

# Basic Classification of HVAC Systems for Selection Guide

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**ABSTRACT:** In industry and commercial world, Air Conditioning is known as HVAC (Heating Ventilation and Air Conditioning) systems. Air conditioning means processing of air in an indoors environment to maintain Temperature, Humidity, Air Quality (Cleanliness), Air motion and Ventilation. Temperature is controlled either by heating or cooling the air, Humidity is controlled either by removing or adding the moisture to air, Air quality is maintained by filtration which prevents entry of dust and particulate matter and supplies clean air and ventilation is achieved by supply of sufficient fresh outside air. Sometimes Noise levels are also reduced by acoustic liners or sound attenuators. To achieve all above processes, HVAC systems are available in large number of variations. Even though the objective is common i.e. to control the indoor environment, HVAC systems differ a lot according to different applications and ground conditions. So decision making is very critical function to select right type of HVAC system. HVAC design engineer must consider various factors like application, special requirements of the process, space available, Load variations, operating reliability, Energy conservation and total cost etc. while selecting the equipments. HVAC systems are broadly classified as All Air systems, All water systems (Hydronic), Air-Water system, Central systems, Unitary systems, Single zone or Multi zone systems. In this paper such classification is explained in detail with suitable examples. This paper will be a quick ready reference for Students of Air conditioning, Practicing Engineers, consultants etc. to help them understand Variety of HVAC systems to suit different applications.

**KEYWORDS:** HVAC, Air conditioning, Chilled water system, AHU, FCU

## I. INTRODUCTION

Today, in the 21<sup>st</sup> century, the term HVAC (Heating Ventilation and Air Conditioning) is no more alien to common man. With increasing Global warming and degrading outdoor air quality due to pollution, the demand for Air conditioning is escalating everywhere around the world. Therefore, we find HVAC systems at almost all places, be it shopping mall, commercial complex, hotels, hospitals, offices or low/ high rise residential buildings. A decade ago, HVAC systems were looked upon as 'Luxury items'. But now, things are changing so quickly in a civilized society, that, HVAC systems have become an essential part of building services. A typical person in modern society spends around 90% of day time indoors<sup>[1]</sup>. So it is not surprising that providing a healthy, comfortable indoor environment has become a vital factor in current economy. Application wise Air conditioning is either for Human comfort or Process control<sup>[2]</sup>. It is further classified as Residential, Commercial, Industrial Air conditioning. Refer below Table 1.

Table 1. Air conditioning Applications<sup>[3]</sup>

Residential	Commercial	Industrial
High/ Low rise Buildings	Hotels, Restaurants	Textile, Paper, Printing
Individual villas	Shopping malls, Retail stores	Food processing, Cold storages
Dwelling units	Offices, Hospitals, Clinics	Dairy, Milk plant
Hostels, Lodging	Theatres, Auditoriums	Pharmaceuticals
	Schools, colleges	IT Data centers
	Labs, Libraries, Medicals	Control rooms
	Gymnasium, Museums	Precision Mfg.

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There is a wide variety of Air conditioning systems available in market. One should have knowledge of all such systems with their merits and demerits as per the requirements. So, the present paper gives a wide overview and introductory information which will help in HVAC system selection as per the application.

In order to maintain required space conditions in the indoors, energy has to be either supplied or extracted from the conditioned space. The energy in the form of sensible as well as latent heat has to be supplied to the space in winter and extracted from the conditioned space in case of summer. HVAC system consists of an air conditioning plant and a thermal distribution system as shown in Figure 1.

