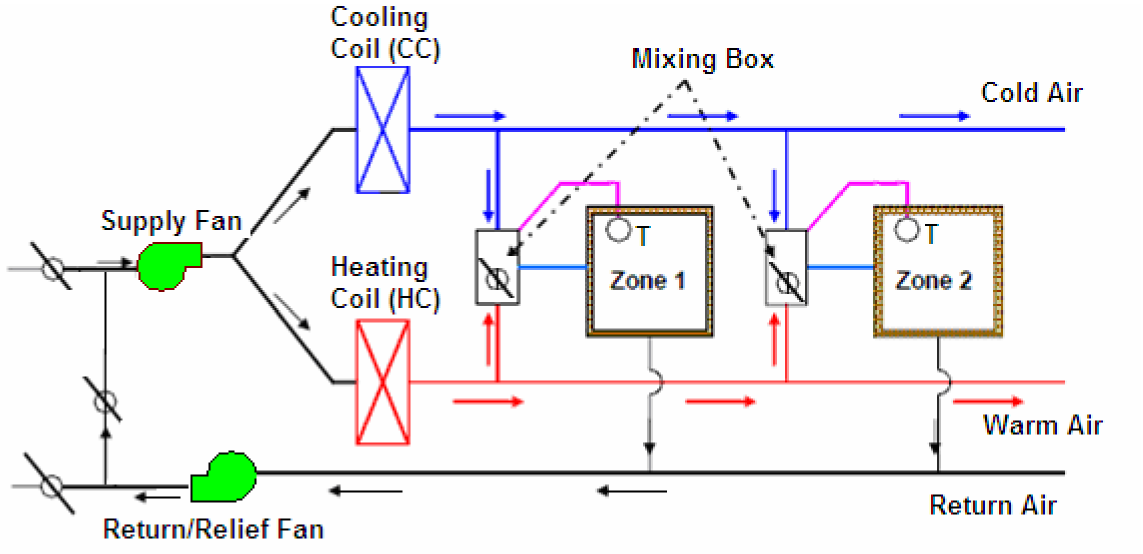
DUAL DUCT SYSTEMS

The dual-duct system employs two air ducts; one cold air duct and one warm air duct from the air-handler to the conditioned spaces. Figure below shows the schematic of a dual duct, constant volume system. As shown in the figure, the supply air fan splits the flow into two streams. One stream flow through the cooling coil and gets cooled and dehumidified to about 52°F, while the other stream flows thru the heating coil and is heated to about 95–110°F.

The cold and hot streams flow through separate and parallel ducts. The ducts are not necessarily of equal size, depending upon building heating and cooling loads. Before each conditioned space or zone, the cold and hot air streams are mixed in required proportions using a mixing box arrangement, which is controlled by the zone thermostat.

The total volume of air supplied to each zone remains constant; however, the supply air temperature varies depending upon load.

The system is well suited for providing temperature control of individual spaces or zones. Return air is accomplished through a single duct system.



Dual Duct, Constant Volume System

Advantages of Dual Duct Systems:

1. Cooling in some zones and heating in other zones can be achieved simultaneously;
2. Good temperature and humidity control - system is very responsive to variations in the zone load, thus it is possible to maintain required conditions precisely;
3. Zoning of central equipment is not required;
4. Adaptable to either constant volume or VAV systems;
5. Since total airflow rate to each zone is constant, it is possible to maintain proper IAQ and room air distribution.
6. No seasonal changeover is necessary.

Disadvantages of Dual Duct Systems:

1. Occupies more space for running of two ducts have to be sized to handle the entire air flow rate, if required.

2. High first cost for installation of two supply ducts throughout the building;
3. Not very energy efficient due to the need for simultaneous cooling and heating of the air streams.
4. Large number of mixing boxes to maintain;
5. Difficult to use economizer cycle;
6. Does not operate as economically as other VAV systems.

Dual duct systems are no longer popular due to their high energy consumption; however, they are occasionally used in hospitals where VAV is inappropriate. Use of VAV control on the main air supply fan to reduce airflow during low loads can improve their efficiency somewhat.

When the humidity must be kept below a specified value under all operating conditions, and the dual duct system cannot accomplish this, these two alternative systems can be considered.

Why use All-Air Central Systems?

1. The arrangement provides uniform air distribution through a network of ducts and is most suitable for large area coverage, irrespective of width, length, or depth of coverage. The constant volume system is suitable for use in areas having similar cooling requirements.
2. The central plant is located in unoccupied areas which consolidates operation and maintenance remotely and permits the optimum choice of filtration systems, odor, and noise attenuation.
3. The complete air conditioning plant including the supply and return air fans can be located away from the conditioned space. Due to this it is possible to use a wide variety of air filters and avoid noise in the conditioned space.
4. Changeover from summer to winter and vice versa is relatively simple in all air systems.
5. It offers the greatest potential for energy conservation by utilizing the outdoor air effectively. Systems can include energy conservation options such as airside economizer and heat recovery devices. During favorable ambient conditions, say

during night, outside air can be conveniently utilized in place of mechanical refrigeration.

6. It provides a wide choice of zoning and humidity control under all operating conditions. It is a good choice where close zone temperature and humidity control is required. By using high-quality controls it is possible to maintain the temperature and relative humidity of the conditioned space within ± 0.15°C (DBT) and ± 0.5%, respectively.
7. It provides good design flexibility for optimum air distribution, draft control, and local requirements.
8. The central system is easily adaptable to fire and smoke removal systems during emergency conditions.
9. It is suited for applications requiring unusual exhaust makeup.
10. It allows simultaneous cooling and heating in various zones to maintain precise zone temperature and humidity conditions.
11. It is possible to provide good room air distribution and ventilation under all conditions of load.
12. Building pressurization can be achieved easily.

Disadvantages of All-Air Central Systems:

1. Significant space, almost 10 to 15% of total depending on the economy of scale, may be needed for AHU room/duct risers.
2. Requires additional duct clearances which may add to building height. Vertical airshafts can reduce the usable floor space.
3. Air balancing requires great care and is difficult to achieve particularly in large systems.
4. The logic control to achieve optimum conditions requires expert design planning and experience. There are various options among all-air systems; to insure the right selection requires a foresight of control logic and sequence.
5. May encounter hot or cold spots, particularly in perimeter zones consisting of large glazing.

6. Installation and accessibility of equipment demands close cooperation between architectural, mechanical, and structural engineers.
7. The reheat control option with all-air systems is very energy inefficient because it requires overcooling, and than reheating, for effective humidity control.

Applications of All Air Systems:

All air systems can be used in both comfort as well as industrial air conditioning applications. They are especially suited to buildings that require individual control of multiple zones, such as office buildings, classrooms, laboratories, hospitals, hotels, ships etc. They are also used extensively in applications that require very close control of the conditions in the conditioned space such as clean rooms, computer rooms, operation theatres, research facilities etc.

PART 2 VARIABLE AIR VOLUME (VAV) SYSTEMS

In previous sections we have discussed "All-Air" single duct – single zone, single duct – multi-zone and dual duct systems. The discussion was focused on the constant volume systems where the volumetric flow rate of supply air is always maintained constant. In this section we will discuss single duct - Variable Air Volume (VAV) systems suitable for multi-zone applications. This is alternative to constant volume multi-zone and dual duct systems which consumes significant energy due to reheat.

VAV system versus Constant Air Volume (CAV) System

Constant air volume systems accomplish cooling and heating by varying the supply air temperature while maintaining the air volume constant.

As the name implies, Constant Air Volume (CAV) system delivers a constant air volume to the conditioned space irrespective of load. The air conditioner cycles "on and off", or chilled water is modulated for a chilled water cooling coil, as the load varies. The fan continues to run during the off cycle. Two important things on constant volume systems should be noted:

1. When a fixed flow rate is delivered, it is referred to as a constant volume system.
2. When the load conditions (indoor temperature/humidity) vary from the set point, the constant volume air-conditioning system responds by varying the temperature of the supply air.

A variable air volume (VAV) system changes the quantity of air supplied to a space in response to changes in loads. This is a major operational difference.

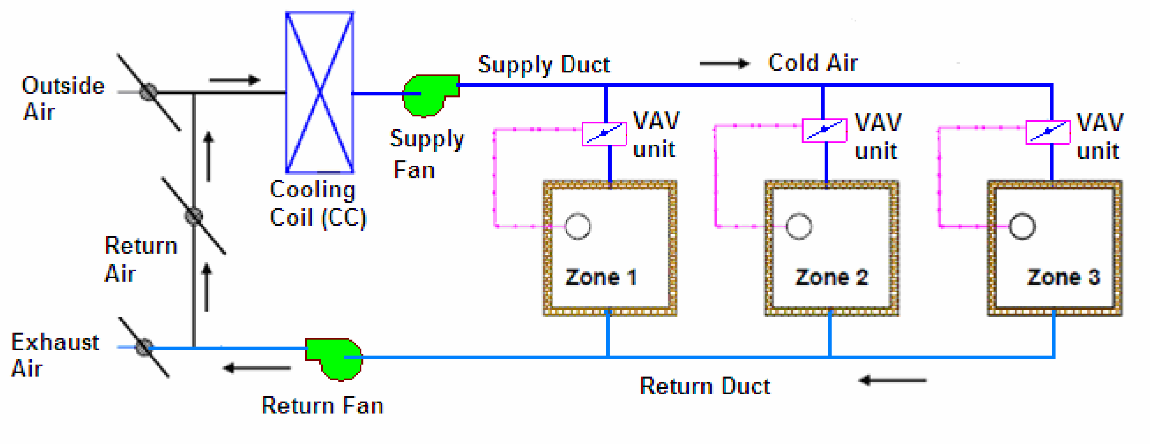
Compared to constant volume systems, the variable air volume systems offer advantages such as:

a. Lower energy consumption during partial load conditions as air is not cooled to very low temperatures and then reheated as in constant volume systems.

b. Lower energy consumption also results due to lower fan power input due to lower air flow rate. Furthermore, the lowered flow rate across the cooling coil causes the leaving air temperature to fall, or if water coil is used, causes the water to leave at a lower temperature. In response, the refrigeration system is throttled-back to stabilize the supply air temperatures, which also results in energy savings of the main plant.

Let's study the VAV system further…

A central air-handling unit supplies air through a common duct pathway to all spaces conditioned by the unit. As shown in Figure below, each zone is provided with a VAV box (terminal control box) that adjusts air supply volume in response to the zone thermostat. The temperature of supply air to each zone remains constant, whereas its flow rate varies depending upon the load on that particular zone. The temperature of air supplied by the air-handling unit may be varied occasionally to adapt to building-wide changes in loads, but instant control of each zone is achieved through modulation of supply airflow rate.



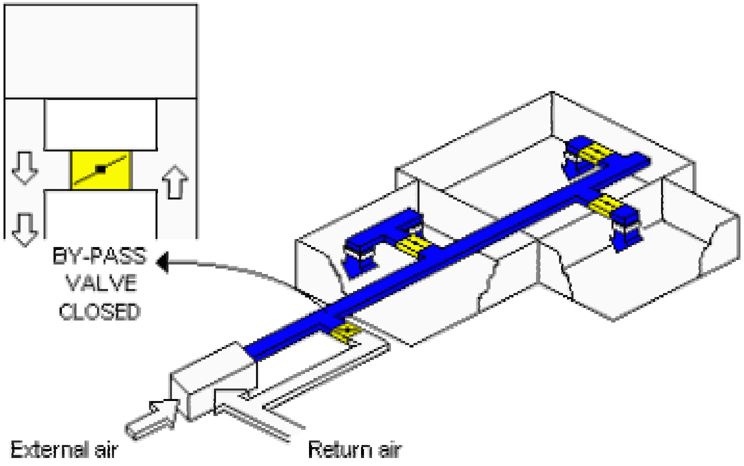
Single Duct, Multiple Zone, VAV System

The variable airflow volume is achieved by VAV boxes. The boxes have a modulating damper that throttles in response to the thermostat setting. When the indoor temperature conditions vary from the set point, the VAV box damper responds by restricting or increasing the supply air volume to the space.

With energy conservation and rising energy costs today, almost all (~98%) of the systems being installed are single duct; with 75% being VAV and 23% being constant volume. To maintain the concept of energy savings and individual control, the variable air volume (VAV) system is a good idea.

Ideally the air-handling unit serving the VAV distribution network should be provided with a variable frequency drive (VFD) to alter the fan speed in relation to the airflow demand. This is the more energy efficient way.

While a VAV system can be exceptionally energy efficient, it may also present serious indoor air quality concerns. As airflow is reduced from design quantities under partial load conditions, it results in reduced ventilation airflow as well. It is a potential indoor air quality problem. ASHARE standard 62 recommends a minimum fresh air supply of 20 cubic feet per minute (cfm) per person.



