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Research Paper

DESIGN OF HVAC FOR A CORPORATE BUILDING USING AHU

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To study and evaluate the technical design requirements of an HVAC, Central Air Conditioning System for a Corporate Office building to achieve indoor Human Comfort conditions, utilizing Heat Recovery Units as per ASHRAE Standards. HVAC (Heating, Ventilation, and Air Conditioning) is the technology of indoor and automotive environmental comfort. HVAC system design is based on the principles of thermodynamics, fluid mechanics, and heat transfer, is an important in the design of medium to large industrial and office buildings such as skyscrapers and in marine environments for safe and healthy building conditions are regulated with respect to temperature and humidity, using fresh air from outdoors. An HVAC system is the major mechanical part of any building construction, validates to about 80% of project cost in an MEP corridor. Air-conditioning is a process that simultaneously conditions air; distributes it combined with the outdoor air to the conditioned space; and at the same time controls and maintains the required space's temperature, humidity, air movement, air cleanliness, sound level, and pressure differential within predetermined limits for the health and comfort of the occupants, for product processing, or both. Heat recovery units are used in Air Conditioning/Air-handling units in order to save energy. The principle of operation is to heat the supply air with the exhaust air heat in cold season and to cool the supply air with the energy of the exhaust air in a warm season. The primary purpose of this project is to design an HVAC System for a Corporate Office building is to achieve Human Comfort conditions for all the occupants, also to implement and effective Heat Recovery System to achieve economical design as per ASHRAE Standards. It considers the various conditions pertaining to the location & orientation of the building, carrying a heat estimate further to evaluate the design values for each of its sub-systems. The equipment/machinery is selected based on the type of routing and the designed Tonnage of the project, installed as per requirement of the project. The HVAC System is primarily designed on basis of international industry standards like ASHRAE, SMACNA which are being followed at corporate level in construction industry both in India and abroad.

Keywords: HVAC system, AHU, Human comfort conditions

INTRODUCTION

Heating, Ventilation and Air Conditioning (HVAC) systems control the temperature, humidity and quality of air in buildings to a set of chosen

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conditions. To achieve this, the systems need to transfer heat and moisture into and out of the air as well as control the level of air pollutants, either by directly removing them or by diluting them to acceptable levels. Heating systems increase the temperature in a space to compensate for heat losses between the internal space and outside. Ventilation systems supply air to the space and extract polluted air from it. Cooling is needed to bring the temperature down in spaces where heat gains have arisen from people, equipment or the sun and are causing discomfort. Heating, ventilation and air conditioning systems vary widely in terms of size and the functions they perform. Some systems are large and central to the building services – these were probably designed when the building was originally commissioned and use ventilation to deliver heating and cooling. Other systems may provide heating through boilers and radiators, with some limited ventilation to provide fresh air or cooling to certain parts of the building such as meeting rooms.

HEATING VENTILATION AND AIR CONDITIONING SYSTEM

HVAC Systems

Heating: Heating is increase in temperature of a substance. A heater is an object that emits heat or causes another body to achieve a higher temperature. Heaters exist for all states of matter, including solids, liquids and gases and there are 3 types of heat transfer: Convection, Conduction and Radiation. The opposite of a heater (for warmth) is an air cooler (for cold) used to keep the user cooler than the temperature originally surrounding them. There are many different types of heating systems. Central heating is often used in cool climates to heat houses and public buildings. Such a system contains a boiler, furnace, or heat pump to warm water, steam, or air in a central location such as a furnace room in a home or a mechanical room in a large building. The use of water as the heat transfer medium is known as hydronics. These systems also contain either duct work for forced air systems or piping to distribute a heated fluid to radiators to transfer this heat to the air. The term radiator in this context is misleading since most heat transfer from the heat exchanger is by convection, not radiation. The radiators may be mounted on walls or installed within the floor to give floor heat.

Figure 1: HVAC System

One type of heat source is electricity, typically heating ribbons made of high resistance wire. This principle is also used for baseboard heaters, and portable heaters. Electrical heaters are often used as backup or supplemental heat for heat pump (or reverse heating) systems. Heat pumps can extract heat from the exterior air (air source) or from the ground (ground source). Initially, heat pump HVAC systems were used in moderate climates, but with improvements in low temperature operation and reduced loads due to more efficient homes, they are increasing in popularity in other climates. Heat pumps can be air to air, air to water, water to air and water to water systems. Water on the supply side of the heat pump is typically geothermal energy from ground water, either surface water or PEX tubing buried in a trench. Due to the construction of wells and site work, geothermal systems are typically more expensive to purchase and install than conventional heating systems.

Ventilation: An air handling unit is used for the heating and cooling of air in a central location. Ventilation is the process of changing or replacing air in any space to control temperature or remove any combination of moisture, odors, smoke, heat, dust, airborne bacteria, or carbon dioxide, and to replenish oxygen. Ventilation includes both the exchange of air with the outside as well as circulation of air within the building. It is one of the most important factors for maintaining acceptable indoor air quality in buildings. Methods for ventilating a building may be divided into mechanical/forced and natural types.

Mechanical or forced ventilation: "Mechanical" or "forced" ventilation is provided by an air handler and used to control indoor air quality. Excess humidity, odors, and contaminants can often be controlled via dilution or replacement with outside air. However, in humid climates much energy is required to remove excess moisture from ventilation air.

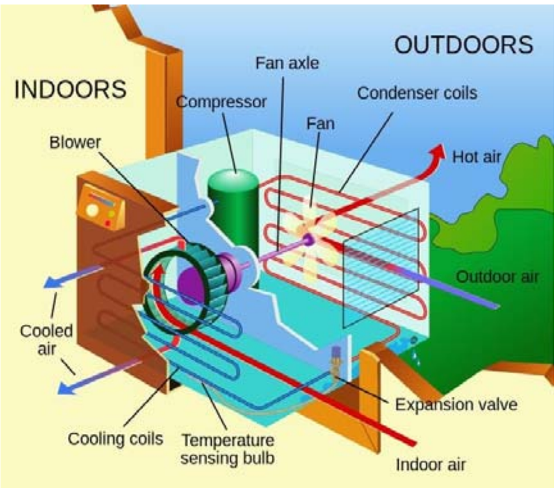
Kitchens and bathrooms typically have mechanical exhausts to control odors and sometimes humidity. Factors in the design of such systems include the flow rate (which is a function of the fan speed and exhaust vent size) and noise level. Direct drive fans are available for many applications, and can reduce maintenance needs. Ceiling fans and table/floor fans circulate air within a room for the purpose of reducing the perceived temperature by increasing evaporation of perspiration on the skin of the occupants. Because hot air rises, ceiling fans may be used to keep a room warmer in the winter by circulating the warm stratified air from the ceiling to the floor.