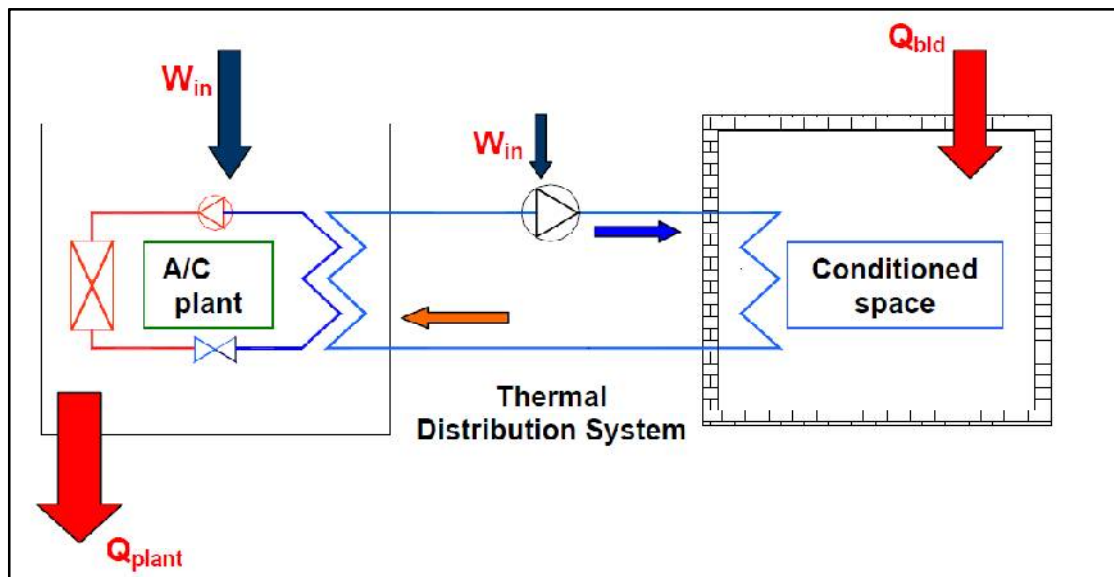


Figure 1. Schematic diagram of summer A/C system<sup>[5]</sup>

As shown in the figure, the air conditioning (A/C) plant acts either as a heat source (for winter) or as a heat sink (for summer). Air, water (hydronic) or refrigerant are used as media for transferring energy from the air conditioning plant to the conditioned space. A thermal distribution system is required to circulate the media between the conditioned space and the A/C plant. Adequate Fresh air has also to be supplied by A/C plant to the spaces to maintain Indoor Air Quality (IAQ)<sup>[2]</sup>.

## II. CLASSIFICATION OF HVAC SYSTEMS

Based on the working fluid used in the thermal distribution system, HVAC systems can be classified as<sup>[3]</sup>:

- A) All Air system
- B) All water system
- C) Air-Water system
- D) Unitary Refrigerant based system

### A) All Air Systems

As the name suggests, Air is used as the media in an all air system. Air transports thermal energy from the conditioned space to the HVAC plant. As shown in Figure 2, In these systems air is processed in the A/C plant namely AHU (Air Handling Unit). AHU consists of Dampers, Mixing chambers, Filters, Cooling/ Heating coils, Humidifiers, Fans/ Blowers etc. in a packaged cabinet. This processed air is then supplied to the conditioned spaces through Air Distribution system. Air Distribution system consists of Ducts, Dampers and Diffusers. This air extracts (or supplies in

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case of winter) the required amount of sensible and latent heat from the conditioned space. The duct that supplies the air to spaces is called Supply Air Duct (SAD). The return air from the conditioned space is conveyed back to the plant, where it again undergoes the required processing thus completing the cycle. The duct that returns the air from spaces to A/C plant is called Return Air Duct (RAD). Adequate Fresh air is always supplied by AHU to maintain Ventilation and Indoor Air Quality (IAQ).ASHRAE 62.1 standards are followed for ventilation, mostly<sup>[4]</sup>.Outside Fresh air and Return air are balanced in proportion by rule ‘Supply Air = Return Air + Fresh Air’.Since Fully treated air is supplied by AHU,No further processing of air is required by terminal units in the conditioned space. All air systems can be further classified into<sup>[3]</sup>:

1. Single duct, constant volume, single zone system
2. Single duct, constant volume, multi zone system
3. Single duct, Variable volume (VAV) system
4. Dual duct, constant volume system
5. Dual duct, variable volume (VAV) system