In some applications the same terminal is used for both heating and cooling; a dual function thermostat, together with the necessary changeover circuitry, makes this possible.

Controls can be pneumatic, electric, analog electronic, or direct digital electronic. Accessories such as round outlets, multiple outlets, and sound attenuators may be added.

Typical Applications:

VAV systems are suitable for use in buildings having many areas of dissimilar cooling requirements. VAV systems lead to significantly lower power consumption, especially in perimeter zones where variations in solar load and outside temperature allows for reduced air flow rates.

Advantages of VAV Systems:

1. One of the major advantages of VAV systems is the flexibility afforded the designer when air conditioning large commercial spaces with diversified load profiles. The ability of the system to handle varying and non-compatible loads in an economic way is the reason for this. With a CAV system, each zone ideally should have an independent system for effective control;
2. It provides energy efficiency and reliable control. Unlike a constant volume system, it relies on air volume control rather than variation of the air temperature.

3. In the VAV system, one air-handling unit can serve multiple zones of the building. In the constant volume system, different zones of the buildings must have a different air-handling unit system for effective control, which means increased mechanical room space;
4. When combined with a perimeter heating system VAV offers inexpensive temperature control for multiple zoning and a high degree of simultaneous heating-cooling flexibility. It has the ability to control temperatures in interior and exterior zones without under-cooling or overcooling;
5. Depending upon building load patterns, it is often possible to shift airflow from one zone to another throughout the day, thus reducing the design capacity of air circulation equipment and main ducts;
6. Large central plant equipment is not required to operate at partial load conditions;
7. VAV is virtually self-balancing;
8. VAV offers an advantage of personalized control with multiple thermostats and humidistats distributed throughout the multiple zones. In the constant volume system the temperature settings are usually available at only one point;
9. It is easy and inexpensive to subdivide existing zones and to handle increased loads as a result of new tenancy or usage, if the load does not exceed the original design simultaneous peak;
10. VAV systems are easy to control, are energy efficient, and allow reasonable room control;
11. Allows simultaneous heating and cooling without seasonal changeover;
12. It is readily adaptable to night set-back and compatible with energy management systems;
13. The system is economical to operate because the amount of air being moved is only that required to satisfy the load; Lower operating cost because,
    - Fans run long hours at reduced volume;
    - Refrigeration, heating, and pumping match the diversity of loads;
    - Unoccupied areas may be fully cut-off.

14. It is suitable for partial operation of a building such as overtime or weekend usage of a particular area;
15. Interface availability with Building Energy Management Systems.

Some drawbacks of VAV boxes that require careful evaluation:

1. High initial cost;
2. Indoor air quality may suffer on low demand at low air flow rates;
3. Supply air distribution throw through diffusers and coverage to the whole room area may be affected at low loads;
4. Balancing of dampers could be difficult if the airflow rate varies widely;
5. Humidity control is difficult under widely varying latent loads;
6. Each terminal unit has an air valve which requires electrical and/or pneumatic service;
7. Maintenance is increased due to multiple boxes within the conditioned space;
8. Suitable false ceiling access is required;
9. Old systems may become noisy;
10. Involves increase expenditure on control and electrical cabling;
11. Accurate adjustment and calibration are required to insure rated and low-load conditions;
12. Duct design and provision of a constant volume supply and exhaust system within the VAV system network is somewhat problematic;
13. Requires engineered diffusers (swirl type) with proven distribution characteristics over a wide range of air flows.

Adopting suitable measures can mitigate the majority of the above listed drawbacks.

VAV VARIATIONS

These systems come in all varieties and complexities; however, in general, a VAV system delivers air at a constant low temperature to a control terminal (VAV terminal box). As the load decreases in the space the terminal box throttles the airflow matching the space requirements. A reheat coil installed in the VAV terminal box can provide heating should it be required.

Shut-Off or Basic VAV: These systems are used for cooling purposes in applications having a year-round cooling load. The volume of the 55°F air is reduced as the cooling load goes down. There is no reheat coil with these boxes and these do not provide heating capability. The VAV box is usually allowed to reduce the airflow to zero during periods of no cooling load. This has the potential to cause indoor air quality problems and therefore, should be evaluated closely during system design. It is more suitable for the interior zone of an office building.

Terminal Reheat VAV: Similar to the simple shut-off system, upon a fall in space temperature, VAV systems with terminal reheat reduce the volume of the air supplied to the space. However, once a predetermined minimum airflow is reached, heat is added to the air prior to delivery to the space. Since the air is never reduced to zero, ventilation can be maintained. This reduces the possibility of indoor air quality problems.

VAV with Constant Zone Volume uses fan-powered terminals to maintain minimum or constant air volume to the zone while the supply air to the zone boxes is varied. This system is useful in zones with a large internal load variation, such as conference rooms, and insures air circulation in occupied spaces during reduced load periods. It is sometimes combined with terminal reheat.

Bypass VAV: The VAV box damper can vary air volume and the excess air is diverted into the return air ceiling plenum. This is particularly important where the air-handler, as well as the return air fan, utilize a constant volume fan. The system will insure that the return air plus the outside air are always equal to the supply air delivery.

Forced Power VAV: A forced power VAV box utilizes its own fan that delivers the flow at constant volume. The box consists of primary air and secondary air openings. When the required temperature conditions are achieved, the primary air damper will close as the fan begins pulling air from the indoor space through the secondary opening. The secondary opening may or may not have the damper. During normal operation the fan will act as booster to the primary air delivery. It does not draw air through the secondary opening as the primary air is at higher pressure. Fan powered VAV boxes, which may be avoidable, are good for maintaining air rotation in a space, but add a level of complexity and cost.

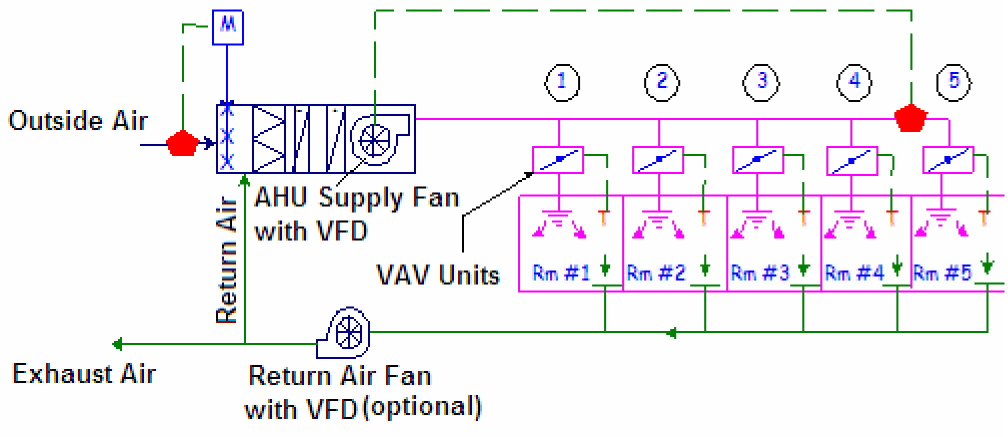
A variation of forced power VAV is parallel fan powered VAV. In these systems, when additional heat is required, primary air at 55°F is throttled; the fan and heating coil in the box are energized to provide the required heat. This system is designed only to power the fan when heat is required. The difference with respect to the “reheat VAV system” is a fan that maintains the air discharge through the diffuser.

Constant Air Box: A constant air box automatically compensates for varying duct pressures to supply a constant flow of air. A constant air box is sometimes utilized in a network of the VAV system for the areas that require constant supply and return/exhaust. For instance, toilets require a fixed amount of exhaust and supply. If these systems are provided with a VAV network with a VFD fan arrangement, the supply will be affected each time there is variation in other VAV boxes. To overcome this, a fixed supply of air for the toilet area is insured by the installation of a CAV box that is not influenced by duct pressures or compensation for the varying pressure in the ductwork.

VAV Control Description

Consider a VAV installation covering 5 rooms as shown. The system consists of air-handling unit (AHU) with an AC drive fan motor. The supply air fan is speed-controlled by a variable frequency drive (VFD) and it delivers the air to individual rooms throughout the building by supply air ducts.

This system is used for multiple zone air-conditioning and has a VAV terminal box for each zone/room.



VAV SYSTEM CONTROL SEQUENCE

Control Philosophy

As the terminal box opens and closes; the static pressure in the ducting increases and decreases. This change in pressure is sensed by the VAV controller, which reacts to vary the air delivered by the unit. The AC drive controls the air volume by keeping the pressure constant in the ductwork.

The temperature in the individual rooms is measured by thermostats, which directly control the dampers in the room terminal units.

The sensor monitors the pressure of the duct. The pressure sensor would be located at the most remote point of the supply main duct, i.e. between room numbers 4 and 5.

If VAV #1 closes down due to low load as sensed by a room thermostat T, it will result in high-pressure build-up in the duct. The pressure sensor would sense the rise in pressure and provide a signal to the AHU fan VFD to reduce the speed (RPM) of the fan. Alternatively, if a VFD is not installed, control could be accomplished by altering the inlet vanes of the fan.

Higher pressures due to the closing of VAV #1 would tend to push more air from VAV #2, VAV #3, VAV #4, and VAV #5. The controlling of fan speed would accurately adjust the discharge volume through these VAV's.

The return fan will be speed adjusted in relation to the supply fan. Instead of having constant static pressure or airflow control of the return air fan, it will track the positive pressure by following the "master" supply fan speed. The idea here is to keep the return airflow equal to the supply airflow, which means that the fans should have equal capacity.

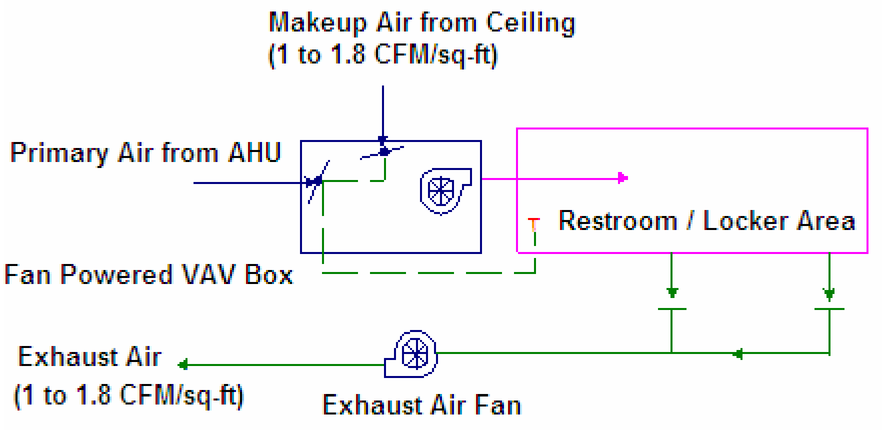
With the VAV system, when supply and return airflow reduces, outside airflow must be maintained constant, all the time, as the ventilation requirements remain unchanged. A velocity sensor is provided in the fresh air intake path for this. When supply airflow is reduced, the velocity is reduced. The velocity sensor senses the reduction and sets the modulating damper on the fresh air intake to actuate wide open in a way that fresh air is maintained constant irrespective of the supply to the indoor spaces.

Controller for VAV Boxes

Units have pressure-independent pneumatic, electronic, or communicating controls capable of maintaining required airflow set points ±5% of the unit's capacity at any inlet pressure up to 6-in. wg. Controllers must be capable of resetting between the factory or field-set maximum and minimum (>350 fpm inlet duct velocity) set points to satisfy the room thermostat demand.

Units can be equipped with an amplified linear averaging flow probe located at 45 degrees opposite the inlet. This sensor will provide a differential pressure signal amplified to equal 3 times the velocity pressure with an accuracy of at least ±10% throughout the range of 350 to 2500 fpm inlet duct velocity, depending on the controller employed.

We have learned about various types of VAV variants. Below is an example of control sequence for the fan powered VAV box for an area that requires a constant exhaust. Consider a restroom area that requires a constant exhaust of 1 to 1.8 cfm per square foot. A thermostat placed in the indoor area will dictate the opening of the primary air through the VAV box. The butterfly damper on the primary air supply path will close on sensing a signal from the thermostat. The make up damper will adjust in relation to the primary damper. The constant air fan in the terminal box will draw the normal secondary make-up air from the ceiling area to compensate for the primary air.



VAV Control for Constant Volume Areas

Advantages of Variable Speed Drives

The use of variable speed AC drives improves the controllability of the entire heating, cooling and air conditioning system, enabling a good possibility of maintaining the Comfort Zone. The use of variable speed drives usually increases the first cost of investment. But through savings in electrical motor energy, an investment in a variable speed drive (VSD) has a payback time between 0.2 and 3 years.