Figure 2: Forced Ventilation

Natural ventilation: Natural ventilation is the ventilation of a building with outside air without the use of fans or other mechanical systems. It can be achieved with operable windows or trickle vents when the spaces to ventilate are small and the architecture permits. In more complex systems, warm air in the building can be allowed to rise and flow out upper openings to the outside (stack effect) thus causing cool outside air to be drawn into the building naturally through openings in the lower areas. These systems use very little energy but care must be taken to ensure comfort. In warm or humid months in many climates maintaining thermal comfort solely via natural ventilation may not be possible so conventional air conditioning systems are used as backups. Air-side economizers perform the same function as natural ventilation, but use mechanical systems in the forms of fans, ducts, dampers, and control systems to introduce and distribute cool outdoor air when appropriate.

Air conditioning: Air conditioning and refrigeration are provided through the removal of heat. Heat can be removed through radiation, convection, and by heat pump systems through

Figure 3: Air Conditioning



the refrigeration cycle. Refrigeration conduction media such as water, air, ice, and chemicals are referred to as refrigerants. An air conditioning system, or a standalone air conditioner, provides cooling, ventilation, and humidity control for all or part of a building. The refrigeration cycle uses four essential elements to cool. The system refrigerant starts its cycle in a gaseous state. The compressor pumps the refrigerant gas up to a high pressure and temperature. From there it enters a heat exchanger (sometimes called a “condensing coil” or condenser) where it loses energy (heat) to the outside, cools, and condenses into its liquid phase. The liquid refrigerant is returned to another heat exchanger where it is allowed to evaporate; hence the heat exchanger is often called an “evaporating coil” or evaporator. A metering device regulates the refrigerant liquid to flow at the proper rate. As the liquid efrigerant evaporates it absorbs energy (heat) from the inside air, returns to the compressor, and repeats the cycle. In the process, heat is absorbed from indoors and transferred outdoors, resulting in cooling of the building.

PURPOSE, DESIGN BASICS, AND FUNCTION OF HVAC SYSTEMS

Purpose: An HVAC system provides adequate indoor air quality by: conditioning the air in the occupied space of a building in order to provide for the comfort of its occupants; diluting and removing contaminants from indoor air through ventilation; and providing proper building pressurization.

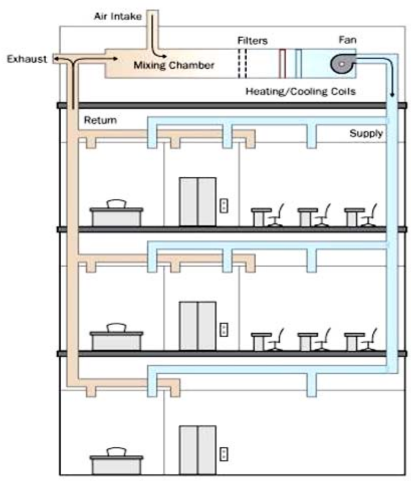
Design: While there are many different HVAC system designs and operational approaches to achieving proper system functionality, and every building is unique in its design and operation, HVAC systems generally share a few basic design elements.

- Outside air intake
- Air handling unit—a system of fans, heating and cooling coils, air-flow control dampers, air filters, etc.
- Air distribution system
- Air exhaust system.

FUNCTION

In general, outside (“supply”) air is drawn into a building’s HVAC system through the air intake by the Air Handling Unit (AHU). Once in the system, supply air is filtered to remove particulate matter (mold, allergens, dust), heated or cooled, and then circulated throughout the building via the air distribution system, which is typically a system of supply ducts and registers. In many buildings, the air distribution system also includes a return air system so that conditioned supply air is returned to the AHU (“return air”) where it is mixed with supply air, re-filtered, re-conditioned, and re-circulated throughout the building. This is usually

Figure 4: Central HVAC Systems



accomplished by drawing air from the occupied space and returning it to the AHU by: (1) ducted returns, wherein air is collected from each room or zone using return air devices in the ceiling or walls that are directly connected by ductwork to the air-handling unit; or (2) plenum returns, wherein air is collected from several rooms or zones through return air devices that empty into the negatively pressurized ceiling plenum (the space between the drop ceiling and the real ceiling); the air is then returned to the air-handling unit by ductwork or structural conduits. Finally, some portion of the air within is exhausted from the building. The air exhaust system might be directly connected to the AHU and/or may stand-alone.

PSYCHOMETRY

Psychrometrics or psychrometry are terms used to describe the field of engineering concerned with the determination of physical and thermodynamic properties of gas-vapor mixtures. Although the principles of psychrometry apply to any physical system consisting of gas-vapor mixtures, the most common system of interest is the mixture of water vapor and air, because of its application in heating, ventilating, and air-conditioning and meteorology. In human terms, our comfort is in large part a consequence of not just the temperature of the surrounding air, but (because we cool ourselves via perspiration) the extent to which that air is saturated with water vapor.

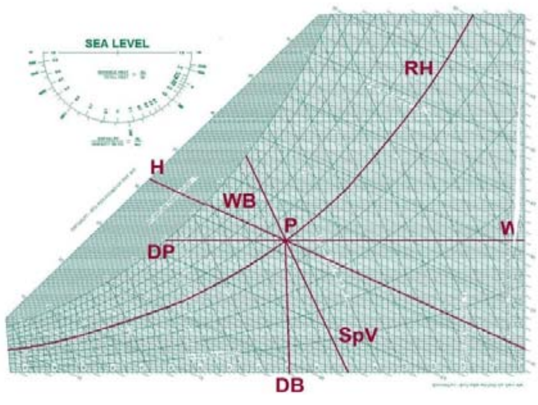
ABSOLUTE HUMIDITY

The mass of water vapor per unit volume of air containing the water vapor. This quantity is also known as the water vapor density.

Mixtures of air and water vapor are the most common systems encountered in psychrometry. The psychrometric ratio of air-water vapor mixtures is approximately unity, which implies that the difference between the adiabatic saturation temperature and wet bulb temperature of air-water vapor mixtures is small. This property of air-water vapor systems simplifies drying and cooling calculations often performed using psychrometic relationships.

A psychrometric chart is a graph of the thermodynamic parameters of moist air at a constant pressure, often equated to an elevation

Figure 5: Psychometric Chart



relative to sea level. The psychometric chart allows all the parameters of some moist air to be determined from any three independent parameters, one of which must be the pressure. Changes in state, such as when two air streams mix, can be modeled easily and somewhat graphically using the correct psychrometric chart for the location's air pressure or elevation relative to sea level. For locations at not more than 2000 ft (600 m) of altitude it is common practice to use the sea-level psychrometric chart.