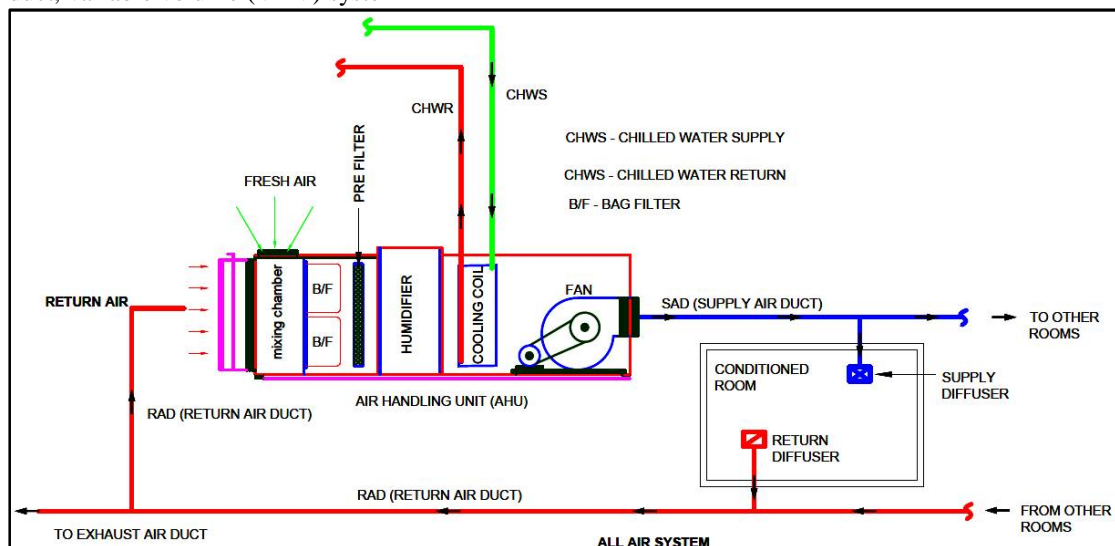


Figure 2.Schematic of All Air HVAC system

The single duct systems can provide either cooling or heating using the same duct, but not both heating and cooling simultaneously. While, dual duct systems can provide both cooling and heating simultaneously.

## 2.1 Single duct, constant volume, single zone system

In a single duct system, there is only one supply duct, through which either hot air or cold air flows, but not both simultaneously. In a constant volume system, 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 Relative humidity (% RH) measured at a single point, as shown in Figure 3.

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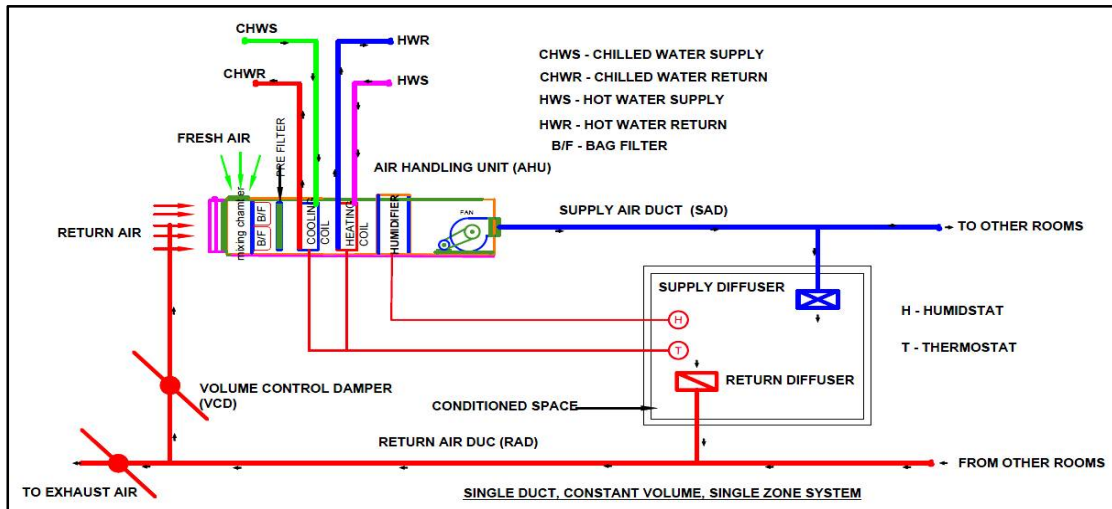


Figure 3. Schematic of Single duct, constant volume, single zone system

Here a zone refers to a space conditions controlled by one thermostat. However, the single zone may consist of a single room or one floor or whole building with several rooms. The cooling/ heating capacity in the single zone, constant volume systems is varied by varying the supply air temperature and humidity, while keeping the supply airflow rate constant. Volume control dampers (VCD) are used to balance the Return air and Fresh air flows.

Since single zone system is controlled by zone thermostat and humidistat, the location of these sensors in the zone is very crucial for performance of system.

Control is achieved by either coil control or face-and-bypass control. In coil control, flow rate of chilled water and hot water through cooling coil and heating coil is varied to vary supply air temperature and humidity. In face-and-bypass control, some of the supply air is by passed off the cooling/ heating coil to control supply conditions.