In addition to savings in electrical energy, there are several important customer benefits of VSD:

1. Fast control to maintain the comfort zone conditions;
2. Accurate control to keep the desired air quality;
3. Reduced consumption of heating and cooling energy;
4. Reduced consumption of electrical energy;
5. Simple to maintain a noise reduction.

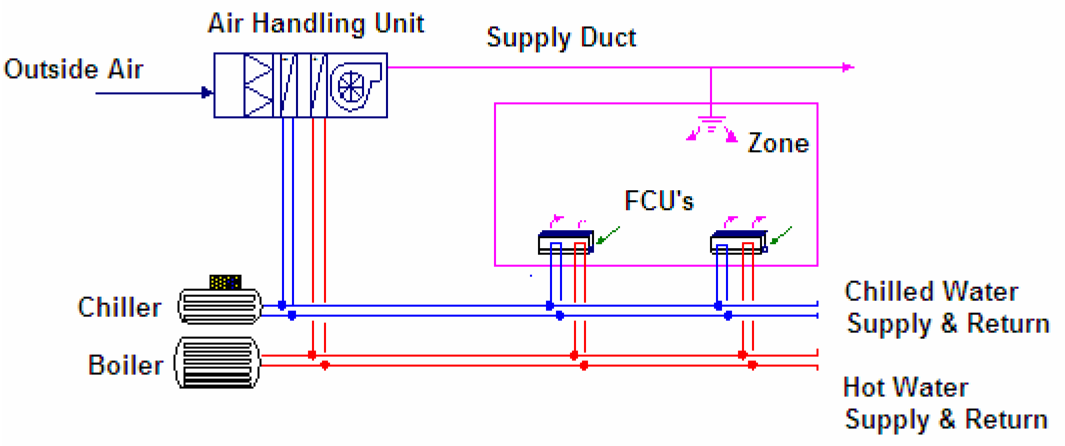
VAV Systems – Are they right for you?

Variable air volume systems are best suited for facilities over 10,000 square feet, which require individual room control, and exhibit varying interior cooling loads. Buildings with a central corridor and rooms with exterior exposures located on both sides of the corridor (double loaded corridors), are usually not good applications for variable air volume.

Potential indoor air quality problems with these systems have become a major design issue. With proper design and installation, ventilation rates can be maintained to satisfy current codes and ASHRAE recommendations, without sacrificing the energy benefits of the variable air volume system.

PART 3 AIR-WATER CENTRAL SYSTEMS

In an “Air-Water” system both air and water are used for providing required conditions in the conditioned space. The air and water are cooled or heated in a central plant. The air supplied to the conditioned space from the central plant is called as primary air, while the water supplied from the plant is called as secondary water. The complete system consists of a central plant for cooling or heating of water and air, ducting system with fans for conveying air, water pipelines and pumps for conveying water and a room terminal. The room terminal may be in the form of a fan coil unit, an induction unit or a radiation panel. Figure below shows the schematic of a basic air-water system. Even though only one conditioned space is shown in the schematic, in actual systems, the air-water systems can simultaneously serve multi-zones.



Air - Water Central System

Air-water systems use the beneficial features from both all-air and all-water systems. The latent energy primarily from outside air is removed in a dedicated air handling unit, which distributes conditioned air for ventilation and pressurization to indoor space. The sensible energy from the indoor space is carried in the water, which reduces space requirements. Let’s study the two portions separately:

The Air Portion of the System:

The airside of the system uses central air components such as an air-handling unit, a distribution duct, and a room terminal. The air supplied is usually constant volume 100% outside air without any recirculation air. It has the following four objectives:

1. Satisfies the ventilation requirement of the conditioned space, which is defined by ASHARE 62 as 20 cfm per person or often 1 to 1.5 air changes, which is a function of space volume.
2. Filters the outside air through high efficiency filtration.
3. The primary AHU meets latent load (moisture removal) of outside air.
4. Keeps the indoor conditioned space pressurized.

For summer air conditioning, the primary air is cooled and dehumidified in the central plant, so that it can offset the entire building latent load. Since the major source of humidity is the ventilation air, the primary air handler cools and removes the moisture from the outdoor air and distributes the dried ventilation air indoors. Pressurization is an important aspect to control moisture infiltration into the building envelope.

Chilled water is supplied to the conditioned space to partly offset the building sensible load ONLY. Since the chilled water coil kept in the conditioned space has to take care of only sensible load, condensation of room air inside the conditioned space is avoided thereby avoiding the problems of condensate drainage and related problems in the conditioned space. As mentioned, the primary takes care of the ventilation requirement of the conditioned space, hence unlike in all-water systems; there is no need for separate ventilation systems. In winter, moisture can be added to the primary air in the central plant and hot water is circulated through the coil kept in the conditioned space.

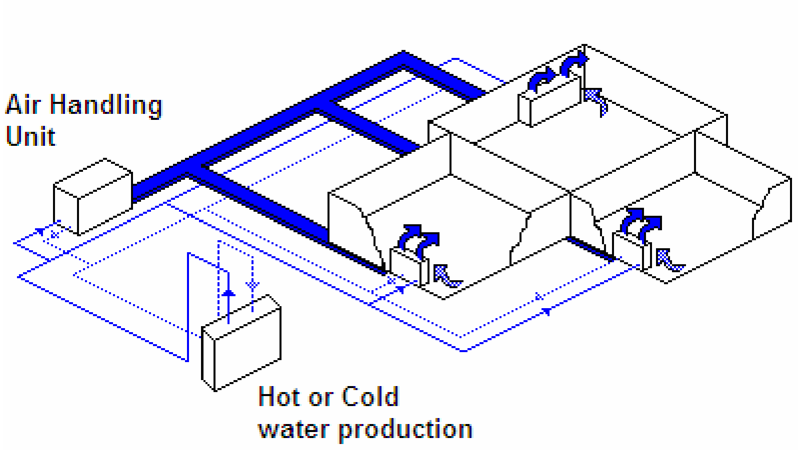
The Water Portion of the System:

The waterside consists of a pump and piping to supply water to transfer heat to the cooling/heating coils located within each conditioned space. A refrigeration chiller produces the chilled water and hot water is produced by a boiler in the central plant.

The heat exchange coils in the conditioned area may be integral with the air terminal (induction units), or fan coil units, or radiant heat panels. The fan coil unit is most popular; it has its own fan that blows air over the coil.

The terminal units placed indoors are 100% recirculation units. The ventilation air requirement is compensated by the primary air handler unit (shown as air conditioning unit in the figure below).

There can be one single coil per terminal unit which is converted to heating or cooling mode depending on the season, or two coils per unit to provide either heating or cooling at all times. In other words, the water system can be arranged as 2, 3, and 4 pipe water systems, the details of which are described in Part 4 "All-water" systems.



Two main delivery approaches are used in air-water systems; the fan-coil and the induction unit.

A **fan coil** unit is a terminal unit that is located inside the conditioned space and consists of a heating and/or cooling coil, a fan, air filter, drain tray and controls. The cold/hot water circulates through the finned tube coil while the blower draws air from the conditioned space and blows it over the coil. As the air flows through the coil it is heated or cooled and dehumidified. In an **induction** unit the cooling/heating coil is an integral part of the primary air system. The primary air supplied at medium to high pressure to the induction unit, induces flow of secondary air from the conditioned space. The secondary air is sensibly cooled or heated as it flows through the cooling/heating coil. The primary and secondary air are mixed and supplied to the conditioned space. The fan coil units are similar to the ones used in all water systems.

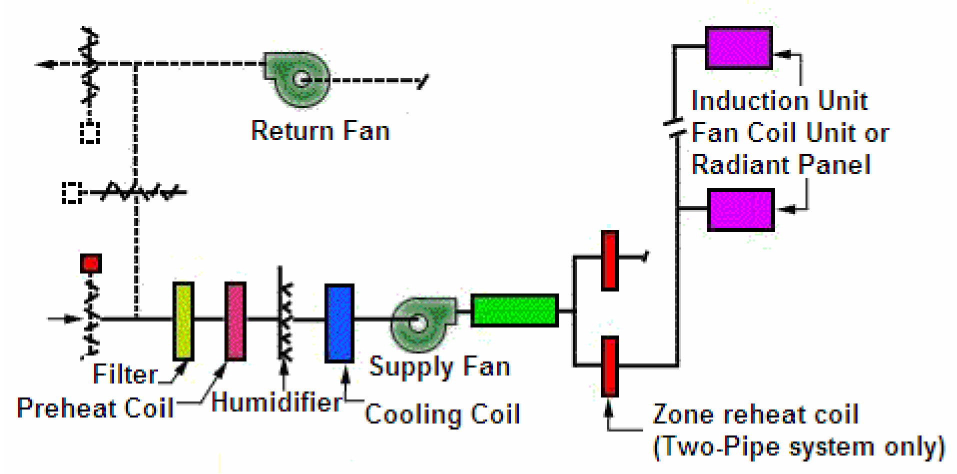
Temperature control

The temperature in each room is maintained by controlling the terminal unit either by modulating the flow of water through the coil, or by the amount of air passing over the coil.

At some outdoor air temperature, mechanical cooling is no longer required and the cooling load can be met with the primary air alone. The terminal units are shut off during such periods.

At lower outdoor temperatures heating may be required. Seasonal changeover is accomplished by gradually raising the primary air temperature as the outdoor temperature drops. At some point hot water is supplied to the terminal units. In some cases electric strip heat is used, and only chilled water distributed.

Air-water systems are primarily used for building perimeter spaces where a wide range of sensible load exists and where close control of humidity is not required. The limitations of these systems are complex controls and tedious maintenance.



The Advantages of Air – Water System:

1. Water has a greater specific heat and density compared to air; therefore, the cross-sectional area of water distribution pipes is less than that of air distribution ductwork;
2. Space needed for the distribution system is minimal. The use of water to provide secondary cooling reduces the space required and the size of the air ducts, thus saving building space;
3. Individual zone control is possible in an economic manner using room thermostats, which control either the secondary water flow rate or the secondary air (in fan coil units) or both;
4. It is possible to provide simultaneous cooling and heating using primary air and secondary water;
5. Positive ventilation can be ensured under all conditions;

6. Since no latent heat transfer is required in the cooling coil kept in the conditioned space, the coil operates dry and its life thereby increases and problems related to odors or fungal growth in conditioned space is avoided;
7. The return air system can be eliminated since the air supplied only has to meet outside air requirements plus any air exhausted;
8. Operating cost will be less; the power required to pump water through the building is usually less than the fan power needed for the supply air and return air systems. Also, because of individual control, the secondary terminal units can be switched off where not required;
9. Space heating can be provided during unoccupied hours by either not running the primary air or, in mild climates, by using 100% return air and no water circulation;
10. Cross contamination is reduced because recirculation occurs within rooms;
11. The versatility of the system is high and it matches that of versatile all air systems. Positive ventilation, filtration, central dehumidification, and winter humidification is performed at a central location;
12. Heating and cooling can be available for all zones, allowing variation of loads;
13. The total building load, instead of the sum of room peaks, dictates capacity requirements;
14. Heating and cooling can be performed without ventilation when a space is unoccupied;
15. The moisture removal takes place in the outside air-handling units and nearly dry air is fed indoors. The terminal units perform only the sensible cooling and the terminal unit coils usually run dry. The dry secondary system coils reduce the chance of microbial growth in the indoor spaces.

Disadvantages of Air-Water System:

1. Compared to all-air systems, controls are more complex and complicated due to the need for handling and controlling both primary air and secondary water;
2. The design for intermediate season operation is critical. Design of between-season operations is crucial as a result of the low primary air delivered;

3. Since a constant amount of primary air is supplied to conditioned space, and room control is only through the control of room cooling/heating coils, shutting down the supply of primary air to unoccupied spaces is not possible;
4. Low dew point air must be provided because all dehumidification is done at a central location. If there is abnormally high latent load on the building, then condensation may take place on the cooling coil of secondary water;
5. The indoor terminal units require a draining arrangement for moisture disposal even though the latent load is handled with an independent primary air ventilation system. This depends however on the possibility of latent load in the indoor spaces;
6. The system should not be used in spaces with high exhaust requirements unless additional ventilation is supplied;
7. Terminal units require frequent in-space maintenance;
8. Occasional cleaning of terminal unit filters is required even though the air is pretreated by the primary air-handler unit;
9. Humidity cannot be tightly controlled. Low chilled water temperatures or chemical dehumidification may by necessary;
10. Initial cost could be high compared to all-air and all-water systems.

Applications of Air-Water System:

These systems are mainly used in buildings with large sensible loads and where close control of humidity in the conditioned space is not required. These are suitable where building ceiling heights are low and floor space is at premium. These are commonly applied for perimeter spaces.

These systems are suitable for office buildings, hospitals, schools, hotels, apartments etc.