DESIGN CONDITIONS OF THE PROJECT

Outside Design Conditions

Outside design condition is a combination of the temperature and the relative humidity of the external environment with respect to building structure.

Outside Conditions

Temperature = 106°F (41°C) Tc = (5/9)*(Tf-32)

Tc = Temperature in degrees Celsius

Tf = Temperature in degrees Fahrenheit

Relative Humidity = 28%

Inside Design Conditions

Inside design condition is a combination of the temperature and the relative humidity within the subjected building structure or the favorable conditions required within the building structure as per standards/clients.

Inside Conditions

Temperature = 76°F (23°C) Relative Humidity = 50%

Calculation of Total Heat Load

The Heat Load Calculation sheets for the project building as per each room/space are as given below. The values required herein for further calculations are the Tonnage and Litre/second flow of air of each room/space. Please refer to Heat Load Sheets at the end of the report.

Air Conditioning Equipment

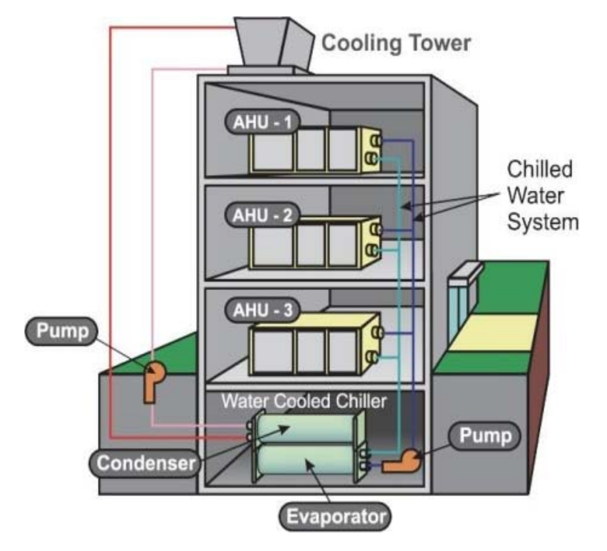
A detailed discussion of air conditioning equipment is provided below.

Cooling Systems

Central Air Conditioning Systems

Central Air Conditioning systems are for applications where several spaces with uniform loads will be served by a single apparatus and where precision control of the environment is required. Cooling coils can be direct expansion or chilled water. Select air cooled or evaporative condensers, cooling towers, and ground-loop systems based on life cycle economics considering operating efficiencies and maintenance costs associated with outdoor design conditions and environment, e.g., high ambient temperatures and dusty conditions could adversely impact the operation of air cooled

Figure 6: Central Air Conditioning Systems



condensers. Consider temperature rise of chilled water supply when selecting chilled water coils, especially for applications requiring precision humidity control.

UNITARY AIR CONDITIONING SYSTEMS

These systems should generally be limited to loads less than 100 tons. Unitary systems are packaged in self-contained or split configurations. Self-contained units incorporate components for cooling or cooling and heating in one apparatus. Thermostatic expansion valves are preferred over capillary tubes and orifices for refrigerant control when available as a manufacturer's option since expansion valves provide better superheat control over a wide range of operating conditions. Split systems may include the following configurations:

a) Direct expansion coil and supply fan combined with a remote compressor and condensing coil; or

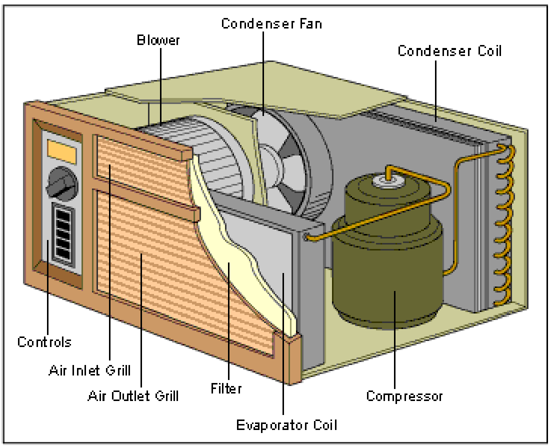
b) Direct expansion coil, supply fan, and compressor combined with a remote condenser, cooling tower, or ground-loop system.

These systems generally have lower first cost than central systems but may have higher life cycle costs. If part load operation is anticipated for a majority of equipment operating life, consider multiple unitary equipment for superior operating efficiencies and added reliability. Refer to ASHRAE Handbook, Equipment for size and selection criteria.

Room Air Conditioning Units

Room Air-Conditioning units are self-contained units serving only one space. These units are typically referred to as window or through-the-wall type air conditioners. Rooms served by these units should have a separate HVAC unit to provide ventilation air for a group of rooms.

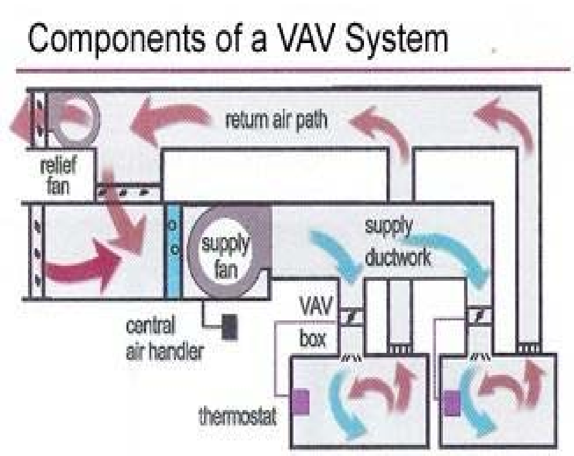
Figure 7: Window Air Conditioner



Variable Air Volume (VAV) Systems

Use VAV systems for buildings with sufficient zones (11 or more zones) and load variation to permit reduction of fan capacity for significant periods during the day. Do not use bypass VAV systems. The complexity of systems should be consistent with minimum requirements to adequately maintain space conditions.

Figure 8: VAV System



CENTRAL AIR-CONDITIONING SYSTEM

Central Air-Conditioning System

A chilled-water applied system uses chilled water to transport heat energy between the airside, chillers and the outdoors. These systems are more commonly found in large HVAC installations, given their efficiency advantages.