## 2.2 Single duct, constant volume, Multi zone system

For very large buildings having variety of spaces and zones differing in requirements of cooling or heating, it is not feasible to provide several individual single zone systems for every zone or space. Multi zone system is selected for such application. In Figure 4, Multi zone system with Reheat terminal units is shown. Constant volume of supply air is supplied to every zone. Reheat coil is controlled by room thermostat as per the zone requirements.

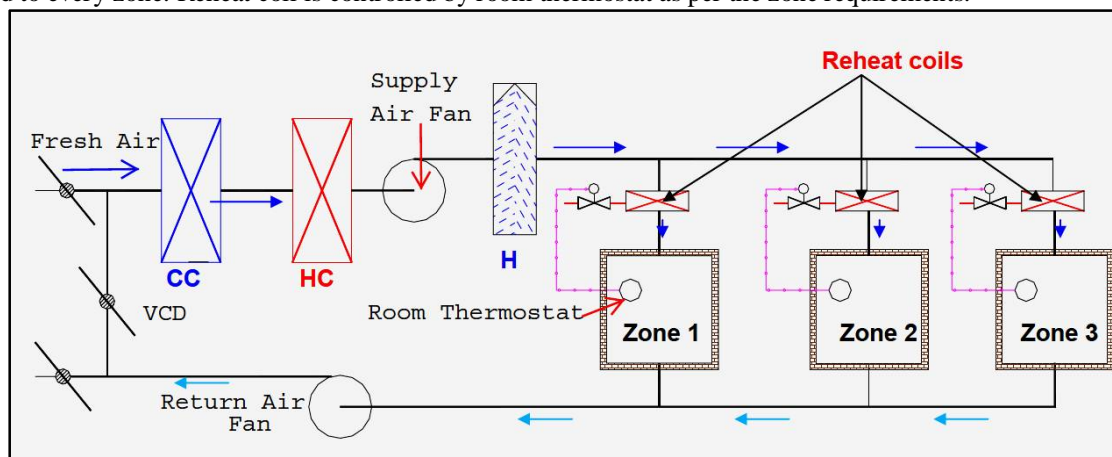


Figure 4. Schematic of single duct, constant volume, multi zone system

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### 2.3 Single duct, variable volume (VAV) system

In this system, Supply air Temperature is kept constant and volume flow rate of supply air is varied as the cooling or heating load varies in the space or zone. Each zone is provided with VAV box consisting of zone damper and thermostat. Thermostat gives signal to zone damper of VAV box, which governs the supply air flow to the zone.

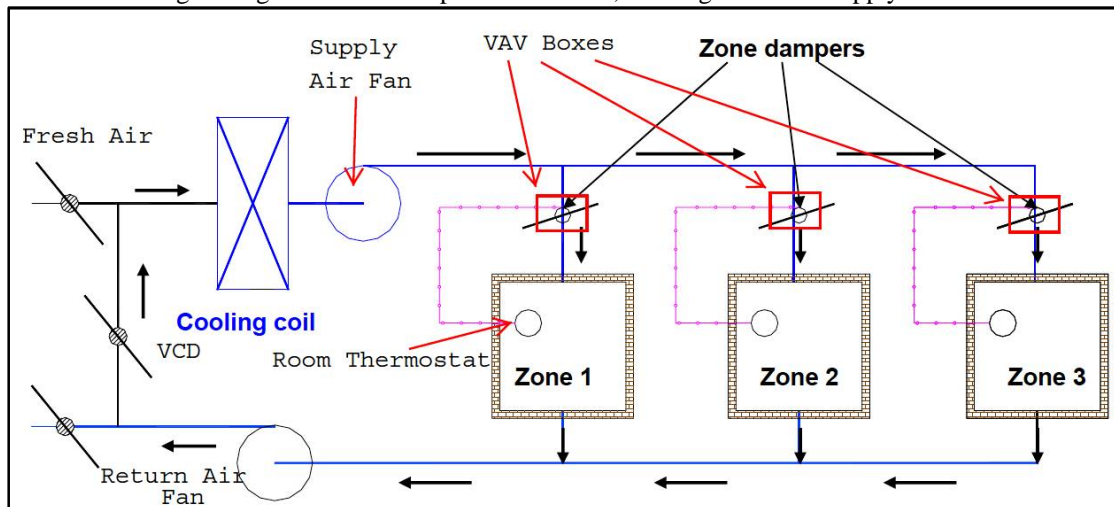


Figure 5. Schematic of single duct, variable volume (VAV) system

#### Advantages of VAV systems:

1. Since supply air flow is varied as per the load, low energy is consumed due to low fan power as compared to full capacity running of fan in constant volume system
2. Since air temperature is maintained constant, energy is saved in cooling system as air is not required to cool to very low temperature and reheat again.