Illustration- Hotel Application

A typical example of an “Air-water” system is in hotel rooms. Each hotel room is provided with a fan coil unit that is supplied from a chilled/hot water source. At the same time, the room is provided with a portion of fresh air through a 100% treated fresh air handler that also feeds the corridor area. Since the occupancy of the hotel room is usually lean during the daytime, the fan coil unit remains off during no occupancy. However, a small amount of fresh air via the 100% treated fresh air-handler is consistently provided so that the room does not become air stagnant. The fan coil unit capacity is designed for the room sensible and latent capacity arising from occupancy, solar, and appliances such as the TV and refrigerator.

This concept provides the following advantages:

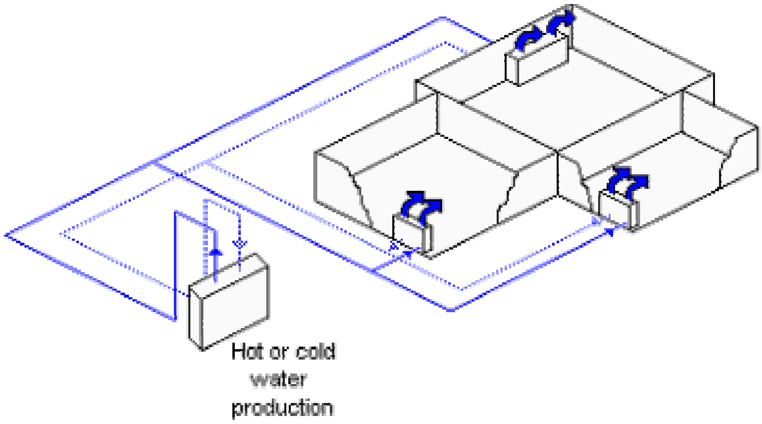
- Provides personalized individual control to the guest by switching the fan on or off, or by changing the speed. Auto-control is possible by adjusting the thermostat to a set position.
- Insures energy efficiency as the unit can be switched off during unoccupied hours.
- Reduce structural costs due to less plenum height and smaller mechanical rooms. The air handler and ductwork are about 1/3 normal size. As there is no need to run large ducts to the room spaces, the terminal fan coil unit requires the routing of typically only 2 to 3 inch diameter chilled water pipe. Main ducts are routed only to the corridor area for general ventilation, providing the pressurization air, and another duct for smoke removal systems during emergency fire situations.
- In a room, a fan coil unit is usually ceiling mounted on a plenum space at the entrance corridor between the wardrobe and the bathroom. Typically 50 to 80 cfm of treated fresh air is supplied to a room while 30 to 50 cfm is constantly exhausted from the bathroom. This keeps the room ventilated and pressurized.
- Lower operating cost due to smaller fans, lower reheat requirements, energy and moisture recovery

PART 4 ALL WATER (HYDRONIC) SYSTEM

This system is based on the distribution of hot or cold-water to individual heat transfer devices (terminal units) located in each room of the building. When cooling is required in the conditioned space then cold water is circulated between the conditioned space and the plant, while hot water is circulated through the distribution system when heating is required. Unlike Air-water systems, no primary air is separately fed indoors.

Whether heating or cooling, “All –water” or *hydronic* system uses the following basic components to control the environment:

1. The use of a chiller (on roofs or plant rooms) to cool water that is circulated via pumps to the occupied space, where it is passed through fan coils (terminal units) that circulate room air over the coil, hence absorbing unwanted heat.
2. The use of boilers located in plant rooms to heat water (a separate circuit from cooling) that is circulated via pumps to the occupied space, where it is passed through the same fan coil which circulates room air, hence adding heat to the space.



All-water cooling-only systems are rare. Valance units, a ceiling-located counterpart of a baseboard radiator, are the most common delivery devices for such systems. All-water heating-only systems employ a variety of delivery devices, including baseboard radiators, convectors, unit heaters, and radiant floors. If full air-conditioning is considered, the most common delivery device is the fan-coil unit.

Fan coil units, unit ventilators, convectors, and radiation units are the most common terminals. Fan coil units and unit ventilators include a fan to circulate air across the cooling coil. Convectors and radiation units use natural convection. Unit ventilators are similar to room fan coil units but have a more elaborate system for introducing fresh air from a wall penetration, and an option for free cooling by outdoor air with an economizer cycle control.

Terminal units are 100% recirculation units. System ventilation is usually accommodated by opening windows, by infiltration, or installing outside wall openings. Note that in Air-water systems ventilation is normally accomplished by a separate system, through a range of AHUs and ductwork distribution systems that are smaller than air systems, which can be localized to the air-conditioned space.

Water Systems only control temperature. Filtering of the air is normally carried out through the indoor fan coil terminal units.

All water systems are applicable where individual space temperature control is desired without close control of humidity, or where prevention of room-to-room cross contamination is advantageous. They are not well suited to interior spaces.

All - Water System Advantages:

1. Water is an effective heat transfer medium; therefore, distribution pipes generally are of relatively small volume compared to air ducts.
2. Recirculation of air is unnecessary, so comingling of odors and contaminants, or concerns over fire and smoke spreading from one zone to another, are minimized.
3. First cost is often less than for other central systems.
4. Less building space is required.
5. More suitable for retrofit applications.
6. Off-hour conditioning does not require central air system operation.
7. Cooling can be easily shut off in unoccupied areas.
8. Quieter than unitary systems.
9. Minimal space needed for air handling rooms and duct clearances.
10. Individual zone temperature control.

11. Variable speed secondary pumps can be used to improve comfort control and reduce operating costs.
12. Can use heat recovery techniques.
13. Flexible and readily adaptable to many building module requirements.
14. Provides individual room control.
15. Prevents cross contamination of recirculated air from one room to another.

All – Water System Disadvantages:

1. All-water system is limited by its inability to control relative humidity, outdoor air content, air composition, and pressure.
2. A separate ventilation system is required for quality installations.
3. No positive ventilation is provided unless wall openings are used. Ventilation is usually from a wall aperture and is not easily controlled due to wind and stack effect. Otherwise it is often accomplished by the opening of windows.
4. Unless dehumidification and latent load is handled with a separate ventilation system such as an air-water system, a condensate drain pan system is required and terminal air filters must be periodically cleaned.
5. Relative humidity may be high in summer, particularly if chilled water flow is modulated for temperature control. No humidification is provided.
6. Seasonal change over is required.
7. Maintenance and service work must be performed in occupied areas.
8. The filters associated with terminal units are the low efficiency type and require frequent changes because of static pressure limitations.

Depending upon the number of pipes used; the all-water systems can be classified into a 2-pipe system or a 4-pipe system.

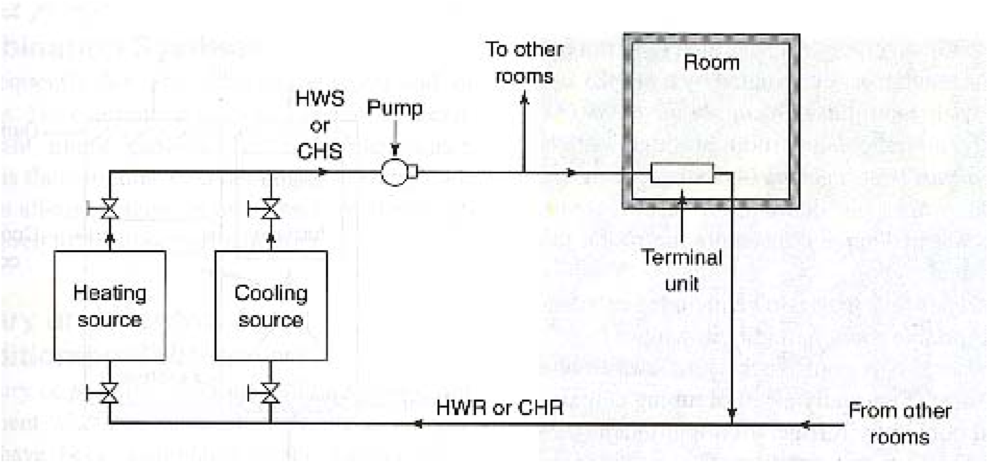
When one coil is used for cooling only, heating only, or heating and cooling at various times, a two-pipe water distribution system is used.

When two coils are used, one for heating and one for cooling, a four-pipe water distribution system is used. Heating may also be accomplished using an electrical strip heater mounted on the terminal unit.

Straight water heating systems will commonly use convectors, baseboard radiation, fin tube radiation, standard fan-coil units, and unit heaters.

TWO PIPE SYSTEMS

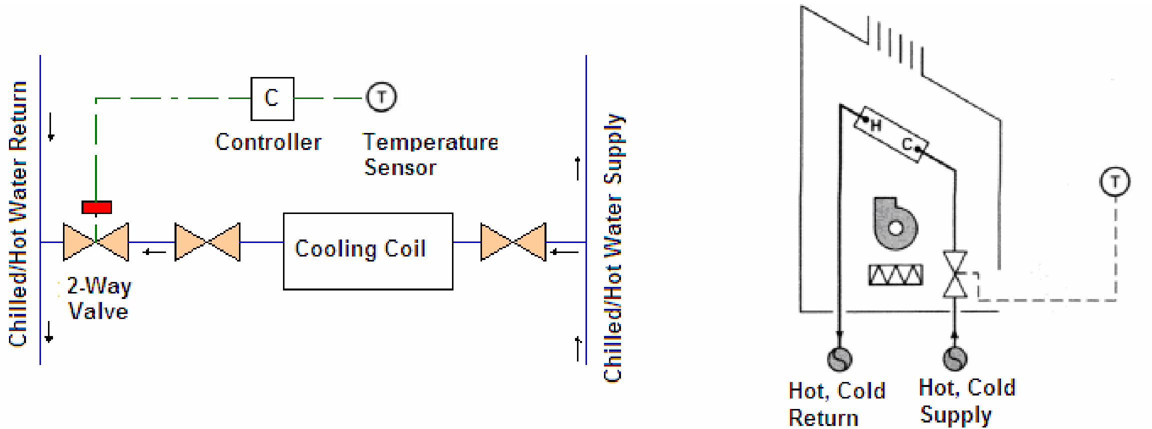
A 2-pipe system is used for either cooling only or heating only application, but cannot be used for simultaneous cooling and heating. Figure below shows the schematic of a 2-pipe, all-water system.



As shown in the figure and as the name implies, a 2-pipe system consists of two insulated pipes – one for supply of cold/hot water to the conditioned space and the other for the return water. A cooling or heating coil provides the required cold or hot water. As the supply water flows through the conditioned space, required heat transfer between the water and conditioned space takes place, and the return water flows back to the cooling or heating coil. A flow control valve controls the flow rate of hot or cold water to the conditioned space and thereby meets the required building heating or cooling load. The flow control valve is controlled by the zone thermostat.

Depending on the season, either of cold water or hot water can be isolated with simple changeover. Problems can occur during the mid-seasons where cooling may be required part of the time and heating part of the time, and no heating or cooling the balance of the time.

Two pipe systems without water-changeover circulate chilled water only, and when heat is needed it is provided by electric strip heat at the terminal units. In some cases, hot water is circulated during the coldest part of the heating season to reduce operating cost.



Two - Pipe System

The primary air quantity is fixed and the primary air temperature control is achieved by varying the water supply through the coil. When the thermostat sensor demands more cooling, the two or 3-way valve located on the line is in the full open position.

Note that the water flow rate required for heating is much lower than the chilled water flow. The piping and pump are sized for the maximum flow of chilled water. Using the same piping system for results in very low velocities during heating. To overcome this, if not all, 50% of pumps may need to be operative. Energy is wasted in terms of pumping cost. It is better to use a four pipe system and lower flow rates with smaller pumps.

The 2- pipe system advantage is:

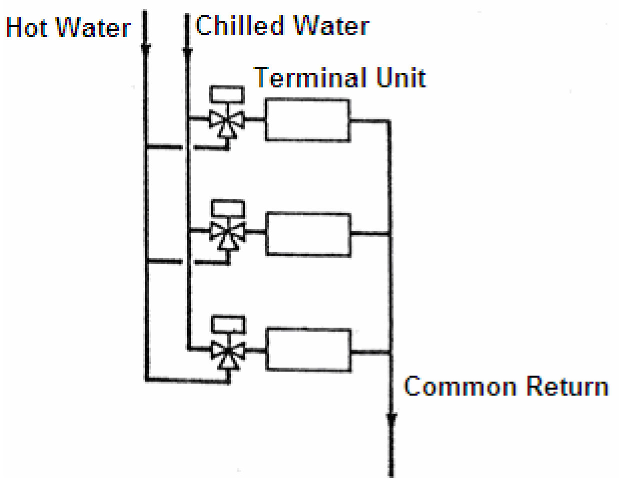
It is usually less expensive to install than the four pipe system.