Equipments: Pumps, Chillers, FCU, Diffusers

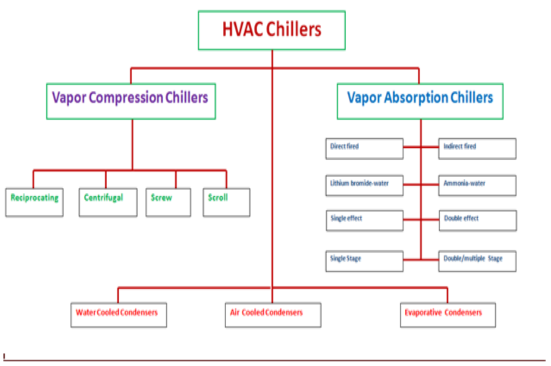
Transport System: Piping, Ducting

The piping is further divided as per its location and application. As per location they are termed as Roof piping, Riser Piping and Floor Piping. As per application they are called as Supply pipe and Return pipe. Similarly ducting is also similarly classified on its application.

Chillers

Heating, Ventilation and Air Conditioning (HVAC) chillers are refrigeration systems that provide cooling for industrial and commercial applications. They use water, oils or other fluids as refrigerants. HVAC chillers include a compressor, condenser, thermal expansion valve, evaporator, reservoir, and stabilization assembly.

Figure 9: HVAC Chillers



Compressing the refrigerant creates a high pressure, s uperheated gas that the condenser air-cools to a warm liquid. The Thermal expansion Valve (TXV) releases refrigerant into the evaporator, converting the warm liquid to a cool, dry gas. Often, a hot gas bypass is used to stabilize the cooling output by allowing the hot gas to warm up the evaporator. This causes a reduction in cooling efficiency, but stabilizes the chilled water temperatures. When water is pumped from the reservoir to the compressor, the chilling cycle begins again.

Figure 10: Chillers

- HVAC chillers vary in terms of condenser cooling method, cooling specifications and process pump specifications.
- They are classified as Air-Cooled and Water-Cooled on basis of condenser cooling methods.
- They can be placed in series or parallel arrangement as required.

The components of the chiller (evaporator, compressor, an air- or water-cooled condenser, and expansion device) are often manufactured, assembled, and tested as a complete package within the factory. These packaged systems can reduce field labor, speed installation and improve reliability. Alternatively, the components of the refrigeration loop may be selected separately. While water- cooled chillers are rarely installed as separate components, some air cooled chillers offer the flexibility of separating the components for installation in different locations. This allows the system design engineer to position the components where they best serve the space, acoustic, and maintenance requirements of the building owner. Another benefit of a chilled-water applied system is refrigerant containment. Having the refrigeration equipment installed in a central location minimizes the potential for refrigerant leaks, simplifies refrigerant handling practices, and typically makes it easier to contain a leak if one does occur.

Factors affecting the decision to select Direct Expansion Unitary or Chilled Water Applied systems include:

- Installed Cost
- Energy consumption
- Space requirements
- Freeze prevention
- Precision
- Building height, size, shape
- System cooling and heating capacity
- Centralized maintenance
- Stability of control
- Individual tenant billing

Air-cooled devices use a fan to force air over the condenser coils. By contrast, water-cooled devices fill the condenser coils with circulating water. Remote air or slit systems locate the main part of the chiller in the application area and position the condenser remotely, usually outdoors. Cooling specifications for HVAC chillers include cooling capacity, fluid discharge temperature, and compressor motor horsepower. Typically, cooling capacity is measured in kilowatts or tons of refrigeration. Compressor motor horsepower is a nominal value. Process pump specifications include process flow, process pressure, and pump rating. HVAC chillers include a local or remote control panel with temperature and pressure indicators. Some devices include microprocessor controls, emergency alarms, and an integral pump.

Fan Coil Units

A Fan Coil Unit (FCU) is a simple device consisting of a heating or cooling coil and fan. The fan is a centrifugal type driven by electric motor with fan mounted on the rotor shaft. FCU's can be both ducted or without ductwork as required by its application. The capacity of an FCU ranges from 100-2000 CFM. The chilled water from the Chillers is pumped into the coil of the FCU which cools up the coils. The blower or fan blows the air thru the coils thus reducing the temperature of the air as required. These are normally placed in the false ceilings randomly as per the zones to supply conditioned air.

Figure 11: FCU Unit

Pumps

Pumps are devices used to force the fluid movement thru the piping system. Types of Pumps:

- Centrifugal Pumps (a) Horizontal Centrifugal Pumps; (b) Vertical Centrifugal Pumps
- Reciprocating Pumps
- Rotary Pumps

Table 1: Nozzle Configuration for Pumps

Suction	Discharge
End	Top
Top	Top
Side	Side

Diffusers

Diffusers are the terminal units located in each space/room to be provided with conditioned air. They are placed in the center of each room for proper distribution of air to every corner.

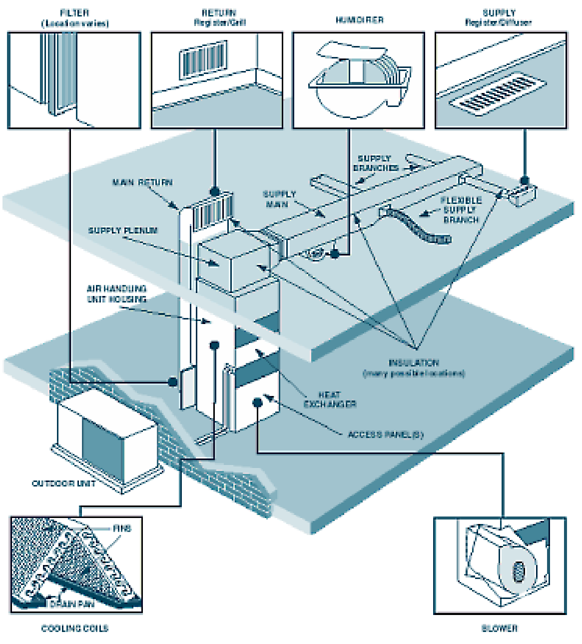
They are different types of diffusers as per the directions of flow like,

- One Way Diffuser
- Two Way Diffuser
- Three Way Diffuser
- Four Way Diffuser
- Circular Diffuser

AIR DISTRIBUTION SYSTEM

Mixing systems generally supply air such that the supply air mixes with the room air so that the mixed air is at the room design temperature and humidity. In cooling mode, the cool supply air, typically around 55 °F (13 °C) (saturated) at design conditions, exits an outlet at high velocity. The high velocity supply air stream causes turbulence causing the room air to mix with the supply air. Because the entire room is near-fully mixed, temperature variations are small while the contaminant concentration is fairly uniform throughout the entire room. Diffusers are normally used as the air outlets to create the high velocity supply air stream. Most often, the air outlets and inlets are placed in the ceiling. Supply diffusers in the ceiling are fed by fan coil units in the ceiling void or by air handling units in a remote plant room. The fan coil or air handling unit take in return air from the ceiling void and mix this with fresh air and cool, or heat it, as required to achieve the room design conditions. This arrangement is known as conventional room air distribution.