#### Drawbacks of VAV systems:

1. At low load conditions, VAV supplies less fresh air, causing problems of Indoor air quality, ventilation and room air distribution.
2. Precise Humidity control is quite difficult in VAV systems.

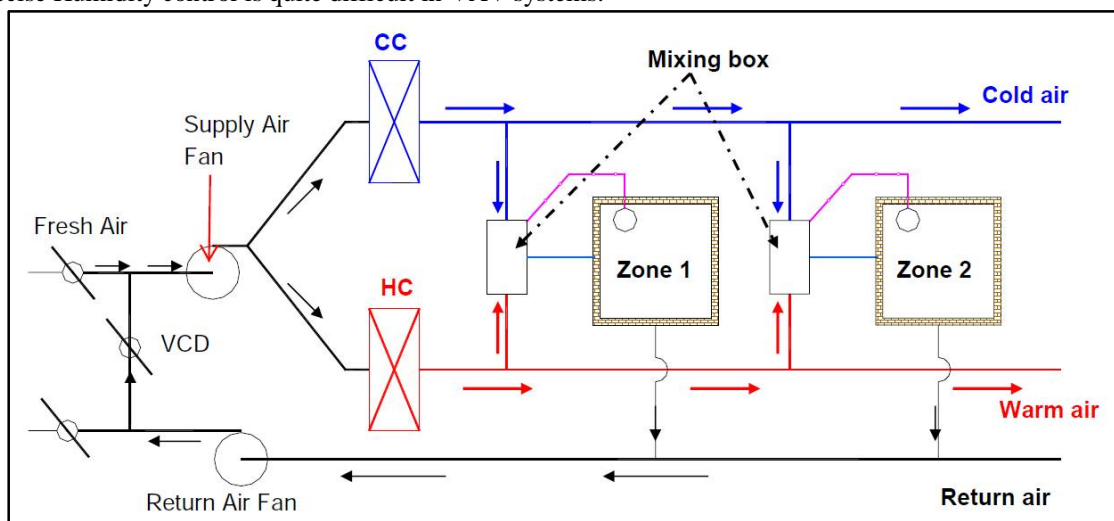


Figure 6. Schematic of Dual duct, constant volume system

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## ✓ Advantages of All Air systems:

1. Effective Room air distribution and Ventilation is possible under widely varying load conditions
2. All air systems present great opportunities for Energy conservation such as heat recovery wheels.
3. Precise control is possible by use of high class controls. Close range of Temperature ( $\pm 0.15^{\circ}\text{C}$ ) and Humidity ( $\pm 0.5\%$ ) can be achieved<sup>[2]</sup>.
4. Simultaneous cooling and heating can be provided by dual duct system. Also, switching between summer and winter mode is quite easy in All air systems.
5. AHU which is a complete package can be remotely located, well away from conditioned spaces. It helps to reduce noise levels in occupied spaces.
6. Stairwell Pressurization, kitchen ventilation etc. can be easily achieved.

## X Disadvantages of All Air systems:

1. Since systems are quite large in size, require separate spaces like AHU Room. It reduces use of effective floor space. Particularly in high rise buildings, it is difficult to provide long runs of ducts, as AHUs are located either on roof or basement.
2. Difficult to install in existing buildings, as large space is required in false ceiling to lay the ducts<sup>[2]</sup>.
3. Testing, Adjusting, Balancing (TAB) may be very difficult task in case of VAV systems

## ➤ Applications of All Air systems:

1. Precision HVAC applications such as IT Data centers, Research Labs, Process industries, Clean rooms, Operation Theatres, Hospitals etc. where accurate and precise control of space environment is required<sup>[3,5]</sup>.
2. Theatres, Auditorium, Functional halls, Retail stores etc. where loads are uniform with small external loads.
3. Large corporate buildings with varied requirements of heating and cooling which can be served by Dual duct systems with simultaneous cooling and heating.
4. Multi zone All air systems are suitable for Offices, classrooms, hotels, ships etc. where individual control is required.