The 2-pipe system disadvantages are:

1. Less capable of handling widely varying loads or providing a widely varying choice of room temperature than the four-pipe system.
2. A separate arrangement must be made for providing the required amount of ventilation air to the conditioned space.
3. Cumbersome to change over.
4. Though the initial cost is economically attractive, it is more costly to operate than four-pipe systems.

THREE PIPE SYSTEMS

Three pipe systems have separate chilled and hot water supplies with a common return. These systems are rarely used because they consume more energy because of excessive mixing of the chilled and hot water in the common return.

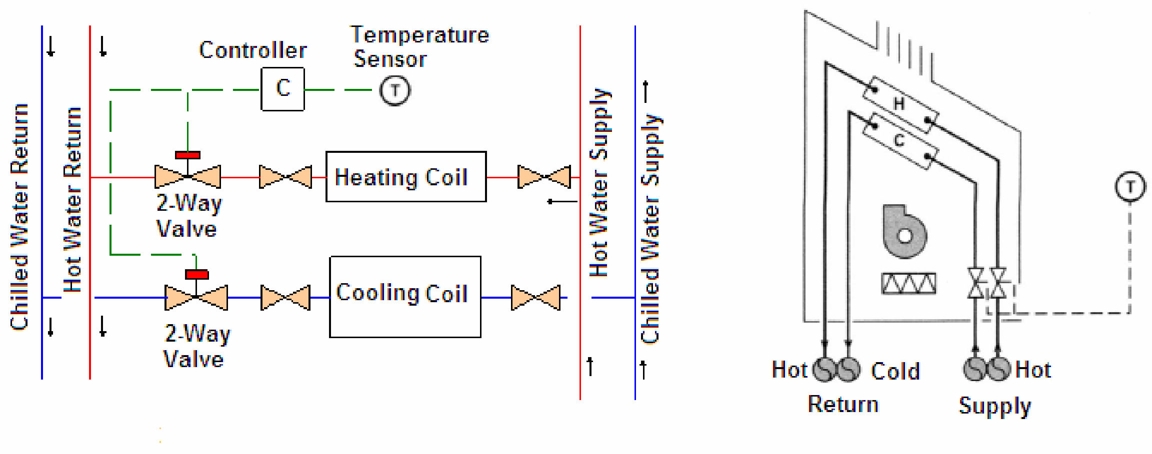


FOUR PIPE SYSTEM

A 4-pipe system consists of two supply pipelines – one for cold water and one for hot water; and two return water pipelines. The cold and hot water are mixed in a required proportion depending upon the zone load, and the mixed water is supplied to the conditioned space. The return water is split into two streams, one stream flows to the heating coil while the other flows to the cooling coil.

The system is further categorized as an independent load or a common load system.

1. Independent load systems have two separate water coils, one served by hot water, the other by cold water. These systems make use of a 2-way on-off valve.
2. Common load systems can have a single coil in the air handler but still be supplied independently with a four-pipe system. These systems make use of a 3-way diverting valve.



Four - Pipe System

The main advantages of 4- pipe system are:

1. All year availability of heating and cooling with individual zone temperature control;
2. Chilled and hot water can be simultaneously supplied during the Spring and Fall seasons;
3. Elimination of zoning cost and complexity;
4. Simpler changeover decisions (no summer-winter changeover and primary air reheat schedule);
5. The lowest and quietest fan speed is adequate most of the time;
6. More flexible and adaptable to widely varying loads.

Disadvantages of 4 – pipe system:

1. Four-pipe systems have a high first cost in additon to the need for either two coils or more costly control valves at each terminal unit;
2. The systems also have a high operating cost because of the two pump operation. They do however provide good flexibility in meeting varying loads.

CONCLUSIVE RECAP

Relationships between All-Air, All-Water, and Air-Water HVAC Systems

1. All the three HVAC distribution systems share one common objective as a system. It is to control the environment of an interior space.
2. All three systems use heating coils to heat the air and cooling coils to cool it. The location of the coils varies from system to system. In the all-air system the heating/cooling coils are located in the central air-handler. In the air-water system the coils are located in the air-handler as well the terminal units. In the in all-water system the coils are located in the multiple terminal units located in the indoor spaces.
3. With regard to air distribution devices, the all-air system uses a central air-handler located in unoccupied area. The air-water system uses a central air-handler (100% outside air) and terminal units (fan coil or induction units) in the occupied areas. The all-water system uses (100% recirculated air) and terminal units (fan coil units) in the occupied areas.
4. One major difference between the all-air, air-water, and all-water systems is that the first two can regulate the outdoor air intake, or air circulation, whereas the all-water system must depend on windows, doors, etc. to provide this. In other words, the all-air and air-water systems allow for room positive pressurization.
5. Briefly, the three systems may have specific equipment differences on the air distribution method, but all three use the distribution of chilled/hot water and allow the space air to come in contact with the heated or cooled fluid to change the environment. In all three systems either the air or water must be delivered to each space using either ductwork and/or piping.

<u>Summarizing</u>

- In all-air system the piping is distributed to the central air-handler outside the conditioned space. The system relies extensively on ductwork to distribute the cold air, with the amount of piping limited. These systems find application in large spaces requiring uniform distribution of air, positive pressurization, near optimum load operation, and such.
- In air-water system, piping is installed to the air-handler unit as well as the terminal units. The system relies extensively on the piping network with ductwork sizes and runs minimized. The system finds application where ceiling heights are low and where cross zoning is to be avoided. The system can yield energy

efficiency by shutting off the terminal units if the space is not in use or space conditions are satisfied.

- In all-water system only piping is installed to the multiple terminal units located inside the occupied spaces. The ductwork is eliminated. The system finds application where ceiling heights are low and where retrofitting is desired as a result of space expansion. The system can yield energy efficiency by shutting off the terminal units if the space is not in use or space conditions are satisfied.

Let's check the relationship between the three systems with respect to their ability to control the six main HVAC parameters. These are temperature, relative humidity, pressure, air composition, particulates, and air velocity.

Parameters	**All-Air Systems**	**Air-Water Systems**	**All-Water Systems**
Temperature	Good using modulation of chilled water through coils in air handling units	Good, it uses central air-handling unit and the terminal unit coils for temperature control. The control is achieved through modulation of chilled water through air-handling coil and usually using "on-off" solenoid valve at the terminal units.	Moderate, using modulation or 'on-off' of valve to the terminal units. Air control is also possible using 2 or 3 speed fan motor.
Relative Humidity	Moderate using coils for dehumidification and humidifiers in	Good, it relies primarily on the dehumidification through the chilled	Poor using chilled water at low temperature at the terminal units.

Parameters	**All-Air Systems**	**Air-Water Systems**	**All-Water Systems**
	air handling units. Since the system relies on the chilled water for dehumidification, the system also simultaneously uses reheat for temperature control, which is waste of energy.	water coil of air-handling unit that processes 100% outside air. The secondary control is at the terminal units, but in practice the primary air control is good enough as high humidity is primary a result of outside air.	Necessary plumbing arrangements need to be considered for taking condensate drainage to the discharge receptacles.
Pressurization	Moderate by permitting requisite amount of outside air	Good by use of 100% outside air handling unit which can easily be controlled	Poor as terminal units use 100% re-circulation
Air composition	Good by modulating the outside air and return air dampers	Good by allowing the right amount of ventilation at the first place.	Poor as the system uses 100% re-circulation units and rely on window/wall openings or natural infiltration for ventilation
Particulates	Good by allowing pre-filtration and high efficiency	Good by allowing pre-filtration and high efficiency	Moderate by allowing filtration at the terminal units.

Parameters	**All-Air Systems**	**Air-Water Systems**	**All-Water Systems**
	filtration in the air handling units	filtration in the air handling units	The filtration efficiency is however low due to static pressure concerns. Maintenance in occupied spaces is another concern.
Air velocity	Good by varying the fan speed and dampers, swirl diffusers with VAV boxes	Moderate by constant supply of fresh air. The throw of terminal units is a concern to cover wide areas.	Poor control as the terminal units have a limited through and are 100% re-circulation units

Clearly, an Air-Water system incorporates the effectiveness and benefits of all-air and all-water approaches and with variations; it can provide control over all six subsystems efficiently. The volume/space saving advantages of an all-water system are combined with the outdoor ventilation benefits of an all-air system. Usually the majority of the space load is carried by conditioned water with just enough central air supply to meet ventilation demands.

Air is not an efficient heat transfer medium, thus, all-air systems may require extensive building volume for ductwork distribution. In situations where ductwork cannot be reasonably accommodated in the building design, air-water or all-water approaches may be considered. Escalating concerns for acceptable indoor air quality may suggest the increasing use of all-air systems.

An all-water system controls the least number of comfort parameters and may find greater popularity in renovation projects, or where a dedicated ventilation air scheme is used for indoor air quality purposes. Depending on other architectural, structural, and financial constraints or intended use of space, all three or hybrids of the three systems must be carefully evaluated.

Examples below illustrate the preferred systems for typical applications:

- A large indoor stadium should have “All air” single duct system.
- A large commercial building office complex should have “Multiple zone, single duct” system.
- Individual rooms of a large hotel should have “Air -water” (star hotels) or All – Water systems (small inns and guest houses).
- An existing building with good ventilation requirement should have “Air-water” system.
- An existing, small office building should have “Unitary” systems
- A large precision laboratory should have “Constant” air volume system
- Perimeter zone of a building should have “Variable” air volume system
- Areas demanding simultaneous cooling and heating should have “Dual duct or VAV” system.

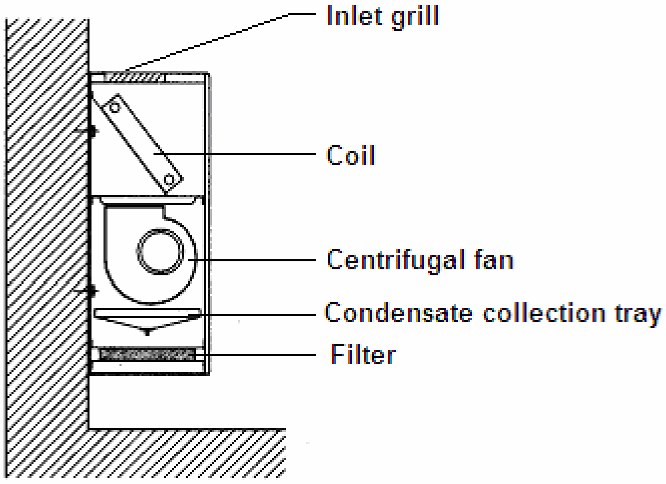
PART 5 TERMINAL UNITS

Heat transfer between the cold/hot water and the conditioned space takes place either by convection, conduction or radiation or a combination of these. The cold/hot water may flow through bare pipes located in the conditioned space or one of the following equipment can be used for transferring heat:

1. Fan coil unit
2. Induction unit
3. Radiators
4. Convectors etc.

FAN COIL UNIT

A fan coil unit is located inside the conditioned space and consists of a heating and/or cooling coil, a fan, air filter, drain tray and controls. Figure below shows the basic components of a fan coil unit used for cooling applications.

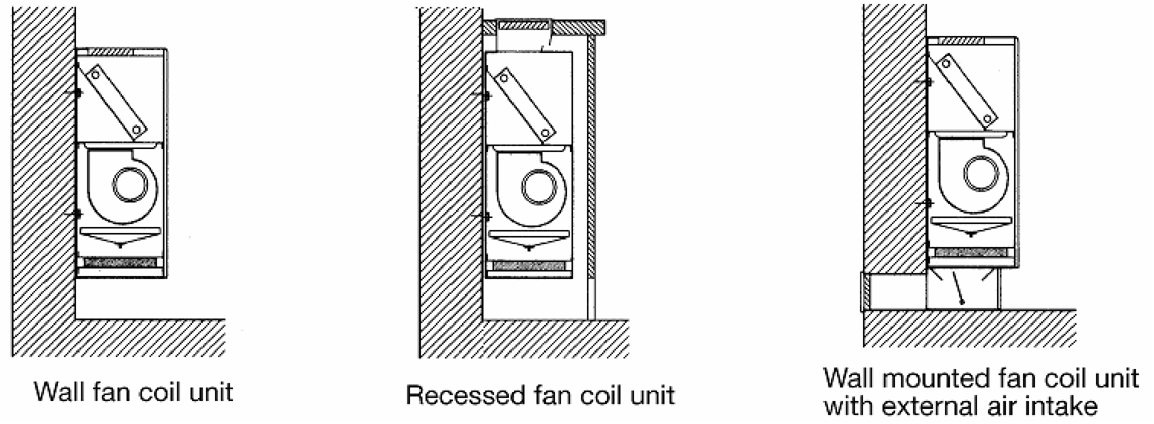


Fan Coil Unit

As shown in the figure, the basic components of a fan coil unit are: finned tube cooling coil, fan, air filter, insulated drain tray with provision for draining condensate water and connections for cold water lines. The cold water circulates through the finned tube coil while the blower draws warm air from the conditioned space and blows it over the cooling coil. As the air flows through the cooling coil it is cooled and dehumidified. The cold and dehumidified air is supplied to the conditioned space for providing required conditions inside the conditioned space. The water condensed due to dehumidification of room air has to be drained continuously and therefore a fan coil unit must have a provision for draining the condensed water. A cleanable or replaceable filter is located in the upstream of the fan to prevent dust accumulation on the cooling coil and also to protect the fan and motor from dust.