Figure 12: Figure Air Distribution System



Ducts

Ducts are used in heating, ventilation, and air conditioning (HVAC) to deliver and remove air. These needed airflows include, for example, supply air, return air, and exhaust air. Ducts also deliver, most commonly as part of the supply air, ventilation air. As such, air ducts are one method of ensuring acceptable indoor air quality as well as thermal comfort.

A duct system is often called ductwork. Planning ('laying out'), sizing, optimizing, detailing, and finding the pressure losses through a duct system is called duct design.

Figure 13: Ducts

Ducts Can be Made out of the Following Materials

Galvanized mild steel is the standard and most common material used in fabricating ductwork. Polyurethane and Phenolic insulation panels (pre-insulated air ducts). Traditionally, air ductwork is made of sheet metal which is installed first and then lagged with insulation as a secondary operation. Ductwork manufactured from rigid insulation panels does not need any further insulation and is installed in a single fix. Light weight and installation speed are among the features of preinsulated aluminium ductwork, also custom or special shapes of ducts can be easily fabricated in the shop or on site. The ductwork construction starts with the tracing of the duct outline onto the aluminium preinsulated panel, then the parts are typically cut at 45^o, bent if required to obtain the different fittings (i.e., elbows, tapers) and finally assembled with glue. Aluminium tape is applied to all seams where the external surface of the aluminium foil has been cut. A variety of flanges are available to suit various installation requirements. All internal joints are sealed with sealant.

Figure 14: Flexible Duct

Flexible Ducting

Flexible ducts, known as flex, have a variety of configurations, but for HVAC applications, they are typically flexible plastic over a metal wire coil to make round, flexible duct. In the United States, the insulation is usually glass wool, but other markets such as Australia, use both polyester fibre and glass wool for thermal insulation. A protective layer surrounds the insulation, and is usually composed of polyethylene or metalised PET. Flexible duct is very convenient for attaching supply air outlets to the rigid ductwork. However, the pressure loss through flex is higher than for most other types of ducts. As such, designers and installers attempt to keep their installed lengths (runs) short, e.g., less than 15 feet or so, and to minimize turns. Kinks in flex must be avoided. Some flexible duct markets prefer to avoid using flexible duct on the return air portions of HVAC systems, however flexible duct can tolerate moderate negative pressures - the UL181 test requires a negative pressure of 200 Pa.

Fabric

Shapes of Ducts

The Ducts are manufactured in different shapes as per the application of each as follows:

(a) Round Duct; (b) Square Duct; (c) Rectangular Duct

Effect of Aspect Ratio

In rectangular duct the best aspect ratio is 1:1, i.e., 1, as the aspect ratio increases the friction per running feet of the duct increases due to increase in surface area.

Aspect Ratio

Aspect Ratio= Long side/Short side = Width of the duct/Height of the duct

Best Aspect Ratio is 1:1

According to SMACNA maximum permissible aspect ratio is 4:1

Classification of Ducts

The conditioned air (cooled or heated) from the air conditioning equipment must be properly distributed to rooms or spaces to be conditioned in order to provide comfort conditions. When the conditioned air cannot be supplied directly from the air conditioning equipment to the spaces to be conditioned, then the ducts are installed. The ducts system convey the conditioned air from air conditioning equipment to the proper air distribution points or air supply outlets in the room and carry the return air from the room back to the air conditioning equipment for reconditioning and recirculation. It may noted that the duct system for proper distribution of conditioned air costs nearly 20 to 30 percent of total cost of the equipments required and the power required by fans forms the substantial part of the running cost. Thus, it is necessary to design the air duct system such a way that the capital cost of ducts and the cost of running the fans are lowest.

The ducts may be classified as follows

1. **Supply air duct:** The duct which supplies the conditioned air from the air conditioned equipment to the space to be considered is called *Supply air duct.*
2. **Return air duct:** The duct which carries the recalculating air from the conditioned space back to the air conditioning equipment is called *Return air duct.*
3. **Fresh air duct:** The duct which carries the outside air is called *Fresh air duct.*
4. **Low pressure duct:** When the static pressure in the duct is less than 50 mm of water gauge, the duct is said to be a *Low air pressure duct.*
5. **Medium pressure duct:** When the static pressure in the duct is up to 150 mm of water gauge, the duct is said to be a *Medium pressure duct.*
6. **High pressure duct:** When the static pressure in the duct is from 150 to 250 mm of water gauge, the duct is said to be a *High pressure duct.*
7. **Low velocity duct:** When the velocity of air in the duct is up to 600m/min, the duct is said to be *Low velocity duct.*
8. **High velocity duct:** When the velocity of air in the duct is more than 600m/min, the duct is said to be *High velocity duct.*

Each of these duct types may also subdivided into headers, main ducts, and branch ducts or run outs. A header is that part of a duct that connects directly to the supply or exhaust fan before air is supplied to the main ducts in a large duct system. Main ducts have comparatively greater flow rates and size, serve a greater conditioned area, and, therefore, allow higher air velocities. Branch ducts are usually connected to the terminals, hoods, and supply outlets, return grilles, and exhaust hoods. A vertical duct is called a *riser*. Sometimes, a header or a main duct is also called a *trunk*.

DUCT DESIGN PROCEDURE AND DUCT LAYOUT

Design Procedure

Before an air duct system is designed, the supply volume flow rate for each conditioned space, room, or zone should be calculated, and the locations of the supply outlets and return inlets should also be settled according to the requirements of space air diffusion (see Chap. 18). For an air duct system, the supply volume flow rate of cold supply air in summer is usually greater than the warm volume flow rate needed in winter. If an air duct system conditions the space with cold air supply in summer, it often also conditions the space with warm air supply in winter.

Computer-aided duct design and sizing programs are widely used for more precise calculation and optimum sizing of large and more complicated duct systems. Manual air duct design and sizing are often limited to small and simple duct systems. Computer-aided duct design and sizing programs are discussed in a later section in this chapter.

The design procedure for an air duct system is as follows:

1. Designer should verify local customs, local codes, local union agreements, and material availability constraints before proceeding with duct design.
2. The designer proposes a preliminary duct layout to connect the supply outlets and return inlets with the fan(s) and other system components through the main ducts and branch takeoffs. The shape of the air duct is selected. Space available under the beam often determines the shape of the duct and affects the layout in high-rise buildings.
3. The duct layout is divided into consecutive duct sections, which converge and diverge at nodes or junctions. In a duct layout, a node or junction is represented by a cross-sectional plane perpendicular to airflow. The volume flow rate of any of the cross sections perpendicular to airflow in a duct section remains constant. A duct section may contain one or more duct segments (including duct fittings).A duct system should be divided at a node or junction where the airflow rate changes.
4. The local loss coefficients of the duct fittings along the tentative critical path should be minimized, especially adjacent to fan inlets and outlets.
5. Duct sizing methods should be selected according to the characteristics of the air duct system. The maximum design air velocity is determined based on the space available, noise, energy use, and initial cost of the duct system. Various duct sections along the tentative critical path are sized.
6. The total pressure loss of the tentative critical path as well as the air duct system is calculated.