## B) All Water systems

In this system, water is used as working fluid that transports thermal energy between conditioned space and A/C plant. Chilled water is circulated for cooling while Hot water is circulated through coils for space heating. As only water is supplied by HVAC plant to the space, Fresh air has to be supplied by another unit to maintain Indoor air quality and ventilation. These systems are also known as Chilled water systems for cooling applications. Based on number of pipes used in system, they are classified as 2-pipe system and 4-pipe system.

A **2-pipe system** can provide either cooling or heating only, but not both at a time. As shown in Figure 7, chiller supplies cold water or heater supplies hot water to different spaces. Out of 2 pipes, one is for supply and the other is for return of water to central plant. Chilled water/ hot water circulates through Fan coil units (FCU), or convectors or Radiators located in the each space. Thermal energy is exchanged between water and air in the conditioned space. Flow control valve controls the water flow rate as per load variation. Flow control valve is driven by zone thermostat which gives signal to adjust flow rate as per load. Since The same inside air is circulated repeatedly by terminal units, Fresh air ventilation must be supplied by external units.

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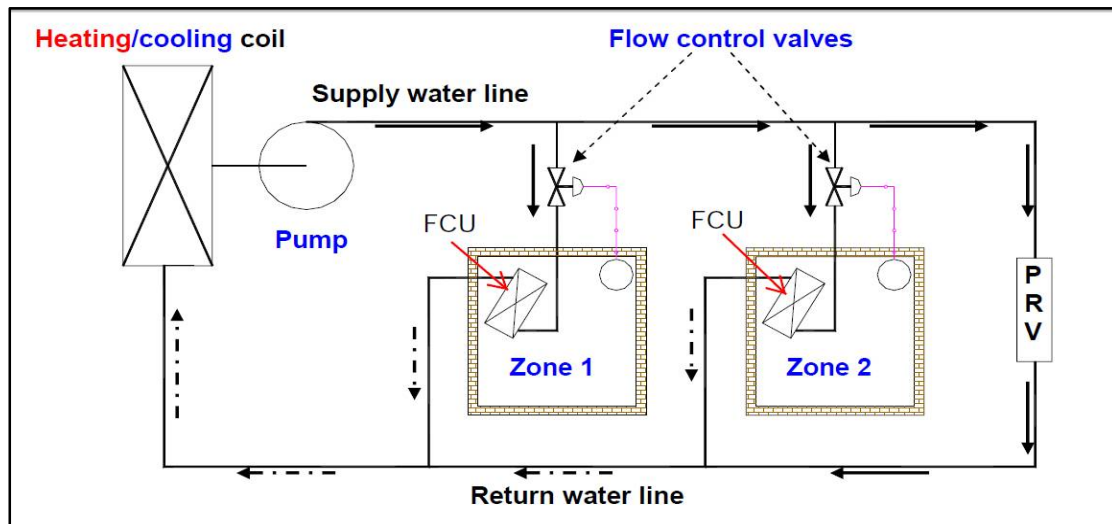


Figure 7. Schematic of All water system<sup>[5]</sup>

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 certain proportion as per the zone load, and the mixed water is supplied to the terminal units in 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.

Terminal units used in all water system are of basically three types namely Fan coil units (FCU), Convector and Radiator<sup>[1]</sup>.

**FCU** is a small package comprising a fan/ blower, cooling/ heating coil, air filters, louvers, condensate drain pipe etc. Typical FCU is shown in Figure 8. Chilled water is circulated through finned tube coils. Fan/ blower draws in the warm air from conditioned space.