In some designs, the fan coil unit also consists of a heating coil, which could be in the form of an electric heater or steam or hot water coil. Electric heater is used with 2-pipe systems, while the hot water/steam coils are used with 4-pipe systems.

The fan coil units are floor mounted, window mounted or ceiling mounted. Fan coil units can be vertical units that are installed directly on the floor, or they can be horizontal units that are hung from the ceiling. Horizontal units can be above a dropped ceiling.

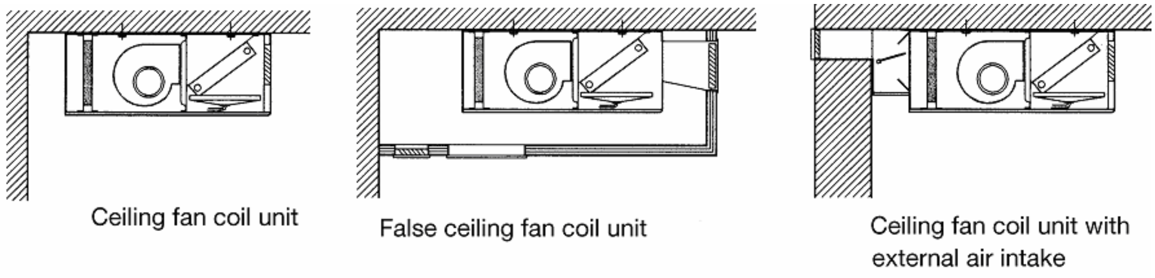


Wall fan coil unit

Recessed fan coil unit

Wall mounted fan coil unit with external air intake

Floor mounted Fan coil units



Ceiling fan coil unit

False ceiling fan coil unit

Ceiling fan coil unit with external air intake

Ceiling mounted Fan coil units

The capacity of a fan coil unit can be controlled either by controlling the liquid flow rate or by controlling air flow rate or both. The airflow rate can be controlled normally by varying the fan speed. The control may be manual or automatic, in which case, a room thermostat controls the capacity. Water flow rate through the coil is achieved using a control signal from the zone thermostat. Occupants can usually adjust supply air louvers to provide some control over air distribution patterns.

A fan coil unit can be used either with an “all - water” system or with an “air-water” system. This supply air can either be delivered independently of the fan-coil unit through conventional diffusers or registers, or can be introduced at the fan-coil unit itself. A fan coil unit with a provision for introducing treated ventilation air to the conditioned space is called as **unit ventilator**.

Fan coil units for domestic air conditioning are available in standard capacities of 200, 300, 400, 600, 800, and 1,200 cfm.

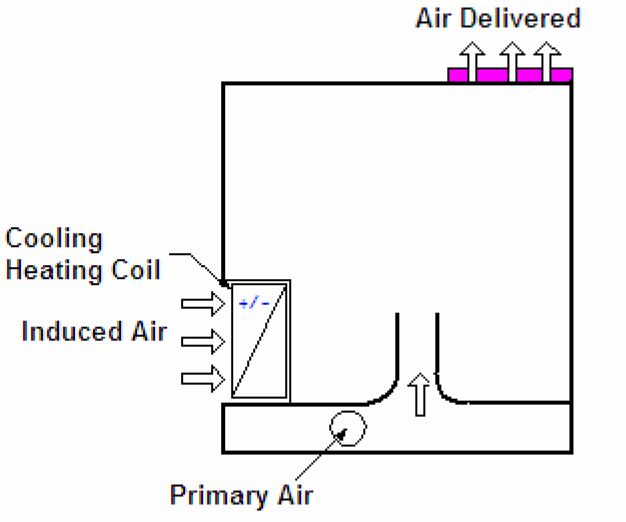
INDUCTION UNIT

Externally, an induction unit looks very much like a fan-coil unit; the difference is internal. An induction unit is used with the “air-water” system only and employs high velocity airflow from a central air-handling unit to induce a flow of room air into and through the cabinet. This induction effect replaces the motive force provided by the fan in a fan-coil unit.

The inducting system is designed for use in perimeter rooms of multi-story, multi-room buildings that may have reversing sensible heat characteristics. It is well suited to handle the loads of skyscrapers that have minimum space available for mechanical equipment.

The inductor is based on the physical venturi principle:

1. The primary air is accelerated through a restricted section of pipe;
2. Because of energy conservation, the pressure at the exhaust of the pipe is higher than the outside pressure;
3. The outside air is therefore attracted by induction through the device that is at a lower pressure.



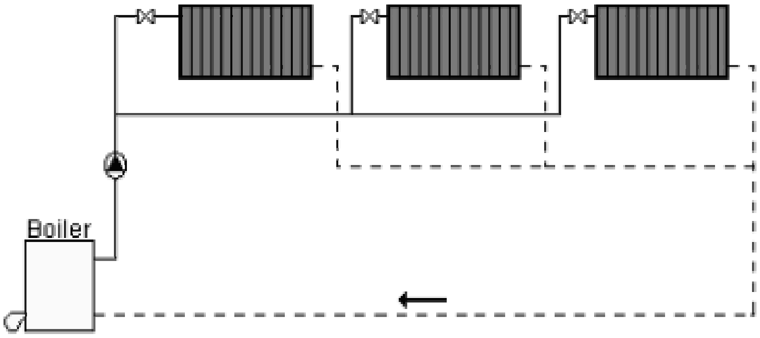
Basic Induction Unit

Induction units are usually installed at a perimeter wall under a window. Some hotel rooms are provided with induction coils.

The induction system employs air ducts to convey treated air to various cooling/heating coil units with higher-pressure levels and correct adjustable quantities. These coil units employ built-in induction nozzles. When high-pressure air goes through them, room air is inducted across the fin surface of the water-circulated coils. This inducted air stream is either cooled or heated after passing through the coil, and then mixed with the air exiting the nozzle. The correct quantity of high-pressure air is adjusted automatically in response to a thermostat located in the conditioned space. The system is well suited to provide temperature control for individual spaces or zones.

RADIATORS

Radiators are heat emitters (made up of elements, panels, tubes or blades) which give out heat by natural convection and radiation. These operate with a fluid, usually water, heated by a boiler. The hot water is circulated to multiple radiator units which is then returned after exchanging heat with the room air. Baseboard radiators induce natural convection as an important means of heat distribution within a space, with warmer air exiting at the top of the unit and cooler air entering at the bottom.



The radiators are the most commonly used systems for room heating in the residential and commercial sector. Radiators can be classified according to type, i.e. cast iron, radiators, steel radiators and aluminum radiators (which pure aluminum or aluminum alloy) according to the material they are made of.

CONVECTORS

Convectors are heat emitters which give off heat mainly by convection. They are constructed with finned heat exchangers and operate under natural "draught" conditions. Convectors can be classified on the basis of their structural characteristics, i.e. those with single finned tube, those with finned channels, cabinet convectors and baseboard convectors.

These heat emitters have the following advantages over radiators:

- They are lighter and less expensive for the same output;
- They have a lower thermal inertia;
- They provide solutions to the specific installation problems.

On the other hand they have the following disadvantages:

- They are difficult to clean so that they should not be used in dusty locations or where satisfactory cleaning is not possible;
- They cannot be used for automatic air temperature control as their heat output curve has a "bend" (i.e. a significant variation in gradient) for fluid temperatures between 45 and 50°C.

Advantages of All - Water Terminal Systems:

1. The thermal distribution system requires very less space compared to all air systems, also the plant size will be small due to the absence of large supply air fans;
2. Individual room control is possible, and at the same time the system offers all the benefits of a large central system;
3. Separate sources of heating and cooling for each space, available as needed, to satisfy a wide range of load variations;
4. Reduced size of central air handling equipment;
5. Dehumidification and filtration performed in a central plant room remote from the conditioned space;
6. Outdoor air supply is positive;
7. Minimal maintenance required for individual induction units, which have no moving parts, i.e. no fans;
8. No fan is associated with the induction units, making the conditioned space quiet. For other equipment, the system can be operated with the primary air turned off;
9. Primary air can be connect directly to the fan-coil unit or be supplied to the room separately;
10. Air duct dimensions are smaller than VAV systems or CAV systems;
11. Zoning of central equipment is not required;
12. It can be used for new as well existing buildings (retrofitting).

Disadvantages of All - Water Terminal Systems:

1. Requires higher maintenance compared to all air systems, particularly in the conditioned space;
2. Draining of condensate water can be messy and may also create health problems if water stagnates in the drain tray. This problem can be eliminated, if dehumidification is provided by a central ventilation system, and the cooling coil is used only for sensible cooling of room air;
3. Control of humidity, particularly during summer is difficult using chilled water control valves.

4. Fan noise may be a concern in some critical occupancies;
5. The primary air supply is usually constant with no provision for shutoff;
6. Higher energy consumption due to the increased power required by the primary pressure drop in the terminal units;
7. The fan-coil system is usually installed in, or adjacent to, occupied spaces, requiring that filter changes and maintenance of fans and coils occur in these spaces;
8. Controls tend to be more complex compared to all-air systems;
9. A low chilled water temperature is needed to control space humidity adequately;
10. Seasonal changeover is necessary;
11. Terminal units take up several inches of perimeter floor space and sometimes impairing the flexibility of furniture arrangement;
12. Initial cost is usually higher than fan coil systems.

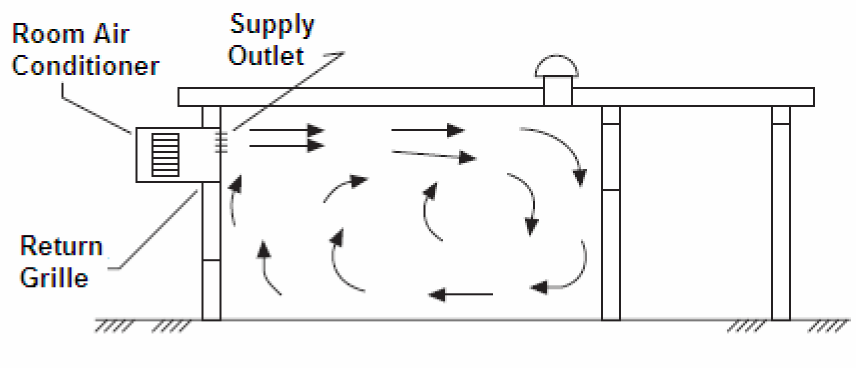
Applications of All - Water Terminal Systems:

All water systems using fan coil units are most suitable in buildings requiring individual room control, such as hotels, apartment buildings and office buildings.

For large spaces such as airports, the usage is limited and confined to perimeter spaces. It is not applicable to spaces with a high exhaust requirement.

PART 6 INDIVIDUAL COMPACT UNITARY UNITS

An individual air-conditioning system also called unitary or self contained unit normally employs either a single, self-contained, packaged room air conditioner (installed in a window or through a wall) or separate indoor and outdoor units to serve an individual room, as shown in Figure below. "Self-contained, packaged" means factory assembled in one package and ready for use.



Individual Air Conditioning System

Individual compact systems are direct expansion (DX) systems. These operate using direct expansion of refrigerant in the finned tubes across the air path, unlike chilled water in central systems.

The refrigeration cycle consists of a direct expansion (DX) cooling coil, one or more reciprocating/rotary compressors, an air or water cooled condenser, refrigerant piping, and associated controls. The components are factory assembled into an integrated package with fans, filters, heating coils, and airside controls.

Some of the advantages of Unitary Units:

1. Units are off-the-self items and normally have low initial cost compared to central plants;
2. Individual room control is simple and inexpensive;
3. Each conditioned space has individual air distribution with simple adjustment by the occupants;
4. Performance of the system is guaranteed by the manufacturer;
5. System installation is simple and takes very less time;
6. Operation of the system is simple and there is no need for a trained operator;

7. Heating and cooling capability is provided at all times, independent of the mode of operation of other spaces;
8. Only one terminal, zone, or controller is affected in the event of an equipment malfunction;
9. Unitary systems are ideal for retrofitting applications as the required floor space is small.