7. The designer sizes the branch ducts and balances the total pressure at each junction of the duct system by varying the duct and component sizes, and the configuration of the duct fittings.
8. The supply volume flow rates are adjusted according to the duct heat gain at each supply outlet.
9. The designer resizes the duct sections, recalculates the total pressure loss, and balances the parallel paths from each junction.
10. The airborne and breakout sound level from various paths should be checked and the necessary attenuation added to meet requirements.

b. Duct Layout

When a designer starts to sketch a preliminary duct layout using Computer-Aided Design and Drafting (CADD) or manually, the size of the air duct system (the conditioned space served by the air duct system) must be decided first. The size of an air duct system must be consistent with the size of the air system or even the air conditioning system. From the point of view of the air duct system itself, a smaller and shorter system requires less power consumption by the fan and shows a smaller duct heat gain or loss. The air duct system is also comparatively easier to balance and to operate.

If the designer uses a more symmetric layout, a more direct and simpler form for the critical path can generally be derived. A symmetric layout usually has a smaller main duct and a shorter design path; it is easier to provide system balance for a symmetric than a non symmetric layout.

The designer then compares various alternative layouts and reduces the number of duct fittings, especially the fittings with higher velocity and high local loss coefficients along the critical path, in order to achieve a duct system with lower pressure loss. When duct systems are installed in commercial and public buildings without suspended ceiling, duct runs should be closely matched with the building structures and give a neat and harmonious appearance.

Duct Sizing Methods

Duct sizing determines the dimensions of each duct section in the air duct system. After the duct sections have been sized, the total pressure loss of the air duct system can then be calculated, and the supply, return or relief fan total pressure can be calculated from the total pressure losses of the supply and return duct systems and the pressure loss in the air-handling unit or packaged unit. Three duct-sizing methods are currently used:

- Equal-friction method with maximum velocity
- Velocity reduction method
- Static regain method

a. Equal Friction (Pressure Drop) Method

In this method, the size of duct is decided to give equal pressure drop (or friction loss) per meter length in all ducts. If the layout of the ducts is symmetrical giving the same length of the various runs, this method gives equal pressure loss in various branches and no dampening is required to balance them. In case the runs are of different lengths, then the shortest run will have minimum loss and consequently high pressure at the outlet. It is therefore, necessary to reduce this high pressure by heavy dampening or modifying this method to provide higher velocities in shorter arms. But the high velocities in short run to reduce high pressure may create objectionable noise.

Thus noise absorbing outlets and fittings must be provided. The dampers if provided near the main duct will help in reducing the noise as the branch duct will dissipate some noise. The velocities, in this method, are automatically reduced in the branch ducts as the flow is decreased. This method does not however balance the pressures at the outlets if the branches are of different length and hence dampers are required for balancing the pressure drops in various branches.

b. Velocity Reduction Method

The ducts are designed in such a way that the velocity decreases as flow proceeds. The pressures drops are calculated for these velocities for respective branches and main duct. The fan is designed to overcome the pressure losses along any single run including the losses of main ducts, branch duct, elbows, valves etc. the pressure at outlet is adjusted by the dampers in the respective ducts. The advantage of this system is that it is easiest among all other methods in sizing ducts and the velocities can be adjusted to avoid noise. The major disadvantage of this system is that considerably judgment is required in selecting velocities to make the system optimum in economy and power.

c. Static Regain Method

For the perfect balancing of the air duct layout system, the pressure at all the outlets must be made same. This is possible if the friction loss in each run is made equal to the pressure gain due to reduction in velocity. The gain in pressure (static pressure) due to change in velocity is given by 0.5 {(V12 – V22) / 2g} Where 0.5 reflects the regain efficiency As for this particular project, the duct sizing is done by using the Mc Quay Duct sizer which uses the principle of equal friction method as explained above. As the Flow Air Quantity derived from the Heat Load Calculations in Liters/second, is used in the Mc Quay software with a pressure drop of 0.8 Pa/m to calculate the Duct Sizes. The same can be done after the Single Line Routing of the ducting including the final location of the equipment.

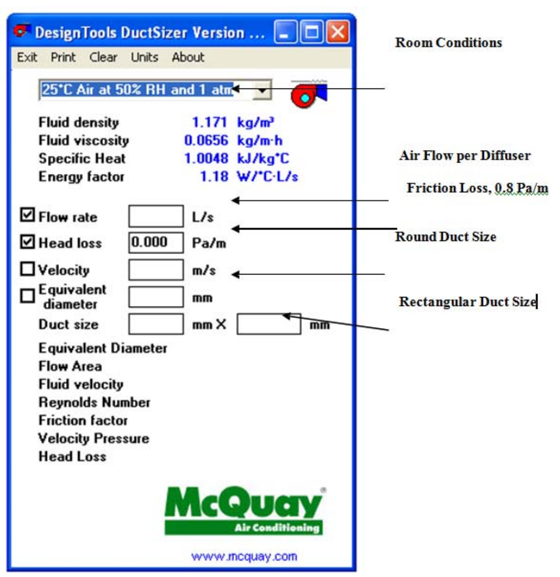
Software Implementation For Duct Design

Therefore all the duct sizes derived from the above software are implemented into the drawing with the help of AutoCAD software in the Single Line Drawing. The same is further developed to full detailed double line ducting layout.

CHILLED WATER SYSTEM

Chilled water is a commodity often used to cool a building's air and equipment, especially in situations where many individual rooms must be controlled separately, such as a hotel. The chilled water can be supplied by a vendor, such as a public utility or created at the location of the building that will use it, which has been the norm.

Figure 15: McQuay Software



Chilled water cooling is very different from typical residential air conditioning where a refrigerant is pumped through an air handler to cool the air. Regardless of who provides it, the chilled water (between 4° and 7°C) is pumped through an air handler, which captures the heat from the air, then disperses the air throughout the area to be cooled.