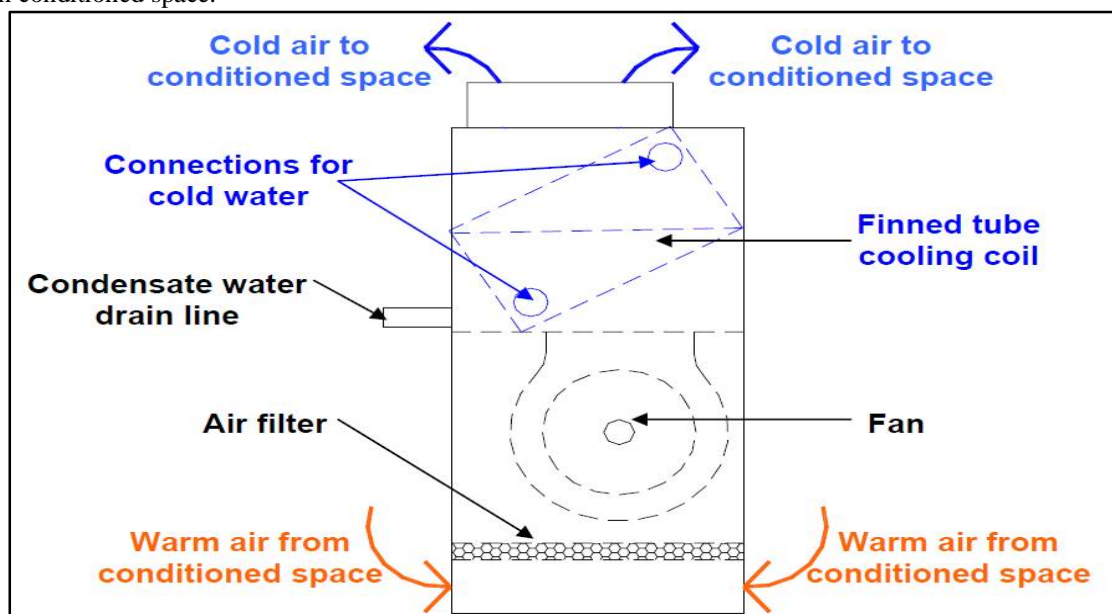


Figure 8. Components of FCU

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Warm air passes over cooling coils, where it is cooled and dehumidified to supply conditions. Condensate is collected in drain pan after dehumidification and then discharged through condensate drain pipe. Sometimes ductable FCU is used for relatively large spaces. A short duct runs to 3-4 spaces from FCU which supplies air to supply diffusers. Return diffusers are also provided. This duct system ensures proper air distribution. FCUs are available upto 5-10 TR capacity (Ton of Refrigeration). FCU can supply upto 2000 CFM air. Generally for FCU, by a thumb rule, 1 TR  $\equiv$  400 CFM<sup>[5]</sup>. Mostly FCUs are ceiling mounted in the false ceiling. Capacity is controlled by varying chilled water flow rate. Room thermostat senses and signals the variation in space temperature to control valves to regulate chilled water flow.

**Convectors** are mainly used for heating applications. Hot water is circulated through heating coil. Space air heating takes place by natural convection.

**Radiators** are also used for space heating applications. Heat transfer occurs majorly by radiation. Recently radiators are also being used for cooling applications by **Radiant cooling** or **chilled beam technology**<sup>[4]</sup>.

## ✓ **Advantages of All Water systems:**

1. All water system needs very less space as compared to all air systems for same capacity. Because, water is used as transport media, which has higher specific heat capacity and density than air. Hence, pipe sizes are very small as compared to large sized ducts. Therefore, system consumes very less space due to absence of big duct works and fans<sup>[1]</sup>.
2. Less expensive Central A/C plant solution is offered by all water system<sup>[1]</sup>.
3. It is more suitable for Individual room/ zone control.
4. Simultaneous cooling and heating is possible with 4-pipe system<sup>[2]</sup>
5. It can be easily installed in the old buildings without making much changes in the existing space setting.

## X **Disadvantages of All water systems:**

1. Multiplicity of fan coil units means a great deal of maintenance work and cost<sup>[1]</sup>.
2. Control of space humidity is limited, as only cooling and dehumidification occurs and FCUs do not have humidifiers or reheat coils<sup>[5]</sup>.
3. Separate ventilation system must be used to supply fresh air, which adds to cost. Also control of ventilation air is not precise.
4. Condensate may cause problems of dampness in ceiling or walls if condensate drain fails.

## ➤ **Applications of All water systems:**

1. All water systems are suitable for use as low cost central HVAC systems in multi zone High Rise commercial applications<sup>[1]</sup>.
2. All water system is best solution to replace All air system in High Rise Tall buildings, as it is much easier to carry water through small sized pipes than air through very big sized ducts across farther heights<sup>[5]</sup>.
3. It is very effective system in certain applications where space extremely limited, such as narrow ceiling and shafts.i.e. Buildings which were originally not designed for HVAC systems.
4. In case of Individual room control as required in hotels, multi storey apartments, offices etc. all water systems are more famous.

## C) **Air-Water systems**

Air water system employs best features of all air and all water systems. Combination air-water system distributes both chilledwater and /or hot water and conditioned air from a central system to the individual spaces. Terminal units in each zone provide cooling or heating to that zone. One type of air water system uses FCU as terminal units to provide major part of air conditioning and central AHUs are used to supply only ventilation air directly into the space<sup>[1]</sup>. Another type uses 'Induction units' as terminal units. It receives supply air from central AHU, called as *primary air* and chilled / hot water from central chiller<sup>[1]</sup>. Primary air is delivered at high pressure in Plenum chamber and discharged into space through high velocity nozzles. This induces room air into induction unit, where it mixes with primary air. Room air is called as secondary air. Supply air is mixture of primary and secondary air. Therefore no fan is required in induction unit. Figure 9 shows schematic of basic induction unit.