Some of the disadvantages of Unitary Units:

1. As the components are selected and matched by the manufacturer, the system is less flexible in terms of air flow rate, condenser and evaporator sizes. Most unitary equipment is usually designed for a 70% sensible load factor and it has a fixed airflow, usually 400 cfm per ton of refrigeration;
2. Power consumption per TR could be higher compared to central systems of same capacity;
3. Noise level in the conditioned space could be higher;
4. Limited ventilation capabilities;
5. Systems are generally designed to meet the appliance standards, rather than the building standards;
6. The space temperature may experience a swing if on-off control is used as in room air conditioners;
7. Limited options for controlling room air distribution;
8. Equipment life is relatively short.

Application of Unitary Units:

Unitary refrigerant based systems are used where stringent control of conditioned space temperature and humidity is not required and where the initial cost should be low with a small lead time. These systems can be used for air conditioning individual rooms to large office buildings, classrooms, hotels, shopping centers, nursing homes etc. These systems are especially suited for existing building with a limitation on available floor space for air conditioning systems.

Cooling capacity can range from a fractional tonnage for window-type units, to 100 tons of refrigeration or more, for packaged units. A unitary system that uses the refrigeration system as the primary heating source is referred to as a heat pump. Commercial-grade unitary systems are called packaged units. A packaged unit designed to be placed on the roof is called a rooftop unit.

Several types of individual air conditioning units are briefly described below:

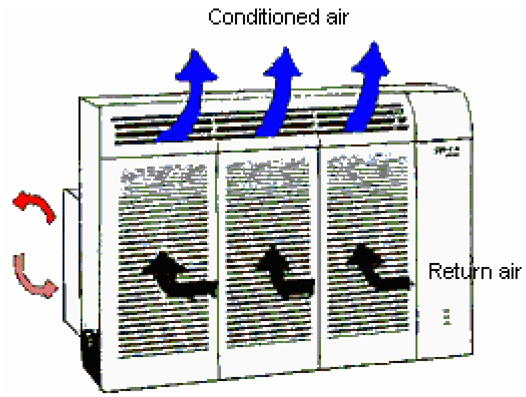
WINDOW UNITS (CONSOLES)

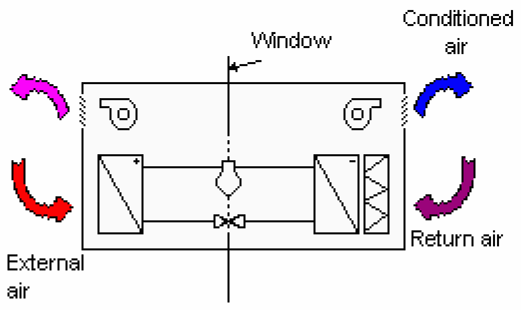
Window-mounted air conditioners cool the individual conditioned spaces. A window unit is an encased assembly designed primarily for mounting in a window, through a wall, or as a console. These units are designed for comfort cooling and provide delivery of conditioned air to a room without ducts. They include a prime source of refrigeration, dehumidification, means for circulating and cleaning air, and may also include means for ventilating and/or exhausting, and heating.

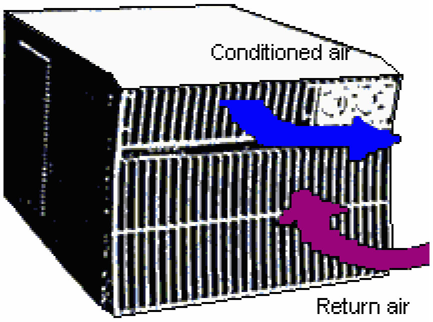
They have a low initial cost and are quick and easy to install.

Sometimes they are also used to supplement a central heating or cooling system or to condition selected spaces when the central system shuts down. When used with a central system, the units usually serve only part of the spaces conditioned by the central system. In such applications, both the central system and the window units are sized to cool the particular conditioned space adequately without the other operating. In other applications, where window units are added to supplement an inadequate existing system, they are selected and sized to meet the required capacity when both systems operate.

Window units require outside exposure for heat rejection and cannot be used for interior rooms. Split unit option will be used in such places.





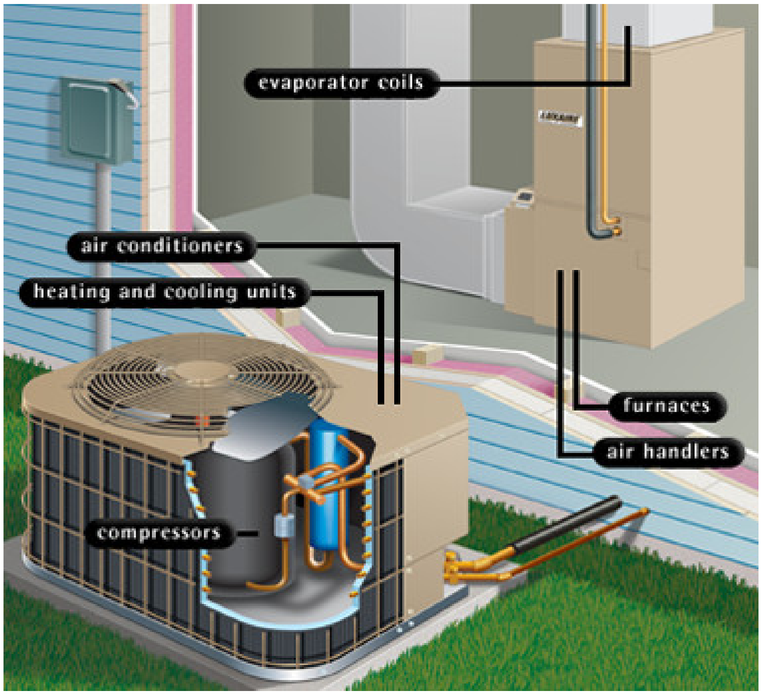


The refrigerant compressor is part of the machine located in the window area. Since this compressor generates noise, along with other components, the window unit makes the room acoustically inferior to other air conditioning systems. Fresh air exchange for the room can be provided by:

- Setting the "ventilator" switch of the window air conditioner to the "open" position;
- Installing a ventilating exhaust fan in the room to extract room air to the outside – caution should be taken not to oversize the fan.
- Natural leaking of air in and out of the room

SPLIT AIR CONDITIONING SYSTEMS

As the name suggests, split systems are individual systems in which the two heat exchangers are separated, one outside, one inside. In other words, the evaporator or cooling portion is located indoors, and the condensing or heat rejection unit is located outdoors. The separate systems are connected by refrigerant pipes.

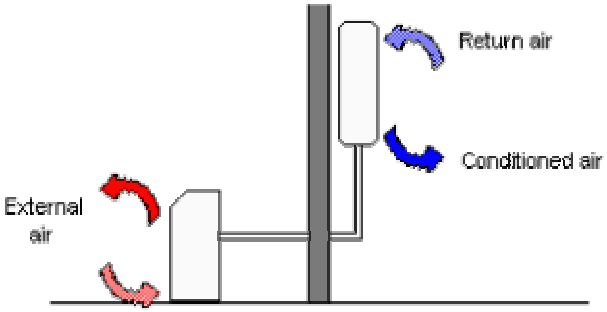


The refrigerant compressor, which usually is installed inside the outdoor unit, pumps the refrigerant through the indoor and outdoor units. Consequently, compressor generating noise remains outside.

The refrigerant picks the heat from the indoor unit evaporator coil, and rejects energy to the outside atmosphere as it goes through the outdoor unit condensing coil. Energy rejected is the sum of the energy taken indoors plus the energy consumed by the compressor in pumping the refrigerant through the refrigerant circuit. This refrigerant circuit is closed, and if the pipe joints are correctly installed, no leakage of refrigerant should occur.

Air circuits

The indoor unit fan pulls or pushes air around the outer surfaces of the coil inside the indoor unit, taking warm air from the room and injecting cooled air into the room in summer. The air passing through the indoor unit is cooled, say to 15 degrees centigrade, before being recirculated to the room.



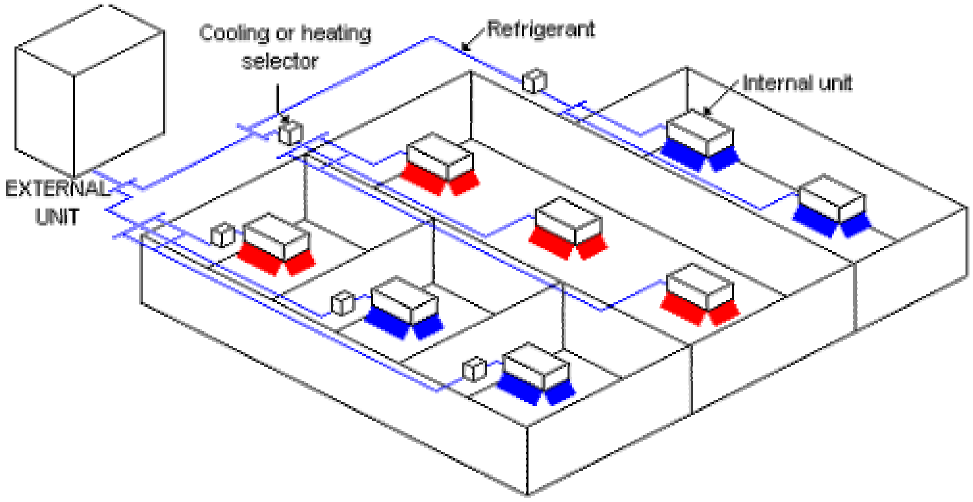
The refrigerant has no direct contact with the air, so the heat of the room air is transferred into the refrigerant in the indoor unit. Inside the coil, refrigerant evaporates, and therefore engineers commonly call the indoor unit an evaporator. The indoor unit can be wall mounted or ceiling mounted.

In an air-cooled outdoor unit, heat exchange occurs in the same way as the indoor unit. However, in addition to having a finned coil and motor-driven fan, the outdoor unit contains a refrigerant compressor. The refrigerant does not have direct contact with the air. Refrigerant going through the outdoor coil loses its energy across the metal surface of the coil to the atmosphere, as outside air is drawn pass the surface of the finned coil by the fan. By passing through this finned coil, the outside air is heated up, by normally about a 5 degree rise in temperature. The outside air passing through the outdoor unit is an open circuit. That is, the air path is not recirculated.

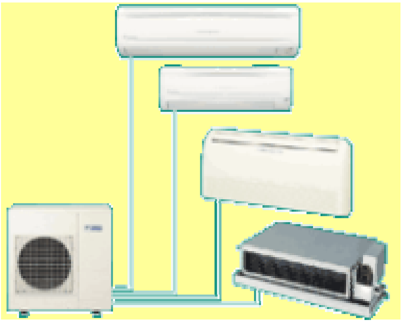
The split unit is a choice in applications that require interior zone cooling. Remember, a window unit requires outside exposure for heat rejection and cannot be used for interior rooms. In a window air conditioner, the indoor unit and outdoor unit of the split system is contained in a single unit.

Single splits and multiple splits

1. **Single split** – one indoor unit is connected to one outdoor unit by insulated copper refrigerant pipes.
2. **Multiple splits**– several indoor units are connected to one outdoor unit by insulated copper refrigerant pipes. This is not a very popular choice because precise capacity control of the compressor is difficult to achieve. Additionally, this type of installation must consider the lengths and diameters of refrigerant tubing to equalize the pressure drops.



Multiple Splits with Single Condensing Unit



PACKAGE AIR CONDITIONING SYSTEMS

A package air-conditioner system is a variant of the large split system. If the refrigerant compressor of the outdoor unit of the split air conditioning system is installed together with the indoor unit, it is called a packaged system. The compressor now is put indoors, making this machine less quite than the split system. However, this allows a larger cooling capacity for the indoor unit.

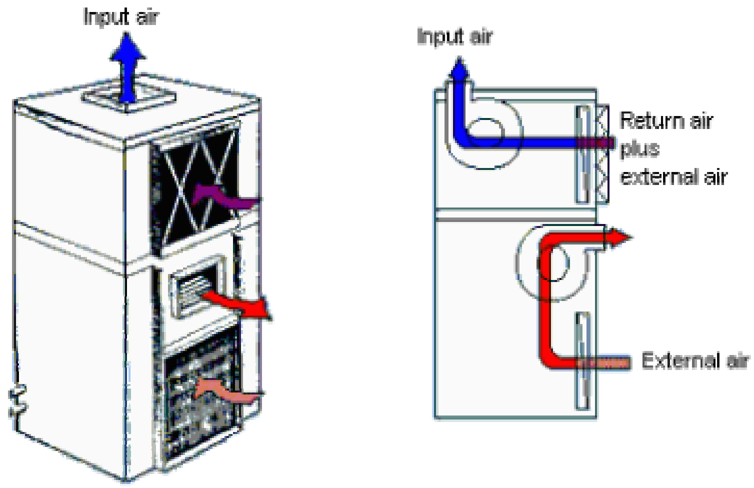
A packaged system is needed if the outdoor unit, now called a condenser, is put on the rooftop, with the indoor unit a few floors below. Taking note on terminology, when we say condensing unit when explaining the split air-conditioning system, it implies both the condenser and the compressor.