The condenser water absorbs heat from the refrigerant in the condenser barrel of the water chiller, and is then sent via return lines to a cooling tower, which is a heat exchange device used to transfer waste heat to the atmosphere. The extent to which the cooling tower decreases the temperature depends upon the outside temperature, the relative humidity and the atmospheric pressure. The water in the chilled water circuit will be lowered to the Wet-bulb temperature or dry-bulb temperature before proceeding to the water chiller, where it is cooled to between 4° and 7°C and pumped to the air handler, where the cycle is repeated. The equipment required includes chillers, cooling towers, pumps and electrical control equipment. The initial capital outlay for these is substantial and maintenance costs can fluctuate. Adequate space must be included in building design for the physical plant and access to equipment. The chilled water, which absorbed heat from the air, is sent via return lines back to the utility facility, where the process described in the previous section occurs. Utility generated chilled water eliminates the need for chillers and cooling towers at the property, reduces capital outlays and eliminates ongoing maintenance costs. The physical space saved can also become rentable, increasing revenue.

Pipe

A Pipe is a cylindrical conduit used for the transportation of fluids and solids from one place to another under pressure.

Fluids: Liquid (Ex: Water) and Gas (Ex: Steam)

Solids: Ex: Powder and Pellets

Semi Solids: Ex: Slurry

Pipe Sizing

The Piping system in Centralized HVAC System is a closed type. The Closed systems are made up of two components:

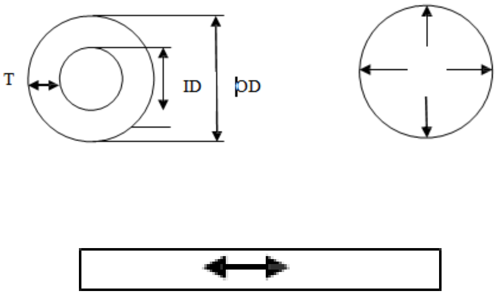
1. A supply system that ends at a terminal air conditioning equipment unit.
2. A return system that starts at the terminal equipment.

The system shown is a reverse return system with both supply and return sections. Closed systems are not affected by atmospheric pressure. The pump head of open systems include atmospheric pressure.

The calculation of size and the thickness (also called as Schedule Number) of a pipe can be done on the basis of Hydraulic Design & Pressure Design. For HVAC Systems carrying medium/ atmospheric pressures, Hydraulic design is used. For higher pressures the pipe requires higher thickness, so Pressure design based on ASME codes will be applicable.

Designation of Pipe Size: Nominal Pipe Size (NPS) (OD of pipe in inches) Designation of Pipe Thickness: Schedule Number (Wall thickness of pipe in Inches)

Figure 16



Stress Acting on a Pipe

OD = ID +2T

1. Hoop Stress/ Circumferential Stress: S = P.D/ 2 t

Where P is the Internal Pressure

D is Outer Diameter of the Pipe t is the Pipe Thickness

2. Longitudinal Stress: S = P.D/4t

3. Radial Stress: S = P

Pipe Length

Pipe length are commercially provided in as,

- Single Random Length = ±20 ft or ±6m
- Double Random Length = ±40 ft or ±12m
- Customised Length = As per customer requirement

Piping Elements: The commonly used piping elements for both its flexibility and directional changes are

Figure 16

Figure 90° Elbow Figure 45° Elbow Figure Tee

Figure 17

Table 2: Maximum Water Velocity to Minimize Erosion

Normal Operation (Hr/Yr)	Water Velocity(FPS)
1500	12
2000	11.5
3000	11
4000	10
6000	9
8000	8

Elbow: An elbow is a pipe fitting installed between two lengths of pipe or tubing to allow a change of direction, usually a 90° or 45° angle.

Tee: It is used to either combine or split a fluid flow. It is a type of pipe fitting which is T-shaped having two outlets, at 90° to the connection to the main line.

Figure Reducer

Reducer: A reducer allows for a change in pipe size to meet hydraulic flow requirements of the system, or to adapt to existing piping of a different size. Reducers are usually concentric but eccentric reducers are used when required to maintain the same top- or bottom-of-pipe level.

Other Elements

Cap: A type of pipe fitting, usually liquid or gas tight, which covers the end of a pipe.

Nipple: A nipple is defined as being a short stub of pipe which has external male pipe threads at each end, for connecting two other fittings. Nipples are commonly used for plumbing and hoses, and second as valves for funnels and pipes.

Valves: Valve is equipment designed to stop or regulate flow of any fluid (liquid, gas, condensate, stem, slurry etc.) in its path.

Coupling: A coupling connects two pipes to each other. If the size of the pipe is not the same, the fitting may be called a reducing coupling or reducer, or an adapter.

Union: A union is similar to a coupling, except it is designed to allow quick and convenient disconnection of pipes for maintenance or fixture replacement

Valves: The functions of valve include:

- Isolation (On/OFF)
- Throttling/Regulation/Control (of Volume and Speed)
- Control of direction

Pipe Sizing: The pipe sizing for a line can be done with following values:

For Air/Steam: Volume Flow rate (CFM) & Velocity (FPM)

For Water: Volume Flow rate (GPM) & Velocity (FPS)

Formula:

GPM = 2.4 x TR (Tonnes of Refrigeration)

FPS is calculated basing on number of hours of operation per year

Ex: @HYD operating for 5 months per year = 5 months x 30 days x 24 hrs = 3600 hrs/year

Water Velocity:

- Roof Piping - 10 FPS
- Riser Piping - 8 FPS
- Floor Piping - 6 FPS

The Pipe diameter values of each can be derived from the below chart as per the GPM and the velocity at the required at each point. These values are depicted on the drawing along with the GPM values for each FCU.

GREEN BUILDING CONCEPT

What is a Green Building?

A Green Building, also known as a sustainable building, is a structure that is designed, built, renovated, operated, or re-used in an ecological and resource efficient manner.

Sustainable development is maintaining a delicate balance between the human need to improve lifestyles and feeling of well-being on one hand, and preserving natural resources and ecosystems, on which we and future generations depend

Objectives of a green building:

- Protecting occupant health
- Improving employee productivity
- Using energy, water and other resources more efficiently
- Reducing overall impact to the environment
- Optimal environmental and economic performance
- Satisfying and quality indoor spaces

Benefits of Green Buildings

Environmental Benefits

- Reduce the impacts of natural resource consumption

- Reduced operating costs
- Increased building valuation
- Optimizes life-cycle performance cost

Concept in HVAC

The main purpose of commercial HVAC (Heat, Ventilation and Air conditioning) systems is to provide the people working inside the building with "conditioned " air ."Conditioned" air means that air is clean and odour-free, and the temperature, humidity, and movement of the air are within certain comfort ranges.