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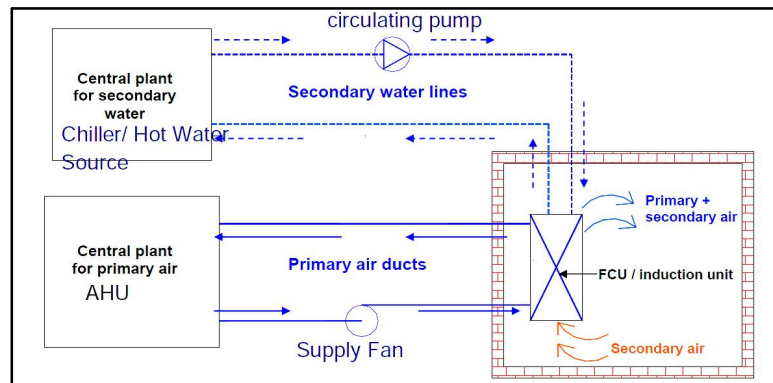


Figure 9. Schematics of Basic induction unit<sup>[3]</sup>

Normally terminal unit like FCU keeps on cooling the room air again and again with the help of cooling coil circulating chilled water. Therefore sensible cooling load is handled by water system. Ventilation air is supplied by central AHU of air system. AHU supplies cooled and dehumidified fresh air which can take care of room latent loads. Because of this, there is no condensation problem with cooling coils. Similarly, in winter system heated and humidified fresh air is supplied by AHU and hot water circulates through heating coil of terminal unit.

### ✓ Advantages of Air-Water systems

1. Simultaneous heating and cooling is possible in air-water system.
2. Lot of space is saved, as only ventilation air is supplied through ducts and chilled/ hot water is passed through pipes<sup>[2]</sup>.
3. Economic control of individual zones is possible using room thermostats which can either regulate secondary air or secondary water in FCUs.
4. Since there is no latent load on cooling coil, troubles due to condensation do not occur. It prevents marshy or damp regions in the conditioned space.
5. Servicing, Repair, Replacement, Maintenance works etc. are relatively easier than all water systems.
6. Positive pressures can be maintained in conditioned spaces under all varying loads<sup>[3]</sup>.

### X Disadvantages of Air- Water systems

1. There are a lot of complications in system operation and controls as both air and water have to be handled carefully.
2. Mostly air- water systems find limited applications in perimeter zones<sup>[2]</sup>.
3. Constant supply of fresh air has to be supplied to all zones, no matter whether spaces are occupied are not. Because control is only for cooling/ heating coil through room thermostat<sup>[5]</sup>.
4. In case of unusual high latent loads, excessive condensation may cause damp environment and discomfort in the zone.
5. As systems are complicated with greater extent of controls, normally air-water systems are costlier than all water systems.

### ➤ Applications of Air water systems:

1. It is much suitable for retrofitting of existing buildings, where there is space restriction.
2. It is very good solution for perimeter zone buildings with large sensible loads<sup>[2]</sup>.
3. It can be used where close control of humidity in the space is not necessary
4. It serves well for large office buildings, hotels, lodges etc.

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## III. CONCLUSION

In this paper very basic and broad classification of HVAC systems is discussed. This gives us some primary idea of what types of systems are available as of now and how they are arranged. So broadly there are four large groups under which all categories of HVAC systems fall. All Air system, All Water system, Air-Water system are Central A/Cs while DX (Direct Expansion) system is Unitary Non central A/C. All these HVAC systems with their subtypes are explained along with their Merits and Drawbacks. Typical applications for variety of spaces are also described. This will help in selecting the right type of HVAC systems to suit particular application. To name a few, All air systems are used in IT data center, hospitals, cleanrooms etc. where precise control of space humidity is required. All water systems are used for existing buildings with limited space. Air-Water combination is suitable for buildings with large exposures. Unitary systems are best for low cost and very low load intermittent applications. Such examples help to understand system selection criteria and make the decision making easier for planning engineer, client or engineering students. So this article is a Quick Reference/ Guide for HVAC system selection.

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