Direct expansion air conditioning equipment consists of factory-matched refrigeration cycle components which are field designed to meet the needs of the user.

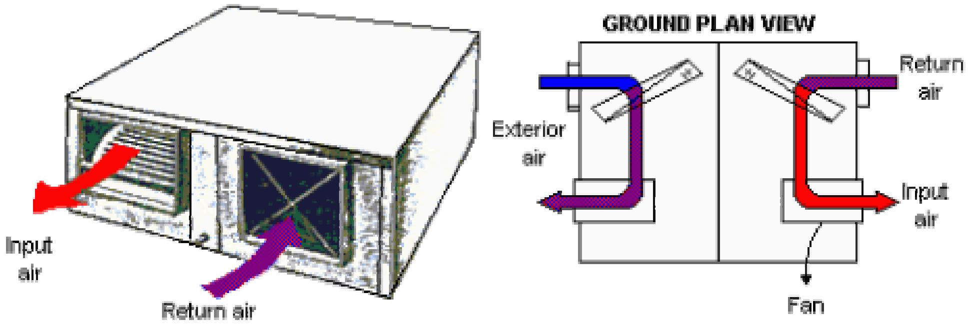
These are available in 3 to 100 ton refrigeration capacities and are available in both air-cooled and water-cooled condenser options. For a larger area, multiple packages are sometimes used. They are characterized by a number of air conditioning units, each with its own refrigeration cycle.

The packaged unit system is efficient, flexible, and versatile, and has low initial and operating costs. These systems cannot however be relied on where close humidity control is essential.

Package units are used in almost all types of building applications, especially in situations where performance requirements are less demanding, and relatively low initial cost and simplified installation are important. Applications include office, residential use, hotels, manufacturing plants, motels, multi-occupancy dwellings, nursing homes, schools, shopping centers, and other buildings with limited life or limited income potential. Packaged units are also used in applications where dedicated, high performance levels are required, such as computer rooms and laboratories.



Vertical self-contained floor mounted units



Horizontal self-contained ceiling mounted package units

ROOFTOP AIR CONDITIONERS

These are commonly air-cooled units.

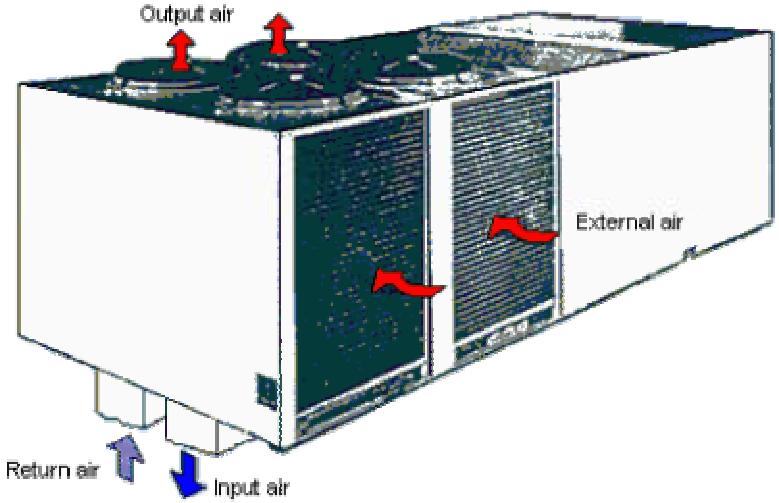
These units are the floor-standing type designed for installation outdoors or on the roof.

A supply air duct and a return air duct are connected to the cooling unit.

Applications:

These systems are commonly applied to low-rise buildings and have the bulk of the equipment on the roof, either as a factory package or in a built-up penthouse. They usually use reciprocating or screw compressors with air-cooled condensers. *Unitary Systems* have all of the components on the roof. *Split Systems* have the compressor and condenser on the roof and the evaporator coil and air handling components in separate packages located inside the building.

These units are popular for general air-conditioning of stores, residences, schools, offices, etc. They are particularly suitable for single, flat buildings, with extensive floor areas.



Unitary systems require large roof penetrations for the ducts. Split systems have only small penetrations for the piping, but do require field refrigeration piping and system evacuation and charging with refrigerant.

A remote controller is installed on an easily accessible wall, incorporating a temperature selection switch and a thermostat.

Rooftop systems can utilize single-zone, multizone, or VAV cycles.

Their advantages include:

1. Ease of installation because the roof is readily accessible;
2. Reduced first cost because of the elimination of an indoor machinery room;
3. No loss of rental space;
4. Factory-packaged guaranteed performance units are available from the manufacturer;
5. Each tenant can own, operate, and maintain a separate unit, or the owner can individually meter and bill each tenant for energy;
6. Each tenant can set its own operating hours without regard to others, unlike a central plant which must operate whenever any tenant requires cooling or heating.

Their disadvantages include:

1. Because of the factory set sensible heat ratio in packages, oversized units may be needed to achieve both the required sensible and latent capacity for an individual zone;
2. Step controls on cooling and heating limit the quality of temperature and humidity control;
3. Difficulty in trouble-shooting and maintenance during inclement weather;
4. Problems meeting building code exhaust requirements under fire conditions;
5. Problems locating air intakes away from condenser air discharges and plumbing vents;
6. Failure to install adequate access walkways to each unit, or of personnel using them, can result in roof damage and cause water leaks into the tenant space.

HEAT PUMPS

Heat pumps are similar to cooling only systems with one exception. A special valve in the refrigeration piping allows the refrigeration cycle to be operated in reverse; consequently, it can heat or cool the space.

A cooling only system cools the indoor air and rejects heat to the outdoors. A heat pump can also cool the indoor air, but when the valve is reversed, the air is heated. A supplementary electric resistance heater may also be used to assist the heat pump at lower outdoor temperatures. In colder climates, heat pumps require a defrost period. During defrost periods the electric heater is the only means of heating the interior of the building. These units can be supplied as split or packaged systems.

Heat pumps for air conditioning service may be classified according to:

- Type of heat source and heat sink;
- Heating and cooling distribution fluid;
- Type of thermodynamic cycle;
- Type of building structure;
- Size and configuration.

Air-to-Air Heat Pumps

The air-to-air heat pump is the most common type of heat pump. It is particularly suitable for factory-built unitary heat pumps, and has been widely used in residential and commercial applications. Air is used as the heat source and heat sink. Extended surface, forced convection heat transfer coils are normally employed to transfer the heat between the air and the refrigerant. When selecting or designing an air-source heat pump, two factors in particular must be taken into consideration:

1. The variation in temperature experienced in a given locality.
2. The formation of frost.

Water-source Heat Pumps

The water-source heat pump uses water and air as the heat source or heat sink depending on the mode of operation. When cooling, water is used as the heat sink, and the heat pump operates as a water-cooled air conditioner. When heating, water is used as the heat source and the equipment operates as a water chiller.

The water-source heat pump is suitable for many types of multi-room buildings, including office buildings, hotels, schools, apartment buildings, manufacturing facilities, and hospitals.

Advantages:

1. Affords opportunity for energy conservation by recovering heat from interior zones and/or waste heat, and by storing excess heat from daytime cooling for night time heating;
2. No wall openings are required;
3. Longer expected life than air-cooled heat pump;
4. Lower noise level because condenser fans are eliminated;
5. Energy for the heat pumps can be metered directly to each tenant;
6. Total life cycle cost frequently compares favorably to central systems when considering relative installed cost, operating costs, and system life.

Disadvantages:

1. Space required for boiler, heat exchanger, pumps and heat rejecter;
2. Higher initial cost than for most other multiple-packaged unit systems;
3. Reduced airflow can cause the heat pump to cycle cutout. Good filter maintenance is imperative.

DELIVEVERY ITEMS

Air outlet selection and application is no less important than any other facet of the HVAC system. If the air outlets are improperly applied or selected, it could have a cascade effect on occupant comfort, air quality, noise, and energy conservation. The proper selection of air outlets cannot be overlooked. The selection of air diffusers and terminal devices has a lot to do with aesthetics, as these become a part of the reflected ceiling plan.

The air distribution equipment selection must combine a proper choice of engineered products efficiently providing conditioned air to the space, while adding architectural features which complement the interior design. The architect’s consent is usually very important.

Diffuser:

A diffuser generally refers to ceiling mounted air delivery devices, which “diffuse” the supply air along the ceiling and induce the room air from below. Diffusers provide good mixing of the supply air with the room air and minimize and integrate well aesthetically. Diffusers are intended for ceiling installation and are available in many shapes, sizes, styles, finishes, and capacities. In many buildings the only portions of an HVAC system seen by occupants on a day-by-day basis are the supply diffusers and return air registers or grilles.

There are however certain other types of ceiling elements such as the jet nozzle and the laminar flow panel which are termed diffusers but actually have the aerodynamic characteristics of grilles. To maintain architectural continuity diffusers can also be used as extraction terminals.

Register:

Registers are similar to diffusers except that they are designed and used for floor or sidewall air supply applications, or as return air inlets.

Grille:

Grilles are simply decorative covers for return air inlets; they are used to block sightlines so that occupants cannot see directly into return air openings. A grille is different from a register in that it usually doesn’t have a volume control damper.

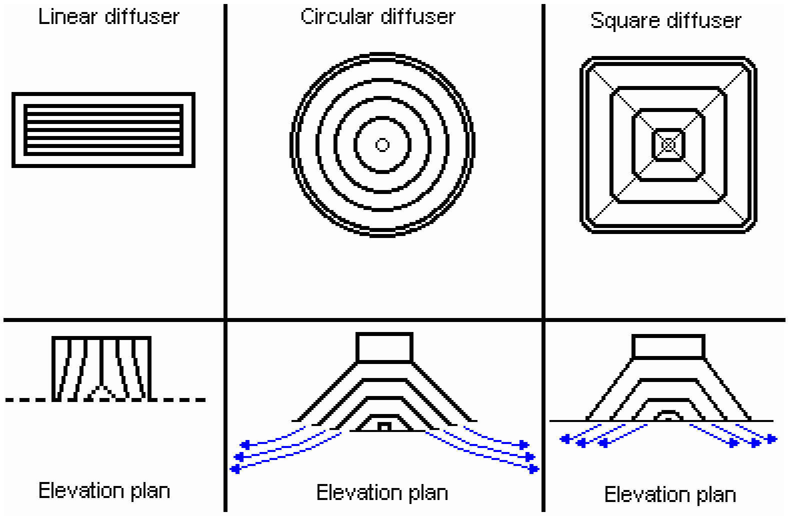
Damper

Air dampers are used in conjunction with grilles and diffusers to provide a means of balancing or regulating the air flowing through the terminal. Various types are available to suit round, square, or rectangular terminal necks.

Plenums and Neck reducers

These are used as a means of conveying air from the system ducting to the grille or diffuser and are essentially sheet steel shrouds attached to the neck of the delivery device.

Many different designs of air diffusers/terminal devices exist; however linear, circular and square diffusers are most common overhead displacement systems.



Course Summary

Proper selection of air-conditioning system is essential to achieve desired performance within economical limits. This includes primary influence from the architect and consideration of both the cost and design aspects during selection of system by the HVAC design engineer.

The HVAC equipment configuration and variants available in the market today provides enough options.

- If thermal distribution is only by means of heated or cooled air, the system is termed an all-air system.
- If thermal distribution is only by means of hot or chilled water, the system is termed an all-water system.
- If thermal distribution is by a combination of heated/cooled air and hot/chilled water, then the system is termed an air-water system.

Further the systems are classified as single zone, multi-zone, reheat, constant volume or variable volume systems.

- In a constant volume system the volume of air is held constant while the temperature is varied to meet the changing load conditions.
- In a VAV system, the volume of constant temperature air modulates to meet the changing load conditions. The popularity of VAV systems has grown rapidly due to their ability to save large amounts of heating, cooling and fan energy when compared to other HVAC systems.

The air-conditioning could be achieved through the central systems or the compact unitary systems, the choice of which is essentially governed by economy of scale and energy usage.

- Central systems are intended to condition multiple spaces in a building that usually have distinctly different equipment elements for each function.
- Compact systems generally serve only one space or zone of a building (local systems) often incorporate all functions in a single piece of equipment. Domestic window, split, package, rooftop, heat pump equipment are the examples.

A good understanding of the various types of commercial HVAC systems is essential for HVAC designer to meet the needs of fast track projects and at the same time ensure that the building gets the environmental system that will best fit its needs.

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