- Systems may be clustered at a central location and serve an entire campus of buildings
- Locate system away from acoustically sensitive areas of the building
- Selecting efficient air conditioning based on your climate.
- Selecting the proper type of and efficient heating system for your climate
- Designing and sealing air distribution systems properly.
- Replace CFC-based refrigerant.
- Consider non-refrigerant based cooling such as evaporative cooling in dryer climates.
- Consider photovoltaic, solar thermal, geothermal, wind, biomass, and bio-gas energy technologies.
- Sophisticated Electrical Management Systems, Building Automation Systems or Direct.
- Digital Control systems inherently include most of the required monitoring points.
- Combine carbon dioxide monitors with demand based ventilation.
- Include carbon dioxide sensor points in BAS/ DDC for system design automation.
- Consider adjustable underfloor air diffusers, or thermostat controlled VAV boxes.
- Operable windows can be used in lieu of comfort controls for occupants of areas that are 20 feet inside of and 10 feet to either side of the operable part of the window

The American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) has established standards which outline air quality for indoor comfort conditions that are acceptable to 80% or more of a commercial building's occupants. Generally, these indoor comfort conditions, sometimes called the "comfort zone," are between 68 ^{o}F and 75 degrees F for winter and 73^{o}F to 79^{o}F during the summer. Both these temperature ranges are for room air at approximately 50% relative humidity and moving at velocity of 30 feet per minute or slower.

REPORT AND ANALYSIS

Shop Drawing

Shop drawings are typically required for prefabricated components. Drawings, diagrams, illustrations, schedules and other data intended to illustrate details of a portion of the work which are provided to the registered professional of record. We have shown of two sizings done in our project.

a) DUCT Design b) PIPING Design

a) DUCT Design

Duct design is provided for the air distribution for the space given.

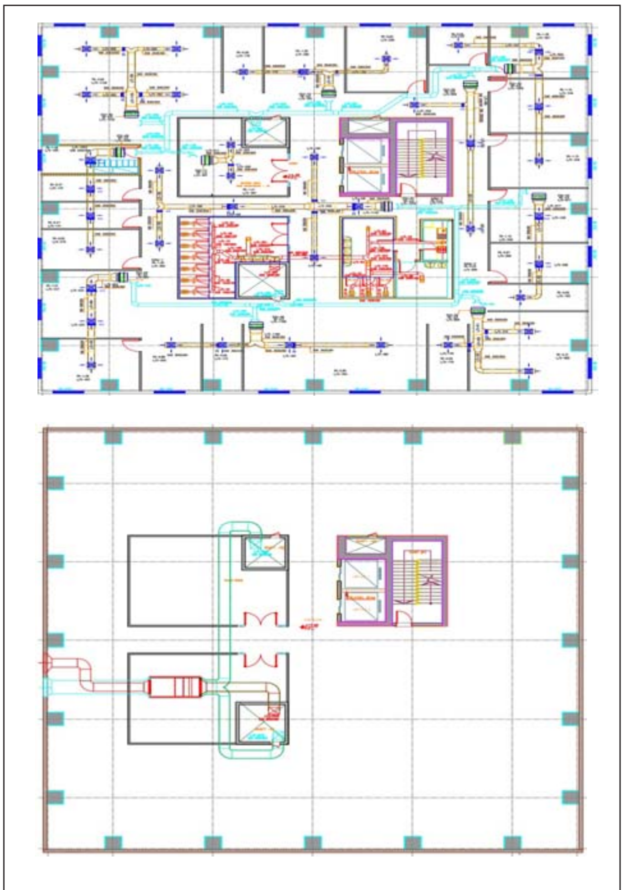
SPACE	SHEET NO.
FIRST FLOOR	AR-02
SECOND FLOOR	AR-03
THIRD FLOOR	AR-04
ROOF DECK	AR-04

b) Piping Design

Piping design is for chilled water system to flow into the space needed.

SPACE	SHEET NO.
FIRST FLOOR	AR-02
SECOND FLOOR	AR-03
THIRD FLOOR	AR-04
ROOF DECK	AR-04

DUCT LAYOUT



CONCLUSION

The parasitic equipment (pumps and fans) used in commercial building HVAC systems for thermal distribution and ventilation represent a considerable amount of total HVAC energy use: about 1.5 quads annual national primary energy use. The major users of this parasitic energy are fans associated with the air handling units and exhaust fans. While some of the supply fans, especially large VAV units, are fairly efficient at design load and are controlled to vary flow efficiently, many small-size fans have low or modest efficiencies, especially when installed in tightly packaged air conditioning systems. Energy use of fans is significantly affected by system design practice, installation procedures, whether the system is properly commissioned, and whether the system receives proper maintenance. While the national impact of some of these factors cannot readily be determined, it is clear that A&E firms, installers, and users have a significant impact on system energy use.

The energy use associated with chilled water pumps, condenser water pumps, cooling tower fans, condenser fans, and heating water pumps, while not insignificant, is dwarfed by that of supply, return, and exhaust fans. The upcoming second phase of this study will focus on opportunities for energy savings. However, a few recommendations do become clear at this stage:

1) An investigation of the impact of departures from as-designed energy performance of HVAC systems is in order. Quantification of this issue will help significantly in guiding future energy reduction efforts.

2) Research and development of high-efficiency fans is an area that has a dramatic potential to impact national energy use. Peak efficiencies achieved in centrifugal compressors approach 80%. It is reasonable to assume that such efficiencies could be achieved in HVAC fans. Our interviews with industry representatives suggests that little is currently being done to boost fan design-load efficiencies. More focus has been on part load efficiency achievable with variable volume operation.

   However, many smaller systems and exhaust fans do not operate with variable volume. Furthermore, these smaller fans are typically not as efficient. Trade-offs exist between cost and efficiency. Fans in smaller packaged units must be compact. Typical blade design is forward- curved, which provides for good pressure rise for a given diameter and speed. However, the introduction of low-cost, higher-speed airfoil fan blades could improve the energy performance while minimizing cost impact.

3) Development of lower-cost variable-speed drives, especially in smaller sizes, wouldincrease the proliferation of variable-speed air-conditioning. In many market sectors, installation cost is still one of the most important issues, and the cost of these drives is prohibitive. Further research into lower-cost power electronics would help to reduce these costs.

4) High-efficiency motors are an option that would reduce fan and pump power in all applications. While many large-hp motors are relatively efficient, reduction of the cost premium of high-efficiency motor technology could make a dramatic impact. For instance,5% average reduction of motor power is worth 100 TBtu of primary energy in commercial HVAC parasitic applications.

5) Further study of potential energy saving options is necessary. The impact of advanced cooling techniques that don't rely on air as the primary thermal transport fluid may be significant. Lower-cost ways to efficiently satisfy varying cooling loads while also satisfying ventilation needs in commercial buildings need to be identified and discussed within the HVAC design community.

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